轮 机 概 论

Introduction to Marine Engineering

（英文版）

主编　李文华　李可顺　王艳华
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Abstract

This book focuses on the general marine engineering equipment and systems in eight chapters. Chapter 1 introduces the fundamentals of marine engineering management; Chapter 2 introduces the marine diesel engine power plants; Chapter 3 introduces ship propulsion systems; Chapter 4 introduces marine auxiliary machinery; Chapter 5 introduces marine deck machinery; Chapter 6 introduces ship service systems; Chapter 7 introduces electrical equipment and safety equipment; Chapter 8 introduces international maritime conventions.

This book is to be used as a text book for the course of Introduction to Marine Engineering in Dalian Maritime University. It can also be used as reference for people in the field of marine engineering.

Preface

Introduction to Marine Engineering is one of the compulsory or restrictive optional courses for the Nautical Science, Transportation Management (Shipping Management) and Maritime Law specialties etc. In this course, students will learn about marine engineering, including items, working principles and basic constructions of marine equipment.

In the English teaching process of Introduction to Marine Engineering in Dalian Maritime University, it has become necessary to have an English text book to present this course. This textbook has been compiled in accordance with the syllabus of the course required by Dalian Maritime University, and with reference to bibliographies on Marine Engineering, both in China and abroad.

Editors for this book: Chapters 1 to 6 were edited by Li Wenhua; Chapters 7 to 8 were edited by Li Keshun; Ms Wang Yanhua was involved in the proofreading of the book from the perspective of the use of English and prepared part of Chapter 8; some of the illustrations in the book were accomplished by Wang Gang, Miao Yanqi and Yang Zhenqi, Zheng Jin and Wang Yong. The whole book was audited by Professor Chen Haiquan. The authors sincerely appreciate his support and would like to thank him for providing a thorough review to the book.

Acknowledgments: The book is written with reference to some excellent books and teaching materials on the internet. Reference is especially made to Introduction to Marine Engineering (Second Edition, Taylor D. A., 2003). I would like to express my sincere thanks to the authors of the above book. Thanks go to Dalian Maritime University Press, College of Marine Engineering and Academic Affairs Office of Dalian Maritime University. Thanks go to the students of Class No. 1 in Grade 2013 of Transportation Management specialty and those of Class No. 1 in Grade 2012 of Shipping Management specialty. Thanks also go to many others who helped in the course of the publication of this book.

In addition, as it is unavoidable that this book may still contain deficiencies, all critics and corrections from experts and readers are welcome.

Li Wenhua

March 2014

Contents

Chapter 1

Fundamentals of Marine Engineering Management

1.1 Ships

As an introduction to marine engineering, we might reasonably begin by taking an overall look at the ship. The various duties of a marine engineer all relate to the operation of the ship in a safe, reliable, efficient and economic manner. The main propulsion machinery installed will influence the machinery layout and determine the equipment and auxiliaries installed. This will further determine the operational and maintenance requirements for the ship and thus the knowledge required and the duties to be performed by the marine engineer. The general arrangement of the ship is shown in Figure 1-1.

Ships are large, complex vehicles which must be self-sustaining in their environment for long periods with a high degree of reliability. A ship is the product of two main areas of skill, those of the naval architect and the marine engineer. The naval architect is concerned with the hull, its construction, form, habitability and ability to endure its environment. The marine engineer is responsible for the various systems which propel and operate the ship. More specifically, this means the machinery required for propulsion, steering, anchoring and ship securing, cargo handling, air conditioning, power generation and its distribution. Some overlap in responsibilities occurs between naval architects and marine engineers in areas such as propeller design, the reduction of noise and vibration in the ship's structure, and engineering services provided to considerable areas of the ship.

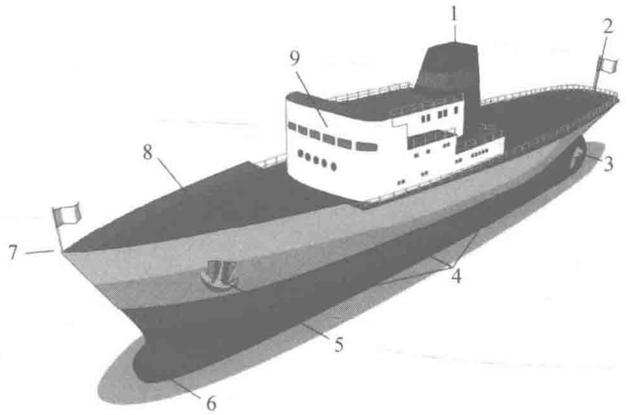


Figure 1-1 The general arrangement of the ship

1—Smokestack or funnel; 2—Stern; 3—Propeller and rudder; 4—Portside (the right side is known as Starboard); 5—Anchor; 6—Bulbous bow; 7—Bow; 8—Deck; 9—Superstructure

A ship might reasonably be divided into three distinct areas: the cargo-carrying holds or tanks, the accommodation and the machinery space. Depending upon the type each ship will assume varying proportions and functions.

An oil tanker, for instance, will have the cargo-carrying region divided into tanks by two longitudinal bulkheads and several transverse bulkheads. There will be considerable quantities of cargo piping both above and below decks.

The general cargo ship will have various cargo holds which are usually the full width of the vessel and formed by transverse bulkheads along the ship's length. Cargo handling equipment will be arranged on deck and there will be large hatch openings closed with steel hatch covers. The accommodation areas in each of these ship types will be sufficient to meet the requirements for the ship's crew, provide a navigating bridge area and a communications centre. The machinery space size will be decided by the particular machinery installed and the auxiliary equipment necessary.

A passenger ship, however, would have a large accommodation area, since this might be considered the "cargo space". Machinery space requirements will probably be larger because of air conditioning equipment, stabilizers and other passenger related equipment.

1.1.1 Ship's types

Depending on the nature of their cargo, and sometimes also the way the cargo is loaded/unloaded, ships can be divided into different categories, classes, and types, some of which are mentioned in Table 1-1.

The three largest categories of ships are container ships, bulk carriers (for bulk goods such as grain, coal, ores, etc.) and tankers, which again can be divided into more precisely defined classes and types. Thus, tankers can be divided into oil tankers, gas tankers and chemical tankers, but there are also combinations, e. g. oil/chemical tankers.

Table 1-1 provides only a rough outline. In reality there are many other combinations, such as "multi-purpose bulk container carriers", to mention just one example.

Table 1-1 Ship's type

Dry cargo		Liquid cargo	Passenger
Unit cargo —Container vessel —Roll-on/Roll-off —Heavy cargo vessel —Refrigerated ships —Cattle ship	Bulk cargo —Bulk carrier —Ore carrier	—Crude carrier —Product tanker —Chemical tanker —LPG/LNG carriers	—Passenger ship —Car and passenger ferries —Cruise ship
Multi-purpose ship			
Navy	Fishing	Dredgers, etc.	Work ships
—Aircraft carrier —Cruiser —Destroyer —Frigate —Submarine —Mine sweeper	—Trawler —Other types of fishing vessels	—Trailing hopper suction dredger —Cutter suction dredger —Rock-dumper	—Crane vessel —Cable-layer —Buoy-layer —Oil-recovery vessel —Shear leg crane
Auxiliary craft	Pleasure craft	Various	Offshore material
—Seagoing tug —Harbor tug —Icebreaker —Pilot vessel —Coast guard vessel —Research vessel	—Motor yacht —Sailing yacht	—Hydrofoil —Floating dock —Submersible platform —Pontoon, barge	—Drilling rig/Jack up —Drill ship —Pipe layer —Floating storage and offloading vessel

1.1.1.1 Container ships

Container ships are cargo ships that carry all of their load in truck-size intermodal containers, in a technique called containerization. They form a common means of commercial intermodal freight transport. The container ships are shown in Figure 1-2.

As the TEU is an inexact unit, it cannot be converted precisely into other units. The related unit forty-foot equivalent unit (often FEU or feu) however is defined as two TEU. The most common dimensions for a 20-foot (6.1 m) container are 20 feet (6.1 m) long, 8 feet (2.44 m) wide, and 8 feet 6 inches (2.59 m) high, for a volume of 1,360 cubic feet (39 m^3).

The Triple-E class container ships (see Figure 1-3) are to be the largest container ships in the world, with a container carrying capacity of 18,000 TEU. The ships will be 400 metres long and 59 metres wide.

Triple-E vessels are powered by a "twin-skeg" propulsion system integrating two 30,000 kW slow running ultra-long stroke engines and two propellers. Each engine will produce 43,000 hp

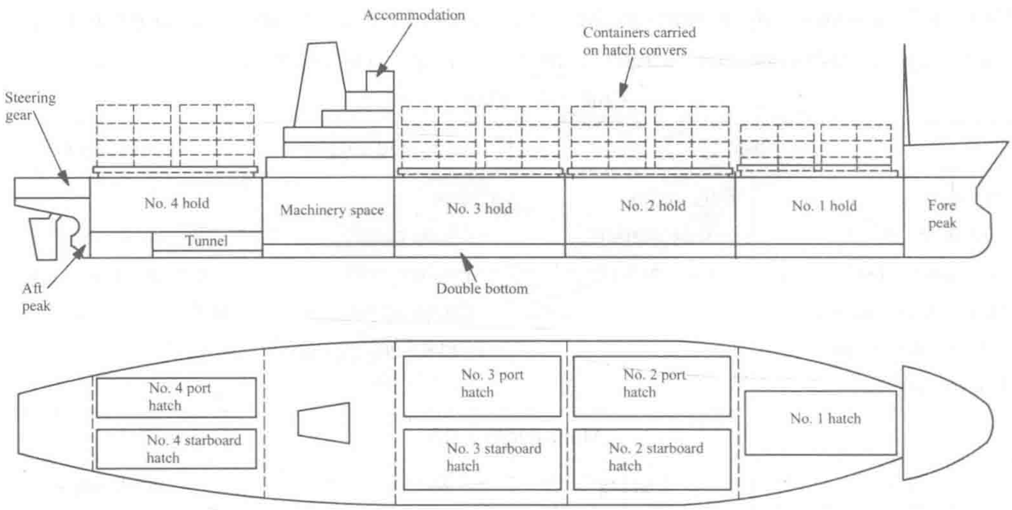


Figure 1-2 Container ships

and weigh 910 t. Each will consume 168 g bunker oil per kW · h produced. Each of the two propellers will be of 9.8 m diameter and have four blades. The waste heat recovery system will capture the exhaust gas from the engine and use it to run the turbine to produce mechanical energy, which in turn, will be used to run a generator. It will trim down fuel consumption and CO_2 emission by about nine percent. The two engines and two propellers combination will generate further savings of four percent energy when compared to a combination of one engine and one propeller. The vessels will be fitted with two shaft generator motors (SGM) with a rated capacity of 3 MW each. The motors will act as variable power generation units.

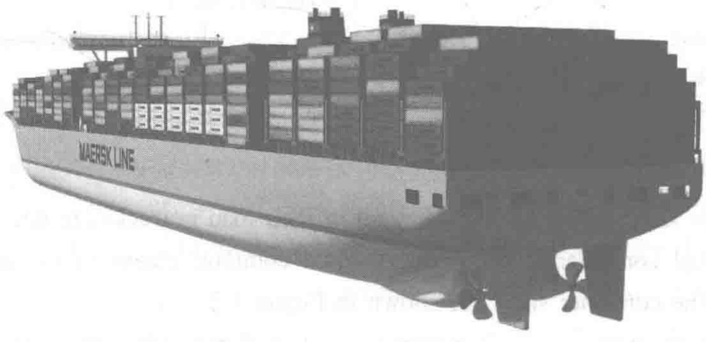


Figure 1-3 The Triple-E class container ship

Container ships under 3,000 TEU are typically called feeders. In some areas of the world, they might be outfitted with cargo cranes.

1.1.1.2 Bulk carrier

A bulk carrier, bulk freighter, or bulker is a merchant ship specially designed to transport unpackaged bulk cargo, such as grains, coal, ore, and cement in its cargo holds. A number of specialized designs exist: some can unload their own cargo, some depend on port facilities for unloading, and some even package the cargo as it is loaded. The bulk carrier is shown in Figure 1-4.

The engine room on a bulker is usually near the stern, under the superstructure. Larger bulkers usually have a single two-stroke low-speed crosshead diesel engine directly coupled to a fixed-pitch propeller. Electricity is produced by auxiliary generators and/or an alternator coupled to the propeller shaft. On the smaller bulkers, one or two four-stroke diesels are used to turn either a fixed or controllable pitch propeller via a reduction gearbox, which may also incorporate an output for an alternator.

The loading method used depends on both the cargo and the equipment available on the ship and on the dock. We can use the cranes on board or shore-based gantry cranes for loading or unloading cargo. Self-discharging ships can use conveyor belts.

(a) The Sabrina I bulk carrier

(b) The 175,000 DWT bulk carrier

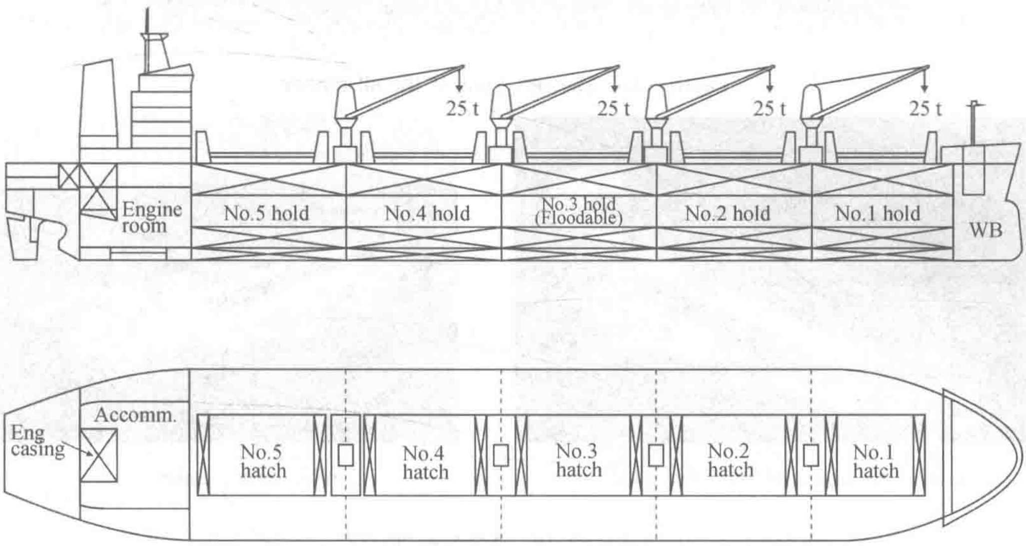


Figure 1-4 Bulk carrier

1.1.1.3 Tankers

A tanker (or tank ship or tankship) is a ship designed to transport liquids in bulk. Major types of tankship include the oil tanker, the chemical tanker and the gas carrier.

(1) Oil tanker

An oil tanker, also known as a petroleum tanker, is a merchant ship designed for the bulk transport of oil. There are two basic types of oil tankers: the crude tanker and the product tanker. Crude tankers move large quantities of unrefined crude oil from its point of extraction to refineries. Product tankers, generally much smaller, are designed to move petrochemicals from refineries to points near consuming markets. The oil tankers are shown in Figure 1-5 and Figure 1-6.

An oil tanker's inert gas system is one of the most important parts of its design. Inert gas systems deliver air with an oxygen concentration of less than 5% by volume. As a tank is pumped out, it's filled with inert gas and kept in this safe state until the next cargo is loaded. Loading an oil tanker consists primarily of pumping cargo into the ship's tanks. When unloading cargo, it is the ship's cargo pumps that are used to move the product ashore. On most crude-oil tankers, a special crude oil washing (COW) system is part of the cleaning process. The COW system circulates part of the cargo through the fixed tank-cleaning system to remove wax and asphaltic deposits. Tanks that carry less viscous cargoes are washed with water. Fixed and portable automated tank cleaning machines, which clean tanks with high-pressure water jets, are widely used.

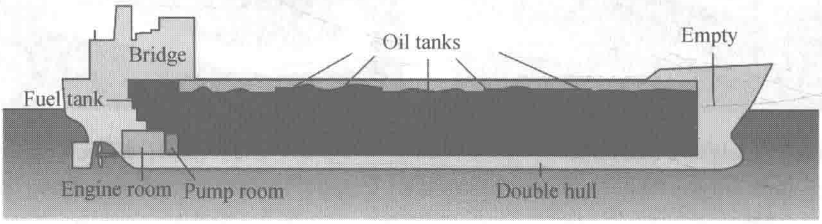
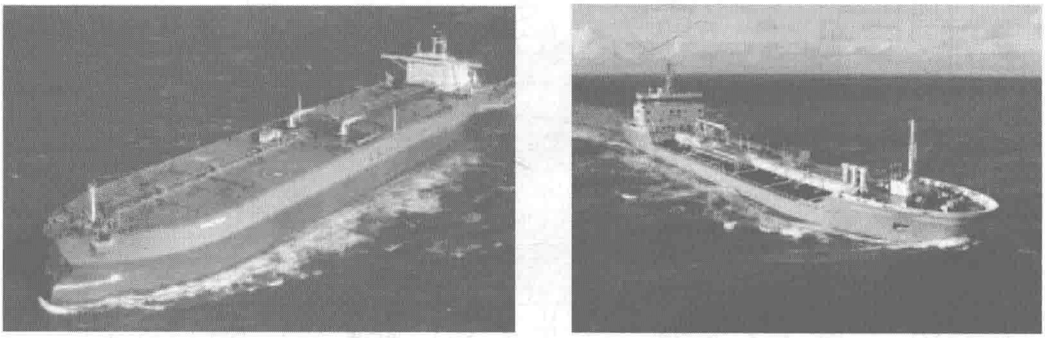


Figure 1-5 The side view of the oil tanker



(a) The very large crude oil carrier (VLCC)

(b) The product tanker

Figure 1-6 Oil tankers

(2) Chemical tankers

A chemical tanker is a type of tanker designed to transport chemicals in bulk. As defined in MARPOL Annex Ⅱ chemical tanker means a ship constructed or adapted for the carriage in bulk of any liquid product listed in chapter 17 of the International Bulk Chemical Code. The chemical tankers are shown in Figure 1-7.

Chemical tankers often have a system for tank heating in order to maintain the viscosity of

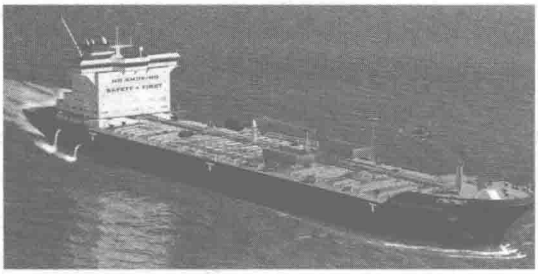



Figure 1-7 The chemical tankers

certain cargoes, typically by passing pressurized steam through stainless steel "heating coils" in the cargo tanks, transferring heat into the cargo which circulates in the tank by convection. Many modern chemical tankers have one tank for each pump with separate piping, which means that each tank can load a separate cargo without any mixing. Cargo tanks, either empty or filled, are normally protected against explosion by inert gas blankets. Often nitrogen is the inert gas used, supplied either from portable gas bottles or an inert gas generator (IGS) system.

Chemical tankers normally have a series of separate cargo tanks which are either coated with specialized coatings such as phenolic epoxy or zinc paint, or made from stainless steel. The coating or cargo tank material determines what types of cargo a particular tank can carry: stainless steel tanks are required for aggressive acid cargoes such as sulfuric and phosphoric acid, while "easier" cargoes—e. g. vegetable oil—can be carried in epoxy coated tanks. There are very strict requirements and regulations for chemical tankers because of the toxicity and flammability of the typical chemical cargo.

(3) Gas tankers

Gas tankers are ships that are used to carry compressed or liquefied gas. Gas carriers are special types of ships that are used to carry highly inflammable gases under controlled temperature and pressure. Gas tanker's type includes fully pressurized gas carrier, semi-refrigerated/semi-pressurized gas carrier, semi-pressurized/fully-refrigerated gas carrier, fully refrigerated liquefied petroleum gas (LPG) carrier, ethylene carrier and liquefied natural gas (LNG) carrier.

A cargo containment system is the total arrangement for containing cargo including, where fitted: (a) a primary barrier (the cargo tank); (b) a secondary barrier (if fitted); (c) associated thermal insulation; (d) any intervening spaces, and (e) adjacent structure, if necessary, for the support of these elements.

The basic cargo tank types utilized on board gas carriers are in accordance with the list below: (a) independent tanks (type "A"—fully refrigerated, type "B"—typical LNG tank, type "C"—fully pressurized); (b) membrane tanks (typical LNG tank); (c) semi-membrane tanks; (d) internal insulation tanks (type "1" and type "2"); (e) Integral tanks.

In general, there are two kinds of liquefied gases: liquefied petroleum gas (LPG); liquefied natural gas (LNG).

Liquefied petroleum gas (LPG) carriers are designed to carry mainly butane, propane, butadiene, propylene, and are also able to carry anhydrous ammonia. All gas cargoes are transported in liquid form. The LPG carriers are shown in Figure 1-8.

An LNG carrier is a tank ship designed for transporting liquefied natural gas (LNG).

A typical LNG carrier (see Figure 1-9) has four to six tanks located along the center-line of the vessel. Inside each tank there are typically three submerged pumps. There are two main cargo pumps which are used in cargo discharge operations and a much smaller pump which is referred to as the spray pump. The spray pump is used for either pumping out liquid LNG to be used as fuel (via a vaporizer), or for cooling down cargo tanks. It can also be used for "stripping" out the last of the cargo in discharge operations. All cargo pumps discharge into a common pipe which runs along the deck of the vessel; it branches off to either side of the vessel to the cargo manifolds, which are used for loading or discharging.

Figure 1-8 The LPG carriers

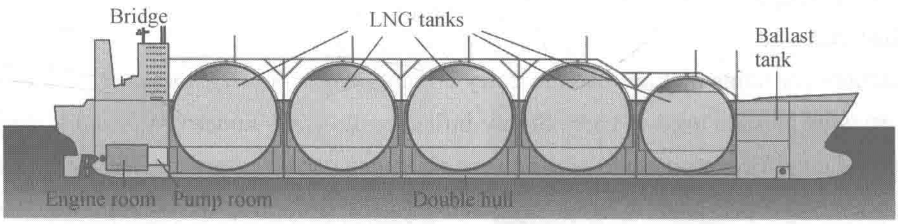


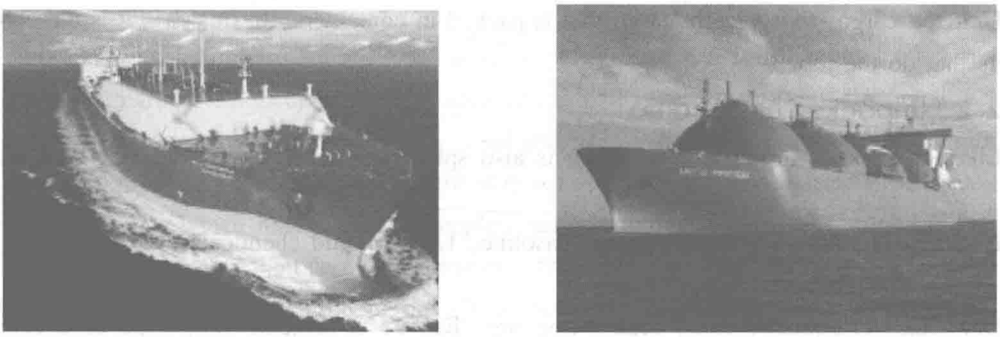
Figure 1-9 The side view of the LNG carrier

Today there are four containment systems in use for new build vessels. Two of the designs are of the self-supporting type, while the other two are of the membrane type (see Figure 1-10 (a)) and today the patents are owned by gaz transport & technigaz (GTT).

(a) Moss tanks (spherical IMO type B LNG tanks) (see Figure 1-10 (b)); (b) IHI (prismatic IMO type B LNG tanks); (c) technigaz Mark Ⅲ; (d) GT 96; (e) CS 1.

In order to facilitate transport, natural gas is cooled down to approximately −163 ℃ at atmospheric pressure, at which point the gas condenses to a liquid. Normally an LNG tanker is powered by steam turbines with boilers. These boilers are dual fuel and can run on either methane or oil or a combination of both.

Recent advances in technology have allowed reliquefication plants to be fitted to vessels, allowing the boil off to be reliquefied and returned to the tanks. Because of this, LNG carriers can use



(a) Membrane type containment system (b) Moss type containment system

Figure 1-10 The LNG carriers

more efficient slow-speed diesel engines as main engine (previously most LNG carriers have been steam turbine-powered or use dual-fuel diesel electric propulsion systems).

1.1.2 Marine cargo

Marine cargo can be divided into two major categories packed/general cargo and unpacked/bulk cargo. Unpacked or packed is related to the goods itself and of course it affects what ship type that should be used for transportation. The marine cargo is shown in Figure 1-11.

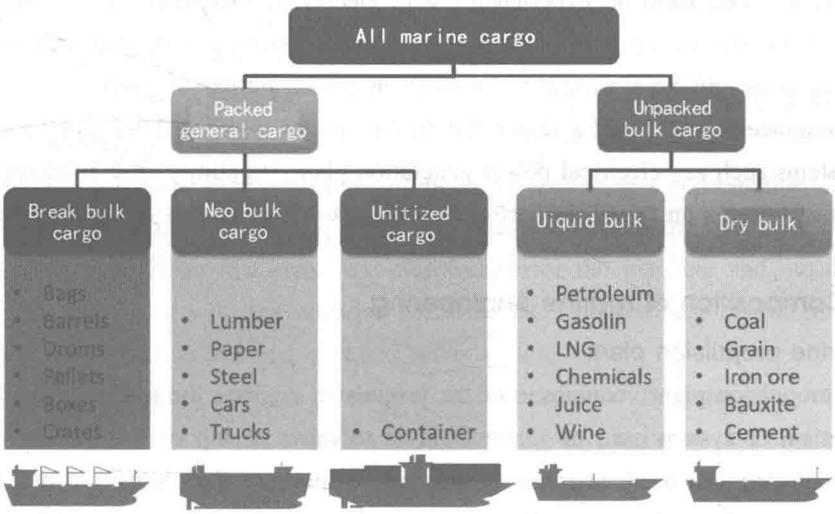


Figure 1-11 Marine cargo

1.1.2.1 Packed/General cargo

Further can general cargo be split into three areas of goods: break bulk, neo bulk and unitized cargo.

Break bulk—is typically when goods is packed in boxes, bags, barrels, crates, drums & on pallets. Ships used for this cargo is bulk carriers or combination ships.

Neo bulk—is typically lumber, paper, steel, cars & trucks. Ships used here are bulk carriers but also specialized Ro-Ro (vehicles carriers) ships for cars & trucks.

Unitized cargo—is typically cargo that is packed in containers. In this case it is the container carriers that do the job.

1.1.2.2 Unpacked/Bulk cargo

Like the packed cargo the bulk cargo is also split into two areas: liquid/wet bulk and dry bulk.

Liquid bulk—is typically petroleum, gasoline, LNG, liquid chemicals, juice & wine. Ships used for liquid bulk are tankers.

Dry bulk—is typically coal, grain, iron ore, bauxite & cement. Ship type used geared or gearless bulk carrier.

1.2 Introduction to marine engineering

1.2.1 Marine engineering

Marine engineering involves the design, construction, installation, operation and support of the systems and equipment which propel and control marine vehicles, and of the systems which make a vehicle or structure habitable for crew, passengers and cargo.

Marine engineering is allied to mechanical engineering, although the old marine engineer requires knowledge (and hand-on experience) with electrical, electronic, pneumatic, hydraulic, chemistry, control engineering, naval architecture or ship design, process engineering, steam generation, gas turbines and even nuclear technology on certain military vessels.

Marine engineering on board a ship refers to the operation and maintenance of the propulsion and other systems such as: electrical power generation plant; lighting; air conditioning; refrigeration; and water systems on board the vessel. This work is carried out by marine engineering officers.

1.2.1.1 Composition of marine engineering

(1) Marine propulsion plant

Marine propulsion plant, composed of the propulsion engine, the shafting and the propeller, it the mechanism or system used to generate thrust to move a ship or boat across water. While paddles and sails are still used on some smaller boats, most modern ships are propelled by mechanical systems consisting a motor or engine turning a propeller, or less frequently, in jet drives, an impeller.

Steam engines were the first mechanical engines used in marine propulsion, but have mostly been replaced by two-stroke or four-stroke diesel engines, outboard motors, and gas turbine engines on faster ships. Nuclear reactors producing steam are used to propel warships and icebreakers, and there have been attempts to utilize them to power commercial vessels. Electric motors have been used on submarines and electric boats and have been proposed for energy-efficient propulsion. Recent development in liquefied natural gas (LNG) fueled engines are gaining recognition for their low emissions and cost advantages.