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Voyage Support System “Sea-Navi[*1]”†

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Abstract:

*In order to reduce greenhouse gas (GHG) emission on international shipping, voyage support system “Sea-Navi[*1]” has been developed. For the purpose to clarify effectiveness of the reduction of GHG emission, onboard trial of the “Sea-Navi[*1]” system has been carried out. As a result, about 10% reduction in rough sea was confirmed and about 3 to 5% reduction can be expected in an annual average.*

1. Introduction

In order to prevent global warming, reduction of emissions of greenhouse gases (GHG) is now demanded internationally. Likewise, in international shipping, the International Maritime Organization (IMO) started regulating the “Energy Efficiency Design Index (EEDI),” which indexes CO_2 emissions per ton-mile in new ships, and the “Ship Energy Efficiency Management Plan (SEEMP),” which promotes efficient operation of existing ships[1]. In order for ship operators to establish SEEMP under these regulations, regular measurement of fuel oil consumption, which is related to the CO_2 emissions of ships, and planning and execution of voyages so as to minimize fuel oil consumption are required.

In light of these circumstances, Japan Marine United Corp. developed an original voyage support system called “Sea-Navi[*1]” for the purpose of supporting CO_2 reduction by optimized operation of the ship. On ships which are equipped with “Sea-Navi[*1],” the optimized route to the destination, considering the saving of fuel oil consumption (CO_2 Emission reduction: CO_2 Emission is proportional to fuel oil consumption) and on-time voyage, is displayed before the start of the voyage, and updated information on the optimized route considering constantly-changed ocean weather is displayed during the voyage. The system also enables instant evaluation of voyage performance after the voyage and provides information for safe, on-time, fuel-saving voyages.

This paper introduces the configuration and functions of “Sea-Navi[*1]” and reports the results of verification of the CO_2 reduction effect by using “Sea-Navi[*1]” based on a demonstration test with an actual ship on which “Sea-Navi[*1]” was installed.

2. Outline of Voyage Support System “Sea-Navi[*1]”

2.1 System Configuration

The configuration of the “Sea-Navi[*1]” system is shown in **Fig. 1**. The functions of the system can be broadly divided into the following two functions.

(1) Optimized Route Search Function

This function calculates the optimized route for safety and economy (energy saving).

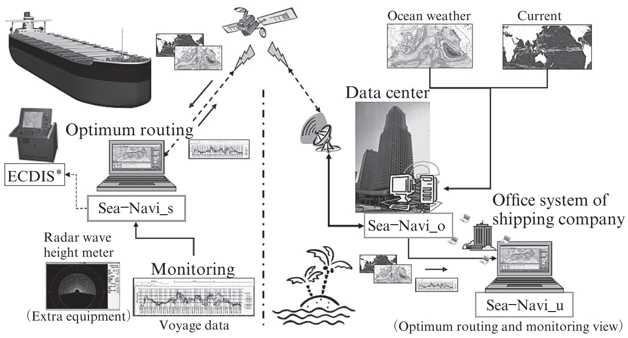

Fig. 1 Configuration of “Sea-Navi[*1]” system

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[*1] “Sea-Navi” is registered trademark in Japan.


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(2) Monitoring Function

This function monitors the present condition of the ship and its engine, and ocean weather, and transmits this information to land. Based on the monitoring data, instant in-service analysis of each voyage is possible.

2.2 Optimized Route Search Function

If the optimized route search function is used, it is possible to calculate the optimized route based on the most recent ocean weather forecast data transmitted daily from land. As optimized routes, it is possible to calculate the route requiring the shortest time from the point of departure to the destination (minimum time route) and/or the route requiring the least fuel for the same arrival time (minimum fuel route). As the user can also input arbitrary user defined routes, it is possible to compare those routes with the above-mentioned optimized routes and evaluate those routes.

Because precise performance data on the ship and main engine are input for individual ships, the “Sea-Navi*1” system can estimate ship response (ship speed, horsepower, fuel oil consumption, etc.) with higher accuracy than the conventional weather routing technique[2)].

It is also possible to display and compare the time series of various types of parameters (ship speed, horsepower, fuel oil consumption, ship motion, encountered ocean weather, etc.) on each calculated route, and because the conditions that will be encountered when sailing on each route can be predicted, it is possible to select the optimized route for safety and economy.

2.3 Monitoring Function

When the monitoring function is used, it becomes possible to grasp the present condition of the ship, its engine, and ocean weather on shipboard. Moreover, since the monitoring data are sent to a land terminal periodically using satellite communications after primary analysis aboard the ship, the condition of the ship can be grasped on land. It is also possible to perform long-term service analyses by accumulating and performing secondary analyses of the monitoring data.

The configuration of the monitoring system is shown in **Fig. 2**. Data such as the ship’s position, speed, etc. are collected from the voyage data recorder (VDR), which is installed on the ship, and equipments in the engine room, then they are transmitted regularly to the onshore “Sea-Navi*1” system via the network.

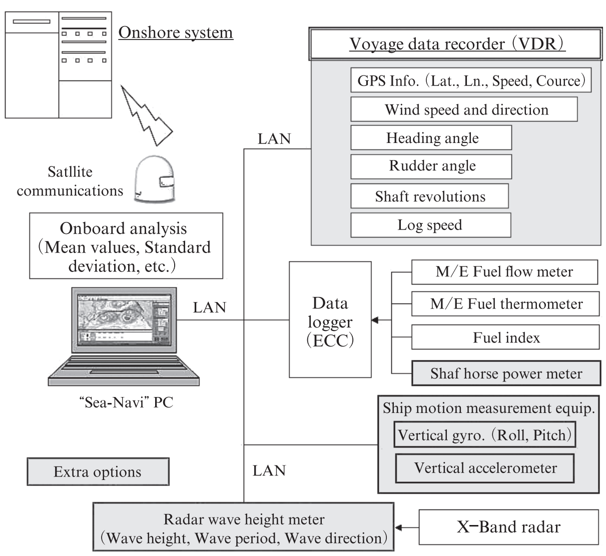

Fig. 2 Configuration of monitoring system

3. Onboard Trial Test

3.1 Purpose of Onboard Trial Test

The system was installed on a ship that was constructed by Japan Marine United Corp., and an onboard trial test was carried out in order to demonstrate the effectiveness of the functions of “Sea-Navi*1,” particularly the effectiveness of the optimized route search function.

The following items were confirmed in the onboard trial test.

(1) Confirmation of difference in fuel oil consumption by typical standard route and optimized route

(2) Verification of the predictive accuracy of ocean weather forecasts used by “Sea-Navi*1” on the optimized route

(3) Verification of the effectiveness of ocean current use and the accuracy of ocean current forecasts using “Sea-Navi*1”

3.2 Outline of Onboard Trial Test

In the onboard trial test, the ship sailed on the route shown by “Sea-Navi*1.” The ship on which the “Sea-Navi*1” system was installed was an ore carrier constructed by Japan Marine United Corp. (at the time of construction, Universal Shipbuilding Corp.). The ship made two round-trip voyages between Japan and Brazil, the first (No. 1 voyage) between July and September, 2011 and the second (No. 2 voyage) between October

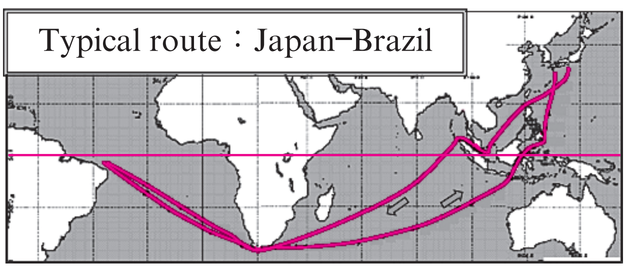

Fig. 3 Typical example of route between Japan and Brasil

2011 and January 2012. Examples of typical routes between Japan and Brazil are shown in **Fig. 3**. In conducting the test, optimized route search calculations were performed before the voyages and once per day during the voyages, and the ship sailed the recommended optimized route (= minimum fuel oil consumption route), which was shown reflecting the most recent ocean weather forecast data. It should be noted that the final judgment on the decision of routes was left to the ship's captain, as the highest priority was the safety of the ship.

3.3 Results of Onboard Trial Test

3.3.1 Verification of accuracy of ocean weather forecast data

The results of a comparison of the measured values of the ocean weather (relative wind velocity, significant wave height, (relative) ocean current speed) encountered in the Indian Ocean voyages in No. 2 voyage, and the forecast values on the actual route (optimized route) and a reference route (typical standard route) are shown in **Fig. 4** (westbound voyage: Japan to Brazil) and **Fig. 5** (eastbound voyage: Brazil to Japan).

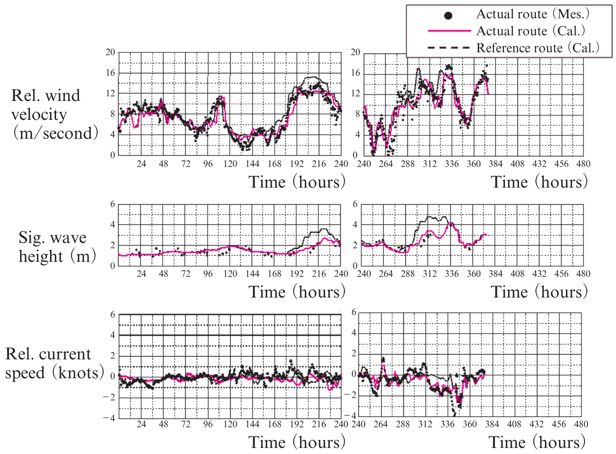

Fig. 4 Comparison of weather forecast and onboard monitoring data (Westbound on Indian Ocean)

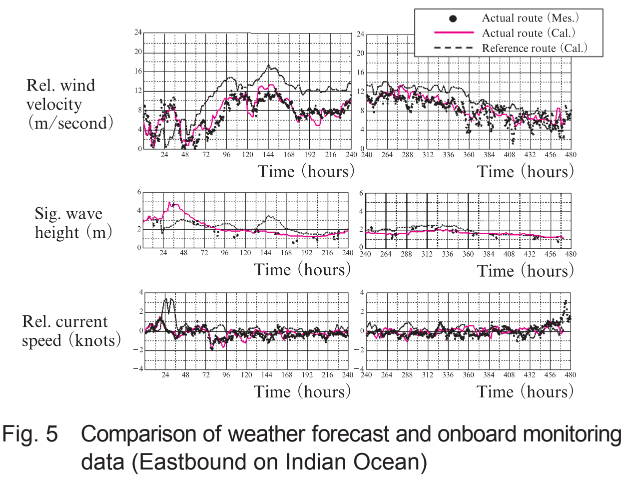

Fig. 5 Comparison of weather forecast and onboard monitoring data (Eastbound on Indian Ocean)

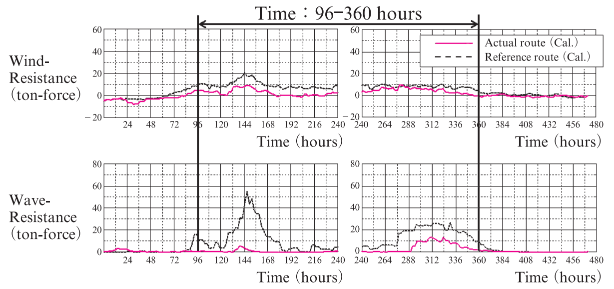

Fig. 6 Difference of resistance caused by difference of voyage route (Eastbound on Indian Ocean)

On both the westbound and eastbound voyages, the measured values of the encountered ocean weather (black circles) and the forecast values on the actual route (red circles) showed good agreement. Therefore, ocean weather forecasts used by "Sea-Navi*1" are considered to have sufficient accuracy for use in weather routing. Furthermore, comparing the actual route and the reference route, when sailing on the reference route, there is a tendency to encounter rough weather on both the westbound and eastbound voyages. Thus, it can be understood that the optimized route search function operates effectively, making it possible to avoid rough weather. **Figure 6** shows the results of calculations of wave and wind resistance acting on the ship while sailing, using the encountered ocean weather forecast information on the reference route and the actual route shown in Fig. 5. On the reference route, the ship experienced extremely large wave and wind resistance in the time range from 96 hours to 360 hours, whereas, the wind and wave resistance during the same time range were not particularly large on the actual optimized route. Since lower resistance due to ocean weather means that it is not necessary to use extra fuel oil because of increase the horsepower of the main engine in order to overcome that resistance, a fuel-efficient voyage is possible by sailing on the optimized route in comparison with the reference route.

3.3.2 Verification of effect of fuel oil consumption reduction

Table 1 shows the results of estimations of the effect of fuel oil consumption reduction on the actual voyage route in comparison with the reference route for No. 1 and No. 2 voyages in the Indian Ocean. From Table 1, it can be understood that there was a large difference in the effects of fuel oil consumption reduction between

Table 1 Reduction of fuel oil consumption on actual voyage route compared to reference route (Indian Ocean)

Route	Loading cond.	1st Voyage	2nd Voyage
Westbound	Ballast	−1.0%	−9.7%
Eastbound	Laden	−2.5%	−15.5%

No. 1 and No. 2 voyages. The difference in the ocean weather conditions encountered during the voyages was a large factor in the difference in fuel oil consumption. In other words, as also described in Section 3.3.1, it is considered that resistance caused by waves and wind was smaller due to the selection of routes with milder ocean weather on both the westbound and eastbound voyages, and as a result of this, the effect of fuel oil consumption reduction was larger than that on the reference route.

4. Estimation of Effect of Fuel Oil Consumption Reduction by Using "Sea-Navi[*1]"

The possibility of reducing fuel oil consumption by using "Sea-Navi[*1]" was confirmed by the onboard trial test. Therefore, a study was carried out by simulation in order to estimate the effect of fuel oil consumption reduction that can be expected over a 1 year period by regular use of "Sea-Navi[*1]."

The simulation was performed for 36 voyages between April 1 and the end of March of the following year with departure dates at 10 day intervals. The voyages were the same round-trip voyage between Japan and Brazil as that in the onboard trial test. The effect of fuel oil consumption reduction was calculated from the difference between fuel oil consumption in voyages on the reference route and optimized routes by using Eq. (1).

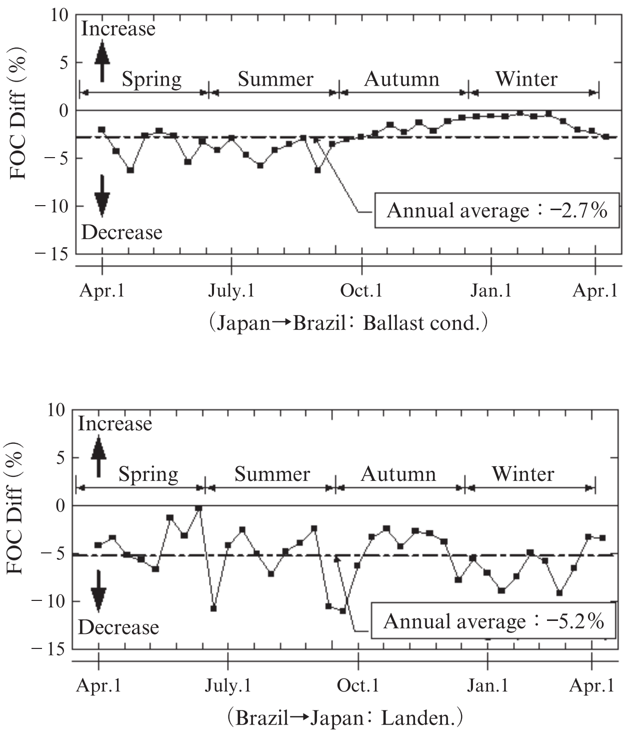

Fig. 7 Estimation of reduction of fuel consumption by using "Sea-Navi™"

$$\text{FOC Diff} = \frac{\text{FOC}(\text{Opt.}) - \text{FOC}(\text{Log.})}{\text{FOC}(\text{Log.})} \times 100\,(\%) \quad \text{..........} (1)$$

Where, FOC (Log.) is fuel oil consumption during the voyage on the reference route and FOC (Opt.) is that on the optimized routes.

The simulation results are shown in **Fig. 7**. The seasons noted in the figure are seasons in the Northern Hemisphere. On both the Japan to Brazil voyages and the Brazil to Japan voyages, the effect of fuel oil consumption reduction increased from the second half of April to the second half of September, that is, during the fall-to-winter seasons in the Southern Hemisphere. During those months, ships encounter rough weather caused by low pressure systems from the South Polar region. It can be understood that a large effect of fuel oil consumption reduction can be expected by using "Sea-Navi[*1]" to avoid rough weather during this period. From the results of the simulation for 36 voyages, the average fuel oil consumption reduction, i.e., CO_2 reduction effect through the full year, is approximately 3–5%.

5. Conclusion

A new voyage support system "Sea-Navi[*1]" was developed to support reduction of CO_2 emissions by optimized operation of the ship in international shipping. The developed system was installed on an actual ship, and an onboard trial test was carried out, in which the ship sailed on the optimized routes calculated by "Sea-Navi[*1]" on two voyages between Japan and Brazil. As a result, the following points were clarified.

(1) Ocean weather forecasts used by "Sea-Navi[*1]" show good agreement with actual ocean weather and are reliable as weather forecast values.

(2) In comparison with sailing on typical standard routes, when "Sea-Navi[*1]" was not used, the onboard trial test showed that the effect of fuel oil consumption (CO_2 emission) reduction of approximately 10% can be expected when rough weather is encountered, thus verifying the navigation optimization effect of "Sea-Navi[*1]".

A simulation of voyages between Japan and Brazil was also performed, revealing that the effect of fuel oil consumption (CO_2 emission) reduction of approximately 3–5% is possible by using "Sea-Navi[*1]" for navigation optimization.

Based on these verification results, Japan Marine United Corp. plans to promote application of the developed system to operation optimization of the ship by promoting installation/dissemination of "Sea-Navi[*1]" on actual ships, and will also carry out further research and development so as to make a large contribution to reduction of CO_2 emissions in international shipping.

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