Return to Session Directory

DYNAMIC POSITIONING CONFERENCE
October 12-13, 2010

Design Session

The Development Process of the DSME & Honeywell DP System for a Submerged Heavy Lift Carrier

Kim Se Won, Ji-Hwang, Choi Jin Woo, Lee Jin Kwang, Jin Eun Seok

Daewoo Shipbuilding & Marine Engineering Co. Ltd

Moon Hee Gun, Park Nea Heon

Honeywell Korea

Contents

Introduction 3
Heavy Lift Carrier: 50,000 DWT Block Carrier 3
Figure 1. Sea Route of Heavy Lift Carrier 4
Figure 2. Heavy Lift Carrier; TPI MEGA PASSION 4
Operating Scenarios Defined 5
Table 1. Operating Scenarios 5
Figure 3. Heavy Lift Carrier Submerging 5
Hydrodynamic Analysis 6
Table 2. Environmental Conditions of Heavy Lift Carrier 6
Figure 4. CFD Calculation Model without Cargo 6
Figure 5. Calculation Model of the Cargo Loaded Condition 7
Figure 6. Wind Profile of the Cargo Loaded Condition 7
Figure 7. Wind & Current Load Coefficients with Cargo Condition 7
Figure 8. Wave Load Analysis Results 8
Controller Design 9
Figure 9. Simplified Heavy Lift Carrier DP Controller 9
HMI (Human Machine Interface) Development Process 10
Figure 10. Simplified HMI Design Process 10
Table 3. User Profiles & HMI Improvements 11
Figure 11. Shows the User Defined Cargo Panel 11
Simulator 12
Figure 12. Stand Alone Heavy Lift Carrier Time Domain Simulator 12
DP System Hardware Configuration 13
Figure 13. Hardware Concept Diagram 13
Figure 14. OIB on DP Operation Station 13
Figure 15. PLC (Programmable Logic Controller) & UPS 14
Sea Trials 14
Figure 16. Sea Trial 14
Figure 17. Vessel Thruster Response & Trajectory Recording in Normal Operating Conditions 15
Figure 18. Vessel Thruster Response & Trajectory Recording in Submerged Operation Conditions 16
Conclusion 17
Acknowledgements 17
References 17

Introduction

As the demand of floating structure transportation increases, the business market of Heavy Lift Carriers also has grown gradually. The Heavy Lift Carrier is a vessel designed to transport various types of cargos such as a ship block, submarine, marine structure, etc. The DP (Dynamic Positioning) system is essential to perform these missions safely.

This paper describes the DP system developed for a submergible heavy lift carrier.

During the development process, the following characteristics of the Heavy Lift Carrier had to be considered:

- The Variety of Cargo: from a Small Ship block to a SEMI-Rig
- Submergible Operation Mode (Submerging Function): Which allows for draft variability from 6m to 21m
- Operators do not have any DP operational experience for this type of vessel

The DP controller has been designed so that it could handle the above characteristics through the following procedures:

- Defining the heavy lift operation scenario: Operation mode (Normal, Submerged)
- Defining the cargo operation scenario: Non-Cargo, Half Ship Block, User Define Block Condition
- Analyzing the hydro-dynamic effects associated with a given operating scenario.
  - -Wind/Current Load Analysis using CFD Analysis Tool Fluent 6.4
  - -Wave Load Analysis using Computerized Motion Analysis Tool: WADAM
- Designing the Semi-Adaptable PID Controller based on Operation Scenario
- Designing the Intelligent HMI (Human Machine Interface) for Heavy Lift Carrier Operator

The hydrodynamic characteristics of the vessel change depending on the operation modes. Hydrodynamic analysis is performed according this change; to do this a semi-adaptable PID Controller is applied to the Heavy Lift Carrier DP System. Semi-Adoptable PID Controller can change the PID gain automatically according to the operation scenario.

MAPS^{TM} is the product name of the DSME DP system that stands for Maneuvering Aids and Positioning System. The MAPS^{TM} was developed by DSME and Honeywell.

Heavy Lift Carrier: 50,000 DWT Block Carrier

The TPI Mega-Line Heavy Lift Carrier named “TPI MEGAPSSION” was constructed for operation in the Yellow Sea; between China and the South Korea. The mission of the TPI MEGAPSSION is the transportation of blocks of various vessels between Yantai in China and the DSME Okpo ship yard in South Korea. The trade route is shown in Figure 1.

Figure 1. Sea Route of Heavy Lift Carrier

Operation concepts and principals of the vessel are summarized as follows:

- Operation Concept: Block transport, Multi-purpose Heavy Structure Carrier
- Capacity: 63,000 DWT
- Function: Submergible - (block loading and unloading)
- Principal Dimension
  -Length: 191 m, Breadth: 63m, Design draft: 6.6m, Maximum Submerged draft: 22.0m
  -Control Device: Bow tunnel thruster(1) , Stern tunnel thruster (1), Twin electric propulsion
- Sensor: DGPS, GYRO, Flow Meter, Radar, Anemoemter
- DP System: DP Class 1

Figure 2 shows the seagoing scene of the Heavy Lift Carrier.

Figure 2. Heavy Lift Carrier; TPI MEGA PASSION

Operating Scenarios Defined

The first step in designing the DP system for the Heavy Lift Carrier was to define the operating scenarios. Well defined operating scenarios make the DP controller design process more reasonable. Each operating scenario definition considers the associated change or variation in draft and cargo.

A total of seven operating scenarios were considered in the design of the DP system for the heavy lift carrier.

Operating scenario details are shown in table 1.

Table 1. Operating Scenarios

Scenario	Draft	Cargo
Sea Going Condition	6.6m	Non Cargo, Half Ship Block Arbitrary Cargo
During Submerging	6.6m ~ 21m	Non Cargo Half Ship Block Arbitrary Cargo
After Submerging	21m	Non Cargo

Figure 3 shows the scene of the After Submerging scenario of the Heavy Lift Carrier. The submerging operation is used for block loading and unloading as well as ship launching. It takes almost 8 hours to change the vessel's draft from 6 meters to 21 meters.

Figure 3. Heavy Lift Carrier Submerging

Hydrodynamic Analysis

Hydrodynamic analysis is one of the most important steps in the development process of the Heavy Lift Carrier DP system, because the hydrodynamic analysis results are used for the input of DP controller.

Hydrodynamic analysis is divided into two parts:

- Wind/Current load analysis based on operating scenarios.
- Wave load analysis based on operating scenarios.

Table 2 shows the design environmental conditions.

Table 2. Environmental Conditions of Heavy Lift Carrier

	Condition
Wind	10m/sec
Current	1knot
Wave	Wave height: 4m Wave Period: 10 sec

The wind and current load analysis was performed using the commercial CFD code FLUENT. The finite-volume (FV) method is applied in this code. The flow field is subdivided into a finite number of control volumes (CVs). Figure 4 shows the calculation model for the non-cargo condition.

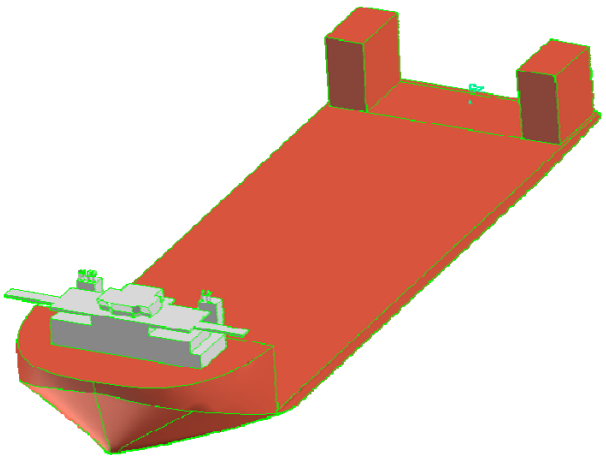


Figure 4. CFD Calculation Model without Cargo

Numerical analysis was done with various cargo conditions. Figure 5 shows the example of ship block cargo loaded on the Heavy Lift Carrier for numerical calculation.

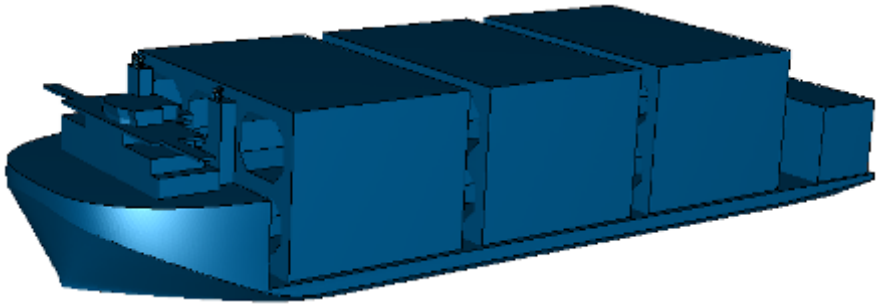


Figure 5. Calculation Model of the Cargo Loaded Condition

Figure 6 shows the wind flow pattern of the cargo loaded case calculated by FLUENT.

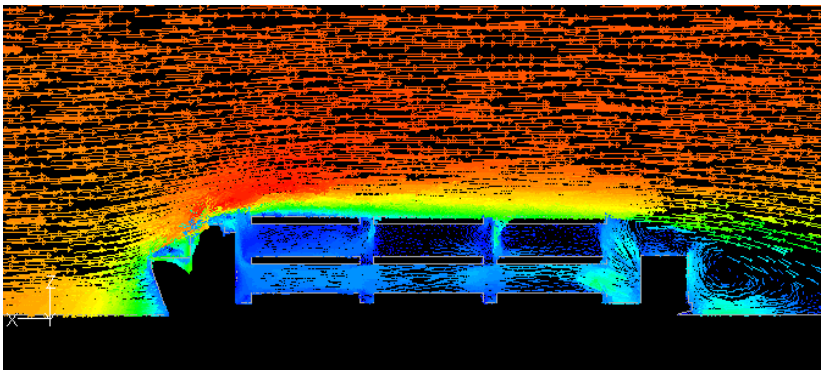


Figure 6. Wind Profile of the Cargo Loaded Condition

The calculations were performed for the different operating scenarios. Figure 7 shows the wind and current load coefficients that were analyzed by numerical calculation. Wind coefficients were calculated for various relative wind/current heading angles.

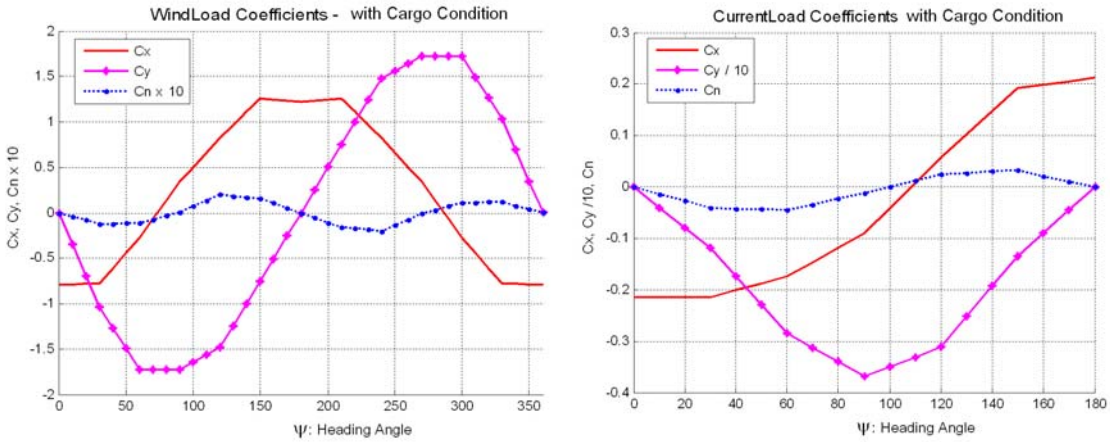


Figure 7. Wind & Current Load Coefficients with Cargo Condition

The wave load analysis was performed using the commercial code WADAM developed by DNV. The results from the wave load analysis include the Quadratic Transfer Function (QTF) and force Response Amplitude Operator (RAO), The force RAO was used to calculate the linear wave forces and the QTF was used to calculate the non-linear wave drift forces.

Figure 8 shows calculation results of the wave load analysis, QTF, and force RAO.

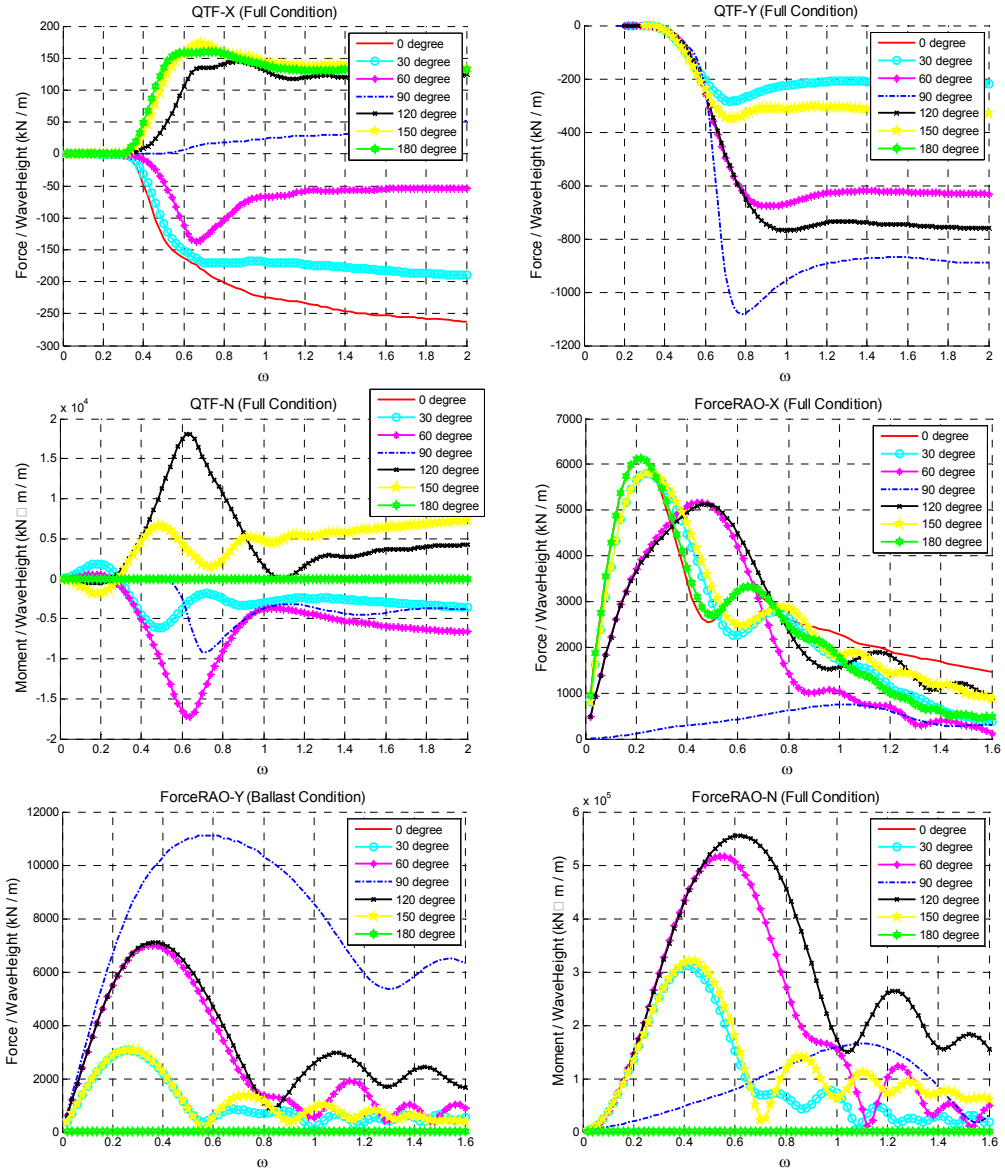


Figure 8. Wave Load Analysis Results

Controller Design

The controller design was based on the hy drodynamic analy sis results. The following controller design scheme was applied to our DP controller:

- Estimator: Extended Kalman Filter
- Controller: Adaptable PID controller based on hydrodynamic analysis results
- Controller Object Function: Minimizes fuel consumption

Figure 9 shows a simplified DP controller diagram for the vessel.

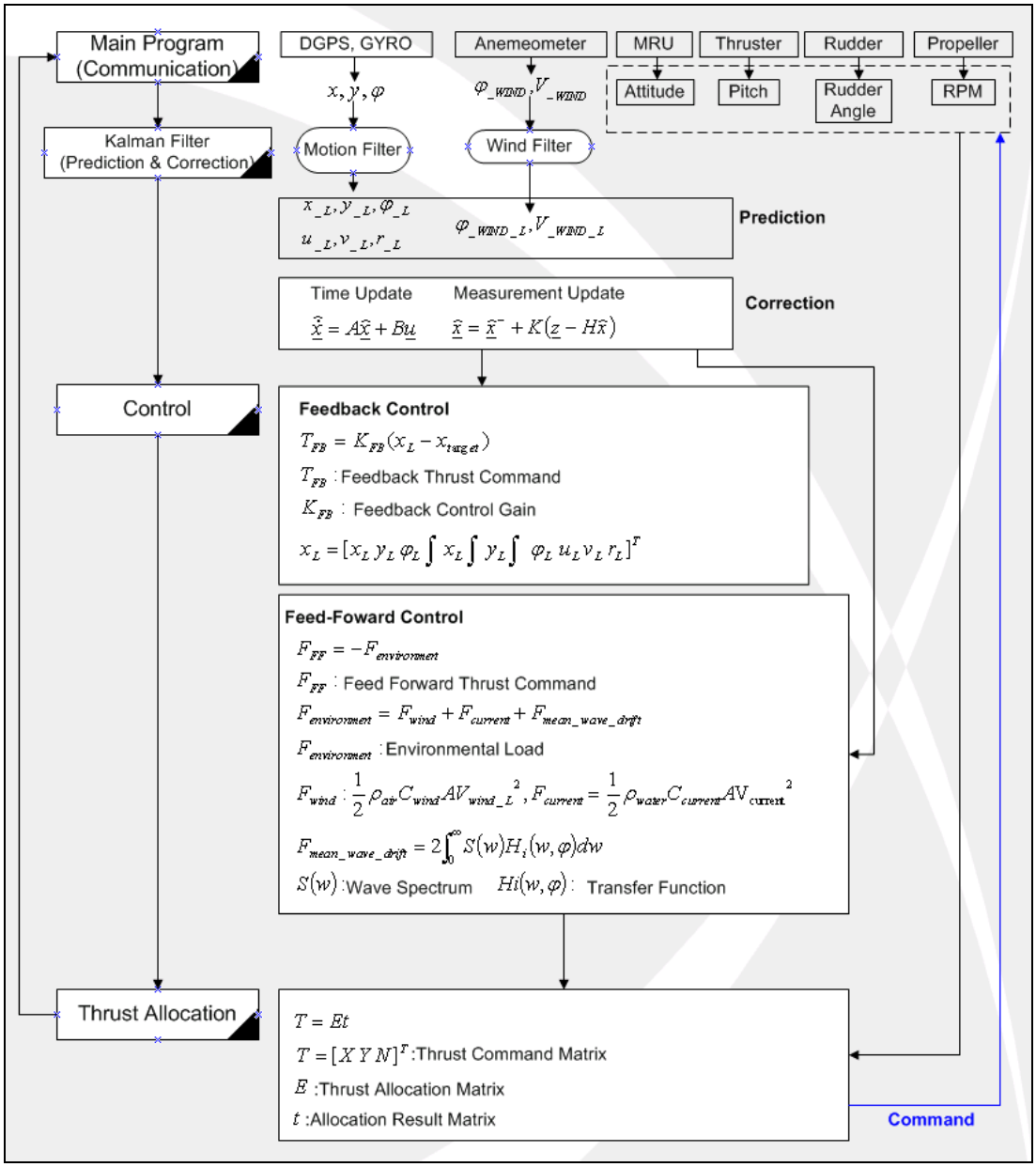


Figure 9. Simplified Heavy Lift Carrier DP Controller

Semi-adaptable PID controller is the special sche me of the DP control s ystem. In the 'standard' DP

vessel, draft is fixed during DP operation; however, in the case of the submerged Heavy Lift Carrier the draft could be changed. With the change of draft, a ship's wetted surface area is also changed and this affects the ship's environmental loads and hydrodynamic characteristics. This was taken in to consideration in the semi-adaptable PID controller. The semi-adaptable DP controller of the submerged Heavy Lift Carrier compensates for these changes by varying the PID gains according to the operating scenarios.

HMI (Human Machine Interface) Development Process

In the HMI development process, engineers intended to make a simple and easy to use HMI that would make the operator comfortable. So, an intelligent interface design method was applied for the heavy lift carrier's HMI.

An intelligent HMI is easy to learn and use. An intelligent HMI is very intuitive, so it could minimize human error and training time.

The needs of the operator are the key focus in the HMI design procedure.

We have divided the whole process of intelligent interface design into three phases: Analysis, Design, and Construction. This method is widely used in computer software development. [1]. Figure 10 shows the simplified HMI design process.

Figure 10. Simplified HMI Design Process

During the analysis phase, first the scope of operation and the operating scenarios were defined. Next DSME focused on understanding the operator and DP operation tasks; a field study and an operator survey were performed. The following user profile resulted from the study:

- Operator age: over 50
- Operator experience: operator does not have any experience of DP system.
- Software environment preference: Microsoft Window
- Operator needs: DP capability check for various cargo transport, user defined cargo sizes

In the design phase, all of th e infor mation from the analy sis phase w as applied in the HMI development. Table 3 shows the HMI improvements developed to satisfy operator characteristics and needs.

Table 3. User Profiles & HMI Improvements

User Profile	HMI Improvement
Operator age	Use the big font, clear message
Experience	Make the command flow very easy. Arrange the similar function
Preference S/W	Window
Needs	Capability Program/ User Defined Cargo Panel
Safety	Add safety steps for mis-operation

After the design phase, a proto type of the HMI was constructed. After additional HMI discussions with operators were conducted, their opinions were incorporated in to the second version of the HMI. These procedures were repeated until finally the HMI development was co mpleted. The final versio n of the HMI was installed on the vessel and used during FAT and sea trials.

Figure 11 shows one of t he final products that came from the intelligent HMI design procedure. With this panel, the operator can enter the car go information and then the DP controller will control the ship's positioning using user defined cargo information.

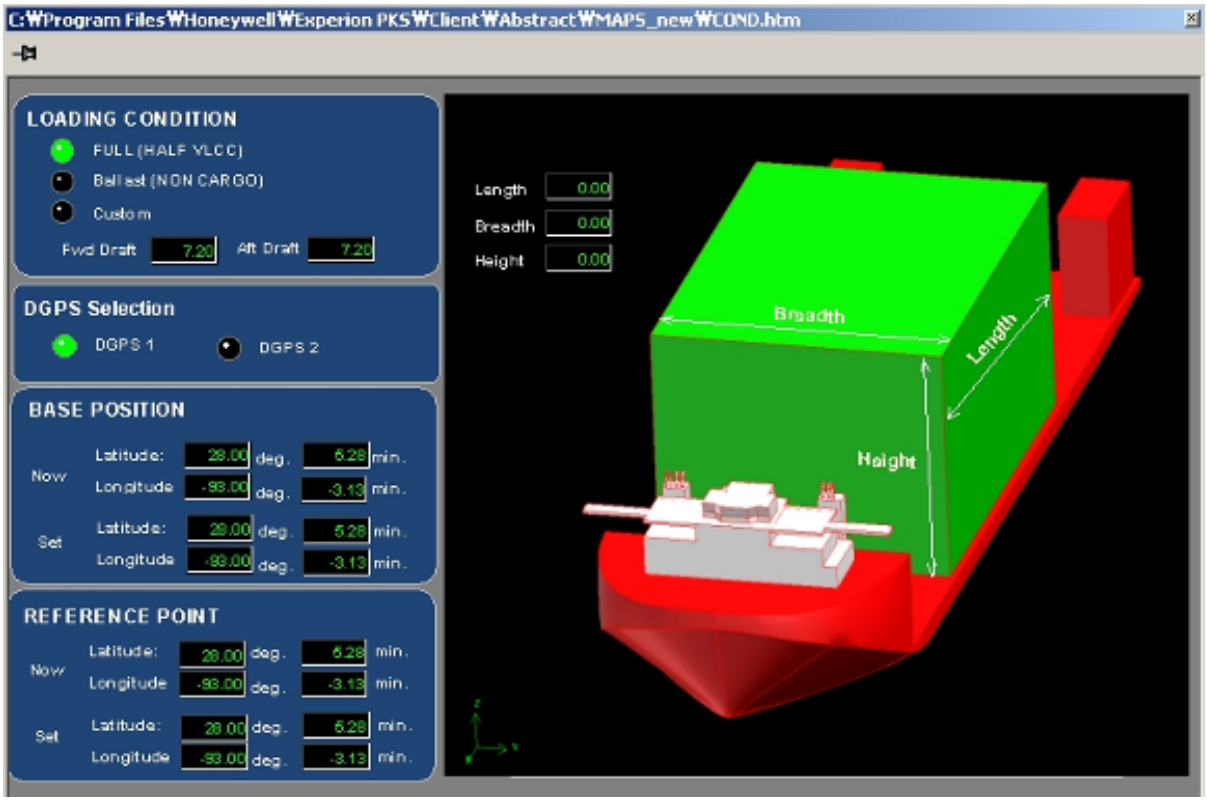


Figure 11. Shows the User Defined Cargo Panel

Simulator

The duration of the vessel's sea trials were short, due to the heavy lift carrier's tight building schedule. So a simulator was developed to minimize gain tuning time during sea trial testing. The simulator was based on a real DP System and simulated real time DP operations.

The si mulator was also used for sy stem validati on. Sy stem vali dation is an essential pro cess in minimizing the risks asso ciated with s ea trials and real world operation. All functions of the D P system were checked before sea trials.

Operator trai ning was per formed using the si mulator. 'How to o perate the DP sy stem' an d 'how to minimize the operation risk and human error' were included in the training program.

Time domain simulator is shown in Figure 12.

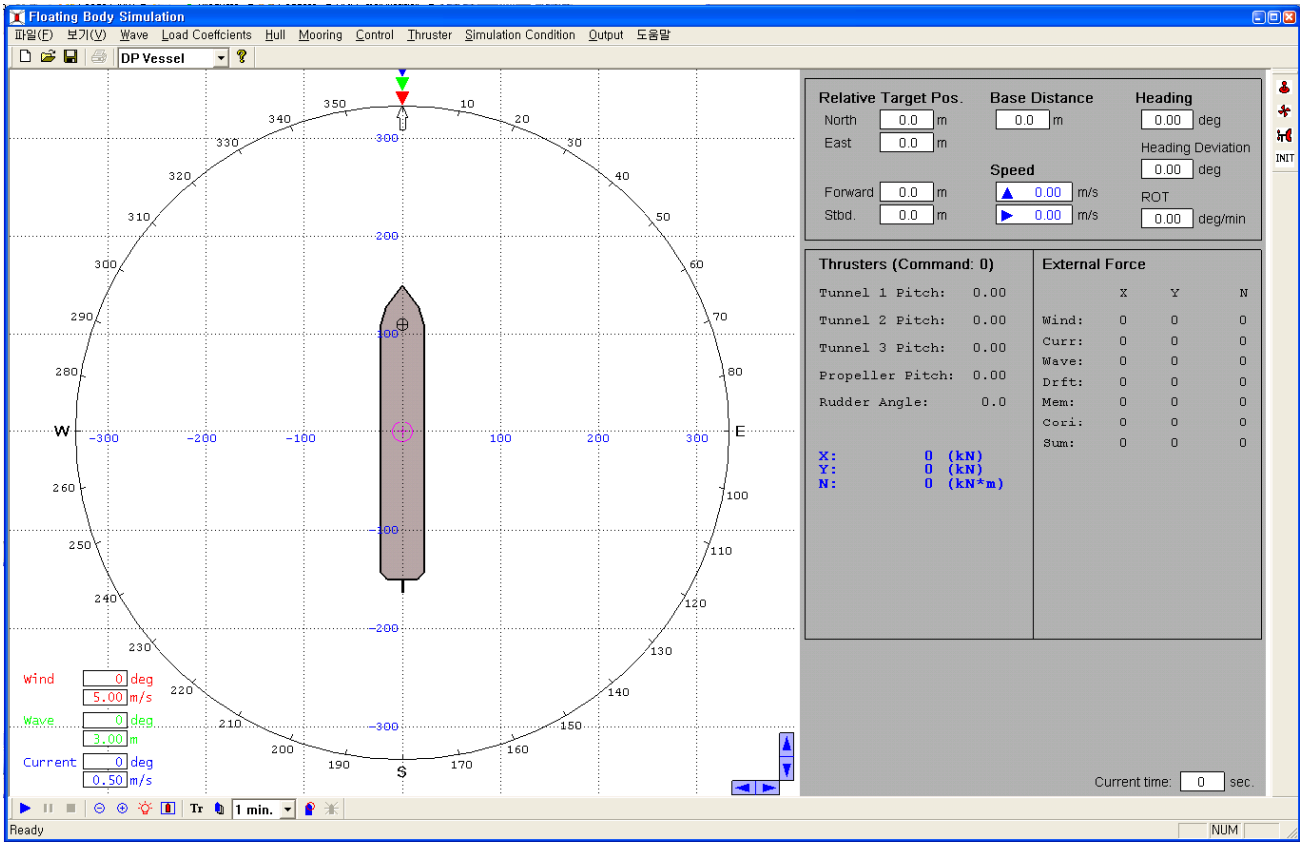


Figure 12. Stand Alone Heavy Lift Carrier Time Domain Simulator

DP System Hardware Configuration

The DP system hardware of the Heavy Lift Carrier consists of sensing devices, control devices, PLCs, and monitoring systems. Sensing devices consist of DGPS (for measuring vessel position), Gyro (for measuring vessel heading), Anemometer (for measuring wind speed), and direction control devices, which produce thrust for DP -- consisting of stern & bow thrusters, propellers and rudders. PLC (Programmable Logic Controller) is a digital computer used for automation of electromechanical processes. Control logic for the DP-system is arranged in the PLC. The operator monitors the status of devices and gives commands to the DP using the monitoring system, which consists of an operator station and an OIB (Operator Interface Board). Figure 13 shows a simplified hardware diagram of the heavy lift carrier.

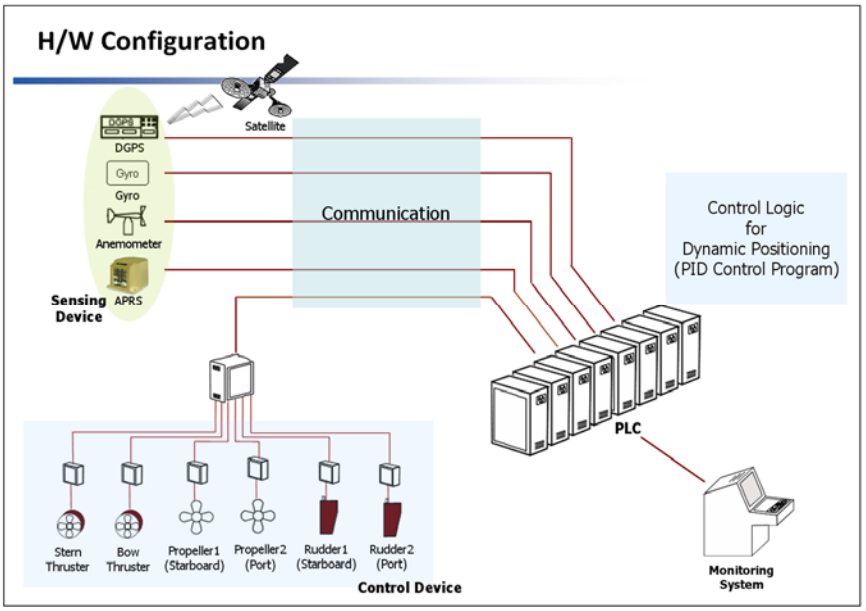


Figure 13. Hardware Concept Diagram

Figure 14 shows the DP station installed in the wheel house

Figure 14. OIB on DP Operation Station

Figure 15 shows the PLC and UPS installed in the wheel house cabinet.

Figure 15. PLC (Programmable Logic Controller) & UPS

Sea Trials

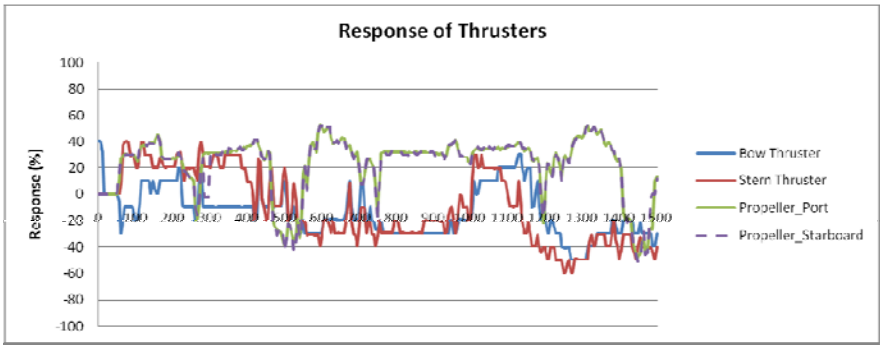
In May 2010, the MAPS DP test was carried out in 3 days during the sea trials. In the first two days of testing, PID gains were tuned then the Owner Acceptance Test was performed on the last day. The sea trials procedure consists of following tests:

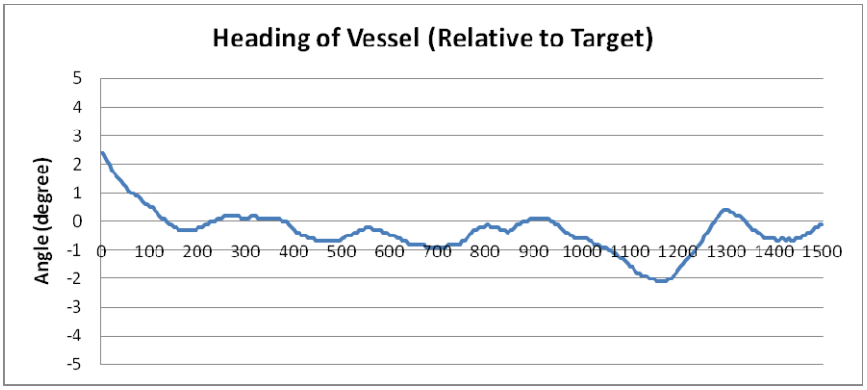
- Communication test: check the communication with sensor (DGPS, GYRO, Anemometer)
- Control device response test: check the response with bow thruster, stern thruster, propellers and rudders
- Manual mode test: check the manual function using OIB
- Automatic DP test: check the Dynamic Positioning function (Normal / Submerged Mode)

Figure 16 shows a scene of the sea trial.

Figure 16. Sea Trial

Figure 17 shows the recorded time histories of a tr ajectory during sea trials whil e in norm al operation conditions. The position keeping ability satisfied the design crit eria. Maxi mum trajectory deviation from the tar get was within the 10 m eters. Maxi mum error of heading was less than two degrees . Control devices used only 40% power.





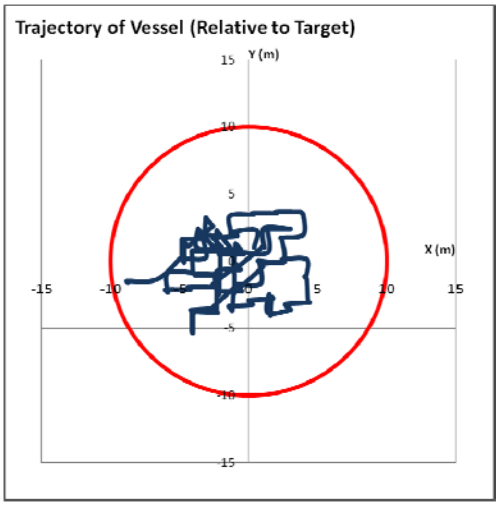


Figure 17. Vessel Thruster Response & Trajectory Recording in Normal Operating Conditions

Figure 18 shows the time histories of the vessel's trajectory recorded during the sea trials while in a submerged operation condition. The position keeping ability of the vessel was quite good in the submerged condition. Maximum trajectory deviation from the target was less the 10 meters with an error in heading below four degrees. In submerged conditions, the environmental load becomes higher than normal operation condition, so the required power for the control device is higher.

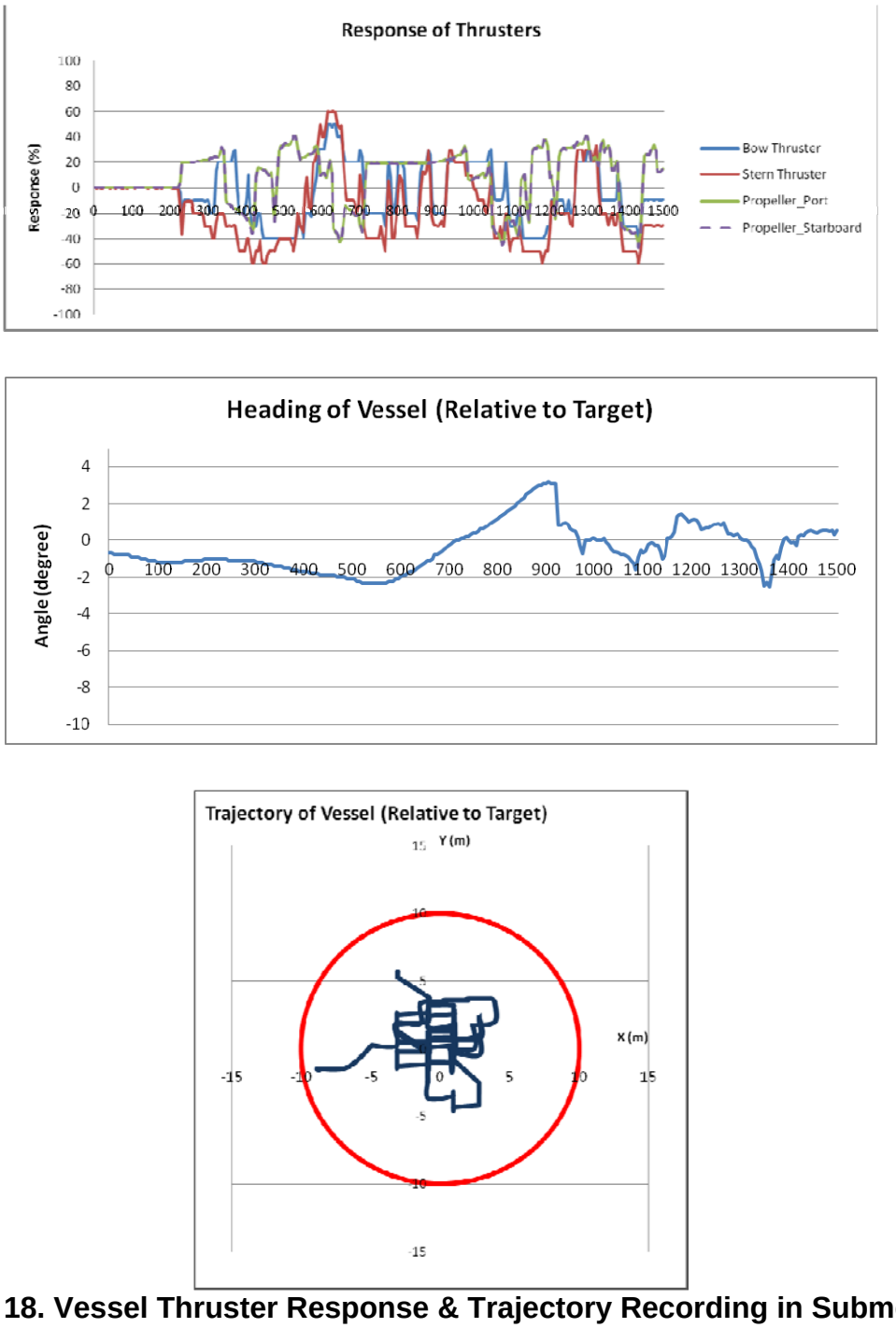


Figure 18. Vessel Thruster Response & Trajectory Recording in Submerged Operation Conditions

Conclusion

The DP system for the Heavy Lift Carrier was successfully installed and delivered to her owner after proving the positioning keeping abilities in the sea trials. These trails demonstrated that it was possible to hold vessel position in normal and submerging conditions.

To develop the smart DP controller a hydrodynamic analysis was performed. An intelligent HMI was created according to characteristics of heavy lift carrier. Then the system was validated in design state using the simulator.

This paper suggests the method to design a DP controller for a submerged heavy lift carrier. A DP developer could reference this research to design an adaptable PID controller.

If model tests are added to hydro-dynamic analysis in the design stage this could make a safer and more effective DP controller.

Acknowledgements

The author would like to thank the owner (TPI MEGA Line) and operator of the Heavy Lift Carrier (Mega Passion).

References

[1] Susan Weinsheunk, Pamela Jamar, Sarah C. Yeo. (1997), “GUI design essentials”, *Wiley Computer Publishing*

[2] David Bray FNI. (1990), “Dynamic Positioning”, *Oilfield Publication Inc.*

[3] Mohider S. Gerewal (2008), “ Kalman Filtering”, *Wiley*