Design Theories of Ship and Offshore Plant

Part I. Ship Design

Ch. 1 Introduction to Ship Design

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Ch. 1 Introduction to Ship Design

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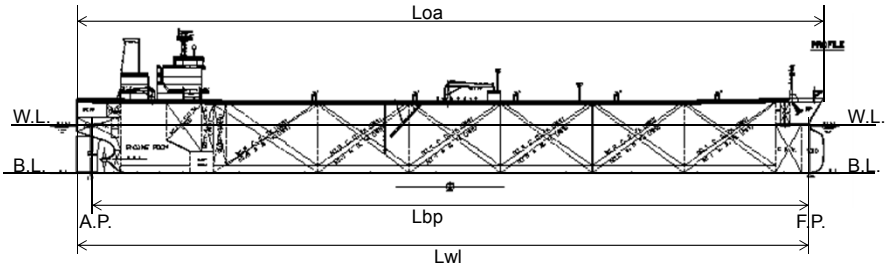
1. Main Terminology

Principal Dimensions (1/2)



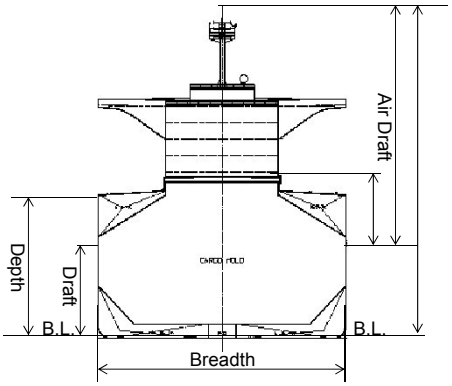
☑ LOA (Length Over All) [m]: Maximum Length of Ship

☑ LBP (Length Between Perpendiculars (A.P. ~ F.P.)) [m]
- A.P.: After perpendicular (normally, center line of the rudder stock)
- F.P.: Inter-section line between designed draft and fore side of the stem, which is perpendicular to the baseline

☑ Lf (Freeboard Length) [m]: Basis of freeboard assignment, damage stability calculation
- 96% of Lwl at 0.85D or Lbp at 0.85D, whichever is greater

☑ Rule Length (Scantling Length) [m]: Basis of structural design and equipment selection
- Intermediate one among (0.96 Lwl at Ts, 0.97 Lwl at Ts, Lbp at Ts)

Principal Dimensions (2/2)



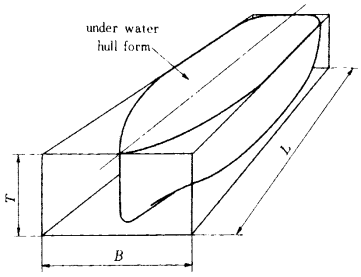
- B (Breadth) [m]: Maximum breadth of the ship, measured amidships
  - B_{molded}: excluding shell plate thickness
  - $B_{extreme}$: including shell plate thickness
- D (Depth) [m]: Distance from the baseline to the deck side line
  - D_{molded}: excluding keel plate thickness
  - $D_{extreme}$: including keel plate thickness
- Td (Designed Draft) [m]: Main operating draft
  - In general, basis of ship's deadweight and speed/power performance
- Ts (Scantling Draft) [m]: Basis of structural design
- Air Draft [m]: Distance (height above waterline only or including operating draft) restricted by the port facilities, navigating route, etc.
  - Air draft from baseline to the top of the mast
  - Air draft from waterline to the top of the mast
  - Air draft from waterline to the top of hatch cover
  - …

Weight and COG (Center Of Gravity)

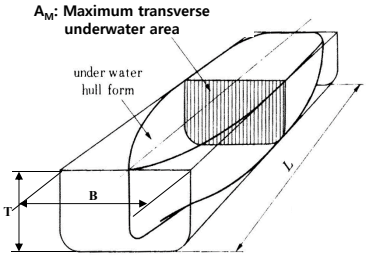
- ☑ **Displacement** [ton]
  - Weight of water displaced by the ship's submerged part
- ☑ **Deadweight** (DWT) [ton]: Cargo payload + Consumables (F.O., D.O., L.O., F.W., etc.) + DWT Constant
  = Displacement - Lightweight
- ☑ Cargo Payload [ton]: Weight of loaded cargo at the loaded draft
- ☑ DWT Constant [ton]: Operational liquid in the machinery and pipes, provisions for crew, etc.
- ☑ **Lightweight** (LWT) [ton]: Total of hull steel weight and weight of equipment on board
- ☑ Trim: difference between draft at A.P. and F.P.
  - Trim = {Displacement x (LCB - LCG)} / (MTC x 100)
- ☑ LCB: Longitudinal Center of Buoyancy
- ☑ LCG: Longitudinal Center of Gravity

* F.O.: Fuel Oil, D.O.: Diesel Oil, L.O.: Lubricating Oil, F.W.: Fresh Water

Hull Form Coefficients (1/2)

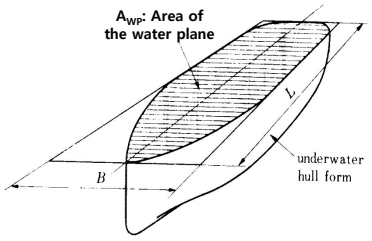


- C_B (Block Coefficient)
  = Displacement / (L x B x T x Density)
  where, density of sea water = 1.025 [Mg/m^3]



- C_M (Midship Section Coefficient)
  = A_M / (B x T)
- C_P (Prismatic Coefficient)
  = Displacement / (A_M x L x Density)

Hull Form Coefficients (2/2)



- C_{WP} (Water Plane Area Coefficient) = A_{WP} / (L x B)

Speed and Power (1/2)

- ☑ **MCR (Maximum Continuous Rating) [PS x rpm]**
  - **NMCR (Nominal MCR)**
  - **DMCR (Derated MCR) / SMCR (Selected MCR)**
- ☑ **NCR (Normal Continuous Rating) [PS x rpm]**
- ☑ **Trial Power [PS x rpm]: Required power without sea margin at the service speed (BHP)**
- ☑ **Sea Margin [%]: Power reserve for the influence of storm seas and wind including the effects of fouling and corrosion.**
- ☑ **Service Speed [knots]: Speed at NCR power with the specific sea margin (e.g., 15%)**

Speed and Power (2/2)

☑ **DHP: Delivered Horse Power**
- Power actually delivered to the propeller with some power loss in the stern tube bearing and in any shaft tunnel bearings between the stern tube and the site of the torsion-meter

☑ **EHP: Effective Horse Power**
- Required power to maintain intended speed of the ship

☑ **η_D: Quasi-propulsive coefficient = EHP / DHP**

☑ **RPM margin**
- To provide a sufficient torque reserve whenever full power must be attained under unfavorable weather conditions
- To compensate for the expected future drop in revolutions for constant-power operation

Tonnage

☑ **Tonnage: normally, 100 ft^3 (=2.83 m^3) = 1 ton**
- Basis of various fee and tax
- GT (Gross Tonnage): Total sum of the volumes of every enclosed space
- NT (Net Tonnage): Total sum of the volumes of every cargo space
  - GT and NT should be calculated in accordance with "IMO 1969 Tonnage Measurement Regulation".
- CGT (Compensated Gross Tonnage)
- Panama and Suez canal have their own tonnage regulations.

Unit (1/2)

☑ LT (Long Ton, British) = 1.016 [ton], ST (Short Ton, American) = 0.907 [ton], MT (Metric Ton, Standard) = 1.0 [ton]

☑ Density ➡ [ton/m^3 or Mg/m^3]
- e.g., density of sea water = 1.025 [ton/m^3], density of fresh water = 1.0 [ton/m^3], density of steel = 7.8 [ton/m^3]

☑ 1 [knots] = 1 [NM/hr] = 1.852 [km/hr] = 0.5144 [m/sec]

☑ 1 [PS] = 75 [kgf·m/s] = 75×10^{-3} [Mg]·9.81 [m/s^2]·[m/s] = 0.73575 [kW] (Pferdestarke, German translation of horsepower)
- NMCR of B&W6S60MC: 12,240 [kW] = 16,680 [PS]

☑ 1 [BHP] = 76 [kgf·m/s] = 76×10^{-3} [Mg]·9.81 [m/s^2]·[m/s] = 0.74556 [KW] (British horsepower)

Unit (2/2)

☑ SG (Specific Gravity) ➡ No dimension
- SG of material = density of material / density of water
- e.g., SG of sea water = 1.025, SG of fresh water = 1.0, SG of steel = 7.8

☑ SF (Stowage Factor) ➡ [ft^3/LT]
- e.g., SF = 15 [ft^3/LT] ➡ SG = 2.4 [ton/m^3]

☑ API (American Petroleum Institute) = (141.5 / SG) - 131.5
- e.g., API 40 ➡ SG = 0.8251

☑ 1 [barrel] = 0.159 [m^3]
- e.g., 1 [mil. barrels] = 159,000 [m^3]

2. Basic Functions of a Ship

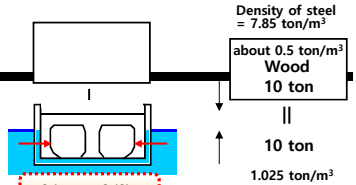
Basic Functions of a Ship

☑ **Going fast on the water**
- Hull form: Streamlined shape having small resistance
- Propulsion: Diesel engine, Helical propeller
- The speed of ship is represented with knot(s). 1 knot is a speed which can go 1 nautical mile (1,852 m) in 1 hour.

☑ **Containing like a strong bowl**
- Welded structure of plates (thickness of about 20 ~ 30mm), stiffeners, and brackets
- A VLCC has the lightweight of about 45,000 ton and can carry crude oil of about 300,000 ton.

☑ **Navigable safely**
- A ship has less motion for being comfortable and safe of passengers and cargo.
- Maneuvering equipment: Rudder

Basic Requirements of a Ship



■ The basic requirements of a ship

(1) Ship should float and be stable in sea water. — Ship stability

➡ Weight of the ship is equal to the buoyancy* in static equilibrium.

(2) Ship should transport cargoes. — Ship compartment design

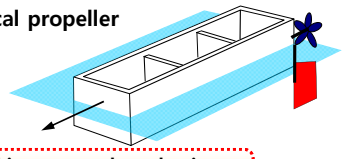
➡ The inner space should be large enough for storing the cargoes.

(3) Ship should move fast to the destination and be possible to control itself. — Hull form design, Ship hydrodynamics, Propeller design, Ship maneuverability and control

➡ Shape: It should be made to keep low resistance (ex. streamlined shape).

➡ Propulsion equipment: Diesel engine, Helical propeller

➡ Steering equipment: Steering gear, Rudder



(4) Ship should be strong enough in all her life.

➡ It is made of the welded structure of steel plate (about 10~30mm thickness) and stiffeners. — Ship structural mechanics, Structural design & analysis

* Archimedes' Principle: The buoyancy of the floating body is equal to the weigh of displaced fluid of the immersed portion of the volume of the ship.

Criteria for the Size of a Ship

☑ **Displacement**

- Weight of water displaced by the ship's submerged part
- Equal to total weight of ship
- Used when representing the size of naval ships

☑ **Deadweight**

- Total weight of cargo. Actually, Cargo payload + Consumables (F.O., D.O., L.O., F.W., etc.) + DWT Constant
- Used when representing the size of commercial ships (tanker, bulk carrier, ore carrier, etc.)

☑ **Tonnage**

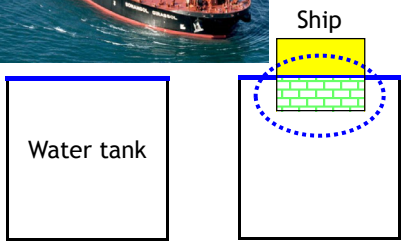
- Total volume of ship
- Basis for statics, tax, etc.
- Used when representing the size of passenger ships

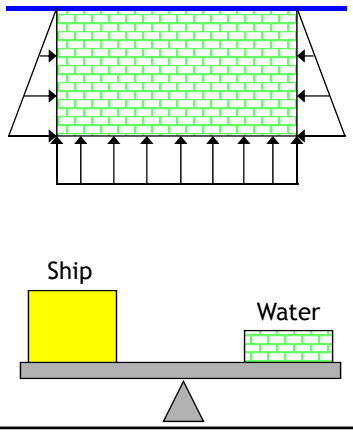
* F.O.: Fuel Oil, D.O.: Diesel Oil, L.O.: Lubricating Oil, F.W.: Fresh Water

How does a ship float? (1/3)

☑ **The force that enables a ship to float ➡ "Buoyant Force"**

- **It is directed upward.**
- **It has a magnitude equal to the weight of the fluid which is displaced by the ship.**





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How does a ship float? (2/3)

☑ **Archimedes' Principle**

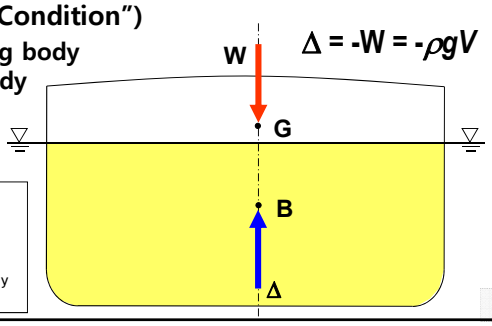
- **The magnitude of the buoyant force acting on a floating body in the fluid is equal to the weight of the fluid which is displaced by the floating body.**
- **The direction of the buoyant force is opposite to the gravitational force.**

Buoyant force of a floating body
= the weight of the fluid which is displaced by the floating body ("Displacement")
➡ Archimedes' Principle

☑ **Equilibrium State ("Floating Condition")**

- **Buoyant force of the floating body**
  = Weight of the floating body

∴ Displacement = Weight



G: Center of gravity
B: Center of buoyancy
W: Weight, Δ: Displacement
ρ: Density of fluid
V: Submerged volume of the floating body (Displacement volume, ∇)

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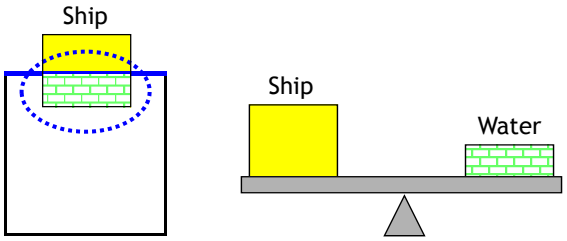
How does a ship float? (3/3)

☑ **Displacement(Δ) = Buoyant Force = Weight(W)**

$$\Delta = L \cdot B \cdot T \cdot C_B \cdot \rho$$
$$= W = LWT + DWT$$

T: Draft
C_B: Block coefficient
ρ: Density of sea water
LWT: Lightweight
DWT: Deadweight

☑ **Weight = Ship weight (Lightweight) + Cargo weight(Deadweight)**



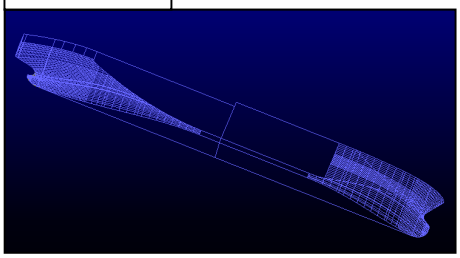
What is a "Hull form"?

☑ **Hull form**
- **Outer shape of the hull that is streamlined in order to satisfy requirements of a ship owner such as a deadweight, ship speed, and so on**
- **Like a skin of human**

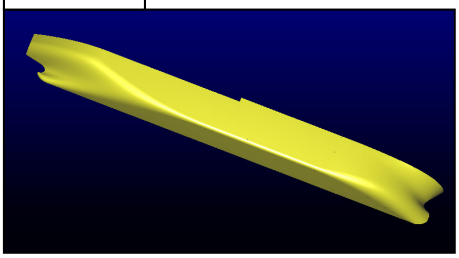
☑ **Hull form design**
- **Design task that designs the hull form**

Hull form of the VLCC(Very Large Crude oil Carrier)

Wireframe model

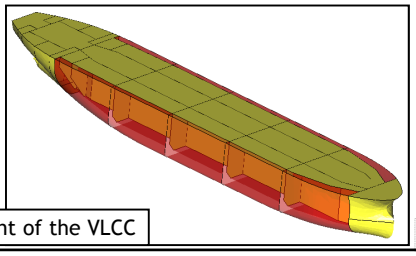


Surface model



What is a "Compartment"?

- ☑ **Compartment**
  - Space to load cargos in the ship
  - It is divided by a bulkhead which is a diaphragm or peritoneum of human.
- ☑ **Compartment design (General arrangement design)**
  - Compartment modeling + Ship calculation
- ☑ **Compartment modeling**
  - Design task that divides the interior parts of a hull form into a number of compartments
- ☑ **Ship calculation (Naval architecture calculation)**
  - Design task that evaluates whether the ship satisfies the required cargo capacity by a ship owner and, at the same time, the international regulations related to stability, such as MARPOL and SOLAS, or not



Compartment of the VLCC

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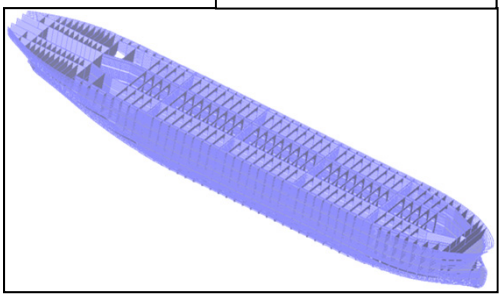
What is a "Hull Structure"?

- ☑ **Hull structure**
  - Frame of a ship comprising of a number of hull structural parts such as plates, stiffeners, brackets, and so on
  - Like a skeleton of human
- ☑ **Hull structural design**
  - Design task that determines the specifications of the hull structural parts such as the size, material, and so on

Hull structure of the VLCC



What is a "Outfitting"?

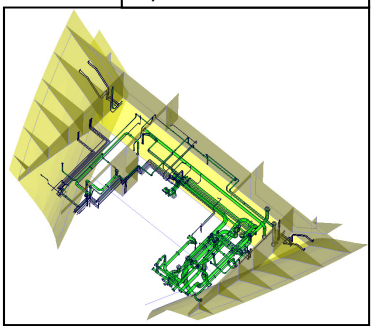
☑ **Outfitting**

- **All equipment and instrument to be required for showing all function of the ship**
  - Hull outfitting: Propeller, rudder, anchor/mooring equipment, etc.
  - Machinery outfitting: Equipment, pipes, ducts, etc. in the engine room
  - Accommodation outfitting: Deck house (accommodation), voyage equipment, etc.
  - Electric outfitting: Power, lighting, cables, and so on
- **Like internal organs or blood vessels of human**

☑ **Outfitting design**

- **Design task that determines the types, numbers, and specifications of outfitting**

Pipe model of the VLCC



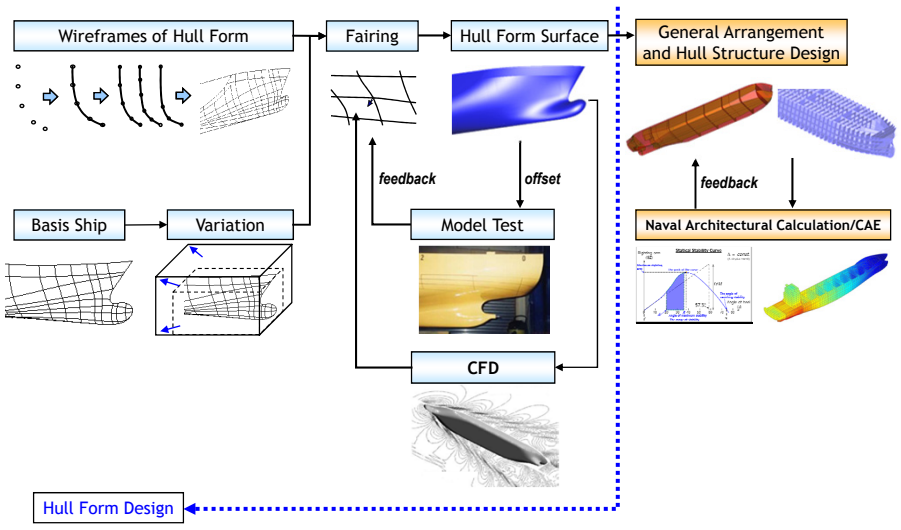
3. Comparisons of a Ship with Other Structures

Features of a Ship

☑ **Comparison with Other Structures (Building, Automobile, Airplane)**

- **Objective**
- **Moving or fixed**
- **External force acting on the structure**
- **Design concept**
- **Production method**

Procedure of Hull Form Design



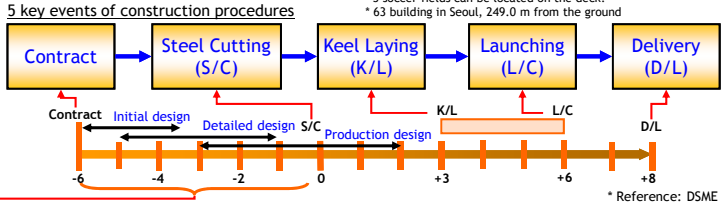
* CFD: Computational Fluid Dynamics, CAE: Computer-Aided Engineering

4. Construction Procedure of a Ship

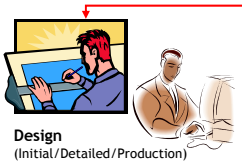
Construction Procedures of a Ship (Overview)

* Deadweight 300,000 ton VLCC, L: 320.0 m, B: 58.0 m, D: 31.2 m, 3 soccer fields can be located on the deck.
* 63 building in Seoul, 249.0 m from the ground

5 key events of construction procedures



* Reference: DSME



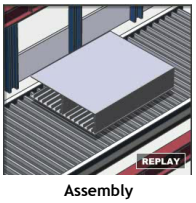
Design
(Initial/Detailed/Production)

Construction period of 300K VLCC (on December 2006)

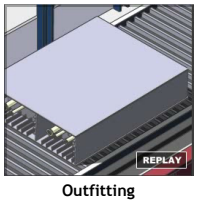
Key Event	Duration
Contract	-6 months
S/C or W/C*	Base date
K/L	+3 months
L/C	+6 months
D/L	+8 months
Total	14 months

* W/C: Work Commence. Starting date when S/C is made.

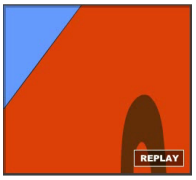
Steel Cutting



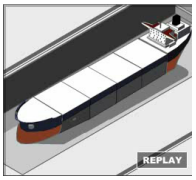
Assembly



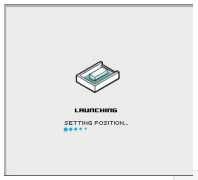
Outfitting



Painting



Erection



Launching

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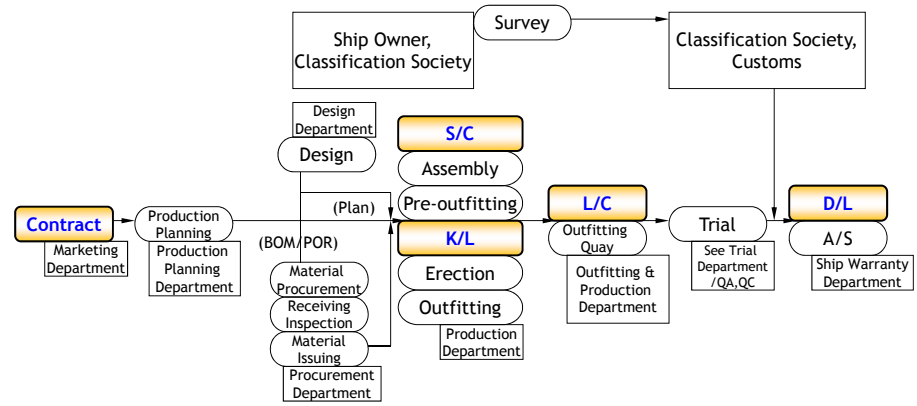
Construction Procedures of a Ship (Detailed)

: 5 key events of construction procedures



* S/C: Steel Cutting, K/L: Keel Laying, L/C: Launching, D/L: Delivery
* BOM: Bill Of Material, POR: Purchase Order Request, QA: Quality Assurance, QC: Quality Control

Construction Procedures of a Ship (Detailed)