SHIP DESIGN AND BUILDING

Seung Kyun Park
Samsung Heavy Industry, Korea

Keywords: Ship design, cargo, bulk carries, tanker, container ship, car carrier, gas carrier, naval architectural knowledge, buoyancy, displacement, loaded draft, light weight, dead weight, stability, hull form lines, main dimension, tonnage, block coefficient, Simpson's rule, sectional area curve, still water bending moment, shear, slamming, sloshing, midship section, ballast, bow, stern, vibration, main engine, propeller, wake, model test, engine auxiliaries, generators, engine room layout, accommodation, cargo stowage, cargo handling equipment, hatch, container lashing, cell guide, mooring, equipment number, anchor, windlass, rudder, dynamic positioning, turret, block division, outfitting, advance outfit block, transporter, dry dock operation, dock gate, floating dock, movable shelter, goliath crane, floating crane, welding, gas torch, butt joint, fillet joint, electrode, welding holder, weld bead, flux, inert gas shield, welding position, non-destructive test, welding sequence, block assembly, plate edge preparation, one side welding, nesting, NC cutting(numerical control cutting), line heating, panel block, computer aided design, computer aided manufacturing, computer aided engineering, cost estimation, shipyard layout

Contents

Summary

Shipbuilding is an integrated industry utilizing all kinds of engineering knowledge to make versatile and super-size marine transportation equipment. Many good technical books are available for the students of regular universities and the limited numbers of well-educated and experienced specialists but there are few of those good for the growing youngsters, most of shipyard general staffs, laborers and those in the shipbuilding related industries. This chapter deals comprehensively with all aspects of ship design and ship building such as types of ships, requirements, ship design process, structure and layout, shipbuilding process, shipbuilding methods/techniques, production and manufacturing (CAD/CAM/CAE), cost estimation, and shipbuilding yard.

1. Introduction

This chapter deals comprehensively with all aspects of ship design and ship building such as the following:

Type of Ships: Types of ships are categorized as cargo carrying and various task performing ships ranging from offshore oil and gas related floaters to navy ships, port construction work boats and leisure boats. Even though there are many different types of task performing ships, majority of ships in terms of tonnage and scales are cargo carrying ships. Major cargo carrying ships are dry bulk carriers for coal, iron ore and grains, liquid bulk carriers for crude oil, product oil and chemicals, container ships, car carrier and liquefied gas carriers for LNG and LPG.. Key points of competitiveness of cargo carrying ships are carrying more cargoes, loading / unloading more efficiently and requiring less effort and less fuel consumption per ton-mile service. Key points of competitiveness of task performing ships cannot be generally graded or valuated because the usage in the purpose of operation is very specific and unique. Those ships shall be compared with similar kind competing partners in the limited arena encountered.

Requirement: Owner's requirements are categorized as given in the tables for the purpose of constructing the intended ship in the intended manner safely on schedule in time. The ship shall be operable in natural sea conditions through all navigating routes considered and in social environments such as registry, calling port condition, passing canals limitations and adaptation to navigational telecommunication facilities. The requirement defines the characteristics such as ship size, speed, main propulsion horse power, fuel consumption, loading/ unloading methods, number of crews and major equipment supply vendors. The requirement defines the right to approve and inspect design drawings and construction procedures to ensure performance, quality, schedule keeping and safe working. The requirement defines also commercial matters such as price, payment, delivery time, insurance, variation, penalties, guarantee, and cooperation activities for the yard residing owner's supervision team.

Ship Design Process: Ship shall be designed to carry intended amount of cargo with intended speed within the main dimensions limitation. To be commercially competitive, the self weight and the propulsion power should be less relative to similar kind of competing ships, while the ship is strong enough, stable enough and durable to meet intended life time service. As the starting guidance of ship design, a fullness coefficient of ship form is used. When a ship is full, she carries more but has larger propulsion resistance. When a ship is slender the propulsion resistance is less but carries less. The fullness coefficient is named as Block Coefficient (C_b) and calculated as the fraction of volume of wetted part of the ship over the surrounding parallelepiped. Once C_b is determined then the ship form lines can be drawn. As the ship's self weight and power-speed are ascertained, hull form lines are optimized accordingly to find the best one. This kind of iterative design process used to take very long time in the past, but not now, thanks to the computers.

Structure and Layout: A ship structure should have longitudinal, transversal and local strength. The longitudinal strength bears longitudinal bending load and shearing load. The transversal strength bears the racking load and twisting load in addition to

transversal bending and shearing load. Skin plating around the main hull and longitudinal strength members form major sources of longitudinal strength. Transverse web framings and transverse bulkheads are the major transversal strength members in addition to skin plating around the main hull. Since ship hull is quite big and mostly made of panel structure a professional way of design is too much specialized and complicated to introduce principle effectively. It is attempted in this section to show figures illustrating loads and responding structural members. A simple example of main member sizing for a plane barge is shown to give readers a general understanding of how to approach in the basic way of structural mechanics. Principle of ship layout is to maximize cargo stowing areas which means to minimize remaining areas such as propulsion engine room and crew accommodation. Since those working and staying areas have minimum required area for reasonable operation and maintenance, the word "minimize" should be understood as "optimize". Most of cargo carrying ships presently have stern engine room and crew accommodation on it. The sub-division of compartmentation against the vulnerability of flooding by damage and anti-vibration oriented design against vibration occurrence at the stern part will be considered in adequate detail and depth.

Shipbuilding Process: A recently prevailing ship building mode is to make very large size blocks with high rate of completeness thus to shorten dock erection period and post-launch outfit work period as well. To maximize indoor fabrication work, to maximize automated welding, to minimize remaining fire burning work which cannot but be welded after block painting, to minimize the usage of welding type scaffold stage pieces and so on are the main ways to save working periods, working man-hours and to improve working quality. Erection on shore and skidding out to submersible launch barge or erection on floating dock using super size marine cranes are newly emerging and may be competitive building methods against construction in conventional dry dock.

Shipbuilding Methods/Techniques: Since ship structure is made of plain steel plate and straight section steel members, major works are cutting, forming and welding. Cutting works are done by well developed numerically controlled cutting machines having multiple nozzles but large parts of forming and welding works are still dependent on handcraft of skilled workers. To avoid serious contraction and/or deformation, the welding sequences and heat input adjustment shall be carefully managed by experienced and skilled people. Remarkable amount of welding automation has been achieved but it should be further developed. Accuracy of welding line alignment should be well kept for automation and robot welding. Increasing the grade of completeness of all kinds of fire burning work including outfit works to the maximum level until start of block painting work should be the goal to pursue.

Production and Manufacturing (CAD/CAM/CAE): Application of computer programs to find optimum ship form and related large scale calculations greatly contribute to reduction of efforts and time duration. Integration of structural design drawing system and those for outfit systems facilitates concurrent work carried out by different discipline engineers in real time base. These combinations reduce design time and errors and therefore enable us to perform large size integrated block making. Numerically controlled cutting is an important success of computer aided manufacturing field in shipbuilding. Robot application in welding is still in initial

developing stage and has far way to go. Engineering works of large scale calculations, simulation analysis and predictions suggest good findings and guidance for new design directions and problem solutions. The application of good computer systems is regarded an important factor of change that a 1300men design office sized for building 40 ships a year recently issued drawings for more than 100 ships a year without much increase of designers.

Cost Estimation: Cost comprises direct cost for material procurement and labor man-hours and indirect cost for managerial expenses with the premise that material cost and the productivity of laborers are similar, difference of competitiveness comes from indirect cost. In other words, indirect cost represents the efficiency of a yard operation. Indirect cost goes up when work load is down by the nature, therefore, shipyards make best efforts to maintain proper working load, improve productivity and reduce indirect costs.

Shipbuilding Yard: Shipyard site should be located in the advantageous area in terms of both natural and social conditions. A wave protected, properly deep water along the shore having plane and wide site of solid soil without rocks in dry and mild weather zone may be one of the best natural conditions. Layout should consider ideal material flow line from steel coming quay to shops, shops to pre-erection site and finally to dock. To maximize weather free indoor work, movable shelters under traveling gantry crane are a good solution. To maximize block size and completeness of pre-painting fire work for advanced outfit, heavy lift cranes, heavy lift transporters, wide roads and big painting shops shall be provided. Shipyard operation is stably settled when it has proper work load and schedule keeping capability. Ship owners place order to the shipyards which can keep the building schedule. Shipyards having enough work loads can offer competitive price due to light burden of managerial expenses. Key for survival and way for prosperous future is to maintain the capability to keep the building schedule.

Sections 1.1 to 1.8 introduce ship kinds. The total fleets of 4~5 kind major cargo ships occupy more than 90% of all ships in terms of tonnage. Some explanations are given as to characteristics of those major ship kinds and rests are tabulated with simple notes. Photos and general arrangement drawings of various ship kinds are shown. Section 2 summarizes ship owner's usual requirement. Sections 3 and 4 are written for design. Methods are given how to decide size and shape of a ship and her propulsion engine to satisfy the intended carrying capacity and sailing speed with strong and stable hull. Rough but simple and easy examples were given to understand the way to do. Practical design in the industry is done very finely in professional way through sophisticated calculations and analyses in addition to referring to big pile of empirical data base. In Sections 5 and 6 for ship construction, prevailing trends of construction modes in competitive ways are introduced. These are maximizing the completeness of outfitted hull block fabrication under the weather protected roof and minimize dock erection period. To do these, heavy cranes, big transporters, wide roads, numbers of moving shelters, big painting cells are required to be provided. Section 7 briefs computer utilization criteria and shows several outputs. Section 8 briefs the concept of cost estimation logics and methods. Section 9 shows how a shipyard layout is made to have reasonable material/product flow and to do minimize civil construction work in the given geographical condition. A shipbuilding schedule/work load chart is shown to

demonstrate the importance of good balance among facility sizes, number of staffs and work loads for continuous yard operation. In the attempt to digest knowledge of ship design and construction in the easily understandable expression, sufficient numbers of figures and several examples for most important subject were shown. For further study, famous books are introduced in the bibliography at the end and they do not need annotations. It is hoped that the writing can give some help to one who wants to learn about ship design and building.

1.1. Types of Ships and Their Trends

Cargo ships account for the greatest number of ships. Due to the demands of mass consumption all types of ships are becoming increasingly large. VL class tankers, bulkers and containers carrying over 10,000TEU and car carriers carrying more than 6,000 cars are among those exhibiting this recent trend for growth. Bulkers, tankers and containers account for nearly a billion DWT and 85% of all cargo ships. Old-fashioned ships are gradually being reduced in number.

As deep sea offshore drilling and production continue to increase, additional numbers of deep sea floaters are needed. Ice breaking, winterization and chill protection technology need to be developed for oil and gas production in the harsh weather conditions of such places as the Barents Sea, the Kara Sea, the Baltic Sea, Sakhalin and Alaska. Most of major oil companies have been studying the need for investment in offshore liquefaction to bring gas from the deep sea. In addition, as weaponry continues to undergo development conventional methods of sea battle will need to change to adapt to new concepts. Missiles can be launched from ship-based airplanes, destroyers and submarines against targets anywhere in the world. Navy ships of various kinds with different task roles will evolve in line with the changes.

1.2. Bulk Carrier Hold Shape

Dry bulk cargo moves down from a central high peak to repose naturally in a cone shape with a mild slope. Therefore, when loading cargo to a central hatch, it is difficult to fill up the surrounding upper part of a rectangular cargo hold. This vacancy in the hold also allows cargo to shift according to roll and pitch motions, which results in further severe ship motions. To prevent such instability, topside tank concept with slanted bottom has been adopted. These tanks are used as ballast tanks and contribute by serving as longitudinal strength members. Similar slanted hold bottoms are provided in the bilge area. They cause cargo to gather in the central part of the hold in addition to providing ballast and strength reinforcement.

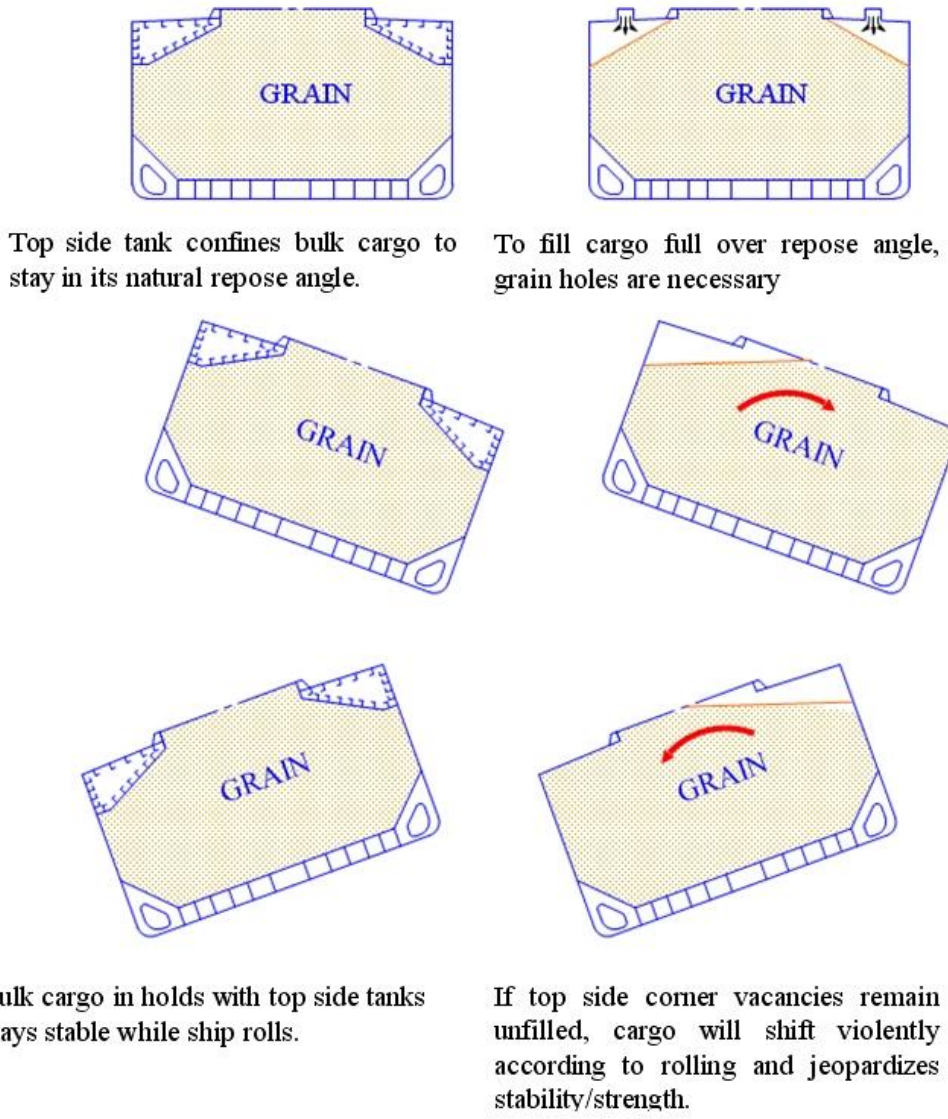

Figure 1. Role of top side tank

1.3. Cargo Oil Tank Fill / Discharge, Inerting, Breathing

To prevent possibility of ignition and to keep reasonable tank pressure, inert gas system supplies inert gas to tanks while pumping out and vent out from tanks while oil filling. This results any void spaces of cargo oil tanks are filled with inert gas always. Oxygen Content is regulated automatically to be below 5 percent in cargo oil tanks. See Figure 2.

1.4. Principle of Pressure/Vacuum Breather Valve

The breathing of tanks is critically important to the prevention of excessive tank pressure and vacuum. When the tank pressure exceeds 0.07 bar, the release side of the valve should be opened to release the gas in the tank. During oil filling and discharge inert gas system dominates tank pressure control. When the tank pressure is less than -0.07 bar, the inhaling side of the valve should be opened to draw fresh air into the tank. Simple view of self open/shut pressure/vacuum breather valve is shown in Figure 3.

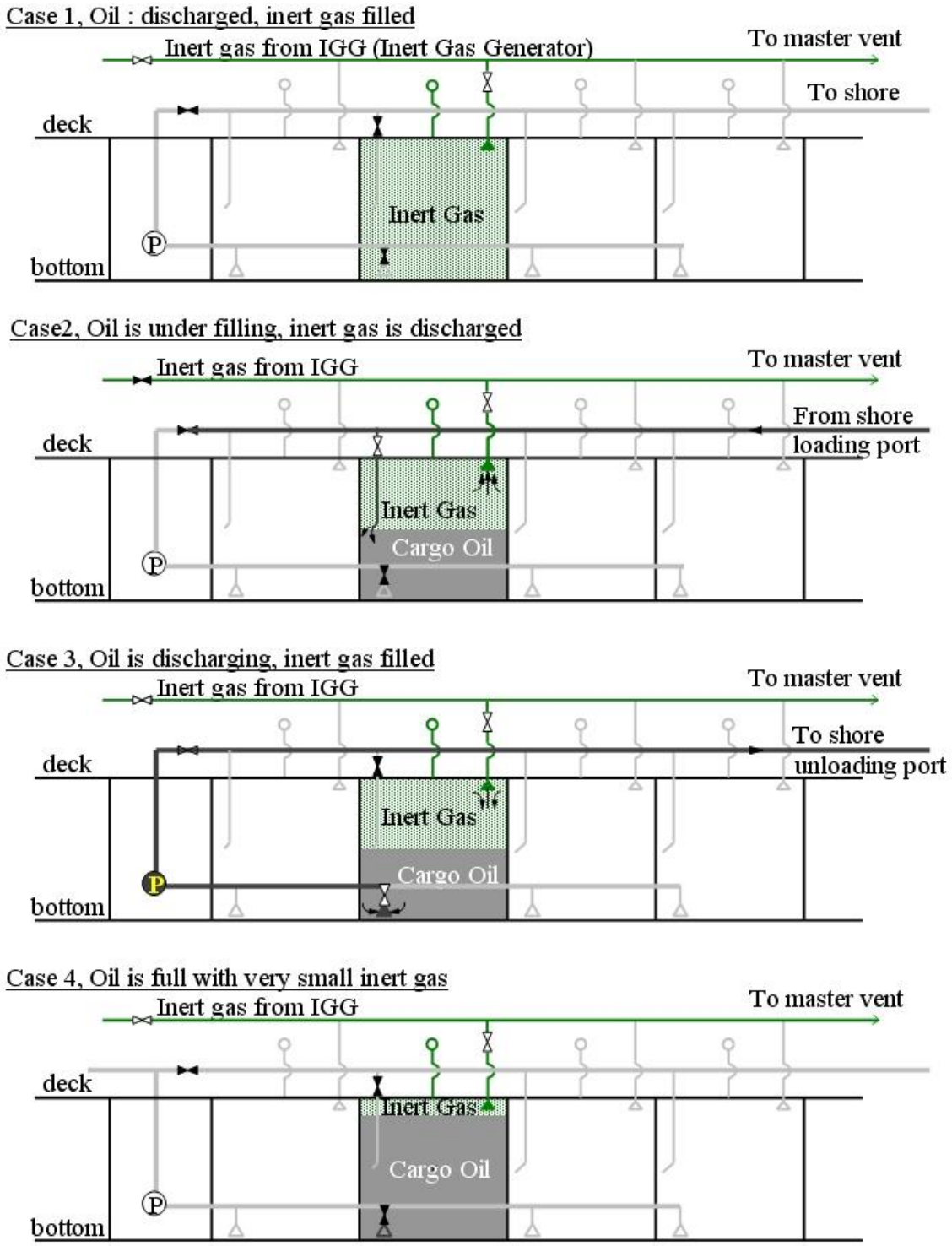

Figure 2. Diagrammatic view of cargo tank operation

Only one (1) central tank with associated pump and pipe system is selectively exhibited. Black marked valves are closed ones.

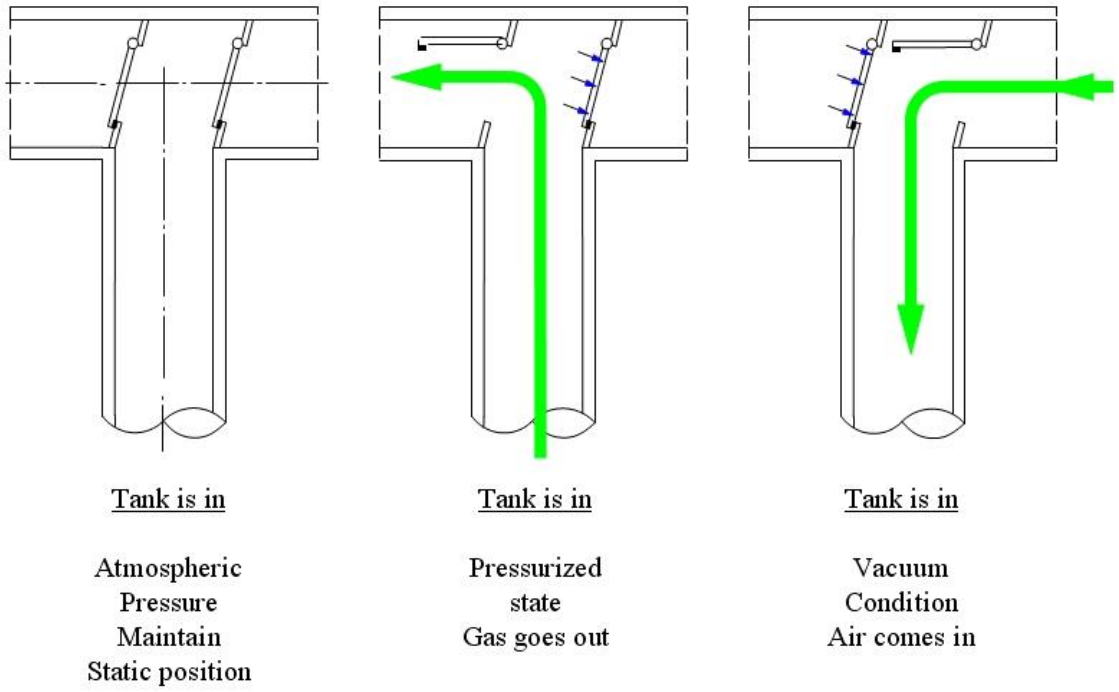

Figure 3. Pressure control by P/V valve

-
-
-

Bibliography

Howard B. Cary (2004*). Modern Welding Technology* ,Prentice-Hall Inc. USA

JOSUNGONGHAK YUNSP (造船工學演習) (1995). Society of Naval Architects of Korea published by Dong Myung Sa, Korea

SNAME, Principle of Naval Architecture (1988). The Society of Naval Architects and Marine Engineers, USA [Referred For vertical bending moment in text Section 4.4.2.6, For vertical shearing force in text 4.4.4.4. and For equipment number in Section 4.4.21]

ABS, (2010) Rules for Building and Classing Steel ,Part 3. Hull construction and Equipment (American Bureau of Shipping)

Park S.K. (1998). Haesul Josun Jisik Ipmoom (해설 造船知識入門). Dong Myung Sa, Korea

SNAME (2003) Ship Design and Construction (The Society of Naval Architects and Marine Engineers, USA)

Zosen seke benran (造船 設計 便覽) by The Society of Naval Architects of Japan

Biographical Sketch

Seung Kyun Park, A naval architect, was born in Kangwon province, Korea, in April 1943. He graduated from the Department of Naval architecture of the Institute of Technology in Seoul National University in 1967. Entered Korea shipbuilding and Engineering Corporation, presently Hanjin Heavy Industries, and worked for shipbuilding department as outfitting field engineer. He was trained in Japanese shipyard for 6 month by Colombo Plan (U.N). Moved to Hyundai Heavy Industries co., Ltd. in 1972 and worked as design engineer until 1995 titled senior vice president, worked for yard facility and utility management till 1998. Worked for offshore division till 2004 and joined Samsung Heavy Industries co., Ltd. as technical advisor. He contributed to establish ship basic design capabilities and pursues to do the same for offshore oil and gas related construction projects.