船舶工程专业英语

Fundamentals and New Concepts for Shipbuilding Engineering

黄德波 主编

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内容简介

本书内容包括船舶设计、原理、结构、生产建造、造船经济等方面。读者通过对本书有关造船学的主要方面的英文文献的学习,可提高相关专业英语的阅读、理解及运用水平。本书可作为高等院校船舶与海洋工程专业学生的专业英语教材,也可作为相关专业工程技术、研究人员的培训或自学材料。

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前　言

21世纪是走向海洋的世纪，蓬勃发展中的我国船舶与海洋工程，将在更深广的范围融入世界．正在或将要从事船舶与海洋工程专业的人员亟需掌握有关的专业英语的运用能力，作为新知识和信息的获取与交流的必要手段；不少中青年技术骨干对此体会更深。有感于此，正值学校教学急需，本人受嘱编写船舶工程方面的专业英语教材。

造船学是一较大系统，涉及船舶的设计，水动力与结构性能，生产建造等广泛内容，因教学大纲、篇幅以及编者能力所限，难以面面俱到；编者尽力从描述专业基础知识、原理概念、历史发展等较新、较经典的原文资料中选择较恰当的部分，加上术语解释，编成此书。本书具体内容为船舶设计（概述，船舶分类，主尺度，船形及参数，船级社等）；船舶基本原理（稳性，阻力，推进，运动与操纵性，船模试验等）；船舶结构（结构性能与型线的关系，船舶强度，结构应力，结构完整性等）；船舶生产建造（造船过程、计划与进度制订，船厂与设施，船舶CAD与CAM等）和少量造船经济（造船工业状况，成本估算与合同管理等）。

相信通过学习本书，读者对有关专业英语水平会有所提高。

此书可用作本科生教材，建议安排36学时讲授，教师可按各课的难度和长短适当调节内容与进度，部分内容可作为课后阅读资料。应鼓励读者在阅读或教师讲授之前先浏览每课后的问题。也可供从事船舶工程专业人员阅读。读者若能努力回答各课后问题，可望有更好的收效。

感谢邓三瑞教授于百忙中审阅初稿，并提出宝贵意见。

编者能力不足，又兼时间紧迫，书中必有错漏，望读者指正。

编者

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Chapter 1 Ship Design

Lesson 1 Introduction

1.1 Definition

The term basic design refers to determination of major ship characteristics affecting cost and performance. Thus, basic design includes the selection of ship dimensions, hull form, power (amount and type), preliminary arrangement of hull and machinery, and major structure. Proper selections assure the attainment of the mission requirements such as good seakeeping performance, maneuverability, the desired speed, endurance, cargo capacity, and deadweight. Furthermore, it includes checks and modifications for achievement of required cargo handling capability, quarters, hotel services, subdivision and stability standards, freeboard and tonnage measurement; all while considering the ship as part of a profitable transportation, industrial, or service system.

Basic design encompasses both concept design and preliminary design. It results in the determination of major ship characteristics, permitting the preparation of initial cost estimates. In the overall design process, basic design is followed by contract design and detail design. Contract design, as its name implies, develops plans and specifications suitable for shipyard bidding and contract award. Well prepared contract plans and specifications will be clear and in sufficient detail to avoid costly contingency items and protect bidders from obscure or inadequate description of requirements. Detail design is the shipyard's responsibility for further developing the contract plans as required to prepare shop drawings used for the actual construction of the vessel.

An understanding of the entire design sequence is essential to anyone seeking to develop a basic design. The four steps involved are illustrated in the Design Spiral, Evans (1959)[1] as an iterative process working from mission requirements to a detail design, Fig. 1.1. These steps are amplified further below:

a. ***Concept Design***. The very first effort, concept design, translates the mission requirements into naval architectural and engineering characteristics. Essentially, it embodies technical feasibility studies to determine such fundamental elements of the proposed ship as length, beam, depth, draft, fullness, power, or alternative sets of characteristics, all of which meet the required speed, range, cargo cubic, and deadweight. It includes preliminary light-ship weight estimates usually derived from curves, formulas, or experience. Alternative designs are generally analyzed in parametric studies during this phase to determine the most economical design solution or whatever other controlling parameters are considered determinant. The selected concept design then is used as a talking paper for obtaining approximate construction costs, which often determine whether or not to initiate the next level of development, the preliminary design.

b. ***Preliminary Design***. A ship's preliminary design further refines the major ship characteristics affecting cost and performance. Certain controlling factors such as length, beam, horsepower, and deadweight would not be expected to change upon completion of this phase. Its completion provides a precise definition of a vessel that will meet the mission requirements; this provides the basis for

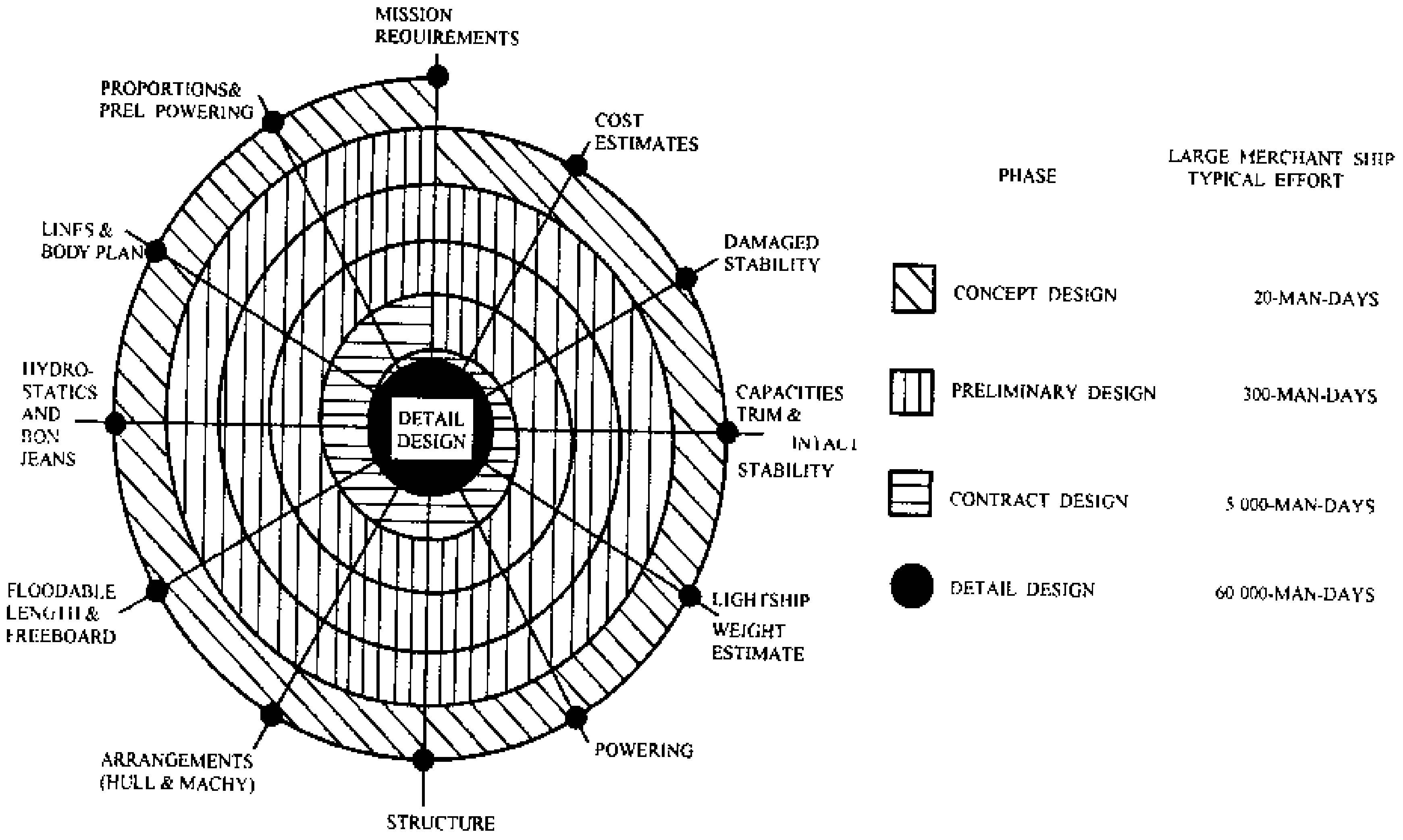


Figure 1.1 Basic design spiral

development of contract plans and specifications.

c. Contract Design. The contract design stage yields a set of plans and specifications which form an integral part of the shipbuilding contract document. It encompasses one or more loops around the design spiral, thereby further refining the preliminary design. This stage delineates more precisely such features as hull form based on a faired set of lines, powering based on model testing, seakeeping and maneuvering characteristics, the effect of number of propellers on hull form, structural details, use of different types of steel, spacing and type of frames. Paramount, among the contract design features, is a weight and center of gravity estimate taking into account the location and weight of each major item in the ship. The final general arrangement is also developed during this stage. This fixes the overall volumes and areas of cargo, machinery, stores, fuel oil, fresh water, living and utility spaces and their interrelationship, as well as their relationship to other features such as cargo handling equipment, and machinery components.

The accompanying specifications delineate quality standards of hull and outfit and the anticipated performance for each item of machinery and equipment. They describe the tests and trials that shall be performed successfully in order that the vessel will be considered acceptable.

Table 1.1 shows a typical list of plans developed in the contract design of a major ship. Smaller, less complex vessels may not require every plan listed for adequate definition, but the list does provide an indication of the level of detail considered in contract design.

d. Detail Design. The final stage of ship design is the development of detailed working plans. These plans are the installation and construction instructions to the ship fitters, welders, outfitters, metal workers, machinery vendors, pipefitters, etc. As such, they are not considered to be a part of the basic design process. One unique element to consider in this stage of design is that up to this point, each phase of the design is passed from one engineering group to another. At this stage the interchange is from engineer to artisan, that is, the engineer's product at this point is no longer to be interpreted, adjusted, or corrected by any other engineer. This engineering product must unequivocally define the desired end result and be producible and operable.

In summary, this chapter considers basic design as that portion of the overall ship design process which commences with concept design and carries preliminary design to the point where there is reasonable assurance that the major features have been determined with sufficient dependability to allow the orderly development of contract plans and specifictions. This development will form a basis to obtain shipyard prices within a predetermined price range that will result in an efficient ship with the requisite performance characteristics.

1.2 General Aspects

The late 1960's and 1970's saw a number of major new developments which in one way or another had an impact on the general basic design problem. Among the most significant was the computer. While the computer affects how basic design is performed, other changes have impacted on what constitutes the basic design problem. For example, one revolutionary development was the change from breakbulk to containerized cargos in the liner trades. Other developments in other ship types created similar new considerations. For tankers, size mushroomed; the increasing demand for petroleum and other raw materials by the industrialized nations of the world has necessitated ever larger tankers and bulk carriers to meet the enormous demand at acceptable costs.

Man is looking increasingly to the sea for all major resources; offshore drilling for oil and gas has burgeoned from a small industry located mainly in the shallow areas of the Gulf of Mexico to a worldwide colossus moving into deeper water and more severe sea conditions (Durfee et al, 1976). These developments have caused a revolution in the design of offshore drilling rigs/ships/units and the entire support fleet necessary for such a challenging undertaking. This includes crew boats, offshore supply boats, high powered towing vessels, pipe laying barges/ships, and countless other specialized craft. Future developments cannot be foretold, but it seems certain that other minerals will be sought from the sea necessitating entire new fleets of vessels designed for tasks not yet known.

Thus, the difficulty of basic ship design will vary with the degree of departure from past practice. Some ship operating companies are closely tied to successful previous designs, and they will permit little variation from these baselines in the development of replacement vessel designs. If the prospective mission appears to parallel existing operations, this may be a sound approach. Consequently, in such situations, basic design may be limited to examination of minor modifications to dimensions, powering, and arrangements.

At the other extreme, totally new seagoing missions, such as the ocean transportation of liquified natural gas (LNG), when first introduced, caused the designer to begin with a blank piece of paper and proceed through rational design engineering with crude assumptions subject to frequent and painstaking revision and development.

Table 1.1—Typical Plans Developed
During Contract Design Stage

Outboard Profile, General Arrangement
Inboard Profile, General Arrangement
General Arrangement of All Decks and Holds
Arrangement of Crew Quarters
Arrangement of Commissary Spaces
Lines
Midship Section
Steel Scantling Plan
Arrangement of Machinery—Plan Views
Arrangement of Machinery—Elevations
Arrangement of Machinery—Sections
Arrangement of Main Shafting
Power and Lighting System—One line Diagram
Fire Control Diagram by Decks and Profile
Ventilation and Air Conditioning Diagram
Diagrammatic Arrangements of all Piping Systems
Heat Balance and Steam Flow Diagram—Normal Power at Normal Operating Conditions
Electric Load Analysis
Capacity Plan
Curves of Form
Floodable Length Curves
Preliminary Trim and Stability Booklet
Preliminarty Damage Stability Calculations

（摘自<Ship Design and Construction>，R. T. Taggart，The SNAME. One World Center，NewYork，NY，1980）

课外阅读

Additional reading 1

General Considerations

In such general comparisons and categorizations it is necessary to return to a practical perspective. It is all very well to arrange type categories with respect to the common denominator of supporting force or mission, but the question of relative significance in harder terms must ultimately be answered.

How many ships of each of these categories can justify themselves in terms of economic support and environmental capabilities? How many are purely experimental? What can be expected of their future? Where these questions apply to the problems faced by the ship designer, an attempt has been made in the following chapters to provide the background for adequate evaluation.

A more detailed discussion of these comparative factors can only be made after the technical presentations of this book has been absorbed. But it must be emphasized here that most of this book will deal with the physical nature of displacement ships, simply because almost all of the ships on the world's oceans are and probably will be of this type. They carry the raw materials of world commerce and a nation's military strength to most parts of the globe. Without them the civilized industrialized world would quickly collapse.

The ships of recent years have noticeably progressive features in their external configuration. The old stacks or funnels have been replaced by raked, streamlined stacks or transverse pairs of slim diesel funnels. Superstructures have become crisp and uncluttered. Hulls of tankers and bulk carriers have become monstrous in volume. Fast cargo carriers and naval vessels have acquired new grace in their sheer and flare. Below the waterline, improved hydrodynamic knowledge has resulted in bulbous forefoot extensions and improved rudder configurations. There are a multitude of internal developments provided by modern technology, including the less visible changes in strength and performance allowed by improved metals and other materials.

Additional reading 2

The Systems Approach

The greatest change in new ships, however, is not very evident in their structure. This is because designers, planners, and operators recognize that a ship is an extremely complex but integrated total system.

It is increasingly difficult to design and build a ship without regard to the systems engineering approach. Because of the rapidly mushrooming technology of this century, there has been growing specialization within the engineering professions. This has led to the need for a way to deal with complex assemblies made up of many specialized components. If they are to be capable of optimum performance, such complex assemblies as the Trident submarine or the nuclear aircraft carrier must be designed in an orderly manner. This integrated approach is ordinarily referred to as systems engineering.

Systems engineering is employed in the design of all naval vessels and most commercial craft today, and the student of ship design should become familiar with it early in his engineering education. We might define the approach as a process for achieving significant objectives, allocating resources, and organizing information so that all major aspects of a problem can be presisely determined and coordinated according to a plan. Systems engineering supplies the bridge between what is needed and what is technically feasible.

Systems in Ships—Systems engineering, whether it is applied to a large ocean transport ship, a warship, or a very small vessel, implies total integration of all subsystems to provide a functional unit that achieves the basic mission of the ship. This means that ship control must function through the internal and external communications systems, and the machinery and propulsion systems must react to control, signaling their responses on display instruments at the central control station. The weapons systems of a warship must function on order with simultaneous execution and respond to all safety and protective systems. Systems engineering includes all automatic control systems as well as a multitude of engineering and electronic subsystems that maintain order and perform daily living and emergency functions. In the last century or more of successful mechanical propulsion, the ship has undergone fundamental changes; no longer is she merely a large floating vessel with a relatively isolated power plant, isolated cargo holds and living quarters, and a lonely navigation bridge with its crude mechanical or sound-signaling device to the engine room. In a sense, the ship of century ago was a system too, but her design lacked the systematic, integrated approach demanded for the successful modern ship.

（摘自 < Introduction to Naval Architecture > T. Gillmer & B. Johnson London, E. & F. N. SPON, 1982）

术语解释

sea keeping performance	耐波性能
maneuverability	操纵性
endurance	续航力，全功率工作时间
cargo handling	货物装卸
subdivision	分舱
stability	稳性
freeboard	干舷
tonnage	吨位
basic design	基本设计
concept design	概念设计
preliminary design	初步设计
contract design	合同设计
design spiral	设计螺旋循环方式
bidder	投标人（者）
iterative process	迭代过程
naval architecture	造船学
feasibility study	可行性研究
beam	船宽，梁
depth	船深
draft	吃水
fullness	丰满度
cargo cubic	货舱舱容，载货容积

deadweight	总载重量(吨)
talking paper	讨论文件
light-ship	空船
a faired set of lines	经过光顺处理的一套型线
hull form	船形,船体外形
frame	船肋骨,框架,桁架
fresh water	淡水
living and utility spaces	居住与公用舱室
outfit	舾装
trial	实船试验
major ship	大型船舶
detail design	详细设计
ship fitter	船舶装配工
welder	焊工
metal worker	金属工
machinery vendor	机械(主机)卖方
outfitter	舾装工
pipe fitter	管装工
artisan	技工
shipyard	船厂
breakbulk	件杂货
containerized	集装箱化
liner trade	定期班轮营运业
tanker	油轮
bulk carrier	散装货船
offshore drilling	离岸钻井
drilling rig	钻架
pipe laying barge	(海底)铺管驳船
fleets of vessels	船队

outboard profile	侧视图
inboard profile	纵剖面图
general arrangement	总布置
hold	船舱
crew quarters	船员居住舱
commissary spaces	补给库舱室，粮食库
lines	型线
plan views	设计图
midship section	舯横剖面
elevations	高度，高程，船型线图的侧面图、立视图、纵剖线图，海拔
sections	剖面，横剖面
main shafting	主轴系
power and lighting system	动力与照明系统
diagram	图，原理图，设计图，流程图
ventilation and air conditioning diagram	通风与空调敷设设计图
normal operating condition	常规（正常）运作状况
capacity plan	舱容图
curves of form	各船型曲线
floodable length curve	可浸长度曲线
trim	纵倾
damage stability	破损稳性

问　　题

1. What kinds of design have been mentioned in the introduction?

2. What is the main purpose of basic design?

3. Should the contract design be completed before bidding for a ship?

4. What kind of cargo ship has gradually become the substitution of breakbulk carrier?

5. In which industry will the shipbuilders like to get involved, in addition to building ships?

Lesson 2 Ships Categorized

2.1 Introduction

The forms a ship can take are innumerable. A vessel might appear to be a sleek seagoing hotel carrying passengers along to some exotic destination; a floating fortress bristling with missile launchers; or an elongated box transporting tanks of crude oil and topped with complex pipe connections. None of these descriptions of external appearance, however, does justice to the ship system as a whole and integrated unit—self-sufficient, seaworthy, and adequately stable in its function as a secure habitat for crew and cargo. This is the concept that the naval architect keeps in mind when designing the ship and that provides the basis for subsequent discussions, not only in this chapter but throughout the entire book.

In order to discuss naval architecture, it is helpful to place ships in certain categories. For purposes of this text, ships are classified according to their means of physical support and their designed purposes.

2.2 Ships Typed According to Means of Physical Support

The mode of physical support by which vessels can be categorized assumes that the vessel is operating under designed conditions. Ships are designed to operate above, on, or below the surface of the sea, so the air-sea interface will be used as the reference datum. Because the nature of the physical environment is quite different for the three regions just mentioned, the physical characteristics of ships designed to operate in those regions can be diverse.

Aerostatic Support

There are two categories of vessels that are supported above the surface of the sea on a self-induced cushion of air. These relatively lightweight vehicles are capable of high speeds, since air resistance is considerably less than water resistance, and the absence of contact with small waves combined with flexible seals reduces the effects of wave impact at high speed. Such vessels depend on lift fans to create a cushion of low-pressure air in an underbody chamber. This cushion of air must be sufficient to support the weight of the vehicle above the water surface.

The first type of vessel has flexible "skirts" that entirely surround the air cushion and enable the ship to rise completely above the sea surface. This is called an air cushion vehicle (ACV), and in a limited sense it is amphibious.

The other type of air-cushion craft has rigid side walls or thin hulls that extend below the surface of the water to reduce the amount of air flow required to maintain the cushion pressure. This type is called a captured-air-bubble vehicle (CAB). It requires less lift-fan power than an ACV, is more directionally stable, and can be propelled by water jets or supercavitating propellers. It is not amphibious, however, and has not yet achieved the popularity of the ACVs, which include passenger ferries, cross-channel automobile ferries, polar-exploration craft, landing craft, and riverine warfare vessels.

Hydrodynamic Support

There are also two types of vessels that depend on dynamic support generated by relatively rapid forward motion of specially designed hydrodynamic shapes either on or beneath the surface of the water. A principle of physics states that any moving object that can produce an unsymmetrical flow pattern generates a lift force perpendicular to the direction of motion. Just as an airplane with (airfoil) produces lift when moving through the air, a hydrofoil, located beneath the surface and attached by means of a surface piercing strut, can dynamically support a vessel's hull above the water.

Planing hulls are hull forms characterized by relatively flat bottoms and shallow V-sections (especially forward of amidships) that produce partial to nearly full dynamic support for light displacement vessels and small craft at higher speeds. Planing craft are generally restricted in size and displacement because of the required power-to-weight ratio and the structural stresses associated with traveling at high speed in waves. Most planing craft are also restricted to operations in reasonably calm water, although some "deep V" hull forms are capable of operation in rough water.

Hydrostatic Support

Finally, there is the oldest and most reliable type of support, hydrostatic support. All ships, boats, and primitive watercraft up to the twentieth century have depended upon the easily attained buoyant force of water for their operation.

This hydrostatic support, commonly recognized as flotation, can be explained by a fundamental physical law that the ancient philosopher-mathematician Archimedes defined in the second century B.C. Archimedes' Principle states that a body immersed in a liquid is buoyed up (or acted upon) by a force equal to the weight of the liquid displaced. This principle applies to all vessels that float (or submerge) in water—salt or fresh. And from this statement the name of the ships in the category are derived; they are generally called displacement hulls.

Although this ship type is very familiar, its subcategories warrant special discussion. For example, in some vessels reasonably high speed must be combined with the ability to carry light cargo or to move more comfortably in rough water than a planing hull. High-speed planing-hull characteristics can be modified to produce a semidisplacement hull or semiplaning hull. These compromise craft, of course not as fast as full-planing hulls but faster than conventional displacement hulls, must have more power and less weight than the latter. Such types are obviously the result of "tradeoffs."

The example cited above lies between clear-cut physically defined categories—it is not a good example of a variation of a true displacement-type ship. The latter must be recognized primarily as a displacement vessel, and its variations depend primarily on the distribution of buoyant volume—the extent of the depth and breadth of the hull below the water.

The most ubiquitous type of displacement ship can be generally classified as the common carrier, a seagoing vessel. It may be employed for passenger service, light cargo-carrying, fishing by trawling, or for hundreds of other tasks that do not require exceptional capacity, speed, submergence, or other special performance. It is the most common and easily recognizable type of ship, with moderate displacement, moderate speeds, moderate to large lengths, and moderate capacities. It usually embodies the maximum in cruising range and seaworthiness. It is the "Ship for all seasons." It is the standard to which all other ship classifications in the displacement category may be referred.

The closest relative to this standard vessel, which plays a crucial role not only in world commerce but in the survival of the industrial world as well, is the bulk oil carrier, the tanker, or supertanker. These terminologies are common but unspecific, and in this discussion they are inadequate, for what was called a supertanker several years ago is today not a supertanker. The industry itself has created a far more explicit nomenclature. Based upon the index of 100 000 tons oil cargo capacity, the size categories are LCC (Large Crude Carrier), VLCC (Very Large Crude Carrier), and ULCC (Ultra Large Crude Carrier). Any tanker greater than 100 000 tons but less than 200 000 is a LCC, those between 200 000 and 400 000 are VLCCs, and those over 400 000 are ULCCs. The current necessity for these designations becomes clear when we realize that before 1956 there were no tankers larger than 50 000 tons, and not until the early sixties were any ships built larger than 100 000 tons. In 1968 the first ship over 300 000 tons was built. With their bulk and enormous capacity (four football fields can be placed end to end on one of their decks), these ships are designed and built to be profit-makers, enormously long, wide, and deep, carrying thousands of tons of crude oil per voyage at the least cost. Few of these elephantine tankers have more than one propeller shaft or rudder. Their navigation bridges are nearly one quarter of a mile from their bows. Their top service speed is so low that a voyage from an Arabian oil port to a European destination normally takes two months.

Such vessels belong to a category of displacement ship that has a great range of buoyant support. They have a very large and disproportionate hull volume below the surface when fully loaded. Indeed, the cargo weight far exceeds the weight of the ship itself. The draft or depth of water required for a fully loaded VLCC runs to

50 or 60 feet and the ULCC may be 80 feet. Such ships belong in the exclusive category of displacement vessels called deep displacement ships.

There exists another type of displacement hull with extreme draft. However, is similarity to the crude-oil carrier of the preceding discussion goes no further than that. This type of vessel is called the SWATH (Small Waterplane Area Twin Hull). Briefly, this rather rare breed of ship is designed for relatively high speed and stable platform in moderately rough water. Its future is problematical, but the theory of placing the bulk of the displacement well below the surface and extending the support to the above-water platform or deck through the narrow waterline fins or struts is sound. Twin hulls connected by an upper platform provide the necessary operating stability.

The most significant class of displacement hull for special application is the submarine, a vessel for completely submerged operation. The nature of the submarine and a description of her various operational attitudes, both static and dynamic, is covered in subsequent chapters. It is only necessary here to emphasize that submerisible vessels are specifically displacement vessels applying the theory of Archimedes' Principle and all that it implies.

Multihull Vessels

There is one other type of hull in common use that has not yet been mentioned, primarily because it fits into none of the categories described but rather can exist comfortably in any. This craft is the so-called multihull vessel—the catamaran and the trimaran. These vessels are most frequently displacement hulls in their larger sizes, such as the SWATH mentioned above, or more conventionally, ocean research vessels requiring stable platforms and protected areas for launching equipment. There are also the twin-hulled CAB vessels mentioned earlier and high-speed planing catamarans. Actually, the multihull ship is an adaptation of any of the basic hull categories to a special application that requires exceptional transverse stability and/or the interhull working area.

Figure 2.1 indicates the body profiles (with no relative scale) that have just been described and relates them to their means of physical support. They are arranged from high to low speed, except for the multihull types, which may be either speed, depending upon their purpose.

2.3 Other Criteria

There are other criteria that justify the widely varied configurations of ship design. They are the result of trade-offs concerning cost, mission, speed, endurance, payload (cargo or weapons capacity), operating environment (stability, survivability, and port requirements), reliability, appearance, personal comfort and habitability, and political considerations. The relative importance of the various factors is dictated by the purpose of the vessel, which is set by the commercial firm, government, or individual who purchases the vessel. A useful classification based on purpose includes the following categories: merchant and commercial ships, naval vessels, and pleasure craft.

Merchant and Commercial Ships

Merchant and commercial ships are generally bought to earn a profit. The previously discussed cargo ships are designed for the minimum (or at least competitive) "required freight rate," which involves predicting the "life-cycle cost" of the ship, including the acquisition costs, the operating and maintenance costs, and anly

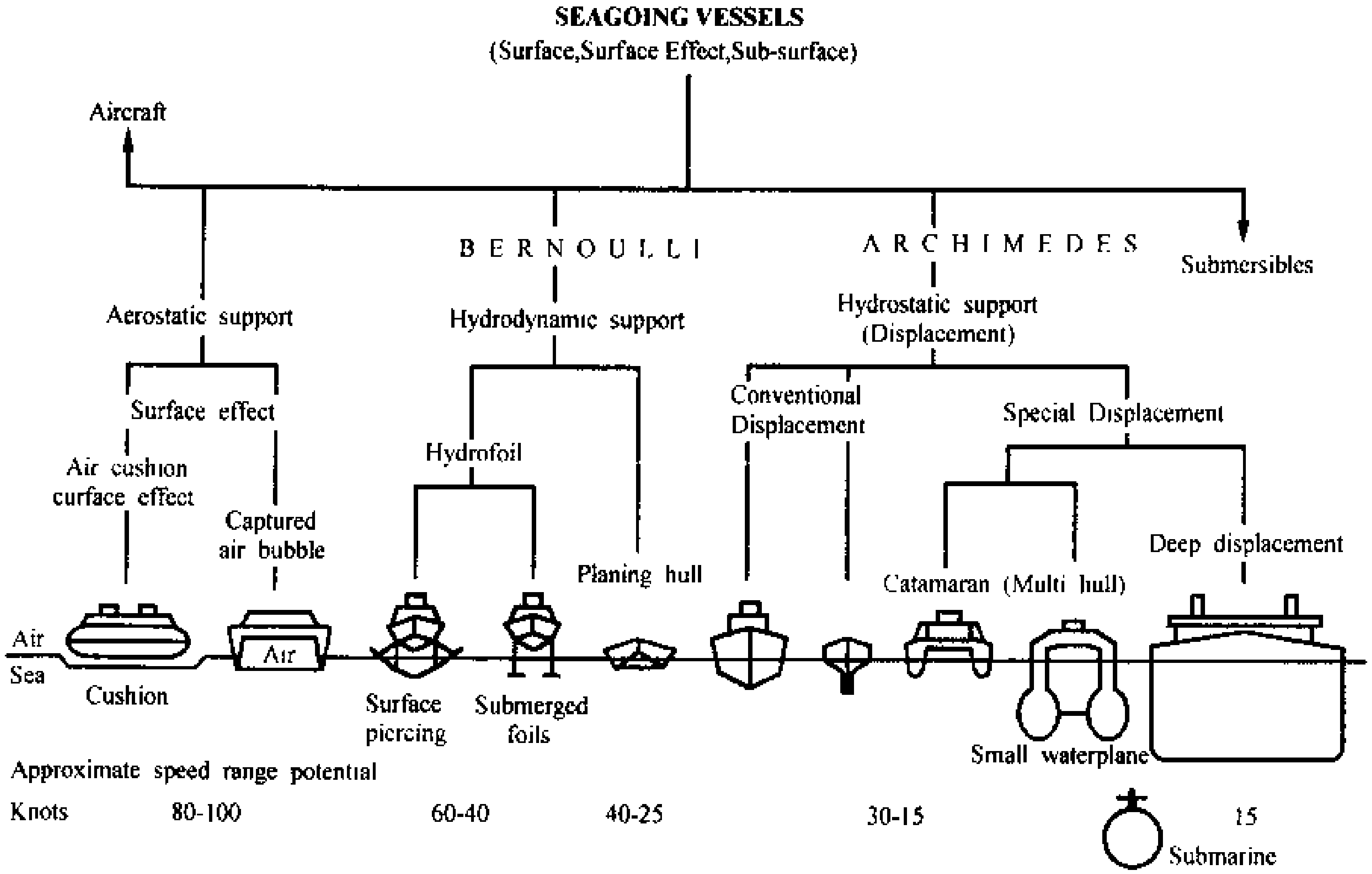


Figure2.1 Categories of seagoing vessels arranged according to their mode of support on or in the sea

salvage value remaining when the ship is sold. A "cashflow analysis" is made to establish what rate of return can be expected on the owner's investment.

New designs of all commercial vessels, including cargo ships, passenger liners, fishing boats, offshore supply vessels, and tugboats, must compete economically with similar vessels available from the many worldwide shipbuilders. Government subsidies protecting the national shipbuilding industry from foreign competition can result in lower costs to the purchaser, even when the actual ship construction costs are higher. Thus, political considerations can play an important role in the economics of commercial ship design and construction.

Appearance, personal comfort, and reliability are necessary for a luxury passenger liner to attract customers, whereas payload, endurance, and ability to survive a hostile sea environment are important considerations in the design of fishing vessels. Offshore supply vessels are concerned with speed for oil-rig crew transport or emergency services, but slower speeds may be acceptable when payloads such as drill pipe and drilling mud are the principal cargo. Operating environment includes both wind and wave conditions at sea and port and harbor capabilities ashore. Thus, deep-draft vessels may be excluded from certain geographic areas. Special-purpose cargo-handling devices such as the unloading ramps on roll-on/roll-off (Ro/Ro) ships may be necessary for quick turn around both at principal worldwide ports and those of underdeveloped countries. The latter ports impose other cargo-handling restrictions on the ship designer.

Naval and Coast Guard Vessels

Naval vessels are generally classified as combatants or auxiliaries, although there are special-purpose craft that do not fit easily into either category. For large combatant warships such as aircraft carriers, guided-missile cruisers, destroyers, and nuclear submarines, all of the previously mentioned factors become important—hence the enormous cost of such ships. Their military mission is of prime importance, but carrying out the mission depends on speed, endurance (possibly aided by at-sea replenishment for surface ships), weapons payload, and ability to operate and survive in hostile environments. Reliability under combat conditions, the appearance of military power, crew habitability that influences reenlistments, and the political importance of who becomes the prime contractor and principal weapons-system subcontractors: all these are factors that must be taken into consideration, making the construction and operation of warships very expensive for taxpayers.

Naval auxiliaries are more closely related to commercial ships in appearance, but their mission may involve operating with warships, which requires compatibility in terms of speed, endurance, required payload, and the ability to conduct replenishment operations during poor sea conditions. Thus, one can expect the cost of such ships to be greater than that of their commercial counterparts.

Oceanographic research vessels, Coast Guard cutters, and ice-breakers all have missions in which endurance, reliability, ability to operate in difficult environments, and habitability are important. Since smaller vessels have limited fuel capacity, there is a trade-off between speed and endurance; hence two types of power plant are frequently used to optimize both speed and endurance. The more exotic craft discussed in the previous sections generally sacrifice payload and endurance for speed.

Pleasure Craft

Pleasure craft, both motor powered and sail powered, come in a wide variety of sizes and shapes to suit individual requirements and tastes. The economic tradeoffs are based on what the potential buyer can afford or thinks he can afford. Appearance, speed, personal comfort and habitability, and stability are the major criteria for designs that satisfy the purpose of the craft, which is the enjoyment of leisure time.

(摘自<Introduction to Naval Architecture> T. C. Gillmer & B. Johnson, London E. &F. N. SPON, 1982)

术语解释

naval architect	造船师
naval architecture	造船工程
categorize	分类
aerostatic	空气静力学的
self-induced	自身诱导的
cushion of air	气垫
lift fan	升力风扇
skirt	(气垫船)围裙
air cushion vehicle	气垫船
amphibious	两栖的
rigid side walls	刚性侧壁
captured-air-bubble vehicle	束缚气泡减阻船
supper cavitating propeller	超空泡螺旋桨
ferry	渡轮,渡口,渡运航线
cross-channel automobile ferries	横越海峡车客渡轮
polar-exploration craft	极地考察船
landing craft	登陆艇

riverine warfare vessel	内河舰艇
hydrodynamic	水动力学的
flow pattern	流型,流线谱
airfoil	气翼,翼剖面,机面,方向舵
hydrofoil	水翼
surface piercing	穿透水面的
strut	支柱、支撑构形
planing hull	滑行船体
V-section	V 型剖面
deep V hull	深 V 型船体
rough sea	汹涌的海浪
buoyant	浮力的
displacement	排水量
common carrier	通用运输船
trawling	拖网
crussing range	航程
seaworthness	适航性
bulk oil carrier	散装油轮
tanker	油轮
supertanker	超级油轮
LCC(Large Crude Carrier)	大型原油轮(载重 10~20 万吨)
VLCC(Very Large Crude Carrier)	巨型(原)油轮(载重量>20 万吨)
ULCC(Ultra Large Crude Carrier)	超级大型(原)油轮 (载重量>40 万吨)
SWATH(Small Waterplane Area Twin Hull)	小水线面双体船
multihull vessel	多体船
catamaran	双体船
trimaran	三体船

launch	发射,下水
launching equipment	(向水中)投放设备
configuration	安排,构型,配置
submersible	潜器
endurance	续航力
payload	有效载荷
merchant ship	商船
survivability	生存力
babitability	适居性
commercial ship	营利用船
freight rate	运费率
life-cycle cost	生命周期成本
acquisition cost	购置(获取)成本
pleasure ship	游乐用船
naval ship	军船
liner	定期航班船
tugboat	拖船
hostile sea	凶险的波浪
oil-rig	钻油架
roll-on/ro-off(Ro/Ro)	滚装
aircraft carrier	航空母舰
guided-missile cruiser	导弹巡洋舰
destroyer	驱逐舰
at-sea replenishment	海上补给
reenlistment	重征服役
icebreaker	破冰船
Coast Guard cutte	(美国)海岸警备队快艇

问　题

1. How many main categories of vessels are there in reference to the principles of supporting the hulls?

2. Please list at least ten types of ship mentioned in the text?

3. What does the Archimedes' Principle state?

4. What are the purposes mentioned in the text regarding using catamaran or multihull vessel concepts?

5. What are the main factors that influence the configurations of ship design?

6. Please indicate the ship types based on the purposes of the vessels?

Lesson 3 Principal Dimensions

Before studying in detail the various technical branches of naval architecture it is important to define various terms which will be made use of in later chapters. The pupose of this chapter is to explain these terms and to familiarise the reader with them. In the first place the dimensions by which the size of a ship is measured will be considered; they are referred to as 'principal dimensions'. The ship, like any solid body, requires three dimensions to define its size, and these are a length, a breadth and a depth. Each of these will be considered in turn.

3.1 Principal Dimensions

Length

There are various ways of defining the length of a ship, but first the length between perpendiculars will be considered. The length between perpendiculars is the distance measured parallel to the base at the level of the summer load waterline from the after perpendicular to the forward perpendicular. The after perpendicular is taken as the after side of the rudder post where there is such a post, and the forward perpendicular is the vertical line drawn through the intersection of the stem with the summer load waterline. In ships where there is no rudder post the after perpendicular is taken as the line passing through the centre line of the rudder pintals. The perpendiculars and the length between perpendiculars are shown in Figure 3.1.

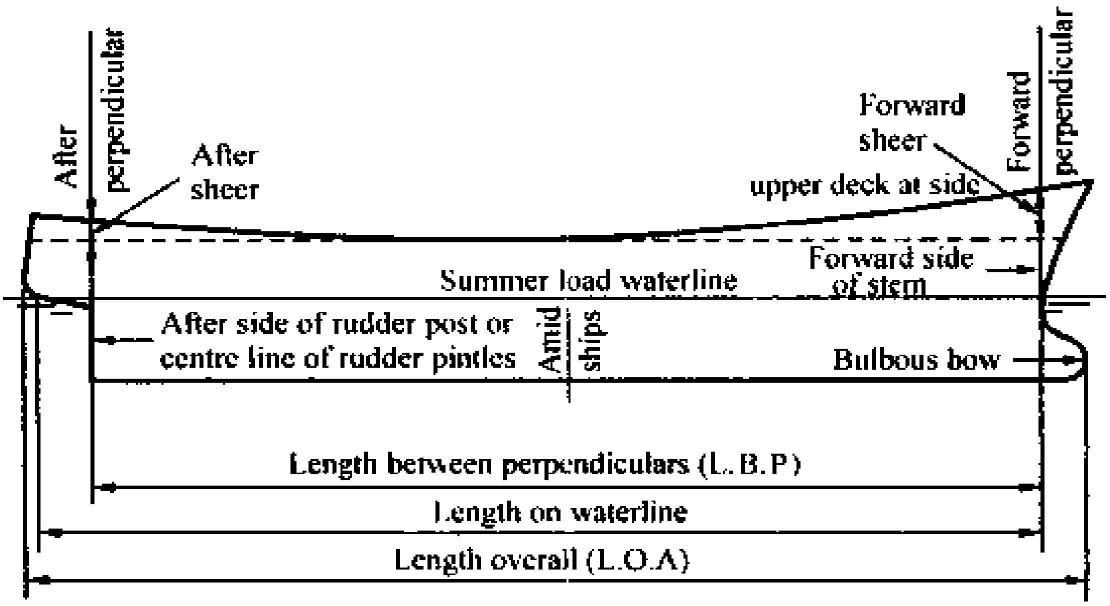


Figure 3.1

The length between perpendiculars (L.B.P.) is used for calculation purposes as will be seen later, but it will be obvious from Figure 3.1 that this does not represent the greatest length of the ship. For many purposes, such as the docking of a ship, it is necessary to know what the greatest length of the ship is. This length is known as the 'length overall' and is defined simply as the distance from the extreme point at the after end to a similar point at the forward end. This can be clearly seen by referring again to Figure 3.1. In most ships the length overall will exceed by a considerable amount the length between perpendiculars. The excess will include the overhang of the stern and also that of the stem where the stem is raked forward. In modern ships having large bulbous bows the length overall (L.O.A.) may have to be measured to the extreme point of the bulb.

A third length which is often used, particularly when dealing with ship resistance, is the length on the waterline (L.W.L.). This is the distance measured on the waterline at which the ship is floating from the intersection of the stern with the waterline to the intersection of the stem with the waterline. This length is not a fixed quantity for a particular ship, as it will depend upon the waterline at which the ship is floating and upon the trim of the ship. This length is also shown in Figure 3.1.

Breadth

The mid point of the length between perpendiculars is called 'amidships' and the ship is usually broadest at this point. The breadth is measured at this position and the breadth most commonly used is called the 'breadth moulded'. It may be defined simply as the distance from the inside of plating on one side to a similar point on the other side measured at the broadest part of the ship.

As is the case in the length between perpendiculars, the breadth moulded does not represent the greatest breadth of the ship, so that to define this greatest breadth the breadth extreme is required (see Figure 3.2). In many ships the breadth extreme is the breadth moulded plus the thickness of the shell plating on each side of the ship. In the days of riveted ships, where the strakes of shell plating were overlapped the breadth extreme was equal to the breadth moulded plus four thicknesses of shell plating, but in the case of modern welded ships the extra breadth consists of two thicknesses of shell plating only.

The breadth extreme may be much greater than this in some ships, since it is the distance from the extreme overhang on one side of the ship to a similar point on the other side. This distance would include the overhang of decks, a feature which is sometimes found in passenger ships in order to provide additional deck area. It would be measured over fenders, which are sometimes fitted to ships such as

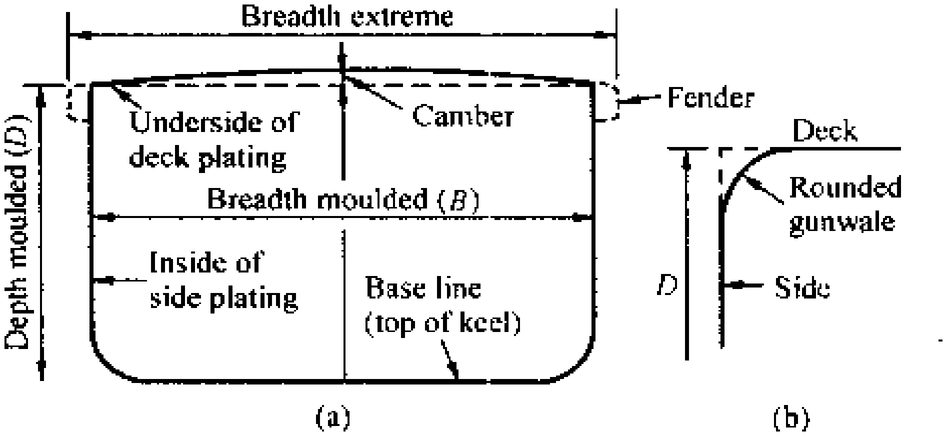


Figure 3.2

cross channel vessels which have to operate in and out of port under their own power and have fenders provided to protect the sides of the ships when coming alongside quays.

Depth

The third principal dimensions is depth, which varies along the length of the ship but is usually measured at amidships. This depth is known as the 'depth moulded' and is measured from the underside of the plating of the deck at side amidships to the base line. It is shown in Figure 3.2(a). It is sometimes quoted as a 'depth moulded to upper deck' or 'depth moulded to second deck', etc. Where no deck is specified it can be taken the depth is measured to the uppermost continuous deck. In some modern ships there is a rounded gunwale as shown in Figure 3.2(b). In such cases the depth moulded is measured from the intersection of the deck line continued with the breadth moulded line.

3.2 Other Features

The three principal dimensions give a general idea of the size of a ship but there are several other features which have to be considered and which could be different in two ships having the same length, breadth and depth. The more important of these will now be defined.

Sheer

Sheer is the height of the deck at side above a line drawn parallel to the base and tangent to the deck line at amidships. The sheer can vary along the length of the ship and is usually greatest at the ends. In modern ships the deck line at side often has a variety of shapes: it may be flat with zero sheer over some distance on either side of amidships and then rise as a straight line towards the ends; on the other hand there may be no sheer at all on the deck, which will then be parallel to the base over the entire length. In older ships the deck at side line was parabolic in profile and the sheer was quoted as its value on the forward and after perpendiculars as shown in Figure 3.1. So called 'standard' sheer was given by the formulae:

$$\text{Sheer forward (in)} = 0.2L_{\text{ft}} + 20$$

$$\text{Sheer aft (in)} = 0.1L_{\text{ft}} + 10$$

These two formulae in terms of metric units would give:

$$\text{Sheer forward (cm)} = 1.666L_{\text{m}} + 50.8$$

$$\text{Sheer aft (cm)} = 0.833L_{\text{m}} + 25.4$$

It will be seen that the sheer forward is twice as much as the sheer aft in these standard formulae. It was often the case, however, that considerable variation was made from these standard values. Sometimes the sheer forward was increased while the sheer after was reduced. Occasionally the lowest point of the upper deck was some distance aft of amidships and sometimes departures were made from the parabolic sheer profile. The value of sheer and particularly the sheer forward was to increase the height of the deck above water (the 'height of platform' as it was called) and this helped to prevent water being shipped when the vessel was moving through rough sea. The reason for the abolition of sheer in some modern ships is that their depths are so great that additional height of the deck above water at the fore end is unnecessary from a sea keeping point of view.

Deletion of sheer also tends to make the ship easier to construct, but on the other hand it could be said that the appearance of the ship suffers in consequence.

Camber

Camber or round of beam is defined as the rise of the deck of the ship in going from the side to the centre as shown in Figure 3.2(a). The camber curve used to be parabolic but here again often nowadays straight line camber curves are used or there may be no camber at all on decks. Camber is useful on the weather deck of a ship from a drainage point of view, but this may not be very important since the ship is very rarely upright and at rest. Often, if the weather deck of a ship is cambered, the lower decks particularly in passenger ships may have no camber at all, as this makes for horizontal decks in accommodation which is an advantage.

Camber is usually stated as its value on the moulded breadth of the ship and standard camber was taken as one-fiftieth of the breadth. The camber on the deck diminishes towards the ends of the ship as tbe deck breadths become smaller.

Bilge Radius

An outline of the midship section of a ship is shown in Figure 3.3(a). In many 'full' cargo ships the section is virtually a rectangle with the lower corners rounded off. This part of the section is referred to as the 'bilge' and the shape is often circular at this position. The radius of the circular arc forming the bilge is called the 'bilge radius'. Some designers prefer to make the section some curve other than a circle in way of the bilge. The curve would have a radius of curvature which increases as it approaches the straight parts of the section with which it has to link up.

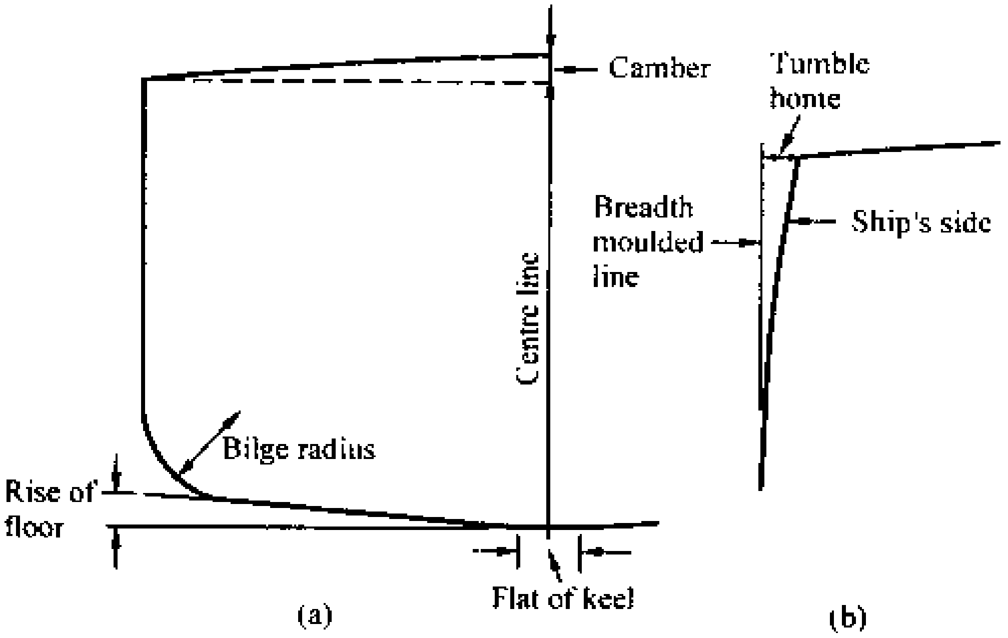


Figure 3.3

Rise of Floor

The bottom of a ship at amidships is usually flat but is not necessarily horizontal. If the line of the flat bottom is continued outwards it will intersect the breadth moulded line as shown in Figue 3.2(a). The height of this intersection above base is called the 'rise of floor'.

The rise of floor is very much dependent on the ship form. In ships of full form such as cargo ships the rise of floor may only be a few centimetres or may be eliminated altogether. In fine form ships much bigger rise of floor would be adopted in association with a larger bilge radius.

Flat of Keel

A feature which was common in the days of riveted ships was what was known as 'flat of keel' or 'flat of bottom'. Where there is norise of floor, of course, the bottom is flat from the centre line to the point where the curve of the bilge starts. If there was a rise of floor it was customary for the line of the bottom to intersect the base line some distance from the centre line so that on either side of the centre line there was a small portion of the bottom which was horizontal, as shown in Figure 3.3(a). This was known as the 'flat of bottom' and its value lay in the fact that a rightangle connection could be made between the flat plate keel and the vertical centre girder and this connection could be accomplished without having to bevel the connecting angle bars.

Tumble Home

Another feature of the midship section of a ship which was at one time quite common but has now almost completely disappeared is what was called 'tumble home'. This is the amount which the side of the ship falls in from the breadth moulded line, as shown in Figure 3.3(b). Tumble home was a usual feature in sailing ships and often appeared in steel merchant ships before World War II. Ships of the present day rarely employ this feature since its elimination makes for ease of production and it is of doubtful value.

Rake of Stem

In ships which have straight stems formed by a stem bar or a plate the inclination of the stem to the vertical is called the 'rake'. It may be defined either by the angle to the vertical or the distance between the intersection of the stem produced with the base line and the forward perpendicular. When ships have curved stems in profile, and especially where they also have bulbous bows, stem rake cannot be simply defined and it would be necessary to define the stem profile by a number of ordinates at different waterlines.

In the case of a simple straight stem the stem line is usually joined up with the base line by a circular arc, but sometimes a curve of some other form is used, in which case several ordinates are required to define its shape.

Draught and Trim

The draught at which a ship floats is simply the distance from the bottom of the ship to the waterline. If the waterline is parallel to the keel the ship is said to be floating on an even keel, but if the waterline is not parallel then the ship is said to be trimmed. If the draught at the after end is greater than that at the fore end the ship is trimmed by the stern and if the converse is the case it is trimmed by the bow or by the head. The draught can be measured in two ways, either as a moulded draught which is the distance from the base line to the waterline, or as an extreme draught which is the distance from the bottom of the ship to the waterline. In the modern welded merchant ship these two draughts differ only by one thickness of plating, but in certain types of ships where, say, a bar keel is fitted the extreme draught would be measured to the underside of the keel and may exceed the moulded draught by 15～23cm (6～9in). It is important to know the draught of a ship, or how much water the ship is 'drawing', and so that the draught may be readily obtained, draught marks are cut in the stem and the stern. These are figures giving the distance from the bottom of the ship. In imperial units the figures are 6in high with a space of 6in between the top of one figure and the bottom of the next one. When the water level is up to the bottom of a particular figure the draught in feet has the value of that figure. If metric units are used then the figures would probably be 10cm high with a 10cm spacing.

In many large vessels the structure bends in the longitudinal vertical plane even in still water, with the result that the base line or the keel does not remain a straight line. The mean draught at which the vessel is floating is not then simply obtained by taking half the sum of the forward and after draughts. To ascertain how much the vessel is hogging or sagging a set of draught marks is placed amidships so that if $d_a, d_{\otimes}$ and d_f are the draughts at the after end, amidships and the forward end respectively then

$$\text{Hog or sag} = \frac{d_a + d_f}{2} - d_{\otimes}$$

When use is made of amidship draughts, it is necessary to measure the draught on both sides of the ship and take the mean of the two readings in case the ship should be heeled to one side or the other.

The difference between the forward and after draughts of a ship is called the 'trim', so that trim $T = d_a - d_f$, and as previously stated the ship will be said to be trimming by the stern or the bow according as the draught aft or the draught forward is in excess. For a given total load on the ship the draught will have its least value when the ship is on an even keel. This is an important point when a ship is navigating in restricted depth of water or when entering a dry dock. Usually a ship should be designed to float on an even keel in the fully loaded condition, and if this is not attainable a small trim by the stern is aimed at. Trim by the bow is not considered desirable and should be avoided as it reduces the 'height of platform' forward and increases the liability to take water on board in rough seas.

Freeboard

Freeboard may be defined as the distance which the ship projects above the surface of the water or the distance measured downwards from the deck to the waterline. The freeboard to the weather deck, for example, will vary along the length of the ship because of the sheer of the deck and will also be affected by the trim, if any. Usually the freeboard will be a minimum at amidships and will increase towards the ends.

Freeboard has an important influence on the seaworthiness of a ship. The greater the freeboard the greater is the above water volume, and this volume provides reserve buoyancy, assisting the ship to rise when it goes through waves. The above water volume can also help the ship to remain afloat in the event of damage. It will be seen later that freeboard has an important influence on the range of stability. Minimum freeboards are laid down for ships under Internationl Law in the form of Load Line Regulations.

(摘自<Naval Architecture for Marine Engineers>W. Muckle, 1975)

术语解释

principal dimensions	主尺度
perpendicular	(船艏、艉)柱，垂直的，正交的
forward/after perpendicular	艏/艉柱
length between Perpendicular	两柱间长
stem	船艏
summer load water line	夏季载重水线
rudder post	舵柱
pintle	销，枢轴
dock	泊靠
length overall	总长
overhang	外悬

stern	艉
rake	倾斜
bulbous bow	球状船艏,球鼻艏
trim	纵倾
amidships	舯
breadth moulded	型宽
breadth extreme	最大宽,计算宽度
shell plating	船壳板
fender	护舷
quay	(横)码头,停泊所
depth	船深
rounded gunwale	修圆的舷边
sheer	(甲板)舷弧
sheer forward	艏舷弧
sheer aft	艉舷弧
deck line at side	甲板边线
camber	梁拱
drainage	排(泄)水
rise of floor	底升
bilge	舭,舱底
flat of keel	平板龙骨
rivet	铆接,铆钉
girder	桁梁,桁架
bevel	折角
bar	型材,材
tumble home	(船侧)内倾
seakeeping	适航性
base line	基线
trim by the stern/bow	艉/艏倾

bar keel	棒龙骨,方龙骨,矩形龙骨
draught(=draft)	吃水,草图,设计图,牵引力
imperial unit	英制单位
metric unit	公制单位
hog	中拱
sag	中垂
dry dock	干船坞
freeboard	干舷
weather deck	露天甲板
seaworthness	适航性
Load Line Regulations	载重线公约、规范
sheer profile	纵剖线
accommodation	居住(舱室)
bilge radius	舭半径
reserve buoyancy	储备浮力
heel	横倾

问　题

1. What kinds of length have been referred to for a ship in this text?

2. What are the terms indicating the greatest length and width of a ship?

3. Should the uppermost deck of a ship be cambered for the sake of drainage?

4. What does it mean by saying that a ship is "trimmed by the stern"?

5. Why is it necessary to consider a minimum freeboard in designing a ship?

Lesson 4 Basic Geometric Concepts

The main parts of a typical ship together with the terms applied to the principal parts are illustrated in Fig. 4. 1. Because, at first, they are of little interest or influence, superstructures and deckhouses are ignored and the hull of the ship is considered as a hollow body curved in all directions, surmounted by a watertight deck. Most ships have only one plane of symmetry, called the middle line plane which becomes the principal plane of reference. The shape of the ship cut by this plane is known as the sheer plan or profile. The design waterplane is a plane perpendicular to the middle line plane, chosen as a plane of reference at or near the horizontal; it may or may not be parallel to the keel. Planes perpendicular to both the middle line plane and the design waterplane are called transverse planes and a transverse section of the ship does, normally, exhibit symmetry about the middle line. Planes at right angles to the middle line plane, and parallel to the design waterplane are called waterplanes, whether

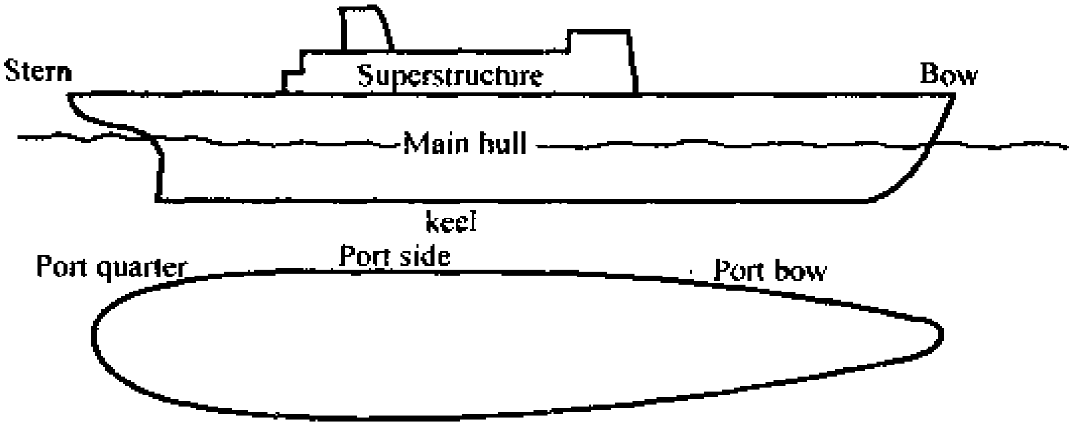


Figure 4.1

they are in the water or not, and they are usually symmetrical about the middle line. Waterplanes are not necessarily parallel to the keel. Thus, the curved shape of a ship is best conveyed to our minds by its sections cut by orthogonal planes. Figure 4. 2 illustrates these planes.

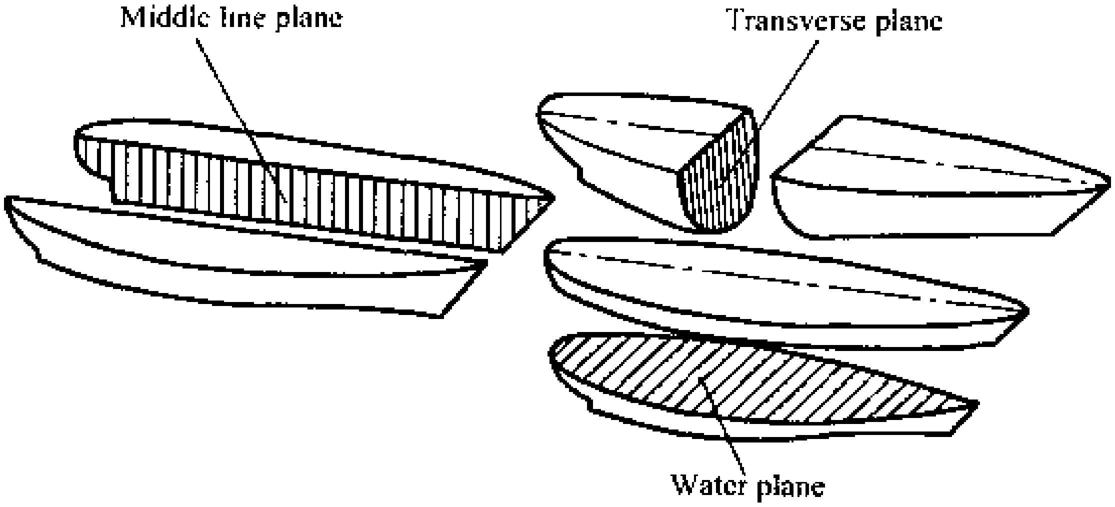


Figure 4.2

Transverse sections laid one on top of the other form a body plan which, by convention, because the sections are symmetrical, shows only half sections, the forward half sections on the right-hand side of the middle line and the after half sections on the left. Half waterplanes placed one on top of the other form a half breadth plan. Waterplanes looked at edge on in the sheer or body plan are called water lines. The sheer, the body plan and the half breadth collectively are called the lines plan or sheer drawing and the three constituents are clearly related. (See Fig. 4. 3)

It is convenient if the waterplanes and the transverse planes are equally spaced and datum points are needed to start from. That waterplane to which the ship is being designed is called the load

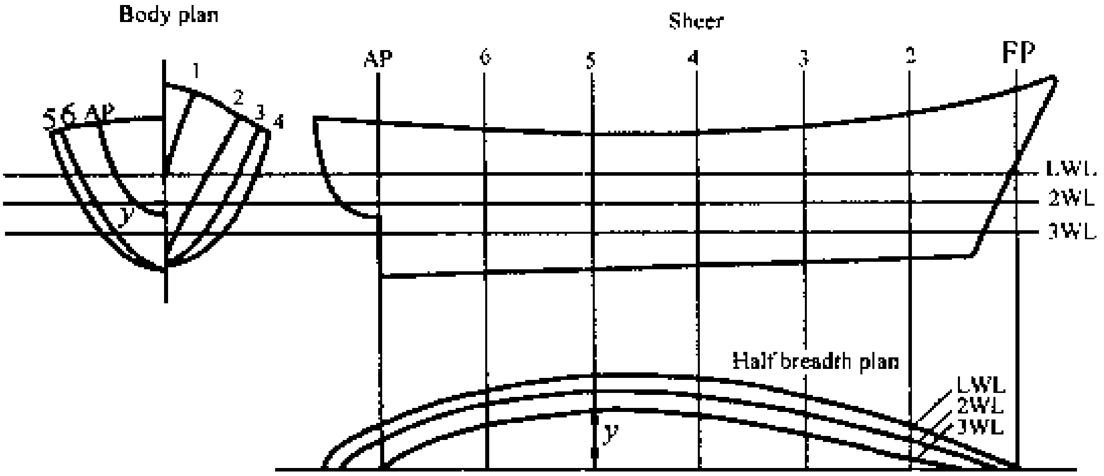


Figure 4.3

waterplane (LWP) or design waterplane and additional waterplanes for examining the ship's shape are drawn above it and below it, equally spaced, usually leaving an uneven slice near the keel which is best examined separately.

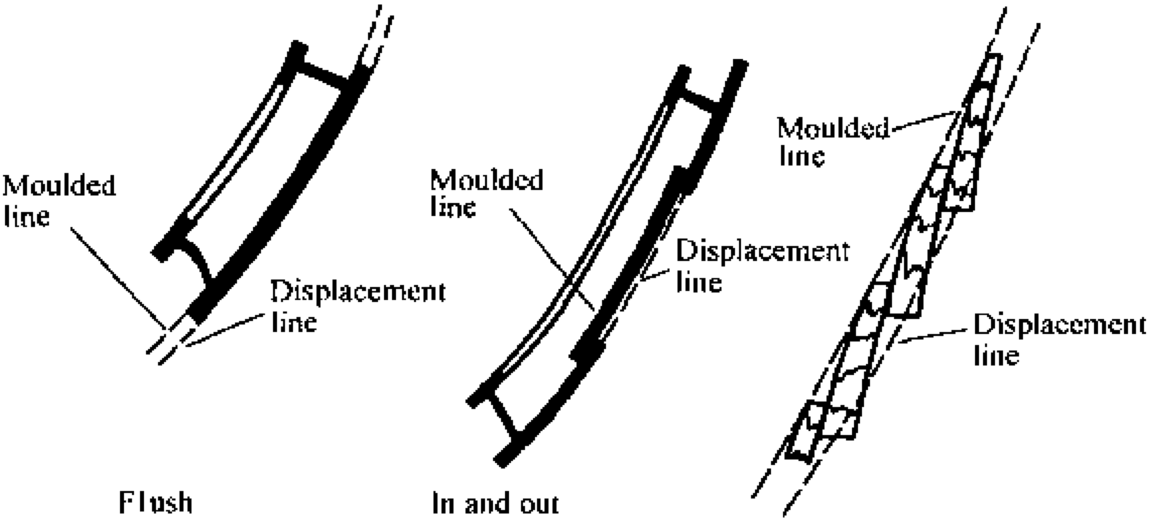
A reference point at the fore end of the ship is provided by the intersection of the load waterline and the stem contour and the line perpendicular to the LWP through this point is called the fore perpendicular (FP). It does not matter where the perpendiculars are, provided that they are precise and fixed for the ship's life, that they embrace most of the underwater portion and that there are no serious discontinuities between them. The after perpendicular (AP) is frequently taken through the axis of the rudder stock or the intersection of the LWL and transom profile. If the point is sharp enough, it is sometimes better taken at the after cut up or at a place in the vicinity where there is a discontinuity in the ship's shape. The distance between these two convenient reference lines is called the length between perpendiculars (LBP or LPP). Two other lengths which will be referred to and which need no further explanation are the length overall and the length on the waterline.

The distance between perpendiculars is divided into a convenient number of equal spaces, often twenty, to give, including the FP and the AP, twenty-one evenly spaced ordinates. These ordinates are, of course, the edges of transverse planes looked at in the sheer or half breadth and have the shapes half shown in the body plan. Ordinates can also define any set of evenly spaced reference lines drawn on an irregular shape. The distance from the middle line plane along an ordinate in the half breadth is called an offset and this distance appears again in the body plan where it is viewed from a different direction. All such distances for all waterplanes and all ordinates form a table of offsets which defines the shape of the hull and from which a lines plan can be drawn. A simple table of offsets is used to calculate the geometric particulars of the form.

A reference plane is needed about mid-length of the ship and, not unnaturally, the transverse plane midway between the perpendiculars is chosen. It is called amidships or midships and the section of the ship by this plane is the midship section. It may not be the largest section and it should have no significance other than its position halfway between the perpendiculars. Its position is usually defined by the symbol Φ.

The shape, lines, offsets and dimensions of primary interest to the theory of naval architecture are those which are wetted by the sea and are called displacement lines, ordinates, offsets, etc. Unless otherwise stated, this book refers normally to displacement dimensions. Those which are of interest to the shipbuilder are the lines of the frames which differ from the displacement lines by the thickness of hull plating or more, according to how the ship is built.

These are called moulded dimensions. Definitions of displacement dimensions are similar to those which follow but will differ by plating thicknesses.



Flush In and out

Figure 4.4 Moulded and displacement lines

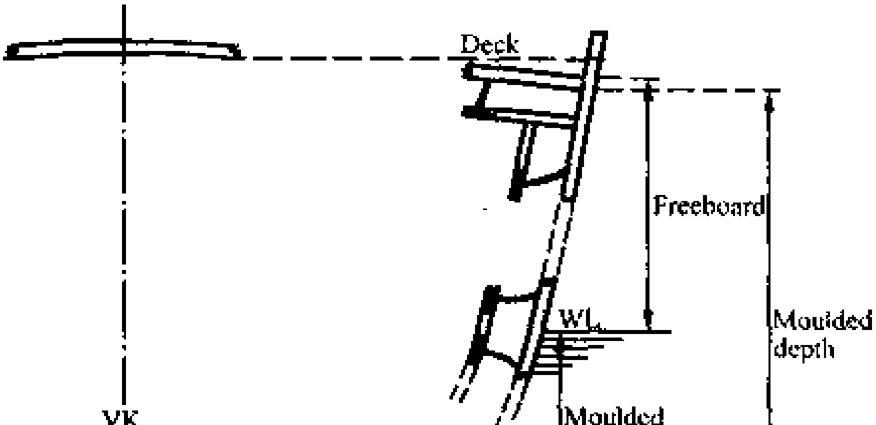


Figure 4.5

The moulded draught is the perpendicular distance in a transverse plane amidships. The draught amidships is the mean draught unless the mean draught is referred directly to draught mark readings.

The moulded depth is the perpendicular distance in a transverse plane from the top of the flat keel to the underside of deck plating at the ship's side. If unspecified, it refers to this dimension amidships.

Freeboard is the difference between moulded depth at side and moulded draught. It is the perpendicular distance in a transverse plane from the waterline to the upperside of the deck plating at side.

The moulded breadth extreme is the maximum horizontal breadth of any frame section. The terms breadth and beam are synonymous.

Certain other geometric concepts of varying precision will be found useful in defining the shape of the hull. Rise of floor is the distance above the keel that a tangent to the bottom at or near the keel cuts the line of maximum beam amidships. See Fig. 4.6.

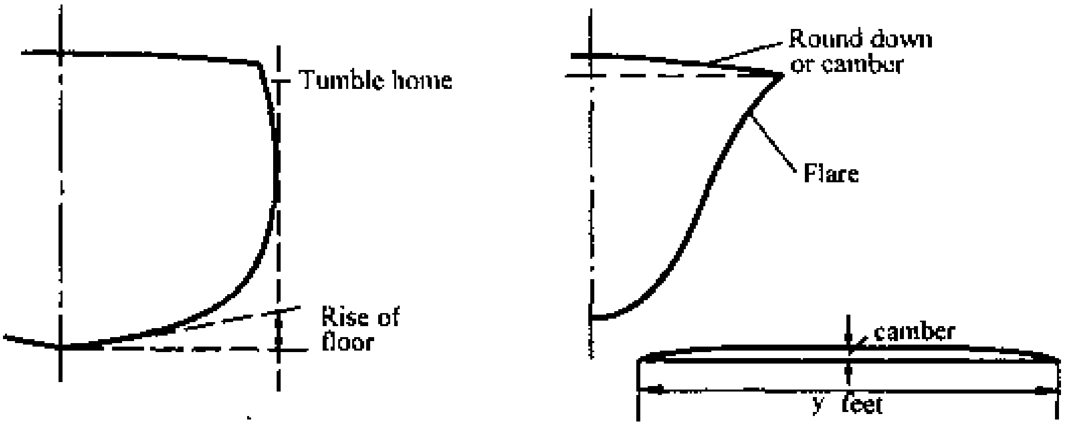


Figure 4.6

Tumble home is the tendency of a section to fall in towards the middle line plane from the vertical as it approaches the deck edge.

The opposite tendency is called flare. See Fig.4.6.

Deck camber or round down is the curve applied to a deck transversely. It is normally concave downwards, a parabolic or circular curve, and measured as x inches in y feet.

Sheer is the tendency of a deck to rise above the horizontal in profile.

Rake is the departure from the vertical of any conspicuous line in profile such as a funnel, mast, stem contour, superstructure, etc. (Fig.4.7).

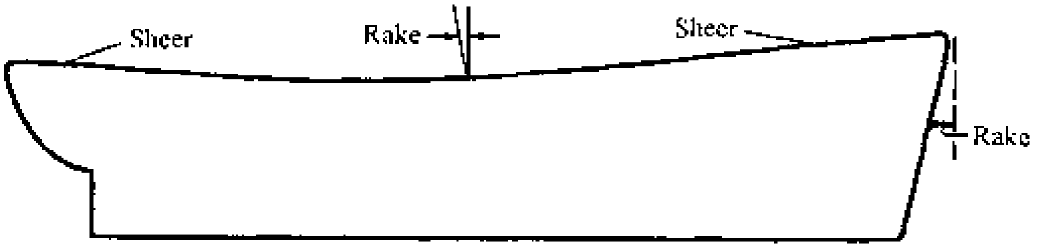


Figure 4.7

There are special words applied to the angular movements of the whole ship from equilibrium conditions. Angular bodily movement from the vertical in a transverse plane is called heel. Angular bodily movement in the middle line plane is called trim. Angular disturbance from the mean course of a ship in the horizontal plane is called yaw or drift. Note that these are all angles and not rates, which are considered in later chapters.

There are two curves which can be derived from the offsets which define the shape of the hull by areas instead of distances which will later prove of great value. By erecting a height proportional to the area of each ordinate up to the LWP at each ordinate station on a horizontal axis, a curve is obtained known as the curve of areas. Figure 4.8 shows such a curve with number 4 ordinate, taken as an example. The height of the curve of areas at number 4 ordinate represents the area of number 4 ordinate section; the height at number 5 is proportional to the area of number 5 section and so on. A second type of area curve can be obtained by examining each ordinate section. Figure 4.8 again takes 4 ordinate section as an example. Plotting outwards from a vertical axis, distances corresponding to the areas of a section up to each waterline, a curve known as a Bonjean curve is obtained. Thus, the distance outwards at the LWL is proportional to the area of the section up to the LWL, the distance outwards at 1WL is proportional to the area of section up to 1WL and so on. Clearly, a Bonjean curve can be drawn for each section and a set produced.

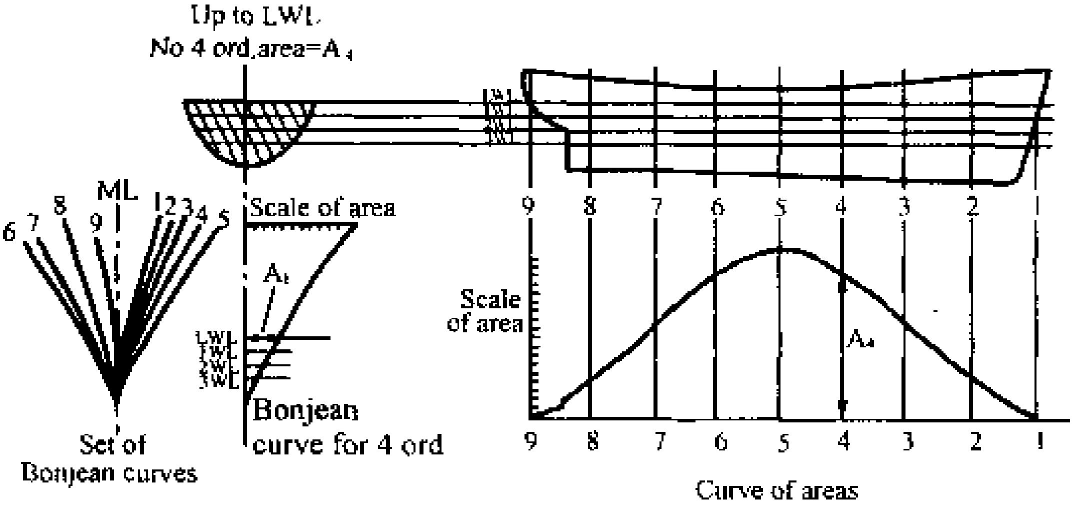


Figure 4.8

The volume of displacement, ∇, is the total volume of fluid displaced by the ship. It is best conceived by imagining the fluid to be wax and the ship removed from it; it is then the volume of the impression left by the hull. For convenience of calculation, it is the addition of the volumes of the main body and appendages such as the slices at the keel, abaft the AP, rudder, bilge keels, propellers, etc., with subtractions for condensor inlets and other holes.

Finally, in the definition of hull geometry there are certain coefficients which will later prove of value as giuides to the fatness or slimness of the hull.

The coefficient of fineness of waterplane, C_{WP}, is the ratio of the area of the waterplane to the area of its circumscribing rectangle. It varies from about 0.70 for ships with unusually fine ends to about 0.90 for ships with much parallel middle body.

$$C_{WP} = \frac{A_W}{L_{WL}B}$$

The midship section coefficient, C_M, is the ratio of the midship section area to the area of a rectangle whose sides are equal to the draught and the breadth extreme amidships. Its value usually exceeds 0.85 for ships other than yachts.

$$C_M = \frac{A_M}{BT}$$

The block coefficient, C_B, is the ratio of the volume of displacement to the volume of a rectangular block whose sides are equal to the breadth extreme, the mean draught and the length between perpendiculars.

$$C_B = \frac{\nabla}{BTL_{PP}}$$

Mean values of block coefficient might be 0.88 for a large oil tanker, 0.60 for an aircraft carrier and 0.50 for a yacht form.

The longitudinal prismatic coefficient, C_P, or simply prismatic coefficient is the ratio of the volume of displacement to the volume of a prism having a length equal to the length between perpendiculars

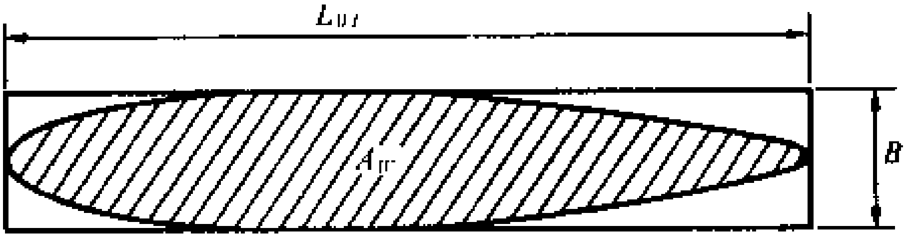


Figure 4.9 Waterplane coefficient

and a cross-sectional area equal to the midship sectional area. Expected values generally exceed 0.55.

$$C_P = \frac{\nabla}{A_M L_{PP}}$$

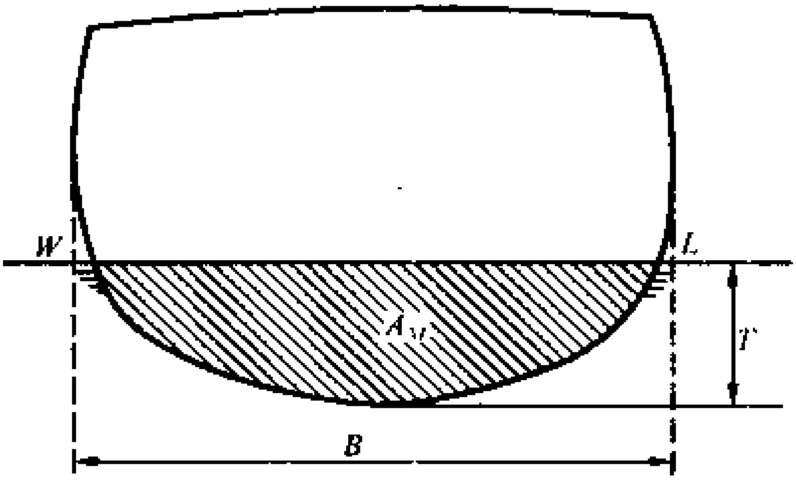


Figure 4.10 Midship coefficient

The vertical prismatic coefficient, C_{VP} is the ratio of the volume of displacement to the volume of a prism having a length equal to the draught and a cross-sectional area equal to the waterplane area.

$$C_{VP} = \frac{\nabla}{A_W T}$$

Before leaving these coefficients for the time being, it should be observed that the definitions above have used displacement and not

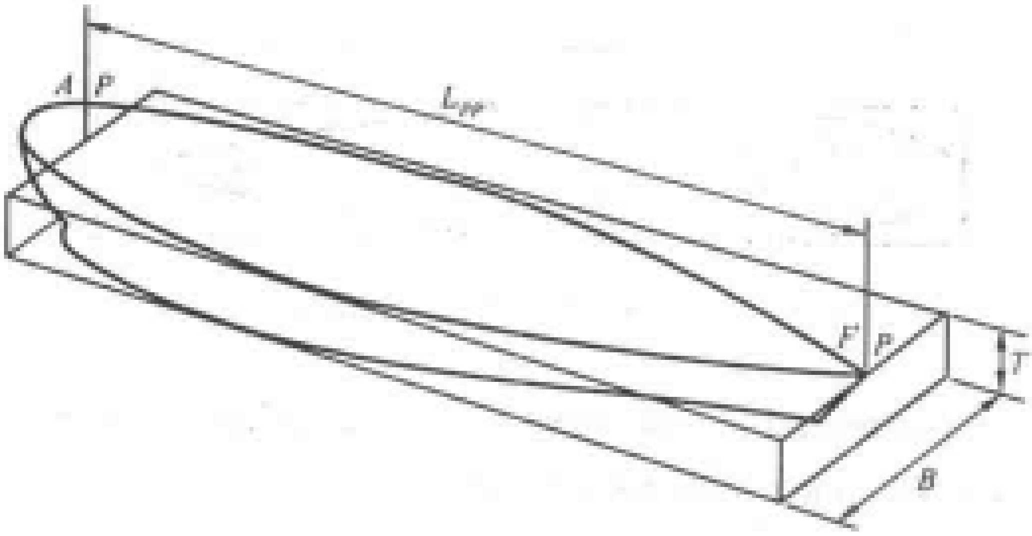


Figure 4.11 Block coefficient

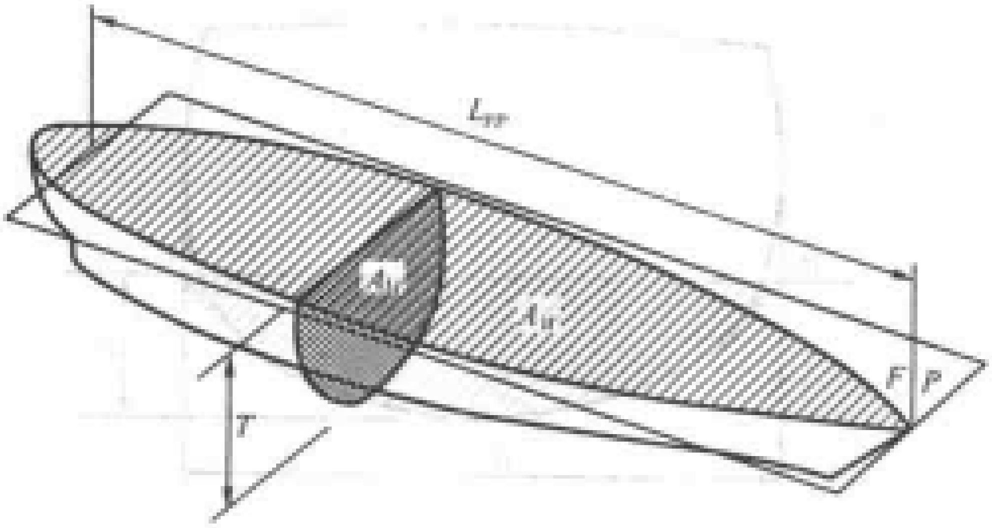


Figure 4.12 Longitudinal prismatic coefficient

moulded dimensions because it is generally in the very early stages of design that these are of interest. Practice in this respect varies a good deal. Where the difference is significant, as for example in the structural design of tankers by Lloyd's Rules, care should be taken to check the definition in use. It should also be noted that the values of the various coefficients depend on the positions adopted for the perpendiculars.

课外阅读

Additional reading I

Properties of Irregular Shapes

Now that the geometry of the ship has been defined, it is necessary to anticipate what properties of these shapes are going to be useful and find out how to calculate them.

Plane Shapes

Waterplanes, transverse sections, flat decks, bulkheads, the curve of areas and expansions of curved surfaces are some of the plane shapes whose properties are of interest. The area of a surface in the plane of Oxy defined in Cartesian coordinates, is

$$A = \int y \mathrm{d}x$$

in which all strips of length y and width δx are summed over the total extent of x. Because y is rarely, with ship shapes, a precise mathematical function of x the integration must be carried out by an approximate method which will presently be deduced.

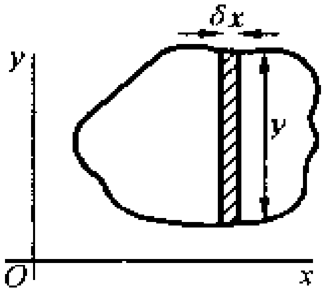


Figure 4.13

There are first moments of area about each axis. (For the figures shown in Fig.4.14, x_1 and y_1 are lengths and x and y are co-ordinates.)

$$M_{yy} = \int x y_1 \mathrm{d}x \quad \text{and} \quad M_{xx} = \int x_1 y \mathrm{d}y$$

Dividing each expression by the area gives the co-ordinates of the

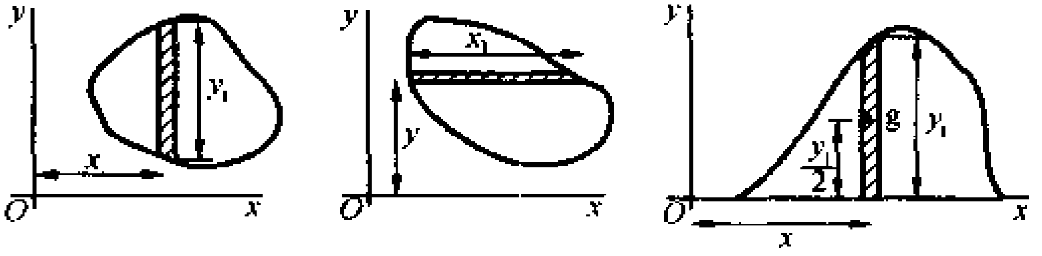


Figure 4.14

centre of area, $(\bar{x}, \bar{y})$:

$$\bar{x} = \frac{1}{A}\int x y_1 \mathrm{d}x \quad \text{and} \quad \bar{y} = \frac{1}{A}\int x_1 y \mathrm{d}y$$

For the particular case of a figure bounded on one edge by the x-axis

$$M_{y}^{*} = \int \frac{1}{2} y^2 \mathrm{d}x \quad \text{and} \quad \bar{y} = \frac{1}{2A}\int y_1^2 \mathrm{d}x$$

For a plane figure placed symmetrically about the x-axis such as a waterplane, $M_{xx} = \int x_1 y \mathrm{d}y = 0$ and the distance of the centre of area, called in the particular case of a waterplane, the centre of flotation (CF), from the y-axis is given by

$$\bar{x} = \frac{M_{yy}}{A} = \frac{\int x y_1 \mathrm{d}x}{\int y_1 \mathrm{d}x}$$

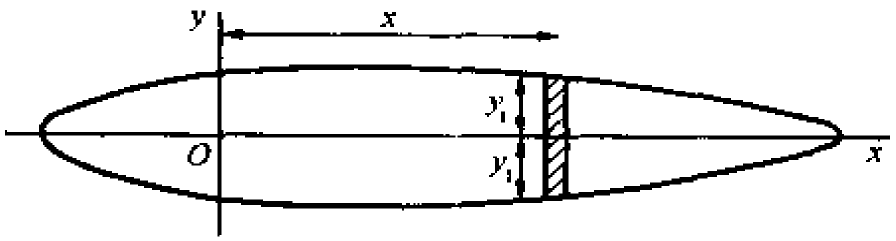


Figure 4.15

Additional reading 2

Some Tools

No occupation can be properly developed without tools, whether it be gardening or naval architecture or astro-navigation. Many tools needed for the study of naval architecture are already to hand, provided by mathematics, applied mechanics and physics and it will be necessary to assume as the book progresses that knowledge in all allied subjects has also progressed. Knowledge, for example, of elementary differential and integral calculus is assumed to be developing concurrently with this chapter. Moreover, the tools need to be sharp; definitions must be precise, while the devices adopted from mathematics must be pointed in such a way as to bear directly on ship shapes and problems. As a means of examining this science, these are the tools.

It is convenient too, to adopt a terminology or particular language and a shorthand for many of the devices to be used. In this chapter, which lays a firm foundation from which to build up the subject, some of the machines of use to the naval architect are examined. Finally, there are short notes on statistics and approximate formulae.

(摘自<Basic Ship Theory> K. Kawson & E. Tupper. Vol. 1, 1998)

术语解释

Superstructure	上层建筑
deckhouse	舱面室,甲板室

surmount	顶上覆盖,越过
middle line plane	中线面
sheer plane	纵剖面
water plane	水线面
keel	龙骨
transverse section	横剖面
orthogonal	正交的,矩形的
body plan	横剖面图
by convention	按照惯例,按约定
half breadth plan	半宽图
lines plan	型线图
sheer drawing	剖面图
load waterplane	载重水线面
slice	一部分,薄片
intersection	交点,交叉,横断(切)
fore/aft perpendicular	艏/艉 柱
vicinity	邻近,附近
length between perpendiculars	垂线间长
maximum beam amidships	舯最大宽
tumble home	内倾
flare	外飘,外张
rake	倾斜,倾斜度,倾斜角
conspicuous	显著的,值得注意的
funnel	烟囱
deck camber	甲板梁拱
concave	凹,凹的,拱形(的)
mast	桅杆
stem contour	艏柱型线
heel	横倾

yaw	艏摇
drift	漂移,偏航
Bonjean curve	邦戎曲线
conceive	设想,想像
impression	模槽,型腔,印痕,印象
appendage	附体
abaft	朝向船尾
rudder	舵
bilge	舭
circumscribe	外接,外切
rectangle	矩形
yacht	快艇
midship section coefficient	舯横剖面系数
block coefficient	方形系数
longitudinal prismatic coefficient	纵向棱形系数
vertical prismatic coefficient	垂向棱形系数
cross-sectional area	横剖面面积
Lloyd's Rules	劳埃德(船级社)规范
adopt	采用
principal dimensions	主尺度
length overall	总长
port	左舷
starboard	右舷
freeboard	干舷
beam	船身最大宽,横梁
girder	桁,梁
chine	舭,舷,脊
soft chine	圆舭
hard chine	尖舭

transom(stern)	方尾
cruiser stern	巡洋舰尾

问　　题

1. What is middle line plan?

2. What are the components of the lines plan? How do they relate to each other?

3. State the definitions of displacement, block coefficient, and vertical prismatic coefficient.

4. What are of primary interest to the theory of naval architecture?

Lesson 5 Ship Form and Form Coefficients

5.1 Introduction

The outside surface of a ship is the surface of a solid with curvature in two directions. The curves which express this surface are not in general given by mathematical expressions, although attempts have been made from time to time to express the surface mathematically. It is necessary to have some drawing which will depict in as detailed a manner as possible the outside surface of the ship. The plan which defines the ship form is known as a 'lines plan'. The lines plan consists of three drawings which show three sets of sections through the form obtained by the intersection of three sets of mutually orthogonal planes with the outside surface.

Consider first a set of planes perpendicular to the centre line of the ship. Imagine that these planes intersect the ship form at a number of different positions in the length. The sections obtained in this way are called 'body sections' and are drawn in what is called the 'body plan' as shown in Figure 5.1. When drawing the body plan half-sections only are shown because of the symmetry of the ship. The sections aft of amidships (the after body sections) are drawn on one side of the centre line and the sections forward of amidships (the fore body sections) are drawn on the other side of the centre line. It is normal to divide the length between perpendiculars into a number of divisions of equal length (often ten) and to draw a section at each of these divisions. Additional sections are sometimes drawn near the ends where the changes in the form become more rapid. In merchant ship practice the sections are numbered from the after perpendicular to the forward perpendicular—thus a.p. is 0 and f.p. is 10 if there are ten divisions. The two divisions of length at the ends of the ship would usually be subdivided so that there would be sections numbered $\frac{1}{2}$, $1\frac{1}{2}$, $8\frac{1}{2}$ and $9\frac{1}{2}$. Sometimes as many as 20 divisions of length are used, with possibly the two divisions at each end subdivided, but usually ten divisions are enough to portray the form with sufficient accuracy.

Suppose now that a series of planes parallel to the base and at different distances above it are considered. The sections obtained by the intersections of these planes with the surface of the ship are called 'waterlines' or sometimes 'level lines'. The lines are shown in Figure 5.1. The waterlines like the body sections are drawn for one side of the ship only. They are usually spaced about 1m (3~4ft) apart, but a closer spacing is adopted near the bottom of the ship where the form is changing rapidly. Also included on the half-breadth plan is the outline of the uppermost deck of the ship.

A third set of sections can be obtained by considering the intersection of a series of vertical planes parallel to the centre line of the ship with the outside surface. The resulting sections are shown in a view called the 'sheer profile' (see Figure 5.1) and are called 'buttocks' in the after body and 'bow lines' in the fore body or often simply 'buttocks'. The buttocks like the waterlines will be spaced 1m (3 ~ 4ft) apart. On the sheer profile the outline of the ship on the centre line is shown and this can be regarded as a buttock at zero distance from the centre line.

The three sets of sections discussed above are obviously not

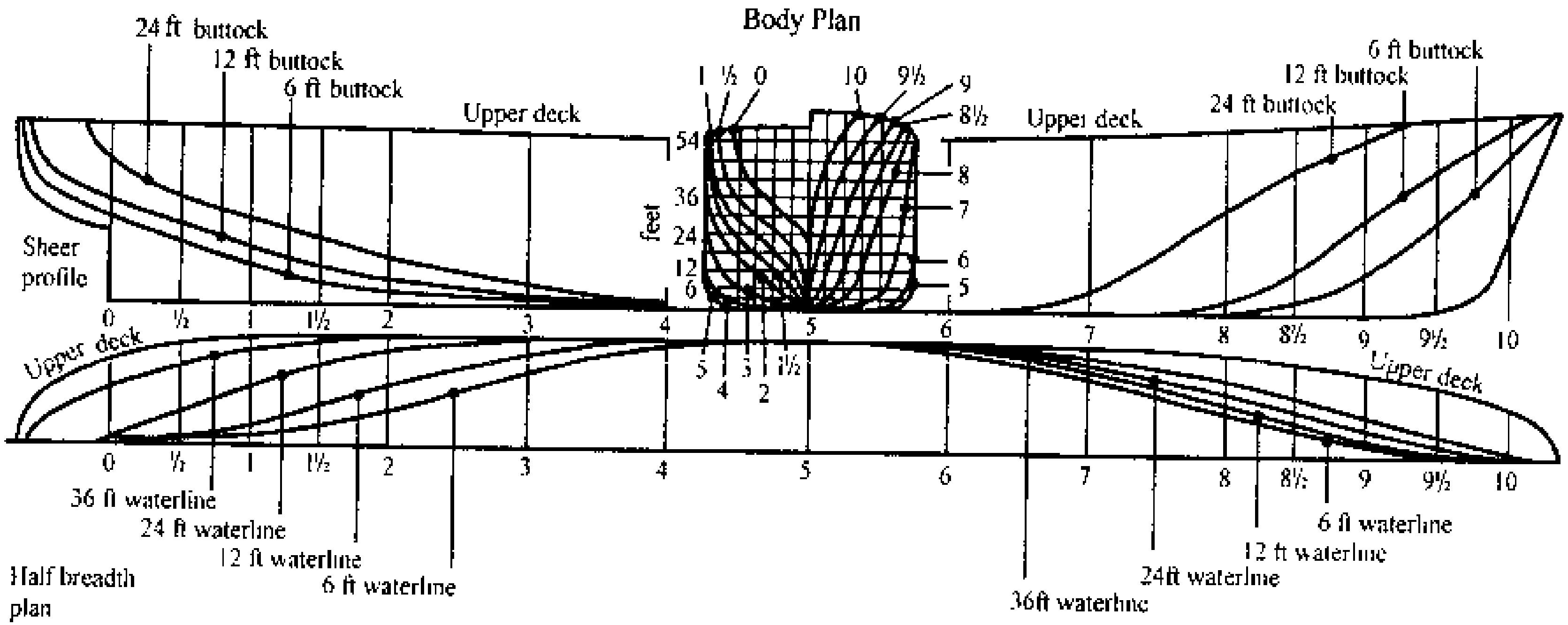


Figure 5.1 Lines plan

independent of one another, in the sense that an alteration in one will affect the other two. Thus, if the shape of a body section is altered this will affect the shape of both the waterlines and the buttocks. It is essential when designing the form of the ship that the three sets of curves should be 'fair' and their interdependence becomes important in this fairing process. What constitutes a fair curve is open to question but formerly the fairing process was done very largely by eye. Nowadays the lines plan is often faired by some mathematical means which will almost certainly involve the use of the computer. However the fairing process is carried out the design of the lines of a ship will normally start by the development of an approximate body plan. The designer when he has such a body plan will then lift offsets for the waterlines and will run the waterlines in the half-breadth plan. This means drawing the best possible curves through the offsets which have been lifted from the sections, and this is done by means of wooden or plastics battens. If it is not possible to run the waterlines through all the points lifted from the body plan then new offsets are lifted from the waterlines and new body sections drawn. The process is then repeated until good agreement is obtained between waterlines and body sections. It is then possible to run the buttocks, and to ensure that these are fair curves it may be necessary to adjust the shape of body sections and waterlines.

The process of fairing is usually done in the drawing office on a scale of 1/4in to 1 ft or on a 1/50 scale drawing. It is clear that a much more accurate fairing of the form is necessary for production purposes in particular, and this used to be done in the mould loft of the shipyard full size. The procedure was for the drawing office to send to the mould loft offsets from the lines as faired in the office and they were laid out full size on the loft floor. A contracted scale was adopted for the length dimension but waterline and section breadths and buttock heights were marked out full size. The same process of fairing was then adopted as used in the office, the fairing being done by using wood battens of about 25mm square section pinned to the loft floor by steel pins. To save space the waterlines and buttocks in the forward and after bodies were overlapped in the length direction. This type of full scale fairing enabled sections, waterlines and buttocks to be produced which represented the desired form with considerable accuracy. From the full scale fairing, offsets were lifted which were returned to the drawing office and made the basis of all subsequent calculations for the ship, as will be seen later.

A more recent development has been the introduction of 1/10 scale lofting, which can be done in the drawing office, and the tendency has been to dispense with full scale loft work. Several methods have also been developed for the mathematical fairing of ship forms and linking this up with production processes. Discussion of these topics, however, is outside the scope of this work.

The lines drawn on the lines plan representing the ship form are what are called 'moulded lines', which may be taken to represent the inside of the plating of the structure. The outside surface of the ship extends beyond the moulded lines by one thickness of shell plating in an all welded ship. When riveting was the usual method of construction, the shell plating was put on in a series of 'in' and 'out' strakes. In this case the outside surface of the ship extended two thicknesses of plating beyond the moulded lines in way of an outside strake and one thickness beyond the moulded lines in way of an inside strake. Actually the outside surface would be rather more than one thickness or two thicknesses of plating, as the case may be, beyond the moulded line in places where there is considerable curvature of the structure, as for example at the ends of the ship or below the level of the bilge.

In multiple screw merchant ships it is customary to enclose the wing shafts in what is called a 'shaft bossing'. This consists of plating, stiffened by frames, and extending from the point where the shafts emerge from the ship and ending in a casting called a 'shaft bracket'. The bossing is usually faired separately and added on to the main hull form. The bossing is treated as an appendage.

In many ships the shape of the cross section does not change for an appreciable distance on either side of amidships. This portion is called the 'parallel middle body' and may be of considerable extent in full ships but may not exist at all in fine fast ships.

Forward of the parallel middle the form gradually reduces in section towards the bow and in like manner the form reduces in section abaft the after end of the parallel middle. These parts of the form are called respectively the 'entrance' and the 'run' and the points where they join up with the parallel middle are referred to as the 'forward' and 'after shoulders'.

5.2 Requirements of Ship Form

The hull form of a ship must be designed to fulfil certain requirements, and the first to be considered is the provision of sufficient buoyancy to carry the various loads such as the weight of the ship itself, plus cargo, fuel, etc. In other words the ship form must provide a certain displacement up to the load waterline. Calling this displacement Δ it follows that

$$\Delta = \rho g V$$

were ρ is the density of the water in which the ship is floating, g is the acceleration due to gravity, and V is the underwater volume. It may be said, therefore, that the designer must so design the form that some underwater volume V is obtained.

Another important requirement of the underwater form is that the centroid of the volume must be in a particular position in the fore and aft direction. The importance of this will be seen in Chapter 5.

5.3 Form coefficients

If the ship form consisted simply of rectangular block of length equal to the length between perpendiculars, breadth equal to the breadth moulded, and depth equal to the draught, then the underwater volume would be given simply by

$$V = L \times B \times d$$

It will, however, be clear that the actual volume is less than the volume of this block, or in other words the ship form can be imagined to have been cut out of this block. What is called the 'block coefficient' is the ratio of the actual volume of the underwater form to the volume *LBd*. In other words

$$\text{Block coefficient } C_B = \frac{V}{L \times B \times d} \qquad (5-1)$$

When the ship designer has decided what volume is required he then has four factors to consider: the length, breadth and draught of the ship, and also the block coefficient. There is an infinite number of combinations of these factors which will give the required result and the problem is to decide what are the best values of the four parameters. In the meantime, however, the block coefficient only will be considered. Generally it is governed by resistance considerations. At this stage it may be said that fast ships require low values of block coefficient while in slow ships high values of the block coefficient are permissible. In slow speed ships, say of the bulk carrier type, a high value of block coefficient means a large displacement on given principal dimensions, which means that there is a large amount of displacement available for the carriage of cargo. In fast ships it is essential to keep down the value of the block coefficient, so they normally have lower block coefficients than slow ships. The influence of block coefficient on the shape of the hull form is that in ships with high values of this coefficient considerable parallel middle is likely to be found and the slopes of the waterlines at the ends are steep, whereas with low block coefficients parallel middle is often quite short or may not exist at all and the slopes of the waterlines at the ends will be small also.

Another coefficient which is useful is what is known as the 'prismatic coefficient'. The ship form could be imagined to have been cut from a prism of length equal to the length of the ship and of constant cross section of area equal to the immersed midship area. Thus

$$\text{Prismatic coefficient } C_P = \frac{V}{\text{Midship area} \times L} \qquad (5-2)$$

This particular coefficient has its use in dealing with ship resistance.

A coefficient which is used to express the fullness of the midship section is the midship area coefficient. If the midship section is imagined to be cut out of a rectangle of dimensions breadth × draught then

$$\text{Midship area coefficient } C_m = \frac{\text{Midship area}}{B \times d} \qquad (5-3)$$

The three coefficients so far discussed are related to one another since

$$C_B = \frac{V}{L \times B \times d} = \frac{V}{\text{Midship area} \times L} \times \frac{\text{Midship area}}{B \times d}$$

$$C_B = C_P \times C_m \tag{5-4}$$

Generally speaking, as the block coefficient becomes finer the midship area coefficient becomes finer, as does the prismatic coefficient.

The waterplane area of a ship, i.e. the area enclosed by any particular waterline, can also be expressed in terms of a coefficient and the area of the circumsecting rectangle. Hence waterplane area coefficient

$$C_W = \frac{\text{Waterplane area}}{L \times B} \tag{5-5}$$

One other coefficient is sometimes used in defining the ship form. This is the ratio of the underwater volume to the volume of a prism of cross-sectional area equal to the waterplane area, and length equal to the draught so that

$$\text{Vertical prismatic coefficient } C_{PV} = \frac{V}{\text{Waterplane area} \times d} \tag{5-6}$$

It will be seen that

$$\therefore \quad \frac{V}{L \times B \times d} = \frac{V}{\text{Waterplane area} \times d} \times \frac{\text{Waterplane area}}{L \times B}$$

or

$$C_B = C_{PV} \times C_W \tag{5-7}$$

The values of these coefficients can give useful information about the ship form. It has already been stated that the value of the block coefficient gives an idea of whether the form is full or fine and will indicate whether the waterlines will have large angles of inclination to the centre line at the ends. A large value of the vertical prismatic coefficient will indicate body sections of U-form whilst a small value of this coefficient will be associated with V-shaped sections.

For any particular ship the form coefficients vary with draught, becoming smaller for lower draughts, and hence they have their greatest values at the load draught. Since the coefficients are nondimensional, they are very useful in comparing one ship with another and for geometrically similar ships they will have the same values at corresponding draughts.

The volume of displacement and the areas used in calculating the coefficients are usually taken to the moulded lines of the ship so that moulded dimensions must be used, i. e. length between perpendiculars, breadth moulded and draught moulded. In special cases it might be found desirable to use volumes and areas to the extreme dimensions, that is the volume of displacement may include the displacement of the shell and cruiser stern, and in modern vessels bulbous bow displacement beyond the forward perpendicular. In such cases extreme dimensions should then be used in calculating the coefficients, i. e. the length on the waterline plus the projection of the bulbous bow forward of the forward perpendicular, the breadth overall and the draught to the bottom of the keel. In like manner where areas are concerned the waterplane area and the midship area may be taken overshell.

（摘自<Basic Ship Theoroy> K. Kawson & E. Tupper. Vol. 1, 1998）

术语解释

ship form	船型
lines plan	型线图
orthogonal	正交的
body section	横剖图
division	站，划分，分隔

base, base line	基线
water line	水线
sheer profile	纵剖图
buttock	后体纵剖线
bow line	前体纵剖线
fair	光顺
offsets	型值
lift offsets	量取型值
(to) run the waterlines	绘制水线
batten	压条,板条
drawing office	绘图室
scale	缩尺,尺度,尺
mould loft	放样间
shipyard	船厂
full scale	全尺度
loft floor	放样台
contracted scale	缩尺
mark out	划线,划记号
pin	钉,销
moulded line	型线
in strake	内列板
out strake	外列板
in way of…	在…处
wing shaft	侧轴
shaft bossing	轴包套
stiffen	加劲,加强
frame	框架,肋骨
shaft bracket	轴支架
appendage	附件,附体

cross section	横剖面
amidships	在舯部，舯
parallel middle body	平行中体
fine fast ship	纤细（细长）高速船
abaft	朝船尾
entrance	进流段
run	去流段
forward/after shoulder	前/后肩
buoyancy	浮力
load waterline	载重水险
from coefficient	船形系数
block coefficient	方形系数
bulk carrier	散装货船
prismatic coefficient	棱形系数
immerse	浸入，浸没
circumsection	外切
midship area coefficient	舯横剖面系数
waterplane area coefficient	水线面积系数
prism	棱柱体
vertical prismatic coefficient	垂向棱形系数
U-form	U 型
V-shaped	V 形的
full form	丰满船型
fine form	瘦长（细长）船型

问题

1. What are the drawings needed for depicting a ship form?

2. Please explain the following terms: lines plan, body plan, body

section, sheer profile and waterline.

3. What is the reason of drawing only half-section of the body plan of common ship forms?

4. Why is it necessary sometimes to have smaller lengths of divisions near the two ends of a vessel?

5. Why are the three sets of sections of a ship dependant on each other?

Lesson 6 Classification Societies

6.1 Introduction

Two important groups of organisations which exert considerable influence on the design, construction and safety of ships are classification societies and governmental authorities. The former have a quite long history and have established standards of construction by the production of rules which have done a great deal to ensure the safety of ships. A shipowner is not compelled to build his ship to the rules of such a society but it will be found that the vast majority of ships are so built. Classification is defined as 'a division by groups in order of merit' and this was precisely what was attempted in the early days of ship classification. It was done for the benefit of shipowners, cargo owners and underwriters in order to ascertain if a particular ship represented a reasonable risk. The origin of classification is associated with the name Lloyd's Register of Shipping, which is the oldest society.

Governmental authorities are concerned with the safety of ships and the well being of all who sail in them. In the UK the authority concerned is the Department of Trade (formerly the Board of Trade) and the rules which they produce are compulsory as far as the shipowner is concerned. Should a ship not meet the standards laid down by such an Authority it would not be allowed to sail.

The work of classification societies and governmental authorities overlap to a certain extent and such is the standing of the former that governments often delegate authority to them. For instance, classification societies are concerned to a very considerable extent with the strength of the ship's structures, so that a government authority would accept the strength of a ship as being adequate if it was built to the rules of such a society.

6.2 Lloyd's Register of Shipping

The original system of classification adopted by Lloyd's was to use the notation A E I O U, referring to the quality of the hull, and to use the letters G, M or B(good, middling or bad) to describe the condition of the equipment (anchors, cables, etc.). In the process of time, however, the idea of setting up one uniform standard of construction developed and this became 100 A1, where 100A referred to the hull when built to the highest standards laid down in the rules of the Society, and 1 referred to the equipment. In addition it will be found that there is a cross placed before 100A1 so that the classification becomes ✠ 100A1. The cross indicated that a ship had been built under the supervision of the Society's surveyors. Lloyd's came into existence before the development of mechanical means of propulsion. It is now common practice for machinery to be surveyed as well as the hull, so that the notation LMC (Lloyd's machinery certificate) will be found in the register.

Since Lloyd's Rules cover a wide variety of ship types the type is indicated after the classification symbol. Thus classes such as 100A1 oil tanker, 100A1 liquefied gas carrier, 100A1 ore carrier, etc., will be found in the Register.

Going back to the early days of classification it was the practice to class ships in terms of age and place of building, ships built in the North of England being given a lower classification than those in the

South. Shipowners became dissatisfied with this practice and in the early nineteenth century they issued their own register (the Green Book), which was really in competition with Lloyd's Register. Eventually, however, it became evident that the two organisations could not survive separately and amalgamation took place in 1834, from which date Lloyd's Register, as it is known today, really began. The Society is free from control by government and is run by a committee composed of members of the Industry, which operates on behalf of the Industry.

The Register is published annually and gives particulars of ships of 100 tons gross and upwards, whether classed by Lloyd's or not, and is thus an extremely useful index of world shipping. Statistics are published quarterly regarding shipbuilding activities throughout the world.

6.3 Activities of Lloyd's Register

Lloyd's Register was originally concerned in the survey of ships' hulls and their equipment. With developments in ships, however, it has become necessary for the Society to deal with other matters as well. It has already been pointed out that the survey of machinery is now included. Other problems with which the Society deals include special types of ships such as oil tankers, liquefied gas carriers, dredgers, hopper barges, etc., and pumping and piping, fire protection, detection and extinction, boilers and other pressure vessels, electrical equipment, refrigerated cargo installations and materials for construction.

With the passage of time and the consequent development in ship technology the rule book produced by the Society, which was originally very simple, has become much more complex and even in recent years, considerable developments have taken place. Before 1939, for example, the scantlings of the structural members of the ship could all be determined from the principal dimensions of the ship, L, B and D. These scantlings were governed by two numbers $L \times (B + D)$ and $L \times D$. This procedure proved inadequate for the developments in the post-1945 era and without going into details it can be said that since that time many revisions have taken place and a much more fundamental look has been taken at the problem of structural strength.

The rules originally developed were largely empirical and the scantlings of the structure laid down were those which practice had shown to be adequate. This approach to the determination of scantlings could be said to exist still. Lloyd's Register collects data on ship casualties and analysis of these data suggests areas where modifications should be made. This empirical process is of course backed up by research work carried out by the Society. There is also co-operation with other research organisations.

In order to ensure that a ship which has been built in accordance with the Rules still complies with the highest standards, surveys are to be carried out from time to time during its life. All steel ships are first of all to be surveyed at intervals of approximately one year. These annual surveys deal with a number of relatively minor items which require a yearly check and also require the freeboard marks on the side of the ship to be verified. More comprehensive surveys called 'special surveys' are to be carried out at four-yearly intervals throughout the ship's life. These surveys include the requirements of the annual survey and become progressively more stringent with the age of the ship. Amongst other things which are required to be checked are the scantlings of the structure because of deterioration oue to corrosion. Where plating, for example, has been reduced in thickness due to this cause, replacement is required. It is not possible to detail here all the requirements of these special surveys: they are listed in Lloyd's Rules and Regulations for the Construction and Classification of Steel Ships.

A brief outline has been given here of the origin and development of Lloyd's Register of Shipping. More detailed information can be found in a paper by Archer, and the reader is also recommended to study the Rules themselves and also the Register for amplification of many of the matters discussed here.

Lloyd's Register is the oldest classification society and has been considered here, but the development of the other societies which now exist throughout the world has followed a somewhat similar pattern. Some of these societies are Bueau Veritas (France). Det Norske Veritas (Norway), American Bureau of Shipping (USA), Germanischer Lloyd (Germany), Registro Italiano Navale (Italy), and Nippon Kaiji Kyokai (Japan). Societies such as these nowadays consult together in matters of common interest in classification and the development of efficient and improved structural standards. Consultation is carried on through the International Association of Classification Societies (I. A. C. S.). Whilst the primary function of classification societies is still that of classifying ships, they now do very much more than this. They give advice to shipowners and builders on special structural arrangements and are always prepared to vet any new proposals. In recent years they have been instrumental in developing new methods of designing and analysing structures and in so doing are fulfilling an important function in improving ship structures while at the same time contributing towards the design of safe ships.

Activities have been extended to other types of marine vehicles such as oil rigs, and some societies do a considerable amount of work with land based structures.

6.4 Governmental Authorities

Legislation regarding the safety of ships is the responsibility of the government of the country concerned with registering the ship. In the UK this originally came under the Board of Trade and at the present time is the concern of the Department of Trade. This Department is empowered to draw up rules by virtue of a number of Merchant Shipping Acts extending back more than a hundred years. The Department of Trade employ surveyors who examine ships to verify that they are built in accordance with the regulations. Some of the matters with which the Department of Trade is concerned are:

Load lines
Tonnage
Master and crew spaces
Watertight subdivision of passenger ships
Life-saving appliances
Carriage of grain cargoes
Dangerous cargoes.

Some of these topics are now the subject of international regulations, e. g. load lines, tonnage, and regulations relative to passenger ships. Some of these will be considered in a little more detail.

6.5 Load Lines

The question of limiting the depth to which a ship can load is one on which there has been much discussion over the last hundred years. In the nineteenth century Lloyd's Register had some simple rules for limiting draught but there was no enforcement of rules as far as the Government was concerned. Lloyd's gave the rule that a ship should have 3in freeboard for each foot of depth of hold. It was not until the last quarter of the nineteenth century that the question of introducing legislation through Parliament was seriously considered. Load line limitation is popularly associated with the name of Samuel Plimsoll, who was the Member of Parliament responsible for introducing a bill to limit the draught to which a ship could load. The familiar mark which is now to be seen on ships is often called the Plimsoll line, although its official name is the 'load line mark'.

It is not proposed to consider the history of the development of load line limitation here, but it is clear that there should be some minimum volume of the ship above water, for three reasons, which will become more evident from later chapters. It is sufficient to state here that, first, a minimum freeboard is required so as to provide reserve buoyancy when a ship moves through waves, so that it can rise as the sea passes. This prevents to a large extent water coming on board and thus makes for a dry ship. Secondly, as will be seen later, the more of the ship there is above water the greater will be the range of stability. The third point is that the ship requires reserve buoyancy so that in the event of damage it can remain afloat, at least for a sufficient length of time to allow those on board to get off.

Although the question of a minimum freeboard is really a dynamic one, the rules as set out at present governing the computation of the freeboard are essentially based on static considerations. It is probable that in the future development of regulations concerning freeboards the dynamic behaviour of the ship at sea will be considered.

Freeboard is measured downwards from a deck which is called the 'freeboard deck'. This is defined as the uppermost complete deck exposed to the weather and sea which has permanent means of closing and below which the sides of the ship are fitted with permanent means of watertight closure. Alternatively, a deck lower than this may be considered to be the freeboard deck, subject to its being a permanent deck which if continuous all fore and aft and athwartships.

Basic freeboards are given in the present Load Line Regulations in two tables, one for ships of Type A and one for ships of Type B. These minimum freeboards depend upon the length of the ship. A Type A ship is one which is designed to carry liquid cargoes only in bulk and has only small gasketed openings to the cargo tanks. A further requirement for a ship of this type is that if over 150m long and designed to have empty compartments it shall be capable of floating with any one of such compartments flooded. A ship of Type B is a ship other than one of Type A. The difference between the tabular freeboards for the two types can be seen from Table 6.1.

Table 6.1 Freeboards of type A and type B ships

length (m)		25	50	100	150	200	250	300	350
Freeboard (mm)	Type A	208	443	1135	1968	2612	3012	3262	3406
	Type B	208	443	1271	2315	3269	4018	4630	5160

6.6 Recent Developments in Tonnage Measurement

Further developments in regard to tonnage measurement have taken place in recent years. In 1969 an International Conference on the Tonnage Measurement of Ships was convened in London by the Inter-governmental Maritime Consultative Organisation (I. M. C. O.). The results of this Conference have been given in a paper by Wilson. The attempt was made to simplify existing tonnage regulations and to reduce the calculation of gross and net tonnages to formulae. The formulae can be stated as follows:

$$\text{Gross tannage } (GT) = K_1 V \tag{6-1}$$

$$\text{Net tonnage } (NT) = K_2 V_c \left(\frac{4d}{3D}\right)^2 + K_3\left(N_1 + \frac{N_2}{10}\right) \tag{6-2}$$

Where

V = total volume of all enclosed spaces of the ship in cubic metres

$K_1 = 0.2 + 0.02\log_{10} V$

V_c = total volume of cargo spaces in cubic metres

$K_2 = 0.2 + 0.02\log_{10} V_c$

$K_3 = 1.25\,\dfrac{GT + 10\ 000}{10\ 000}$

D = moulded depth amidships in metres

d = moulded draught amidships in metres

N_1 = number of passengers in cabins with not more than eight berths

N_2 = number of other passengers

$N_1 + N_2$ = total number of passengers the ship is permitted to carry as indicated on the ship's passenger certificate

When $N_1 + N_2$ is less than 13, N_1 and N_2 shall be taken as zero

GT = gross tonnage of the ship.

In the above the factor $(4d/3D)^2$ is not to be taken as greater than unity and the term $K_2 V_c (4d/3D)^2$ is not to be taken as less than 0.25 GT.

The volumes referred to in these formulae are to be calculated to the inside of plating and include the volumes of appendages. Volumes of spaces open to the sea are excluded.

In the proposed new system of calculating tonnage the tonnage mark referred to in the previous section was abolished, although the inclusion of draught in the formulae suggests the variation of the tonnage with the draught for which the ship is designed.

The regulations shown above for determining the tonnage of ships are embodied in a new International Convention on Tonnage. At the time of writing (1973) this Convention has not replaced existing legislation but when a sufficient number of signatures to the Convention have ratified it, national regulations will be prepared by the governments (in the UK through the Department of Trade).

The proposed new regulations appear to simplify greatly what has been for a long period a very complex subject. However, it could be argued that in the process the basic philosophy behind the assessment of tonnage has been lost, or at least is no longer evident.

6.7 Other Tonnages

The tonnage of a ship calculated according to the existing regulations described in this chapter is accepted for ships today on international voyages, the tonnage of a ship being shown on its Tonnage Certificate. There are, however, special tonnages which are calculated slightly differently and shown on separate certificates. They are for ships trading through the Suez Canal, and the Panama

Canal. The former is at the present time of little interest, since the Suez Canal has now been closed for some years, but formerly the charges for passage through the Canal were based on this Suez Canal Tonnage. Similarly the charges for use of the Panama Canal were based on the Panama Tonnage.

6.8 Passenger Ships

Ships intended for the carriage of passengers are required to comply with very stringent safety regulations. For this purpose a passenger ship is defined as one which carries more than 12 passengers, and such a ship would be issued with a Passenger Certificate on compliance with the regulations. Present day passenger ship regulations are the outcome and interpretation of the findings of various international conferences on this subject which have taken place during the present century. Although the various maritime countries of the world had passenger regulations before 1912, it was the loss of the Titanic in that year which focused attention internationally on the safety of passenger ships. The Titanic sank with great loss of life on her maiden voyage when she struck an iceberg and was demaged in several compartments. In the UK a Bulkhead Committee was set up by the Board of Trade to investigate the strength and disposition of bulkheads in passenger ships, since the ability of a ship to float after damage was a subject which loomed large in the minds of those concerned with legislation after this disaster. The technical problems involved in flooding after damage will be discussed later.

It was considered that the safety of passenger ships was a subject for study on an international basis, so that after the Titanic disaster an international conference was held in 1914. The incidence of World War I interrupted further discussion, although the results of some of the findings were published during the war. It was not, however, until 1929 that another Conference was held and it was 1932 before the International Convention for the Safety of Life at Sea was signed by the major maritime nations. As has already been stated in connection with load lines and tonnage, the Convention then had to be ratified by the signatory nations and the findings incorporated in the law of the individual countries. The 1932 Convention was examined at later Conferences in 1948 and 1960 and certain modifications made in the light of experience. Another Conference will probably be held in 1976, when it is expected that major changes will be made in the whole approach to the assessment of safety.

The Safety Convention was not only concerned with the watertight subdivision of passenger ships and the associated problem of safety in the damaged condition, but also laid down regulations governing other aspects of safety, such as fire detection and extinguishing and fire protection, machinery and electrical installation, life saving appliances such as boats and the means for launching them, radiotelegraphy and radiotelephony, safety of navigation, carriage of grain and dangerous cargoes and regulations relative to nuclear ships.

课外阅读

Additional reading

Inter-governmental Maritime Organisation

The International Conference on the Safety of Life at Sea which took place in 1914 probably represents the first international approach to maritime problems of a technical nature. It has been seen that the subjects of load lines and tonnage have been studied on an international basis and regulations drawn up which are applicable to all countries signing the various conventions. In 1959 a permanent body was set up under the aegis of the United Nations to deal with all such matters in the future. This is called the Inter-governmental Maritime Consultative Organisation (I.M.C.O.). The Organisation has its headquarters in London. It has Committees drawn from the various maritime countries which meet periodically to discuss matters of mutual interest. From time to time I. M. C. O. arranges international Conferences such as the International Load Line Conference of 1966, the Tonnage Conference of 1969, and the International Conference on the Safety of Life at Sea, 1960. Conventions such as the Safety Convention may be amended by unanimous agreement between contracting governments and on the request of a government a proposed amendment will be communicated to the other governments. Alternatively, an amendment may be proposed to the Organisation by a contracting government and if adopted by a two-thirds majority of the Assembly of the Organisation upon the recommendation of the Maritime Safety Committee of the Organisation it will be communicated to the contracting government for their acceptance. A conference of governments to consider amendments to Conventions proposed by a contracting government can be convened at any time on the request of one-third of the contracting governments.

The formation of I. M. C. O. has made it easier to obtain amendments of existing Conventions and it is certain that this Organisation will play a big part in the future development of international legislation with regard to shipping.

（摘自<Basic Ship Theory> K. Kawson & E. Tupper. Vol. 1, 1998）

术语解释

classification society	船级社
governmental authorities	政府当局,管理机构
ship owner	船东
cargo owner	货主
underwriter	(海运)保险商
risk	保险对象,保险金额
Lloyd's Register of shipping	(英国)劳埃德船级社
Department of Trade	(英国)贸易部
Board of Trade	(英国)贸易厅
standard	规章
supervision of the Society's surveyor	船级社验船师的监造书
Lloyd's machinery certificate	(LMC)劳埃德(船舶)机械证书
register	(船舶)登录簿,船名录
fire protection, detection and extinction	防火,探火与灭火
liquefied gas carrier	液化气运输船
Green Book	(船级社)绿皮书,(19 世纪英国另一船级社的船名录,现合并于劳埃德船级社,用于登录快速远洋船)
ton gross = gross ton	长吨 = 1.016 公吨
dredge	挖泥船

hopper barge	(自动)倾卸驳
scantling	材积
casualty	事故,死伤,灾难
corrosion	锈蚀,腐蚀
Bureau Veritas	(法国)船级社
American Bureau of Shipping	(美国)船级社
Germanischer Lloyd	(德国)劳埃德船级社
Registo Italiano Navade	(意大利)船级社
International Association of Classification Society	(IACS)国际船级社联合会
to vet proposals	审查新建议
legislation	立法
Merchant Shipping Acts	商业运输法
life saving appliance	救生设备
carriage of grain cargoes	谷类货物输运机
introduces a bill	提出一项议案
Plimsoll line	普林索尔载重线
reserve buoyancy	储备浮力
freeboard deck	干舷甲板
athwart ships	(船)横向
Type A ship	A 类船
gasketed openings	装以密封垫的开口
compartment	舱室
tabular freeboard	列成表格的干舷船
Suez Canal tonnage	苏伊士运河吨位限制
Panama Canal	巴拿马运河
Stringent safety regulations	严格的安全规章
maritime	海事的,海运的,靠海的,沿海的
titanic	巨大的

the Titanic	泰坦尼克号(巨型游轮)
maiden voyage	处女航
flood	进水,泛滥
Inter-national Convention for the Safety of Life at Sea	(ICSOLAS)海上生命安全性国际公约
permanent body	永久性组织机构
aegis	保护,庇护
Inter-governmental Maritime Consultive Organization	(IMCO)国际政府间海事质询组织
The Register of Shipping of the People's Republic of China	中国船舶检验局

问　　题

1. What is the first ship classification society in the world?

2. How frequent will it be to survey a steel ship in compliance with the Lloyd's Rules?

3. From where can one find the requirements of a ship's special surveys?

4. What good is it to keep a minimum volume of a ship above water?

5. Is it necessary for a boat being built that is to carry 15 persons to get a Passenger Certificate from a classification society?

Chapter 2 Ship Rudiments

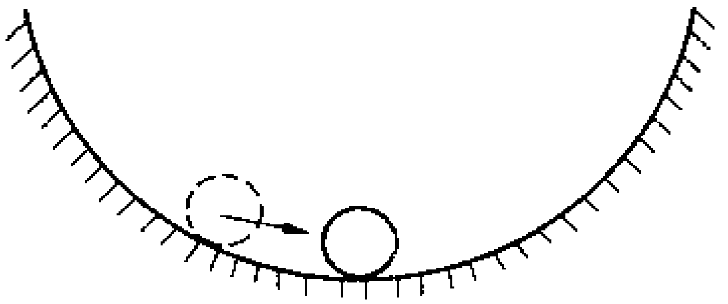
Lesson 7 Equilibrium and Stability

7.1 Introduction

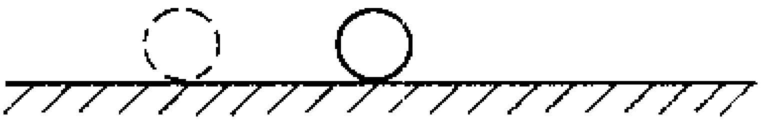
In chapter 2 the condition for static equilibrium was defined in terms of the balance of forces and moments. From Newton's laws of motion, it is seen that a body can be at rest or moving at constant speed only if the sum of all forces and moments acting on the body is equal to zero.

The concept of stability is somewhat more complex. Here, one is concerned with whether or not a body will return to an initial state of static equilibrium when disturbed by an unbalanced force or moment. While in the broader sense equilibrium refers to an overall balance of forces, which involves no acceleration or deceleration, static equilibrium is defined as follows: A body at rest is said to be in static equilibrium.

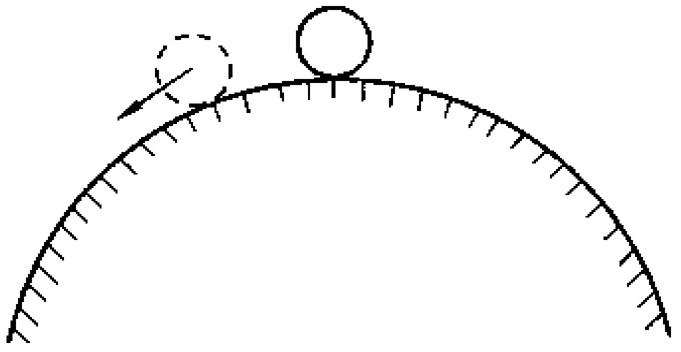
If this body is disturbed by an outside force and returns to its original position when the force is removed, it is said to be in stable equilibrium. An example of this condition is a round ball lying in an upward facing bowl, as in Figure 7.1(a). The ball will always return to its rest position when disturbed by an outside force. Figure 7.1 (b) illustrates the condition of neutral equilibrium. The ball lying on a flat horizontal plane will come to rest at any point on the plane if motion is started and then stopped by an outside force (including friction). Unstable equilibrium is illustrated in Figure 7.1(c), where a round ball is balanced on top of an inverted bowl. Any slight disturbance of the balanced position will result in the ball rolling off the bowl.



(a) Stable equilibrium



(b) Neutral equilibrium



(c) Unstable equilibrium

Figure 7.1 Static equilibrium: stable equilibrium (a), neutral equilibrium (b), unstable equilibrium (c)

For floating objects, the condition of stable equilibrium is illustrated by all vessels that tend to return to the original upright position when inclined by an external force. Neutral equilibrium is exhibited by a cylindrical, homogeneous cylinder floating in water that will come to rest at any position if imparted motion is stopped. Unstable equilibrium frequently occurs when a child attempts to place a doll in a toy boat before floating it in a bathtub. When released, the boy boat inclines until it capsizes or loses its occupant, at which point the boat may return to an upright position.

7.2 The Basis for Ship Equilibrium

Consider a ship floating upright on the surface of motionless water. In order to be at rest or in equilibrium, there must be no unbalanced forces or moments acting on it. There are two forces that maintain this equilibrium: the force of gravity and the force of buoyancy. When the ship is at rest, these two forces are acting in the same vertical line, and in order for the ship to float in equilibrium, they must be exactly equal numberically as well as opposite in direction.

The force of gravity acts at a point or center of gravity where all of the weights of the ship may be said to be concentrated. Gravity always acts vertically downward.

The force of buoyancy acts through the center of forces is considered to be acting. This force always acts vertically upward. When the ship is heeled, the shape of the underwater body is changed, thus moving the position of the center of buoyancy.

Now, when the ship is heeled by an external inclining force and the center of buoyancy has been moved from the centerline plane of the ship, there will usually be a separation between the lines of action of the force of gravity and the force of buoyancy. This separation of lines of action of the two equal forces, which act in opposite directions, forms a couple whose magnitude is equal to the product of one of these forces (that is, displacement) and the distance separating them. In Figure 7.2(a), where this moment tends to restore the ship to the upright position, the moment is called a positive righting moment, and the perpendicular distance between the two lines of action is the righting arm ($\overline{GZ}$).

Suppose now that the center or gravity is moved upward to such a position that when the ship is heeled slightly, the buoyant force acts in a line through the center of gravity. In the new position, there are no unbalanced forces, or in other words, the ship has a zero moment arm and a zero moment. In Figure 7.2(b) the ship is in neutral equilibrium, with both the righting moment and the righting arm equal to zero.

If one moves the center of gravity still higher, as in Figure 7.2 (c), the separation between the lines of action of the two forces as the ship is inclined slightly is in the opposite direction from that of Figure 7.2(a). In this case, the moment does not act in the direction that will restore the ship to the upright, but rather will cause it to incline further In such a situation, the ship has a negative righting moment, or capsizing moment, and a negative righting arm ($\overline{GZ}$).

These three cases illustrate the forces and relative position of their lines of action in the three fundamental states of equilibrium.

7.3 The Position of the Metacenter and Equilibrium

The metacenter M, discussed in chapter 3, is defined as the intersection of the vertical through the center of buoyancy of an inclined body or ship with the upright vertical when the angle of inclination approaches zero as a limit. This intersection then lies on both the line of action of the center of gravity when the ship is upright and the line of action of the buoyant force.

Consequently, it can be readily seen from the previous section that when the metacenter is above the center of gravity, as in Figure 7.2(a), there is a positivie righting moment formed when the ship is inclined, and the ship is in stable equilibrium.

When the metacenter and the center of gravity coincide, as in

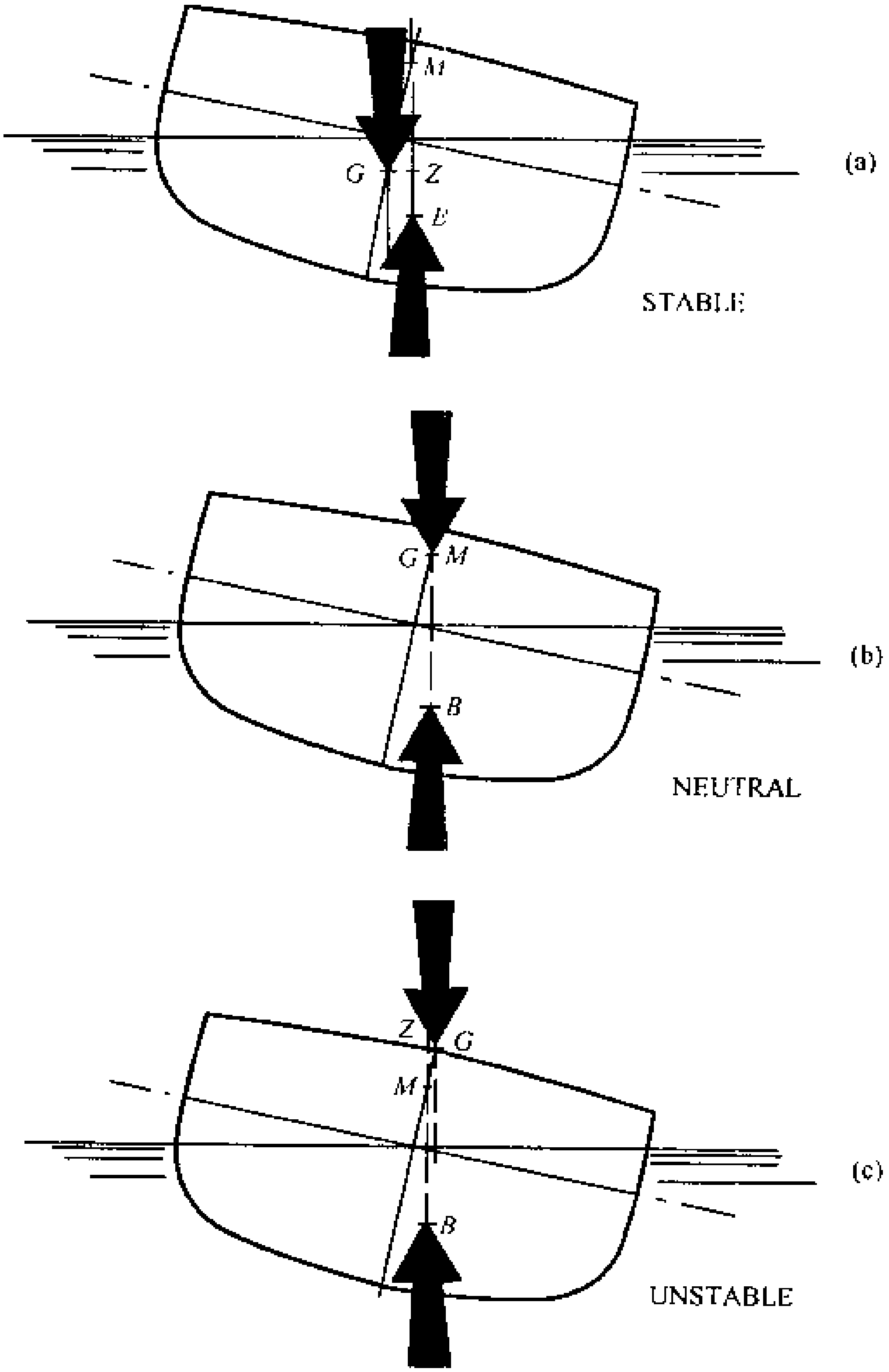


Figure 7.2 Stable (a), neutral (b), and unstable (c) equilibrium in the upright position. The hull is shown inclined by an outside force to demonstrate the tendency in each case.

Figure 7.2(b), no moment is produced and the ship is in neutral equilibrium.

When the metacenter is below the center of gravity, as in Figure 7.2(c), a negative or capsizing moment is formed, and the ship is in unstable equilibrium.

In considering this relation between the metacenter and the ship's state of equilibrium, it is necessary to remember that the definition of the metacenter is actually valid only for angles of inclination from 0° up to the range of 7° to 10°. Beyond this, the intersection of the lines of action of the center of buoyancy and the vertical centerplane of the ship has no significance. Therefore, the use of the relative positions of the metacenter and the center of gravity as a criterion of stability is limited to small angles of inclination. Obviously stability itself cannot be limited to such a restricted range. Consequently, one must differentiate between overall stability at any angle of inclination and initial stability at small angles of inclination ($\phi < 10°$).

7.4 Metacentric Height: A Measure of Initial Stability

The metacentric height, both transverse and longitudinal, is defined as the distance between the center of gravity and the transverse or longitudinal metacenter, measured vertically in the upright equilibrium position.

In Figure 7.3, the metacentric height is $\overline{GM}$, with the ship's center of gravity at either G or G_1. Unless other wise specified, the metacenter and metacentric height refer to the transverse metacentric height. If the longitudinal metacenter is being discussed, the associated metacentric height is designated $\overline{GM_L}$ and spoken of as the longitudinal metacentric height.

If M is above G, the metacentric height is positive. If M is below G, $\overline{GM}$ is negative.

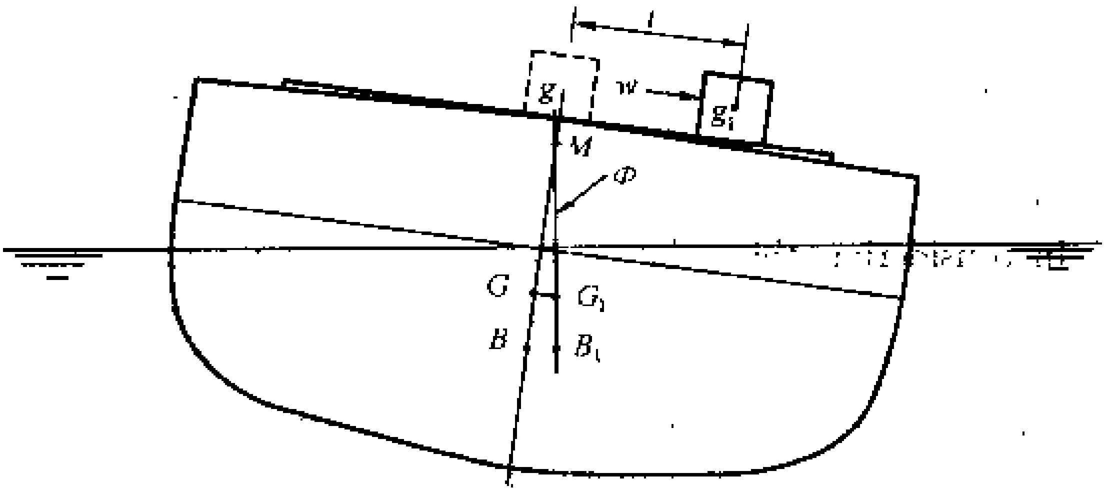


Figure 7.3 Inclined equilibrium

$\overline{GM}$ is the measure of the initial stability or the ability of the ship to resist initial heel from the upright position. A ship with a positive $\overline{GM}$ will tend to float upright and will resist initial inclining forces. A ship with a negative $\overline{GM}$ will not float upright and may be said to be initially unstable. Some ships develop a negative $\overline{GM}$ because of a condition of off-center loading and become unstable in the upright position. Because of the change in the underwater hull form with angle of inclination, such a ship will list to either port or starboard until it reaches a point of stable equilibrium.

Since the longitudinal metacenter M_L is always located quite high above the ship (Figure 7.4), it is possible to state that a negative longitudinal metacentric height GM_L will not occur under normal conditions. Longitudinal stability is discussed in the next chapter.

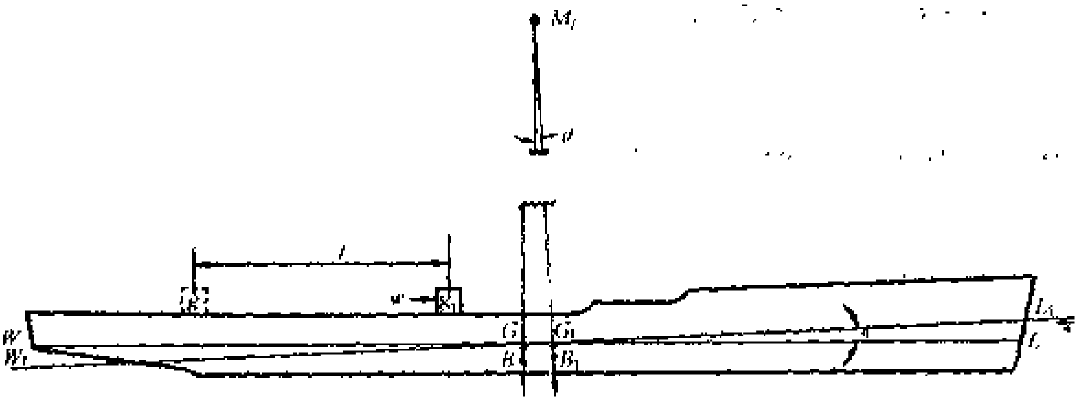


Figure 7.4 Longitudinal stability

7.5 Righting Arm

The couple formed by the forces of buoyancy and gravity in the above discussion is, quantitatively, the product of the weight of the ship and the distance between the two forces. The perpendicular distance between the lines of action of the two forces is commonly called the *righting arm* ($\overline{GZ}$). When the weight or displacement of the ship is constant, we can use the value of $\overline{GZ}$ as a measure of the static stability through all angels of inclination.

For small angles of inclination (that is, where the line of action of the buoyant force when inclined intersects the vertical centerline at M),

$$\overline{GZ} = \overline{GM}\sin\phi \tag{7-1}$$

And the righting moment $= \Delta\,\overline{GZ}$

$$RM = \Delta\,\overline{GM}\sin\phi \tag{7-2}$$

where ϕ is the transverse angle of inclination in degrees (Figure 7.5).

Therefore, the value of $\overline{GM}$ may be used in comparing the initial stability of ships of same type and size.

7.6 Range of Stability

Range of stability is defined as that range of inclination in degrees either to port or starboard, from the position of equilibrium, through which the ship is statically stable.

The magnitude of this range is primarily dependent upon the beam, freeboard, watertight integrity of the deck and superstructure, and location of the center of gravity. This range shows the extent of positive righting arm and does not mean safety of heel throughout without capsizing. Theoretically, the range of stability indicates an angle to which the ship may be gradually inclined—without capsizing—in calm, motionless water by inclining moments not exceeding the righting moment at any angle. The righting-arm curve also shows the angle at which the righting arm is maximum. The range of stability, the maximum righting arm, the angle at which it occurs, and the area under the curve are all crucial elements in assessing the intact stability of a ship.

(摘自 < Introduction to Naval Architecture > T. Gillmer & B. Johnson, London. E. & F. N. SPON, 1982)

课外阅读

Additional reading

Initial Stability: The Computation of the Metacentric Radius and the Location of *M*

Initial stability is discussed before overall stability, because it logically follows the discussion of equilibrium. Metacentric height, the measure of initial stability, is an important tool in buoyancy and stability calculations, but the overall stability (to be discussed subsequently) is the complete measure of the ability of the ship to resist inclining moments.

In order to numberically fix the value for metacentric height, either transverse or longitudinal, one must actually locate the metacenter and the center of gravity in relation to some fixed datum plane, preferably a horizontal plane through the bottom of the flat keel amidships. These values are normally called $\overline{KM}$, $\overline{KM_L}$, and $\overline{KG}$, respectively. The methods of computing these values will be given in the discussions immediately following.

Figure 7.5 shows diagrammatically the cross section of a ship and her waterplane shape. The ship is heeled to a small angle of

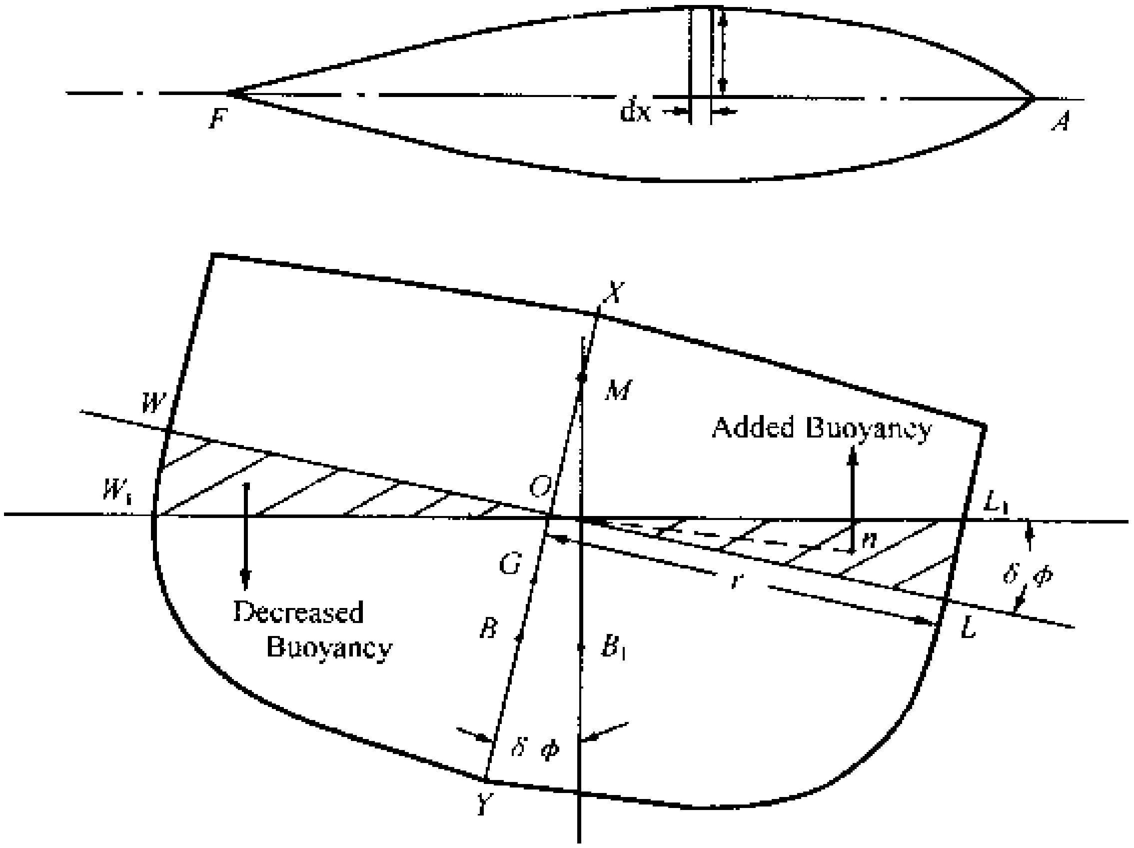


Figure 7.5 Computation of metacentric radius $\overline{BM}$

inclination by an external moment so that she floats at the waterline W_1L_1 instead of at WL. The location of the center of buoyancy shifts from B to B_1 as previously discussed.

Let r = half-breadth of the ship

$\delta\phi$ = small angle of inclination in radians

n = center of gravity(area) of triangle LOL_1

$\mathrm{d}x$ = increment of length L

∇ = volume of displacement

ρ = density of water.

Now, the area of the triangle LOL_1 is approximately $1/2r\ r\delta\phi$. The distance from the apex O to the center of gravity n equals $2/3r$ for a small angle $\delta\phi$. The moment of area of triangle LOL_1 about the longitudinal centerline plane is

$$\left(\frac{1}{2}r\ r\delta\phi\right)\overline{On}$$

$$\left(\frac{1}{2}r\ r\delta\phi\right)\frac{2}{3}r$$

The moment of volume of the wedge(having triangle LOL_1 as its section and $\mathrm{d}x$ as its thickness) about the longitudinal centerline plane is

$$\left(\frac{1}{2}r\ r\delta\phi\right)\left(\frac{2}{3}r\right)\mathrm{d}x$$

or for the entire ship, we have by integration

$$\int_0^L \frac{1}{2}r\ r\delta\phi\ \frac{2}{3}r\mathrm{d}x$$

Because the volume of the emerged wedge WOW_1 is equal to the immersed wedge LOL_1, the added buoyancy due to LOL_1 is exactly equal to the lost buoyancy due to WOW_1. Hence, there are two equal moments acting in the same direction about the centerline plane.

Therefore, the total moment is

$$2\int_0^L \frac{1}{2} r\, r\delta\phi \cdot \frac{2}{3} r \cdot \mathrm{d}x$$

or,

$$\int_0^L \frac{2}{3} r^3 \delta\phi \mathrm{d}x$$

This total moment, or moment of both wedges, is what causes the center of buoyancy to move from B to B_1. The moment of the underwater volume with new center at B_1 taken about the original center at B is $\nabla \cdot \overline{BB_1}$. This must equal the moment of both wedges. Therefore,

$$\nabla\, \overline{BB_1} = \int_0^L \frac{2}{3} r^3 \delta\phi \mathrm{d}x$$

By geometry,

$$\overline{BB_1} = \overline{BM} \sin\delta\phi$$

For small angles,

$$\sin\delta\phi \approx \delta\phi$$

Therefore,

$$\overline{BB_1} = \overline{BM}\delta\phi$$

and

$$\nabla\, \overline{BB_1} = \nabla\, \overline{BM}\delta\phi = \delta\phi \int_0^L \frac{2}{3} r^3 \mathrm{d}x$$

$$\overline{BM} = \frac{\int_0^L \frac{2}{3} r^3 \mathrm{d}x}{\nabla}$$

Since $\int_0^L \frac{2}{3} r^3 \mathrm{d}x$ is the expression for moment of inertia of the waterline plane about the longitudinal centerline I, then

$$\overline{BM} = \frac{I}{\nabla} \tag{7-3}$$

Similarly, it may be shown that

$$\overline{BM_L} = \frac{I_L}{\nabla} \tag{7-4}$$

Where $\overline{BM}_L$ = the longitudinal metacentric radius

I_L = the moment inertia of the waterplane about a transverse axis through the center of flotation.

For the purpose of estimating initial stability during the early design phases of a new ship, the block coefficient

$$C_B = \nabla / LBT$$

and the waterplane inertia coefficients

$$C_{IT} = 12 I_T / B^3 L$$

and

$$C_{IL} = 12 I_L / B L^3$$

may be substituted in equations 7-3 and 7-4 to yield

$$\overline{BM} = \frac{C_{IT} B^3 L/12}{C_B LBT} = \frac{C_{IT} B^2}{C_B 12 T} \tag{7-5a}$$

$$\overline{BM}_L = \frac{C_{IL} B L^3/12}{C_B LBT} = \frac{C_{IL} L^2}{C_B 12 T} \tag{7-5b}$$

Now we can get a parametric estimate of $\overline{KM}$

$$\overline{KM} = \overline{KB} + \overline{BM}$$

$$\overline{KM} = \frac{C_{WP} T}{C_{WP} + C_B} + \frac{C_{IT} B^2}{C_B 12 T} \tag{7-6}$$

Note, however, that C_{WP}, C_B, and C_{IT} are themselves functions of drafts, except for special cases of rectangular barges and wall-sided ships. For illustrative purposes, a rectangular barge or box-shaped lighter(BSL), with

$$C_B = C_{WP} = 1.0$$

and

$$C_{IT} = C_{IL} = 1.0$$

is used to simplify calculations, since for this shape,

$$\overline{KB} = T/2$$

For this shape only,

$$\overline{KM} = \overline{KB} + \overline{BM} = T/2 + B^2/12T \tag{7-7}$$

$$\overline{KM_L} = \overline{KB} + \overline{BM_L} = T/2 + L^2/12T \qquad (7-8)$$

(摘自<Introduction to Naval Architecture>T. Gillmer etal. 1982)

术语解释

static equilibrium	静平衡
neutral equilibrium	中性平衡
upright position	正浮位置
homogeneous cylinder	均质柱状体
capsize	倾覆
resultant	合力
couple	力矩,力偶
positive righting moment	正扶正力矩
righting arm	扶正力臂,恢复力臂
capsizing moment	倾覆力矩
metacenter	稳心
list	倾斜,倾侧
stable equilibrium	稳定平衡
criterion	判据,准则
overall stability	总体稳性
initial stability at small angle of inclination	小倾角初稳性
metacentric height	稳心高
longitudinal(transverse)	纵(横)稳心高
off-center loading	偏离中心的装载
port	左舷
starboard	右舷
lighter	港驳船
wateright integrity	水密完整性

crucial element	重要因素
intact stability	完整稳性
barge	驳船

问　　题

1. What are the definitions of stable equilibrium and unstable equilibrium?

2. Should surface ships have positive righting arm?

3. To make a surface ship stable, should the metacenter be above the center of gravity of that ship?

4. Moving a heavy cargo from the ship hold to the upper deck, will it increase the metacentric height?

5. Will the center of floatation of a ship move as the ship is heeled slightly? Will the center of gravity of it shift in this case?

Lesson 8 Resistance

8.1 Introduction

A ship when at rest in still water experiences hydrostatic pressures which act normally to the immersed surface. It has already been stated when dealing with buoyancy and stability problems that the forces generated by these pressures have a vertical resultant which is exactly equal to the gravitational force acting on the mass of the ship, i.e. is equal to the weight of the ship. If the forces due to the hydrostatic pressures are resolved in the fore and aft and transverse directions it will be found that their resultants in both of these directions are zero. Consider what happens when the ship moves forward through the water with some velocity V. The effect of this forward motion is to generate dynamic pressures on the hull which modify the original normal static pressure and if the forces arising from this modified pressure system are resolved in the fore and aft direction it will be found that there is now a resultant which opposes the motion of the ship through the water. If the forces are resolved in the transverse direction the resultant is zero because of the symmetry of the ship form.

Another set of forces has to be considered when the ship has ahead motion. All fluids possess to a greater or less extent the property known as viscosity and therefore when a surface such as the immersed surface of a ship moves through water, tangential forces are generated which when summed up produce a resultant opposing the motion of the ship. The two sets of forces both normal and tangential produce resultants which act in a direction opposite to the direction in which the ship is moving. This total force is the resistance of the ship or what is sometimes called the 'drag'. It is sometimes convenient to split up the total resistance into a number of components and assign various names to them. However, whatever names they are given the resistance components concerned must arise from one of the two types of force discussed, i. e. either forces normal to the hull surface or forces tangential to that surface.

The ship actually moves at the same time through two fluids of widely different densities. While the lower part of the hull is moving through water the upper part is moving through air. Air, like water, also possesses viscosity so that the above water portion of a ship's hull is subjected to the same two types of forces as the underwater portion. Because, however, the density of air is very much smaller than water the resistance arising from this cause is also very much less in still air conditions. However, should the ship be moving head on into a wind, for example, then the air resistance could be very much greater than for the still air condition. This type of resistance is, therefore, only to a limited extent dependent on the ship speed and will be very much dependent on the wind speed.

8.2 Types of Resistance

It was stated above that it is sometimes convenient to split up the total resistance into a number of components; these will now be considered.

The redistribution of normal pressure around the hull of the ship caused by the ahead motion gives rise to elevations and depressions of the free surface since this must be a surface of constant pressure. The result is that waves are generated on the surface of the water and spread away from the ship. Waves possess energy so that the waves made by the ship represent a loss of energy from the system. Looked at in another way the ship must do work upon the water to maintain the waves. For this reason the resistance opposing the motion of the ship due to this cause is called 'wave-making resistance'. With deeply submerged bodies the changes in the normal pressure around the hull due to ahead motion have only a small effect on the free surface so that the wave resistance tends to be small or negligible in such cases.

The resistance arising due to the viscosity of the water is appropriately called 'viscous resistance' or often 'frictional resistance'. The thin layer of fluid actually in contact with the immersed surface is carried along with it but because of viscosity a shear force is generated which communicates some velocity to the adjacent layer. This layer in turn communicates velocity to the next layer further out from the hull and so on. It is clear then that there is a mass of fluid which is being dragged along with the ship due to viscosity and as this mass requires a force to set it in motion there is a drug on the ship which is the frictional resistance. The velocity of the forward moving water declines in going outwards from the hull and although theoretically there would still be velocity at infinite distance the velocity gradient is greatest near the hull and at a short distance outwards the forward velocity is practically negligible. Forward velocity is therefore confined to a relatively narrow layer adjacent to the hull. This layer is called the 'boundary layer'. The width of the layer is comparatively small at the bow of the ship but thickens in going aft, as will be seen from Figure 8.1, which shows the fall off in velocity at various positions in the length.

The actual thickness of the boundary layer is indeterminate but the point where the forward velocity has fallen to about 1% of what it would be if the water were frictionless is considered to be the outer extremity of the boundary layer. Thus, in Figure 8.1 where the velocity V_1 of the water relative to the body is 0.99 of what it

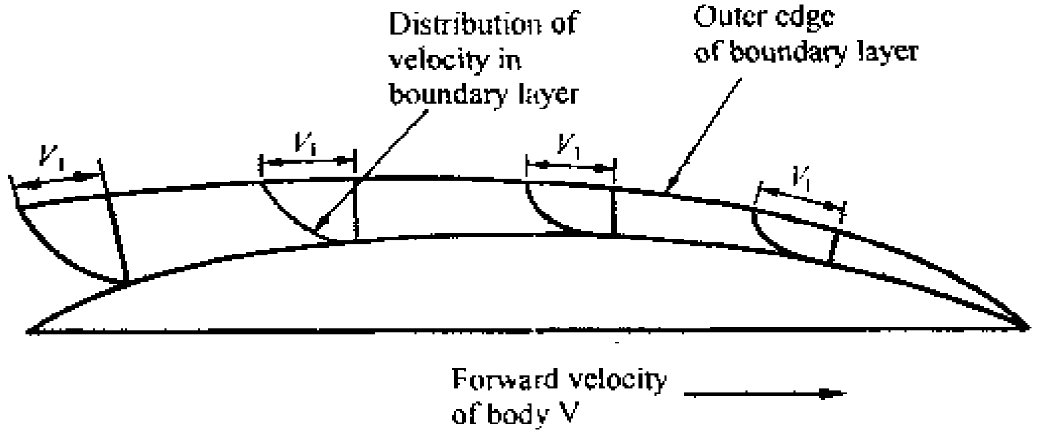


Figure 8.1

would be at the same point if the water was frictionless would be the outer edge of the boundary layer.

Theoretical investigations on flow around immersed bodies show that the flow follows the type of streamline pattern shown in Figure 8.2. However, where there are sharp changes of curvature on the surface of the body, and party due to the viscosity of the fluid, the flow separates from the surface and eddies are formed. This separation means that the normal pressure of the fluid is not recovered as it would be according to theory and in consequence a resistance is generated which is often referred to as 'eddy-making resistance'. This type of resistance, like wave-making resistance, arises from a redistribution of the normal pressures around the hull

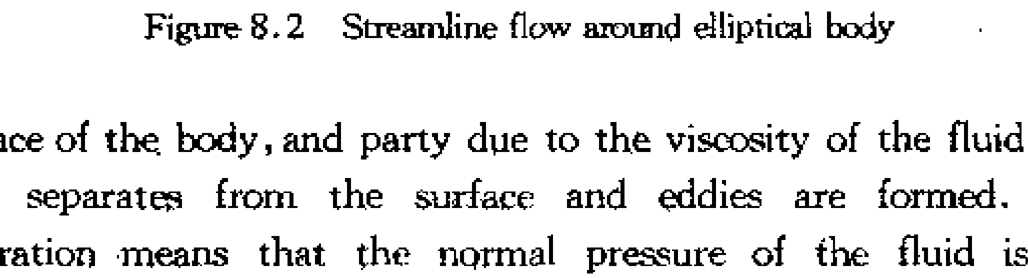


Figure 8.2 Streamline flow around elliptical body

in contrast to the frictional resistance which arises because of tangential viscous forces.

The fourth type of resistance is that due to the motion of the above-water form through the air, as has already been mentioned, and could consist of a combination of frictional and eddy resistance.

(摘自<Basic Ship Theory>K. Kawson & E. Tupper, Vol. 1, 1998)

The shape of a ship hull is determined by many competing influences. For ease of construction, it should be a rectangular box; for adequate transverse stability, it must be wide; for adequate strength as a beam being bent in a longitudinal plane, it must be deep. All these factors influence the shape of a hull, but often the primary factor is the dynamic interaction of the hull with the water. The interactions that govern the resistance of the hull to steady forward motion—a resistance that determines the choice of propulsive power—usually demand the greatest attention from the naval architect.

Resistance to steady forward motion has four components: (1) friction between the water and the hull surfaces, (2) energy expended in creating the wave system caused by the hull, (3) energy put into eddies shed by the hull and its appendages (e. g., the rudder), and (4) resistance by the air to above-water parts of the ship.

Frictional resistance is proportional to the product of water density, area of contact with the water, square of water speed relative to the ship, and a friction coefficient. This resistance can be minimized by reducing the area of a hull's wetted surface, but usually very little can be accomplished in the face of many other demands on hull size and shape. A smooth surface is an obvious factor in reducing fricition, but a surface that is smoother than ordinary painted steel has a benefit that is trivial compared to its cost. The friction coefficient is largely a function of the Reynolds number (the product of water density times ship speed times ship length, divided by water viscosity); it is not controllable by a designer since water density and viscosity are beyond control and ship length and speed are almost inevitably dictated by other considerations. The friction coefficient was the subject of intense research, especially during the first half of the 20th century, but since that time most ship designers have employed values standardized by the International Towing Tank Conference.

Wave making and eddy-making resistance components are often lumped into a single "residuary resistance," especially when resistance measurements are extrapolated from model testing. Wave making is usually by far the larger component of residuary resistance; it is therefore given more attention in research and in the designing of a hull. Indeed, wave making increases so rapidly as ship speed increases that it eventually requires more power to overcome than is practicable to build into a ship. For a ship of conventional type, it is virtually impossible to operate at a speed-to-length ratio (speed in nautical miles per hour, divided by the square root of the waterline length in feet) higher than approximately 1.3. Beyond that realm even a trivial increase in speed requires a virtually infinite increase in power in order to fulfill the energy demand of the wave system. Small craft can escape this limitation by planing, but the amount of power required for the transition to a planing mode is beyond practicality for conventional ships.

（摘自 Encyclopedia Britanica. 1999）

课外阅读

Additional reading

A significant feature of waves generated by the passage of a ship is that they travel at the same speed as the ship and that their speed (like that of surface waves in general) is proportional to the square root of their length. In consequence, when a ship is running at a speed-to-length ratio of 1.0, its waterline length is the same as the crest-to-crest length of its wave pattern, in effect putting it into a hole of its own making. As more power is applied, the hole becomes deeper until any further increase in speed simply poses the impossible task of climbing out of the hole.

Another significant feature of ship-generated waves is their origin at different parts of the hull. A bow wave and a stern wave are always present, and, if the fore and after parts of the hull fair into a straight mid-body with distinct shoulders, then these shoulders also will produce waves. It may well happen that the crests of waves from one source will coincide with the troughs of another; the resulting cancellation will lessen the wave-making component of resistance. A major objective of ship hydrodynamicists is to design hull forms that maximize this benefit. One evident result of their efforts is the underwater bulb often attached to the bows of ships. The purpose of the bulb is to produce a wave that will tend to cancel the ordinary bow wave.

Eddy making by appendages such as rudders and the brackets that support propeller shafts is usually a minor contributor to a hull's resistance to forward motion. It is minimized by giving the appendages airfoil shape and by orienting them, if possible, so that approaching water will have a low angle of attack.

Aerodynamic resistance usually receives much less attention in ship design than hydrodynamic resistance. The aerodynamic contribution to total resistance is small under most circumstances. On occasions when it is not small, as with an exceptionally strong wind from ahead, the resulting waves are likely to require a voluntary reduction in ship speed. The slowing caused by the wind is thus likely to pass unnoticed. The rounding and sloping of deckhouse surfaces is about the only attempt made to design for minimal air resistance.

（摘自 Encyclopia Britannica. 1999）

术语解释

ship hydrodynamics	船舶水动力学
transverse stability	横稳性
eddy	漩涡
appendage	附体
frictional resistance	摩擦阻力
gradient	梯度
wetted surface	湿表面积
Reynolds number	雷诺数
International Towing Tank Conference	国际船模试验水池会议(ITTC)
wave-making resistance	兴波阻力
eddy-making resistance	漩涡阻力
extrapolate	外插
residuary resistance	剩余阻力
speed-to-length ratio	速长比
nautical mile	海里
bow wave	艏波

wave pattern	波型
stern wave	艉波
fair	光顺
hole	水(流)深凹处
mid-body	(船)中体
shoulder	船肩
crest(of wave)	波峰
trough	波谷
bulb	球鼻艏
bracket	轴支架,支架
airfoil	水翼,气翼,机翼,翼(剖)面
angle of attack	攻角
orient	取向,定方位,调整,标定
hydrostatic	水静力的
immerse	浸水,浸没
buoyancy	浮力
viscosity	粘性
tangential	切向的,正切的,相切的
normal	法向的,正交的,法线
resultant	合力
drag	阻力,拖曳力
do work	做功
boundary layer	边界层
streamline	流线
curvature	曲率
tangential viscous force	切向粘性力

问　　题

1. List the resistances mentioned in the text.

2. Is the wavemaking resistance mainly due to the existence of

viscosity of the fluid?

3. If the speed of a ship is increased at some rate, will the frictional and the wave making resistances be increased at nearly the same rate?

4. Is it possible to reach any desired high speed by supplying adequate power to a displacement type of ship?

5. Which component of ship resistance is the main concern of reduction in ship form design optimization?

Lesson 9 Propellers and Propulsion Systems

9.1 Introduction

The first efforts to use mechanical forces to propel ships were made in a tentative way, with indifferent success, probably more often and earlier than is generally realized. Continual frustration with the unreliable and inadequate force of the wind on sails forced men to search for other means to move ships in the water from the earliest days of history. Aside from the simple paddle or manned oars, there is evidence that pre-Christian Romans used paddle-wheel-propelled boats (whose source of power was oxen) to transport soldiers to Sicily. Paddle wheels were apparently used by the Orientals as early as the seventh century, and of course, Leonardo da Vinci designed many mechanical devices for propelling ships.

True mechanical propulsion, however, deriving its power from the energy conversion in a steam engine, came very much later and after many frustrating failures. It is difficult to say where and when such propulsion was first successful, but it is recorded that in 1783, in Lyons, France, a barge-like boat 148 feet in length, equipped with a horizontal double-acting steam cylinder that drove side paddle wheels, was able to move against the current of the Rhone River. This vessel was aptly named the Pyroscaphe. Her inventor-designer, Claude de Jouffroy D'Abbans, is generally accepted as the pioneer in the application of steam-powered propulsion to ships. In America, John Fitch of Philadelphia built and experimented successfully with steampowered vessels as early as 1785 and can be credited with the building of the first commercial steamboat. In 1790 his steamboat, the Experiment, began carrying passengers between Philadelphia and Trenton on a regular schedule. His vessel was not propelled by paddle wheels, however. Her 18-in single-cylinder engine and fire tube boiler powered three "duck leg" paddles at the stern, which moved the 60-ft boat at the respectable speed of 8 knots. James Rumsey of Berkley Springs, Virginia, produced a steam-powered boat in 1787 that was propelled by a water jet. While this boat was intended for ferry service on the Potomac, she was laid up after a successful public demonstration, where she attained a speed of approximately 4.5 knots.

It is interesting to note that in these early efforts, the propelling devices were all dissimilar. The paddle wheel, the mechanical oar, and the water jet all achieved some degree of success a full half-century before the Archimedes' screw propeller was successfully adapted by John Ericsson for the U.S. Navy and Francis Petit Smith for the Royal British Navy. Both men took out patents for screw propulsion in 1836 and proceeded to demonstrate the advantages of the screw propeller over the paddle wheel. The screw propeller is less affected by changes in draft and by severe rolling, requires less effective beam, is well protected from damage, and can operate at higher speeds, using more compact machinery. In 1845 the British Admiralty sponsored a famous "tug-of-war" between the steam warship Rattler, which was screw propelled, and her slightly smaller and less powerful sister ship, the Alecto, which was paddle powered. Although the Alecto was given the advantage of moving off first and towing the Rattler astern at 2 knots, the Rattler arrested her sternway in 5 minutes and proceeded to tow the thrashing Alecto backwards at 2.8 knots(Brown 1977). Although it has been shown that the Alecto could have won some of the races held as part of the trials if she had possessed equal power, the screw-propulsion detractors had been silenced and warship propulsion was permanently headed toward the use of screw propellers.

There are now many types of ship-propulsion devices. Unusual and inefficient devices were invented, tried, and discarded. The paddle wheel, which was used successfully on the Great Western and many other steamers during the middle of the nineteenth century, has subsided into near obscurity as an open-ocean propulsion system. While it still may exist in some remotely located riverboats and special-purpose craft, it has certainly passed its days of significance. Fitch's walking oars were never used again. The water jet has enjoyed a recent successful rebirth and is used with increasing promise (it will be discussed subsequently in this chapter). The marine propeller with its many variations is the prime propulsive device of modern ships.

9.2 Propelling Devices

Of the successful types of propulsive devices presently in use, the following may be grouped in four distinct categories:

1. Screw propellers
   a) fixed-pitch propellers
   b) adjustable-pitch propellers
   c) controllable-pitch propellers
   d) shrouded screws working in tunnels or sleeves (ducted propellers)
   e) contra-rotating propellers
2. Paddle wheels, either side or stern mounted with fixed or feathering blades
3. Jet propeller
   a) water jet through submerged nozzle
   b) water jet through surface nozzle
4. Vertical-axis (cycloidal) propellers

a) Kirsten-Boeing propeller

b) Voith-Schneider propeller

These above types will be individually discussed in the subsequent sections.

Screw Propellers

Because the most widely used propeller is the screw propeller (referred to henceforth, in keeping with common practice, as a propeller), it will be discussed in the greatest detail. Some general propulsive theory that is applicable to other types of propellers as well will also be covered.

It will be useful to consider first the propeller itself in general terms, along with some associated terms and definitions. A propeller has at least two blades projecting from a hub that is keyed to and driven by the propeller shaft. There are three general types of marine propellers in use today. Fixed-pitch propellers have blades that are either an integral part of the hub or are bolted to the hub. In this type of propeller, the position of the blades relative to the hub cannot be altered, with the exception of minor adjustments that may be made during the assembly of some of the bolted-blade types. Adjustable-pitch propellers have blades that can be adjusted to different pitch settings when the propeller is stopped. Controllable-pitch propellers are provided with a mechanism for altering the position of the blades relative to the hub at any time. In the following discussion, refer to Figure 9.1, which shows a three-blade propeller of constant-pitch.

A right-handed propeller is one that rotates clockwise when viewed from astern (counterclockwise when viewed looking aft as in Figure 9.1), while driving the ship ahead. A left-handed propeller rotates counterclockwise when viewed from astern, while driving the ship ahead.

The pressure face of a blade is the after side when going ahead.

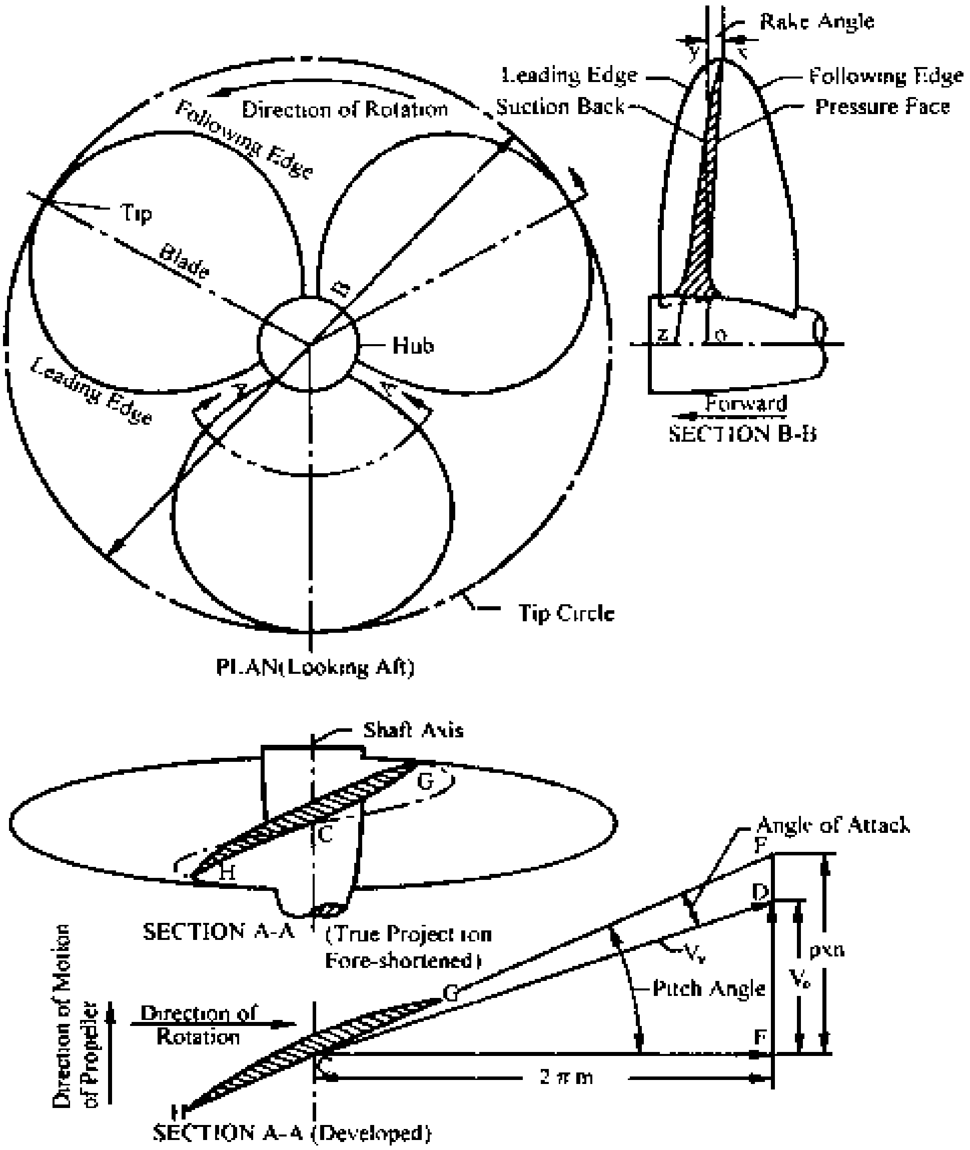


Fig 9.1 Propeller definition diagram
(three-bladed, right-hand, constant-pitch propeller)

The suction back of a blade is the surface opposite the face.

The tip of a blade is the point farthest from the axis.

The leading edge of a blade is the edge that cuts the water first when going ahead.

The following or trailing edge is opposite the leading edge.

The diameter is twice the perpendicular distance from the axis to the blade tip, or is the diameter described by the blade tips.

A helicoidal surface is a surface generated by a line (the generatrix) at an angle with an axis through one of its extremities that revolves about this axis at a constant angular rate and advances along the axis at a constant linear speed. In its simplest form, the pressure face is a portion of a helicoidal surface with the axis along the propeller shaft. Any surface of the thread of a machine screw is a helicoid.

The pitch of any point on a blade is the distance moved parallel to the shaft axis by the generatrix of the helicoidal surface through the point in 360° of rotation. The pitch of point *C* in Figure 9.1 is the distance *FE* for one revolution. When the pressure face is a helicoidal surface, each point on the pressure face has the same pitch, and the propeller is said to be constant or of uniform pitch. It may be seen in Figure 9.2 that each point on the developed blade section has the same pitch as point *C*. Because it is a constant-pitch propeller, every point on other blade sections will have the same pitch as point

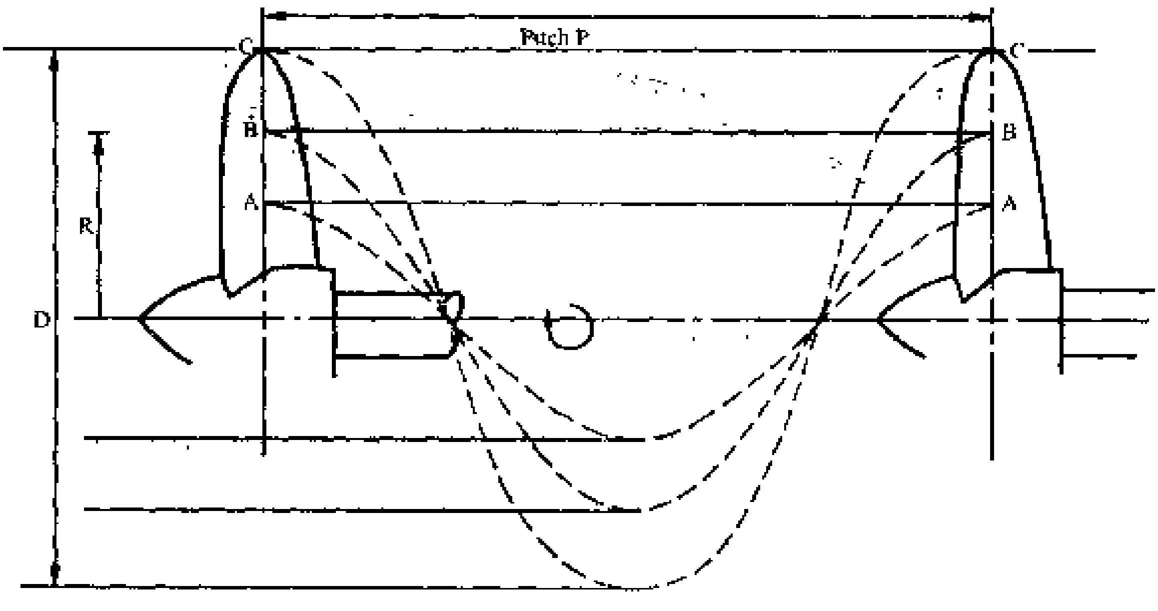


Fig 9.2 Uniform-(constant-)pitch propeller operating at no-slip for one revolution

C. If the pitch increases from the leading to the following edge, the pitch is axially increasing. If the pitch increases from hub to tip, the pitch is radially increasing. When the pitch of the blade varies from point to point, the pressure face is not a helicoidal surface.

The theory of propeller design with variable pitch over the blade is a particular and specialized adaptation. To summarize the purpose of such design it is sufficient here to say that (1) when the pitch varies between leading and following edges, the propeller will be adaptable to a greater range of ship speeds, and (2) when the pitch varies between root and tip, the propeller will take advantage of the variation in velocities of the wake current around the propeller. The former modification extends the range of efficiency and the latter increases the peak efficiency.

课外阅读

Additional reading

Propeller Action

Various theories have been advanced to explain actual conditions encountered in propeller operation. The circulation theory gives the best explanation of the phenomenon. This is discussed very briefly in its relation to the forces on a blade section, such as in Figure 9.1. The section is advancing along the line *CD* with a velocity v_r, which is the vector resultant of the speed of rotation $2\pi rn$ and its axial advance v_A. Similar to an airfoil, the blade section is advancing with an angle of attack $\angle FCD$. An unsymmetrical body, such as an airfoil section of a propeller blade, when placed in a parallel fluid flow, will disrupt the symmetry of this flow. The circulation theory indicates that the new unsymmetrical flow can be represented by a counterclockwise circulatory flow superimposed on the parallel water flow past the blade section. The vector sum of the circulatory flow and a parallel flow will produce the high velocity region on the suction back of the blade. The velocity variation will be proportional to the strength of the circulation flow.

By application of Bernoulli's law, a high velocity region means low pressure and vice versa. It is obvious that the lower velocity on the rear surface or pressure face of the blade increases the pressure of the water on and near that surface in imparting a positive thrust. The higher velocity on the opposite surface of the blade or suction back creates a negative pressure distribution, which may amount to a greater pressure differential than on the pressure face. Together, the total pressure differential on both sides of the blade account for the increase in velocity of the water and for the lift or forward thrust on each blade, from which the overall thrust T is derived. The component at right angles to the shaft is the required force that produces the torque Q.

The pressure distributing from the leading to the following edge of both the pressure face and the suction back is irregular. The pressure reduction on the suction back is greater than the pressure increase on the face, indicating that the greater portion of the propeller thrust is contributed by the suction back of the blades.

Cavitation

When the minimum value of the absolute pressure on the back is reduced below the vapor pressure of the water, which will occur at relatively high propeller speeds, vapor pockets or cavities are formed that disrupt the flow and reduce the propeller efficiency. This phenomenon, known as cavitation, generally occurs first in the tip vortex. When the vapor pockets collapse on the blade surface, erosion of these surfaces results and noise is emitted. Advanced cavitation produces a very slow increase in thrust for increasing shaft horsepower, while speed of rotation increases more rapidly than usual. Fully developed cavitation noise is violent and can be heard easily in the vicinity of the stern.

（摘自＜Introduction to Naval Architecture＞T. Gillmer & B. Johnson, London, E. & F. N. SPON, 1982）

术语解释

paddle	桨
oar	橹，桨
paddle-wheel-propelled	明轮推进的
Leonardo da Vinci	莱昂纳多·达·芬奇
Admiralty	海军部，海军上将
tug-of-war	拔河比赛
arrest her sternway	中止她（指军舰 Rattler）的倒驶
barge	驳船
double-acting steam cylinder	双向作用的蒸汽气缸
single-cylinder engine	单缸引擎
fire tube boiler	火水管锅炉
water jet	喷水（推进）管
Archimedes's screw propeller	阿基米德的螺旋桨推进器
patent	专利
rolling	横摇
steamer	汽轮船，汽船，轮船
fixed-pitch	固定螺距式
adjustable-pitch	可调螺距式
controllable-pitch	可控螺距式
shrouded screw	有套罩螺旋桨，导管螺旋桨
tunnel	隧道
sleeve	套管，套筒，套环

ducted propeller	导管螺旋桨
contra-rotating propellers	对转桨
feathering blade	顺流变距桨叶,顺桨桨叶
jet propeller	喷水推进器
submerged nozzle	浸没式喷口
surface nozle	水面式喷口
vertical-axis(cycloidal) propeller	直叶(摆线)推进器
Kristen-Boeing propeller	正摆线推进器,克斯坦－波音推进器
Voith-Schneider propeller	外摆线直翼式推进器,沃伊斯－施奈德直翼推进器
hub	桨毂,轴毂,轮毂,毂,套筒
bolt	螺栓,上螺栓固定
astern	朝船尾(的),倒车(的)
right-handed propeller	右旋进桨
left-handed propeller	左旋进桨
suction back of a blade	桨叶片抽吸叶背
tip of a blade	桨叶叶梢
leading edge	导缘,导边
helicoidal	螺旋面(的),螺旋状(的)
generatrix	母线,产生线
extremity	末端;尽头
thread(of a machine screw)	(机螺丝的)螺纹
constant-pitch propeller	定螺距螺旋桨
following edge	随边,尾缘
wake current	伴流,尾流
circulation theory	环流理论
blade section	叶元剖面
axial advance	轴向进速
unsymmetrical	非对称的
Benoulli's law	伯努利定律

thrust	推力
torque	扭矩
vapor pocket	汽化阱
cavity	空腔
cavitation	空泡、空化、空蚀
tip vortex	梢涡
worm gear	蜗轮，蜗杆(传动装置)

问题

1. What are the main types of propeller mentioned in the lesson?

2. Is the paddle wheel propeller efficient as compared with screw-or jet propulsion devices?

3. What are the general types of propellers for ocean-going ships in use today?

4. What are the advantages of using variable pitch screw propellers?

5. What is the pitch of a screw propeller?

Lesson 10 Maneuverability, Motions and Estimating Power Requirements

10.1 Ship Maneuvering and Directional Control

A ship is said to be directionally stable if a deviation from a set course increases only while an external force or moment is acting to cause the deviation. On the other hand, it is said to be unstable if a course deviation begins or continues even in the absence of an external cause. A directionally unstable ship is easy to maneuver, while a stable ship requires less energy expenditure by its steering gear in maintaining a set course. A compromise between extremes is therefore desirable. In a rough sense, directional stability or instability can be determined by examination of the ship's underwater profile. If the area of the hull and its appendages is concentrated toward the aft end, then the ship is likely to be directionally stable.

Neither stability nor instability obviates the need for devices to maintain a course or to change it on command. The near-universal gear for such directional control is a rudder (or rudders) fitted to the stern and activated by an electrohydraulic steering engine mounted within the hull just above. The rudder is an appendage that has a cross section much like an airfoil and that develops lift when it is turned to produce a nonzero angle of attack relative to the water. The lift produces a turning moment around a point that is located somewhere along the mid-length of the hull.

For a given angle of attack, rudder lift is proportional to the square of the water velocity relative to the rudder. Therefore, the preferred position for a rudder is within the high-velocity wash generated by a propeller. In the case of a multi-propeller ship, multiple rudders may be fitted (one behind each propeller) in order to take advantage of high water velocity. In addition, a ship that must maneuver well while backing is often fitted with a pair of "flanking rudders" for each propeller. These are positioned forward of the propeller, one on each side of the shaft.

Maneuvering at very low speeds is a special problem, since low water velocity means insufficient lift developed by the rudder. If the rudder is positioned directly behind a propeller, then a few seconds of high propeller speed can develop lift sufficient to push the stern sideways before generating significant forward motion of the hull. Pushing the stern sideways is tantamount to changing the direction of the hull, but this expedient is often not sufficient for low-speed maneuvering. For this reason, many ships are fitted with a "bow thruster," a propeller mounted in a transverse tunnel near the bow. This thruster can push the bow sideways without producing forward motion. If a similar thruster is fitted near the stern, a ship can be propelled sideways—or even rotated in place, if the two thrusters act in opposite directions.

10.2 Ship Motions in Response to the Sea

In maneuvering, a ship experiences yaw (rotation about a vertical axis) and sway (sideways motion). More generally, motions are possible in all six degrees of freedome, the other four being roll (rotation about a longitudinal axis), pitch (rotation about a transverse axis), heave (vertical motion, and surge (longitudinal motion superimposed on the steady propulsive motion). All six are unwanted except in the special circumstance where yaw is necessary in changing course.

Roll is probably the most unwanted of all, since it produces the highest accelerations and hence is the principal villain in seasickness. It can be described as a forced vibration, since the mass, damping, and restoring force typical of any mechanical vibrating system are present. However, attempts to find the natural frequency of a rolling ship through analysis are far from simple, because the coefficients of the fundamental equation are themselves a function of frequency. Further, the mass term must include a rather indefinite amount of water that moves with the ship as it rolls, and there may be coupling between roll and one of the other motions. Nonetheless, natural rolling periods can be found approximately from simplified formulas. Rolling is most severe when the period of encounter with a major part of a wave spectrum equals the roll period.

Many ships are fitted with "bilge keels" in an attempt to dampen roll. These are long, narrow fins projecting from the hull in the area where the bottom of the hull meets the side. Bilge keels are effective in reducing roll, but they are much less effective than other measures. The most effective are antiroll fins that extend transversely from the side of the ship for perhaps 30 feet(10 metres) and are continuously rotated about their axes to develop forces that oppose the roll. Among the sizable costs associated with these fins is the necessity to retract them within the hull when the ship is to be docked.

Pitch is simply roll about a different axis, but consequences and solutions are different. Because a ship is much longer than it is wide, an angle that may seem trivial when it measures roll may lift the bow out of the water when it measures pitch. When the period of encounter with head seas is close to the natural pitching period of the hull, slamming of the bow and cascading of waves upon the forward decks are possible consequences. The most common response to such a hazard is slowing the ship to avoid the resonance. Experiments have been made with anti-pitching fins, but they have not entered into general practice.

The study of ship interaction will surface waves has seen intense effort by hydrodynamicists, since it is a difficult field in which to extract meaningful results from theory while being one where the benefits of solutions are great.

10.3 Determination of Propulsive Power by Model Testing

The power required to propel a ship is proportional to its speed times the resistance to its movement. The ability to predict resistance is therefore the essential ingredient in predicting the propulsive power to be required by a prospective ship. For many years hydrodynamic researchers have sought a method for calculating this resistance from first principles, but so far they have not produced a generally practicable method. Estimates can be made based on experience with existing ships or standard models, but the favoured way of making a prediction during design is to test a model of the proposed ship.

Model testing consists of towing a precisely made model of the hull at a precisely controlled speed, in calm water, while measuring the force required to tow it. The essential link between model and ship is obtained by operating the model at the same Froude number as the ship. This number, named after the English naval architect William Froude, is a dimensionless ratio given as $V/(gL)^{0.5}$, in which V is the speed, g the acceleration of gravity, and L the waterline length. At this common reference point the wave patterns developed by the ship and by the model are the same, and residuary resistances per ton of displacement also are the same. Unfortunately, equality of Froude numbers means a gross inequality in Reynolds numbers, causing a serious mismatch between the frictional resistances of model and ship. The technique of scaling from model to ship therefore must follow a somewhat devious path whose principal steps are as follows: (1) Total resistance of the model is measured. (2) Frictional resistance of the model is calculated, using data and techniques published by the International Towing Tank Conference. (3) Residuary resistance for the model is found by subtracting the frictional component from the total. (4) Residuary resistance for the ship is taken to be the same, per ton of displacement, as for the model. (5) Frictional resistance for the ship is calculated. (6) Total resistance is obtained by adding the resistance components found in steps 4 and 5.

（摘自 Encyclopedia Britanica, 1999）

术语解释

set course	设定航线
deviation	偏离，偏差
steering gear	操纵装置，舵机
near-universal gear	准万向舵机，准万向齿轮
activate	作动
electrohydraulic	电动液压的
wash	下洗
multi-propeller	多桨船
flanking rudders	侧翼舵
tantamount	等值的，相当的
thruster	推力器，助推器
bow thruster	艏侧推器
six degrees of freedom	六自由度
yaw	艏摇，摇艏
sway	横荡
roll	横摇

pitch	纵摇
surge	纵荡
heave	垂荡
bilge keel	舭龙骨
seasickness	晕船
antiroll fins	减摇鳍
cascading of waves upon…	海浪跌落于
Froude number	傅汝德数
Reynolds number	雷诺数
anti-pitching fins	减纵摇鳍
hydrodynamicist	水动力学家
calm water	静水
dimensionless ratio	无量纲比值
wave pattern	波型
mismatch	不匹配

问 题

1. What kind of ability is the most significant concerning the prediction of propulsive power required by a prospective ship?

2. What is the purpose of conducting ship model towing tests in calm water?

3. How to obtain the total resistance of a ship through model test as described in the text?

4. Why is it more difficult to maneuver a ship at very low speed?

5. What ways have been mentioned in the text on the reduction of ship motions at sea?

Lesson 11　Model Testing

11.1　Resistance Tests

Many great men attempted to use models or to show how they could be used to predict full-scale behaviour, including Bouguer, Tiedemann, Newton, Chapman, Euler and Beaufoy, but it was not until the time of William Froude that full-scale prediction became a practical proposition.

It was William Froude who postulated the idea of splitting the total resistance into the residuary resistance and the frictional resistance of the equivalent flat plate. He also aruged that air resistance and the effects of rough water could be treated separately. By studying the wave patterns created by geometrically similar forms at different speeds, Froude found that the patterns appeared identical, geometrically, when the models were moving at speeds proportional to the square root of their lengths. This speed is termed the corresponding speed, and this is merely another way of expressing constancy of Froude number. He also noted that the curves of resistance against speed were generally similar if the resistance per unit displacement was plotted for corresponding speeds. Proceeding further, he found that by subtracting from the total resistance an allowance for the frictional resistance, determined from flat plates, the agreement was very good indeed.

This led to Froude's law of comparison which may be stated as:

If two geometrically similar forms are run at corresponding speeds (i. e. speeds proportional to the square root of their linear dimensions), then their residuary resistances per unit of displacement are the same.

Thus the essentials are available for predicting the resistance of the full-scale ship from a model. The steps as used by Froude are still used today, refinements being restricted to detail rather than principle. For each particular value of the ship speed:

(a) measure the resistance of a geometrically similar model at its corresponding speed.

(b) estimate the skin friction resistance from data derived from experiments on flat plates,

(c) subtract the skin friction resistance from the total resistance to obtain the residuary resistance,

(d) multiply the model residuary resistance by the ratio of the ship to model displacements to obtain the ship residuary resistance.

(e) add the skin friction resistance estimated for the ship to obtain the total ship resistance.

It should be noted that any error in estimating frictional resistance applies both to the model and ship. Thus, only the effect on the difference of the two is significant.

It is now possible to see why earlier attempts to correlate the total resistance of ship and model failed. Two models with identical resistances could only represent ships with identical resistances if the ratios of their residuary and skin friction resistance were the same. In general, this could not be true unless the forms were themselves the same. Indeed, if model A had less total resistance than model B it did not even follow that ship A would be less resistive than ship B. Thus, even the qualitative comparisons made between models, used so frequently even today in many branches of naval architecture, may be invalid.

11.2 Resistance Test Facilities and Techniques

With the aid of a grant from the Admiralty, Froude constructed the world's first model tank at Torquay in 1871 where R. E. Froude continued his father's work on the latter's death in 1879. The work of the Froudes proved so useful that, when the lease on the Torquay site expired in 1885, a grant was made to erect another at Haslar in 1887. This was the beginning of the Admiralty Experiment Works (AEW) which has grown over the years and has always remained one of the world's leading establishments in this field.

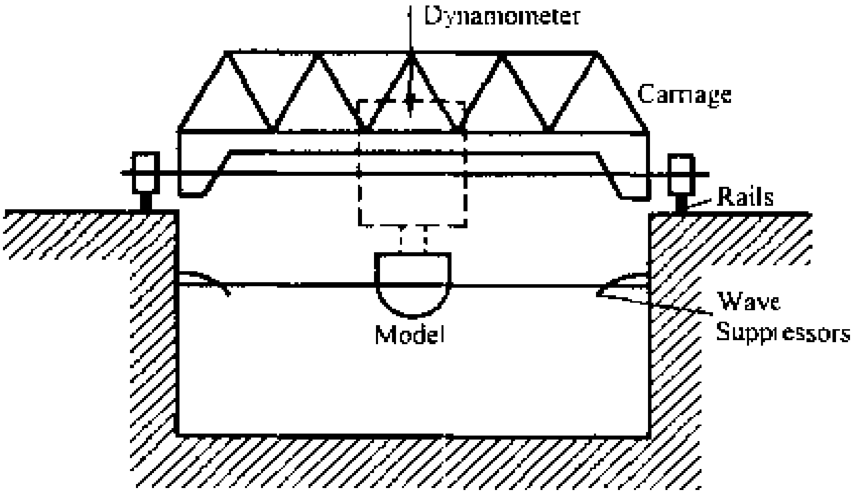


Fig. 11.1 Typical ship tank section

Modern ship tanks for measuring model resistance are fundamentally the same as the first tank made by Froude. Such a facility is essentially a long tank, of approximately rectangular cross-section, spanned by a carriage which tows the model along the tank. Improvements have been made over the years in respect of the methods of propelling the carriage, in the constancy of speed maintained by the carriage and in the dynamometers used to record the model resistance.

In a typical run, the carriage is accelerated up to the required speed, resistance records and measurement of hull sinkage and trim are taken during a period of constant speed and then the carriage is decelerated. With increasing ship lengths and service speeds, there has arisen a demand for longer and longer tanks to cope with the longer acceleration and deceleration runs.

Several very interesting features of model test procedures are described in Ref. 6 and arise from the very methodical and painstaking approach used by W. and R. E. Froude. As early as 1880, R. E. Froude was aware of unexplained variations in the resistance measured in repeat experiments on a given model. He suspected currents set up in the tank by the passage of the model and variations in skin friction resistance due to temperature changes. Methodical investigation into the first of these two features led to the adoption at AEW of small propeller type logs to record the speed of the model relative to the water. Investigation of the temperature effect led Froude to postulate that a 3 per cent decrease in skin resistance for every 10°F rise temperature could be adopted as a fair working allowance and linked this with a standard temperature of 55°F.

In the temperature experiments, R. E. Froude used the model of HMS Iris, a 300 ft, 3700 tonf despatch vessel, as a 'standard' model to be tested at various times throughout the year. Final proof that, even after correcting for tank currents and temperature, significant variations in resistance were occurring, came in tests on the Iris model in the tank at Haslar to correlate with those previously run at Torquay. This led to the application of a so-called Iris correction obtained by running the standard model at frequent intervals and applying a correcting factor to the resistance of a new model depending on the variation of the Iris resistance from its standard value. Generally, the Iris correction varies between 1 and 6 per cent, but during abnormal periods, commonly referred to as 'storms', the correction can be more than 10 per cent. The cause of the storms is now believed to be due to the presence in the water of substances having long chain molecules. The concept of a standard model has since been adopted by other ship tanks.

11.3 Model Determination of Hull Efficiency Elements

Experiments must be carried out with the hull and propeller correctly combined as illustrated in Fig. 11.2.

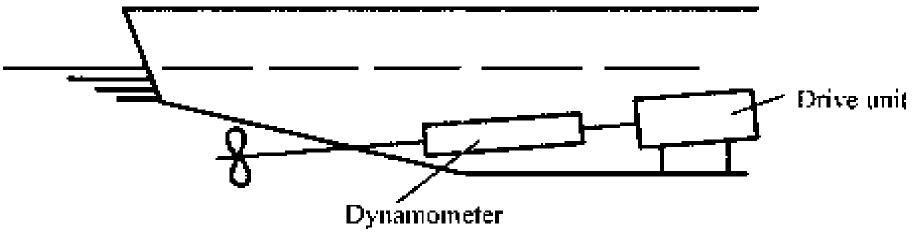


Fig. 11.2 Experimental technique

With the model at the correct speed, corresponding to that of the ship under study, a series of runs is made over a range of propeller r. p. m. straddling the self-propulsion point of the model. Model speed and resistance are recorded together with the thrust, torque and r. p. m. of the propeller. Results are plotted to a base of propeller r. p. m., as shown for thrust in Fig. 11.2, to find the model self-propulsion point.

The model propeller then has its thrust and torque measured in open water at a speed of advance estimated to be that of the flow through the propeller when behind the hull, i. e. making allowance for the wake. By comparing this curve with that obtained in the combined experiment, the correct speed for the propeller in open water can be calculated. The difference between the model speed in the combined experiment and the corrected open water speed is the wake. The relative rotative effciency follows as the ratio between the torques measured in the open water and combined experiments at self-propulsion r. p. m. The augment of resistance is obtained as illustrated in Fig. 11.3.

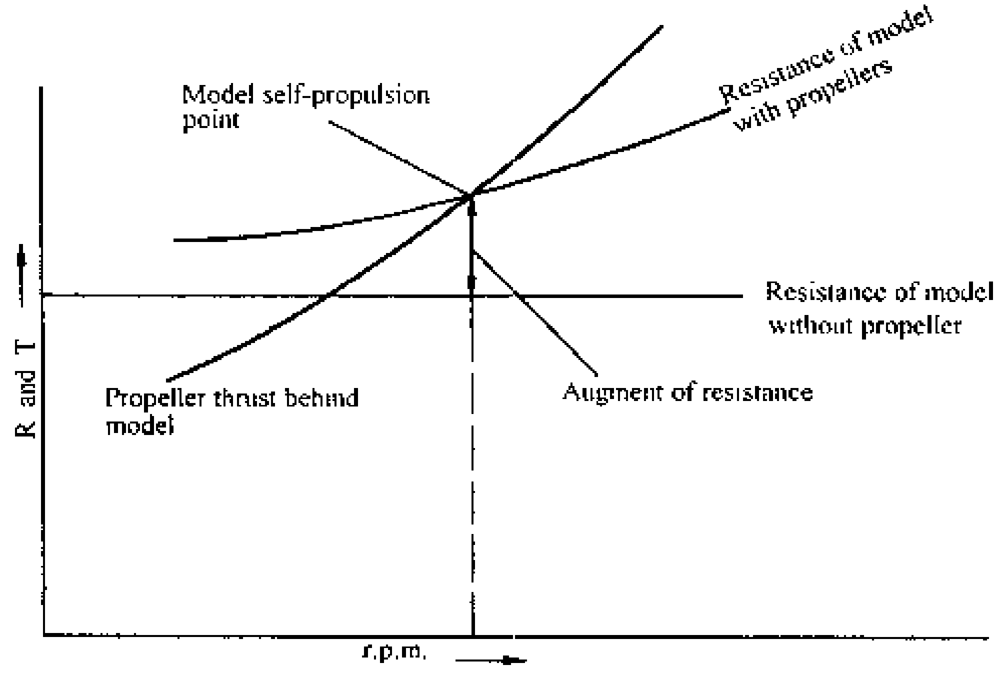


Fig. 11.3 Determination of model self-propulsion point

It should be noted that, although the propeller used in these experiments is made as closely representative of the ship propeller as possible, at least the first estimate of its geometry, the scale is too small to enable the thrust and torque figures to be used directly. Instead, the hull efficiency elements calculated as above are used with either methodical series data or specific cavitation tunnel measurements in order to produce the propeller design.

11.4 Propeller Tests in Open Water

It is important that the designer has data available on which to base selection of the geometric properties of a propeller and to determine likely propeller efficiency. Such data is obtained from methodical series testing of model propellers in open water. Such testing eliminates the effects of cavitation and the actual flow of water into a propeller behind a particular ship form, and makes comparisons of different propellers possible on a consistent basis.

The tests are carried out in a ship tank with the propeller mounted forward of a streamlined casing containing the drive shaft. The propeller is driven by an electric motor on the carriage. Thrust, torque, propeller r. p. m. and carriage speed are recorded and from these K_T, K_Q, J and η can be calculated. Usually runs are carried out at constant r. p. m. with different speeds of advance for each run.

11.5 Cavitation Tunnel Tests

It is impossible to run a model propeller in open water so that all the nondimensional factors are kept at the same values as in the ship. In particular, it is difficult to scale pressure because the atmospheric pressure is the same for ship and model and scaling the depth of the propeller below the surface does not provide an adequate answer. If cavitation is important, the pressure of air above the water must be reduced artificially and this is the reason for using cavitation tunnels to study propeller performance. Such a tunnel is shown diagrammatically in Fig. 11.4, and is usually provided with means for reducing the air content of the water to improve viewing.

In practice, experiments are usually run under the following conditions:

(a) the water speed is made as high as possible to keep Reynolds' number high to avoid serious scaling of skin friction;

(b) the model propeller is selected to have as large a diameter as is compatible with the tunnel size (tunnel wall effects must be avoided);

(c) model is run at the correct J value. This fixes the rate of

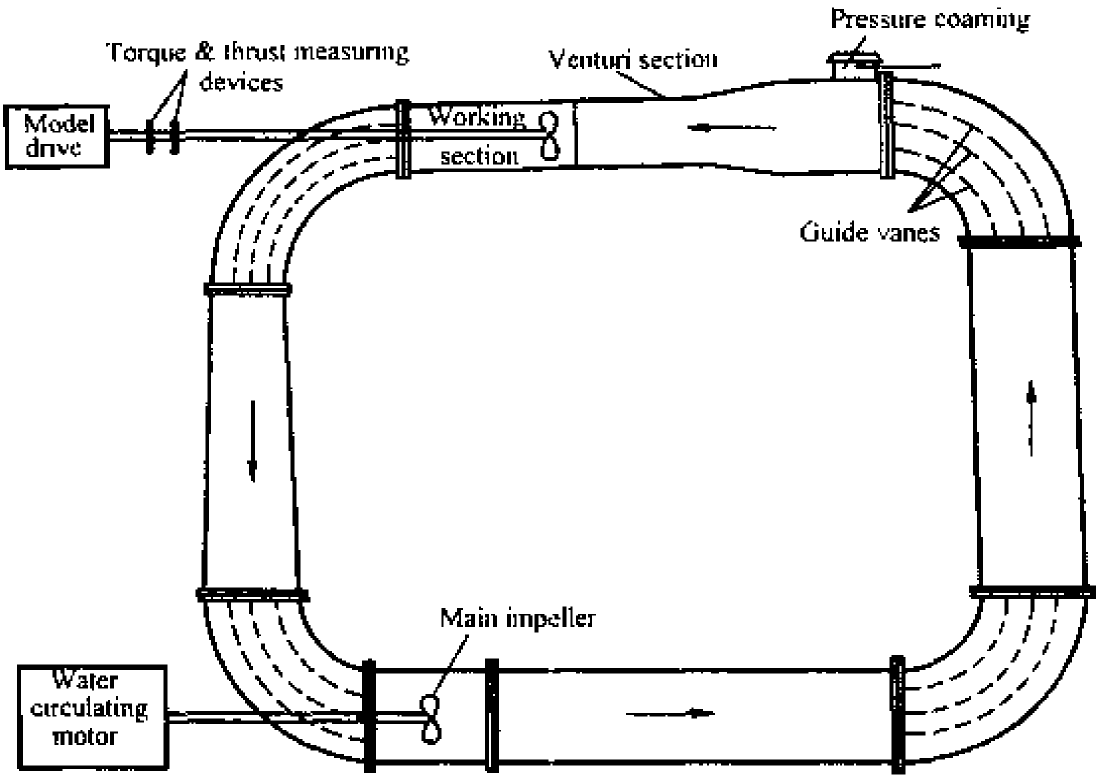


Fig. 11.4 Diagrammatic arrangement of a cavitation tunnel

propeller revolutions;

(d) the pressure in the turrnel is lowered to produce the correct cavitation number at the propeller axis.

Since the propeller revolutions are the most easily adjusted variable, it is usual to set the tunnel water speed, adjust the tunnel pressure to give the correct cavitation number and then vary the propeller r. p. m. systematically to cause a variation in the advance coefficient. The whole series can then be repeated for other σ values.

The tunnel shown in Fig. 11.4 is a fairly simple one and suffers from the fact that it is difficult to simulate the actual flow conditions at the after end of the ship. In some cases, attempts to reproduce this have been made using specially designed grids to control the local flow conditions. Also, the flow is from right to left in the working section so that the drive shaft on the model propeller is aft of the disc rather than forward of it as is the case for the ship. In big tunnels, both objections can be overcome by modelling the after end of the hull complete inside the tunnel and driving the propeller from inside this model hull.

In spite of these limitations tunnels have produced useful information on cavitation and the various forms it can take.

11.6 Ship Trials

Speed Trials

When a ship has been completed, speed trials are carried out to confirm that the ship has met its specification as regards design speed. Such trials also provide useful data to help the designer in producing subsequent designs.

The trials are carried out over a 'measured mile' which is a precisely known distance although it need not be precisely a nautical mile. The distance is marked clearly by prominently marked posts set up on land. A typical arrangement is illustrated in Fig. 11.5.

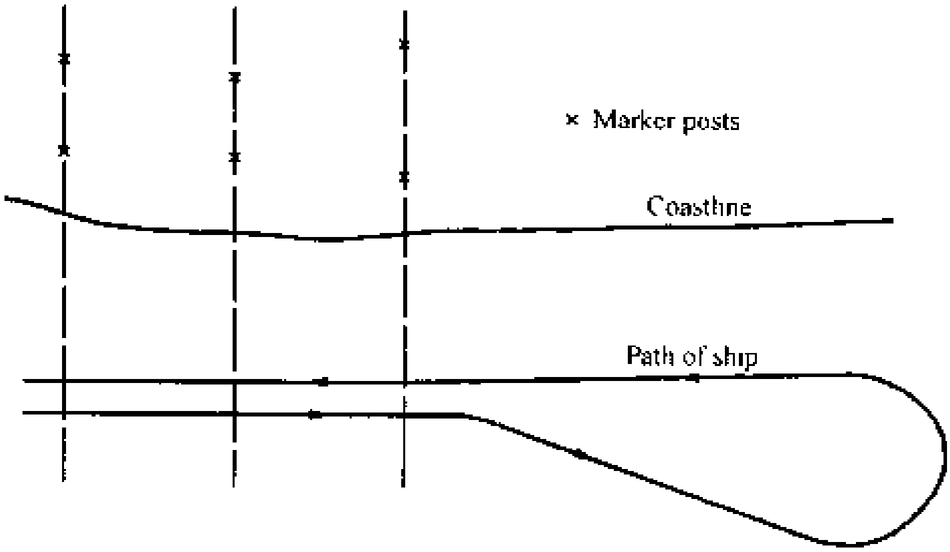


Fig. 11.5 Measured mile trials

(Note: Drawing not to scale. A straight approach run of about 3 miles is used.)

The ship approaches on a course normal to the lines joining corresponding pairs of 'mile' posts and sufficiently far off shore to ensure adequate depth of water to eliminate the effect of depth of water on resistance. The time to traverse the measured distance is accurately noted together with shaft thrust, torque and revolutions. A fine day with little wind and calm seas is chosen. To reduce its effect upon resistance the use of the rudder is kept to a minimum during the run. At the end of the run the rudder is put over to a moderate angle and the ship is taken round in a large sweep, as illustrated, to provide adequate run-up for the next pass to ensure that the ship has stopped accelerating by the time it passes the first pair of posts.

课外阅读

Additional reading 1

In studying the powering of ships, it is essential that the hull and propulsion device be considered together. The shaft horsepower required to drive a ship at a given speed can be derived from a series of model tests and calculations. The basic elements in the assessment of the shaft horsepower have been established and are summarized in Fig. 11.6.

It remains to show how model data is presented and the necessary calculations carried out. This is done in the next chapter.

Concluding Remarks

Basic elements of the resistance and propulsion of ships have been presented here. There remain many areas which have been much further developed, for which there is no room in a book of this sort. For example, considerable work has been done on the nature of the wake of a ship in the vicinity of a propeller so that the

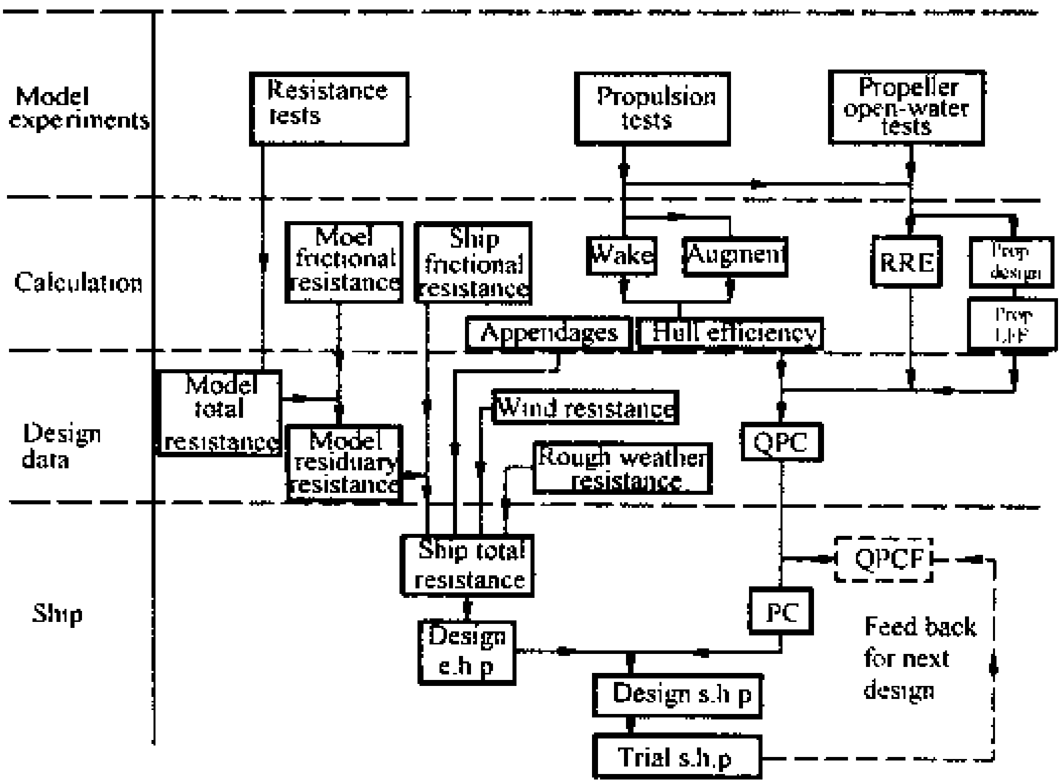


Fig. 11.6 Assessment of ship s. h. p.

interaction between hull and propeller may be better understood and allowed for. This has resulted in wake-adapted propellers in which the pitch varies with the radius and these are now quite common. The ducted propeller has become more common following development of a theory and a better understanding of the interference between the boundary layer on the inside of the duct and the tips of the propeller blades.

New facilities at ship model basins include devices for suppressing waves—and the effects of Froude Number—by a solid air/surface interface around a ship model in a closed circulating water channel. This permits a better representation of Reynolds' number for the ship, although correspondence of Reynolds' number for ship, propeller and appendages remains a problem. From all facilities in model basins, direct digital recording of resultsl has also become common, to be recalled from the computer and manipulated in accordance with prescribed programs.

These and many other important advances make it even more important to understand the general principles which this chapter has outlined.

Additional reading 2

Experiments at Full Scale

Ship trials over a measured distance in calm water can confirm, or otherwise, the accuracy of the prediction of ship speed for a given power. They cannot, however, prove that the fundamental arguments underlying these estimates are valid. In particular, they cannot prove that the estimation of e. h. p. was accurate because the influence of the ship propulsion system is always present.

William Froude realized this and with Admiralty assistance carried out full-scale resistance measurements on HMS Greyhound in 1874. More recently, full-scale resistance trials were carried out using the Lucy Ashton and HMS Penelope.

In the earlier trials, the screw sloop Greyhound was towed from an outrigger fitted to HMS Active, a vessel of about 3100 tonf displacement. This method (Fig. 11.5) was adopted to avoid, as far as possible, any interference between the towing and the towed ship. Trials were carried out with the Greyhound at three displacements and covered a speed range of $3 \sim 12\frac{1}{2}$ knots. Some trials were with and some without bilge keels. For some runs the tow rope was slipped and the deceleration of the ship noted.

William Froude concluded that the experiments:

> ... substantially verify the law of comparison which has been propounded by me as governing the relation between the resistance of ships and their models.

In the BSRA trials the problems associated with towing a vessel were overcome by fitting the ship with four jet engines mounted high on the ship and outboard of the main hull to avoid the jet efflux impinging either on the hull or on the water in the immediate vicinity of the hull. Accurate measurement of thrust, totalling just over 6 ton from the four engines, was achieved by using hydraulic load measuring capsules. Speeds were measured over measured mile distances.

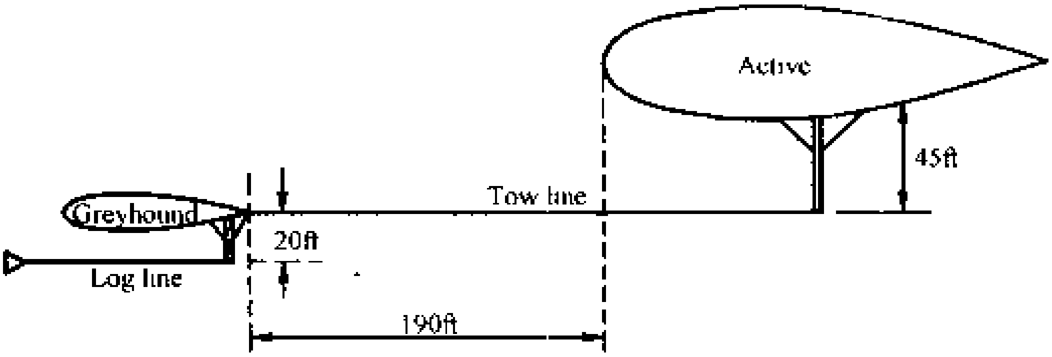


Fig. 11.7 Greyhound experiments

Resistance tests were made over a speed range of knots with a clean naked hull with first a red oxide paint surface and then a bituminous aluminium paint. Each trial was repeated for sharp seams of plating and with the seams faired off with a plastic composition. Additional trials were run to study the effect of dummy twin-screw bossing, with twin-screw 'A' brackets and shafts and with a hull surface which had been allowed to foul for about a month.

The main purpose of the trial was to compare the various methods available for scaling model resistance to full-scale. The results indicated that Froude's law of comparison is valid for the scaling-up of wave-making resistance, but that the usual assumption that the skin friction of models and ships is the same as that of the corresponding plane surface of the same length and wetted surface is not strictly correct. Fortunately, the error is not very important in practical calculations. The results also indicate that over the range of models tested, the interference between the skin-frictional and wave-making resistance is not significant.

（摘自<Basic ship theory>K. Kawson & E. Tupper. Vol. 1, 1998）

术语解释

full-scale	全尺度的
rough water	汹涛海面
geometrically similar form	（几何）外形相似船型
Froude law	傅汝德定律
skin friction	表面磨擦（力）
admiralty	海军部
model tank	船模（试验）水池
facility	设备，实验室，装置
carriage	拖车，拖架
dynamometer	测力计，功率计
wave suppressor	消波器，消波板
sinkage	升沉
trim	纵倾
AEW (Admiralty Experiment Works)	海军部试验场
propeller type log	螺旋桨推进器型测程仪
HMS=Her[HIS]Majesty's Ships	英国皇家海军舰艇
working allowance	有效使用修正量
Iris correction	Iris 修正
storm	扰动，风暴
storm correction	水池"风暴"修正（试验水池中测试数据异常的修正）

open water	敞水
run	(船模试验中拖车)走车
cavitation tunnel	空泡水筒
streamlined casing	流线形套管(罩)
drive shaft	驱动器轴
speed of advance	进速
straddle	跨立,外包式叶片
self-propulsion	自航
wake	伴流
augment of resistance	阻力增额
tunnel wall effect	水筒(或风洞)壁面效应
cavitation number	空泡数
advance coefficient	进速系数
grid	格栅,网格
ship trial	实船试验
nautical mile	海里
mile post	里程标,测速标柱
solid interface	不间断的交面
e.h.p.(=effective horse power)	有效马力
BSRA(=British Ship Research Association)	英国船舶研究协会
HMS Greyhound	英国皇家海军舰艇高速船灵猩号
Venturi section	文丘里试验段
Pressure coaming	阻力式舱口防水挡板
main impeller	主推叶轮

问　　题

1. Who was it that proposed for the first time the use of model tesk tank to determine ship resistance?

2. Please state the Froude's law of comparison.

3. Are the modern ship model tanks quite different from the first one in the principle of determinating ship resistance?

4. What is the cause of demanding longer tanks for ship resistance tests?

5. What is the purpose of conducting open water test for propeller?

Chapter 3 Ship Structure

Lesson 12 The Function and Design of Ship Structural Components

12.1 Definitions

The strength deck, bottom, and side shell of a ship act as a box girder in resisting bending and other loads imposed on the structure. The weather deck, bottom, and side shell also form a tight envelope to withstand the sea locally, and to provide the buoyancy which keeps the ship afloat. The remaining structure contributes either directly to these functions, or indirectly by maintaining the main members in position so that they can act efficiently.

The bottom plating is a principal longitudinal member constituting the lower flange of the hull girder. It is also part of the watertight envelope, and subject to the local water head. At the forward end, it must withstand the additional dynamic pressure associated with slamming, and there the plating thickness is usually increased to provide the necessary strength.

When fitted, the inner bottom also makes a significant contribution to the strength of the lower flange. The inner bottom and bottom shell, together with the bottom floors and girders, work as a double-plate panel to distribute the secondary bending effects caused by hydrostatic loads and cargo loads to main supporting boundaries, i. e. , bulkheads or the side shell. The inner bottom provides local support when it forms a tank boundary for the double-bottom tanks and is subject to the local pressures of the liquid contained therein. In addition, it is subject to the local loads from above, usually from cargo placed in the holds.

One or more strength decks form the principal members of the upper flange, usually provide the upper watertight boundary, and are subject locally to water, cargo, and equipment loadings. The remaining decks, depending upon their extent in the longitudinal direction, their distance from the neutral axis of the hull, and their effective attachment to the main hull, contribute to a greater or lesser extent in resisting the longitudinal bending loads. Locally, internal decks are subject to the loads of cargo, equipment, stores, living spaces, and, where they form a tank boundary or barrier against progressive flooding, liquid pressure.

The side shell provides the webs for the main hull girder and is an important part of the watertight envelope. It is subject to static water pressures, as well as the dynamic effects of pitching, rolling, and wave action. Particularly forward, the plating must be able to withstand the impact of the seas. Aft, extra plate thickness is beneficial in way of rudders, shaft struts, and stern tubes for strength, panel stiffness, and reduction of vibration. Additional thickness is necessary between the maximum winter and minimum service waterlines for navigation in ice and, more locally, for resisting the loads imposed by striking quays, piers, locks, and vessels alongside.

Bulkheads are one of the major components of internal structure. Their function in the hull girder depends on their orientation and extent. Main transverse bulkheads act as internal stiffening diaphragms for the girder and resist in-plane torsion loads, or racking loads, but do not contribute directly to longitudinal strength. Longitudinal bulkheads, on the other hand, if extending more than about one-tenth of the length of the ship, do contribute to longitudinal strength, and in some ships are nearly as effective as the side shell itself. Bulkheads generally serve other structural functions, such as forming tank boundaries, supporting decks and load-producing equipment such as king-posts, and adding rigidity to reduce vibration. In addition, transverse bulkheads provide subdivision to prevent progressive flooding. All applicable loads must be considered during design.

The foregoing structural elements of a ship are basically large sheets of plate whose thicknesses are very small compared with their other dimensions, and which, in general, carry loads both in and normal to their plane. These sheets of plate may be flat or curved, but in either case they must be stiffened in order to perform their required function efficiently. Corrugated bulkheads, stiffened by the corrugations, may also be used.

The various stiffening members have several functions: the beams stiffen the deck plating; the girders, in turn, support the beams, transferring the load to the pillars or bulkheads; for transverse framing, the transverse beams stiffen the side shell and support the ends of transverse deck beams and are, in turn, supported by the decks and stringers; for longitudinal framing, the frames supporting the plating run fore-and-aft and are in turn supported by transverse members. The stiffening members are generally rolled, extruded, flanged, flat, or built-up plate sections with one edge attached to the plate they reinforce.

Vertical plates connect the bottom shell and inner bottom. Those fitted transversely are called floors, and those fitted longitudinally are called center girders or side girders, as appropriate.

12.2 Interaction of Structural Components

Stiffening members do not, of course, act independently of the plating to which they are attached. A portion of the plate serves as one flange of the stiffener, and properties such as section modulus and moment of inertia used in the strength analysis of the stiffener must reflect this.

Stiffening members serve two functions, depending on how they are loaded. In the case of loads normal to the plate, such as fluid loading on a transverse bulkhead, the stiffeners provide edge restraint for the plate. In the case of in-plane loads, such as those induced in the deck by longitudinal bending of the hull girder, the beams serve to maintain the deck plating in its designed shape. If the deck beams are longitudinally fitted, they will, of course, carry the same hull bending stress as the plating, and may contribute substantially to the hull girder strength.

The decks, side shell, inner bottom, bottom, and bulkheads interact to provide overall edge restraint for each other. For example, a transverse bulkhead's ultimate support is provided by the side shell, decks, and bottom. At the same time, the bulkhead provides edge restraint for the large stiffened plate panels of the decks, side shell, and bottom which span between major transverse structural elements such as bulkheads. This interaction causes a complex stress pattern at stiffened plate intersections.

Pillars are used to support deck girders or deck transverses. These supports, in addition to carrying local loads from cargo, eduipment, etc. , serve to keep the deck and bottom from moving toward each other as a result of longitudinal bending of the hull girder.

In general, the concept of which structural component supports which other structural component is a simplified description of the actual structural interaction. On a ship or any other structure, all the elements tend to act together to provide the proper support and to carry the loads for which they are designed. This structural interaction, which in general can be very complex, can be very well represented by comprehensive finite-element three-dimensional mathematical models analyzed with the help of structural computer programs.

12.3 Design Based upon Engineering Calculations

Since the classification rules do not cover all design aspects in specifics, and in order to encourage innovative designs, most of the classification societies will review under special consideration any design supported by rational calculations. Such design may deviate from the published classification rules, and yet be accepted if the supporting engineering analysis proves it to be structurally sound. For example, according to the ABS Classification Rules (American Bureau of Shipping, Annual), alternative arrangements and scantlings will be considered if "they can be shown through… a systematic analysis based on sound engineering principles, to meet the overall safety and strength standards of the Rules." The design procedure, in this case, combines both intuition based on past design experience and structural analysis aimed at determining satisfactory structural response.

Nowadays, many computer programs are available for rational engineering analyses. The number and capabilities of these programs are constantly increasing. Typical capabilities cover various types of analyses, such as small displacement, large displacement, incremental plasticity, creep, thermal effects, temperature-dependent materials, natural frequencies, mode shapes, transient response and structural instability.

The complexity of engineering problems encountered in the marine industry has led to extensive and ever-expanding computer usage. In addition to the conventional static and dynamic problems of design, the problems encountered in assessing marine structural response are compounded by the unpredictable nature of sea, and sometimes cargo loads. Special phenomena associated with the dynamic interaction of waves and ships at sea must be taken into account. Springing, for example, is a vibration of the complete vessel induced by the wave frequency in conjunction with the ship's elastic properties. Other areas of concern are local vibrations, which may be induced by waves or action of the propeller and drive shafts. Other loading conditions include those due to thermal effects, sloshing of liquid in cargo tanks, bottom slamming, and sea ice.

Mathematical techniques, such as matrix methods, finite element methods, and statistics, have been available for a long time. The advent of electronic digital computers makes possible the full utilization and implementation of these techniques in an efficient engineering approach to the solution of the numerous problems associated with the design, construction, and analysis of ships and other marine structures.

The computer allows a more rigorous determination of structural response to the specified loads than has been previously possible, even though the load specification remains somewhat indeterminate. In effect, the use of computers lessens the need to make simplifying assumptions in one area of the total problem, and hence the accuracy of the final solution is improved, even though a certain level of possible inaccuracy relating to the uncertainty of the load input must still be acknowledged.

12.4 Optimum Design Using Numerical Methods

Rational design of ship structures has forced the designer to determine quantitatively as many as possible of the factors affecting the safety and performance of the structure throughout its life, and to use this information to determine that particular design which optimizes performance and provides adequate safety. This process involves many calculations, but the use of a computer can simplify the task, providing an automated optimum rational design.

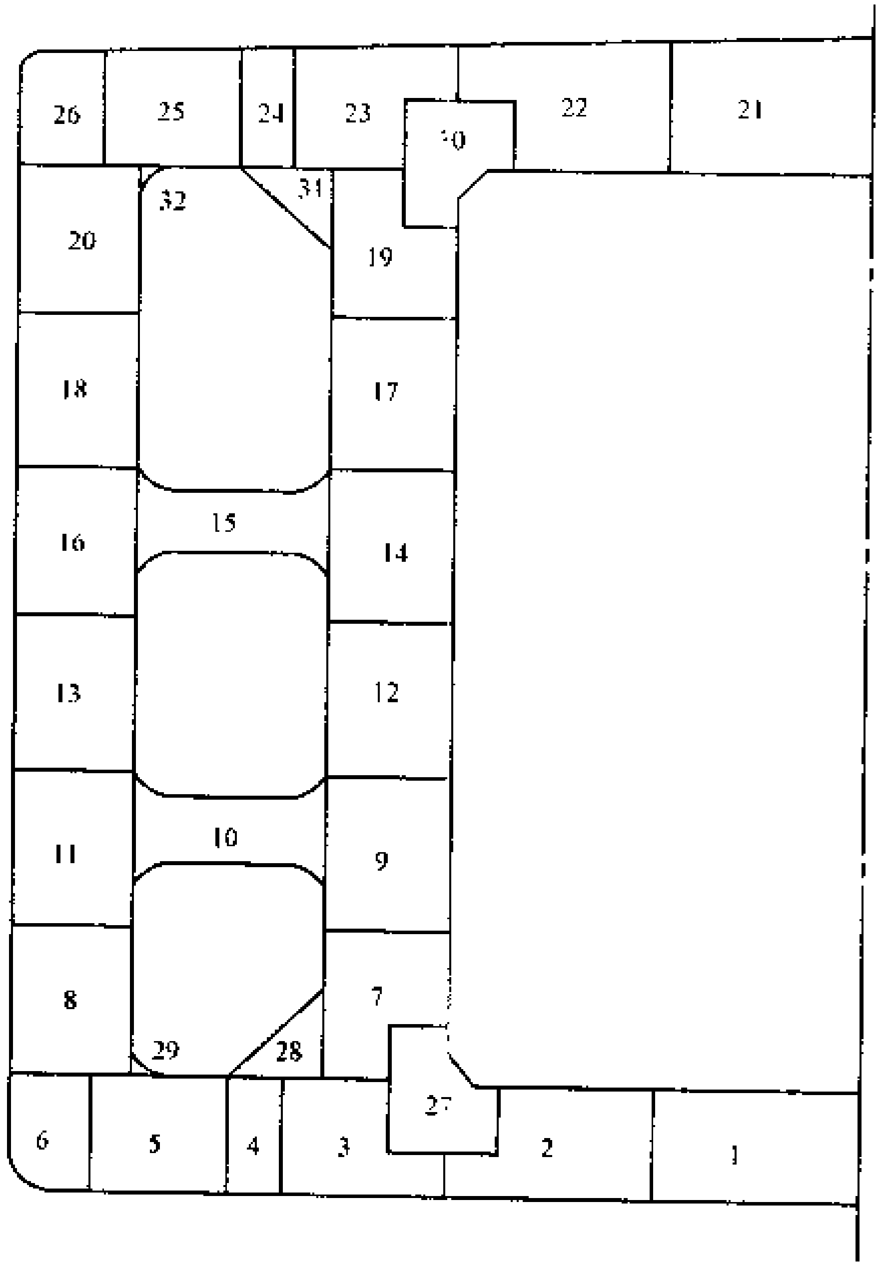


Fig. 12.1 Zones of constant thickness for structural optimization

Ship structural optimization is a complex task involving structural analysis to determine the response to multiple loads, and application of optimization techniques for resizing of the individual structural members to achieve an optimum design. Different optimization techniques combined with various structural analysis methods for ship design have been used.

Structural optimization determines the design variables which will minimize (or maximize) a specified objective function, while satisfying a constraint condition. Typically, the objective function is the weight or the cost of the structure, and the constraints are the stresses, displacements, or other response characteristics.

An example of optimization design for the web frame of a tanker is shown in Figs. 12.1 and 12.2. The web frame was divided into zones of constant thickness, as indicated by each numbered panel in Fig. 12.1. The extent of this decomposition is arbitrary, and it depends on the size and availability of steel plates, convenience, ease of construction, etc.

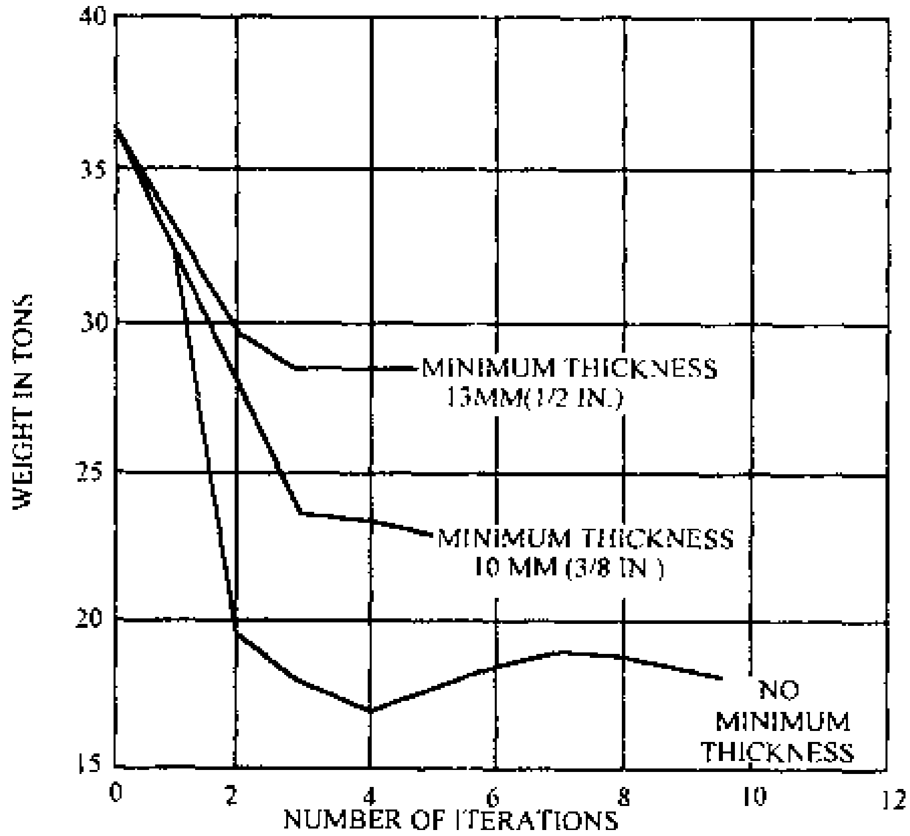


Fig. 12.2 Reduction in weight using structural optimization

An optimality criterion based on fully-stressed design was used to minimize the weight of the web frame with a double-iteration procedure developed for the efficient use of the finite-element analysis in the optimization program. The shell, deck, and bottom plating which are attached to the web frame were not allowed to vary in the optimization procedure, since their thicknesses are determined from longitudinal strength requirements and other considerations.

The main conclusion is that it is possible to minimize the weight of the web frame, with the reduction in weight being dependent on the minimum allowable plate thickness, not on the allowable stress in the web frame. Three different thickness requirements were used, and the corresponding reductions in weight are shown in Fig. 12.2.

The optimization procedure is general and is applicable to any web frame or similar structure. Possible extensions of the procedure could relate the number of stiffeners required to prevent shear buckling and vibration to the minimum plate thickness of the webs.

课外阅读

Additional reading

Classification Society Rules

Although direct engineering design might be preferable, the design of structural members of merchant ships is greatly influenced by the rules of classification societies; in fact, the principal scantlings of most merchant ships are based directly on these rules. Classification societies were created to serve the marine industry by establishing certain standards which provide assurance that a vessel possesses the structural and mechanical fitness for its intended service. Classification societies were recognized by governments under a provision of the 1930 Load Line Convention and were urged to confer from time to time "…with a view to securing as much uniformity as possible in the application of the standards of strength on which freeboard is based."

Since the 1930, Load Lines Convention was signed, great changes have occurred in ship design and construction, shipbuilding technology, and ship operation. New types of closing appliances, in particular metal hatch covers, have improved the watertight integrity of ships. Other technical developments (the extensive use of welding, rounded gunwales, etc.) have also become widespread. The vast increase in the size of ships, particularly tankers and bulk carriers, has made it necessary to extend the existing freeboard tables to cover ships up to a length of 366m (1200ft). All these considerations, together with the experience gained from the use of the 1930 Convention, merited a thorough examination with a view to the adoption of an up-to-date Convention on Load Lines.

Another international conference on load lines was therefore convened in 1966, in order to draft a new convention and bring the load line regulations into accord with the latest developments and techniques in ship construction. The regulations developed by this convention are now in force. Since the societies were not only recognized as the source of strength requirements, but were also designated as Load Line Assigning Authorities by their respective governments and the governments of many other countries, application of the Load Line Convention was the major subject of discussion, with a view to achieving the intended uniform treatment of all ships under its provisions. It was only natural, however, that other subjects of common interest should be discussed and, as the shipping and shipbuilding industries became more international following World War Ⅱ, the desirability of some degree of uniformity among the classification requirements became readily apparent.

The rapid increase in the scope of the cooperation among the societies, and the creation in 1959 of the Inter-Govern mental Maritime Consultative Organization (IMCO), led classification societies to join as a group to establish liaison with IMCO. This group is called the International Association of Classification Societies (IACS) and was formed in 1968. As of mid-1979, it had nine members and three associate members. Its work falls into two general catego ries: development of uniform classification rules called Unified Requirements, and collaboration with outside organizations.

The unification of classification requirements is a long-term effort. To date, more than one hundred Unified Requirement have been adopted by all the members, ranging from uniform specifications for hull steel to the maximum steam temperature in tanker pump rooms. Unified Requirements developed by the various working parties or correspondence groups are submitted to the IACS Council for approval. Following this, they are subject to the normal rule-making procedure of each classification society before they may be incorporated into the Rules, since the governing bodies of the individual societies still retain control over their own rules.

The majority of merchant vessels are classed under the Rules of the American Bureau of Shipping (ABS) or Lloyd's Register of Shipping (LR). These rules are listed as ABS and Lloyds Rules, and most of the specific rule requirements in the sections that follow are taken from these two sources. Other classification societies have similar rules, and sometimes several standards are applied to the same ship.

Classification society rules contain a great deal of useful information relating to the design and construction of the ship's various structural components, so that determinations can be made of some rule scantlings, i.e., the dimensions of a ship's frames, girders, plating, etc., directly from equations and tables given in these publications. The possibility of choosing structural members directly from tables has been reduced in recent years due to a trend for classification societies to present their requirements in terms of section properties rather than in terms of actual sizes required. In many cases, for various structural components, the classification rules indicate by sketches and descriptive matter good-practice construction methods for the designer.

In recent years, modifications to Rule thicknesses have been permitted when high-strength steel is used or where special protective preservative coatings are used to reduce the need for corrosion allowances. In such cases, careful consideration must be given to plate instability, since standard Rule panel sizes are based on full Rule plate thicknesses. Other modifications and special requirements have been incorporated for vessels intended to carry oil, ore, bulk cargos, liquefied gases, etc. The study and use of these rules is essential in merchant ship structural design.

(摘自<ship Design and constuction>. 12. Taggart. The SNAME on World Trade Center NewYork, 1980.)

术语解释

strength deck	强力甲板
box girder	箱桁
weather deck	露天甲板
flange	突边(缘),法兰(盘)
local water head	局部水头
inner bottom	内底
progressive flooding	累进进水

quay	码头(与岸边平行的码头)
watertight	水密
pier	码头(与岸边垂直的码头)
lock	船闸
king-post	主桅杆
stiffen	加劲,加强
corrugated	波纹形的,瓦垅形的,有槽的,有加强肋的
corrugation	波纹,槽纹,瓦垅
rolled	滚轧制的
extruded	压(挤)成的
flanged	起折边的,作法兰边的,作凸缘的
pillar	柱
stringer	纵梁(桁,栈),桁条
floor	地肋,底板
section moulus	剖面模数
in-plane load	面内载荷(沿板面的载荷)
built-up plate section	组合型材
finite element	有限元
to be structurcally sound	在结构上是坚固(合理、安全可靠)的
thermal effect	热效应
incremental plasticity	增量(步进)塑性
mode shape	模式形状
transient response	过渡响应
structural instability	结构不稳定性
springing	颤振
drive shaft	驱动器轴
sloshing	(液体)晃动
matrix method	矩阵法

uncertainty	不确定性
web	腹板
web frame	腹肋板
decomposition	分解
optimality criterion	最优性准则(判据)
double iteration procedure	双重迭代法
stiffener	换强材,加劲杆(条)
shear buckling	剪切性屈曲
resizing	尺寸再生,恢复到原来尺寸
specified objective function	指定的目标函数
contraint condition	约束条件
provision	规定,条款,措施
confer	比较,参照
hatch cover	舱口盖
Load Line Convention	载重线公约

问　题

1. What is the significance of having an inner bottom for building tankers?

2. What are the reasons for additional side shell thickness?

3. List the main functions of various stiffening members?

4. What is the usage of finite-element method in ship building?

5. In what way would an architect minimize the scantling of a shiphull? Is he allowed to determine the thickness based on his strength calculations?

Lesson 13 Relation of Structure to Molded Lines

13.1 Nature of Molded Lines

The molded lines are a delineation of the ship's form. They are first drawn to relatively small scale in the early stages of a ship's design. In order to construct the ship, these small-scale lines must be redrawn at a large enough scale to define the shape accurately so that structure may be cut and formed, systems located and designed, etc. Traditionally, this larger scale was full size, the lines being laid down on a mold loft floor and templates made from the full-scale lines for use in guiding cutting and forming operations. This system is still used, but in many large shipyards the full-size mold loft has been replaced by other systems, as described latter.

13.2 Need for Molded Lines

Lines, however produced, define mathematical surfaces of no thickness rather than the actual shell, deck and bulkhead plating, frames, longitudinals, and so on. For these structures to fit together when assembled, the surfaces represented by the molded lines must be clearly defined and due allowance made for the thickness of the structure. In order to do this, when the loftsmen and ship fitters undertake to transform detailed working drawings of the ship's structure into actural structural members, they must have very definite understandings regarding the relation of the structure to the molded lines. The molded line represents the junction between the shell, deck, and bottom plating and the supporting structure; hence, one line defines the inner line of the shell, deck, and bottom as well as the outer line of the supporting structure. Conventional relationships in this respect have developed which are fairly standard throughout the industry. Figs. 13.1 and 13.2 illustrate some of there practices.

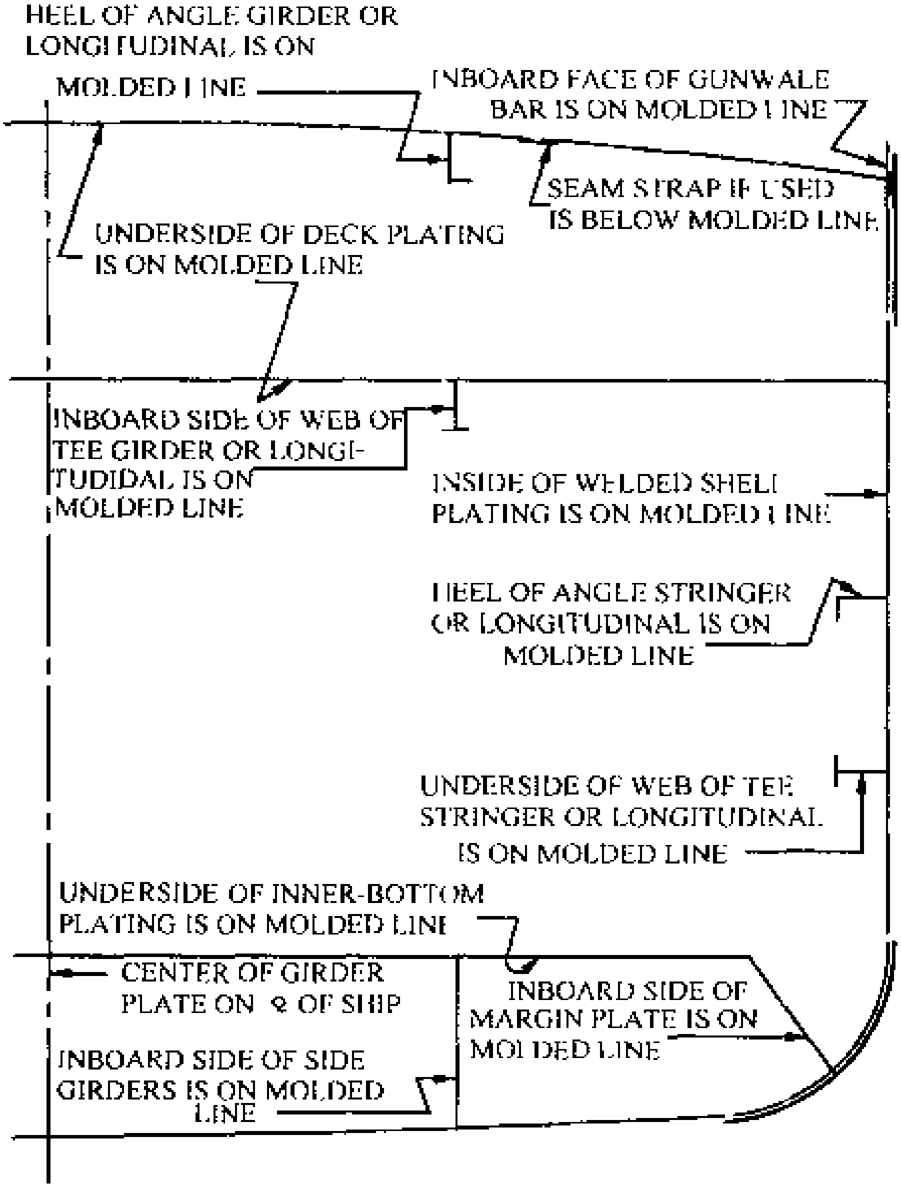


Fig. 13.1 Relation of longitudinal structure to molded lines

The spatial disposition of the molded lines of the hull and internal structure is described by their vertical distances from the

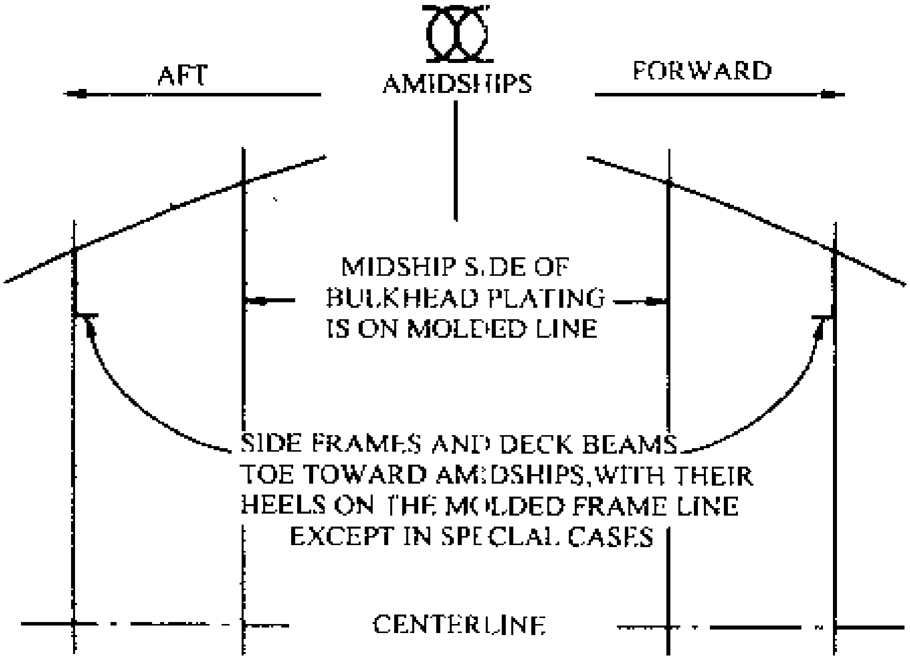


Fig. 13.2 Relation of transverse structure to molded lines

horizontal reference plane indicated on drawings as the base line, and by their horizontal distances from the vertical reference planes, one located at the longitudinal centerline of the vessel and one located transversely at the mid-length of the vessel. The horizontal reference plane generally coincides with the molded line of the horizontal bottom-shell plating.

13.3 Molded Lines

a. Shell Plating. The inner surface of welded shell plating is usually flush and is on the molded line. This arrangement eliminates the necessity of joggling shell frames crossing welded seams where the plates vary in thickness.

b. Double Bottoms. The underside of the inner-bottom plating is usually flush, and is placed on the molded line.

The vertical keel plate is located on the centerline of the hull, with half its thickness on each side. Side longitudinals and a sloping margin plate are normally set with the inboard side of the plate to the molded dimension.

c. Deck Plating. The underside of deck plating is normally set to the molded line of the deck with differences in thickness showing above the deck. Where the stringer strake is thicker than the remainder, this results in a ledge at the inner edge of the stringer strake which, as seen in the midship section, would seem to interfere with drainage, but actually the sheer and camber of the deck are such that this condition is not objectionable.

When unusual thicknesses of deck plating are used, it is not uncommon to make special definitions of the molded line of the deck plating to suit conditions. For instance, in naval vessels where 6 mm (0.25in.) plating may be used at the ends in association with heavy plating amidships, the molded line sometimes has been run 6 mm below the top of the plating throughout the deck, regardless of the thickness of the plating. Similarly, if a thin deck covering is used, such as rubber tile, with a very minimum of leveler beneath it on a deck with substantial differences in plate thickness, the plating may be arranged to be flush on top with the differences in thickness showing on the underside of the plating. Where such departures from usual practice of a shipyard are followed, they will be defined on the structural drawings.

d. Bulkhead Plating. Transverse bulkhead plating usually has its after surface on the molded frame line in the forebody and its forward surface on the molded frame line in the afterbody. Longitudinal bulkhead plating generally has its inboard surface on the molded line.

If a bulkhead has varying thicknesses of plating and the stiffeners are located on the side away from the molded line, the bulkhead can be made flush on the stiffener side to avoid joggling or notching the stiffeners, and the thinner plates can be moved from the molded line.

e. Frames and Beams. Shell frames and deck beams are normally toed toward amidship with their heels on the molded frame line, as in Fig. 13. 2. This facilitates access for welding and inspection of side frames at the forward and aft ends of the vessel where there is more shape to the shell. Where the side shell is longitudinally framed using angles or bulb plates, the angles or bulb plates toe down and the heel is on the molded line; when tees are used, the lower side of the web is on the molded line. Where decks are longitudinally framed using angles or bulb plates, the angles or bulb plates toe outboard, and the heel is on the molded line; when tees are used, the inboard side of the web is on the molded line.

Good coordination must exist among draftsmen, loftsmen, and shipfitters, based on a clear understanding of the importance of the relationship of structural members to the molded lines. This relationship must be standardized, in order to avoid assembly problems and discontinuity of structure.

13.4 Structural Alignment and Continuity

The classification society rules and the methods of structural analysis provide means for determining the size and thickness of various parts of ship structures. When these soures are properly used, the designer may be reasonably sure that he has provided adequate strength. Of equal importance, however, are structural alignment and continuity.

Structure is aligned when the loads in structural members have a direct path to the supporting structure. Alignment usually concerns two connected members in the same plane. Their connection may be direct by a butt weld to each other, or intercostal by a fillet weld connection of each member to the opposite sides of a continuous member in a plane perpendicular to the members. This is fundamental, but many ships have suffered severe problems when other design requirements have been assigned undue priority over structural alignment. The problem is twofold, i. e. , alignment during design, and alignment during construction.

During design, support for vertical loads at one level must be aligned with support below. Thus, a bulkhead designed to prevent racking of a deckhouse is less effective when not aligned vertically with adequate structure in the main hull. Similarly, pillars must, if at all possible, be placed one under the other. If a line of pillars must be stepped, specially reinforced girders or other means must be provided to transfer the load.

The second aspect of alignment is the assurance during construction that the position of structure the designer intended is actually achieved. Not every shipfitter appreciates that misaligning a chock on one side of a bulkhead with the girder flange on the other side subjects the bulkhead plating to loads that would be otherwise carried by an alignment clock. In some areas, the designer has little control over this particular construction problem. The problem can be overcome, however, by avoiding where possible design details which require alignment of structure on opposite sides of a plate where the fitter putting in the backing structure has no convenient means, visual or simple direct measurement, for precise location of the back-up member.

The alignment which the designer controls directly must be provided early in the development of plans. It is more expedient to develop arrangements within the framework of given bulkhead, pillar, and girder locations which provide the necessary support, than to develop a set of arrangements and then try to find consistent locations for structure within them. Close collaboration between structural and arrangements design people in the early stages is essential for a balanced design. If one group or the other goes too far in development without consultation, unsatisfactory results are inevitable.

13.5 General Description of Problem

Structure has continuity when it is capable of transferring the loads in the structure without creating abrupt changes in stress levels. It is axiomatic that poorly aligned structure has little continuity. Good alignment, however, does not insure continuity. A 150-by-10-mm flat bar may be perfectly aligned with a 50-by-10-mm flat bar, but continuity would be lacking unless the deeper member is tapered to 50mm. Gererally, a designer compensating for a cut in a bulkhead is preserving continuity, while the designer assuring that this bulkhead is supported by structure on the far side of an intervening deck is said to be providing alignment (and, hopefully, continuity). The distinction between alignment and continuity is not important, but providing both is essential to good design and construction.

(摘自<Ship Design and Construction>R. Taggart, the SNAME on World Trade Center, NewYork, 1980)

术语解释

molded lines	型线
mold loft floor	(型线)放样间地板
template	样板
forming operation	成型加工
longitudinal	纵向的,纵梁
flush	平贴,磨光
joggle	折曲,榫接,弯合

strake	船体列板
ledge	副梁材
rubber tile	橡皮瓦
leveler	调平器,矫平机,矫直机
notch	开槽,开凹口
bulb plate	球头扁钢
angle plate	角钢
transverse bulkhead plating	横隔舱壁板
toed towards amidships	趾部朝向船舯
heel	柱脚,踵材,底基,倾斜
shell	船壳板
tee	T 形构件,三通管
there is more shape to the shell	船壳板的形状较复杂
drafsman	绘图员
loftman	放样工
shipfitter	船体安装工
allowance	公差,余(裕)量,加工裕量,补贴
structural alignment	结构校准,组合,组装
butt weld	对缝焊接
intercostal	肋间的,加强肋
fillet weld connection	贴角焊连接
racking	倾斜,变形,船体扭转变形
alignment chock	组装校准用垫楔(或填料)
back-up member	焊接垫板
axiomatic	理所当然的,公理化的
taper	弄细,变尖
intervening deck	居中甲板
pillar	支柱
backing structure	垫衬结构

问　　题

1. What are molded lines? Do they depict the outside surface of a ship?

2. Why should the loftman and ship fitters in a shipyard have definite understanding of the relation of the structures to the molded lines?

3. To ensure providing adequate strength in the stage of ship structure assembly, what kind of production process is considered to be very important?

4. Would it be too early for a designer to consider the alignment problem in the stage of development of plans?

Lesson 14 Ship Strength

14.1 Strength

The structure of ships is more complex than most other man-made structures for several reasons. In addition to satisfying the general arrangements required by its mission and payload (and tonnage measurement rules for merchant ships), the exterior hull and internal tankage must be watertight structural envelopes able to withstand the anticipated loads encountered at sea. The exterior hull must also conform to the rules of good hydrodynamic design practice, which involves more complex geometries than are customarily found in land-borne structures.

It is in the area of anticipated loads that the most difficulty is encountered. These loads are the static and dynamic loads of the weights of cargo, machinery, and structures as well as the buoyant force of the seawater and the environmental loads of winds, waves, ice, and thermal effects. The dynamic environmental loads, especially the wave loadings in a hostile sea, are indeterminate in nature and can only be described in a statistical sense. These external and internal loads, resulting from the relative motion between the ship and the sea, require that the ship structure withstand the impact loads of slamming and deck wetness, the wave-induced vibrations of propellers and machinery, fatigue from repeated bending, and many other phenomena associated with seagoing vessels.

At present, the approach to structural design is considerably enhanced by extended research into the statistical description and effects of sea conditions, together with the powerful analytical capabilities of digital computers. With this combination of research and computers, an attempt is being made to answer complex questions concerning the optimization of structural design to satisfy both strength and cost requirements.

For this introduction to the design of ship structures, ship strength will be approached by the traditional route, with methods that have long been used and are still the basis of structural design. More recent applications of strength studies will then be considered as extension of the basic approach described.

A ship in a seaway can be considered similar to a beam with supports and distributed loads. The supports are buoyant forces of the waves and the loads are those of the weight of the ship's structure and load within such as fuel, water, and cargo. The worst condition of loading and support for a ship occurs when it heads into or away from the sea, with waves approximately as long as the length of the ship. A quartering sea can also produce this condition if the ship's bow and stern are either in troughs or on crests at the same time, in which case torsional loads must also be considered.

The ship shown in Figure 14.1 is supported by waves with the bow and stern each riding a crest and the midship region in the trough. This ship will bend with compression at the top and tension at the bottom. The ship is said to be sagging, and in this condition the weather deck wants to buckle due to compressive stress while the bottom plating stretches due to tensile stress.

When the ship advances half a wave length, so that the crest is midships and the bow and stern are over troughs, as in Figure 14.2, the stresses are reversed. The weather deck is in tension and the bottom plating is in compression, and the ship is said to be hogging (as in carrying a pig over your shoulder).

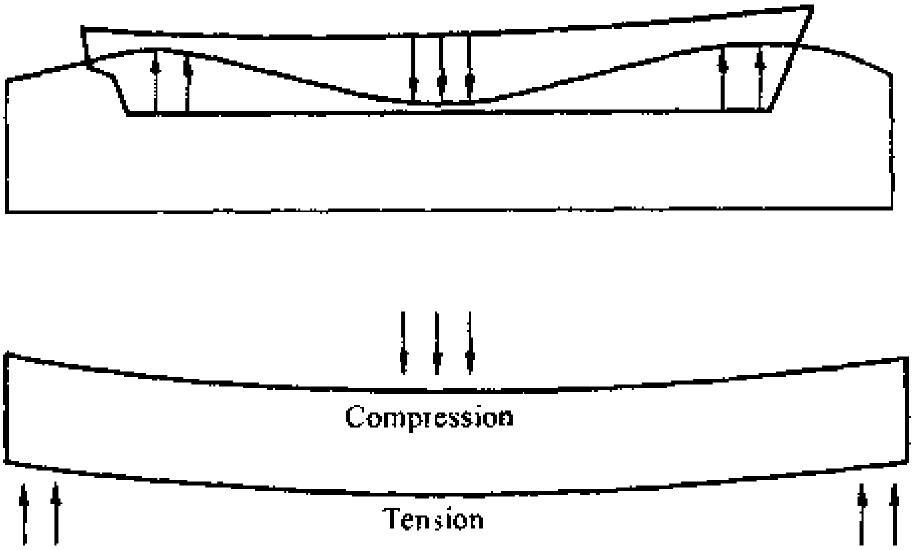


Fig. 14.1 Sagging condition

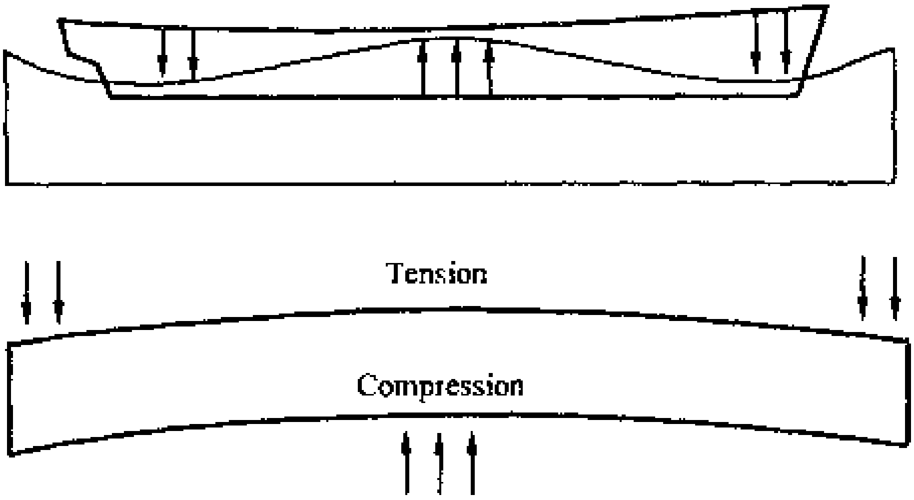


Fig. 14.2 Hogging condition

Ship Strength and the Beam Theory

The beam theory assumes that a ship, for purposes of strength considerations, may be likened to a hollow, nearly rectangular girder. Basically, the comparison is correct. Assuming first continuity of the material structure and second the known distribution of forces, calculations can be made for the strength of such a beam of known cross section, regardless of size. However, because of the complexity of the ship's structure, the discontinuity of various members, the variations in fastenings (rivets and welding), the openings in the hull, the dynamic loads as well as complex static loads imposed, to cite but a few of the discrepancies, the simple beam theory becomes a general rather than an exact criterion. This is not to say that it is of little value—beam theory is a primary tool used in ship design. In all cases of structural damage, beam theory should be the basic method employed in analyzing any reduction in structural strength and the basic guide in considering restorative measures.

Although discrepancies exist in assuming the ship is a simple girder, beam theory has produced a reliable basis upon which an analysis may be made. It is an approach universally used, and hence provides a standard upon which strength calculations may be made, and upon which results may be analyzed and compared.

14.2 Beam and Load Classification

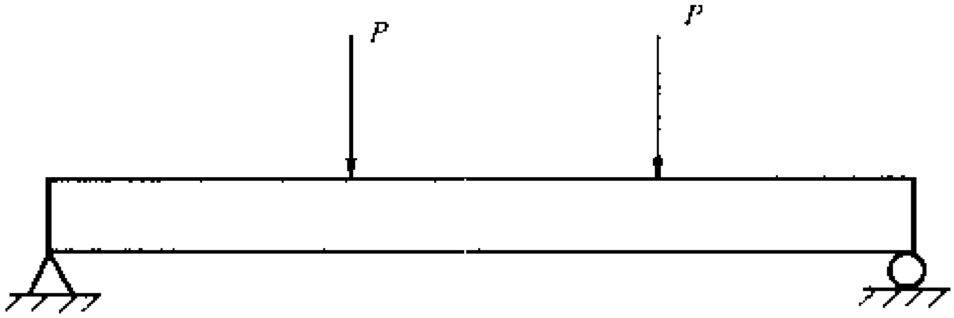
Before discussing the application of beam theory to ship problems, the essential elements of the study of solid mechanics (strength of materials) will be presented. This involves analysis of the effects of different types of loads on beams supported in various standard configurations, as illustrated in Figure 14.3.

1. Concentrated loads or point loads are considered to exist when the area of contact is small relative to the size of the beam.

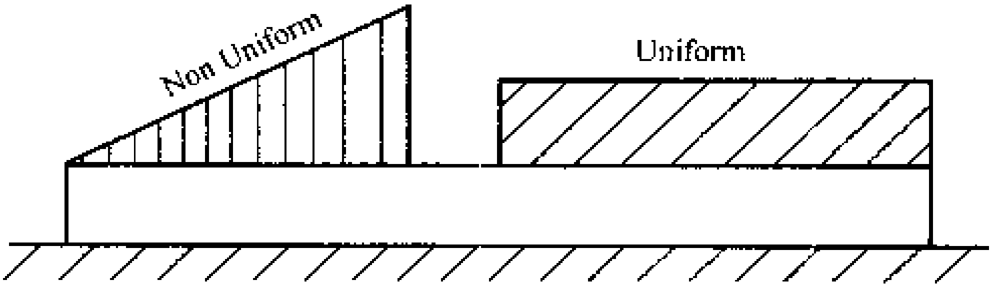
2. Distributed loads are considered to exist when the area of contact is large relative to the size of the beam. Distributed loads may be uniform and stated in terms of the load per unit length of the beam. They may also vary uniformly according to some mathematical relationship or they may vary in an arbitrary fashion.

Special cases of the above loads include

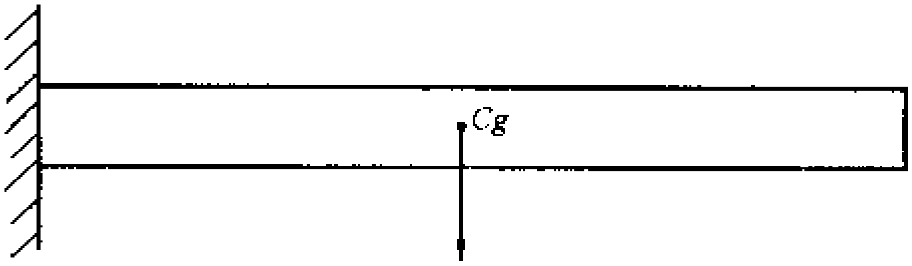
3. Frictional loads, which act parallel to the area of contact and



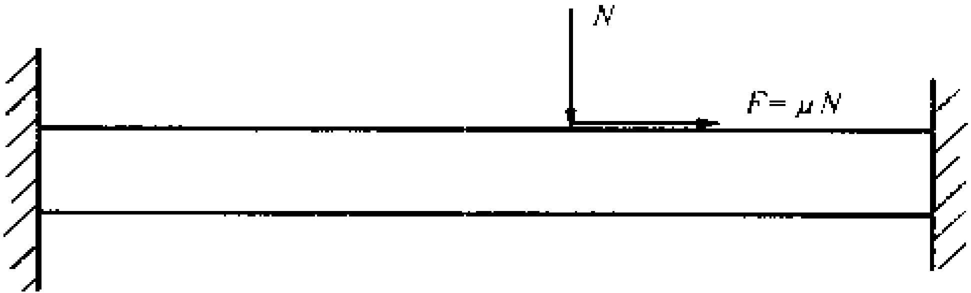
(a) Concentrated loads on a simply supported beam



(b) Distributed loads on a continuously supported beam



(c) Gravitational load on a cantilevered beam



(d) Frictional and concentrated loads on a fixed end beam

Fig. 14.3

are generally a function of the normal force times the coefficient of friction.

4. Gravity loads, which are those caused by the weight of the beam and may either be considered as a distributed load or a concentrated load at the center of gravity of the beam. To simplify some problems, the beam is considered to be weightless.

5. Thermal, inertial, and magnetic loads, which, like gravity loads, do not depend on body contact, but apply throughout the beam.

Loads may also be classified with respect to the types of deformation they produce or with respect to the time of action of the load.

1. Axial loads pass through the centroid of the beam sections and produce tensile or compressive strains.

2. Torsional loads or torque loads cause the loaded member to twist or rotate relative to itself about some axis. Torsional loads are found in shafts used to transmit power and in the suspensions of some automobiles and racing cars.

3. Bending or flexural loads are caused by forces that produce moments and couples on a beam and result in variations of stress and strain across a section of the beam.

4. Shearing loads are those that produce shearing strains in a beam.

5. Combined loads are combinations of the above that produce complex deformations of the structural member.

In terms of the time of action of the load, the classifications are

1. Static loads, which are applied gradually and may or may not be sustained over a long period of time (dead loads). Static equilibrium is maintained unless failure occurs.

2. Dynamic loads, which vary with time and generally fit the following categories.

a) Repeated or fatigue loads, which involve large numbers of cyclic loading over a period of time. Resonant vibrations in the structure may or may not be induced, depending on the frequency of the repeated load.

b) Impact or energy loads, which are rapidly applied loads producing vibrations and occasionally permanent deformation in the structure. Equilibrium is not reestablished until the vibrations dampen out.

(摘自< Introduction to Naval Architecture > T. Gillmer & B. Johnson, London. E. & F. N. SPON, 1982)

术语解释

anticipated loads encountered at sea	在波浪中遭遇到的预期载荷
land-borne	陆基的,装在陆地的
hostile sea	汹涌波浪
impact load	冲击载荷
slamming	砰击,拍击
deck wetness	甲板淹湿
distributed load	分布载荷
quartering sea	尾斜浪,从船斜后方来的浪
torsional	扭转的
buckle	屈曲
tensile stress	拉(张)应力
sagging	中垂
hogging	中拱
member	部件
fastening	坚固件
configuration	构形,配置
normal force	法向力

deformation	变形
centroid	形心，重心，质心，矩心
strain	应变
torque	扭矩
flexural	挠曲的
shear	剪切，剪力
dead load	恒(静载荷)
fatigue	疲劳
damp out	阻息，逐渐降低
kips(=kilo-pounds)	千磅
statically determinant	静定的
statistical	统计学(上)的

问　　题

1. Where do the internal and external loads of a ship result from?

2. In what way can the complex problems be solved concerning the optimization of structural design to satisfy both strength and cost requirements?

3. Why is beam theory very important in the analysis of ship strength?

4. What types of loads are involved in the study of solid mechanics relating to beams?

5. What kinds of loads are there if classified by the types of deformation they produce?

Lesson 15 Ship Structural Stresses and Strength Curves

15.1 Structural Stresses Within a Ship

The foregoing section emphasized the likeness of a ship to a single structural beam. This is, in fact, a basic premise in ship-strength calculations; however, because of the complexity of structure and the forces imposed, all of the stresses of the ship's structure must be accounted for in the design in order to check the adequacy of the ship's strength. Therefore, in order to differentiate their origin and effects, the stresses are ordinarily considered in two groups: (1) hull girder stresses and (2) local stresses.

Hull Girder Stresses

A ship afloat is supported throughout by buoyant forces that vary longitudinally and transversely with the distribution of the ship's displacement or buoyant volume. These comprise the upward forces on the hull. The downward forces are the result of the distribution of all the various weights within the ship, including the weight of the ship's structure, machinery, fuel, cargo, and ballast. The difference between the upward and downward forces results in a load on the ship's girder that varies throughout its length and produces an overall bending moment with the associated shear stresses.

It should be noted that the stresses resulting from a transverse bending moment are usually less severe and less important than those due to a longitudinal bending moment. In general, the size of the structural members required to give the ship adequate longitudinal and local strength will keep the transverse bending within reasonable limits.

In calculating the longitudinal strength, the simple beam theory becomes the basis of computations, and the relationship set forth previously is used. This relationship for any section x in the ship's length is

$$\sigma_x = \frac{M_x y}{I_x}$$

The members included in the calculation for the moment of inertia of any section must be continuous longitudinally (fore and aft).

At any section, the severest stresses occur in that portion of the structure most remote from the neutral axis, in the deck and bottom plating (Figure 15.1). At any section, M_x and I_x are constant for a particular condition of loading for that section; however, M_x and I_x will vary from section to section along the length of the ship. The stress will therefore be maximum in the deck or bottom plating of that section where M_x/I_x is maximum (assuming that the maximum value of y will vary appreciably), usually near the midship section in most ships. The superstructure and deck houses found on destroyers (not indicated in Figure 15.1) are, of course, farther from the neutral axis than the deck or bottom plating. This upper structure is often designed to be noncontinuous at intervals along the length through the use of expansion joints to prevent the structure from taking a portion of the longitudinal bending stresses.

From the discussion regarding the neutral axis of a beam, it was seen that a maximum horizontal shear stress developed along the plane of the neutral axis. Depending upon the longitudinal distribution of vertical forces (load), vertical shearing forces will develop along the ship's length. Because of the essential similarity in ship's form and distribution of load for ships with machinery amidships, this vertical shear force is maximum near the quarter-lengths from the forward and after ends, and the bending moment is maximum near midships.

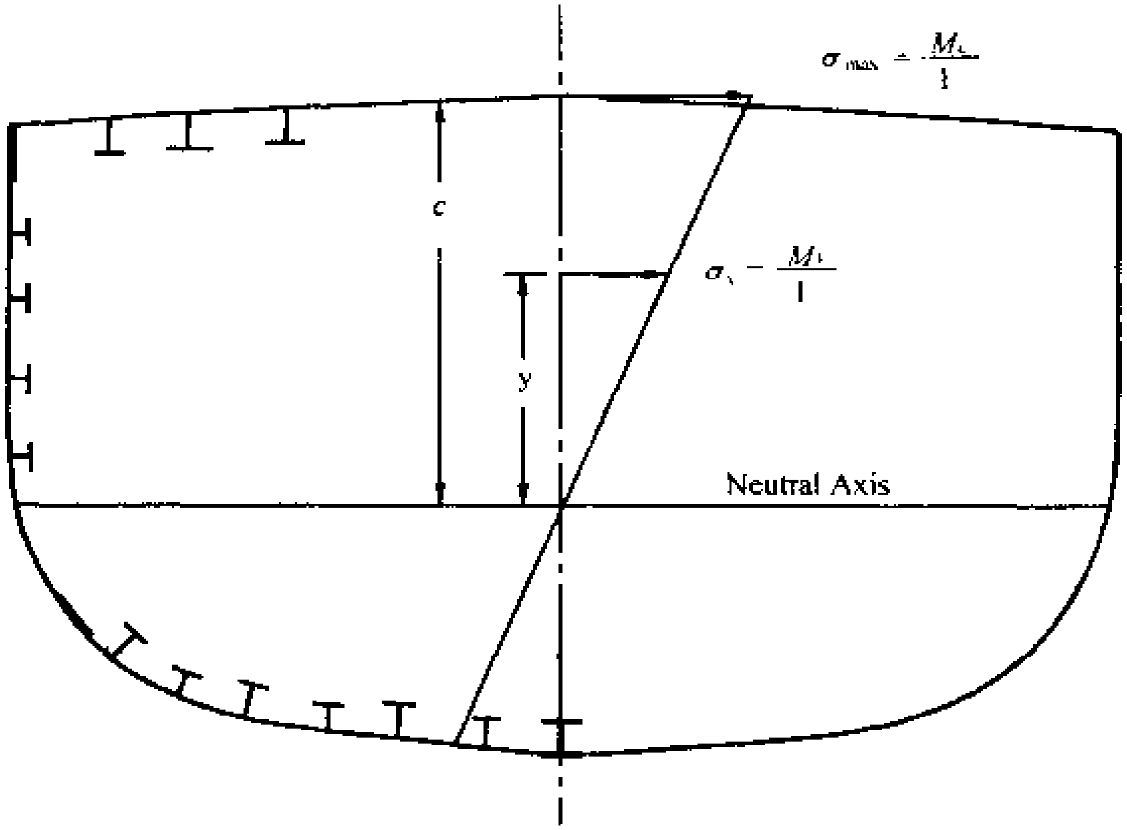


Fig. 15.1 Neutral axis on a ship

A general corollary, then, for this type of ship, is that the maximum shear stresses occur in the vicinity of the neutral axis at the quarter-lengths, and the magnitude of these shear stresses often requires local strengthening at these locations in and near the side of the ship.

It should also be further stated that because of Newton's third law (for every action there is an equal and opposite reaction) and the fact that equilibrium is maintained, an opposing force equal to the shearing force is set up. This means there is a force couple at 90° to the shearing forces for both vertical and horizontal shear. In effect, the vertical shear and horizontal shear stresses are interdependent.

Local Stresses

Local stresses are caused by hydrostatic pressure, concentrated loads of equipment, and dynamic loading.

Each unit area of the underwater body is subjected to a water pressure proportional to its depth of immersion. The vertical component of the water pressure applied to the shell is transmitted through the internal framework and opposes the various loads of the ship. Although the horizontal components of the water pressure acting on each side cancel each other, preventing an athwartships movement of the ship, the force of the horizontal pressure components still acts on the shell. The hull and its internal framing must resist the tendency of the water to crush the hull. When the skin of the ship is ruptured and flooding follows, the hydrostatic pressure formerly exerted on the shell is placed on the internal boundaries of the flooded space. These internal boundaries must be stiffened sufficiently to prevent their failure and hence to confine the flooding. Hydrostatic pressure is also imposed on the boundaries of intact fuel and water tanks.

The weight of each object rests at some point in the ship. These loads must be transmitted downward through the internal structure to the shell, where they are opposed by the vertical component of the hydrostatic pressure. To prevent the excessive stress of concentrated loads, extensive foundation support is used to distribute the load over a large area.

In addition to the local stresses imposed by static loads, the ship's structure may be subjected to the buffeting action of the wind, waves, liquid load, and on naval ships, the blasts of missiles and torpedo and mine explosions.

Damage to the structure will impose greater stresses on undamaged members, not only because of reduced effective cross section of the members, but also because of the discontinuities in the structure that may result in stress concentrations.

15.2 Means of Determining Ship's Strength Curves

Weight calculation for use in strength curves, as well as displacement, stability, and other considerations, is begun in the early stages of design. For purposes of determining the strength curves, both the magnitude and the location of the weights must be accurately made. It will be advantageous to discuss the general practice followed in such weight calculations.

Weight Groups. To proceed with the weight calculations in an orderly fashion, the weights are classified and subdivided into groups. In naval designs, the current practice is to classify all of the component weights of the ship, its equipment, and its complement into seven primary weight groups as follows:

Group (1)—Hull structure
Group (2)—Propulsion plant
Group (3)—Electric plant
Group (4)—Command and surveillance
Group (5)—Auxiliary systems
Group (6)—Outfit and furnishings
Group (7)—Armament

The above weight groups are now standard in naval-ship weight calculations, and under each of these main groups are further detailed subdivisions. The complete description of the detailed subgrouping will be found in Ship Work Breakdown Structure.

Weight Calculations. In the early design stage, weights are estimated by comparisons with corresponding weight groups on similar existing ships. Main structural items are laid out, and the weight is calculated directly. The weights are recalculated in much more detail in the subsequent preliminary and contract design stages and in still more detail in the detail design made at the building yard.

The weights of such standard articles as guns, pumps, and anchors are relatively easy to determine—either by reference to the manufacturer's records or the article's specifications. Other parts, such as frames, hull plating, and bulkheads, must be calculated item by item from the ship's plans. The weight of items such as turbines, boilers, and other large units must be broken down by component parts and determined from the manufacturer's specifications.

The first ship of a class to be built is frequently weighed in component form; that is, each piece of material and equipment put aboard is actually placed on a scale and its weight recorded. Later the components are totaled to give the final weight check.

The weights of the various groups are summarized, along with their vertical and longitudinal moment arms, about the keel and midship section respectively. It is from this summarization that the weight data per unit length is determined and plotted as the weight curve.

Buoyancy Calculations. The calculations for buoyancy are relatively simple compared to those for weight. There values are determined by computing the sectional areas below the waterlines corresponding to the several loading conditions for which weight calculations are made. For any given waterline or displacement condition, these sectional areas are plotted as ordinates to some convenient scale throughout the length of the ship. A smooth curve is faired through these ordinate points resulting in a curve that describes the buoyancy distribution longitudinally along the ship.

Load, Shear, and Bending-Moment Curves. After the weight and buoyancy curves have been determined, the subsequent procedure is straightforward. The net-load curve is obtained by merely subtracting the buoyancy values from the weight values at selected intervals along the length and plotting the resulting differences at each location. This curve is then integrated by approximate means to obtain the shear curve, which in turn is integrated in a similar manner to obtain the bending-moment curve. For cargo-carrying ships, shear and bending-moment curves for various loading conditions are calculated to determine those conditions of loading that must be avoided for structural reasons. The principles involved in the actual procedure of obtaining the ship's strength curves are obviously identical to those for the simple loaded barge described previously. The meaning is also identical; however, becaue of the complexities of weight distribution and ship form, the analysis is tedious (if done by hand) and the irregular curves reveal a more complex strength problem. This becomes increasingly apparent when one considers the condition of the ship no longer in still water but at sea among waves.

(摘自< Introduction to Naval Architecture > T. Gillmer & B. Johnson, London. E. & F.N. SPON, 1982)

术语解释

origin and effect	因与果,来源与效果
hull girder stress	船体桁应力
local stress	局部应力
neutral axis	中性轴,中和轴线
corollary	推论,必然结果
vicinity	邻近
force couple	力偶
crush	挤(碾)压、压扁、压碎
buffet	冲击,打击,振颤
stress concentration	应力集中

Lesson 16 Structural Integrity

The simplest structural description of a ship is that its hull is a beam designed to support the numerous weights that rest upon it (including its own weight), to resist the local forces produced by concentrated weights and local buoyant forces, and to resist the several dynamic forces that are almost certain to occur. As with any structure, stresses at all points must remain below the limits allowable for the construction material. Likewise, deflections both local and overall must be kept within safe limits.

In a long-favoured application of beam theory to the design of a ship's hull, the ship is assumed to be supported by a quasi-steady wave (i. e. , not moving with respect to the ship) of a length equal to the length of the ship and one-twentieth of this length in height. The ship is taken to be supported by wave crests located at its bow or stem or by a single crest at its mid-length. The hull length is divided into 20 segments, and the weights and buoyant forces within each segment are carefully tabulated. The difference between the sum of all weights and the sum of all buoyant forces within each segment is treated as a load uniformly applied over the segment. The 20 loads are then plotted as a function of position along the hull, and the resulting curve is integrated over the entire ship's length to give what is known as the shear curve. In turn, the shear curve is integrated over the length to give the bending moment curve—a curve that usually has its maximum near mid-length. A value for bending stress can then be obtained by dividing the maximum bending moment by a beam section modulus of the hull structure, which is calculated from a detailed structural plan. For protection against loads neglected in the analysis, such as dynamic wave loads, ample design margins are employed in the calculations.

Since about 1990 the quasi-static treatment of wave loading, as described above, has been recognized as inaccurate. The preferred treatment has become one of finding a still-water (i. e., level sea surface) bending moment, then adding to it a wave-bending moment found by an empirical formula and based only on the size and proportions of the ship. Coefficients in the formula are based on data obtained from at-sea measurements and from tests of structural models, as a consequence, the formula has been found to give predictions that seem to be in satisfactory agreement with reality. The formula is published among the rules of the classification societies that govern the design of commercial ships.

Nevertheless, although a single formula may serve well for ships of typical configuration in sea conditions encountered in typical service, it is not sufficient for all ships in all circumstances. For this reason, research continues into the interactions between the sea and floating structures, the goal being to be able to calculate a load resulting from any interaction between the sea and a floating body. The task is difficult because the analyst must be able to calculate the motion of a ship as caused by waves, the effect on waves of the motion of the ship, and buoyant, damping, and inertial forces present. Such a task would be impossible without extensive at-sea measurement and model testing and without the use of major computing resources. The computing resources became generally available in the 1970s and have encouraged efforts that will likely continue well into the 21st century.

Interactions between waves and hull also may occur in a dynamic mode. An obvious example lies in the impact between moving wave and moving hull. Generally, the results of this impact are of small consequence, but the slamming that can occur in rough weather, when the bow breaks free of the water only to reenter quickly, can excite "whipping" of the hull. Whipping is a hull vibration with a fundamental two-noded frequency. It can produce stresses similar in magnitude to the quasi-static wave-bending stresses. It also can produce very high local stresses in the vicinity of the reentry impact.

Another wave-excited hull vibration that can produce significant stress is known as springing. The cause of springing is resonance between the frequency of wave encounter and a natural vibratory frequency of the hull. Slamming and the consequent whipping can be avoided by slowing or changing course, but springing is more difficult to avoid because of the wide range of frequencies found in a typical sea state. Fortunately, springing has not been identified as a cause of any known structural failure.

Adequate calculation of such dynamic forces and their consequences also requires large computing resources, and hence it was not seriously attempted until about 1980. Major progress has been made, but techniques still have not been reduced to standard design practice.

The traditional ship hull structure consists of a keel, transverse frames, and cross-ship deck beams that join the frame ends—all supporting a relatively thin shell of deck, sides, and bottom. This structural scheme, which became prevalent with European ships during the Middle Ages, has continued into the age of steel shipbuilding. However, it has a significant drawback in that the frames and deck beams contribute nothing toward resisting longitudinal bending. Frames that run longitudinally do contribute to such resistance and thus permit thinner shell plating. This scheme of framing is strongly favoured in applications where weight saving is important. However, longitudinal frames require internal transverse support from bulkheads and web frames—the latter being, in effect, partial bulkheads that may extend only three to seven feet in from the shell. This requirement obviously reduces the weight advantage of longitudinal framing but not enough to negate the advantage entirely. Web frames also have the drawback of interfering with some uses of interior space, and as a consequence the simple transverse system of framing continues to be employed in many ships.

（摘自 Encyclopedia Britanica,2000）

术语解释

deflection	挠曲,弯曲
quasi-steady wave	准定常波(相对于船水静止的波)
tabulate	表列出,做成表
uniformly apply	均匀施加(力或载荷等)
shear curve	剪力曲线
section modulus	剖面模数
ample design margin	足够(充分)的设计裕量
quasi-static	准(拟)静态(定)的
empirical formula	经验公式
damping	阻尼
whipping	击振,骤动,抖动,甩动
two nodded frequency	双节点频率
springing	颤振
frequency of wave encounter	波浪遭遇频率
sea state	海况
changing course	改变航线(航向)
scheme	方案,计划
web	腹板

问　题

1. How to determine the shear curve of a ship?

2. What is the main reason for employing ample margins in structural strength calculation?

3. Why is it so difficult to calculate the loads due to interaction between the sea and a ship?

4. Can springing be easily avoided? Is it a significant factor that causes structural failure?

5. What kinds of frames will contribute to resisting longitudinal bending?

Chapter 4 Ship Production

Lesson 17 The Shipbuilding Process

Shipbuilding is an industry that produces products (ships, offshore structures, floating plants, etc.) for customers (private owners, companies, governments, etc.). In most cases, the product is built to order and customized to the specific requirements of the purchaser. This applies even in cases where a similar series of ships is being built. The entire process is likely to vary somewhat, depending on the customer involved, but it generally involves a number of specific stages. These may be summarized as:

- development of owner's requirements
- preliminary/concept design
- contract desin
- bidding/contracting
- detail design and planning
- construction

The first stage in the shipbuilding process is the formulation of the product requirements by the customer. For example, a shipping line may forcast the need for a means of transporting 250 000 automobiles per years between Japan and California, a state transportation agency may need to ferry 150 000 passengers per day across an inland water way over 10 routes averaging 30 trips per route, an oil company may need to transport 10 million tons of crude oil per year from the Caribbean to the Northeast U.S., or the U.S. Navy may need a ship capable of delivering supplies to support a battle group anywhere in the world on short notice. Alternatively, a shipping line owner may forecast an increase in container trade between the U. S. and the People's Republic of China of an unspecified nature and amount. The definition of the use or mission of a new ship may be narrow or broad, but the end product should reflect the owner's needs and intended use.

Once an owner has identified the need for a new ship and defined operational requirements, the next stage involves preliminary definition of the basic characteristics of the vessel. This preliminary or concept design stage can be done internally by the owner's staff, by a design agent hired by the owner, or by the staffs of one or more shipards. Common practice in the United States has been to use a design agent for preliminary design. A notable exception is the U. S. Navy, which has a large internal preliminary design section. Owners with considerable experience with particular ship types may, in order to satisfy specific operational requirements, approach a shipyard directly. The aim is to develop a design that will meet the requirements while taking advantage of the building experience and capability of a particular shipyard to minimize construction time and cost. The end product of this stage is a general definition of the ship, including dimensions, hull form, general arrangement, powering, machinery arrangement, mission systems definition (such as cargo capacity and handling equipment, combat systems, or habitability), capacities of variable weights (such as fuel oil, water, crew, and stores) and preliminary definition of major systems (such as structural, piping, electrical, machinery and HVAC).

Based on the general description of the ship to be built, as determined by the end product of the preliminary design stage, more detailed information is required to permit bids and/or contracts to be prepared. This information called the contract design, must be of sufficient detail to permit the preparation of cost and time to build estimates by shipyards interested in the shipbuilding project. As in the preliminary design stage, this work can be performed by the owner's staff, by design agents, or by shipyard personnel. Preparation of contract design packages by the owner's staff is uncommon.

Following completion of the contract design stage, a specific shipyard is chosen to build the vessel. Unless an owner has involved a shipyard in the preliminary and/or contract design stage and thus is negotiating a contract based on a mutually agreeable design, competitive bidding based on the contract design and specifications is common practice. Due to the high cost of a new ship, contracts are generally very long and complex. The most significant factors are cost, delivery date, and performance requirements.

After the bidding process is complete and a contract has been signed, the fifth stage of the shipbuilding process, detail design, planning and scheduling, proceeds. Shipbuilding involves the purchasing of tons of raw material and many thousands of components, the manufacturing of thousands of parts from the raw materials, and the assembly of these parts and components. Therefore, complex and very detailed planning is required. Detail design and planning must answer the questions of "what, where how, when and by whom." Determining what parts, assemblies, and systems are to be built and what components are to be purchased is primarily detail design. Where and how are facility-use questions that include determination of the location within the shipyard and construction tools and techniques to be used. Considerations of subcontracting and in house manufacture versus purchasing are also answered here. These questions are resolved as part of planning. When determines the sequencing of all operations, including purchasing and manufacturing, as well as need times for information (design, planning, approvals, etc.). This is the scheduling function. Finally, by whom relates to the utilization of the shipyard workforce. Clearly there is considerable interdependence among the answers to these questions. The success of any shipyard or shipbuilding project is directly related to the answers to the questions or to the detail design and planning process.

The final stage of the shipbuilding process is the actual construction of the vessel. Ship construction can be considered to occur in four manufacturing levels. The first is parts manufacturing using raw materials (such as steel plate and sections, pipe, sheet metal and cable) to manufacture individual parts. The purchasing and handling of components can be considered to be a part of this lowest manufacturing level. The next manufacturing level involves the joining of parts and/or components to form subassemblies or units. These small collections of joined parts are then combined in the third manufacturing level to form hull blocks. Hull blocks are commonly the largest sections of ships built away from the final building site. Erection, the final manufacturing level, involves the landing and joining of blocks at the building site (such as launching ways, graving dock, or drydock). The actual construction phase of shipbuilding is primarily involved with assembly, whether of parts, subassemblies or blocks, to form a completed vessel. An important part of the construction phase is verification that the ship complies with the contractual requirements. Consequently, the vessel is subjected to a series of tests and trials prior to delivery to the owner.

Shipbuilding can therefore be viewed as a process that begins when an owner perceives a need for a vessel to perform some set of functions, that proceeds through a number of stages of paperwork (design, contracting, planning, etc.) and that culminates in a massive collection and joining of parts and components to manufacture the desired vessel. Productive shipbuilding is highly dependent on careful consideration, control, and performance in each of these stages.

The shipbuilding industry is centuries old, paralleling the history of man. Shipbuilding techniques have changed in response to changes in vessel design, materials, markets, and construction methods. The organization of shipbuilding companies has also changed to match this progression.

Throughout its early history, shipbuilding, like most early industries, was craft oriented. As such, it was almost exclusively dependent on the skills of the craftsmen doing the work. Little planning was performed prior to beginning the construction. As owners became more specific in defining the desired characteristics of a new ship, shipbuilders were required to do more planning. Nevertheless, prior to the use of iron and steel for ships, little more than a scale model or a simple drawing of a proposed ship was used to guide construction.

As industrial processes became more complex and efficient, shipbuilders kept pace with changing technology. Shipbuilding began to be subdivided into specialties, such as hull construction, machinery, outfitting, and painting. More recently, the development of mass production techniques and welding both had profound impacts on shipbuilding. As late as the 1960's and 1970's, shipbuilders continued to try to employ mass production or assembly line approaches. Since then, a different approach to shipbuilding has emerged and has proven to be better suited to the economic and technical condition of the industry. This approach is based on the application of group technology to shipbuilding.

The goal of this textbook is to describe the principles and practice of shipbuilding employing group technology. As in any industry that has existed for many years, any system used is a mix of old and new techniques. The system described in this book is drawn from many sources, combining pieces of current practice from many places. Undoubtedly, no shipyard anywhere in the world operates precisely as is suggested herein. What is presented includes many parts that in combination produce a system aimed at optimizing productivity in shipbuilding under current economic and technological conditions. It is presented in a way that will provide the reader an opportunity to gain some knowledge of all aspects of the industry as it is currently evolving.

(摘自＜Ship Production＞R. L Srorch, C. P Hammon & H. M. Bunch, Cornell Maritime Press. 1988)

术语解释

preliminary/concept design	初步/概念设计
contract design	合同设计
detail design	详细设计
shipping line	船运航线
ferry	轮渡(载运),渡轮,渡口
owner's staff	船东的雇(职)员
shipyard	船厂
operational requirement	军事行动需求,运作要求
dimension	尺度,元,维
hull form	船形
general arrangement	总布置
cargo capacity	载货量,货舱容量,舱容
handling equipment	装卸设备
piping	管路
HVAC(= heating, ventilating and cooling)	取暖,通风与冷却
raw material	原材料
bid	投标
sections	(铁、钢)型材,轧材
hull block	船体垫块,船体支座

erection	(船体)组装
offshore structure	离岸工程结构物
floating plant	水上机械设备
be built to order	按订单建造,按定货单制作
customize	定制(造)
graving dock	槽式船坞
dry dock	干船坞
delivery	交船,交货
launching way	(船舶)下水滑道
to be craft oriented	与行业有关的,适应于行业性的
scale model	缩尺船模(模型)
outfitting	舾装
group technology	成组建造技术

问　　题

1. What are the usual specific stages involved in shipbuilding process?

2. Who will, as stated in the text, organize the preliminary or concept design for a ship to be built?

3. What are the four levels involved in practical manufacturing of a common ship?

4. Do you think that the shipbuilding quality exclusively dependent on the skills of the craftsment in the shipyard?

5. Do you agree in that the modern shipyards should employ the assembly line principles?

Lesson 18 Planning and Scheduling

18.1 Preliminary Planning

Preliminary planning is done at the time of bidding and before contract signing. The first step is to determine dates for such key events as keel laying, launching, and delivery. Due to uncertainties of the final design, the material market, and the general labor situation, it may be desirable to modify these dates in order to provide a margin of time in meeting definite commitments. This is a management prerogative. Key dates are usually shown on a shipway schedule chart; these dates become increasingly critical when the number of shipways is decreased (just one or two shipways or building sites available). Estimating the shipway schedule for new designs is difficult, especially if development work is necessary or if new facilities are required. Experience is extremely valuable in this connection because there is seldom time for any in-depth analysis.

For any efficient operation, whether the plans are prepared in the shipyard or by a subcontractor, the engineers and draftsment must work closely with the building yard. The only way to minimize potential problem areas and to ensure a maximum degree of success is to consider each step in the construction and scheduling process, no matter how trivial the step may appear. This applies to machinery installation and outfitting as well. It is imperative that a design engineer be familiar with all of the pertinent factors affecting production, such as maximum size and weight of plates, subassemblies, and erection units. But most important is the time and effort needed to plan construction at the very beginning of the design stage.

In order to provide some flexibility in design and construction, specifications are often written to give the contractor reasonable options, such as to use a casting, a forging, or a weldment for a stern frame or to use either radiography or ultrasonic testing for weld inspection. In other cases, the specification will describe the construction method or system preferred by the contractor.

a. Purchase of Working Plans. When a series of ships is built in different shipyards, one yard usually has the option of purchasing working plans from the other, with no obligation on either party. However, it is difficult for one yard to build efficiently a ship to another yard's plans because of the physical constraints peculiar to each yard. Normally, there are enough differences in desired fabrication and erection procedures to require more than just a small amount of plan revision, and allowances must be made for this contingency. The same may be said when working to plans prepared by a design agent unless the design agent has worked closely with the building yard. At best, the results are not likely to be very satisfactory.

b. Purchase of Outfitting and Machinery. Outfitting and machinery items may be purchased in several ways. First, some of the more standard items such as rigging fittings, valves, fans, and pumps can be bought off-the-shelf. Second, the more complex items such as boilers, steering gears, main propulsion machinery, and loading instruments require a technical specification to be prepared by the engineering department. For example, a steering gear specification would include hydrodynamic rudder torques for ahead and astern, maximum rudder angle, rudder rate, maximum ram pressure, and rudder stock size. The specification would be sent to vendors for quotations. Third, certain items may be prepared and installed by outside contractors. Such items are joiner work, floor covering, and insulation work.

c. Owner Furnished Equipment. The owner will usually wish to furnish certain items such as radio and navigational equipment, washing machines and dryers, mattresses and linens, galley equipment and dishes, and many of the spare parts. In naval vessels, essentially all of the weaponry and detection equipment is government furnished. In some instances, the government furnished equipment has been under development at the time of contract signing, and this made planning and scheduling more difficult.

d. Special Facilities. Shipyards have been called upon to construct unusual types of ships such as LNG carriers and semi-submersible drilling rigs. In some instances completely new facilities had to be built. Notable among these new facilities are those required for the construction and handling of the large tanks and spheres for some of the LNG carriers. The 850-ton spheres for one ship design had to be moved out of the construction site by a specially designed transporter to a barge, built specifically for the job, and then transported 900 miles to the shipyard where a new 1200-ton crane had been installed to handle the spheres.

In addition to new facilities, new methods for constructing and installing unusual structures and equipment may have to be developed, such as for nuclear powered ships or for various LNG containment and insulation systems. Some new methods may require rigid temperature and humidity controls. Intensive training and control programs are usually required when integrating these new methods with normal shipyard practices.

18.2 Engineering and Design

The engineering department is called upon to aid in preliminary planning due principally to the many rules and regulations which must be satisfied and to the complexity of both yard and shipboard equipment. It is important to note that new regulations, such as those of Intergovernmental Maritime Consultative Organization (IMCO) and the U.S. Coast Guard (USCG), have greatly increased the amount of engineering work necessary for both the preliminary and final designs. Engineering work is started at the earliest possible time, even before schedules are prepared.

The extent and thoroughness of engineering wrok done on contract plans and specifications by the owner or the owner's design agent varies considerably, and this can markedly influence the engineering effort required by the building yard. The building yard is often required to make an independent weight estimate and to conduct basic design studies which will enable the drawing room to develop working plans and the purchasing department to proceed with ordering component parts.

The shipyard drafting department prepares detail working plans and bills of material. Plan schedules are prepared which list the plans to be developed and scheduled dates for start and completion, approval, and yard issue. The lead time required to order materials will often determine the start date of drawings. Whenever material, including steel, is in short supply, or whenever there is a liklihood of a long delivery period, orders are often placed before plan approval. This, of course, is done at the shipyard's risk.

Design changes are inevitable as the design develops and during construction. These changes can affect schedules, procurement, and even the ship's delivery date. Changes affecting the ship's weight, center of gravity, or cubic must be reviewed to determine their influence on the ship's characteristics. The effect of such changes and related costs must be acceptable to all interested parties before the changes are authorized. However, most contracts require that the shipbuilder, without prior agreement on cost, put in hand those changes, identified as Essential Changes, which result from applicable rules and regulations which were not in effect at the time of contract signing. Any addition or change by either the owner or builder should obviously be brought forward at the earliest possible time.

18.3 Production Planning

A schematic diagram as shown in Fig. 18.1 is useful for providing the various departments with a guide for the general division and sequence of work. For a ship with machinery amidships, the sequence of assembly usually starts amidships and proceeds toward the after end and then forward. When machinery is aft, the first sections are set aft to provide early availability of machinery space.

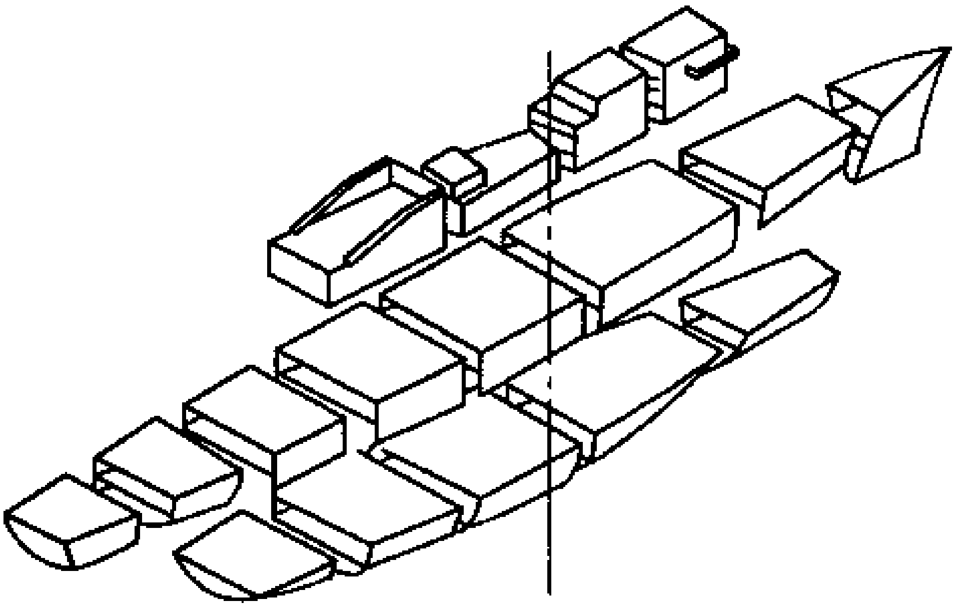


Fig. 18.1 Schematic diagram for scheduling sequence of work

Scheduling methods are unique to each yard and generally reflect practices developed from experience. An overall schedule which is most useful to both management and production departments is one which highlights major tasks and events, and which shows the sequence of work and the relation of the various tasks to each other and to the whole project. Such a schedule can be prepared using the simple principles employed in network flow techniques.

The basic principle in network flow is the task-to-task relationship. That is, task C cannot start until its two prerequisite tasks A and B are completed. These is, of course, the usual task-to-time relationship for each task. These principles have always been employed in one form or another throughout industry, but the computer has now made it possible to utilize to the fullest these principles in network form.

a. Network Flow Scheduling Technique. This technique is often used for controlling large, complex, and possibly non-repetitive projects such as the Polaris submarine project where the nuclear-powered submarine, the missile, and the inertial guidance system were planned and scheduled simultaneously. Examples of the technique are PERT (Program Evaluation and Review Technique) and CPM (Critical Path Method), both of which provide a means of representing graphically the different operations that make up a project. These networks can be revised to show the effects of adjustments to a schedule necessitated by changes in design, delays, etc. It is also possible to treat the nework statistically in order to obtain an idea of the probable longest and shortest times for completion of a project.

Fig. 18. 2 shows a CPM network for a small portion of an overall ship schedule. The tasks are diagrammed in network form, an arrow representing each task. The length of line representing each task has no time significance. The total length of each path through the network can be calculated and the longest path is the Critical Path for this particular portion of the network.

The amount of spare time (that portion of allotted time not actually needed) connected with tasks not on the Critical Path is called float. These tasks may be accomplished any time within their respective time ranges without delaying the project.

b. Practical Aspects of Network Flow. It is important to keep networks as simple as practicable and to eliminate all relatively unimportant tasks; otherwise, the network will be too cumbersome to be of significant value.

If it is found necessary to reduce the total time along the Critical Path, overtime, rescheduling, or subcontracting work may be employed. Due to the branching effect of the network, it is usually more economical to reduce the time allotted for ealier tasks.

Overlapping of tasks is always a difficult problem to handle. In some instances, there will be several overlapping steps between the start of a drawing room activity for a particular job and the completion of the job. For example, in the case of ventilation systems, one portion of a job might be drawn and fabricated before the drawing room activity for the remaining portion of the same job has been completed.

As revisions are made to a schedule, a new Critical Path may be created. It is important to point out that there will be several paths, perhaps in different areas, which will be considered critical. In fact, each department will have its own critical tasks.

Abbreviated networks are useful for investigating selected areas of interest and for simplifying the more complex networks for management use. Occasionally, it may be necessary to blend one network with networks of other contracts to aid in maintaining a fairly constant work force or to make multiple purchases for several contracts.

18.4 Gantt Chart

This type of chart is particularly useful for management in general and for the less complicated jobs such as for shipyard work in particular. The Gantt type chart is a multiple-bar chart showing the main activities with accompanying key dates laid out along a time base. Since this chart must show the relationship between various ativities, the same principles as employed in network flow are used in its development.

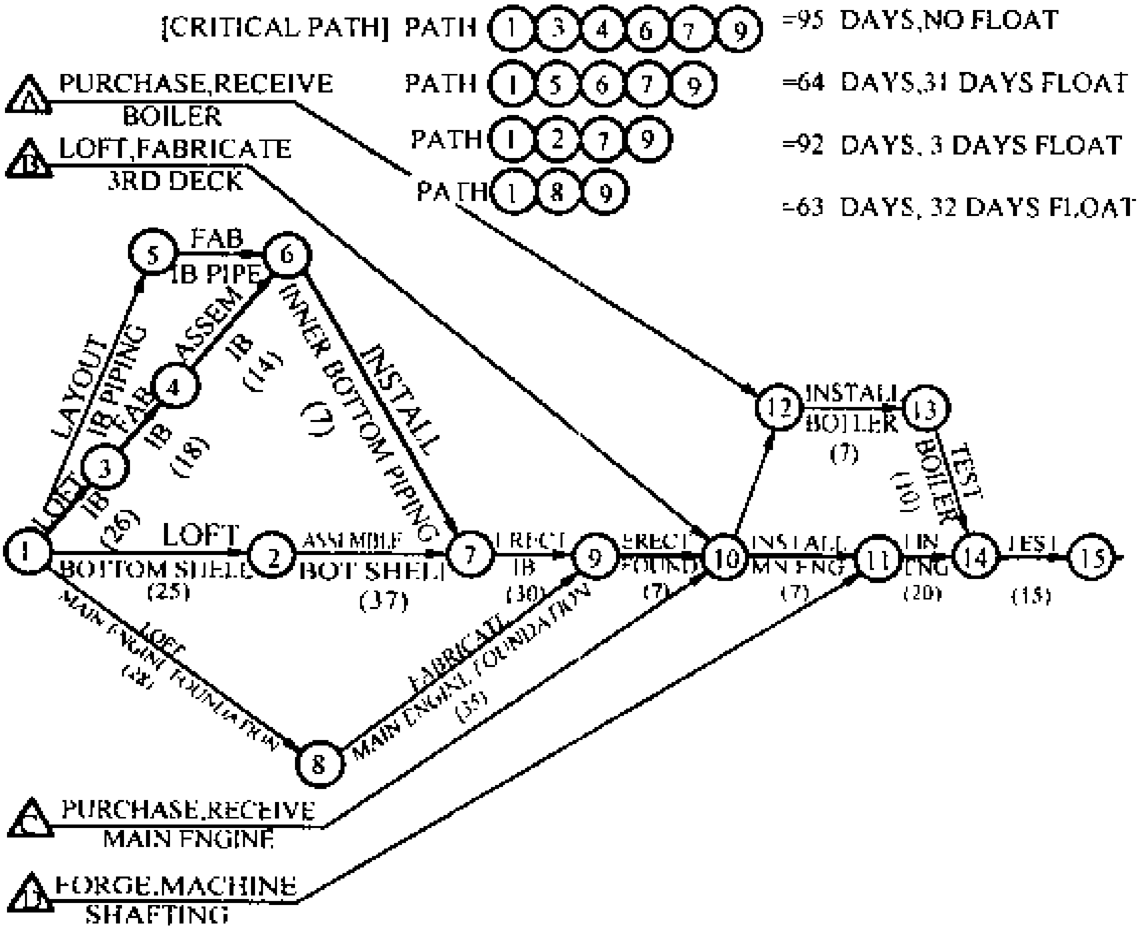


Fig. 18.2 Scheduling network for critical path method

(摘自 < Ship Design & Construction > R. Taggart, The SNAME, One World Trade Center, New York, NY. 1980)

术语解释

keel laying	开始船舶建造(原意为“铺设龙骨架”)
delivery	交船
prerogative	显著特点,特性
shipyard schedule chart	船厂施工进度图
shipway	(造)船台
in-depth analysis	深入研究
pertinent factor	相关因素
subassembly	(局部)分部装配
erection	装配,安装
forging	锻件,锻造
contingency	偶发(意外)事故
weldment	焊件,焊接装配
stern frame	艉构架,艉框架
radiography	X射线照相术,X射线探伤
ultrasonic	超声波的
weld inspection	焊缝检测
off-the-shelf	成品(方式),成品的,畅销的,流行的
ahead and astern	正车和倒车
rudder rate	舵率
ram pressure	速压头,冲压,全压力
rudder stock	舵杆
quotation	报价,报价单
galley	(船舰,飞机的)厨房
spare part	备件
semi-submersible drilling rig	半潜式钻井架

large tank and sphere	大型油罐和球罐
LNG containment	液化天然气容器
insulation	绝缘,隔离
Intergovernmental Maritime Consultative Organization	国际海事质询组织
standard item	标准(部)件,标准产品
rigging fittings	索具装配部件
steering gear	操纵装置
main propulsion machinery	主推机械
dryer	(衣物)烘干机
mattress	褥,垫
linen	各种布(或亚麻布)制品
U.S. Coast Guard	美国海岸警卫队
bills of material	材料(细目)单
yard issue	船厂开工任务发布书
lead time	设计至投产、定货至交货的时间
at the shipyard's risk	船厂自己负责(风险损失)
be in short supply	供应短缺、俏销
procurement	采购,获得
identified as Essential Changes	标记作“必备变更项”
machinery space	机舱
network flow	网络流程
Polaris (submarine)	北极星级(潜艇)
Program Evaluation and Review Technique	规划评估与复核法
Critical Path Method (CPM)	关键路径法
float	浮动时间,机动时间
overtime	加班加点(费)
Gantt Chart	施工进度表
branching effect	分流效应
overstocking	存货过剩

multi-bar chart	多重(统计)柱状图(条线图)
semi-finished item	半精加工件
switchboard	控制台,开关板
sublet	转包,分包
joiner	细木工(匠)
issue periodically	定期发布(公布)
budget	预算,作预算
remedial action	补救措施

问　　题

1. At the beginning of the production of a new ship, what factors are considered to be the most important that influence the whole process?

2. Which part of the shipyard should be responsible for the detail working plan and lists of material?

3. Do you think that, in the future, to make the shipbuilding advanced, a general scheduling method be developed for all the shipyards?

4. What is the basic principle in network flow?

5. Should there be only one critical path within a schedule when employing critical path method?

Lesson 19 Shipyard Facilities

19.1 General Introduction

There has been a notable attempt in new and modernized yards to achieve an assembly line type of flow of materials to assembly areas and an orderly flow of assemblies to the final building site. Due primarily to the unpredictability of the market, it is difficult to achieve a balance between introducing expensive assembly line equipment to suit one type of ship and, at the same time, maintaining the yard's capability to construct different types of ships and other marine structures. It is not unusual to have several different types of ships building in a yard at the same time, and with the building periods ranging from a few months to several years. The justification for large expenditures is more precise in multi-ship programs. Nevertheless, the general scheme is to adopt some method whereby an orderly flow of material will be achieved.

The trend toward larger assembly areas and fewer building sites has led to the building site being incorporated more fully into the overall scheme of material flow.

19.2 Building Sites

The building site may be a conventional sloping shipway, a building basin, or a ground level assembly area where the ship is completed for launch. In modern yards, it is significant that the building basin or ground level assembly area has been adopted in lieu of the traditional shipway. Some modernized yards have retained a few shipways to maintain some flexibility for constructing different types of ships at the same time.

a. The Building Basin. A graving dock type of building basin is generally preferred for constructing the very large ships. The principal advantages of the basin over the sloping way are that the headroom limitation for cranes is minimized, the ship can be built without the inconvenience of declivity corrections, and the launching operation is eliminated. In the larger basins, more than one moderately sized ship can be built at the same time. Quite often construction of the stern of a second ship may be well underway in the basin before the first ship is floated out. This is done to shorten the time between floatouts and to maintain a more even labor force. In order to make basins even more flexible, some basins have been provided with a portable gate to seal off one end of the basin while the other end is flooded.

b. The Ground Level Building Site. This requires a special launching facility. Unique methods of launching have been developed where the ship is transferred to a special floating drydock facility and then undocked in the usual manner. One method is to transfer sideways the completed ship to the drydock facility, Fig. 19.1. This facility is held in place by ballasting it down onto a supporting structure while the transfer is made, after the transfer, the drydock is de-ballasted, floated clear of the supporting structure and then ballasted again to permit the ship to float free. Another method is to transfer end-on the forward half of a ship to one portion of a floating drydock and the after half of the ship to another portion of the drydock. After and two drydock portions are brought together and aligned, the two halves of the ship are welded together.

19.3 Steel Storage

In a typical modern shipyard there is a compact plate and shape storage area from which steel is fed, via an automatic roller conveyor system, through automatic blasting and paint priming facilities into a large enclosed fabrication shop where assembly units over 200 tons can be constructed.

Plate storage areas as well as plate handling areas within some fabrication shops are usually serviced by multiple-magnet gantry or bridge cranes having lifting capacities up to 20 tons. When non-magnetic plates, such as aluminum, are lifted, suction cups instead of the magnetic heads are used. In fact the air suction, or vacuum technique of plate handling is used exclusively in some facilities for handling large bottom and side plates in barge construction.

19.4 Steel Fabrication and Assembly

One of the first notable examples of an assembly line type of assembly system was the one at Gotaverken's Arendal yard in Sweden where material flows into a single assembly line. Ship sections, complete with some outfitting, are assembled under cover and then joined to previously completed sections. The completed portion of the ship is systematically moved out of the covered area and into the building basin as new sections are added. This operation continues until the completed ship is entirely in the basin ready for floatout. In another yard, the completed sections are moved out of a covered shop onto a sloping way, and the ship, when completed, is launched in the conventional manner.

In contrast to Arendal's assembly system, Ingalls' Pascagoula yard, features several parallel assembly flow lines, each beginning at the fabrication shops and extending through the subassembly area to the module assembly area. These structural modules are essentially complete sections of the ship, including most outfit. The modules are then moved to the final ship assembly area.

The assembly systems begin with plates and shapes being

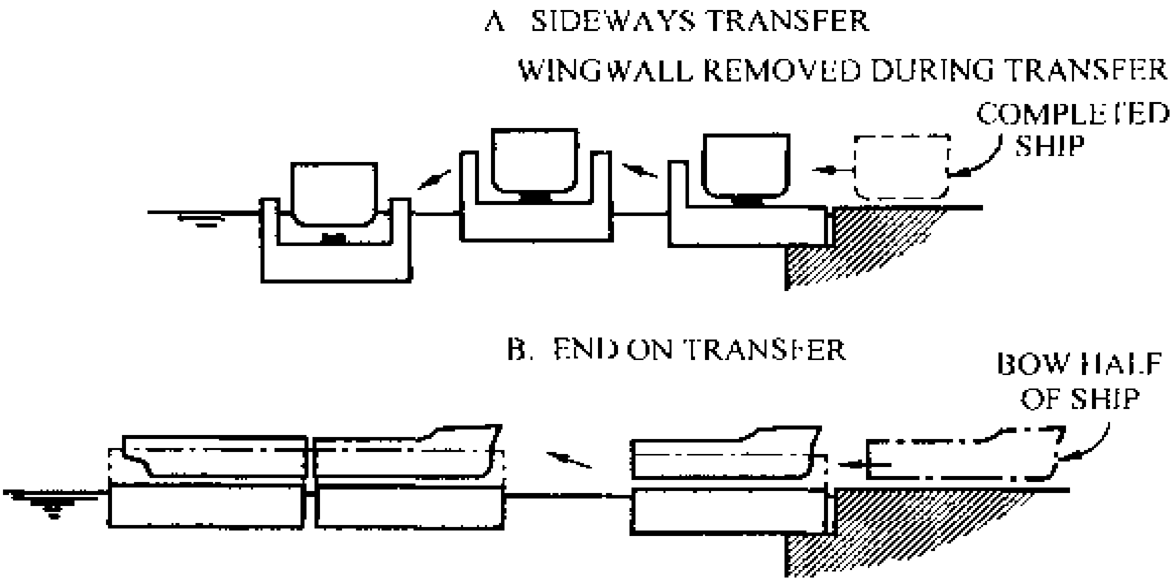


Fig. 19.1 (Schematic)methods used in launching operation from a ground level building site

moved into a fabrication shop, from a steel storage area. The first step in many fabrication operations is the cutting of plates. The numerically controlled (N/C) burning machine, is one of the most versatile of steel cutting machines. It can cut automatically duplicate pieces and make mirror-image pieces as a first step in flat-plate fabrication.

Some shipyards fabricate stiffener angle and T shapes in the depth range of 200 to 460mm (8 to 18 in.)rather than purchase mill shapes and remove one of the flanges. In some cases the work is moved past fixed automatic welding machines which can weld several shapes at a time. Shapes over 460mm deep must be fabricated in any case. In connection with angle shapes, some European mills can furnish rolled shapes up to 500mm (19.7 in.) deep and fabricated shapes, consisting of a rolled angle butt welded to a flat plate, up to 1000mm (39.4 in.)deep.

Many shipyards now have a panel line system included in their fabrication area. This system provides for welding together flat plate panels, attaching stiffeners with automatic welding, and moving the panels along a line where webs and other steel members may be attached.

Assemblies with curved surfaces are assembled on specially prepared forms or on pin jigs.

a. Painting Facilities. Another unique facility installed by several shipyards is the large blast and paint facility which can accommodate large units such as those coming off of a panel line. In some installations, the whole assembly can be rotated while it is being blasted.

b. Buffer Area. As the completed assembly units accumulate from the panel line, the paint facility and other assembly areas, space must be found to store these units until needed. This space is sometimes called a buffer area, i. e. an area which can absorb any overflow of units. An ideal area, of course, would be one alongside a building basin where a large gantry crane would extend over the area alongside the basin as well as over the basin, thus making it possible to transfer the largest and heaviest units from the side of the basin as well as from the end.

19.5 Materials Handling

Movement of heavy units, some of more than 200 tons, from a panel line or painting facility is usually accomplished using a self-propelled trailer type transporter employing a hydraulic mechanism within the vehicle. These vehicles are capable of lifting the units unaided. For light weight transfers, mobile cranes, straddle trucks, and forklift trucks are used wherever practicable. Inside shops, crane capabilities often dictate the method of construction.

The most noticeable of material handling facilities are the giant gantry cranes recently installed in a few U.S. yards. In one yard, a 1200 ton crane over 60m (200ft) high was installed to handle large aluminum spheres for LNG carriers. In another yard a 900 ton crane, with a span of about 165m (540ft) was installed to service not only a building basin but also a large assembly area at the side of the basin. In some cases the cranes extend out over the water to permit handling waterborne loads.

Other yards employ two or four revolving cranes in tandem to lift heavy units. There are certain advantages in having several cranes capable of servicing a large area such as a building basin, but the lifting capacity along the side of the basin is limited. In some yards the revolving cranes can be made to travel along two different sets of rails, one set at right angles to the other, by rotating the crane trucks. At outfitting piers, revolving cranes, even those having a small lifting capacity, must have very long booms, some 60m (200ft) long, to reach all parts of the larger ships.

Floating cranes having lifting capacities of 500 tons or more are available in most large ports, and a few shipyards, especially those also engaged in repair work, have their own floating cranes.

Perhaps the most unique transfers are made when whole ships are transferred from the building site to a launching platform or special drydock, or when large units or portions of ships are moved horizontally. This is usually done by synchronized hydraulic equipment. The action principle is simply that of a hydraulic jack; it is not unlike that for installing and withdrawing propellers using hydraulic nuts. Devices are provided to prevent the load from breaking away while the load is being moved; in this respect the difference between starting and moving friction becomes important. Actually, several synchronized units are used together to move ships and other large structures.

(摘自 < Ship Design and Construction > R. Taggart, The SNAME, New York N.Y. 1980)

19.6 Shipyard Facilities

A shipyard generally contains several specific facilities laid out to facilitate the flow of material and assemblies. There is no typical shipyard layout, partly because many shipards were initially constructed in the 19th or early 20th century. These yards have grown according to the availability of land and waterfront as well as in response to production requirements. Figure 19. 2 is a representative layout. Typical important features are listed below.

- a location on land for erecting a ship along with an associated means for getting the ship to the water, such as a graving dock, launching ways, or a floating dry dock
- piers for storing ships afloat to permit work to continue following launching
- shops for performing various kinds of work such as
  —steel marking, cutting and forming shop
  —steel assembly shop
  —surface preparation and coating shop
  —pipe shop
  —sheet metal shop
  —machine shop
  —electrical shop
- storage, marshalling, and outdoor (blue sky) work areas
- offices and personnel support buildings (cafeteria, sick bay, etc.)

Associated with each of these general types of facilities are specific pieces of equipment that are related to the work carried out in that location.

19.7 Organization

Shipyard workers are organized within departments or sections that are responsible for some aspect of the operation of the company. Although each company is likely to have some variation in its organization, the usual subdivision is into six functions. These are (1) administration. (2) production. (3) engineering. (4) purchasing. (5) quality assurance, and (6) project management (contract administration).

Administration includes the chief executive officer and staff, payroll, accounting, personnel, labor relations, safety and job estimating.

Production is the department responsible for the actual construction. Consequently all trades workers are in the production department. Planning scheduling and production control functions may also be in the production department. Gererally 75 to 85 percent of the shipyard employees are in this department.

Engineering is responsible for the preparation of information about the construction project to be used by production in constructing the vessel. Engineering functions include preliminary design, detail design, production engineering, and sometimes bidding of new jobs. Many shipyards subcontract some of the design work to outside design agents. Production engineering, which is playing an increasingly important role in shipbuilding, may in some cases be in the production department. It includes planning and the distribution of responsibilities between planning and production engineering varies widely depending on the specifics of the shipyard organization.

The purchasing department is responsible for obtaining the materials to be used to build the ship. This includes raw materials subcontracted work and components. It may also include tools, and transportation manufacturing, and safety equipment.

Quality assurance is often a separate function within a shipyard that is responsible for documenting for the vessel owner, regulatory

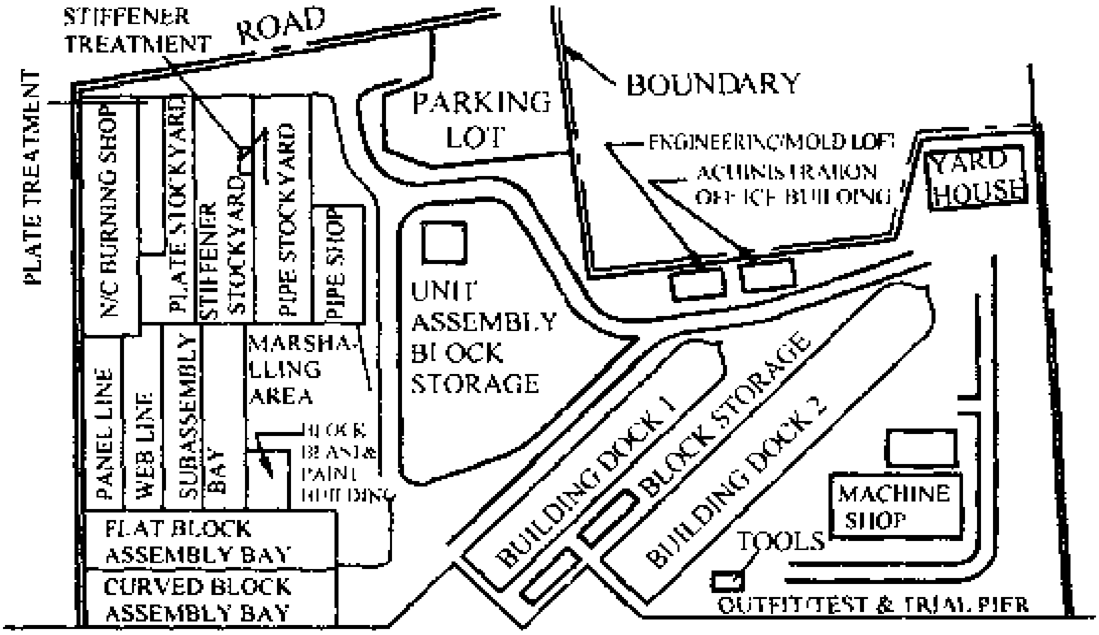


Fig. 19.2 Representative shipyard layout

agency and classification society that the vessel being constructed satisfies applicable rules, regulations and contractual requirements. A separate project management or contract management department is charged with overseeing the progress of a particular shipbuilding project. It monitors compliance with budgets, schedules, materials usage and the overall progress of the shipbuilding program. Within this department, it is common to have shipbuilding superintendents who are responsible for each construction project.

课外阅读

Additional reading

Trades

Within the production department actual ship construction work is subdivided into various trade skills. These are:

- air conditioning equipment mechanic: installs, maintains, and repairs refrigeration and air conditioning equipment
- blaster: prepares surfaces for coating by abrasive blasting(may be combined with painter)
- boilermaker: assembles boilers, tanks and pressure vessels using power tools and hand tools (may also refer to all of the steel working trades)
- carpenter: fabricates and assembles wooden structures gratings, keel blocks and shorings, and is often responsible for launching (may also perform joinery work)
- chipper/grinder: grinds and chips weld splatter, high spots, burrs, weld slag and rust from metal surfaces of ships to improve their appearance or prepare them for painting.
- electrician(inside): installs and maintains wiring fixtures and equipment for shipyard facilities
- electrician(outside): installs and repairs wiring fixtures and equipment for all electricl servises aboard ship
- electronics mechanic: works on various types of electronic equipment to put it in repaired operating condition
- electroplater: sets up operates and maintains metal plating baths to deposit metallic plating for protective purposes, decorative purposes, and to build up worn surfaces
- insulator: installs insulation in designated areas and on piping aboard ship
- joiner: installs finished panels, floor grouting, and tiling in shipboard living quarters
- laborer: performs a variety of shipyard tasks such as carrying, digging, janitorial duties, etc.
- loftsman: lays out lines of a ship to full scale on the mold loft floor and constructs templates and molds to be used as patterns and

guides for layout and fabrication of various structural parts of ships (computer assisted lofting, which has replaced full-scale layout, may be done by loftsmen or by engineers)

· machinist(inside): sets up and operates machine tools as well as fits or assembles parts to make or repair metal parts, tools, or machines

· machinist(outside): installs ship machinery such as propulsion machinery, auxiliary motors, pumps, ventilating equipment, and steering gear

· molder: heats and pours molten metal into hollow forms to produce all manner of metal parts (may also be called foundryman)

· ordinance equipment mechanic: repairs machinery and mechanical equipment such as cranes, pumps, motors, and conveyor systems associated with weapons systems

· painter: mixes and applies paint or other coating materials for protective and decorative purposes by means of spray gun, brush, roller, or immersion (may also perform surface preparation)

· patternmaker: plans, lays out, and performs machine operations and benchwork to construct, alter, and repair three-dimensional wood patterns and core boxes for use in making molds for foundry castings

· pipefitter: fabricates, lays out, installs, and maintains ship's piping systems such as steam heating, water, hydraulic, air pressure, and lubrication systems, using handtools and shop machines (may also perform pipewelding)

· pipewelder: installs, repairs, and maintains shipboard piping systems by means of applicable welding processes

· rigger/crane operator: installs and repairs rigging, and weight handling gear, attaches hoists and handling gear to rigging, and operates cranes and other mobile material handling equipment to lift, move, and position machinery, equipment, structural parts and other heavy loads aboard ships (may also be called operating engineers)

·sheetmetal mechanic: fabricates, assembles, installs, and repairs sheet metal

·shipfitter: lays out and fits up metal structural parts (such as plates, bulkheads, and frames) and maintains them in position for welding

· shipwright: constructs or repairs wooden ships or ship sections, sets and adjusts supports upon which a ship is built or docked, and aligns blocks that are to be joined to form a ship (may be combined with carpenters)

· tacker/burner: cuts steel plate by burning, washes welds, and applies temporary welds to position metals for final welding (may also be called boilermakers)

· welder: makes or repairs structures or parts, using gas or electric welding equipment, soldering equipment, gas or electric cutting equipment, etc. (may also be called boilermakers)

Work practices, work responsibilities, and trade divisions vary between shipyards. However, all actual construction work within a shipyard falls into the domain of trades such as those listed above.

(摘自＜ship production＞R. L. Strorch, C. P. Hammon & H. M. Bunch, Cornell Maritime Press, 1988)

术语解释

assembly line	装配(流水)线
flow of materials	物流
multi-ship program	多种船型建造规划
sloping shipway	有坡度船台,滑道
building basin	船台
headroom	净空高度
declivity	坡度,斜度

portable gate	移动式(可移动)闸门
ground level building site	平地建造场
floating drydock	浮船坞
undock	使船出坞
transfer sideways	横向移动
de-ballast	卸除压载(压舱)
plate and shape	板材与型材
end-on	端对准
blast	喷丸(除锈)
paint priming	涂底漆
enclosed fabrication shop	封闭式装配车间
magnet gantry	磁力式龙门吊
Bridge crane	行车,桥式起重机
suction cup	吸盘
module assembly	模块式组装
burning machine	烧割机
mill shape	轧钢厂型材
rolled angle butt	(轧制)角钢焊接头
panel line system	板材生产线系统
specially prepared form	专门(特殊)加工的模板
pin jig	限位胎架
buffer area	缓冲区
trailer type transporter	拖车式载运车
hydraulic mechanism	液压机构
waterborne	浮于水上的,水基的
revolving crane	旋转式(鹤)吊,转臂吊(车)
boom	吊杆
jack	千斤顶
trade	工种,贸易
steel marking	钢板划线
surface preparation and coating	表面加工处理与喷涂

mobile crane	移动式吊车,汽车吊
straddle truck	龙门式吊运车
forklift(truck)	叉车
in tandem	串列的,一前一后地,协作
sick bay	船上诊所
marshal	调度
superintendent	监督管理人,总段长,车间主任
pressure vessel	压力容器
carpenter	木匠
grating	格栅
shoring	支撑,支柱
joinery	细木工
electroplater	电镀工
metal plate bath	金属板电镀槽
deposit metallic plating	镀上金属镀层
joiner	安装工
grouting	填缝、灌浆
laborer	力工
janitorial	勤杂工,房屋照管者
loftman	放样工
steering gear	操纵装置
molder	造型工
foundryman	铸造翻砂工
patternmaker	木模工
bench work	钳工
core box	型芯
foundry casting	翻砂铸造
rigger	索具装配工
sheet metal work	钣金工,冷作工
ship fitter	舰船装配工
shipwright	船体装配工,造船工人

tacker	定位搭焊工
burner	气焊(割)工
chipper	风铲工,缺陷修整工
spatter	溅出物
burr	毛刺,毛口
slag	渣
ordnance equipment mechanic	军械设备机修工(机械师)
operating engineer	起重工,操作技师
crane operator	起重工

问　题

1. What is the reason for a shipyard nowadays under construction to consider multi-ship program?

2. What kinds of building site have been mentioned in the text?

3. How many ways are there for launching a ship? What are they?

4. Are all the shapes for shipbuilding manufactured by shipyards themselves?

5. What facilities should be furnished with in a shipyard to handle the shipbuilding materials?

Lesson 20 Ship CAD/CAM

The use of computers in the shipbuilding industry began in the early 1950's and has progressed steadily since that time. Used initially as accounting tools, computer applications have expanded to include many of the standard naval architectural computations. The many current or potential uses of the computer in shipyards are not all strictly covered by the CAD/CAM terminology. For example, a list of computer-aided functions could include:

- computer-aided design(CAD)
- computer-aided drafting
- computer-aided engineering(CAE)
- computer-aided manufacturing(CAM)
- computer-aided material definition
- computer-aided process planning(CAPP)

Applications of the computer in shipbuilding include:

- estimating
- design
- engineering
- drafting
- planning
- scheduling
- accounting
- purchasing
- material control
- numerical control (N/C) operations
- robotics
- accuracy control

- quality assurance
- inventory control
- evaluating

Consequently, the term CAD/CAM must be expanded. The resulting process is often referred to as computer-integrated manufacturing (CIM).

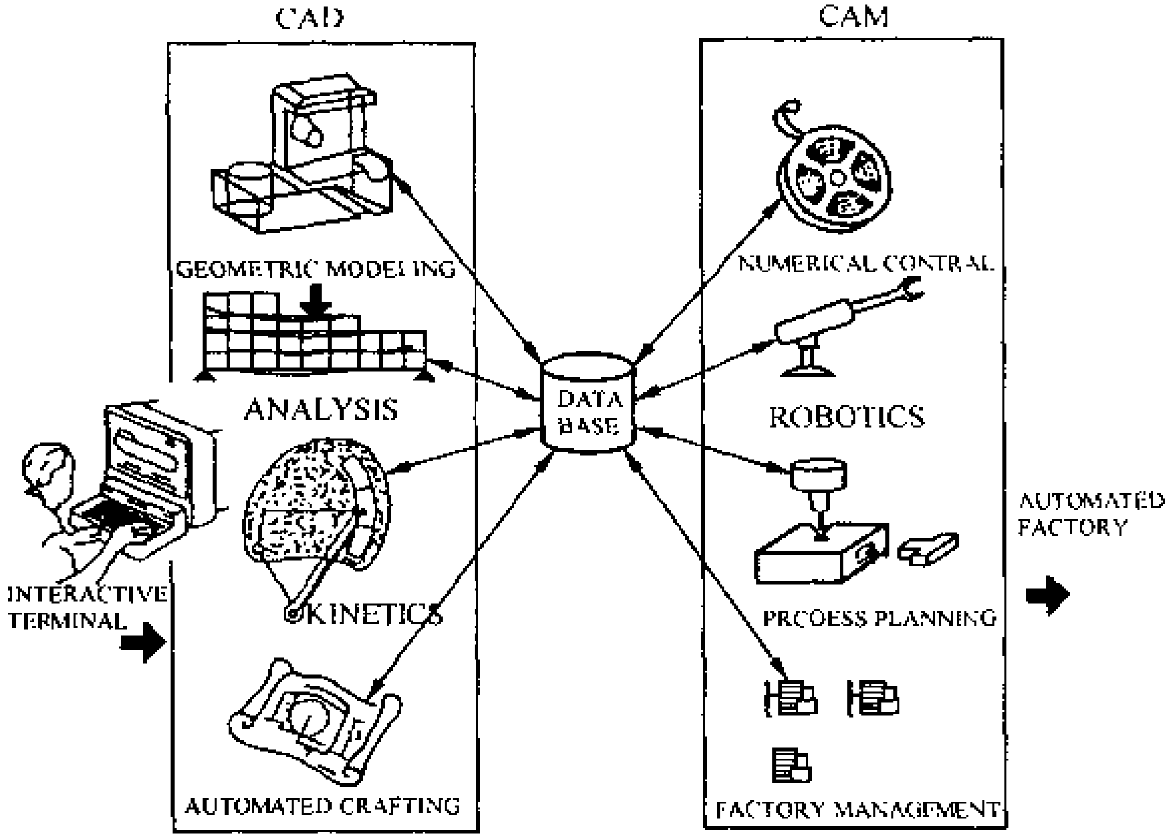


Fig. 20.1 An integrated CAD/CAM system

A CAD/CAM or CIM system is a combination of hardware and software. The ultimate goal of such a system is depicted in Figure 20.1. The user interacts with the computer via a graphics terminal designing and manufacturing a part from start to finish while coordinating with the complete shipbuilding system. Information from the design and manufacturing functions is available and transmitted via a common central data base. Applying the CAD features, the designer may construct a geometric model, perform required engineering analyses, perform kinematic studies, and produce plans and work instructions. Employing the CAM functions, the user creates N/C instructions, controls robots, performs process planning for the entire construction process, and coordinates with a shipyard management system. Purchasing and material control are also coordinated through the common data base. While many systems have the CAD functions interfaces, with the exception of some N/C programming capability, most systems do not have CAM interfaces. The major problem facing shipbuilders in the application of CIM is the lack of a unified shipbuilding data base that provides the capability of interfacing with all the applications mentioned above.

20.1 Hardware and Software

CAD/CAM systems have been developed in two ways, hardware alone or hardware software combinations. While numerous systems of both types are available, there is no industry standard. Of critical importance in any integrated system is a central data base that can link to all the required functions. Development of an integrated data base remains a high priority for the eventual coordinated application of CAD/CAM or CIM systems in shipbuilding. Information required in the data base includes:

- numerical data on past designs
- geometric data on past designs, e. g. , hull forms
- weight and space scaling laws
- systems and equipment
- structural design data
- resistance and propulsion data
- engine performance data
- sea spectra
- cost data

- typical block plans
- typical outfit units
- shipyard (or national) standards
- marterial lists (MLS, MLF, MLC, MLP)

20.2 CAD Outputs

The eventual outputs of a CAD system that is part of an integrated CAD/CAM system will be both hard copy materials, including plans, lists, and work instructions, and computer data transmitted to work stations, such as N/C burners, pipe bending machines, and robots. Current systems employ hard copy outputs that are used to perform the necessary functions. Many shipyards employ the computer capability housed within the mold loft to produce the various types of outputs required.

Application of a CAD/CAM system permits the evaluation of additional design options as well as consideration of alternate building strategies. Computer-generated plans, lists, and work instructions may be used for the various deign cycle stages as well as shipbuilding management functions, including:

- general arrangements; basic design
- key plans; functional design
- yard plans; transition design
- work instructions; work instruction design
- schedule reviews
- material lists
- purchase lists

Many other types of computer-generated outputs can be used.

20.3 CAD/CAM Potential

The ultimate goal of a CAD/CAM system is improvement in shipbuilding productivity. Among the advantages of such a system

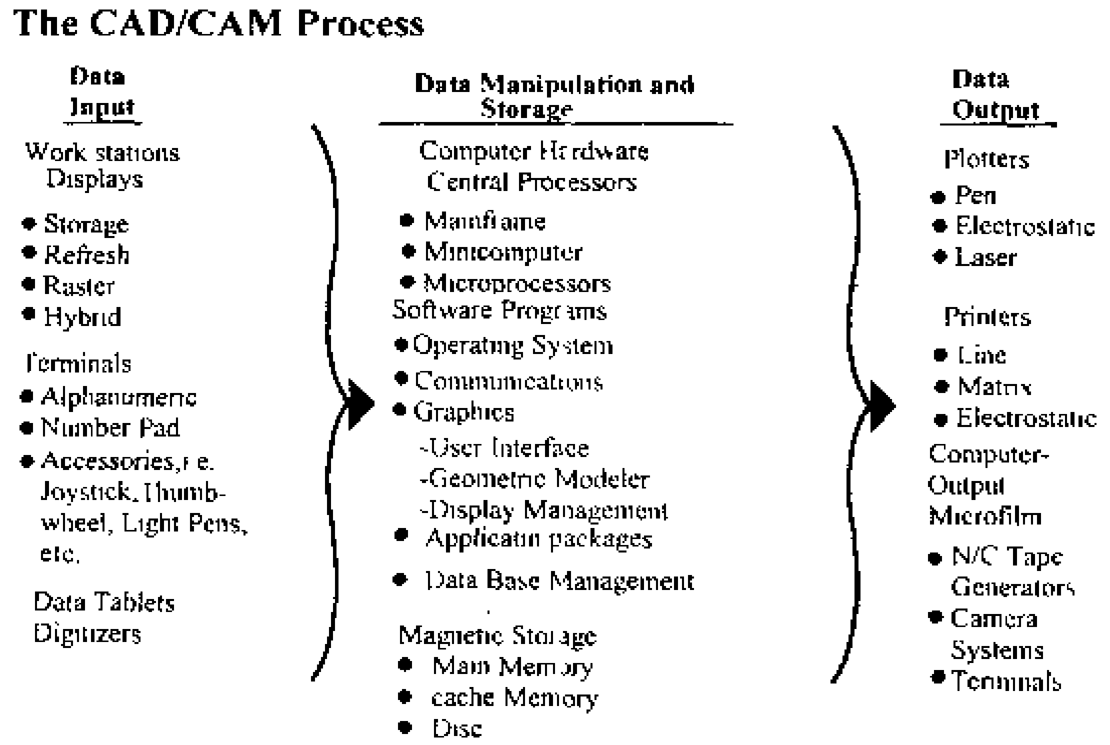


Fig. 20.2 The CAD/CAM process

are:

· the ability to produce concept and feasibility ship design studies more quickly and accurately than by conventional methods

· the ability to rapidly evaluate design options and to optimize required features

· the reliance on a proven, coherent data base, and hence the ability to perform design calculations with confidence

· the ability to assemble and "lock-in" successful design experience and procedures

· the ability to add attractive design solutions to augment the data base for future use

· the ability to interface with computer graphics

· the ability to transfer data in digital form to shipyard design offices and manufacturing facilities

·the ability to establish and employ shipyard standards

· the abilitty to assemble and "lock-in" successful building strategies and procedures

With these added capabilities, support for production efforts by other shipyard organizations, such as design engineering, purchasing, and material control is enhanced. The coordinated systen will lead to simplification of all aspects of the design and production process.

The design cycle has as a major feature the transition from system to zone during transition design. The composites produced during this design stage are critically important. Since they reflect the way the ship will be built, the composites directly affect the productivity of the shipbuilding project. They also are the basis upon which engineers performing work instruction design do their work. The application of design modeling (or model engineering) has proven to be an effective technique for improving transition and work instruction design. The models also provide significant benefits to production, planning, and scheduling personnel.

Design modeling permits design to be done in three dimensions, rather than on the more traditional two-dimensional drawings. The benefit of visualization of the space and the items to be included within the space are apparent. The greatest benefits from modeling will be obtained if the initial design is performed by the modeler, with output documents then developed from the completed model. In some cases, work instruction drawings may not be required. Depending on the size of the vessel to be built, scale ratios between 1:8 and 1:15 are likely to be most effective. Obviously, modeling has its greatest benefit in complicated outfit zones.

The benefits of design modeling may be summarized as follows:

·an arrangement existing in three dimensions facilitates group thinking and checking, thus minimizing errors in design (interferences) and rework in production

- alternatives in design and production are more easily evaluated
- the model permits better use of less trained personnel in design, planning and production
- building strategy communications between production, production engineers and designers are enhanced
- problem resolution is enhanced
- design progress is readily apparent
- communications with owners concerning vessel operations, requirements for maintenance and overhaul, and other matters are enhanced and are more timely
- communications with regulators are similarly enhanced
- the model is an effective training tool for people in design, planning production, and production control
- a design model is a data bank, permitting retrieval of prior practice and use in negotiations with prospective customers

Developing output documents from models can be accomplished in a number of ways, including manual scaling, the use of photogrammetry, and the use of scanning lasers. Of these, photogrammetry appears to be the most commonly employed. A stereo pair of photographs of the model provides enough data to permit digitizing of the required dimensions. When used in conjunction with a CAD system, the digitized data can be used to provide the output documents.

(摘自 < Ship Production > R. L. Strorch, C. P. Hammon & H. M. Bunch, Cornell Maritime Press, 1988)

术语解释

computer-aided design(CAD)	计算机辅助设计
Computer-aided drafting	计算机辅助绘图

Computer-aided engineering (CAE)	计算机辅助工程
Computer-aided manufacturing (CAM)	计算机辅助制造
Computer-aided process planning (CAPP)	计算机辅助施工计划制订
robotics	自动化技术，机器人技术
quality assurance	质量保证
inventory control	存货管理，库存管理
computer-integrated manufacturing(CIM)	计算机(集成)组合制造
graphic terminal	图象终端
N/C = numerical control	数值控制
N/C programming = numerical programming	数值规划
interface	接口，交面
data base	数据库
interactive computer graphics (IAGG)	交互式计算机图像(技术)
sea spectra	海浪谱
typical block plans	典型分块图
ML(= material lists)	物资清单，物料表
work station	工作站
retrieve	检索
regulatory body	管理机构
schedule reviews	施工(生产)进度审核
purchase lists	采购清单
refresh	刷新，更新
raster	光栅
hybrid	混合的，杂交的
alphanumeric	字母数字(混合编制)的

joystick	游戏杆
thumb-wheel	指拨轮
light pen	光笔
digitizer	数字化仪
mainframe	主机
minicomputer	小型计算机
microprocessor	微处理器
cache memory	缓冲存储,(超)高速缓冲存储器
plotter	绘图仪
pen/electrostatic/Lasar plotter	笔式/静电/激光绘图仪
printer	打印机
line/matrix/electrostatic printer	行式/矩阵式/静电打印机
electrostatics	静电学
lock-in	同步锁定,进入同步
rework	返工,二次加工
manual scaling	手工缩放
photogrammetry	投影照相测量法
scale ratio	缩尺比
data bank	数据库(栈)
scanning laser	扫描激光仪
a stereo pair of photographs	一对立体投影相片

问　题

1. What are the applications of computer in relation to shipbuilding?

2. In what design cycle stages of shipbuilding can CAD/CAM systems play their roles?

3. What does it mean by that ship designing is to be done in three dimensions?

4. How many ways are there for developing documents from

models? What are they?

5. Indicate the paragraph which shows the benefits of design modeling?

Lesson 21 Group Technology

21.1 Group Technology Defined

The purpose of addressing GT in this book is to better undertand shipbuilding and how productivity can be improved in the shipbuilding industry. While the treatment will be rigorous with regard to the description of group technology, the emphasis will be on those aspects of GT which are applicable to and interpretable in the context of shipbuilding.

Group technology may be defined as:

The logical arrangement and sequence of all facets of company operation in order to bring the benefits of mass production to high variety, mixed quantity production.

This general definition emphasizes a system approach to management, as opposed to a technique for organizing a limited aspect of manufacturing process independent of the total system. As such, it supports a crucial precept put forth by Mitrofanov in his pioneering work on the subject.

Mitrofanov stated that the group technological process is a variant of "… the systematization and generalization of the experience of the entire machine building industry …" This book deals with the total management of a shipbuilding or repair activity. The group is the basic production unit of zone or product-oriented ship construction. However, a crucially important characteristic of product-oriented ship manufacture and construction, which sets it apart from traditional shipbuilding, is the total integration of all departments in the company. As cited by Ranson. "There are only two people in a manufacturing organization, the man who sells and the man who makes, everyone else runs their messages. "The group is the basic production element. Everyone and everything in the yard should be organized to support the group.

A second definition of group technology provides further insight.

GT is a technique for manufacturing small to medium lot size batches of parts of similar process, of somewhat dissimilar materials, geometry and size, which are produced in a committed small cell of machines which have been grouped together physically, specifically tooled, and scheduled as a unit.

It is useful to analyze the essential elements of this definition:

· Small to medium lot size batches—Many of the interim products of shipbuilding are one of a kind or only a very few like parts. Group technology is not applicable to lot sizes which can be efficiently produced on an assembly line. Group technology is a means of realizing certain benefits of mass production (i. e. , relative permanency of location and function, moving work to the worker, balanced product flow, etc.) for essentially small batch interim products. It is not mass production. Perhaps one of the major errors made by innovative shipbuilders in the 1960's and 1970's was attempting to adapt mass production assembly line techniques to what is a small batch process. The result was yards which depended on series production with large unrealistic throughputs in order to have any chance for efficient productivity. In essence, these yards depended on government manipulation of the market for productivity rather than adapting the production process to the existing and anticipated market. When the world shipbuilding market collapsed in the 1970's many of the most modern assembly line type yards were the first to go bankrupt or be nationalized.

· Similar process—This implies categorizing interim products by "problem area." A "problem area" is a specific type of work, involving the use of similar production techniques, tools, and worker skills. For example, manufacturing curved pipe pieces and straight pipe pieces are two different problem areas. So too are flat panel and curved panel assembly.

· Somewhat dissimilar materials geometry and size—That the same problem area does not imply identical shape, material, size, etc., is a crucial concept. In a GT product-oriented operation, the installation of curved pipe and curved ventilation ducts may be the same problem area and be accomplished by the same crew. However in traditional shipbuilding these two operations even if physically adjacent would be accomplished at different times by different work crews.

· Processed in a committed small cell of machines which have been grouped together physically—In machining industries where GT has been primarily applied, this is self-explanatory. In shipbuilding, the cell often consists of a crew of workers whose most sophisticated piece of equipment is a spanner wrench or a simple arc welder. The essential concept implied by this phrase is parallelism. A cell in a machining industry consists of a group of machines which complete all processes necessary to complete piece parts in a particulr family, regardless of sequence or machine utilization. Similarly, in shipbuilding, a cell or group is responsible for completing all aspects of a given block or unit, including piping, ducting, painting etc., regardless of overlapping functional systems. Consequently subassemblies can be completed simultaneously, rather than systems being completed sequentially.

· Specifically tooled—In machining, this implies the use of equipment such as turret lathes, where tools need only be adjusted, never removed. Shipbuilding has the added advantage that the operator may be thought of as an essential part of the machine in some cases. Adjustment of tools may imply only moving the operator's anatomy.

• Scheduled as a group—This means that the cell or unit is scheduled as a single machine. In shipbuilding this is comparable to commencing work on a work package assigned to a given group (i. e. ,a subassembly or unit) only when all resources are on hand. This has important implications concerning management, engineering and material control. It means that the former must be responsive to production control in a way not normally expected in conventional shipbuilding.

21.2 Classification and Coding

Group technology is not synonymous with classfication and coding. However, classification of the elements of production is perhaps the first step in the successful implementation of GT. The definition of group technology presented by Ranson is valuable because of its generality and applicability to all aspects of company operation. So too must a classification system be based on the assumption that all elements of the company are subject to classification and coding (see Figrue 21.1).

Classification

The Webster definition of classification is "Systematic arrangement in groups or categories according to established criteria." This definition is straightforward and suitable for the purpose of this discussion. A key word in this definition which perhaps requires some elaboration is "criteria." The hierarchical classification system used in botany or biology is familiar to every scientist. This system of classification is called the Linnean hierarchical taxonomy after the Swedish botanist Karl von Linne. Organisms are classed into kingdom, phylum, subphylum, class, order, family, genus, species, and variety according to mutually exclusive and permanent characteristics.

Edward Brisch, a mechanical engineer and designer, adopted the decision tree type hierarchical classification system derived by von Linne, but added two principles or criteria. In addition to mutual exclusivity and permanent characteristics, he required that the system be all-embracing and based on the user's point of view. Brisch's taxonomy has become one of the standards, for industrial application.

One classification system, the Product Work Breakdown Structure, is introduced in the last section of this chapter. In this subsection, general application of the above four principles is addressed.

· Use's Viewpoint—A classification system must be responsive to the objective of the next higher system of which it is part. A primary application of a classification system is to define families of parts in order to facilitate engineering or manufacturing decisions. Shape might therefore be an important attribute. However, shape is important only as it relates to problem area or work process. For example, two nearly identically shaped parts might present two completely different problem areas because of differences in chemistry. Extrusion or casting are two very different mathods of producing identically shaped parts of different material. A familiar example is the classification of playing cards. A bridge player might categorize the population in samples of 13 cards arranged first by suit and second by value with the ace at the high value end. This classification system would be of little value to a poker player. For poker the population would be broken into samples of five or seven cards ranked according to certain combinations of cards, such as flush, straight, pair, etc. Within these classes ranking is determined by card value, with the ace high.

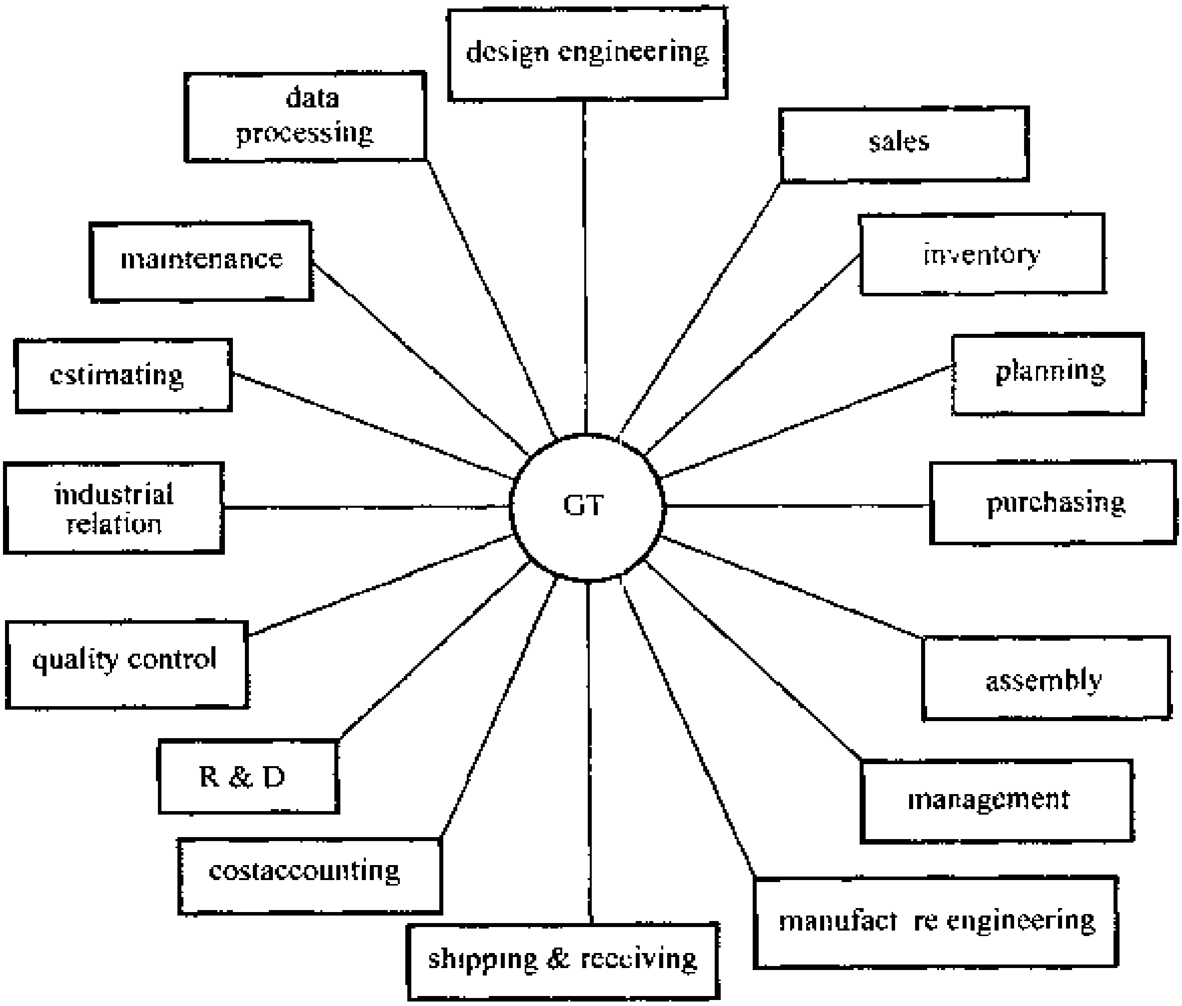


Fig. 21.1 Company functions affected by group technology

· Scope of the Classification—A classification system must be able to accommodate the product, the means of production and the controls over production. In line with the second principle, that the system be all-embracing, the scope must be defined based on the population as well as the objective of the classification system. This means that numbers of categories must be sufficient to accommodate all of the characteristics which are of interest to the particular business. It also means that information should be stored and be retrievable according to the specific user. For example, a production engineer, a salesman, and a purchasing agent are interested in different characteristics, even though those characteristics might identify the same item. The supplemental characteristics required by different users must therefore be stored in the data base so that each user receives or inputs only the required information.

·Mutually Exclusive—Any given set of identical characteristics must describe a unique object. This may seem too obvious to receive more than passing interest. In a company dealing with thousands of parts, however, it may be of more than academic interest. In the absence of a high level of discipline it is not uncommon to find the same part described by more than one set of code characters.

·Permanent Characteristics—Permanence is, of course, relative to the user's point of view. In general, a permanent characteristic is one that describes what an object is, not how or where it is used. Where a pipe piece is used is important to an assembler, but there are ways of identifying where it is used which are distinct from the classification system. Material, size, permanent, easily identified attributes which affect design and manufacture decisions.

Coding

Classification and coding are often used as if they are one word. They are not. The code is the vehicle by which a classification system is made operational. A classification system based on key words, such as is used for some library searches, is feasible. In general, however, a code consisting of numbers, letter characters, or symbols is much more effective. A sequential numbering system should not be confused with coding. A code must not only identify an object but must be based on permanent, mutually exclusive attributes according to some user objective. For purposes of retrieval and ease of use, it is desirable that the code reflect yes or no questions. An object either has a certain characteristic or it doesn't. This does not mean that codes must be binary. A particular hierarchical category such as size may be described by the digits zero through nine to describe ten different sizes.

Codes may also be memonic. Letters corresponding to the first letter of key words may be used to represent certain attributes. For example, one shipyard uses IL10 to identify a ten-foot-inclined ladder. Where coding will be discussed in more detail.

课外阅读

Additional Reading

Group Technology and the Shipbuilding Model

It was shown in Section I that a major source of low productivity (high costs) in shipbuilding is unanticipated changes in production rate. This takes many forms (increased manning, overtime, rapid fluctuations in manning idleness, etc.) and can be traced to more than one direct cause (poor cost estimation, design instability, bottleneck delays because of missing material or plans, high turnover, etc.). The effect of such cost drivers is exacerbated by accounting and production control procedures which are oriented to functional ship systems. Functional system orientation contributes to a highly sequence-dependent production operation. For example, a fire main system spans nearly the entire ship. The labor and material required to fabricate and install a fire main system would not be difficult to estimate if the system were laid out in an open field. However the system must interface both in time and space with the remainder of the ship. This creates a massive accounting and control problem. It also creates a practical problem having to do with "human nature."

If a work order is issued for the entire system, as is common practice in many yards it must remain open for nearly the entire construction cycle. This work order then becomes a prime candidate for "creative progress reporting" by various shops. Sometimes the manhours and material budgeted for another work order are used up before the work is completed. A work order having a large budget and spanning a long time frame, such as the fire main work order, then becomes a logical source of borrowed budget. Shop foremen simply charge resources expended for one job to the job with the remaining budget. It is something like a pyramid club. The final accounting can be deferred as long as some work orders are still open. The shop foremen of course, hope to bring budgets into line through various efficiencies before the final accounting. Even if this is done, it is impossible to properly account for expended costs of some sections of the ship. As a result estimating future jobs of even simple ones, the same series is very inexact. Additionally, areas where productivity might be improved may be disguised. Management doesn't know that such areas are contributing to costs in excess of what was planned. Consequently, no effort may be made to correct the situation.

Another source of low productivity is idleness. A major source of idleness is a breakdown in resource scheduling and control. Workers report to a job and find someone from another trade in their way because of a lack of schedule coordination. The workers wait. Workers need some part to complete a task. One goes to find the part. The rest wait. Drawings are not available as needed or a change to the drawings is incomplete. The workers wait. A critical previous task is not completed, or some owner provided equipment does not arrive on time. The workers wait. The list goes on and on.

So, too, the list of apparent causes of low productivity goes on and on. What is important is that these are inherent in the management system not in the performance of the individual workers. Borrowing man-hours or idleness are not an indictment of the work force as sneaky and lazy people. Rather, the indictment is against the management system. Group technology is one possible approach to improving the management system.

（摘自＜ship production＞R. Strorch, C. Hammon & H. Bunch, Cornell Maritime Press, 1988）

术语解释

GT(＝group technology)	成组建造技术，成组加工法
precept	技术规则
mass production	大规模生产
product oriented	适于生产的
a committed cell	一个指定组织，完成特定使命的组织
innovative shipbuilder	有创新性的造船厂家
throughput	物料流量，生产量(率)
problem area	同类生产问题区
spanner wrench	开脚板手
turret lathe	六角(转搭)车床
anatomy	组织构造
classification and coding	分类与编码
Linnean hierarchical taxonomy	林氏等级式分类学
phylum	门(类)
extrusion and casting	挤压成型与铸造
data base	数据库
retrieval	[计]检索，回收
turnover	工程维持费，周转营业额
schedule coordination	生产规程(进度)协调
fire main system	主干灭火系统

conduit	管路，导管
reduction in congestion and idleness curve	减少（建造）中的（劳动力）拥塞与闲散生产进度曲线
sequential numbering system	顺序编号系统
mutually exclusive attribute	相互排它性的属性
efficiency	供给能力，供给量
disguise	隐藏，不被识别
indictment	起诉书
mnemonic	助记忆的

问　　题

1. Does the Group Technology stated in the text imply the technology of dividing ship production parts into some groups according to their functions?

2. What is the main purpose of applying Group Technology in shipbuilding?

3. Is mass production assembly line technique suitable for ship production?

4. Can Group Technology be adopted in production of small size batches?

Chapter 5 Shipbuilding Economy

Lesson 22 Status of Shipbuilding Industry

There were few surprises in the 1996 ~ 1997 rankings of the world's principal shipbuilding countries, with Japan and South Korea leading the field again. According to figures released by Lloyd's Register of Shipping for the June quarter of 1997, Japan and South Korea headed the world order book with, respectively, 15 147 000 gt (gross tons) and 14 926 000 gt - 30.9% and 30.5% respectively of the world total. By comparison, Western Europe totaled 8 649 000 gt (17.7%), Eastern Europe 4 565 000 gt(9.5%), and the rest of the world 5 574 000 gt (11.4%). There were 2 548 ships totaling 48 861 000 gt in the world order book (ships currently under construction plus confirmed orders placed but not yet started). The cargo-carrying component of the order book was 2 008 ships of 67.5 million dwt (deadweight tons), with oil tankers leading the way at 24.1 million dwt.

Japanese order books were healthy, and major yards were booked until 1998. The depreciation of the yen from about 90 to the U.S. dollar in 1995 to about 114 in early 1997 helped secure orders. Japan's main rival, South Korea, had to contend with higher inflation and a strong currency. As a result, the 10% price advantage that South Korea had enjoyed in 1993 had been eliminated by 1997. Throughout 1996 South Korean yards invested in extra capacity, which prompted concern over the possible effect of lowering prices for ships. Consequently, Japan and South Korea held negotiations on limiting their shipbuilding.

In the European Union new orders for shipbuilders in 1996 fell by 29%, and some builders faced possible closing. The European Commission voted to maintain through 1997 its 9% subsidy for the construction costs of large ships. The hope was that this would enhance prospects at those yards where competitive, profitable pricing had proved elusive.

The cruise ship market remained buoyant with the delivery of several new vessels, including the 77 000gt cruise liner Dawn Princess delivered from Fincantieri's Monfalcone yard to P&O Princess Cruises. The world's largest cruise ship, P&O's 109 000gt superliner Grand Princess, was floated out of Fincantieri's yard. The 2 600 passenger-capacity ship was to sail from Southampton, Eng., to Istanbul on her maiden voyage in 1998. The 74 140gt cruise ship Grandeur of the Seas was delivered from Kvaerner Masa-Yards in Finland to the Royal Caribbean Cruise Lines. The 2 440 passenger liner was equipped with diesel-electric propulsion having a total output of 50 400 kw. Meyer Werft delivered the 77 713gt cruise ship Galaxy to Celebrity Cruises.

A noticeable building trend was the increasing popularity of floating production, storage, and off-loading unite (FPSOs). Demand for FPSOs had grown quickly in recent years, and shipyards and their suppliers responded well. FPSOs in 1997 were dominating the development of new oil fields throughout the world because in many cases an FPSO was much less expensive than a fixed offshore platform, which was burdened with long construction times, inflexibility, and high capital, operating, and abandonment costs. In the North Sea alone, FPSOs were to be used to develop many fields. In other parts of the world, FPSOs were being employed in fields at Terra Nova off the coast of Canada, Zafiro off the coast of Equatorial Guinea, Bayu-Undan and Laminaria/Corallina in the Timor Sea, and Liuhua 11 - 1 and Lufend 22 - 1 in the South China Sea.

According to Merchant Shipbuilding Return issued by Lloyd's Register, as of June 1994 there were 1 098 steamships and motorships being built around the world. They represented a gross tonnage of 15 844 647 gt (gross tons), up 149 823 gt from the previous quarter. There were also 1 050 ships that had been ordered but on which building had not yet started. If they were all built, their tonnage would amount to 24 997 199 gt, an increase of 1 621 252 gt over the previous quarter. These combined figures, 2 148 ships of 40 841 846 gt, constituted the total world order book, which was 1 600 081 gt more than the 1993 world order book. The principal types of ships in the order book were oil tankers (13 151 800gt), bulk carriers (13 756 934 gt), and general cargo vessels (7 291 487 gt). Of the total order book, tankers represented 32.2%, bulk carriers 33.7%, and general cargo ships 17.9%. The proportion of the order book tonnage that was to be registered in countries other than the country where it was built rose to 77.9% (31 819 128 gt-an increase of 2 080 401 gt).

The major players in world shipbuilding were Japan, South Korea, and China (both the People's Republic and Taiwan). At June 1994 these countries together accounted for 64.38% of the world's shipping order book. European countries and Brazil also had significant percentages of the total

In mid-July-after negotiations at the Organisation for Economic Co-Operation and Development in Paris-Japan, South Korea, the European Union, the U.S., Finland, Norway, and Sweden agreed to halt subsidies for their shipyards. The move was expected to avert a new found of subsidy grants.

Competition from shipbuilders in South Korea and Europe forced Japanese builders to take drastic action to cut costs. Hitachi Zosen Corp. Laid off 10% of its 2 000 workers, and NKK Corp. planned to reduce costs by 30% at its Tsu shipyard by amalgamating its design and construction departments. South Korean competition also forced Mitsubishi Heavy Industries, Ltd. , to cut 900 jobs from its workforce of 7 000.

South Korea was not without its own labour problems, and Hyundai Heavy Industries Co. locked out 15 000 workers. The trade union was seeking a guaranteed montthly salary plus a series of improvements in working conditions. Demands amounted to a 13% increase, well above the government's 5% incomes-limit policy.

The sinking of the Baltic "roll-on, roll-off" ferry Estonia, with the loss of some 900 lives, revived concerns over the safety of this type of ship. Taken together with the loss of the Herald of Free Enterprise off Zeebrugge, Belgium, in 1987 with the loss of 188 lives, this incident caused serious doubts about a ship design that incorporated large open car decks. Britain's Royal Institution of Naval Architects rebuked ferry operators for being slow to install stabilizers or watertight bulkheads on their ships. Losses of bulk carriers and oil tankers also continued despite some remedial action. A notable example was the loss with all 24 crew of the 93 355 deadweight ton bulk carrier Iron Antonis off South Africa. Some light was thrown on bulk carrier losses by the finding of the wreck of the Derbyshire, which and sunk in 1980 without trace. A remotely operated submersible provided evidence that the vessel broke apart at frame 65 and the aft accommodation section sank immediately. Photographs indicated that the bow fell off the carrier before the remainder of the vessel sank. This might suggest a previously unknown stress point at a quarter of the ship's length on this and other simllar bulk carriers.

（摘自<Encyclopedia Britanica>, 1999）

术语解释

World order book	订单表(此处指造船订单)
gross ton	长吨(1.016 公吨)
depreciation of the yen	日元的贬值
inflation	通货膨胀
European Commission	欧洲委员会
diesel-electric propulsion	柴油发电机推进
abandonment cost	船舶废置成本费用
Merchant Shipbuilding Return	商船建造统计表
steam ship	轮船
motor ship	汽船
player	参与者,局中人
to avert a new round of subsidy	避免新一轮的补贴拨款
grants	许可,拨款
subsidy	(政府)补贴
elusive	难以捉摸的
cruise liner	定期游船,定期航班,定期邮轮
maiden voyage	首航,初航
amalgamate	合并,联合
lock out	解雇,闭厂

问　　题

1. Can you name at least four important shipbuilding countries in the world?
2. What event did it cause the concerns over the safety of Ro/Ro ferry ships in recent years?
3. In which year did the European shipbuilding industry show drastic

decrease?

4. Which meeting in 1994 did it help to stop the trend of a new round of subsidy grant?
5. What types of ships were in the order book of 1994?

Lesson 23 Shipbuilding Costing and Contract Arrangements

23.1 Purpose

Naval architects and engineers in structured organizations are frequently excluded from participating in the contracting and financing arrangements of vessel construction. This exclusion is most unfortunate and it is anticipated that this section will assist naval architects and engineers in contributing to these arrangements.

Far too often the approach to vessel selection and financing involves lawyers, accountants, financial planners, and ship construction people working independently of each other without the continuing interchange of ideas that is so essential during the planning stage. The widest knowledge of any proposed vessel construction and the fullest participation in the mission aspects of new vessels provide the best climate for producing the most effective design and construction.

If continuing interaction of the interested parties is not feasible, the next best thing is to have those entering the field of vessel construction understand fully (1) the various contributions of the lawyers, the accountants, the financial planners, and the operators to the design, and (2) the documents and instruments developed over the years to ensure the continuum of events which must occur timely to produce the desired vessel within the desired time at an acceptable price. With the intellect considered to be the prerequisite of such understanding comes the patience to accept a less perfect alternative when it is more important to see the project move onward.

23.2 Scope

Accordingly, this section is proceeding on a format which is intended first as a narrative of a typical ship design genesis, its subsequent contracting and construction, and its delivery and operating inception. After this over-simplified case history approach, a more detailed discussion of the legal and financial aspects and impacts, including the documents usually involved in such transactions will be presented. Where deemed appropriate, a sampling of alternative approaches will be included, all to show the reader that the kinds of agreements which can be made between a purchaser and a builder or between a financier and a purchaser/borrower are limited only by the law of the land and the ingenuity of the parties dealing in the matter—the assumption being in all cases that the objective is the best product at the least all-inclusive cost to the owner.

Also, where the narrative leads to identifiable problem areas, sufficient analysis will be outlined to permit understanding and insight into the course of these problems so that the naval architect or marine engineer might be better prepared to avoid controversial approaches in preparing ship construction documents for the clients or principals.

23.3 Definitions

In discussions of shipbuilding costing and contract arrangements, a number of terms are used that have specific connotations in this aspect of the shipbuilding process. For the purposes of this chapter the following definitions can be considered to apply.

· Architect of Contract: A term borrowed from the legal profession to indicate the person or entity that authored the contract document.

·Builder: In this text, builder, contractor, and shipyard are used synonymously. It is the entity that signs the construction contract and undertakes to physically build the vessel. The various forms are used as these terms are encountered in invitations, contracts and specifications.

·Owner: In this chapter, this term is used to identify the buyer of a vessel to be constructed. In the parlance of MarAd contracts the term purchaser is usually substituted for buyer. Primarily, the intent is to name the party who selects the design and causes the initiation of the contract to build. It is recognized that in leveraged lease situations the owner of record of the constructed vessel may be someone or some group having only a financial interest. In such cases owner as used herein is the charterer.

· Naval Architect: Anyone having decision authority over the design of the vessel to be constructed or reconstructed. In-house naval architects are those on the wage payroll of the shipowner or entity contracting for a vessel. Outside or Contract naval architects are those persons whose business is the design and engineering of vessels, and who contract with owners or shipyards to perform their services for a fee.

·Design Agent: A term used interchangeably with an outside or contract naval architect. It has come into use as shipyard designs have become prevalent. Shipyards are frequently design agents. They do employ naval architects, and those who work at design are usually in the engineering department or the planning department.

· Reps: Abbreviation for representatives; as, for instance, owner's reps are the inspectors and plan approvers working on-site during ship construction.

·Lead Ship: The first vessel built to a new set of plans and specifications. It is not necessarily the first vessel delivered because under circumstances of the order being alloted to two or more yards, the first vessel in one of the other yards may be delivered first. This occurs because of better production methods, or because of unforeseen delays in the lead yard.

- Following Ships: Ships built to the same plans and specifications whether in the same yard as the lead ship, or in other yards, are following ships.
- Berth Term: This refers to dry cargo liner operations utilizing publicly issued schedules of port calls.
- Cease and determine: A phrase used in Maritime contracts to indicate a full unconditional stop action plus an inventory of the financial position as of that moment.

23.4 How the Decision to Build Vessels Germinates

Except sometimes in the world of chartering (where new ventures generated by the ability to secure long term charters lead to ship contracts), the impetus for new ship construction usually comes from established companies already operating some tonnage and sufficiently well indoctrinated in the every day workings of their business to be planning a continued future, utilizing newer and better ships. Entrepreneurs who can develop a bona fide commitment to charter a vessel for a sufficiently long term, can and do build new vesels with the help of the banking community's eagerness to accept a bona fide charter commitment as collateral for the credit required.

The climate for speculative ship building varies with the bullishness of the world economy and the presence or absence of over-tonnaging of the kind of vessels best suited to a trade or service. When the movement of foreign-source crude oil appeared to be on a steady growth curve, entrepreneurs and oil companies worked out deal upon deal. When the embargo occurred in 1973, confidence was shaken and continued deliveries of previously contracted vessels built up a world-wide stockpile of unemployable tonnage. This over-tonnaging cast a pall on speculative construction which tended to limit risk-taking in new construction.

Accordingly, this narrative will use the berth term, established operator's vessel construction program because it illustrates a wider spectrum of contractual possibilities involving the architect. The entrepreneurial vessel built for chartering out is most likely to be one more of a class built for someone else and modifications or changes are considered items to be sacrificed in the interest of timely signing of the contract. The banking community feels most secure with concrete examples described in the documents and would rather know the ship is a sister ship to one identified in a previous deal than cope with new specifications.

In the commercial world, the initiation of planning for new vessels is a decision by a commercial company's top management that new vessels, particularly those employing innovation and improved reliability, will improve the company's profitability. If the company is a subsidized company, or if the company has certain other statutory arrangements with the government, a contractual obligation to build one or more vessels may exist, and may be the impetus to start management's vessel replacement planning.

Vessels have always been costly enough structures that their acquisition is and continues to be a priority item for action by the company's board of directors. Prior to management's submitting a proposal to the board, an indeterminate development period or stage must be anticipated. During this period, many ideas will be forthcoming from almost every participant in the business. Management usually begins with suggestions for characteristics which it hopes will improve earnings. These are most likely to be simply stated and will include, as a rule, desires for higher speeds and greater capacities. Some owners, however, tend to emphasize the goal of low-cost carriage of cargo which relates to a low acquisition cost per-ton or per container.

23.5 Design Data, Origin, and Infusion into the Accepted Design

Suggestions for the selection of ship design in this period come also from shipyards, customers, vessel component vendors, interested friends, seagoing personnel, shore staffs, agents, etc. The company's outside naval architect or the company's in-house vessel replacement department culls all these suggestions and molds what is good into a concept which also considers naval architectural practices, shipyard availability and limitations (present day term for this is producibility), initial cost impacts, rules and regulations, etc. From this work a conceptual design or designs is produced with a table of characteristics and a precise description of the salient features.

It has not been without precedent to have a design competition at this stage. Design competitions were common in shore-side construction but only rarely used in modern shipbuilding. Owners will consider a design competition if they are not committed to a favorite architect, if the workload for architects is so limited all are actively seeking the owner's work, and if choosing from several designs suits the owner's posture at that particular time. For those owners contemplating building under construction differential subsidy (CDS), the federal government may effectively influence the choice of design to enable participation in multi-ship programs.

23.6 Shipyard Developed Design

Since the advent of the negotiated contract in the United States and in recognition of long standing tradition in other countries, owners will nowadays tend to progress from in-house conceptual outlines to a shipyard developed design, either by-passing the outside naval architect entirely, or using him as a consultant to evaluate a shipyard design and to suggest to the owner ways to incorporate owner's preferred features in the shipyard concept. Thus, the owner may benefit from a proven design and, hopefully, at a favorable price.

If the construction is to be built with government aid, the owner begins informal discussions with the government's staff to acquaint them with a preliminary economic analysis of the proposed service, the conceptual design and to insure that the design meets with the standards currently advocated by the government.

One should be mindful of the fact that up to this point minimal expenditures have been made. Most of the work has been done in-house by the owner's staff and if anything has been spent outside, it has been on travel to various shipyards and, perhaps, 2 000 or 3 000 man-hours of engineering effort by an outside architect. These kinds of expenditures fall into the category of day-to-day expenses.

23.7 Government's Financial Involvement in the Ship Design

At some point in time, top management, armed with a suitable draft proposal, sketches, plans, and economic analyses, presents the new construction proposal to its board. Assuming the construction is to proceed, the board will in due course authorize the further development of the plans, subject to refined estimates, financing and contracts satisfying some particular set of conditions or the management's best judgement. When so authorized, the owner's staff undertakes to have contract plans and specifications developed either by an outside naval architect, by the shipyard whose design was acceptable to management, or by the owner's own organization.

Simultaneously, if the vessel is eligible to receive government aid, an application is prepared by the owner to be submitted to the government. This application will incorporate a rather complete set of plans and data from which the government staff is able to understand the vessel's concept, and make predictions as to cost, and as to delivery. Such applications are usually conditional on the owner's board of directors accepting the available financial aid rate and contract conditions, if any.

During the course of time in which government is considering the application, the owner will be editing and reediting the plans and specifications; determining the estimated domestic cost; cost to construct in another country, if applicable; source of equity; plan approval and inspection estimated; loan arrangements, etc.

23.8 Invitation to Bid, or Request for Proposal

If the vessel is to be bid or negotiated, at the earliest date that the design is set and contract plans and specifications are ready, an Invitation to Bid or Request for Proposal (RFP) is sent to a list of prospective builders describing briefly the vessel to be built and the conditions under which it is to be built. Such prospective builders as are interested respond by posting a cash bond to insure return of all bidding material received by them and by requesting the full set of plans and specifications prepared by the owner and his naval architect, if one has been employed. It could well be that the owner's list of builders in deference to the location of his business may not include all the builders. The government may, however, insist upon an expanded list of bidders.

The Invitation to Bid specifies the date on which sealed construction bids are to be opened and sets out the conditions under which bids are determined to be responsive. Similarly, the Request for Proposal sets forth the conditions under which designs and construction proposals are to be submitted.

The bidding period is usually chosen by the owner upon consultation with selected shipyards and the government, if it is to be involved; it is set at the minimum practical period, usually 60 to 90 days, in which a shipyard can secure quotations and establish its proper selling price.

The contractor is guided by his own order book, his potential opportunities with other customers, his problems in the yard as to availability of trades, market conditions, etc., to determine whether he is in a position to compete for the new work. If he considers that the new work will not conform to his own production schedule, he makes no attempt to bid, but returns the bidding material and repossesses his bond.

If he deems the work a practical possibility, he begins the process of estimating. This process is excellently set forth by Mack-Forlist and Goldbach (1976).

Contracts may be of the fixed price or escalating type wherein the bid price may or may not be adjusted to reduce the risk to the shipbuilder of the escalating costs of labor and material. Responding to a bid request for an escalating type of contract is a costly and time-consuming process. Not all bidders or proposers can complete their version of the bidding processes in the time allotted. Any party can ask for an extension of time. unless there are circumstances which prevent such an extension, it is the practice to grant any requests for reasonable extensions.

Bid or RFP responses, although requested in a set form, usually vary from "no bid" to careful compliance with the bid form; others will include explanations, exclusions, differing times of completion, or other non-conforming items. Shipyards may thus become non-responsive legally.

The true low bidder is rarely discoverable by casual inspection. Analysis is necessary to establish those bids which are non-responsive and then to establish the low bidder from the remaining competitors. The government, if involved, or the owner, or both, mutually may then announce the low bidder; or, reject any or all bids, a condition generally written into the Invitation to Bid or Request for Proposal.

23.9 Award of Contract

If the low bid price is viable and reasonable, an award may be announced. The proforma contract which was included in the Invitation to Bid, or RFP, for general information, is finalized and perfected after receipt of bids, or RFP, including the amount of government support. At this juncture, the owner's management is in a position to calculate the required equity for its program, the contract price, the estimated delivered price, the amount of construction loans, fees, legal costs, plan approval, engineering, inspection, etc. A rather close estimate of the capital cost and the required cash flow is now available. The management is in a position to either use the authority previously granted by its board of directors, or refer back to the board for final approval. At this stage, any or all of the parties can find themselves in the position of having the venture frustrated by failure to obtain their respective boards' approval. Sometimes there are penalties involved in failure of the shipyard to conclude a contract, but the action is taken after deliberation and with full awareness of the penalties, monetary or otherwise.

In recent years, at least one shipyard refused to build the vessel on which it was low bidder, and more than one owner has forsaken construction after seeing the bids. On occasion, government has been dissatisfied with the results of bidding.

.It is not unheard of to see the venture salvaged through negotiation after taking bids. Usually it is accomplished by changing the scope of work, or by changing conditions of contracts, guarantees, etc. At these times, the value of an independent, outside naval architect can be immense because his guidance to the owner is objective and professional; whereas the owner is more concerned with a business decision. If the contract is executed, a significant milestone in the vessel's construction is reached.

(摘自 < Ship Design and Construction >. R. Taggart, The SNAME, On World Trade Center, NewYork, 1980)

课外阅读

Additional reading

Progress Payment Schedules

Reverting to the narrative of events, the progress payment schedule will be spelled out in the contract. It is important both to the builder and to the buyer that major expenditures for both labor and materials be made early and the builder compensated before escalation takes its toll. With vessel prices escalating as they have, it is usual nowadays to see contracts requiring periodic payments twice monthly. Because a good deal of outside procurement is undertaken at the outset of a new building contract, the shipyard progress payment curve is heavy on the front end. Also, as the delivery date approaches, more labor and premium time are spent to finish. Accordingly, the progress payment curve is a bath tub curve. In series construction, the curve for each vessel is plotted against time, and a composite curve of aggregate semi-monthly payments can be predicted.

Actual billings will be made by the shipyard on the basis of completed points in the case of most United States shipbuilding contracts. In the usual approach to determining the status of completion, each shipyard generally assigns weighted points to the various sub-divisions, or crafts, including engineering, lofting, and all the production departments. These weighted points are the total manhour selling price and material costs, plus surcharges to cover overhead. The accountant will, as a rule, equate the contract price of the vessel to 10 000 weighted points, which total may include direct application of points for major vendors.

At any given time, the shipyard accountants, utilizing work tickets and material assignments, can produce a substantially accurate summation of completed points. If the other parties accept these completion figures, the progress billings are made accordingly. This affirmation process requires a judgment by owner's representative on-site as to the percentage completion. He is not under pressure to be absolutely precise because the process is self-correcting as the construction work continues. In U. S. yards there is also a nominal holdback, of say two percent during progress payments, part of which is paid upon ship completion and the balance after the warranty period.

International shipbuilding practice, other than in the United States, is quite likely to be different. In a majority of cases, the vessel is constructed under some form of national credit assistance or guarantee. These financing arrangements usually involve a twenty percent equity payment by the purchaser, with eighty percent financing through banks having a construction loan arrangement with the shipyard. The national government usually has a guarantee relationship with those banks so as to foster shipbuilding.

In such cases, the traditional approach most widely encountered is one requiring the purchaser to pay a portion of his equity at contract signing, followed by payments at launching and at delivery.

A formula often used is ten percent of the contract price at contract signing, and five percent again at launching, and at delivery. By delivery time, the shipbuilder has taken down the eighty percent of contract price from the banks and the exchange of documents at delivery essentially transfers the bank mortgages from the shipyard to the purchaser. In matter of form, these are always newly written mortgages which are drawn to suit the flag of registry and the banks. As a matter of information, the usual term of these mortgages has settled around eight years, but, of course, terms and conditions change to suit the finanical climate and national policy.

The take-down from the banks by the builder is in accordance with local custom, but is always based on a formula equating certain principal events to a percentage of completion.

Thus, the principal event schedule for such construction is quite important to cash flow projection. Additionally, certain public relations efforts are contrived, as a rule, to take advantage of keel layings, launchings, etc. It is quite normal in the United States to have the launching and christening combined, and to make this an occasion for improving relationships with political figures, union leaders, press, and customers. In many other countries, the same weight is not given to these events, and the gala might be saved for christening, which may take place at time of delivery (or even later) rather than at launching. One can foresee a decline and passing of the launching ceremony in the future because of the disruptive impact of the ceremony on production work in the shipyard, as well as the exposure to liability for claims which can be expected when crowds gather in heavy construction areas.

术语解释

accountant	会计
climate	观念,一般趋势,环境,风气,气候
genesis	成因,来历
operating inception	开始营运,运作开端
marine engineer	造船工程师
prerequisite	先决条件
transaction	交易,处理
ingenuity	独创性,创造性
principal	委托人,负责人
controversial	有争议的
connotation	含义,内涵
architect of contract	合同设计人(或实体)
entity	实体
invitation	招标
parlance	说法
in the～of MarAd contracts	按 MarAd 合同的说法
MarAd = Marine Administration	(美)海事管理局
leveraged Lease	杠杆利率
charterer	租船人
in-house	自身的,国有的
design agent	设计代理人(商)
rep	代表(缩写)
inspector	验船师,监工,检查员
lead ship	首船(批量建造船舶的第一艘船)
following ship	后续船
berth term	停泊期

port call	沿途到港停靠(寄航)
cease and determine	中止与终结
inventory	存货盘存,存储,清点
germinate	萌发,发芽
venture	投机,冒险,(具有风险的)商业运作
indoctrinate	灌输,教育
entrepreneur	企业家,承包者,中间商
bona fide	真诚,善意(的)
collateral	间接的,副的,第二位的
credit	信用,信誉,信贷,债权,贷方
bullishness	牛(市)气,股市看涨
banking community	银行业团体
speculative	投资性的,思考、推测的
to cast pall on	止住,刹住
stockpile	储存,堆放,积累
innovation	革新
statutory	法定的,制定的
cull	选出,择出
board of directors	董事会
vessel component vender	造船部件销售商
interested friends	利益相关的赞助商
replacement department	替换人员部
producibility	可生产性,可延长性
construction differential subsidy (CDS)	(美)建造差异性补贴
invitation to bid	招标(邀请书)
negotiate	谈判,商议
proposal	投标,申请,计划,建议
request for proposal(RFP)	邀标
prospective builders	有希望的厂家

deference	服从,听从,尊重
secure quotations	获取市场行情,得到报价单
repossesses his bond	取回其抵押金
escalating type (of contract)	(价格)伸缩式(合同)
time consuming process	很耗时的过程(工序,工艺过程,工程作业)
bidder or proposers	投标人
differing times	不一致的时序
non-conforming items	非相符性条款
non-responsive legally	法律上非应答性的
viable	可生存的,可实行的
proforma	形式上的
equity	投资资本
penalty	罚款,惩罚
conclude a contract	缔结(订立)合同
forsake	放弃
award of contract	签订合同
loan	贷款(额)
fee	费(用),税
legal cost	法律费用
plan approval	图纸(方案)审批
inspection	检验
deliberation	慎重斟酌,反复思考
monetary	金融的,财政(上)的
progress payment schedule	(施工)进度付款时间表
escalation	涨价
outside procurement	外(采)购
premium	额外费用
premium time	加班
surcharge	附加费
overhead	经常开支

weighted point	加权点
billing	记帐,编制帐单
nominal holdback	少量章制费,象征性的暂扣款
warranty period	保证(质)期
mortgage	抵押,保证
flag of registry	(船舶)登记所挂国旗
take down	取下
christen	命名

问　　题

1. What are the goals a ship owner usually pursues when planning to build a new ship?

2. Do you think that it is a good idea to arrange some sort of design competition for a new ship?

3. Is there any difference between 'Invitation to bids' and 'request for proposals'?

4. Should all the contracts for shipbuilding be signed at fixed price?

Lesson 24　General Aspects of Contracts

24.1　The Ship construction Contract

Regardless of who is the architect of the Ship Construction Contract, be it builder or purchaser, it will include by reference and by direct instruction, additional prepared documents, such as contract plans, guidance plans, specifications, rules and regulations applicable to the construction of such vessels, and standard codes, statutes, general provision, and legal precedent. Additionally, the contract is subject to the jurisdiction of the law of the land which in itself is a matter of such impact that it is usual to specify in the contract which law applies. Frequently, the language of the contract can take an unexpected meaning when viewed from the position of the Standard Contract Code in one country, versus the code in another country. Such items as Statutes of Limitations vary from country to country (as well as from state to state within the United States). Also, there may be a distinction in interpreting whether the ship contract is a contract or a sales agreement (i. e., Sale of Goods Contract appears to be beyond legal redress much sooner than is the case for a construction contract). Similarly, time begins to toll at different thresholds for different contracts, thus the Statutes of Limitations begin to run from the occurrence of different events.

One can appreciate also the wide difference in litigation costs for both parties if the contract has been executed with a clause naming the applicable law. Otherwise, the parties are likely to resort to litigation in whatever location is to their own advantage, thus precipitating counrtesuits in other locations, all of which greatly increases the cost of dispute settlement.

As a minimum, all parties to a Ship Construction Contract have the right to expect:

· that the contract documents can be drawn with sufficient expertise to describe the vessel to be built in sufficient detail so that both buyer and builder agree on the end product with complete confidence;

· that the price stated in the contract is the delivery price, and the delivery price will be that price, plus only such extra costs as are explicity permitted by the contract;

· that the vessel will be delivered on the day stated, unless modified by time extensions explicitly permitted by the contract; and

· that all perils which could impact on the foregoing are identified and the curative action and procedures in the event such risks obtain are stated.

These basic elements of the contract must be stated without ambiguity. It is the elimination of ambiguities which concerns the naval architect most. If he fails to be clear and precise, and if he fails to be consistent in the plans and specifications which are included in the contract, then he has failed to provide the owner who has engaged him with the expertise required to protect the owner's interest.

The rule of thumb is that he who writes the contract suffers the burden of any ambiguity. If the financial climate is good, and if the relationship between the buyer and the builder is amicable, most minor ambiguities are settled in day-to-day compromises. If the builder is in a financially disadvantageous contract, then even an item such as identifying a component by name and model becomes a serious problem should the manufacturer discontinue the model, or cease his business. Builder will invariably claim a price increase in such event, to which he may be entitled.

These things are equally important in foreign contracts, and the problem may be compounded, particularly if American standards and interpretations are depended upon to describe the vessel to be constructed in another country. Under these circumstances, it behooves the naval architect to be certain that contract compliance is viewed in the same light and with equal importance by the builder as it would be in the United States. Frequently, local contract law is entirely different and compliance in a legal sense may allow rather broad interpretation—a fact known to the builder, but not necessarily to the buyer. Obviously, under these circumstances, buyer will be disappointed and frustrated.

Furthermore, it does no good to specify American components in another country's contract if local law limits the content of the manufactured vessel to substantially local flag sources. In fact, such a contract will be fraught with ambiguities arising out of mandated changes of vessel components. In the business of buying vessels constructed in other countries, the owner soon discovers that the usual solution to coping with components is to supply the component built by a domestic licensee in the country where the ship is being constructed.

It is, ultimately, the long term of the shipbuilding contract that precipitates the adversities. In a high priced contract extending over two or more years, particularly in an escalating market, the time factor gives opportunity for prices to change, profitability to erode, managements and management strategies to change, etc. Thus a contract entered into in good faith can later create administrative difficulties.

The naval architect must be thoroughly familiar with government assistance programs and all government design and engineering requirements.

As to the details in any construction contract, the naval architect can be very helpful to his client and his client's lawyers. In the international contract, for instance, local customs and usages may be much better known by the local naval architect who can interpret the accepted (and, therefore, most likely to occur) practice for his client. The client may also be totally unfamiliar with the regulatory bodies having jurisdiction over the construction and thus be disappointed in the results, unless the contract especially covers those areas where higher quality is important to the client. A similar area of competence for the naval architect is the arbitration clause. The naval architect may be more familiar from past experience in the procedures, and in the forum named in the contract.

It is, however, in the matter of pricing that the naval architect must have thorough competence. This is true in all shipbuilding contracts. A naval architect with international operations is doubly valuable to his client in the course of a United States CDS contract because he is best situated to provide substantive documentation of the comparable low cost foreign price estimate for purposes of his client's efforts to obtain a true differential to establish the price net of subsidy. If the naval architect has had recent experience in the foreign locality in which a client is building vessels, he may also further his client's interests by advising him on the currency to be preferred for the contract price; on export permits, documentation and fees; and on other delivery matters, including renegotiation.

As to this last, it is not unusual in times of building way shortages to see an owner with a perfectly good contract forced to renegotiate to secure delivery of his vessel. A contract is an understanding between the parties and can be mutually amended at any time, including the eve of delivery.

Similar factors are equally important in private contracts because the owner's board of directors is entitled to make its decisions based on accurate information submitted to the board by the officers of the naval architect. Overruns of time and money resulting from owner-induced changes are disastrous developments in the eyes of the board of directors and everyone else involved. Overruns do not enhance the credibility of the staff which is forced to correct the price estimates; even if the causes could not be foreseen.

Additional cost can impact upon the owner, particularly when competitive bids are taken, because of the location of the builder. To the owner, all expenses incurred up to the moment the vessel arrives at its first loading berth, are part of the capital cost of the vessel; accordingly, a construction contract in a yard distant from the owner's regular service is not advantageous, unless the price differential or other factors cover all out-of-pocket expenses of positioning the vessel at a regular berth in the owner's service. Obviously, a possibility exists for a one-way charter, or other hire which could help offset the positioning costs, but, as a rule, the owner prefers to get a delivered vessel into his intended deployment as quickly as possible.

Before leaving the topic of contracts, one clause which invites some discussion is the so-called liquidated damage clause. Should the builder fail to deliver a vessel on the date of delivery stated in the contract, the presumption is that the owner suffers damage in that his business is disrupted. If the builder has been unable to document the reasons for the delay with sufficient proof to have been granted excused delays, those days not excused are multiplied by the dollar amount stipulated in the contract to arrive at the payment to be made to owner by builder. The contract identifies this dollar amount per diem as liquidated damages and not as a penalty.

Even as early as at contract signing, the owner can make a rather accurate calculation of the interest lost on his equity and the interest obligated on his construction funds. In a financial climate of high interest and big prices, interest can be $ 10 000 to $ 20 000 per day. It is illogical to stipulate damages of $ 3 000 or $ 4 000 per day in such a case. However, the liquidated damages are frequently stipulated at something less than actual out-of-pocket interest costs. Proposed liquidated damages are usually agreed to by contractor and owner prior to contract signing.

24.2 Non-performance of Contract

There are grave risks attendant in every shipbuilding contract, both for the builder and for the owner (and, where an interest appears, for government). In these days of large, complicated vessels, the costs are so high that a single contract which goes wrong may well precipitate a financial crisis, or bankruptcy, for one or the other of the parties.

The greatest risk is the one of non-performance. Nondelivery, cancellation and default are the most devastating events. In these cases, a party to the contract is unable to conduct the business in which he is engaged as planned.

Once the event of non-performance is upon the parties, it behooves both to move quickly and in accord with the procedures and remedies set forth in the contract to minimize the damage and permit recovery. It is as this point approaches that the naval architect's advice to his client is valuable. If he has been the inspection agent also, he should have been able to identify the crisis long before the other party has given notice. Moreover, he is in a position to broadly inventory delivered components and the progress status of non-delivered items, as well as the status of the work. His client will make his own decisions, but both the client and the client's legal advisors must rely on the best up-date of facts from a reliable and competent technical source.

It is a widely respected rule that in situations of one party damaging another in business events, both parties must thereafter at all times act in a way to minimize the damage. When working together to minimize the effects of a cancellation of failure to deliver, both will look to each other and their advisors to generate ideas for ameliorating the effects. Frequently, the naval architect is helpful in that he is aware of alternative uses for the engines, or the hull, etc.

At this juncture, it is necessary to comment on the government's obligations, if any, in the event of cancellation or default. The contract will specify a procedure for builder to give notice in event of default to the owner, and to the government. If the MarAd Subsidy Board is involved, it must within a time period (usually 15 days) be given written notice to undertake one of the following courses of action:

- Assume the payments required under the contract to be paid by the owner, or
- Elect to complete certain vessels and to optionally terminate other vessels in the contract, or
- Elect to optionally terminate all contract work.

Optional termination is a cease and determine action. The contractor must carry out prescribed functions under the control of the Maritime Subsidy Board to transfer title to the work (including all purchased items) to the Board and the purchaser, or to either, and to liquidate or preserve for future disposition the work (and the materials). This includes settling all claims of subcontractors, and other parties damaged, to the extent authorized by the Board.

Termination is expensive and the amounts payable include the cost of settling and paying all claims, plus a prescribed rate of profit (unless it can be determined that builder would have sustained a loss if the contract had been completed, in which event a profit would not be payable).

In the event of default by the contractor (failure to proceed on the contract with due diligence, bankruptcy, etc.), the owner and the Board, where their interests appear (provided the builder fails to cure the default timely) occupy the yard to perform the work and complete the vessels; or to sell the uncompleted vessels. These rights are stipulated to be in addition to, and not in substitution of, any rights the damaged parties would have in law or in equity upon experiencing the events of default.

24.3 Disputes

Disputes in the U.S. are frequently agreed to be remanded to an arbitration as codified by a recognized arbitration association. It is also possible for disputes in U.S. CDS contracts to be remanded to an arbitrator or arbitration panels. Both parties to the contract must agree to be bound by the arbitration, or in lieu of thereof, proceed to the Courts for recourse. In the United States, it is usual to refer to the Commercial Arbitration Rules of the American Arbitration Association.

It is important to the parties to the contract to understand the rules of arbitration, to understand the forum for arbitration, and to amend the contract to the extent mutually agreeable to limit the expense and imconvenience to both parties. Unless the owner guards against it, the builder will desire that the arbitration be at a location convenient to him, which is excellent if it is also convenient to the owner. Usually in construction in the United States this is not a problem unless the owner is on one coast and builder on another. In non-U.S. construction, it is a more difficult situation if arbitration is at the site of the builder. Frequently, in foreign building contracts, arbitration is stipulated in a neutral country such as Switzerland, or in a recognized arbitration capital such as London.

If the non-U.S. construction contract permits either party to sue rather than arbitrate, the contract must be carefully negotiated; otherwise, lawsuits in the builder's country may tend to advantage the builder who at a minimum need not underwrite substantial travel expense and two sets of corresponding lawyers. Furthermore, local law may not permit a non-national citizen the same rights in Court. In at least one shipbuilding country, for example, a party to the contract has no rights in the Courts unless the contract was preregistered at a cost for registry determined as a percentage of the total value.

The practical aspects of the non-national contract disputes procedure may be so overwhelming in cost impacts as to effectively undermine the disputes procedures in the contract, a fact which may be more apparent to one of the parties than to the other.

By and large, the greatest impetus to settlement of disputes is the high cost in dollars and time of permitting the dispute to be settled by others. To begin with, once the dispute leaves the hands of the supervisors of both the shipyard and the owner, knowledge of the facts grows increasingly less important than knowledge of the law or other extraneous impacts. At this time, the professional advice of a naval architect in suggesting alternative disposition of a problem may eliminate the cause of a dispute, or, if the work must be done, provide owner with the facts whereby he can make a decision to do the work after delivery.

The aim of every owner should be to associate himself with specifications and plans sufficiently explicit to permit a zero change construction effort, Additionally, one cannot escape the fact that the faster one can have a vessel built, the less the opportunity for escalation and dispute. The benefits of high productivity are substantial. The owner is most always advantaged by early delivery and it is quite obvious on the face of it that builder overheads are reduced below those used in the original estimate. The cash flow is at higher levels giving the builder more cash to manage, and reducing the owner's construction interest payments. All the impacts of labor contracts and regulatory body changes are mitigated because the impending rules are visible relative to the vessel construction deliveries.

Unfortunately, however, shipyard productivity in many yards is not generally improving on a broad front. One of the identifiable reasons comes under the heading of social legislation. And, it is not the traditional agencies, such as the U. S. Coast Guard and the American Bureau of Shipping, Lloyd's, the Veritas bodies, etc., but the environmental groups and the safety of work groups that create new constraints. For example, in the United States, the Occupational Safety and Health Act (OSHA) impedes production work by requiring procedures and approaches which delay the work and add significantly to its cost. Shibuilding has always been hazardous work, and shipyards have always fostered safety programs, but some work has always been treated as involving hazards, even after all practicable precautions have been taken. OSHA and other social legislation directly affects ship construction costs as well as ship repair costs aboard an operating vessel.

(摘自 < Ship Design and Construction >. R. Taggart, The SNAME, On World Trade Center, Newyork, 1980)

课外阅读

Additional reading

Other Naval Architectural Roles

Contracting arrangements for vessels are very intricate and very complex. Whereas every vessel must perform its design function (or the function for which it is converted), the action impetus for contracting may be as remote from operation, as, for instance, a financial investment. Profitability may be measured in part against the financing expertise for construction rather than the voyage returns in the life of the vessel.

A naval architectural consulting organization would be advised to be informed and knowledgeable in changing financial aspects of vessel construction including all government assistance programs, tax shelter and other tax aids, equity financing, debt structuring, and various current chartering agreements. It should be familiar with documentation and its possibilities insofar as a client has a free choice as to the flag of operation. In this respect, it must have the acumen to advise on, and to facilitate, both direct construction and off-the-balance-sheet acquisition or contracting. If possible, it should be sufficiently well versed in maritime law to assist the owner in contracting in various shipbuilding countries with a view to reducing the owner's risks and assuring him of timely delivery. This facet of his expertise requires an understanding of marine insurance and international finance in that the risk of late delivery can be ameliorated sometimes by insurance and sometimes by purchasing futures in currency.

The foregoing account of the fields of expertise needed to be a well-rounded naval architectural organization is by no means all inclusive, but it suffices to say that in addition to the foregoing, the firm must know the engineering and technical aspects of its business so that it can produce specifications and plans for designs which will do the job for the owner. It must know how the work should be done by the shipyard, how to inspect it, how the trials should be conducted, and how the efficient operation of the vessel's plant should be conducted.

To the uninitiated, the naval architect's work is narrowly defined and his product is thought to be plans and specifications. To those who know the intricacies of ship construction, the naval architect's really important work may well be in the general counseling areas previously mentioned.

术语解释

contract plans	合同图纸
specifications	说明书
standard code	标准法典
statute	法令
precedent	先例
general provission	一般规定,总则
jurisdiction of the law of the land	所在地(国)法律裁判权(司法权)
Standard Contract Code	标准合同法
sales agreement	销售协议
legal redress	法律赔偿(付)
toll	收费
threshold	分界点,门限,阈值
Statutes of Limitations	限制法令(规)
litigation	诉讼
clause	条款
precipitating countersuit	导致反诉讼
dispute settlement	纠纷处理
expertise	评论,鉴定,专长,专门知识,专家
ambiguity	二义性,多义性,含混性,模糊
rule of thumb	经验法则
amicable	友好的,友善的

entitle	给以权利
behoove	应该
it behooves both to	双方均应(该)……
in the same light	同样
discontinue	中止,停止,停付
local flag source	当地特征的资源
precipitate adversity	陷于逆境
accepted practice	公认的做法
arbitration clause	仲裁条款
liquidate	偿还,清算
liquidate damage clause	违约罚金条款
CDS(= construction differential subsidy)	(美)建造差异性补贴
substantive documentation	真实的文档资料
price net	实(净)价
document	以文件资料证明
per diem	每日
equity	投资资本
out-of-pocket cost	实际费用(成本)
non-performance of contract	不履行合同
grave risks attendant	严肃认真的(保险公司)保险业务员
ameliorating the effect	改善(修正)该影响
claim	索赔,要求,损失,赔付
diligence	偿债,查封,勤勉
due diligence	到期偿债
bankruptcy	破产,经营失败
default	违约
remand	还,退回
codify	编成法典
arbitration	仲裁

arbitration association	仲裁联合会(协会,公司)
arbitration panel	仲裁小组(委员会)
arbitrator	仲裁人
recourse	追索
underwrite	同意负担费用
mitigate	缓和,减轻
voyage returns	船舶航行的利润率
tax shelter	可减免税之处,躲避征税的场所
equity financing	提供财政资本,融资
debt structuring	债务构成
flag of operation	(船舶)营运所挂国旗
acumen	才智
off-the-balance-sheet	非资产负表上的
MarAd Subsidy Board	(美)海事管理局补贴事务局
termination	终结(文中指终结合同)
optional termination	选择性中止
cease and determine	中止及结束
futures in currency	流通期货

问　　题

1. Why does a naval architect concern most of elimination of ambiguities in the process of making contract?

2. What is liquidated damage clause?

3. Will sometimes the government get involved into some events of default or cancellation of shipbuilding contract?

4. Why is it expensive, and what do the amounts payable include in case of termination due to non-performance of a contract?