SEVENTH EDITION

SHIP CONSTRUCTION

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B|H

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Notices

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Preface

This text is designed as an introductory text for students of marine sciences and technology, including those following BTEC National and Higher National programs in preparation for careers at sea and in marine related industries. The subject matter is presented in sufficient depth to be of help to more advanced students on undergraduate programs in Marine Technology and Naval Architecture, as well as those preparing for the Extra Master examination. Students converting from other disciplines for higher degrees will also find the information useful. Other students following professional courses in shipbuilding will also find the book useful as background reading.

Many professionals from other disciplines, including law, insurance, accounting, and logistics joining the businesses will find the basic technical information on ship construction of value.

Considerable changes have occurred in ship design and shipbuilding practice with the introduction of new technology, and this book attempts to present current shipyard techniques without neglecting basic principles. Shipbuilding covers a wide field of crafts and, with new developments occurring regularly, it would be difficult to cover every aspect fully within the scope of a single textbook. For this reason further reading lists are given at the end of most chapters, these being selected from books, transactions, and periodicals that are likely to be found in the libraries of universities and other technical institutions.

In this edition the authors have also added a listing of some useful websites at the end of most chapters relating to the subject matter of the chapter. Those listed contain further information, drawings, and photographs that complement the text and/or add further knowledge to the subject. Some of the websites that are referenced also deal with regulations that apply to ships and their construction. The rapid development of available information makes it impossible to provide a completely up-to-date set of websites. Therefore, there is space for students to add further websites recommended by their tutors or that they may have found informative. However, it is important to consider the sources of information on any new sites to confirm their currency and validity.

Acknowledgments

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Shipping Research Services A/S
Hugh Smith (Glasgow) Ltd
Stone Manganese Marine Ltd
Wavemaster International

Lloyd's Register of Shipping also gave permission to refer to various requirements of their 'Rules and Regulations for the Classification of Ships'.

D.J.E. and G.J.B.

Contents

Part One

Introduction to Shipbuilding

1 Basic design of the ship

Chapter Outline

The key requirement of a new ship is that it can trade profitably, so economics is of prime importance in designing a merchant ship. An owner requires a ship that will give the best possible returns for the owner's initial investment and running costs. The final design should be arrived at taking into account not only present economic considerations, but also those likely to develop within the life of the ship. This is especially the case for some trades, for example LNG, where the ship is expected to work the same route for its working life. Design for operation is the result. For other ships, including bulk carriers, the first cost of the ship is the major factor for the owner and the ship may be designed for ease of production. Resale value is also often a major consideration, leading to design for maintenance.

With the aid of computers it is possible to make a study of a large number of varying design parameters and to arrive at a ship design that is not only technically feasible but, more importantly, is the most economically efficient. Ideally the design will take into consideration first cost, operating cost, and future maintenance.

Preparation of the design

The initial design of a ship generally proceeds through three stages: concept; preliminary; and contract design. The process of initial design is often illustrated by the design spiral (Figure 1.1), which indicates that given the objectives of the design, the designer works towards the best solution adjusting and balancing the interrelated parameters as the designer goes.

A concept design should, from the objectives, provide sufficient information for a basic techno-economic assessment of the alternatives to be made. Economic criteria that may be derived for commercial ship designs and used to measure their profitability are net present value, discounted cash flow, or required freight rate.

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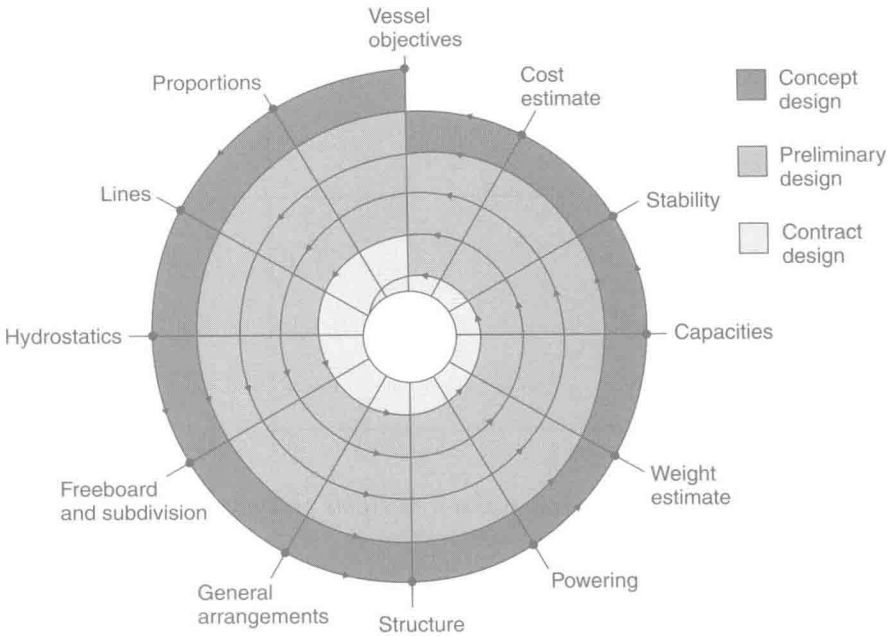

Figure 1.1 Design spiral.

Preliminary design refines and analyzes the agreed concept design, fills out the arrangements and structure, and aims to optimize service performance. At this stage the builder should have sufficient information to tender. Contract design details the final arrangements and systems agreed with the owner and satisfies the building contract conditions.

The design of the ship is not complete at this stage, rather for the major effort in resources it has only just started. Post-contract design requires confirmation that the ship will meet all operational requirements, including safety requirements from regulators. It also entails in particular design for production where the structure, outfit, and systems are planned in detail to achieve a cost- and time-effective building cycle. Production of the ship must also be given consideration in the earlier design stages, particularly where it places constraints on the design or can affect costs. The post-contract design will also ideally consider the future maintainability of the ship in the arrangement of equipment and services.

Information provided by design

When the preliminary design has been selected the following information is available:

- Dimensions
- Displacement
- Stability

- Propulsive characteristics and hull form
- Preliminary general arrangement
- Principal structural details.

Each item of information may be considered in more detail, together with any restraints placed on these items by the ship's service or other factors outside the designer's control.

1. The dimensions of most ships are primarily influenced by the cargo-carrying capacity of the vessel. In the case of the passenger vessel, dimensions are influenced by the height and length of superstructure containing the accommodation. Length, where not specified as a maximum, should be a minimum consistent with the required speed and hull form. Increase of length produces higher longitudinal bending stresses requiring additional strengthening and a greater displacement for the same cargo weight. Breadth may be such as to provide adequate transverse stability. A minimum depth is controlled by the draft plus statutory freeboard, but an increase in depth will result in a reduction of the longitudinal bending stresses, providing an increase in strength, or allowing a reduction in scantlings (i.e. plate thickness/size of stiffening members etc.). Increased depth is therefore preferred to increased length. Draft is often limited by area of operation, but if it can be increased to give a greater depth this can be an advantage.

Many vessels are required to make passages through various canals and straits and pass under bridges within enclosed waters, and this will place a limitation on their dimensions. For example, locks in the Panama Canal and St Lawrence Seaway limit length, breadth, and draft. At the time of writing, the Malacca Straits main shipping channel is about 25 meters deep and the Suez Canal could accommodate ships with a beam of up to 75 meters and maximum draft of 16 metres. A maximum air draft on container ships of around 40 meters is very close to clear the heights of the Gerard Desmond Bridge, Long Beach, California and Bayonne Bridge, New York. Newer bridges over the Suez Canal at 65 meters and over the Bosporus at 62 meters provide greater clearance.

2. Displacement is made up of lightweight plus deadweight. The lightweight is the weight of vessel as built and ready for sea. Deadweight is the difference between the lightweight and loaded displacement, i.e. it is the weight of cargo plus weights of fuel, stores, water ballast, fresh water, crew and passengers, and baggage. When carrying high-density cargoes (e.g. ore) it is desirable to keep the lightweight as small as possible, consistent with adequate strength. Since only cargo weight of the total deadweight is earning capital, other items should be kept to a minimum as long as the vessel fulfills its commitments.

3. In determining the dimensions, statical stability is kept in mind in order to ensure that this is sufficient in all possible conditions of loading. Beam and depth are the main influences. Statutory freeboard and sheer are important together with the weight distribution in arranging the vessel's layout.

4. Adequate propulsive performance will ensure that the vessel attains the required speeds. The hull form is such that economically it offers a minimum resistance to motion so that a minimum power with economically lightest machinery is installed without losing the specified cargo capacity.

A service speed is the average speed at sea with normal service power and loading under average weather conditions. A trial speed is the average speed obtained using the maximum power over a measured course in calm weather with a clean hull and specified load condition. This speed may be a knot or so more than the service speed.

Unless a hull form similar to that of a known performance vessel is used, a computer-generated hull form and its predicted propulsive performance can be determined. The propulsive performance can be confirmed by subsequent tank testing of a model hull, which may suggest further beneficial modifications.

The owner may specify the type and make of main propulsion machinery installation with which their operating personnel are familiar.

5. The *general arrangement* is prepared in cooperation with the owner, allowing for standards of accommodation particular to that company, also specific cargo and stowage requirements. Efficient working of the vessel must be kept in mind throughout and compliance with the regulations of the various authorities involved on trade routes must also be taken into account. Some consultation with shipboard employees' representative organizations may also be necessary in the final accommodation arrangements.

6. Almost all vessels will be built to the requirements of a classification society such as Lloyd's Register. The standard of classification specified will determine the structural scantlings and these will be taken out by the shipbuilder. The determination of the minimum hull structural scantlings can be carried out by means of computer programs made available to the shipyard by the classification society. Owners may specify thicknesses and material requirements in excess of those required by the classification societies and special structural features peculiar to the trade or owner's fleet may be asked for.

Purchase of a new vessel

In recent years the practice of owners commissioning 'one-off' designs for cargo ships from consultant naval architects, shipyards, or their own technical staff has increasingly given way to the selection of an appropriate 'stock design' to suit their particular needs. To determine which stock design, the shipowner must undertake a detailed project analysis involving consideration of the proposed market, route, port facilities, competition, political and labor factors, and cash flow projections. Also taken into account will be the choice of shipbuilder, where relevant factors such as the provision of government subsidies or grants or supplier credit can be important as well as the price, date of delivery, and the yard's reputation. Most stock designs offer some features that can be modified, such as outfit, cargo handling equipment, or alternate manufacture of main engine, for which the owner will have to pay extra.

Purchase of a passenger vessel will still follow earlier procedures for a 'one-off' design, but there are shipyards concentrating on this type of construction and the owner may be drawn to them for this reason. A nonstandard cargo ship of any form and a number of specialist ships will also require a 'one-off' design. Having decided on the basic ship requirements, based on the intended trade, after an appropriate project

analysis the larger shipowners may employ their own technical staff to prepare the tender specification and submit this to shipbuilders who wish to tender for the building of the ship. The final building specification and design is prepared by the successful tendering shipbuilder in cooperation with the owner's technical staff. The latter may oversee construction of the vessel and approve the builder's drawings and calculations. Other shipowners may retain a firm of consultants or approach a firm who may assist with preliminary design studies and will prepare the tender specifications and in some cases call tenders on behalf of the owner. Often the consultants will also assist the owners in evaluating the tenders and oversee the construction on their behalf.

Ship contracts

The successful tendering shipbuilder will prepare a building specification for approval by the owner or the owner's representative that will form an integral part of the contract between the two parties and thus have legal status. This technical specification will normally include the following information:

- Brief description and essential qualities and characteristics of the ship
- Principal dimensions
- Deadweight, cargo and tank capacities, etc.
- Speed and power requirements
- Stability requirements
- Quality and standard of workmanship
- Survey and certificates
- Accommodation details
- Trial conditions
- Equipment and fittings
- Machinery details, including the electrical installation, will normally be produced as a separate section of the specification.

Most shipbuilding contracts are based on one of a number of standard forms of contract that have been established to obtain some uniformity in the contract relationship between builders and purchasers. There are a number of 'standard' contract forms, all very similar in structure and content. Four of the most common standard forms of contract have been established by:

1. CESA—Community of European Shipyards Associations
2. MARAD Maritime Administration, USA
3. SAJ—Shipbuilders Association of Japan
4. Norwegian Shipbuilding Contract—Norwegian Shipbuilders Association and Norwegian Shipowners Association.

The CESA standard form of contract was developed by the predecessor organization, the Association of Western European Shipyards (AWES).The contract form can be downloaded from the CESA website. The sections of the contract are:

1. Subject of contract (vessel details, etc.)
2. Inspection and approval

3. Modifications
4. Trials
5. Guarantee (speed, capacity, fuel consumption)
6. Delivery of vessel
7. Price
8. Property (rights to specifications, plans, etc. and to vessel during construction and on delivery)
9. Insurance
10. Default by the purchaser
11. Default by the contractor
12. Guarantee (after delivery)
13. Contract expenses
14. Patents
15. Interpretation, reference to expert and arbitration
16. Condition for the contract to become effective
17. Legal domicile (of purchaser and contractor)
18. Assignment (transfer of rights)
19. Limitation of liability
20. Addresses for correspondence.

Irrespective of the source of the owner's funds for purchasing the ship, payment to the shipbuilder is usually made as progress payments that are stipulated in the contract under item 7 above. A typical payment schedule may have been five equal payments spread over the contract period, but in recent years payment arrangements advantageous to the purchaser and intended to attract buyers to the shipyard have delayed a higher percentage of payment until delivery of the ship. The payment schedule may be as follows:

- 10% on signing contract
- 10% on arrival of materials on site
- 10% on keel laying
- 20% on launching
- 50% on delivery.

Because many cargo ships are of a standard design, and built in series, and modification can be very disruptive to the shipyard building program, item 3 in the standard form of contract where modifications are called for at a late date by the owner can have a dramatic effect on costs and delivery date given the detail now introduced at an early stage of the fabrication process. Many shipyards will refuse to accept modifications once a design is agreed and detailed work and purchasing commences. Item 3 also covers the costs and delays of compulsory modifications resulting from amendment of laws, rules, and regulations of the flag state and classification society.

Further reading

Rawson, Tupper: *Basic Ship Theory.* ed 5, vol 2. Chapter 15: Ship design, 2001, Butterworth Heinemann.

Watson DGM: *Practical Ship Design*, 2002, Elsevier.

Some useful websites

www.cesa.eu Community of European Shipyards Associations.
www.sajn.or.jp/e Shipbuilders Association of Japan; provides links to member shipyard sites.