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# An 18680 dwt Multipurpose/ Heavy Lift Cargo Vessel, Part II

Professional paper

In the article the second part of the significant design features of an 18680 dwt multipurpose/heavy lift cargo vessel is presented. The specific features of the ship structure design are first dealt with. Then, the propulsion assembly, including the main engine, the gearbox/coupling and the controllable pitch propeller system, is described. Also, features of the electrical system are given, with special emphasis laid on the supply, driving and controlling system of the heavy cargo deck cranes. Finally, the 3D finite element modelling of the engine room is described, pointing out the advantages of such a design technique.

**Keywords:** deck cranes, design features, propulsion systems

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## Višenamjenski brod za dizanje teških tereta nosivosti 18680 dwt, II. dio

Stručni rad

U članku je prikazan drugi dio značajki projekta višenamjenskog broda za prijevoz teških tereta nosivosti 18680 dwt. Prvo su opisane značajke projekta brodske strukture. Zatim je prikazan pogonski sklop uključujući glavni stroj, reduktor/spojku i sustav vijka s promjenjivim usponom. Također, dane su značajke sustava električne energije, s posebnim naglaskom na sustav napajanja, pogona i upravljanja palubnih dizalica za teške terete. Konačno, opisano je 3D modeliranje brodske strojarnice s konačnim elementima, s isticanjem prednosti ovakve tehnike projektiranja.

**Ključne riječi:** palubne dizalice, projektne značajke, pogonski sustavi

## 1 Instead of an introduction

In the preceding issue of the journal, the first part of the heavy lift cargo vessel design was presented, where specific contract particulars, ship design features, heavy cargo loading cases and ship damage stability were described.

In this issue, the other part of this design, including the ship structure, propulsion assembly, electricity system and the engine room modelling, will be presented.

## 2 Ship structure

The preparation of the ship structure classification drawings was contracted with the ship design office *Navtec Marine* of Rijeka. As the main input for the structure design a 3D model from 3. maj was used, where most spaces and a part of the main equipment were added. Also, *Navtec Marine* designers added specific cargo securing equipment structure reinforcements to the structure drawings i.e. Technical Specification, in accordance with the requirements from the Owner. 2D drawings in DGN-format were taken over and examined by the shipyard 3. maj. Then, they were delivered in PDF-format to the client BigLift for approval. After being approved by BigLift, and corrected by *Navtec Marine* where necessary, the documentation was forwarded to the LR EMEA office in Rotterdam for a final approval. In addition, in accordance with the BigLift request, at a very early stage of the structure design, *Navtec Marine* started with a complete cargo zone FEM modelling in order to prepare the FEM analysis before

the final delivery of the drawings. The LR EMEA office has delivered the approved drawings together with the design appraisal document in PDF-format to the shipyard 3. maj.

Thus, the entire preparation/acceptance/examination/approval procedure of the hull structure classification documentation was accomplished by using only electronic means of communication.

### 2.1 Specific features of the ship structure design

Here, some essential features related to the ship structure are presented.

#### Class notation

*Lloyd's Register of Shipping* for the class: 100 A1 Ice class 1A (Finish) "Strengthened for Heavy Cargoes", "Timber Deck Cargoes", "Container Cargoes in Hold on Deck and on Upper Deck Hatch Covers", LA, +LMC, UMS, IWS, PCWBT, SCM, NAV1.

#### Hull longitudinal strength

The longitudinal strength of the hull structure elements is defined according to the greater value either of the maximum still water bending moment for all loading cases with a 10 % increase or of the permissible still water bending moment according to the classification rules with a 10 % increase. For illustration, the latter moment makes:

- $M_{B\ hog} = 753\ 400\ \text{kNm}$
- $M_{B\ sag} = -672\ 000\ \text{kNm}$

### Increase in plating thickness

The client Biglift, in accordance with the building experiences with preceding ships of the same purpose, required the increase in the plating thickness beyond the classification rules for the following parts:

- hull shell plating for 5 mm in the marine propeller area
- lower part of the bulkhead for 2 mm in the hold
- double bottom top plating for 2 mm.

### Heavy lift deck cranes

Two deck cranes, each heaving a 900 t lifting capacity, are installed on the ship starboard side. During the structure design, *Navtec Marine* proposed to *Huisman* the solution of the basic structure within the crane double side areas and, after some co-ordination activities, *Huisman* and *Navtec Marine* agreed about the best structural and equipment arrangement. Both cranes and the double side structure below them will be delivered by the crane manufacturer *Huisman*.

### Non-symmetry of the hull structure

The position of the cranes on the ship starboard side stipulates certain non-symmetry of the hull structure with respect to the longitudinal symmetry plane. In the cargo hold the breadth of the starboard double side is 4800 mm and that of the port double

side is 3980 mm. On the fore part with the superstructure, the half breadth of the superstructure lower part with the crew accommodations is 8000 mm on the starboard side and 8800 mm on the port side.

### Mobile pontoon tweendeck covers and mobile transverse bulkhead

The supports for the pontoon covers, as a part of the double side structure in cargo holds, enable various positions in the height of the tweendeck pontoon covers.

## 2.2 Midship section – geometry

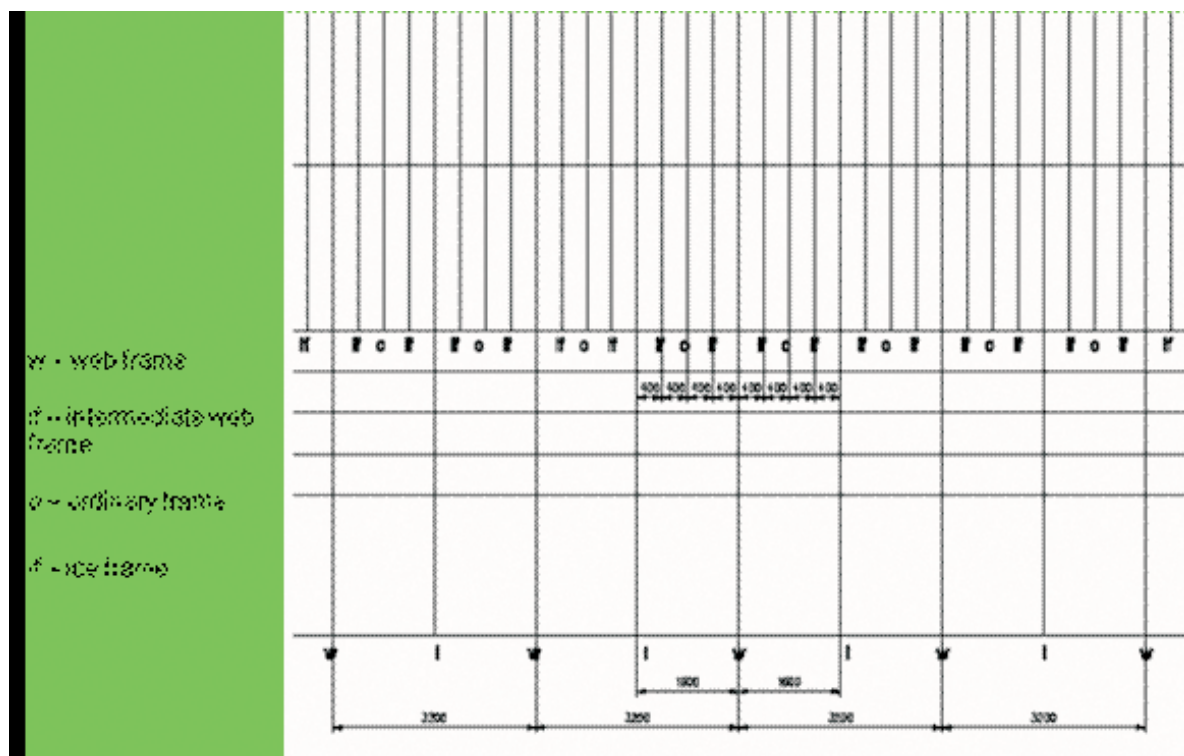
A requirement of the client BigLift was to design the structure of the ship cargo holds by including the structural solutions of an already built similar vessel in the BigLift fleet. Here, it should be pointed out that the breadth of the existing ship is 22.8 m and that of the presented design 26.5 m. In addition, the presented design has wider double sides at approximately the same breadth of the cargo hold as the existing ship.

As principal elements of the cargo hold transverse strength, the following frames are present in the structure:

- web frame (wf)
- intermediate web frame (iwf)
- ordinary frame (of)
- ice frame (if)

The disposition of the given frames in the ship hull longitudinal direction is given in Figure 1.

Figure 1 Longitudinal disposition of frames  
Slika 1 Uzdužni raspored rebara



As an example, the web frame in the transverse sectional view is presented in Figure 2.

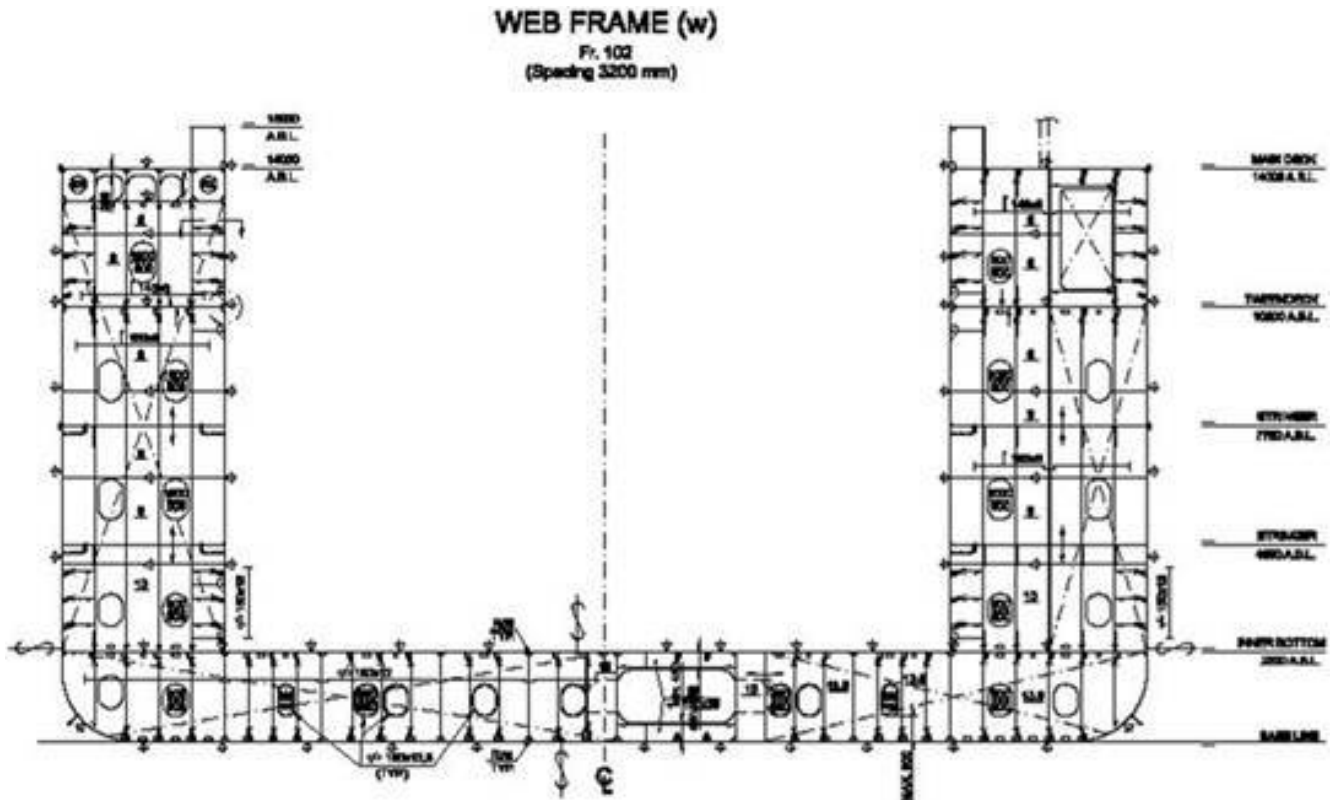


Figure 2 Web frame  
Slika 2 Okvirno rebro

### 2.3 3D FEM analysis of the cargo hold structure

It should be pointed out here that the classification society (*LR EMEA*) did not require this analysis, but it was the client BigLift who insisted on making the analysis in accordance with the experience with the vessels already in exploitation.

For carrying-out the mentioned analysis, *Navtec Marine* used the programming package POSEIDON 7.0 GL. A 3D finite element model of the cargo hold from station 34 to 157 was made. The applied mesh size in the model varied from 300×300 mm up to 800×800 mm.

Two main ship loading conditions were analysed: ship at sea and ship in port with cranes in operation.

#### Ship at sea

Within the framework of this state, several sub-states were considered:

- Ship in ballast – departure,  $d_{mean} = 7.445$  m
- Loaded ship – 15 384 t on double bottom (20 t/m<sup>2</sup>),  $d_{mean} = 9.500$  m
- Ship loaded with containers 14 t – departure,  $d_{mean} = 9.500$  m
- Ship loaded with maximum number of containers on main deck (5 rows) – 8 400 t on main deck and 6 984 t in hold,  $d_{mean} = 9.500$  m
- Ship loaded with cargo on tweendeck covers – 16 652 t (10.5 t/m<sup>2</sup>),  $d_{mean} = 9.500$  m

#### Ship in port with cranes in operation

Several sub-cases were considered here:

- Jibs of both cranes outside of starboard side
- Jibs of both cranes on port side
- Jib of aft crane on starboard side and of fore crane on port side
- Jib of aft crane on port side and of fore crane on starboard side

In each of these four sub-cases, on each crane a cargo of 990 t in weight was set in reach of 27.5 m.

Based on the results of the 3D FEM analysis, several parts of the ship structure are reinforced, like, for example, the container supports, pillar supports on the double bottom, pipe duct area, the main deck and grommet store space, etc.

### 3 Propulsion assembly and main engine systems

The propulsion assembly consists of a medium-speed, 4-stroke main engine, which drives the assembly of the controllable pitch propeller by means of flexible coupling and the gearbox. A certain amount of the main engine power is separated via the gearbox power-take-off (PTO) for driving the shaft generator that produces the electrical energy for the ship service as well as for the operation of bow thrusters during manoeuvre.

### 3.1 Main engine

The characteristics of the main engine are as follows:

- Power: 8775 kW
- Revolution number: 500 min<sup>-1</sup>
- Fuel: HFO, viscosity 380 cSt/50°C, maximum density 1010 kg/m<sup>3</sup> at 15°C

The following three main engine manufacturers were considered:

- *Wärtsilä*, type 9/8L46, power 8775/7800 kW at 500 min<sup>-1</sup>
- *MaK*, type 9/M43 C, power 9000 kW at 500 min<sup>-1</sup>
- *MAN*, type 8L48/60B, power 9600 kW at 500 min<sup>-1</sup>

All three engines satisfied the given technical conditions, but, in the contact with the manufacturer, attempts to achieve the same delivery range, such as the same volume of the associated equipment, attendance systems, etc., were made. A very important (if not the most important one) condition was the fuel consumption, which at 85% MCR ranged from 175 g/kWh to 178 g/kWh with a 5 % tolerance.

Due to the fact that the decision about the final choice of the main engine was on the client's side, a preliminary ER arrangement for each of the given main engines was made in the design phase. In the later phase of the design development, the client decided in favour of the *WÄRTSILÄ* 8L46 main engine, with the power of 8775 kW at 500 min<sup>-1</sup>. Therefore, the detailed documentation was made in accordance with the manufacturer's recommendations.

### 3.2 Gearbox/coupling

For the propulsion assembly, a single reduction gear box with vertical motion and with PTO connection for the shaft generator will be installed. The gearbox arrangement includes the built-in thrust bearing as well as the cooling and lubricating system. The main engine/propeller transmission ratio is 500/140, and the gear box/PTO transmission ratio is 500/1800.

Three kinds of gearboxes were considered: Reintjes, type SVA 1200A, Renk RSV-1120 and Renk RSV-1060. The client decided to choose Renk RSV-1060, so that, after defining the final dimensions, the gear box and the flexible coupling were fitted into the

propulsion assembly arrangement. The main engine manufacturer will deliver the flexible coupling, whose final characteristics depend on the torsional vibration analysis.

### 3.3 Controllable pitch propeller system

This system consists of a controllable pitch propeller (four blades, medium skew) of 5000 mm in diameter, a propeller shaft, an oil lubricated stern tube system and of a hydraulic pitch actuating and control system. Three manufacturers were considered: *Schottel*, *Ulstein-Rolls Royce* and *Wärtsilä-Lips*. The client chose *Wärtsilä-Lips*, which will also deliver the complete line shafting. Figure 3 presents a drawing of the line shafting disposition.

## 4 Features of the electrical system

### 4.1 Main sources of electric energy

The ship electric power plant consists of:

- Three diesel-generators of 1200 kVA (960 kW)/900 min<sup>-1</sup>,  $\cos\varphi = 0.8$
- One generator driven by the main engine in the constant speed mode, of 1560 kVA (1248 kW)/1800 min<sup>-1</sup>,  $\cos\varphi = 0.8$
- One emergency/harbour diesel-generator, of 375 kVA (300 kW)/1800 min<sup>-1</sup>,  $\cos\varphi = 0.8$

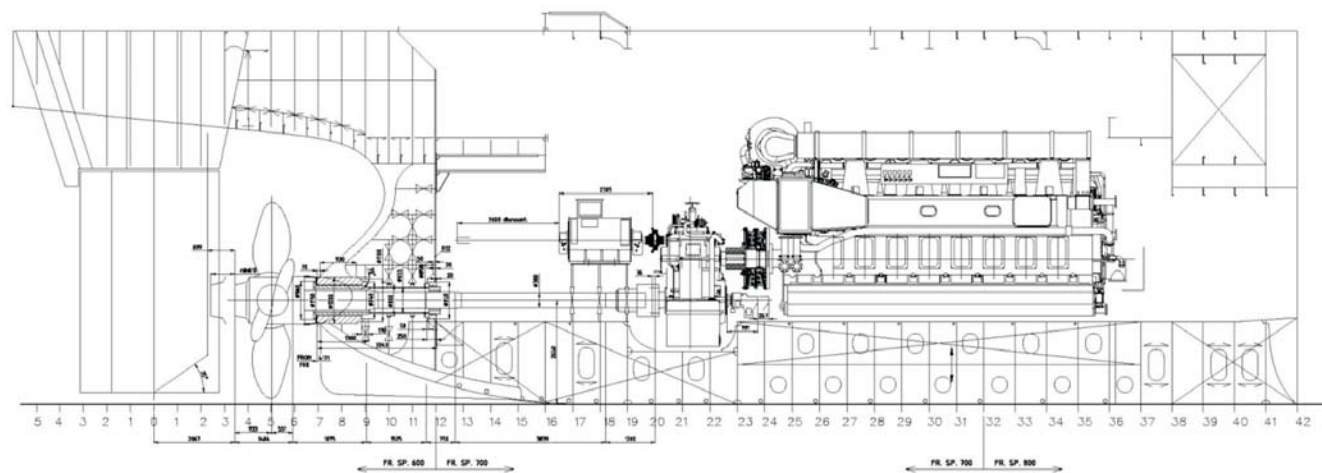
The system of electric energy distribution for the power and lighting consists of a three-phase, three-wired insulated system, 3×440 V and 3×220 V, 60 Hz.

### 4.2 Consumers of electric energy

The major electric loads are as follows:

- Cargo cranes – 2×1100 kW
  - Bow thruster – 1010 kW
  - Cargo hold ventilation – 120 kW
  - Ballast, bilge, anti-heeling, dewatering, drenching and water spraying pumps
    - o at cargo unloading, about 200 kW
    - o at emergency (open cargo hold mode), about 210 kW
- It is obvious that the cargo cranes are the greatest consumers of electric energy; therefore, they deserve more attention.

Figure 3 Disposition of the line shafting  
Slika 3 Položaj osovinskog voda





### 4.3 Heavy lift cranes

#### Main characteristics

Crane type: Huisman Heavy Lift Mast Crane (HLMC) having Safe Working Load 900 t at 27.5 m radius or 600 t at 33 m radius.

#### Driving system

The cranes have a redundant electric AC drive system with static frequency converters without the use of any hydraulics. Deceleration occurs by means of electric braking ("0" speed control). All drives have two brakes each.

#### Drive motors

Main hoist	2×300 kW
Luffing	200 kW
Auxiliary hoist	200 kW
Trolley travel	100 kW
Slewing	6×60 kW
Tugger	2×54 kW
Sling hoist	54 kW

#### Electric power production

The ship supply 2×440 V, 60 Hz, 1250 kVA is transformed to 12-pulse 690 V by means of a transformer having one primary and two secondary parts, i.e. 6 phases with a 30° shift for reducing the harmonic distortion. Each crane has its own rectifier system and static inverters for a stepless control of the driving speed. The generators should accomplish the maximum driving power within 4 s; otherwise the drives operate with a lower acceleration than the nominal one.

Auxiliary supply:	about 100 kVA
Emergency supply:	about 20 kVA

#### Inverter system

The inverters of individual drives are supplied from common DC bus. The flux vector controlled AC motors are fitted with pulse generators for a precise speed and moment control. The control range is 1:1000 for the speed and 1:100 for the moment.

Total installed power:	1820 kW
Maximum simultaneous power consumption of one crane:	1100 kW
Maximum simultaneous power consumption of both cranes:	1600 kW

#### Control and supervision of cranes

The cranes are controlled by means of programmable logic controllers in the control cabinet of each crane. The remote control is achieved by means of portable wireless control/supervision units having docking stations and LCD displays in the wheelhouse.

### 5 3D modelling of the engine room

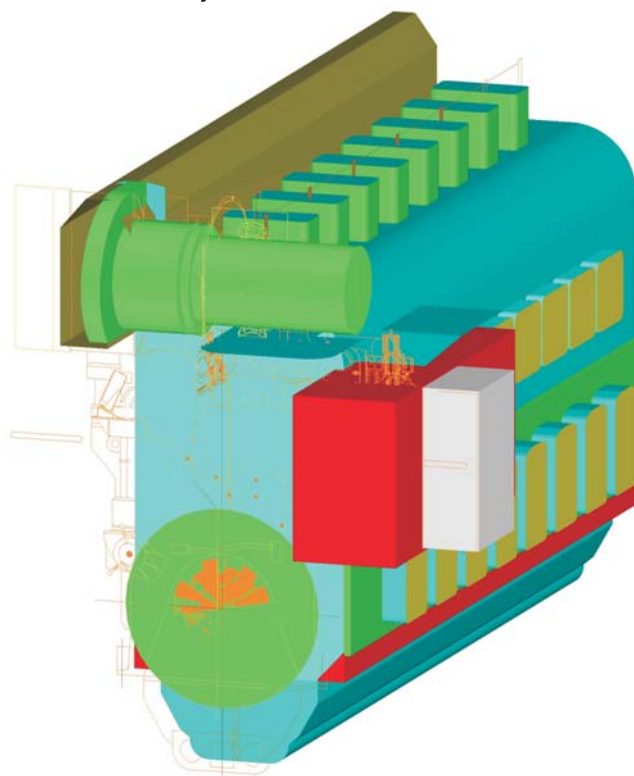
When designing the 3D model of the ship engine room, it was necessary to satisfy the following conditions:

- The forward bulkhead limited by the cargo hold for placing 14 bays of TEU containers

- The breadth of the engine room determined by a relatively fine stern form
- The maximum height of the engine room (9.3 m from the double bottom up to the main deck) is limited above the engine room for the CO<sub>2</sub>, emergency diesel generator and stern fans accommodation
- The arrangement of the engine equipment on two engine room platforms and on the engine room floor limited due to a very low room height
- The dimensions of the engine room hatch and the funnel, placed on the ship port side, were limited because of the necessary area for manipulation and placement of heavy cargo from the ship stern towards the stem
- The placement of one part of the tweendeck covers on the stern position in the engine room recess
- The requirement of a "box shape" cargo hold, so that the stern ventilation ducts as well as the way down into the hold are made on account of one part of the engine room space
- A greater number of fuel and lubrication oil tanks in the engine room than in ordinary ships
- The position of the ventilation ducts for the engine room ventilation system through the stern cargo crane body and the side passage

The 3D modelling of the engine room was carried out in order to satisfy the above-mentioned design requirements. For this purpose, 3D models of the ship form in the engine room area, the engine room structure, the main engine and the propulsion assembly arrangement were developed. In Fig. 4, a 3D model of the main engine is presented.

Figure 4 Main engine - 3D model  
Slika 4 Glavni stroj – 3D model



The 3D modelling of the engine room in the initial design phase enables to the designer a quicker recognition of all critical positions in the space of the ship engine room.

A 3D design model enables the time reduction when making the technical documentation for the engine room outfitting because, after the hull classification documentation is made, the developing of the final 3D engine room arrangement model can start without having to wait for the completion of the hull workshop documentation.

In particular, the checking of the 3D design model versus the 2D hull drawings is very important and useful.

## 6 Summary

The most significant design features of a 18680 dwt multi-purpose/heavy lift cargo vessel are presented in two issues of this journal. The presented design was completely developed by the designers of the shipyard *3. maj* in Rijeka and was introduced for the first time to the experts in the field at the annual meeting of the Croatian ship designers held in Rijeka. On that occasion it was decided to publish it in the journal *Brodogradnja*.

In the first part, the contract particulars are described, with a special focus given to the cooperation of the designers and the client in making the choice of the propulsion assembly items, and also to the agreement that the crane manufacturer will deliver not only the cranes but will also provide the hull structure underneath them. Then, the basic ship concept with a list of requirements and classification/regulation rules is given. Here, the ship stability calculation in the survival condition for "open ship", in accordance with additional stability criteria, is pointed out. Results of the stability analysis for 5 heavy cargo loading cases are presented, showing that in all cases the client's and the USCG requirements are fulfilled. Finally, the subdivision

and damage stability analysis (probability method) is described. Results for three navigation cases, with and without removable bulkhead in hold and with open hatch openings on the main deck, are given, showing that the attained subdivision index in all three cases satisfies the required subdivision index.

In the second part, the specific features of the ship structure design are first dealt with. The following issues are discussed: the increase in plating thickness beyond the classification rules of the hull shell in the propeller area, of the lower bulkhead part in the hold and of the double bottom top; the non-symmetry of the hull structure due to the starboard position of the heavy lift deck cranes; mobile pontoon tweendeck covers and mobile transverse bulkhead; various structural web and ordinary frames as transverse strength elements in the cargo hold area; and, finally, the 3D FEM analysis of the hold structure for two main ship states, is presented. Then, the propulsion assembly, including the main engine, the gearbox/coupling and the controllable pitch propeller system, is described. Also, features of the electrical system, such as main electric energy sources and consumers, are given, with special emphasis laid on the supply, driving and controlling system of heavy cargo deck cranes as the main electric energy consumers. Finally, the 3D finite element modelling of the engine room is described. The advantages of such a design technique, such as the adjustment to the ship form, the appropriate disposition of the fittings and of other equipment and the early recognition of critical position, are pointed out.

## Acknowledgement

Here again, like at the end of Part I, we would like to express our gratitude to all members of the *3. maj* design office. Their contributions and the excellent cooperation with the journal's editorial office have created this article.

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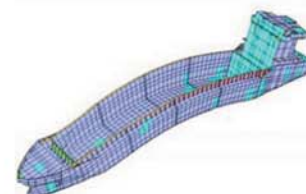
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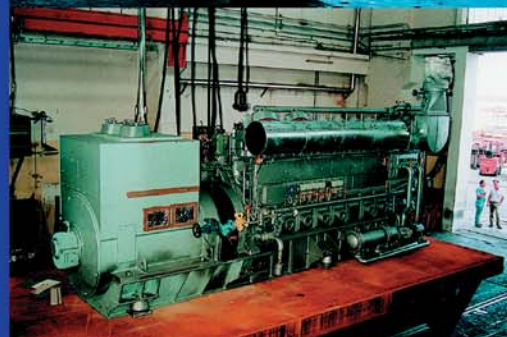
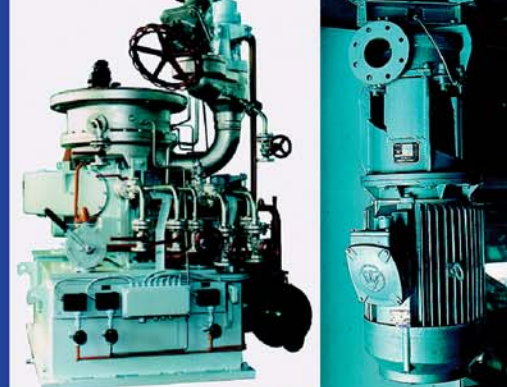
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establishment of links with foreign partners, with a focus on exports and cooperation;

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The continuity of shipbuilding in **KRALJEVICA** has been lasting uninterrupted since 1729, when the Shipyard has been established by the Austrian Emperor Karl VI.



The **KRALJEVICA** Shipyard ranks, in view of its capacities, among medium-sized shipyards (500 employees, area of 110,000 m<sup>2</sup>).

The **KRALJEVICA** Shipyard's activities are divided in three main groups: newbuildings (asphalt tankers, multipurpose vessels, container vessels, dry cargo vessels, paper carriers, RO-RO vessels, car ferries, offshore supply vessels, tugs, yachts, fishing vessels, small aluminum crafts, etc.), navy vessels (patrol vessels, corvettes, coast guard vessels, etc.), shiprepairing/retrofitting (merchant and navy vessels).

As from the end of Second World War, the Shipyard built more than 180 vessels of which 80 navy vessels and more than 100 merchant vessels on two open slipways of up to 10,000 tdw (125 x 21 m) and one sheltered slipway in hall (for vessels up to 60 x 11 m).

Shiprepairing and marine service-conversions for vessels up to 25,000 tdw in two floating docks of 450 tons and 6,500 tons lifting capacity (for vessels of maximum 155 x 21 m), and on shiprepairing quay of 575 meters in length.

The Shipyard have awarded for his quality two prestigious prizes:

- in Year 1989 for RO-RO/Container/paper carrier of 3,400 tdw as one of **the Most Outstanding Ship of the Year** (by US magazine "Maritime Reporter & Engineering News")
- in Year 2005 for Asphalt carrier of 9,200 tdw as one of **the Significant Ship of the Year** (by UK magazine "The Naval Architect")



## KRALJEVICA Shipyard

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## ADRIA-MAR BRODOGRADNJA

je tvrtka specijalizirana za projektiranje, gradnju i remont ratnih brodova i brodova specijalne namjene, te njihove pripadajuće opreme.

NAŠ USPJEH se temelji na pouzdanj suradnji sa klijentima i kooperantima.

## RASPOLAŽEMO

- visokoobrazovanim osobljem školovanim na CAD sustavima
- najnovijim referencama u ratnoj brodogradnji
- tehnologijom remonta sustava brodskog naoružanja

## AKTUALNI PROJEKTI NOVOGRADNJE



## GENERALNI REMONTI

