# Design Theories of Ship and Offshore Plant

## Part I. Ship Design

## Ch. 1 Introduction to Ship Design

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**Myung-Il Roh**

**Department of Naval Architecture and Ocean Engineering**
**Seoul National University**



# Contents

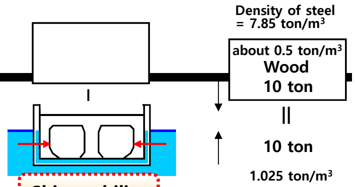
# Ch. 1 Introduction to Ship Design

1. Basic Functions of a Ship
2. Main Terminology
3. Comparisons of a Ship with Other Structures
4. Construction Procedure of a Ship



# 1. Basic Functions of a Ship

## Basic Requirements of a Ship




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

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

**Ship stability**

**(2) Ship should transport cargoes.**

**Ship compartment design**

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

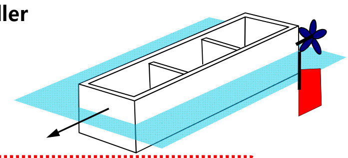
**(3) Ship should move fast to the destination and be possible to control itself.**

**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.



## Basic Functions of a Ship

☑ **Floating in the water**

- **Static equilibrium**

☑ **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.**

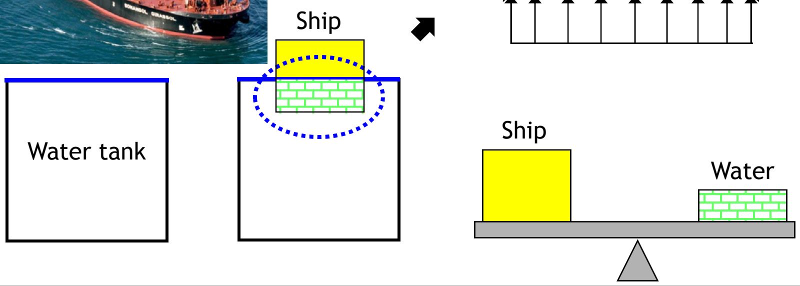
☑ **Going fast on the water**

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

## 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.**




7

## 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.**

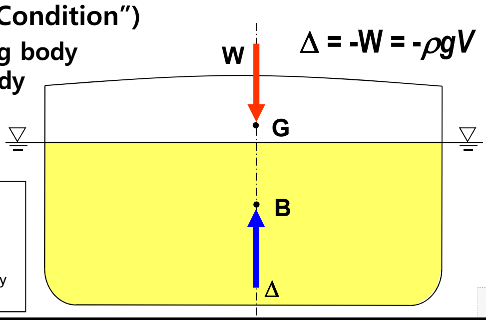
Buoyant force of a floating body
= the weight of the fluid which is displaced by the floating body ("Displacement")
➡ Archimedes' Principle

☑ 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, ∇)




8

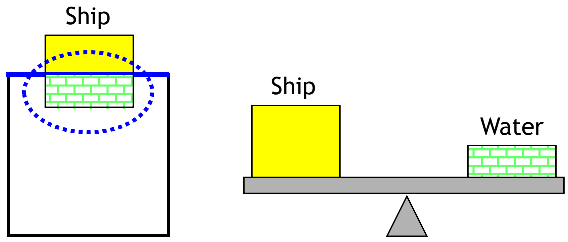
## How does a ship float? (3/3)

☑ **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

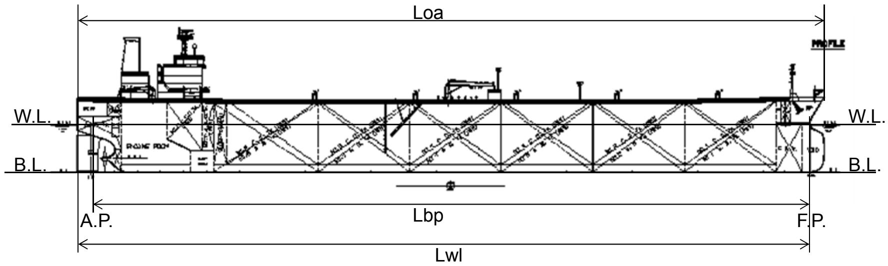
☑ **Weight = Ship weight (Lightweight) + Cargo weight (Deadweight)**






## 2. Main Terminology

# Principal Dimensions (1/2)




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

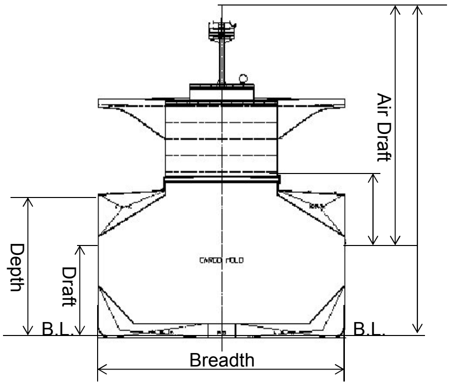
☑ LBP (Length Between Perpendiculars (A.P. ~ F.P.)) [m]
- A.P.: After perpendicular (normally, center line of the rudder stock)
- F.P.: Inter-section line between designed draft and fore side of the stem, which is perpendicular to the baseline

☑ 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

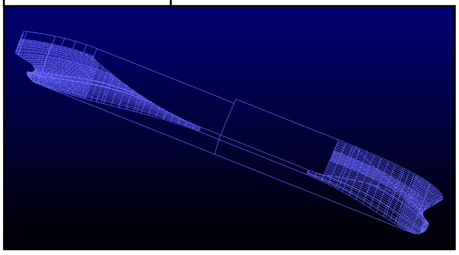
- Air Draft [m]: Distance (height above waterline only or including operating draft) restricted by the port facilities, navigating route, etc.
  - Air draft from baseline to the top of the mast
  - Air draft from waterline to the top of the mast
  - Air draft from waterline to the top of hatch cover
  - …

# What is a "Hull form"?

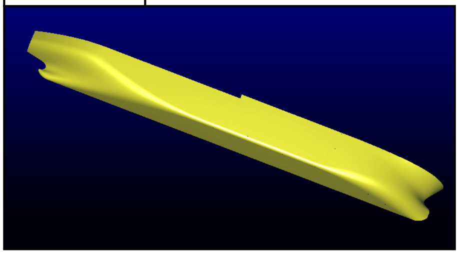
- ☑ **Hull form**
  - **Outer shape of the hull that is streamlined in order to satisfy requirements of a ship owner such as a deadweight, ship speed, and so on**
  - **Like a skin of human**
- ☑ **Hull form design**
  - **Design task that designs the hull form**

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

Wireframe model



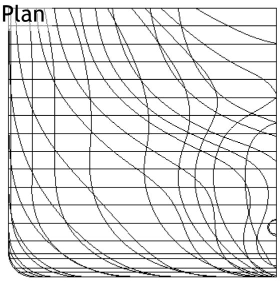
Surface model

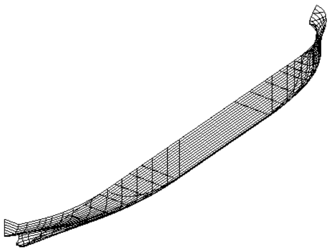




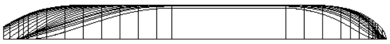
# Lines of a 320K VLCC

Body Plan



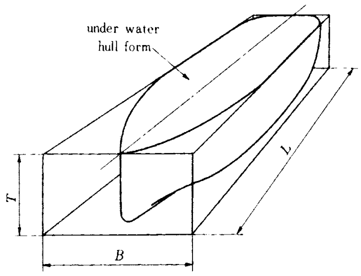


Water Plan
(= Half-Breadth Plan)

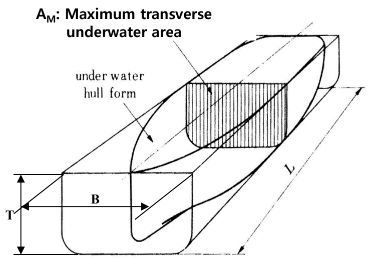


Sheer Plan
(= Buttock Plan)

# Hull Form Coefficients (1/2)



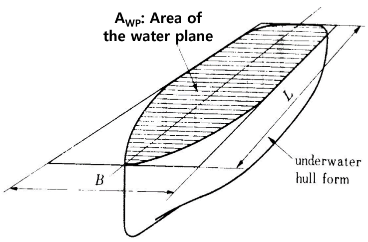

- $C_B$ (Block Coefficient)
  = Displacement / (L x B x T x Density)
  where, density of sea water = 1.025 [Mg/m$^3$]




- $C_M$ (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)

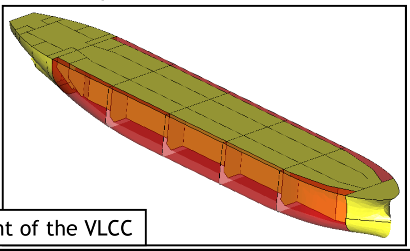
# What is a "Compartment"?

☑ 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

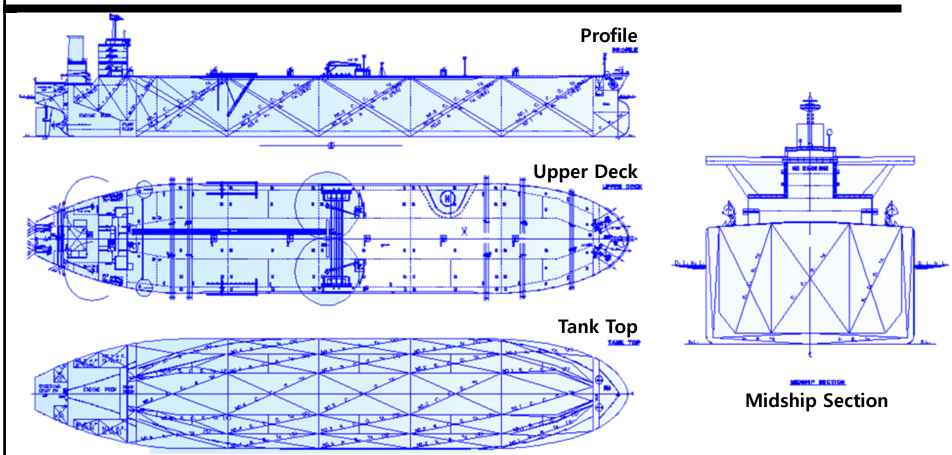
☑ Ship calculation (Naval architecture calculation)
- Design task that evaluates whether the ship satisfies the required cargo capacity by a ship owner and, at the same time, the international regulations related to stability, such as MARPOL and SOLAS, or not



Compartment of the VLCC



# G/A of a 320K VLCC




| Principal Dimensions | |
|---|---|
| LOA | 332.0 m |
| LBP | 320.0 m |
| B | 60.0 m |
| D | 30.5 m |
| Td / Ts | 21.0 / 22.5 m |
| Deadweight at Ts | 320,000 ton |
| Service speed at Td | 16.0 knots |
| at NCR with 15% sea margin | |

| Capacities | |
|---|---|
| Cargo tank | 357,000 m³ |
| Water ballast | 101,500 m³ |

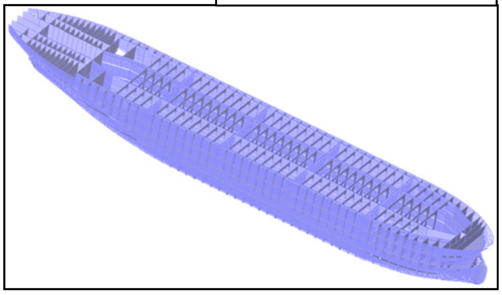
| Main Engine | SULZER 7RTA84T-D |
|---|---|
| MCR | 39,060 PS x 76.0 rpm |
| NCR | 35,150 PS x 73.4 rpm |
| No. of cargo segregation | Three (3) |
| Cruising range | 26,500 N/M |

* Reference: DSME

# What is a "Hull Structure"?

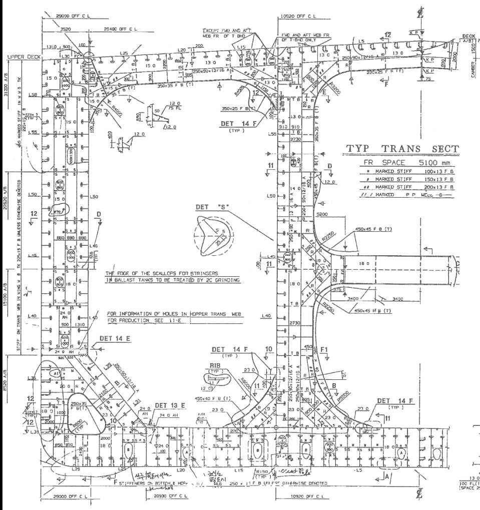
- ☑ **Hull structure**
  - ■ **Frame of a ship** comprising of a number of hull structural parts such as plates, stiffeners, brackets, and so on
  - ■ Like a skeleton of human
- ☑ Hull structural design
  - ■ Design task that determines the specifications of the hull structural parts such as the size,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

Hull structure of the VLCC

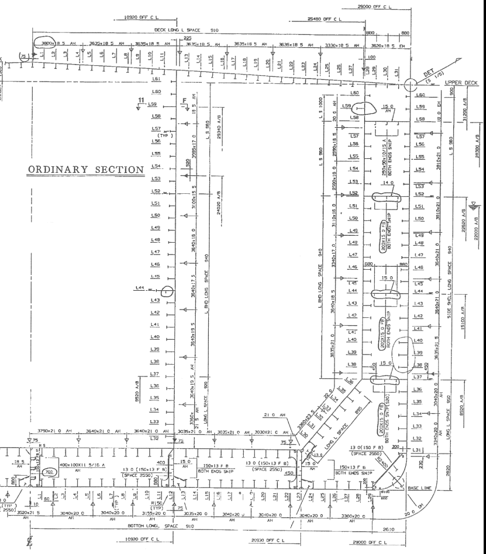




# Structural Drawing of a 320K VLCC



Web Frame Drawing



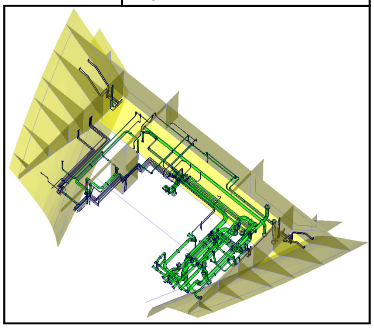
Midship Section (Ordinary Frame Section) Drawing

# 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**

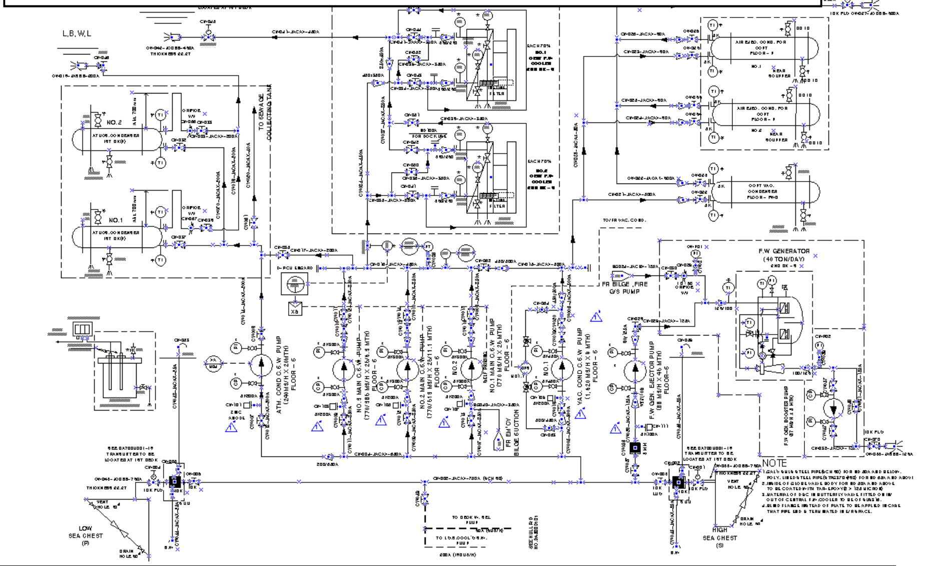
Pipe model of the VLCC






# P&ID of a 320K VLCC

P&ID: Piping & Instrumentation Diagram, Non-scaled drawing representing the relationship between equipment



## 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



## 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

## 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): GT × Conversion Factor
  - Panama and Suez canal have their own tonnage regulations.



## 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

☑ $\eta_D$: 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



## 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 [$m^3$]



## 3. Comparisons of a Ship with Other Structures

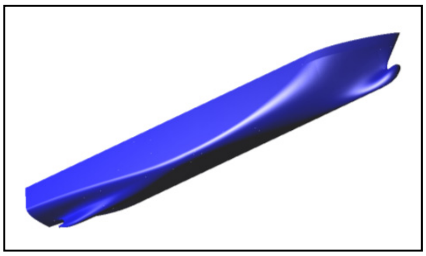
## Features of a Ship

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

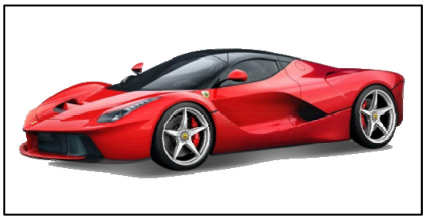
- **Objective: moving or transporting vs. living**
- **Moving or fixed: moving vs. fixed**
- **External force acting on the structure: forces induced by winds, waves, currents, etc. vs. wind force, frictional force, etc.**
- **Design concept: individual design vs. one design**
- **Production method: order (customized) production vs. mass production**



## Hull Form Design vs. Car Exterior Design

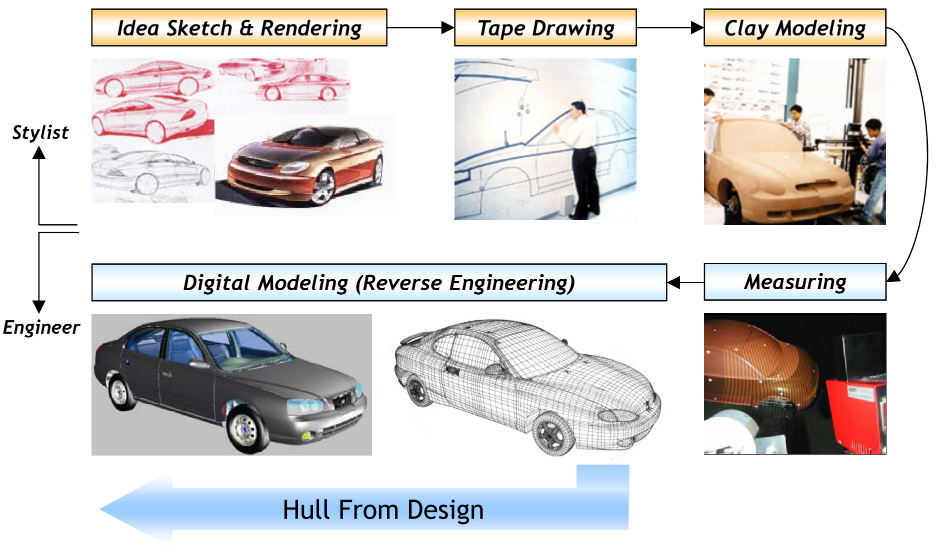


❑ Hull form design
- A hull form is related to **the resistance and propulsion performance** of a ship.
- Order production: new design for each order
- Large structure of about 100~400 m length
- **The performance like speed and deadweight is most important**.



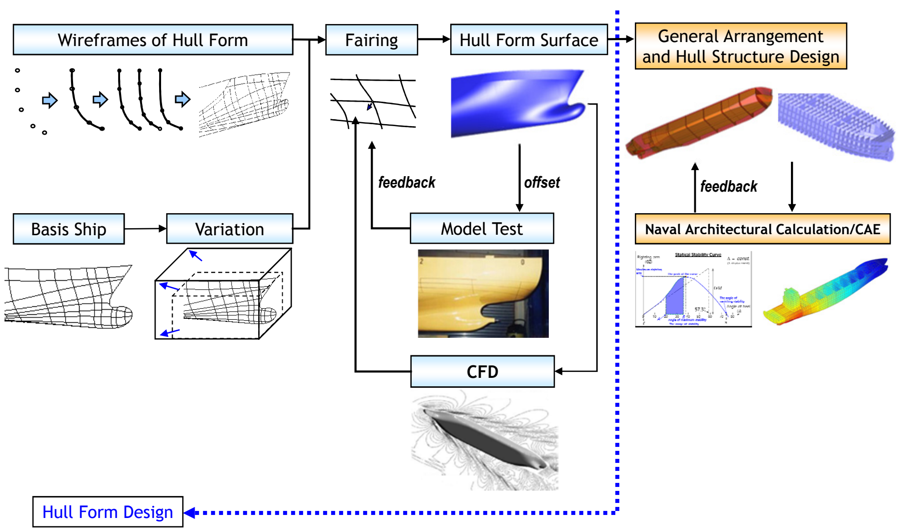
❑ Car exterior design
- A exterior is related to **the air resistance and esthetic design** of a car.
- Mass production: one time design for each model
- Small structure of about 3~5 m length
- **The performance and esthetic design are simultaneously important**.

# Procedure of Car Exterior Design






# Procedure of Hull Form Design




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

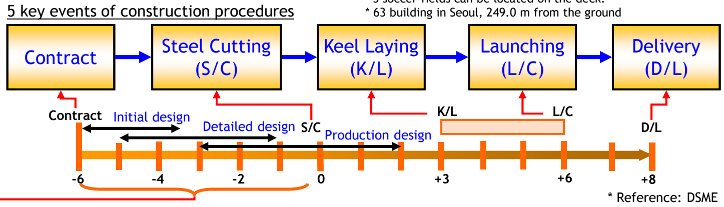
# 4. Construction Procedure of a Ship



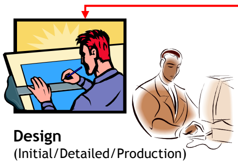
## Construction Procedures of a Ship (Overview)


5 key events of construction procedures

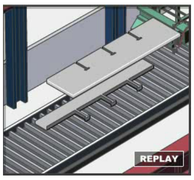
* Deadweight 300,000 ton VLCC, L: 320.0 m, B: 58.0 m, D: 31.2 m, 3 soccer fields can be located on the deck.
* 63 building in Seoul, 249.0 m from the ground



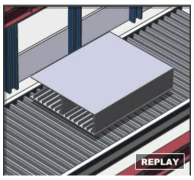

* Reference: DSME



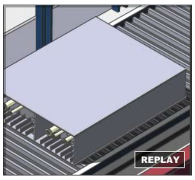
Design
(Initial/Detailed/Production)




Steel Cutting




Assembly

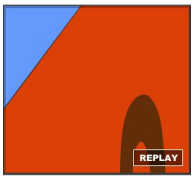



Outfitting

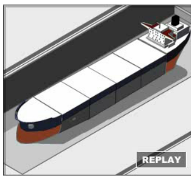
Construction period of 300K VLCC
(on December 2006)

| 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 |

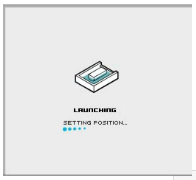
* W/C: Work Commence. Starting date when S/C is made.




Painting

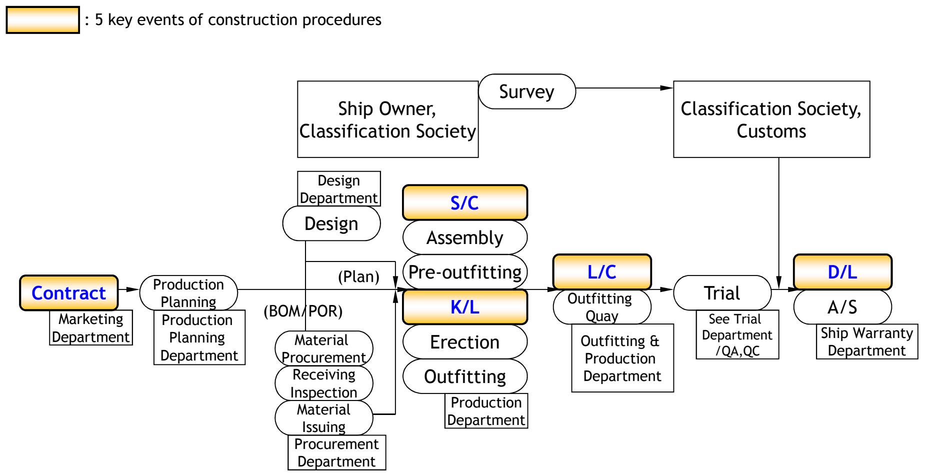



Erection




Launching

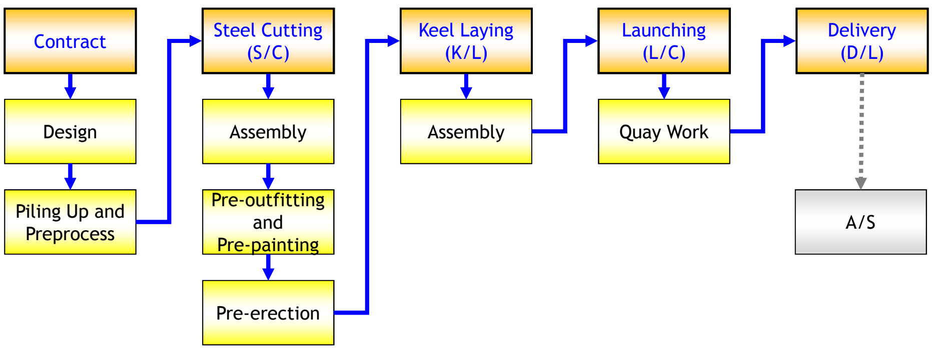
# Construction Procedures of a Ship (Detailed)




* 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



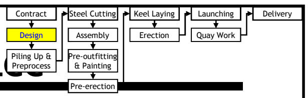
# Construction Procedures of a Ship (Detailed)

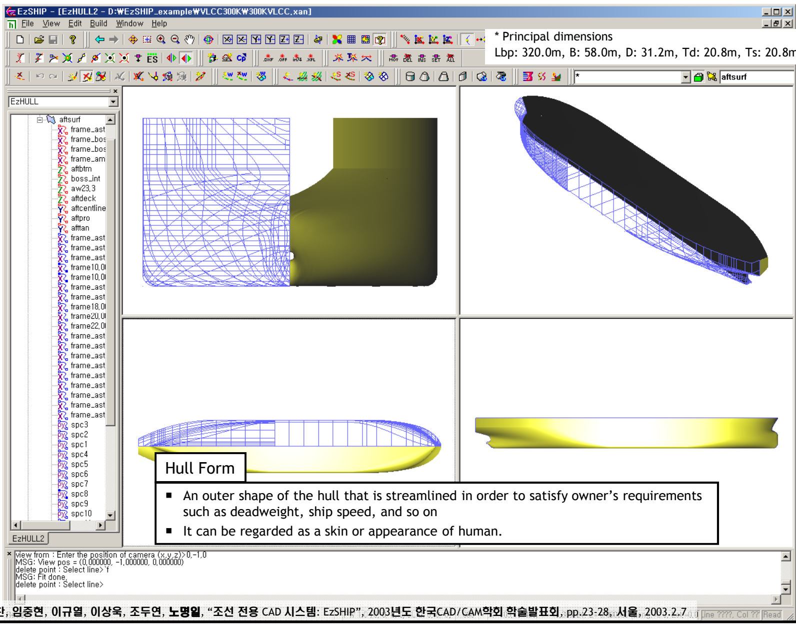


## Design



## Initial Design
## - Hull Form Modeling of a 300,000 ton VLCC



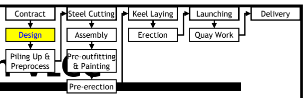

* Principal dimensions
Lbp: 320.0m, B: 58.0m, D: 31.2m, Td: 20.8m, Ts: 20.8m, Cb: 0.8086

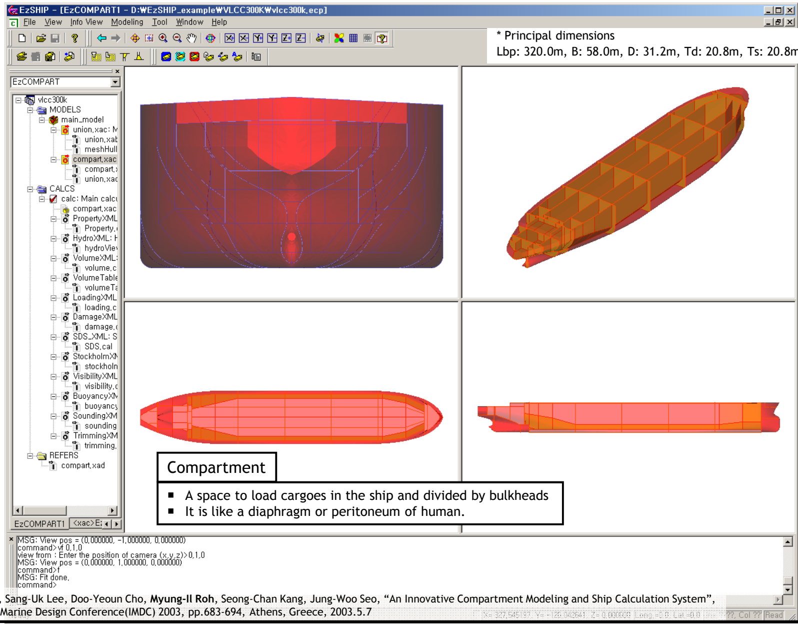
**Hull Form**

- An outer shape of the hull that is streamlined in order to satisfy owner's requirements such as deadweight, ship speed, and so on
- It can be regarded as a skin or appearance of human.

* 서정우, 강성찬, 임중현, 이규열, 이상욱, 조두연, 노명일, "조선 전용 CAD 시스템: EzSHIP", 2003년도 한국CAD/CAM학회 학술발표회, pp.23-28, 서울, 2003.2.7

# Initial Design
## - Compartment Modeling of a 300,000 ton VLCC



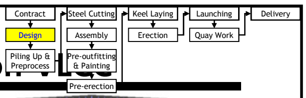



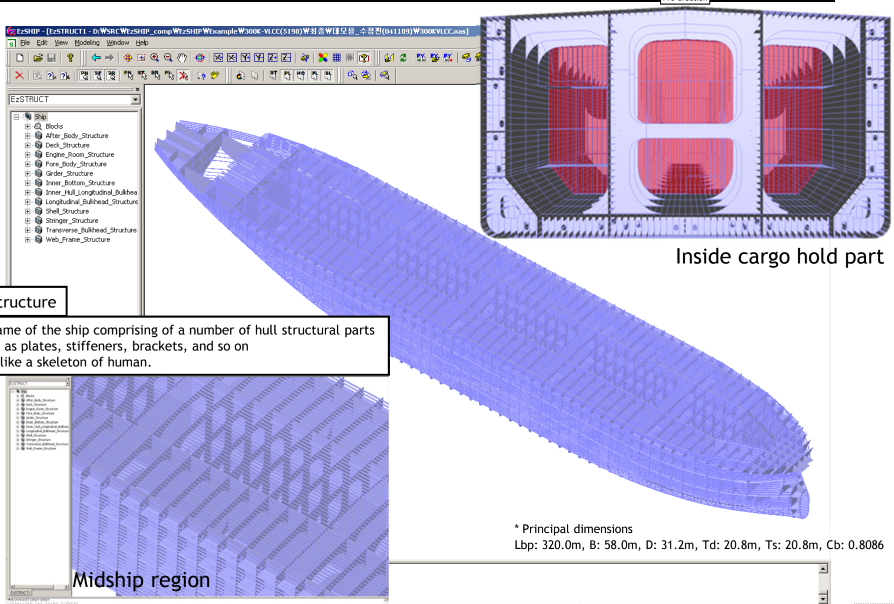

**Compartment**
- A space to load cargoes in the ship and divided by bulkheads
- It is like a diaphragm or peritoneum of human.

* Kyu-Yeul Lee, Sang-Uk Lee, Doo-Yeoun Cho, **Myung-Il Roh**, Seong-Chan Kang, Jung-Woo Seo, "An Innovative Compartment Modeling and Ship Calculation System", International Marine Design Conference(IMDC) 2003, pp.683-694, Athens, Greece, 2003.5.7

41

# Initial Design (Hull Structure)
## - Hull Structural Modeling of a 300,000 ton VLCC



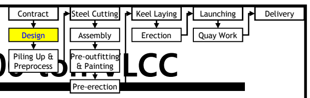



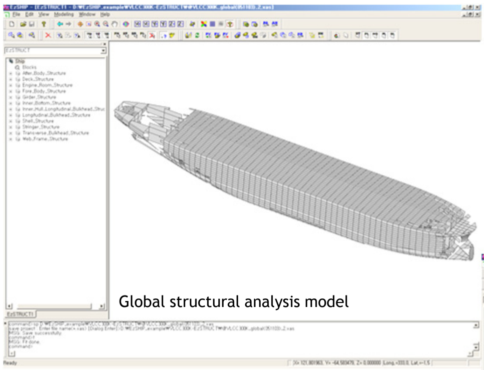

**Hull Structure**
- A frame of the ship comprising of a number of hull structural parts such as plates, stiffeners, brackets, and so on
- It is like a skeleton of human.

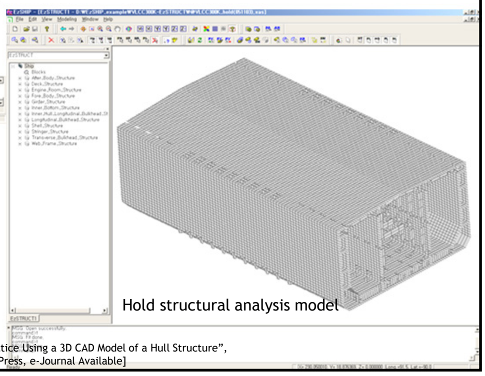
* **Myung-Il Roh**, Kyu-Yeul Lee, "An Initial Hull Structural Modeling System for Computer-Aided Process Planning in Shipbuilding", Advances in Engineering Software, Vol. 37, No. 7, pp.457-476, 2006.7

42

# Initial Design (Hull Structure)
# - Structural Analysis Modeling of a 300,000 ton VLCC



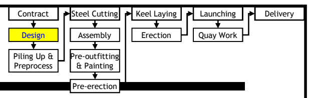




**Structural Analysis**

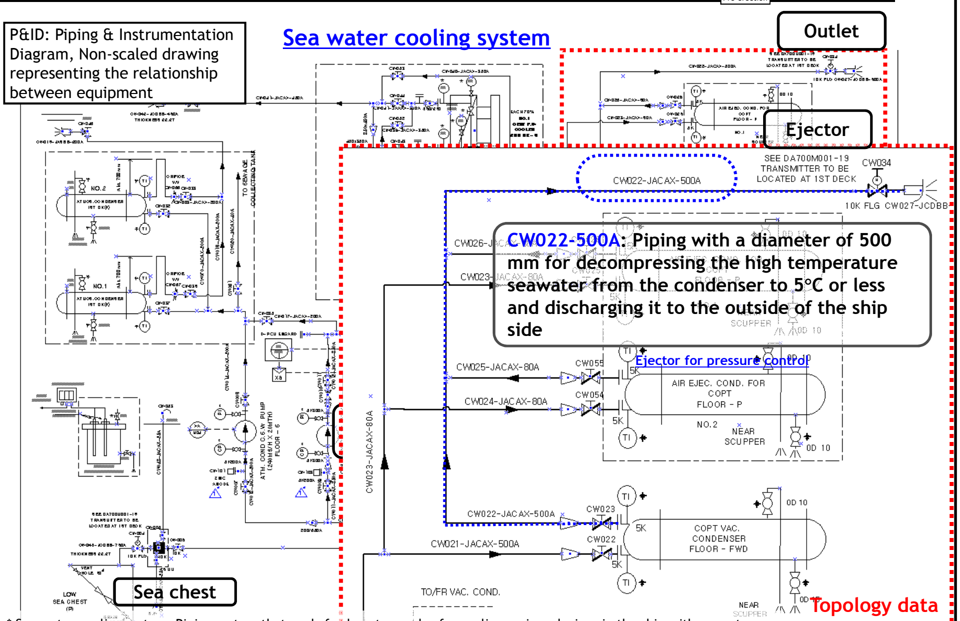
- A task to assess structural strength of a ship
- It is normally based on finite element method.

* **Myung-Il Roh**, Kyu-Yeul Lee, Woo-Young Choi, Seong-Jin Yoo, "Improvement of Ship Design Practice Using a 3D CAD Model of a Hull Structure", Robotics and Computer-Integrated Manufacturing Journal(SCIE/IF:0.699), 2006.10.16[Article in Press, e-Journal Available]

# Initial Design (Pipe Outfitting)
# - P&ID (Piping and Instrument Diagram)

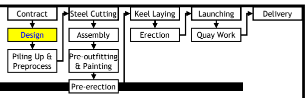



P&ID: Piping & Instrumentation Diagram, Non-scaled drawing representing the relationship between equipment

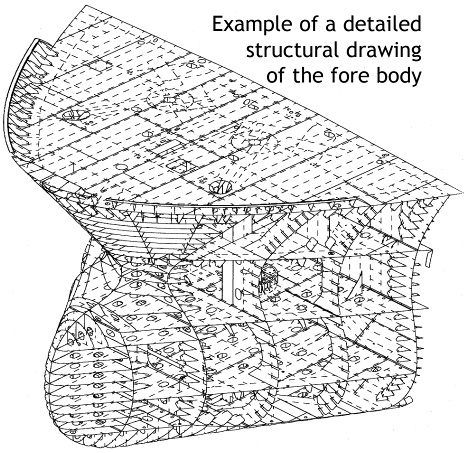



* Sea water cooling system: Piping system that cools fresh water cooler for cooling various devices in the ship with seawater

# Detail/Production Design (Hull Structure) - Result of Detailed/Production Design

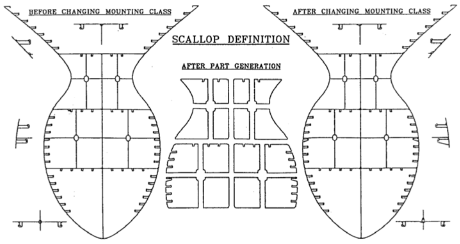



**Detail design**: the stage which detailed specification and performance are determined and detailed drawings for each system are generated

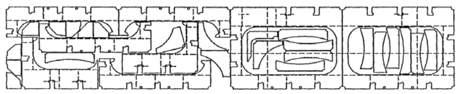


Example of a detailed structural drawing of the fore body

**Production design**: the stage which production drawings (cutting, nesting, piece, and installation drawings) for production of each block are generated



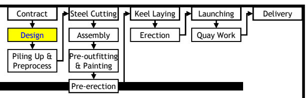

Example of a cutting drawing

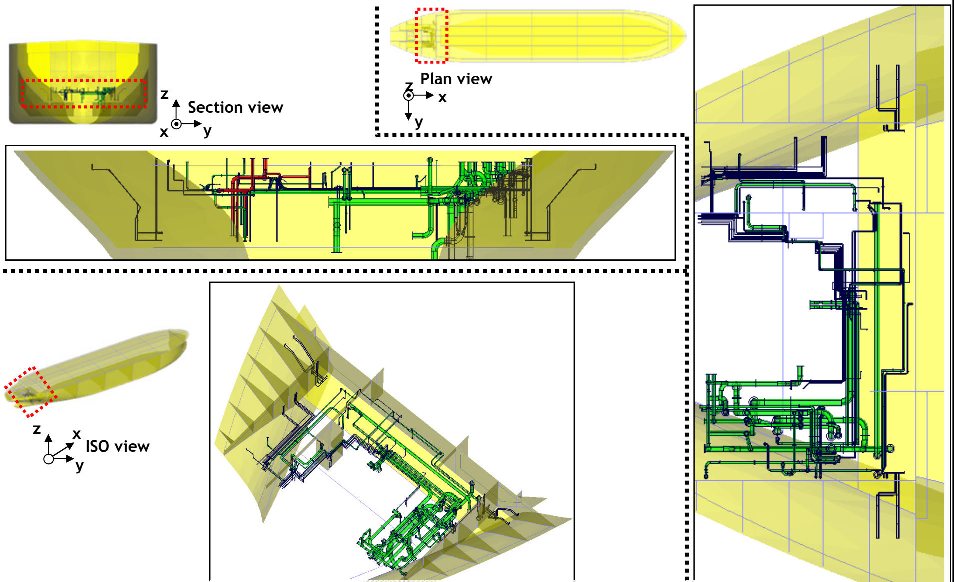


Example of a nesting drawing



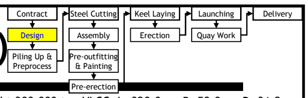
# Detail Design (Pipe Outfitting) - Pipe Modeling of a 300,000 ton VLCC



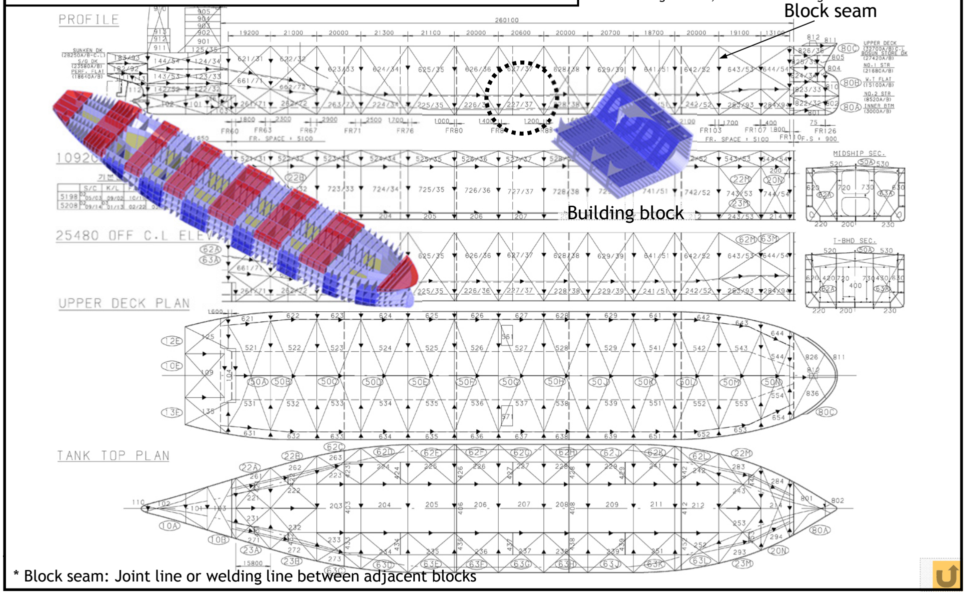

* **Myung-Il Roh**, Kyu-Yeul Lee, Woo-Young Choi, "Rapid Generation of the Piping Model Having the Relationship with a Hull Structure in Shipbuilding", Advances in Engineering Software(SCIE/IF:0.371), 2006.12.1 [Article in Press, e-Journal Available Now]

# Block Division (Production Planning)




Block division drawing of a deadweight 300,000 ton VLCC

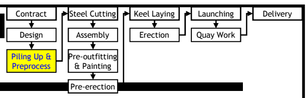
* Deadweight 300,000 ton VLCC, L: 320.0 m, B: 58.0 m, D: 31.2 m, 3 soccer fields can be located on the deck.
* 63 building in Seoul, 249.0 m from the ground




* Block seam: Joint line or welding line between adjacent blocks

## Piling Up and Preprocess of Steel Material

## Piling Up and Preprocess of Steel Material - Piling Up of Steel Material

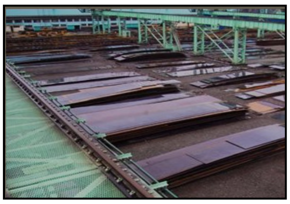



☑ Steel material consists of plates and section steels which have the shape of bar.

☑ Piling up: Process of transporting steel material purchased from steel companies to sea or land and storing it in stockyard

☑ Grouping: Process of sorting steel material according to the specification and production schedule of each ship, and then supplying it to the preprocess shop

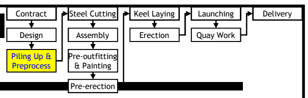
☑ Piling up method: "Using Pallet"




Types of section steels



## Piling Up and Preprocess of Steel Material - Preprocess of Steel Material



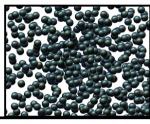

☑ Process for removing the rust on the surface of steel material to improve the adhesion of paint and to prevent rust through shot blasting and shop priming

- Shot blasting: Task to remove rust and mill scale by shooting abrasive (shot ball, cut wire, etc.) to the surface of steel material at high speed
- Shop priming: Task to paint shop primer on steel material that shot blasting is completed to prevent rust during manufacturing/assembly process

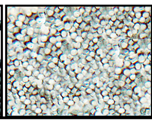
Shot blasting

Shop priming

Types of shots



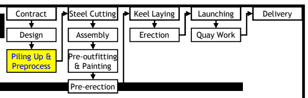
Shot ball



Cut wire

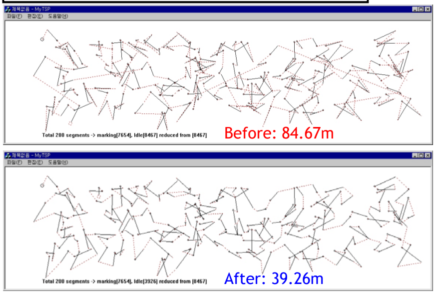
* Mill scale: A thin, black layer of metal oxide on the surface when heating the metal in the atmosphere

# Piling Up and Preprocess of Steel Material - Marking




☑ Marking: **Marking lines and symbols** for cutting, bending, and assembly processes

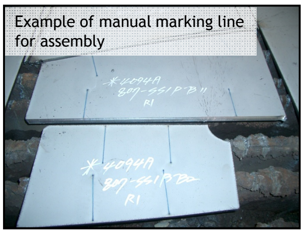
Example of path generation system
for marking torch using optimization technique



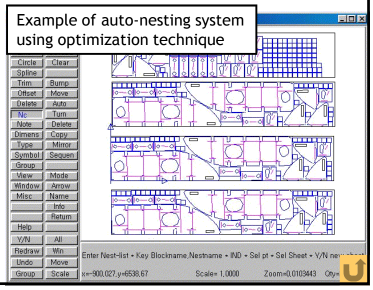

➡ How can we minimize the trajectory of marking torch in the NC (Numerical Control) marking?

➡ Example of application of optimization technique

Example of manual marking line for assembly



Example of auto-nesting system using optimization technique



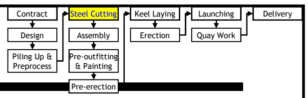
* Nesting: Process to minimize the remnants of the steel sheet which are cut and cut by rotating the member pieces in order to use the standard steel sheet most effectively

➡ How can we automatically obtain the nesting result that maximizes the yield (the ratio of the area of the steel sheet to the area of the standard steel sheet)?

➡ Another application of optimization technique

# Steel Cutting (S/C)

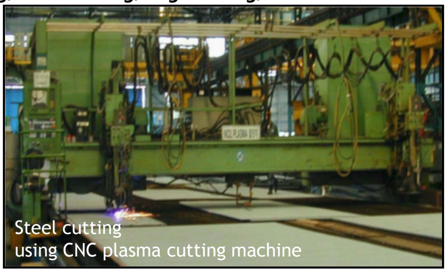
## Steel Cutting (S/C)




☑ Cutting: Process for cutting steel along the marking line to obtain a member of the desired shape
☑ Steel Cutting (S/C) or Work Commencement (W/C): Steel cutting for the first time (called groundbreaking ceremony)
☑ Cutting methods: Gas cutting, Plasma cutting, Laser cutting, Edge milling, etc.

* CNC: Computer Numerical Control


Steel cutting using CNC flame cutting machine

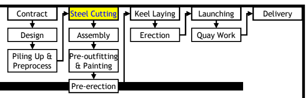

Steel cutting using CNC plasma cutting machine


Steel cutting using edge milling machine (Hyundai Samho Heavy Industries)

* Gas cutting: When the steel is heated to a temperature (800-900 deg) at which the oxidation reaction is likely to occur, an exothermic reaction occurs and iron oxide is formed. At this time, cut the plate by supplying high-pressure oxygen.
* Plasma cutting: When an electric arc discharge occurs in air, hydrogen, gas, etc., the gas is partially plasmaized. It is shrunk by a thermophysical method so that the maximum temperature reaches 20,000-30,000 deg. Using it, dissolve and blow the steel with high pressure gas.
* Laser cutting: Melt locally by injecting the light after amplifying and densifying it and by blowing the steel out with high-pressure gas, and cut the steel
* Edge milling: Still cutting using industrial diamond

53

## Plate Forming




☑ Plate forming: Process for bending plate to a curved surface or curved line
- ■ Cold forming: Causing plastic deformation of the plate by applying mechanical force at room temperature
  - ● Forming of a simple primary curved surface (curvature in one direction) by using bending roller or hydraulic press
  - ● Step before hot forming
- ■ Hot forming: Bending the plate using the property of shrinking the steel when it is locally heated and then cooled
  - ● Line heating
    - – Forming a secondary curved surface (curvature exists in two directions) to obtain permanent deformation by applying high temperature heat to the plate
    - – Currently, most of the shipyards in the world are using the second curved surface as a forming method, but they depend entirely on the manual work of the operator due to the difficulty of automation.

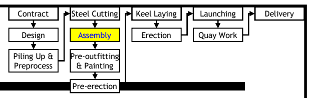
Cold processing using bending rollers


Line heating by operator

# Assembly



# Assembly
## - Sub-assembly/Assembly



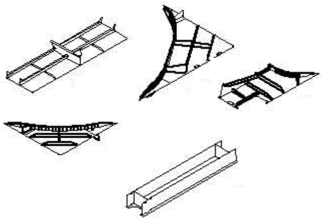

☑ Sub-assembly

- ■ Process for **manufacturing a small-sized part** constituting a block

☑ Assembly

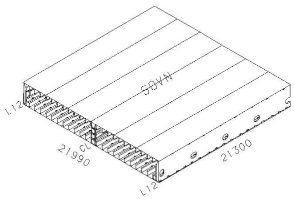
- ■ Process for assembling sub-assembly blocks to **make a large block**
- ■ Process in which about 60% or more of shipbuilding workload is processed
- ■ Depending on the shape of the block, it can be classified into the panel block process and the curved block process.
  - ● **Panel block**
    - Approximately 80% of total assembly
    - The shape of blocks and inner parts is relatively simple and automation system is adopted.
    - Matrix (Egg Box) method, Line welder method, Slit method, Piece by piece method
  - ● **Curbed block**
    - Approximately 20% of total assembly
    - It is difficult to adopt an automation system due to various shapes and complexity of blocks.
    - Line welder method, Piece by piece method

Example of sub assembly blocks

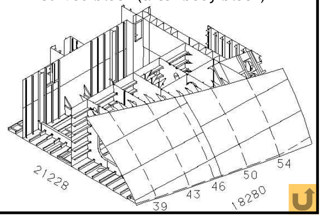


Example of assembly blocks

Panel block (double bottom block)



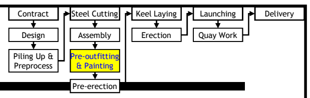

Curved block (after body block)



# Pre-outfitting and Pre-painting

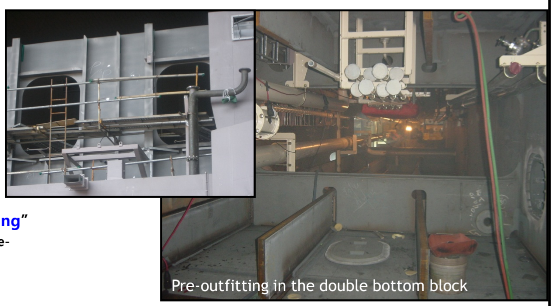


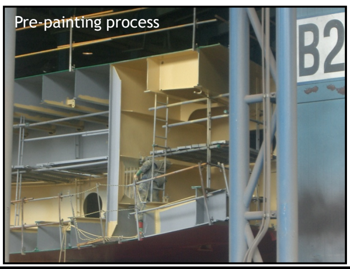
## Pre-outfitting and Pre-painting



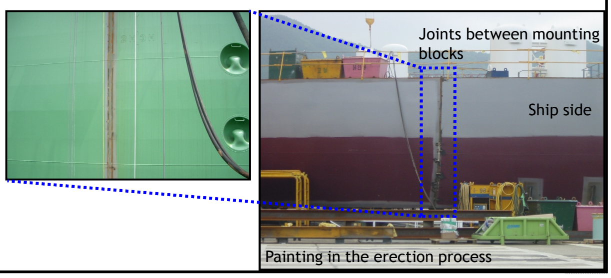

☑ Pre-outfitting
- Process for hastening the installation of outfitting (piping, ducts, etc.) to avoid congestion in the latter part of the construction period
- Categorized into block outfitting, unit outfitting, and erection outfitting

☑ Pre-painting
- Painting in the preprocess of steel material: "Shop priming"
- Painting in the assembly process: "Pre-painting"
  - Perform block pre-process before preceding pre-painting
- Painting in the erection process: "Erection painting"
  - Perform additional pre-process and painting work on joints between mounting blocks


Pre-outfitting in the double bottom block

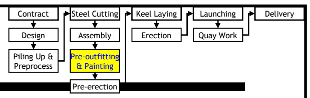


Pre-painting process



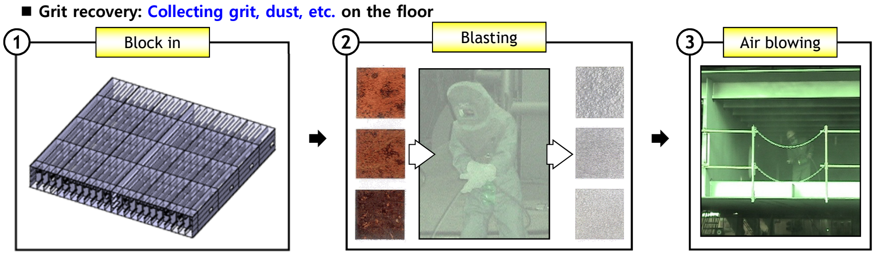
Painting in the erection process

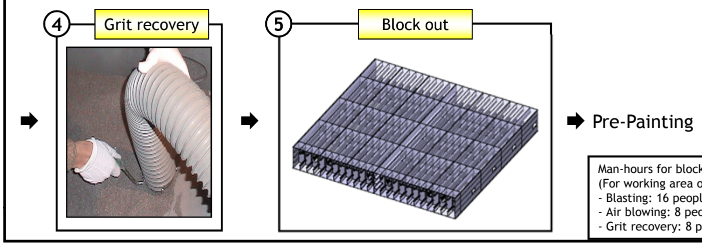
# Block Preprocess




☑ Process of removing the rust on the surface of the plate during the assembly process before the preceding painting to improve the adhesion of the paint

- Consisting of blasting, air blowing, and grit recovery
- Blasting: Removing rust by spraying a small piece of iron (grit) onto the plate
- Air blowing: Drop grit on the top of a stiffener to the floor using air
- Grit recovery: Collecting grit, dust, etc. on the floor




Man-hours for block preprocess of double bottom block of VLCC
(For working area of about 4,000m², surface roughness of SA2.5)
- Blasting: 16 people X 3.5H = 56M/H
- Air blowing: 8 people X 1H = 8M/H
- Grit recovery: 8 people X 1.5H = 12M/H

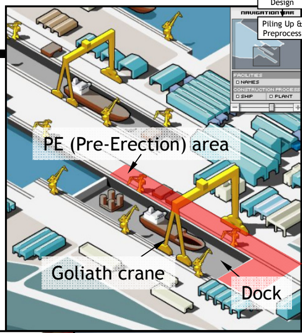
# Pre-erection

# Pre-Erection

Contract → Design → Piling Up & Preprocess | Steel Cutting → Assembly → Pre-outfitting & Painting → Pre-erection | Keel Laying → Erection | Launching → Quay Work | Delivery

☑ Intermediate process between assembly and erection processes to increase erection efficiency

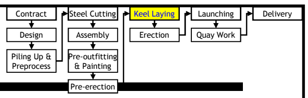
☑ This process makes **"one large PE (Pre-Erection) block"** by combining two or more hull blocks and outfitting near dock






## Keel Laying (K/L)

# Keel Laying (K/L)

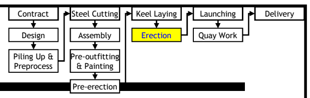


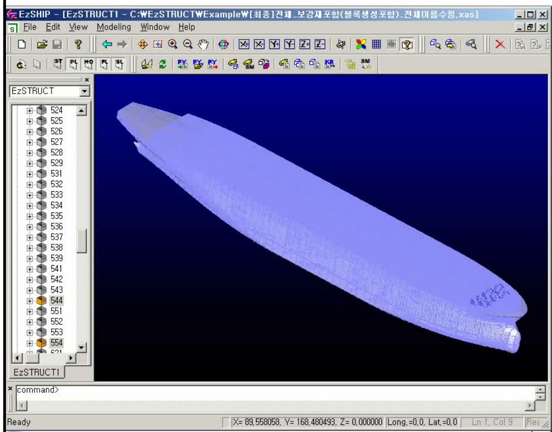

☑ The event when the first block is erected on the dock. That means the starting point of block erection.
☑ At this time, put several supports under the ship for supporting ship's weight



## Erection

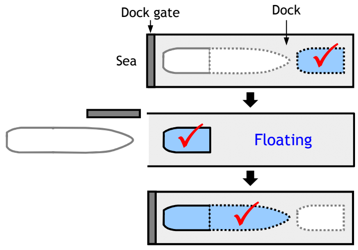
# Block Erection Simulation Considering Semi-tandem Construction Method



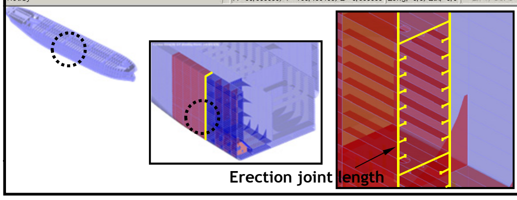



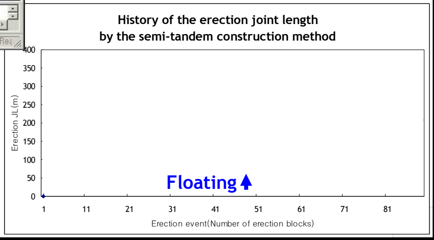
Semi-tandem Construction Method

➡ Construct a complete ship and another ship's after body together in the dock



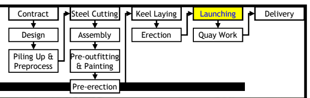

* **Myung-Il Roh**, Kyu-Yeul Lee, "An Initial Hull Structural Modeling System for Computer-Aided Process Planning in Shipbuilding", Advances in Engineering Software, Vol. 37, No. 7, pp.457-476, 2006.7



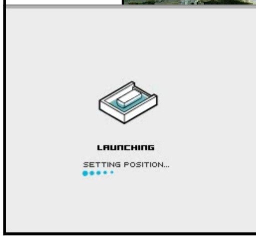




# Launching (L/C)

# Launching (L/C)

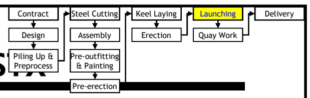



- ☑ Process for launching a ship that is dry in the dock or on the ground for the first time after various tests
- ☑ The date is about 12 months before contract date.




* Reference: DSME

# Launching
## - Ground Launching Method of HHI and S



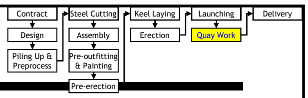

- ☑ Building a ship on land rather than a dock
- ☑ In October 2004, Hyundai Heavy Industries was the first in the world to succeed.
- ☑ Overall procedures of ground launching method
  1. Complete the erection of a ship on land
  2. Two barges are placed next to the land area.
  3. The ship is pulled over the barge ("Load Out") using the principle of submarine in Germany and the principle of mobile system developed by Switzerland
  4. Move a barge carrying the ship to the deep sea
  5. The barge sinks below the surface of the water.
  6. Finish launching of the ship


* Reference: Hyundai Heavy Industries

## Quay Work



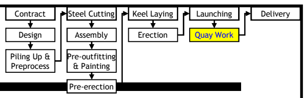
## Quay Work
## - Outfitting/Painting




☑ **After launching the ship, put her on the quay and perform outfitting and painting for the finish.**



## Quay Work
## - Sea Trial

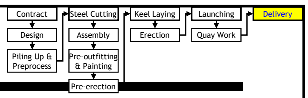



- ☑ The testing phase of the ship for conducting to measure her performance and general seaworthiness.
- ☑ It is usually the last phase of construction and takes place on open water, and it can last from a few hours to many days.
- ☑ The ship's speed, maneuverability, equipment, and safety features are usually conducted.
- ☑ Typical trials: speed trial, crash stop, endurance, maneuvering trials, seakeeping



## Delivery (D/L)

# Delivery (D/L)
# - Naming Ceremony and Delivery




Naming Ceremony of FPSO (Floating Production Storage Off-loading)

☑ **Name the ship and deliver her** to a ship owner