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Development of labor saving support system based on ship onboard operation modeling for super-eco ship

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The global warming problem becomes serious in the world. The Japanese Government has formalized the acceptance of Kyoto Protocol on 4th of June, 2002. Under the Protocol, Japan has an obligation of greenhouse gas emissions reduction of 6% below 1990 levels for the first commitment period of 2008-2012. The Super Eco-Ship Project is conducted by the National Maritime Research Institute of Japan (NMRI) as a national project from April, 2001, controlled by the Ministry of Land, Infrastructure and Transport. The Super Eco-Ship would embody a technical breakthrough in meeting certain requirements of coastal shipping such as reducing the burden on the environment and the logistics costs and improving the living and working conditions on board. Super eco-ship has highly efficient electrical propulsion system featuring the podded propulsor with contra-rotating propeller (CRP). Advanced concept and systems are applied in the research and development of the Super Eco-Ship. Flexibility in the arrangement of main engine and in the hull form design is realized by the electric propulsion system. New design tools based advanced concept and methodology are applied. Hull form design method by means of CFD simulation and CAD are performed to design optimum hull form for electric propulsion system. The high propulsive efficiency due to the combination with the optimum hull design and podded propulsor enables the reduction of CO2 compared with the conventional ship.

The podded propulsor with CRP enables drastically good maneuverability and flexible control system in ship operation as well as high propulsive efficiency. A captain or a pilot makes an easy operation during berthing by using the control device of the podded propulsor. Crew members are engaged in various works throughout all the onboard operational phases, i. e., loading/unloading, mooring, berthing, anchoring and navigation. In order to reduce work loads of crew members, labor-saving support systems are designed to help a basically single operator at each work position, such as a navigation bridge, a bow deck, a stern deck and a cargo deck, to execute each assigned mission.

Onboard ship works are modeled throughout all the operational phases. A typical navigation scenario is selected that represents various works involved in the navigation. According to the scenario, time series of work contents and crew assignments in a conventional ship are drawn as a basic onboard work model. To minimize the crew members and their work loads, functions of the labor saving support system are decided. Navigation according to the typical scenario by the minimized crew members is simulated and compared with that of the conventional ship.

Keywords: *Super Eco-Ship (SES), Labor saving support, Onboard work modeling, Comparison between conventional Ship and SES, Development of labor saving functions*

1. INTRODUCTION

As one of the main target of the development in the Super Eco-Ship (SES) Project of Japan, the development of labor saving functions has been executed. Coastal transportation has been suffering from serious defection of mariners. To activate the coastal transportation, various developments have been promoted under the Ministry of Land, Infrastructure and Transport (MLIT). National Maritime Research Institute (NMRI) was engaged in design and software development on labor-saving functions of support systems for reduction of onboard works and improvement on marine safety budgeted by MLIT.

We focused on labor-intensive work phases, such as bridge navigational watch, berthing, mooring and cargo handling. [Numano, M. (2005)] In each work phase, works of one operator with an appropriate support system are modeled and necessary functions are pointed out taking adequate work load and sufficient safety into account.

NMRI has been cooperated with a shipping company, EIYU Kaiun Co., Ltd., engaged in coastal transportation who had planned to build a demonstration ship equipped with almost full functions of the designed support systems. The target ship is a refined oil carrier, 6,500 kL type, with mechanical driven twin podded CRP propulsor, 11 members of crew, as a conventional ship.

In this paper, onboard works according to a typical navigation scenario were modeled for a conventional ship. Afterward, according to the same scenario, works on the SES with an appropriate support functions are modeled and work loads of both types were estimated and compared.

The designed support functions were developed and equipped on the demonstration ship "Shige-maru" belonging to EIYU Kaiun Co., Ltd.. The images of the actual support systems are shown.

2. SHIP NAVIGATION MODELING

Onboard works are classified in various work phases as shown in Table 2.1. All works onboard are assigned to crew members according to work load, skill and qualification of each member. At a berthing phase, for example, all members are assigned to make a safe and effective touch-down to a pier as shown in Fig. 2.1, so eleven is a minimum number of crew members in a conventional target ship.

For the safety in navigation, it needs at least two crew members in the ordinary bridge navigational watch and one crew member as an anchoring watch by the regulations. The reduced crew members' operation of SES should be appropriately arranged in case of the practical use according to the related regulations.

The onboard works in each phase is analyzed in Chapter 3. Onboard works are modeled in Chapter 4 according to this classification, this assignment and the analyses in Chapter 3.

Table 2.1 Onboard Work Classification

Work Code	Work Contents
a	Stand By
b	Ordinary Navigation
c	Special Navigation
d	Cargo Handling
e	Anchoring
f	Maintenance
g	Catering
h	Crew Meeting
i	Communication to Land
j	Desk Work
k	Others

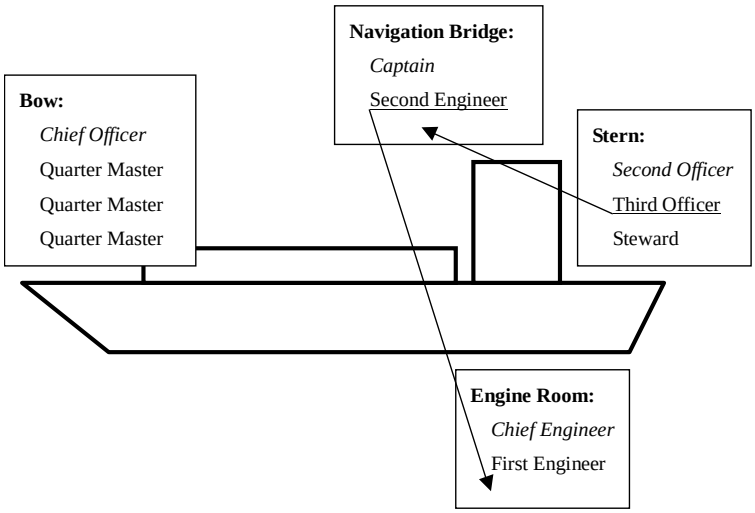

Fig. 2.1 Crew Assignment at Berthing Phase for Conventional Ship (11 members)

3. LABOR SAVING FUNCTIONS IN EACH ONBOARD WORK PHASE

The navigation of the target ship is comprised of a time series of work phases; cargo handling, berthing, ordinary navigation, (anchoring), berthing, mooring and cargo handling again. Works on the conventional ship are analyzed and labor-saving functions are considered to reduce assigned crew members in each phase.

3.1. Ordinary Navigation Phase

Bridge navigational watch in the ordinary navigation phase is comprised of at least two members of deck crew to establish appropriate look-out.[STCW Convention (1978, 1995)] The navigation support system takes part in the watch keeping work to assure continuous look-out of an officer of the watch (OOW).

The support system provides navigational alerts to dangers of collisions and groundings with RADAR/ARPA (Automatic Radar Plotting Aids), AIS (Automatic Identification System) and ECS (Electronic Chart System) through speech communication interface. It realizes a position-free and eye-free communication between a human operator and the support system. One crew member and the support system can make safe and effective navigational watch compatible with the designated look-out in the STCW Convention.

3.2. Berthing Phase

Berthing phase is lying between navigation phase and mooring one. Work position of each crew member is assigned according to the succession of work phases. Almost all members are involved in this phase. Support system for the berthing phase is designed for one crew member in each position; bow, stern, bridge and engine control room to be able to carry out each role by oneself. For the safety in case of emergency, two members should be assigned to each position actually. There needs a powerful maneuvering system that enables a constant heading maneuver at low speed with a joystick control device to the almost all directions; forward, backward, rightward and leftward. [Murata, K. (2009)]

3.3. Mooring Phase

Mooring phase is lying between berthing phase and cargo handling one. Works in the conventional ship are complicated and composed of various labor-intensive sub-works. Non-jammed winches and light-weight mooring rope enables for one crew member to carry out each role at bow and stern. The work load of this phase can be reduced by berthing maneuver performance, i. e.; an excellent berthing maneuver performance gives direct touch to the pier without any mooring operation.

3.4. Anchoring Phase

Anchoring phase is needed for adjustment of time schedule; wait for cargo handling start time. In the anchoring phase, watch keeping is also needed for safety against sudden weather change and unexpected movement of own ship and neighboring anchored ships. An appropriate alarm system reduces bridge watch keeping works that can call an assigned crew member and other members in case of emergency. For an appropriate anchor performance, anchor position databases that include precise positions, depth and sea base conditions, measurements on the anchor chain length should be supported.

3.5. Cargo Handling Phase

Cargo handling phase, especially in liquid cargo carriers, is one of the most labor-intensive works onboard. According to the cargo handling plan, an appropriate pipe-line setting and sequential cargo handling process should be needed to keep safe and effective operations. Remote monitoring, control valves and pumps are now available to be equipped onboard. An appropriate cargo handling plan that decides the actual cargo handling works gives actual handling processes with safety instructions. Support system is designed to control the whole cargo handling sequence by one in the control position and one on the cargo deck.

4. ONBORAD WORK MODELING

4.1. Typical Navigation Scenario

A typical Navigation scenario is selected that starts at navigation to loading port and ends at leaving to the next loading port as shown in Table 4.1. It is comprised of various works in three days and thirteen hours (85 hours). According to the crew assignment and the scenario, onboard works are assigned to crew members and executed sequentially and/or in parallel.

4.2. Onboard Work Modeling of Conventional Ship

According to the typical scenario, onboard works of the conventional Ship (11 members) are modeled as shown in Tables 4.2. The crew assignment is decided based on Fig. 4.1, taking work load (working hours) of each crew member into account.

A crew of the conventional ship is comprised of Captain, Chief Officer, Second Officer, Third Officer, three quarter masters, Chief Engineer, First Engineer, Second Engineer and Chief Steward.

Typical constraints are:

(1) Working hours of each member per day should be less than 8 hours.

(2) At least one officer or engineer should be assigned to all work places.

(3) At least two members are assigned to all work places.

Work Place	Cargo Handling	Leaving Port	Ordinary Navigation	Arriving at Port	Cargo Handling
Bridge		2	2(3)	2	
Bow		4		4	
Stern		3		3	
Engine Room		2	(1)	2	
Cargo Deck	3--6				3--6
Others	1				1

Fig. 4.1 Crew Assignment for Conventional Ship (11 members) in Principal Navigation

Table 4.1 Typical Navigation Scenario

Days	Work Phase	Accumulated Hours	Event	Interval Hours
First Day 00:00	Leaving Loading Port	Start 1.0	Gas Free	1.0
	Draft Condition: Ballast Navigation Distance: 337 NM Average Speed: 13 KT			
Second Day	Navigation: 26h			25.0
	Arrival at Loading Port			26.0
03:00				27.0
	Anchoring			
08:30				32.5
09:00				33.0
10:00	Berthing			34.0
11:00				35.0
	Loading			
16:00				40.0
17:00	Leaving Berth			41.0
17:30	Leaving Port			41.5
Third Day	Draft State: Full Navigation Distance: 337 NM Average Speed: 12 KN			
	Navigation: 28 hrs	68.5	Preparation for Unloading	27.0
21:30	Arriving at Unloading Port	69.5	Arrival and Anchoring Stan By (S/B) in Port – Cast Anchor	1.0
22:30	Anchoring	70.5	Anchoring Start	1.0
Fourth Day		77.0	Meeting before Berthing	6.5h
05:30		77.5	Berthing S/B – Draw Anchor – Shift Start	0.5h
06:30	Berthing	78.5	Finish Berthing - Waiting for Unloading	1.0h
07:00	Unloading	79.0	Meeting for Unloading - Unloading Start	0.5h
12:00		84.0	Finish Unloading	5.0h
12:30	Leaving Berth	84.5	Finish Unloading Documentation – Leaving Berth S/B – Leaving Berth	0.5h
13:00	Leaving Port	85.0	Leaving for Loading Port	0.5h
	Navigation to the next Loading Port			

Table 4.2 Example of Work Contents of Conventional Ship (First Day)

Phase Code	Work Phase	Work Contents	Required Time (hours)	Captain	Chief Officer	Second Officer	Third Officer	Quarter Master A	Quarter Master B	Quarter Master C	Chief Engineer	First Engineer	Second Engineer	Chief Steward	Total Man* Hour
a	Stand By	Leaving S/B	0.5	BR 0.5	BW 0.5	ST 0.5	ST-BR 0.5	BW 0.5	BW 0.5	BW 0.5	ER 0.5	ER 0.5	BR-ER 0.5	ST 0.5	5.5
b	Ordi. Nav.	Coastal Nav.	23.5	BR 5.5	BR 7	BR 7	BR 7	BR 5	BR 5	BR 5		BR 1	BR 2	BR 2.5	47
d	Cargo Hand.	Completion	(0.5)			BR 0.2		UD 0.5	CPR 0.5	UD 0.5	ER 0.5	ER 0.5	ER 0.5		3.2
d	Cargo Hand.	Gas Free Start	(0.8)					UD 0.8	CPR 0.8	UD 0.8	ER 0.3	ER 0.5	ER 0.5		3.7
k	Others	Cleaning	(1.0)					POST 0.3	POST 0.3	POST 0.3			POST 1		1.9
k	Others	Measurement of Fresh Water	(0.2)						ST - Office 0.2						0.2
i	Comm. to Land	Main Office, Agents, etc.	(0.2)	BR 0.2							BR 0.1				0.3
j	Desk Work	Loading Plann.	(0.5)		BR 0.5										0.5
f	Maintenance	Deck Part	(1.0)					UD 1	UD 1						2
f	Maintenance	Engine Part	(4.5)								ER 3.5	ER 3.5	ER 3.5		10.5
b	Ordinary Nav.	M0 Check	(1.5)								ER 1.5				1.5
j	Desk Work	Log Book, ISM Documents, etc.	(0.5)	PR 0.5		PR 0.2	PR 0.2				PR 0.5	PR 0.5	PR 0.5		2.4
c	Special Nav.	Narrow Channel	(1.5)	BR 1.5								ER 1.5			3
g	Catering	Cooking	(5.0)											DK 5	5
		Total Work Load of First Day	24	8.2	8	7.9	7.7	8.1	8.3	7.1	6.9	8	8.5	8	86.7
		Work Load per Member													7.9

(Parenthesized numbers in the required time are included in the ordinary navigation hours.)

(Abbreviations: BR; Bridge, ER; Engine Room, BW; Bow, ST; Stern, UD; Upper Deck, CPR; Cargo Pump Room, POST; Posted Place, PR; Private Room, DK; Dining Room and Kitchen)

4.3. Onboard Work Modeling of SES

According to the typical scenario, onboard works of SES are modeled. A crew of SES is comprised of Captain, Chief Officer, Second Officer, Third Officer, Chief Engineer, First Engineer, Chief Steward. Crew members are assigned to work places; a navigation bridge, a bow, a stern, a cargo deck and an engine room, taking the analyses in Chapter 3 into account.

4.4. Comparison between Conventional Ship and SES

Work load of the conventional ship is summarized in Tables 4.4-1 and 4.4-2, that of SES, in Tables 4.5-1 and 4.5-2. Table -1 shows Work Load for Each Member of Crew, Table -2, Work Load for Each Work Phase. Less crew members of SES than the conventional ship execute the same works almost in the same individual working hours. Work loads in S/B phase and anchoring one are much reduced in SES and that in desk work phase is slightly increased.

According to the restrictions of the related regulations, working hours of SES for ordinary navigation phase and anchoring one should be increased up to those of the conventional ship in the practical operation. The resulting estimated working hours per day per member is 9.8 hours, and is 7.6 hours in case of operated by 9 members (with additional two members).

Table 4.4-1 Work Load for Each Member of Crew in Conventional Ship (11 members)

11 Members	Captain	Chief Officer	Second Officer	Third Officer	Quarter Master A	Quarter Master B	Quarter Master C	Chief Engineer	First Engineer	Second Engineer	Chief Steward	Total Man*Hour
Total Working Hours	28.5	28.2	27.3	28.2	28.3	28.7	29.1	27.6	28.2	28.0	26.8	308.9
Working Hours per Day	8.05	7.96	7.71	7.96	7.99	8.10	8.22	7.79	7.96	7.91	7.57	7.93

Table 4.4-2 Work Load for Each Work Phase in Conventional Ship (11 members)

Phase Code	a	b	c	d	e	f	g	h	i	jr	k	Total Man*Hour
Work Phase	Stand By	Ordinary Navigation	Special Navigation	Cargo Handling	Anchoring	Mainte-nance	Catering	Meet-ing	Communi-cation to Land	Desk Work	Others	
Total Working Hours	52.5	113.0	6.0	40.1	12.0	39.1	16.5	11.0	2.2	13.6	2.9	308.9
Working Hours per Day	1.35	2.90	0.15	1.03	0.31	1.00	0.42	0.28	0.06	0.35	0.07	7.93

Table 4.5-1 Work Load for Each Member of Crew in SES (7 members)

7 Members	Captain	Chief Officer	Second Officer	Third Officer				Chief Engineer	First Engineer		Chief Steward	Total Man*Hour
Total Working Hours	27.6	27.7	26.5	27.4				26.5	27.1		26.4	189.2
Working Hours per Day	7.79	7.82	7.48	7.74				7.48	7.65		7.45	7.63

Table 4.5-2 Work Load for Each Work Phase in SES (7 members)

Phase Code	a	b	c	d	e	f	g	h	i	jr	k	Total Man*Hour
Work Phase	Stand By	Ordinary Navigation	Special Navigation	Cargo Handling	Anchoring	Mainte-nance	Catering	Meet-ing	Communi-cation to Land	Desk Work	Others	
Total Working Hours	21.5	71.4	6.0	27.2	0.0	26.9	13.2	4.2	2.2	14.1	2.5	189.2
Working Hours per Day	0.87	2.88	0.24	1.10	0.00	1.08	0.53	0.17	0.09	0.57	0.10	7.63

5. CONCLUDED REMARKS

Onboard works are modeled according to work phase analysis. Actual support systems have been developed and equipped on the SES Demonstration Ship "Shige-maru".

Although each support function has been already checked in the actual operational navigation, actual onboard crew has not been changed because of constraints from regulations. The Safety at Sea is the first item to be established. It needs careful investigation on the safety. Through the actual navigation in the conventional crew condition, we should show the effectiveness of the labor-saving support systems from viewpoints both of safety and reduction of work load.

Lastly, we show the images of support systems onboard the Shige-maru. Interfaces are integrated on the navigation bridge. A speech interface is adopted to be a human friendly interface, that enables appropriate cooperation between a human operator and support functions.

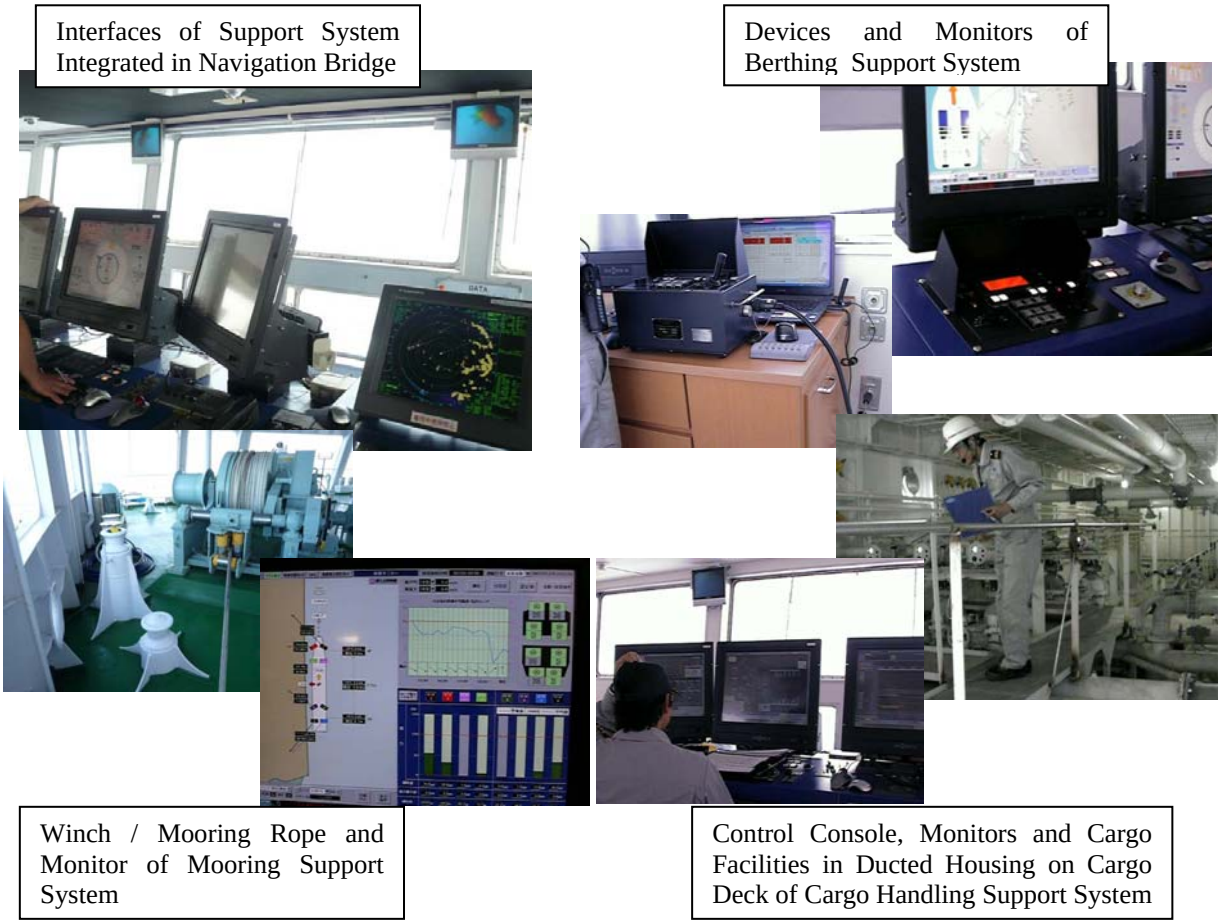

Fig. 5.1 Images of Labor-Saving Support System Equipped on Shige-maru

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