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Joystick Control System for Domestic Product Oil Carrier " SHIGE MARU "

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Abstract: Recently, Japanese National Maritime Research Institute (NMRI) has been studying the engineering for energy and labor saving in vessel's operation, especially for domestic merchant tanker. In 2007, a domestic product oil carrier 'SHIGE MARU' was built to demonstrate this national eco-project. One of the main characteristics of this vessel is system integration and simplification of operation to reduce the operator's burden than ever before. This domestic product oil carrier visits ports around the country very frequently. Then, it was required to simplify its operation for safety and reduce the amount time to enter / leave port.

The harbor operation, leaving / entering port and berthing, is very stressful and hard work for crew because it is required to control the ship very carefully, and it becomes difficult to control the ship at a low velocity. Especially during berthing operation, the ship's velocity has to be kept in dead slow, then the ship's maneuverability becomes worse. The operator has to control all actuators (propeller, rudder, thruster and so on) at simultaneously and handle an anchor to approach the appointed berth safely.

To meet this requirement, Mitsui Engineering & Shipbuilding co., ltd. (MES) installed the Joystick Control System (Mitsui Ship's Maneuvering Control System : MMCS). MMCS makes the vessel's control easy by consolidating and simplifying the man-machine interface to pilot the vessel. This MMCS is called as 'e-Driver' by the vessel's operator, EIYU KAIUN co., ltd., and it was proved that MMCS is very useful system in the actual operation.

In this paper, the main characteristics and actual performance of MMCS are shown.

Keywords: *Eco-project, Safety, Mitsui Ship's Maneuvering Control System (MMCS)*

1. INTRODUCTION

Recently, in Japanese domestic shipping industry, the number of crew is decreasing to save the cost because of the requirement to reduction of cost for transportation. Additionally, it is also demanded to shorten the necessary time. Accordingly, the workload of each crew has been increasing, and ensuring safety becomes more pressing problem than before.

Japanese National Maritime Research Institute (NMRI) has been studying the engineering for energy and labor saving in vessel’s operation, especially for domestic merchant tanker. As a technical approach for this issue, a domestic product oil carrier ‘SHIGE MARU’ was built in 2007 to demonstrate this national eco-project. One of the main characteristics of this vessel is system integration and simplification of operation to reduce the operator’s burden than ever before. This domestic product oil carrier visits ports around the country very frequently. Then, it was required to simplify its operation for safety and reduce the amount time to leave / enter port.

To meet this requirement, Mitsui Engineering & Shipbuilding co., ltd. (MES) installed the Joystick Control System (Mitsui ship’s Maneuvering Control System : MMCS). MMCS makes the vessel’s control easy by consolidating and simplifying the man-machine interface to pilot the vessel. This MMCS is called as ‘e-Driver’ by the vessel’s operator, EIYU KAIUN co., ltd., and it was proved that MMCS is very useful system in the actual operation.

2. ECO-PROJECT FOR DOMESTIC MERCHANT VESSEL

The harbor operation, leaving / entering port and berthing, is very stressful and hard work for crew because it is required to control the ship very carefully with not only keeping watching other ship’s motion in very congested area but also preparing for loading. Especially, during berthing operation, the operator has to control all actuators (propeller, rudder, thruster and so on) at simultaneously and handle an anchor to approach the appointed berth safely, at a specified time.

In the conventional berthing operation, it takes a long time to approach the berth with anchoring or controlling each actuator individually and manually by the operator, and sometime the ship has to have the assist by tag boats.

Then, the workload of each crew in this phase is very high. As one of the engineering solution to reduce this workload, MES proposed to install MMCS to integrate several actuators’ control automatically and simplify the crew’s operation. MMCS makes it possible to shorten the necessary time for entering / leaving port or berthing operation, and also it will contribute to improve the safety in the ship’s operation.

2.1. Principal Dimensions

The principal dimensions are shown in Table 1, and the general arrangement is shown in Figure 1.

Table 1 Principal Dimensions

Length (Lpp)			98.0 (m)
Breadth			16.0 (m)
Draft			6.4 (m)
Dead Weight			4999 (ton)
Complement			11 (persons)
Main Engine	Output	Service	1,238kw / 909min^{-1}
		Max.	1,650kw / 1,000min^{-1}
	Unit	Unit	2

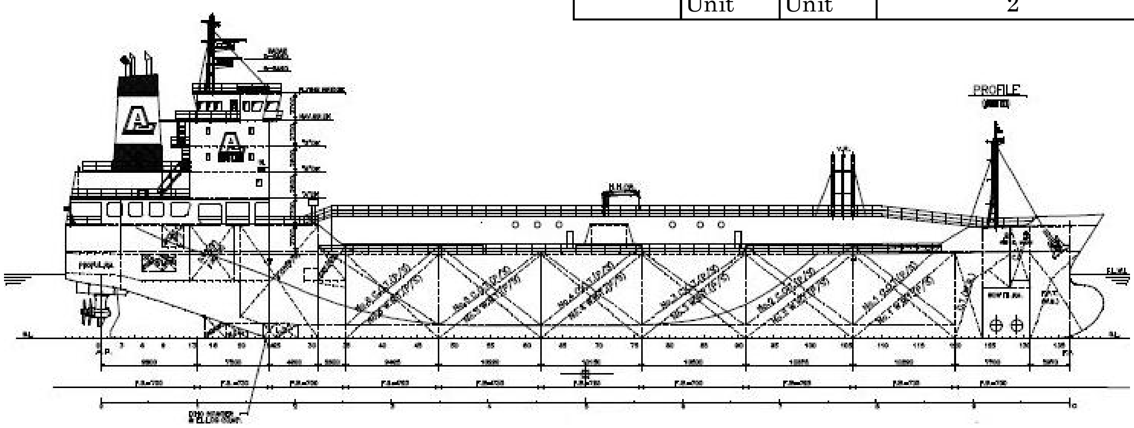

Figure 1. General Arrangement of “SHIGE MARU”

2.2. Bow Thruster and Azimuth Propeller

This ship has 2 Contra Rotating Propeller (C.R.P.) type Azimuth Propellers and 2 Bow Thrusters as shown in Figure 2 and Figure 3. Each azimuth propeller is driven by main diesel engine respectively. When the ship is navigated with slow speed, slipping clutches will be used during MMCS operation because it is necessary to control their propeller speed strictly in low speed range. By using these flexible propulsion systems, it becomes possible to progress the ship's maneuverability.

< C.R.P. type Azimuth Propeller : 2 Units >

- Propeller Diameter : 2.47m (Fore propeller), 2.34m (Aft propeller)
- Maximum Propeller Speed : 135min.$^{-1}$ with slipping clutch
  250 min.$^{-1}$ driven by engine directly
- Maximum Thrust (Bollard) : 11 ton with slipping clutch
- Number of Blade : 4 (Fore propeller), 5 (Aft Propeller)

< Bow Thruster : 2 Units >

- Propeller Diameter : 1.15 m
- Maximum Propeller Speed : 559 min.$^{-1}$
- Maximum Thrust : 4 ton
- Number of Blade : 4

Figure.2 Outline of Azimuth Propellers

Figure.3 Outline of Bow Thrusters

3. JOYSTICK CONTROL SYSTEM "e-DRIVER"

3.1. Required Functions of MMCS "e-Driver"

The main characteristics of MMCS installed in "SHIGE MARU" are as follows.

- Integrate all actuators (Bow Thrusters and Azimuth Thrusters) to reduce the work load of one-man operation.
- Heading / position is controlled automatically.
- Make it possible to carry out effective training by using on board simulator.

3.2. Controlling Logic

In the control diagram for this MMCS, controlling forces are determined to minimize the deviation from the target position and heading against the external disturbances. These forces consist of feed forward forces and feed back ones. Feed back forces are calculated based on the deviation of position and heading using PID (Proportional Integral Derivative) control theory. PID theory is simple, but very reliable proven technique. On the other hand, the feed forward forces are obtained using the wind speed and direction measured by anemometer. This controlling calculation is carried out every 0.5 (sec.).

A number of numerical simulations had been carried out to find the most suitable parameters for controlling gain, and the comprehensive control performance was confirmed in sea trials under several weather conditions.

3.3. System Configuration

The system configuration of MMCS is show in Figure 4. In this MMCS, there are 3 control stations (Port / Starboard side and Aft in bridge) except for Master Panel. Each control station becomes available by connecting the Portable Control Box as shown in Figure 5 and Figure 6.

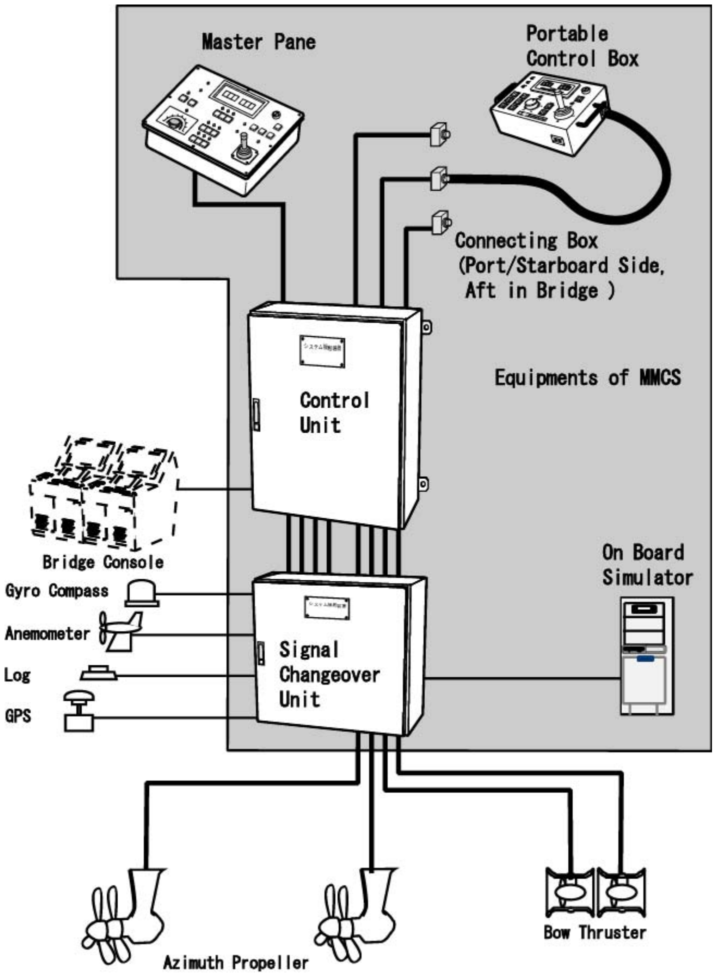

Figure 4. System Configuration of MMCS “e-Driver”

Figure 5. Control Station
(Master Panel)

Figure 6. Control Station
(Portable Control Box)

4. CONTROLLING FUNCTIONS

The MMCS has several useful controlling functions for berthing operation. The characteristics of main functions are as follows.

4.1. DP Mode

In DP mode, all thrusters and propellers are controlled automatically to keep the ship’s motion steady and minimize the deviations of position and heading from the target (DP point and heading) under external disturbances (wind, wave, current etc.). Basically, it isn’t required for operator to operate each actuator manually. Figure 7 shows the conceptual outline of this mode.

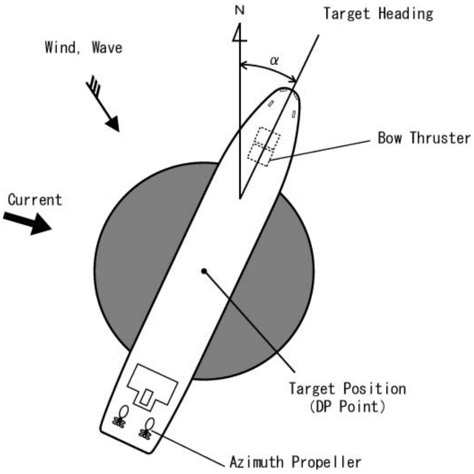

Figure 7. Outline of DP mode

4.2. Auto Head Mode

In Auto Head mode, ship’s heading is kept on the target, and ship will move toward to the ordered direction by using the joystick manually.

4.3. Joystick Mode

In Joystick mode, it is possible to control ship’s motion using the joystick and turning dial at the control station. The calculation of thrust’s distribution is carried out by MMCS, then the operator can control ship’s maneuvering without considering the balance of thrust. Figure 8 shows the conceptual outline of this mode.

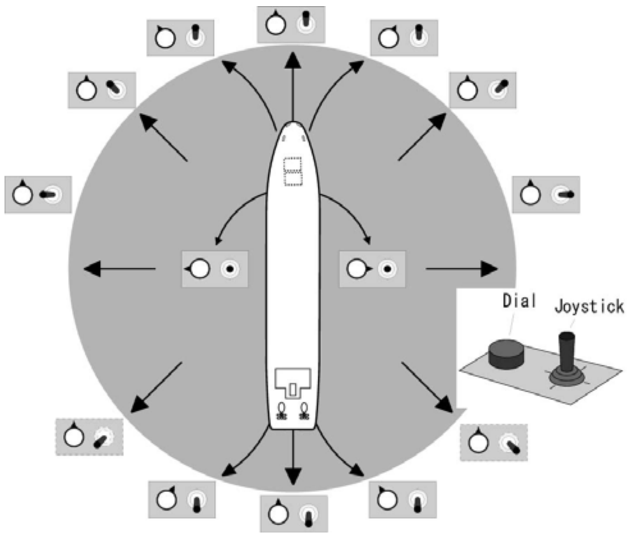

Figure 8. Outline of Joystick Mode

4.4. Tracking Mode

In Tracking mode, ship’s location, speed and heading are controlled automatically with high accuracy based on the route data edited by operator in advance using electric marine chart (EMC). In the route data, it is possible to set the DP point and heading to maintain ship’s position on the end point after the tracking navigation.

4.5. Simulation Mode

Simulator computer is included in the system configuration. In this simulator, not only ship’s motion but also external disturbances (wind, wave, current) are simulated, and simulated ship’s maneuvering is over displayed on EMC. Then, operator can conduct the practical training of MMCS operation on board.

5. ENTERING / LEAVING PORT AND BERTHING OPERATION

After the ship “SHIGE MARU” was delivered, MMCS has been used in all harbor operation at many ports of Japan and contributed to improvement in efficiency. Examples of MMCS operation are shown as follows.

5.1. Operation with Conventional Configuration

In conventional ship, each actuator (propeller, rudder etc.) are controlled respectively and manually by operator during the harbor operation. In harbor, it is required for the operator to keep watching around at any time, and to get ready to prevent any dangerous situation before something happens. Usually, ship’s harbor speed is defined as very slow speed to stop immediately if necessary, but the maneuverability becomes worse when ship’s speed is decreased.

In the berthing operation, the tug boat’s support or anchoring operation (laying down anchor) is necessary to turn heading or drift to approach to the berth safely. Along with this phase, tug boat’s support or anchoring operation (pulling up anchor) is required to leave from the berth. During this operation, it is impossible for the ship to control itself, because rudder doesn’t work well without speed. This operation will take about 10 minutes. These operations are very stressful, and they will take a little long time.

5.2. Operation with MMCS in "SHIGE MARU"

On the other hand, SHIGE MARU can be navigated in harbor faster than conventional ship, because her stopping ability is much better by using actuators with high flexibility. And, she doesn't need to have any tug boat's support or anchor operation because she can move in any direction by using only joystick and dial of MMCS. Then, it becomes possible to carry out the entering / leaving and berthing operation smoothly and simply without any interruption. Additionally, it also becomes needless to handle mooring lines before berthing alongside a pier. Therefore, the necessary time for harbor operation is shortened, and operator's workload is also decreased.

Accordingly, it becomes possible to shorten about 50% - 70% of the amount of time for harbor operation by using MMCS compared with conventional system.

Figure 9 is an example of trajectory in the harbor operation.

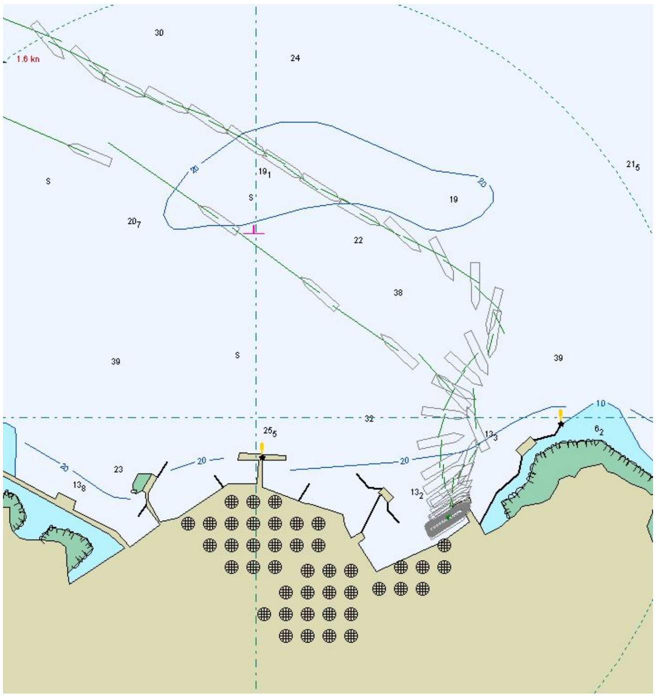

Figure 9. Example of Trajectory in Entering / Berthing and Leaving Operation

It is possible to say that the characteristics in the operation using MMCS and actuators with high flexibility are as follows.

- High maneuverability in low speed navigation.
- Simplified devices to control several actuators automatically and simultaneously.
- Self-supported operation without any assist.
- Prior training using onboard simulator.

5.3. Position Keeping Operation with MMCS

Figure 10 shows a trajectory during position keeping operation in DP mode. In this figure, it is found that ship's position is controlled well on the specified point. For example, by using DP mode to stand by at off-port area, it becomes possible to omit the workload to lay down / pull up anchor. Therefore, the necessary time for entering port will be shortened and ship's operation becomes more flexible and simpler.
SHIGE MARU can keep her position automatically by using MMCS in DP mode. For example, DP mode is used to stand by off-port area without laying down anchor. Then, she can start the entering port operation, and also can shorten the necessary time for the operation. Figure 9 shows a trajectory of position keeping and starting to leave the port.

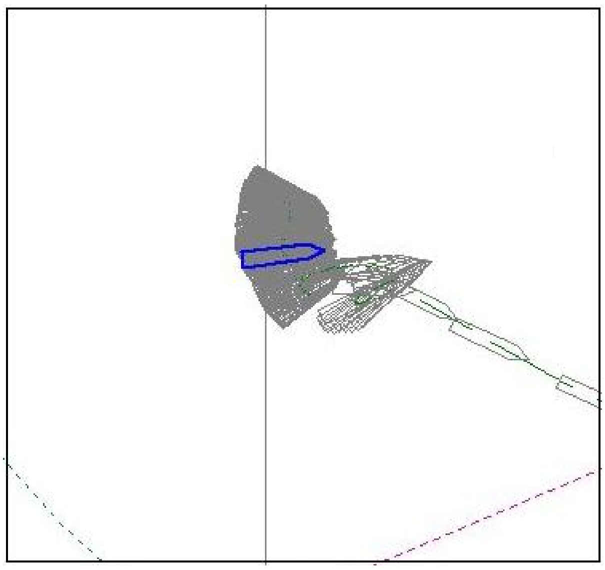

Figure 10. Trajectory of Position Keeping and Starting to Leave the Port

6. CONCLUSIONS

According to the record of actual operation, it was confirmed that MMCS is useful to simplify the ship's operation especially for harbor operation, entering / leaving port or berthing. MMCS contributes the safety operation with high maneuverability by integrating all flexible propulsion system installed in SHIGE MARU. Therefore, it became possible for operators to navigate the ship with staying on the safe side. Additionally, the necessary time for harbor operation was shortened and the crew's workload was drastically reduced.

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