Introduction to PrimeShip-GREEN/EEOI - Energy Efficiency Operational Indicator (EEOI) Calculation and Analysis System

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1. INTRODUCTION

Discussions on reducing CO_2 emissions by the international shipping industry are ongoing at the International Maritime Organization (IMO). The basic concept for regulating CO_2 emissions being advocated by the IMO is the improvement of the energy efficiency of ships. In order to realize this concept, the following three methods are being studied: "technical measures", "operational measures" and "market based measures". Among these, operational measures do not necessarily need to be accompanied by hardware modification related technical measures and, therefore, can be fairly easily implemented in existing ships. The voluntary implementation of these measures is very significant not only from the viewpoint of environmental protection, but also from the viewpoint of reducing fuel consumption, i.e., operational cost. ClassNK has independently developed a calculation and analysis system for EEOI which is an indicator for improving energy efficiency by operational measures, and has been using this system for its appraisal services.

The main functions of the PrimeShip-GREEN/EEOI, which is ClassNK's EEOI calculation and analysis system, are introduced in this report.

2. Improvement in energy efficiency through operational measures

2.1 Operational measures

Operational measures are measures designed to improve the energy efficiency of a ship, which are implemented through operational techniques. There are several different types of operational measures. In general, some measures depend only upon individual management, while others go beyond the scope of independent efforts of a ship management company and need the cooperation of many concerned personnel. Detailed examples are as follows:

- Optimization of the operational plan of individual ships and fleets
- Speed management
- Weather routing
- Just-in-time arrival at port
- Hull maintenance
- Machinery maintenance

The IMO has proposed the Ship Energy Efficiency Management Plan (SEEMP) and the Energy Efficiency Operational Indicator (EEOI) as tools for promoting the implementation of operational measures. Of these, SEEMP is a management plan whose objective is to be prepared for implementing energy efficiency improvements through operational measures. To encourage the implementation of the operational measures, mandatory possession onboard of a SEEMP will be required for all ships beginning 1 January 2013. SEEMP is designed to help implement operational measures that are suitable for each individual ship. The IMO has issued guidance (MEPC.1/Circ.683)[1] that describes the method for preparing a SEEMP.

On the other hand, EEOI is an indicator expressing the energy efficiency of the ship currently in service; it is calculated by the following equation:

$$EEOI\,(\mathrm{g/ton\ mile}) = \frac{CO_2\ conversion\ factor \times fuel\ consumption\,(\mathrm{g})}{Actual\ cargo\ mass\,(\mathrm{ton}) \times Actual\ sailed\ distance\,(\mathrm{mile})} \quad (1)$$

Fig. 1 shows the energy efficiency improvement cycle according to SEEMP Guidance. "Planning", "Implementation", "Monitoring" and "Self-evaluation and Improvement" form one cycle. This cycle is repeated over and over again so that each ship, while monitoring energy efficiency (self-monitoring the EEOI), appropriately implements the planned operational measures, and evaluates the results.

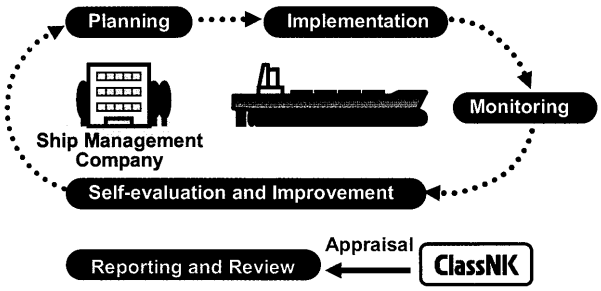

Figure 1 Energy efficiency improvement cycle

The SEEMP Guidance also makes mention of the voluntary disclosure of the self-evaluation results of improvement effects achieved during the energy efficiency improvement cycle (Voluntary reporting and review). This is suggested bearing in mind the various benefits received by the ship because of the favorable social evaluation of ships with high energy efficiency. For instance, setting preferential treatment such as low harbor fees for ships with high energy efficiency at specific ports may be considered. When consumer products companies transport their own products to the market, transportation procedures that give more consideration to the environment are likely to be demanded. Such EEOI evaluation results may be disclosed voluntarily, but if such evaluated results are confirmed by a third party, their effectiveness and trustworthiness is likely to be further increased.

2.2 EEOI calculation method

Equation (1) is used for calculating EEOI. A detailed calculation method is described in the "Guidelines for Voluntary Use of the EEOI" (MEPC.1/Circ.684)[2] published by the IMO. To monitor EEOI, the transition of EEOI calculated values for each consistent calculation period (for instance for each voyage) that represents the operating pattern of the relevant ship has to be observed. Therefore, data such as the fuel consumption, sailed distance and cargo mass carried (Table 1) in the relevant calculation period are necessary for the EEOI calculations. The CO_2 conversion factor C_F necessary for the calculation is given in Table 2, and depends on the type of fuel used. The cargo mass carried is evaluated according to ship type using the units shown in Table 3.

Table 1 Calculation elements of EEOI

Item	Explanation
Fuel consumption	Total amount of fuel consumed within the calculation period on board the ship by main engines, auxiliaries, boilers, incinerators, etc. The unit used is the metric ton (t).
Sailed distance	Distance actually sailed within the calculation period. The unit used is the nautical mile.
Cargo mass carried	Cargo mass carried within the calculation period. For the units used, refer to Table 3.

Table 2 CO_2 conversion factor

Type of fuel	ISO 8217	Carbon content	C_F (t-CO_2/t-fuel)
MDO/MGO	DMX to DMC	0.875	3.206
Light fuel oil (LFO)	RMA to RMD	0.86	3.151
Heavy fuel oil (HFO)	RME to RMK	0.85	3.114
LPG (propane)	-	0.819	3.000
LPG (butane)	-	0.827	3.030
LNG	-	0.75	2.750

Table 3 Cargo mass carried used in EEOI calculation

Type of ship	Cargo units
Dry cargo ship, tanker, gas tanker, Ro-Ro cargo ship, general cargo ship	Cargo weight (t)
Container ship (exclusively for containers)	Number of Containers (TEU) or Weight of cargo and container (t)
Container ship (containers and other cargoes)	Full container taken as 10 t, empty container as 2 t, to which other cargo weight is added to arrive at the final weight (t)
Passenger ship (including Ro-Ro passenger ship)	Number of passengers or gross tonnage
Car ferry, car carrier	Number of Car or occupied lane meters (m)
Railway/Ro-Ro vessels	Number of railway cars and freight vehicles, or occupied lane meters (m)

The equation for calculating EEOI may be expressed by equation (1) above; however, when detailed calculations are to be performed, the equation for calculating the EEOI for each voyage (Port-to-port voyage) is given in the following equation (2):

$$EEOI = \frac{\sum_j FC_j \times C_{Fj}}{m_{cargo} \times D} \qquad (2)$$

To calculate EEOI within the calculation period inclusive of multiple voyages, equation (3) may be used.

$$EEOI = \frac{\sum_i \sum_j \left(FC_{ij} \times C_{Fj}\right)}{\sum_i \left(m_{cargo,i} \times D_i\right)} \qquad (3)$$

Here, FC is the fuel consumption, m_{cargo} is the cargo mass carried, and D is the sailed distance. The suffix i expresses the number of voyages, while the suffix j expresses the type of fuel.

The cargo mass carried used in EEOI calculation varies depending upon ship type as shown in Table 3. Therefore, it is to be noted that the unit of EEOI may vary according to ship type. Fig. 2 shows an example of EEOI calculated for each voyage by the procedure described above. The figure shows the EEOI calculated value (○) together with the load index (◊). It can be seen that the EEOI per voyage varies considerably, being influenced by the load index at the time of the voyage. In

such cases, if the EEOI moving average is determined using an appropriate period such that the operating patterns of said ship is averaged, then the status of change in the average EEOI can be easily understood. Fig. 2 shows the example of a moving average value (□) for every three voyages. By taking this moving average, the influence of change in the load index can be averaged out, and trends in EEOI can be easily grasped.

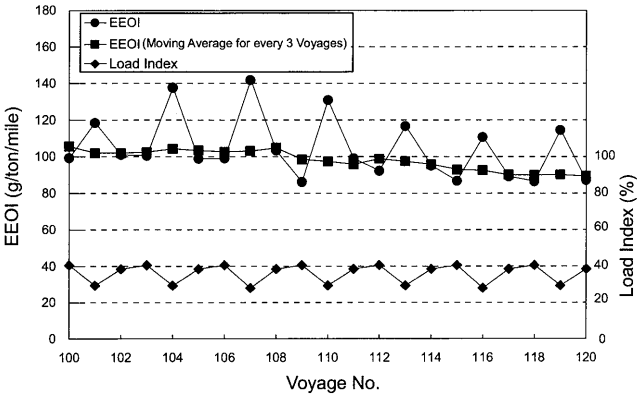

Figure 2 Transition of EEOI by voyage

3. Introduction to PrimeShip-GREEN/EEOI

3.1 Configuration of PrimeShip-GREEN/EEOI

ClassNK developed the EEOI calculation and analysis system PrimeShip-GREEN/EEOI in compliance with the EEOI calculation Guidelines (MEPC/Circ.684) described in the previous section, and released this system in April 2011. As shown in Fig. 3, this system has a very basic configuration. Data inputted on board the ship and sent by e-mail to the Society's server is collected. Then, EEOI is calculated and analyzed via the Internet using said collected data. The user can perform the required operations easily through "EEOI-Onboard", which is special data input software on board the ship, and through "EEOI-Web", which is web-based software that can perform EEOI calculation and analysis. ClassNK has started EEOI appraisal services using this system. Since all of the inputted data is stored on the Society's server, prompt appraisal services can be offered by the Society.

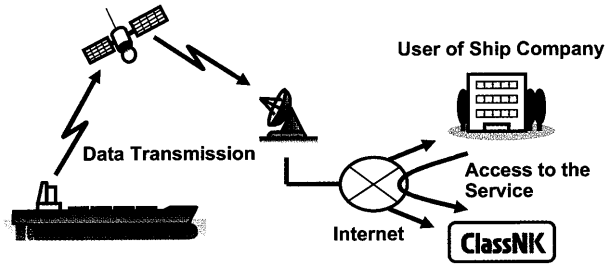

Figure 3 Conceptual diagram of system configuration

The flow of operations and basic functions are introduced below while making reference to the software screen.

3.2 EEOI-Onboard

EEOI-Onboard is software especially designed for data input on board the ship. Fig. 4 shows the main screen of EEOI-Onboard.

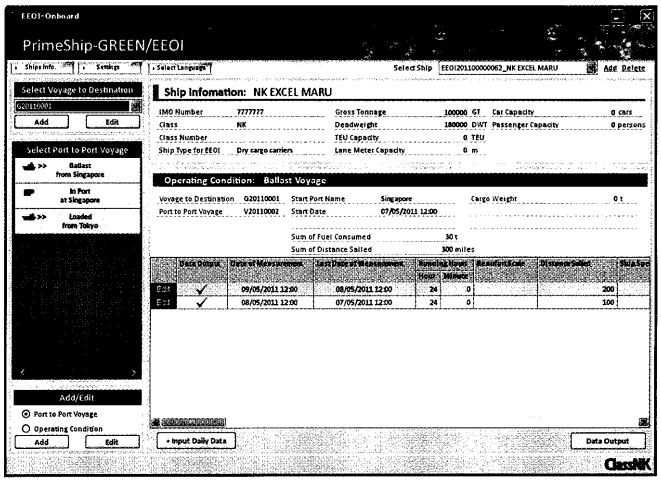

Figure 4 Main screen of EEOI-Onboard

Data input using EEOI-Onboard starts with first registering voyage information, and then entering the cargo mass carried for said voyage. Next, operating conditions such as "Loaded Voyage", "Ballast Voyage" and "In Port" are appropriately selected, and daily operational data (fuel consumption, sailed distance) are then entered for each operating condition. At this stage, fuel consumption is then basically entered for each piece of machinery/equipment (main engine, auxiliary engine, boiler and other). EEOI can be later calculated and assessed according to machinery/equipment and/or according to operating condition by classifying the operating conditions and entering the fuel consumption for machinery/equipment here. Moreover, by entering the Beaufort Scale (BF) (optional), calculations can be performed by excluding data above BF6. Fig. 5 shows the input screen for daily operational data. Data entry can be done in two ways: manually using the input screen or in a specific format using Excel.

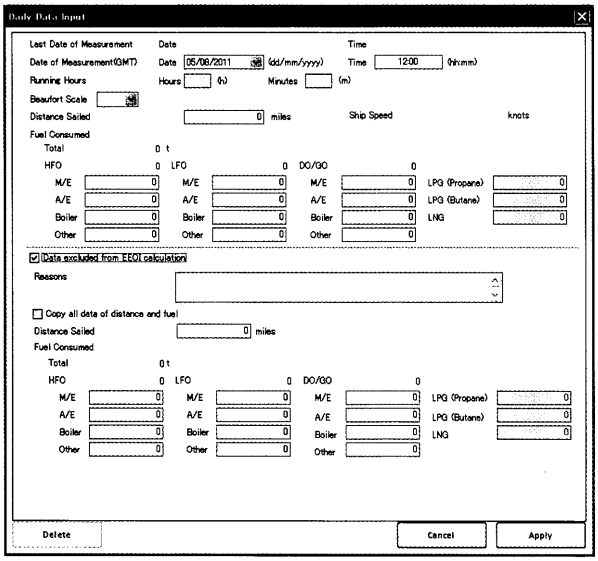

Figure 5 Input screen for daily operational data

3.3 EEOI-Web

EEOI-Web is web-based software for EEOI calculation and analysis. Fig. 6 shows the main screen of EEOI-Web.

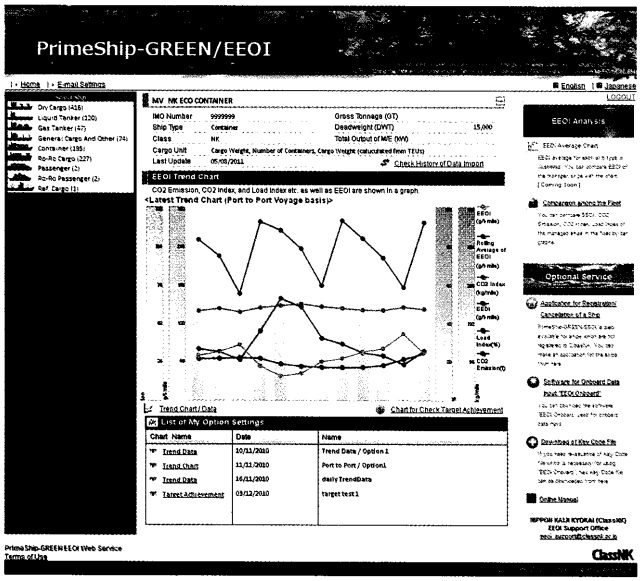

Figure 6 Main screen of EEOI-Web

The major functions of EEOI-Web are as follows:

(1) To display trend graphs of EEOI, EEOI moving average values, CO_2 emissions, load indices, etc.

(2) EEOI checking function for target setting

(3) Comparison among different ships in the fleet (EEOI, CO_2 emissions, load indices, etc.)

(4) EEOI average chart (comparison of average values among ships of the same type)

Fig. 7 shows an example of the trend graph display. From the energy efficiency improvement cycle described in section 3, the effects of the operation and effects of implemented efficiency improvement measures should be validated when monitoring EEOI. By displaying EEOI as trend graph as shown in Fig. 7, the factors that cause changes in energy efficiency can easily be confirmed visually. A flag is shown at the center of the graph in Fig. 7. This position indicates the period of implementation of the energy efficiency improvement measures (if you move the cursor to the flag, explanations of the efficiency improvement measures will be displayed). By displaying the EEOI trends in the same graph, their effects can be confirmed visually.

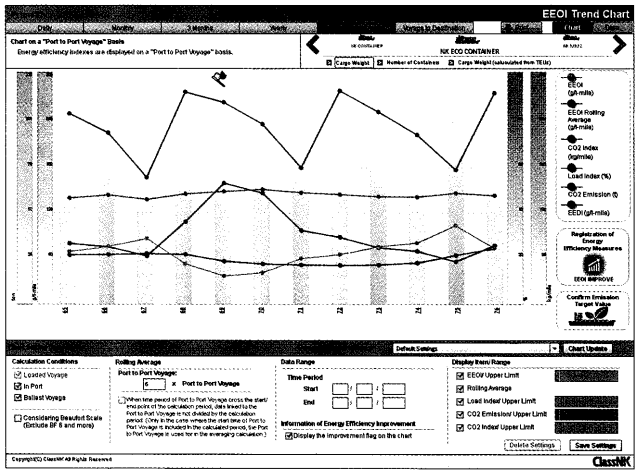

Figure 7 EEOI trend graph

Fig. 8 shows an example of the EEOI checking function display for a target setting. When setting the EEOI target values during the planning stage of the energy efficiency improvement cycle, they can be made by visually comparing past records (trend graphs). The achieved status of set targets can also be easily confirmed.

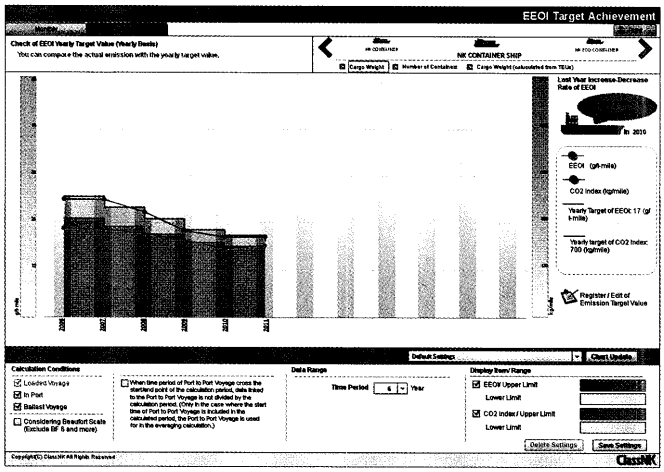

Figure 8 EEOI checking function for target setting

Fig. 9 shows an example of a fleet comparison display. A fleet comparison enables the comparison of the EEOI, CO_2 emissions, load index, and so on, of ships of the same type that are registered under the same management company.

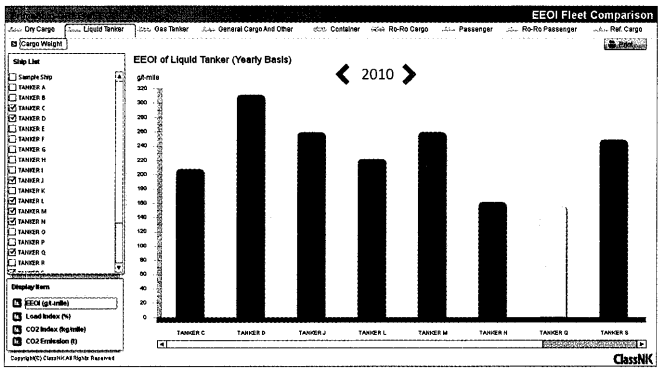

Figure 9 Comparison of ships within the fleet

A display function for the EEOI average chart, which is presently under development, will display the average value of EEOI for each ship type out of the EEOI for all ships that are registered as an exponential function of ship size (DWT), and enables the comparison of the EEOI of ships managed by the company with the average value.

4. Conclusions

In today's world where the realization of a low carbon society is expected to respond to global warming issues, the determination of the actual CO_2 emissions and EEOI value of a ship to improve energy efficiency is a very significant undertaking. The authors will be happy if the PrimeShip-GREEN/EEOI introduced in this paper is able to assist in achieving this objective. This system is naturally expected to be utilized for the appraisal of energy efficiency and CO_2 emissions. In the future, a function to analyze factors that bring about changes in EEOI will be added, and efforts will be made to develop this tool as a technical support tool that effectively assists in improving energy efficiency of ships.

REFERENCES

(1) IMO, "Guidance for the Development of a Ship Energy Management Plan (SEEMP)", MEPC.1/Circ.683, (2009)

(2) IMO, "Guidelines for Voluntary Use of the Ship Energy Efficiency Operational Indicator (EEOI)", MEPC.1/Circ.684, (2009)