

# Active Method to Manage the Use of Fuel Oil Onboard of Ships

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The fuel consumption in maritime transportation is a big fuel consumer. However, to use and to manage the fuel in maritime transportation field is still not proper to actual expect in many countries including Vietnam. The present fuel management on board ships is only based on the set fuel use norm of a country, but not on the actual operating conditions of ships. Therefore, such management method of fuel is not matched to the target of using efficiently and saving energy, but also creates good conditions for crewmember to pilfer the fuel for private profits.

So, in order to overcome the situation, we propose a new method to manage the use of fuel on board a ship. This method is based on “online information” about the actual operating parameters of a ship including the main engine and sea conditions, then a suitable plan of ship operation with optimum fuel consumption will be set and sent to a ship for realization. This method is named as an “active method to manage the use of fuel oil onboard of ships”.

**Keywords:** Active method, parameter, operation regime, main engine, generator, boiler, fuel consumption, fuel loss.

## 1. Introduction

According to statistics of the International Maritime Organization (IMO), the number of global sea freights are over 90% of the total freights and the sea transport have consumed annual over 300 million tons of fuel oil[3]. However, the fuel management and using are still insufficient. The present fuel management method is mainly based on the fixed number norm, without the basic of the operating mode and the operation conditions. This method is not based on saving goals only, but also creating a loophole for dishonest reporting of seafarers and creating residual illegal fuel for sale by seafarers.

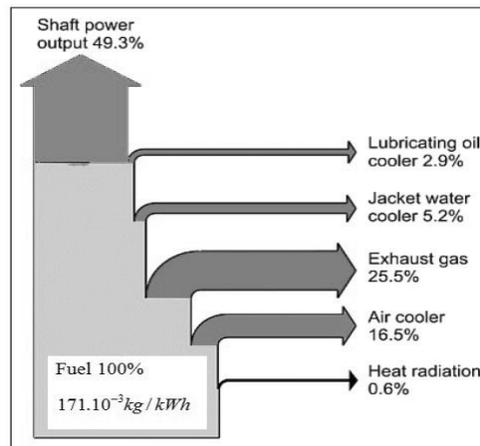
For solving this phenomenon, we have given proposal on a new actively method to manage the use of fuel on board a ship. This new method is based on the online information collecting on the technical operating situation, the actual voyage situation of the ship, after that, the shipping operation plan at reasonable fuel consumption will be made out. The method is named as an “active method to manage the use of fuel oil onboard of ships”.

## 2. Fuel consumption characteristics of marine propulsion plant

According to preliminary statistics, Vietnam's fleets with a tonnage of over 06 million tons (2012) have consumed annual over 03 million tons of DO & HFO. Besides, the inland waterway fleets with main engine's capacity of over 06 million HP (horse power) have consumed annual over 02 million tons of DO. Thus, if we save 05% of this fuel consumption, the businesses will save 250.000 tons of fuel (in Vietnam) & 15 million tons of fuel (in the world) and we also will restrain harmful emissions to the environment [1].

Almost fuel consumption equipment equipped in Vietnam's fleets and the world's fleets are diesel engines and boilers. The marine diesel engines consist of 02 types: propeller driven diesel engines (also called as main engines) and generator driven diesel engine (also called as auxiliary diesel engines). A main engine is designed to drive directly/indirectly FPP (fixed pitch propeller) or CPP (controllable pitch propeller). The basic technical feature of a main engine is operated in accordance with the propeller characteristic [2], in which, the consumption power measured at the hub of propeller is 3rd proportion with propeller revolution:  $N_e = C \cdot n^x$  ( $x = 3$ ) and using heavy fuel oil (HFO). The most important parameters to assess the operation load of a main engine are the engine revolution and the fuel rack of high-pressure pump (load indicator).

The number of generator engines equipped on board ships is often from two to three units, in which, almost diesel engines are medium-speed or high-speed engine which use DO. The boilers onboard a ship are usually auxiliary boiler combined with economizer boiler to make use of heat energy in main engine.



**Figure 1 Thermal energy distribution of the modern main engine**

Currently, according to the trend of economical and efficient use of energy with the advancement of technology, the thermal efficiency of a main engine in modern ships can achieve 50% (Figure 1).

## 2.1 Fuel consumption

The fuel consumption in a period of time can be calculated by the measurement of fuel amount between the two time points (excluding the extra supplied fuel):

$$G_t = G_{t_2} - G_{t_1} \quad (1)$$

Where:  $G_{t_1}$  is the amount of fuel on board at the time  $t_1$ ;  $G_{t_2}$  is the amount of fuel at the time  $t_2$ ; and  $G_t$  is the amount of fuel consumption in the period  $t = t_1 - t_2$ ;

The fuel consumption of ship  $G_t$  is separately calculated for each type of fuel consumption on board including different components such as: fuel consumption of main engine, generators, boiler; fuel loss due to leakage, discharge sludge from filters, purifiers...

The fuel consumption of diesel engine in 1 hour (main engine and generator) is determined based on the effective power of the engine and specific fuel consumption:

$$G_h = N_e \cdot g_e \quad (2)$$

Where:  $G_h$  is the amount of fuel consumption in an hour (kg/h);  $N_e$  is the effective power of diesel engine (kW);  $g_e$  is average effective fuel consumption of engine, g/(kW.h);

For generator, the effective power  $N_e$  can be determined by power that presented on the main switch board. For a main engine, the effective power is difficult to measure or specify calculating in operation.

The fuel consumption of boiler is determined by the formula:

$$G_b = g_b \cdot t \quad (3)$$

Where:  $G_b$  is the fuel consumption of boiler, (kg);  $g_b$  is the capacity of fuel injector, (kg/h);  $t$  is the burner time of boiler,(h);

Basically, the fuel consumption of boilers are largely depended on the oil burning time of boiler.

## 2.2 The fuel loss in ship operation

Currently, the cost of fuel in shipping is highly occupied in comparison with the other costs, sometimes up to 60 % of total ship operating costs. For reducing the fuel costs, we should implement methods for keeping the economical operation mode and reducing the fuel loss (loss). The fuel loss consists of two kinds: objective losses and subjective losses.

### 2.2.1 Objective losses

The fuel loss which belongs to the objective losses in operation  $G_{OL}$  [5], consists of:

- Sludge of purifier: Depending on the quality of fuel, the sludge discharged from the centrifuge purifier may occupy from 0.1 to 0.5 % of fuel consumption on board. Sludge discharged from the centrifuge purifier often is called «sludge», stored in sludge tank;
- Drained sludge: Depending on the quality of fuel, the sludge from sludge tanks, filter and backwash filter,... may occupy from 0.1 to 0.2 % of fuel consumption on board. Sludge often is stored in drain tank;
- Fuel loss due to the leakage: The fuel loss from flange, the crack position, the leakage... which is little in engine room bilge tank... are depending on technical situation of engine ;
- Fuel loss to delivery : Almost contracts are required measurement amount of the fuel supply. In addition, the delivery is not enough due to the difference of temperature, density, air bubble even when supplying of fuel,...
- The other losses: the other losses may include: broken pipe, leaky pipe and others.

According to statistics, the total fuel losses in exploitation may take from 01 to 03 % of fuel consumption, especially may exceed 05 to 10 % [5].

### 2.2.2. Subjective loss

The fuel loss is caused by dishonest report in exploitation  $G_{SL}$ , the essence of this problem is the fuel stolen by crew and selling off or selling to fuel supplier. This fuel has the following characteristics:

- The company has no plans for operation and appropriate fuel management;
- The data is created from the fictitious increasing of fuel consumption of diesel engines and boilers;
- The technical tricks are used to make residual fuel for personal purposes;

According to formula No. 2, the fuel consumption is calculated as:  $G_h = N_e \cdot g_e$  and the power of main engine is calculated as:  $N_e = C \cdot n^3$ ,  $C$  - constant depending on weather conditions, ship hull and propeller technical conditions. It suppose that the operator reduce the revolution of main engine in from  $n_0$  to  $n_1$ , then if the value of  $g_e$  is not significant change, the fuel consumption will be:

$$k = \frac{G_{h(1)}}{G_{h(0)}} \approx \left( \frac{n_1}{n_0} \right)^3 \quad (4)$$

When reducing the revolution of main engine, the revolution of propeller is reduced, and therefore, the ship speed is reduced in according to first order relation. In this case, the reduction of ship speed is very often explained as the bad weather condition or effected by sea current.

Example: The operating speed of main engine is 125 (rpm), ship speed is 12 knots, actual fuel consumption is 17(MT/d). If the operating speed of main engine is reduced to 122 (rpm); actual fuel consumption is 15.8 (MT/d), and thus, ship speed will be reduced as 11,6 or 11,7 knots. This is evident that fuel consumption can be saved as much as 1.2 MT/d while the reduction of speed of the ship is only 7.2 knots/d.

For the generator, which is calculated with highest load; For the boiler, burner time is longer than reality.

The operating loss of fuel oil is normally take from 5% to 10% of total fuel consumption, especially, it can be exceed 20 % or 30 %.

### 3. Features of fuel oil management of Vietnamese fleets

Normally, fuel consumption is determined by data of average fuel consumption amount per hour and actual operating of the engine.

For the main engine, mileage from A to D can be divided into the following modes: AB - Maneuvering mode, BC - Sailing mode, CD - Maneuvering mode. Based on the operating mode, engineers will give the suitable kinds of fuel oil and fuel consumption.

For the generator, there are some modes as sailing, loading and unloading mode, anchoring... in accordance with kind of fuel oil and fuel consumption.

For the auxiliary boiler, there are also the operating mode and fuel consumption.

According to research results, the authors found that the general method for managing fuel oil is not effective and managers of shipping companies can not control correctly the fuel consumption of ships. The shipping companies can only get the all data of fuel consumption of ships only by reports. So the current applied method of managing fuel oil consumption is called «inactive method». This form of fuel use management has disabled the request of ship owners, managers aim to increase savings and fuel efficiency.

### 4. Active method to manage the use of fuel on board of ships

Our research results showed that the Vietnam shipping companies, as well as many worldwide companies annually have lost a large amount of fuel due to operation causes and technical management causes of the marine propulsion plant.

For the operation causes, the crew member, as well as the technical manager have not given operation plans for ships as well as for their propulsion plants in various operating conditions. Therefore, the ship's operation causes relate to the following factors:

- The type of charter party – C/P (voyage C/P, time C/P, bareboat C/P) ;
- The weather conditions on voyage;
- The draft and even keel;
- The ship's cruise speed.

For the technical causes, this is a problem relating to working quality of main engine, generator and technical quality of hull, propeller, especially the matching load between the diesel engines and hulls, propellers. Therefore, the technical causes relate to the following factors:

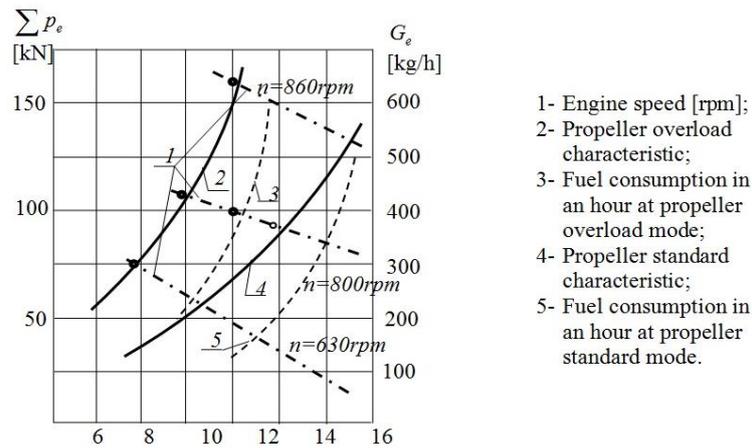
- The maximum generated power of diesel engine;
- The technical state of hull (the ratio of fouling, distortion, ..) ;
- The technical state of propeller (the deformation ratio of propeller's blades, the erosion ratio and sea-acorn, ...);
- The balance of torque between diesel engine and propeller.

In fact, two mainly parameters that affected to the fuel consumption of a ship are the revolution of diesel engine and the unbalanced state between generating torque of diesel engine and load torque of propeller (this state is called overload torque - torque-rich).

In Figure 2, this is research into the variation of operation power characteristics of a diesel engine at torque rich state. If we implement carefully researches in period of one-year operation, we will record the data of variation of engine characteristics affected by load  $v/R_c$ ; Where:  $R_c$  - the resistance of all components (kN, kG) and  $v$ - the variation in their technical state.

The bad technical condition due to reduction of air supply caused by the poor performance of exhaust gas turbine system, and the unsuitable fuel supply caused by the excess clearance of fuel supplied equipment. Besides, there are the variation of propeller due to adhered of sea-foul, erosion and deformation of the propeller's blades.

When the power of diesel engine is reduced due to bad technical conditions, propeller also change the technical state and raised the power consumption, it will lead to the phenomenon known as “Heavy propeller”, in this time, the diesel engine will be overloaded by torque (torque rich) [6]. In the same operation condition, the propeller characteristics curve will be the curve /2/ and the fuel consumption characteristics curve will be curve /3/ on Figure 2. Thus, the fuel consumption will be higher than the standard operation mode (curve /4/- propeller characteristic) as showed by curve /5/ (fuel consumption). The large or small loss of fuel due to bad technical condition of ship strictly depending on the overload level of diesel engine.



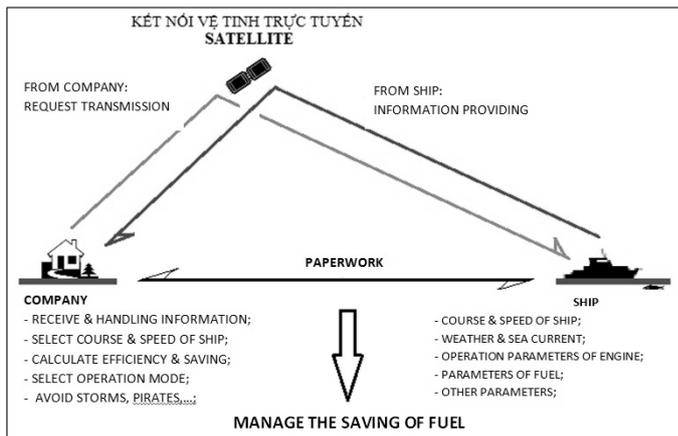
**Figure 2 Change operation power range of diesel engine**

Therefore, for efficient management of fuel use onboard, we propose the new idea “Active method to manage the use of fuel on board a ship”.

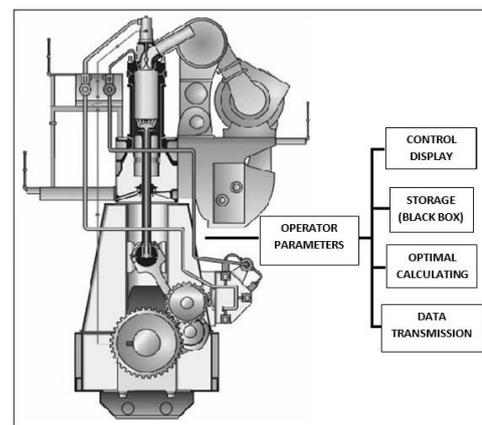
#### 4.1 Management and selection of the best operation state

Selection, measurement and continuous storage of information that is relating to operating regime and using fuel oil of propulsion plant;

- Management, calculation of the operating regime and decision of the optimal operating regime;
- Data transferring and ‘online’ management ability for operators;
- Ensuring two-way communication between ships (providing information and implementation) with the operators (after information processing, computational optimization, extraction mode, ...);



**Figure 3 Exchange and process information on ship management**

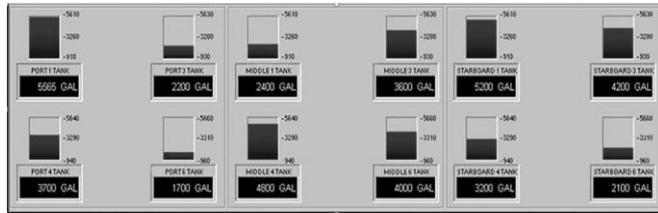


**Figure 4 Measure the operation parameters of the engine**

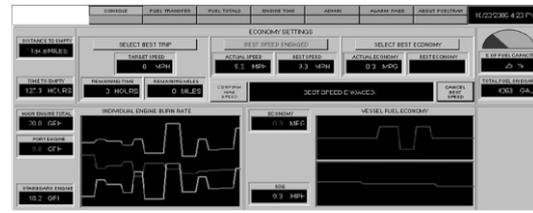
«Active method to manage the use of fuel onboard of ships» based on online exchange of information (Figure 3) is different from previous passive management (offline of exchange information). The information on the operating mode of the engine, ship speed and direction of ship sail, weather conditions,... is transmitted to the ship management office (via satellite). The manager can determine, calculate option, ... and make decisions or recommendations operating mode to use fuel savings and increase fuel efficiency.

Selecting a continuous information measurement to determine operating mode of engine and operating regime is seen as an important first step, as the basis for calculation optimal operating (Figure 4). Along with information on the operation of the engine, the information related to fuel use is also constantly updated and store in “Black Box” (Figure 5).

The information is displayed in the engine control room for the serving vessel operators, is stored as a report data source (Figure 6).



**Figure 5 Measure the amount of fuel used on board**



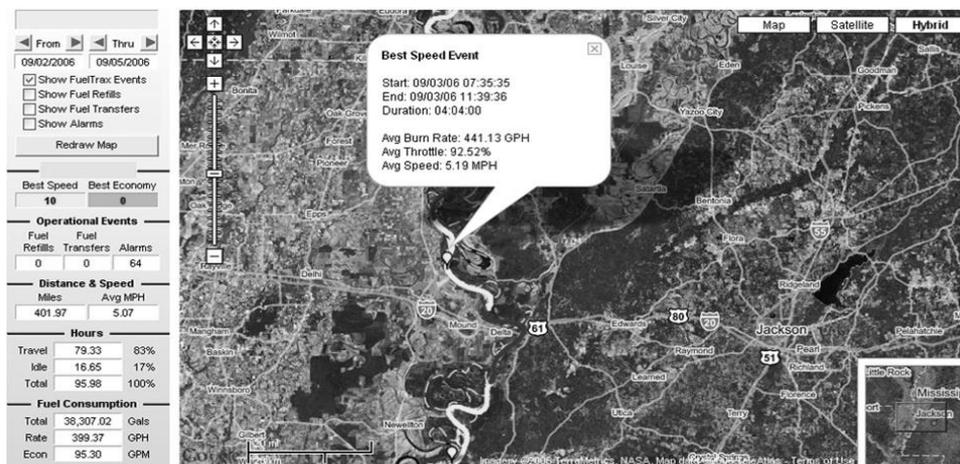
**Figure 6 Analysis and determining the optimal operating regime**

In addition, the information should be selected properly in order to analyze actual operating regime of propulsion plant for the purpose of Economical and Efficient use of energy.

The system allows updating data transmission status of ship operator (Figure 7) which includes sea conditions (weather, waves,...).

With the ability of online communication, the system returns commanding role and regime control for operator at shore side. This management system is not only simply to control fuel consumption on board of ships but also manage ship operator. The system will work exactly with meaning of the terms which have been put by the author: “Active management” alternative to form “passive management” before.

In fact, the Black Box which required by the Ministry of Transport, is attached on road transport vehicles, may have a certain sense similar to this management system. In addition, the management system has been also implemented at some countries in the world. However, building a system that is suitable for ship operators in Vietnam, requires a lot of effort by scientists.



**Figure 7 General view of ship operation**

#### 4.2 Management and technical handling of marine propulsion plant

- Management and technical handling of diesel engine;
- Management and handling overload in torque of diesel engine (torque rich).

The technical situation and the power producing abilities of diesel engine are depended on the age and maintenance quantity. The manufacturers give the recommendations and maintenance procedures, engine recovery under the strict regulations of the International Register Association. However, despite how matter, the engine power always reduced after a period of operation and this one can be up to 30% of rated power and even larger. Thus, if the ship is operated with designed tonnage, the main engine will be an overload in torque, then leading to the fuel consumption will increase significantly. For solving this problem, we must necessarily go in a different direction which is treating the propeller structure.

As we well-known, a power characteristic and a torque characteristic of the propeller depend on a revolution, a pitch factor and dimension of propeller:

$$N_{cv} = f(n^2; H/D; D^4; S) \quad [N] \quad (5)$$

$$Q_{cv} = f(n^2; H/D; D^5; S) \quad [Nm] \quad (6)$$

Where:  $N_{cv}$  và  $Q_{cv}$  - are power and torque required by propeller;

n- revolution of propeller [v/p] ;

H/D- pitch ratio;

D- diameter of propeller [m];

S- The total area of the propeller blades [ $m^2$ ].

Thus, for changing power and torque required by propeller, it only needs to impact on one of variables in the equation No. 5 and No. 6. However, for specific propeller, it can not change pitch ratio (H/D), it can only impact on the diameter (D) or the area of propeller blades (S). If it tries to impact on the diameter, a certain level of pitch ratio will be changed and lead to the changing of thrust coefficient:

$$K_T = \frac{T}{\rho \cdot n^2 \cdot D^4 \cdot 9.81} \quad (7)$$

and torque coefficient:

$$K_Q = \frac{Q}{\rho \cdot n^2 \cdot D^5 \cdot 9.81} \quad (8)$$

and make consequence of chaotic control of propeller features. The our research results show that the best way is to effect on the surface area of blades with lineal impacts to the power and torque of propeller, and easier to control the propeller characteristics after handling.

## 5. Practical application

Currently, the fuel using management of Vietnam shipping company is not relly effective. The huge prodigality are caused by consciousness of seafarers, unsuitable operation plans and dishonest reporting of seafarers to steal fuel oil for sale. The authors also believe that, some countries in the region as well as in the world have the similar fuel management problem. Due to such fuel using management, the research team cooperates with some Vietnam shipping companies for implementation a part of “active method to manage the use of fuel onboard” and we have achieved some positive results.

### 5.1 Fuel oil management at Vietnam Ocean Shipping joint stock company (VOSCO)

The research team applied “active method to manage the use of fuel onboard of ships” for M/V Fortune Freighter and M/V Fortune Navigator in accordance with “management of operation parameters” and proposed suitable operation plans.

#### 5.1.1 Ship’s particulars

**Table 1 Ship’s particulars**

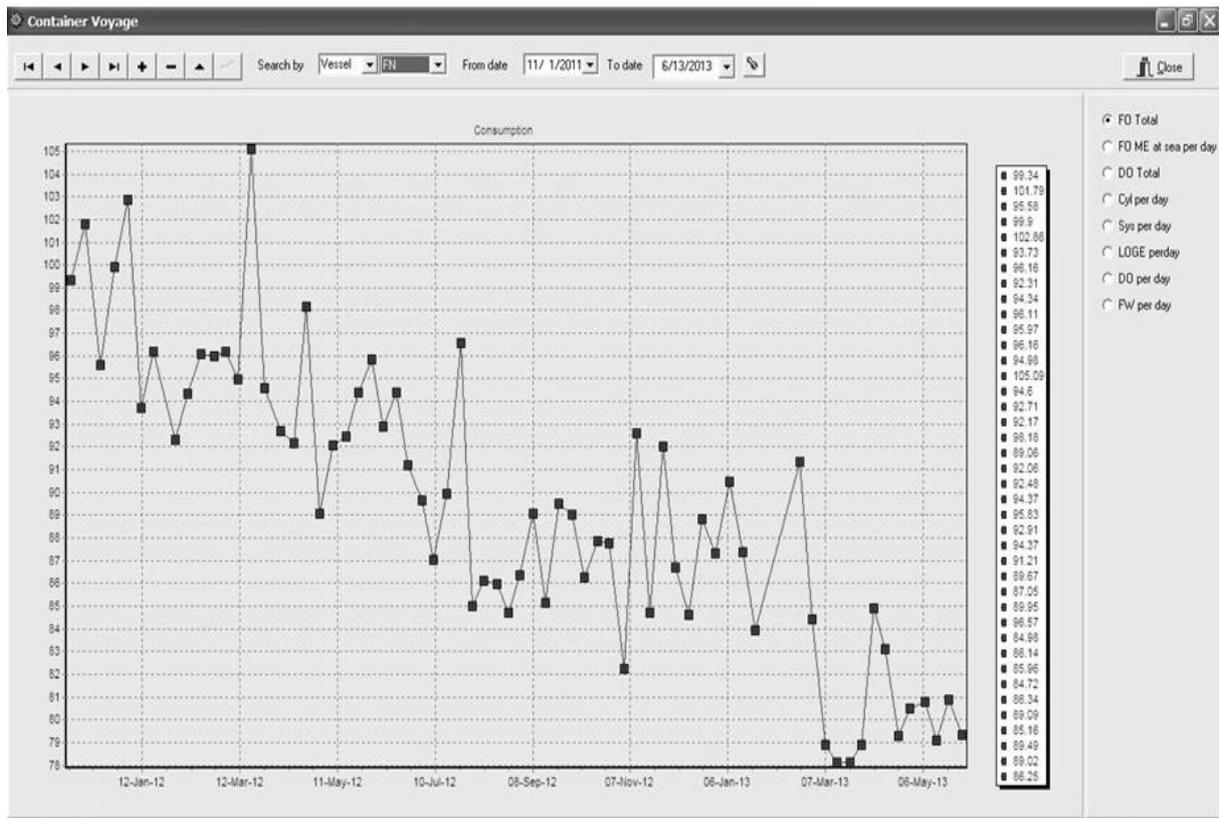
Ship’ name	Deadweight /DWT/	Speed /hl/h/	Power /kW/	Revolution /v/p/
Fortune Freighter	8,937	23	6,062	176
Fortune Navigator	8,515	22	5,983	210

Both vessels have generator YANMAR 6N165L-SN (03 sets) and generator Yanmar S165L-ST (3 sets), boiler TAKUMAX TW - 800SE and composite boiler MKSC 16-700/700.

#### 5.1.2 Methods to manage the use of fuel

##### a. Selection of operating states

Container ships are normally equipped with high speed and large power engine. However, due to increasing fuel costs, the selection of suitable operating states or revolution of engine while ensuring operating schedule with advanced total fuel consumption for a voyage is necessary choice. Data analysis and calculation operation states for vessel, the authors raised result: For the vessel Fortune Freighter is 137 r/m, and for the vessel Fortune Navigator is 173 r/m.



**Figure 8 Analysis the fuel consumption (Source: VOSCO)**

Figure 8 above statistics the fuel consumption for one voyage Haiphong - Saigon - Hai Phong in time for mentioned 2 container ships of the company.

**b. Strengthening the management of operating parameters**



**Figure 9 Operating parameters on main control box**

Aims to ensure the accuracy of the reports from the ship, the company has installed cameras to monitor and record the operating parameters of the main engine and periodically transfer data to company for considering, in comparison with reports from ships. Thus, daily parameters report of ships ensure the accuracy and the fuel consumption is more accurately. The operating parameters to be managed (Fugure 9) including: revolution of the main engine (ME rev), fuel rack indicator (ME FO pump mark), the revolution of the turbine turbocharger (TC rev ME);

**c. The achieved fuel cost reduction**

By the solutions above and together with enhance maintenance equipment, ensuring equipment are always in good technical condition, through continuous follow-up time decreased fuel costs markedly.

For the main engine, in the same quarter of the year (3 months) of two vessels before and after layout solutions of decrease FO consumption, the FO consumption decreased approximately 250 tones / 2 ships. For the boiler, fuel consumption decreased from 1 MT / day to 0.5 MT / day.

## 5.2 Apply the management methods and processing techniques

The research team has applied treatment techniques for ship propellers to reduce fuel consumption. This method was applied to MV Glory Star of K Marine shipping company, which located in Vung Tau, Vietnam.

### 5.2.1 Techniques methods

Before handling, the voyage with operating parameters as prescribed, the ship main diesel engine is often overloaded in heat (high exhaust gas temperature), fuel consumption in one hour quite high and cause some incidents such as damage of valve, fuel injector ...especially, broken crankshaft. The research team carried out inspect the ship's propeller at factory named SG Shipmarin dated 27/10/2012, and main result basic data as follows:

- Difference from actual weight is more than 8,000 kg in comparison with 7,327 kg of design weight;
- Pitch (H/D) is 3,080 in comparison with 3,026 of design pitch;

Basically, the authors can consider that the propeller of Glory Star ship is similar to the original design. However, blades of the propeller of Glory Star ship, though in the error scope, are identified towards to so-called as "heavy propeller".

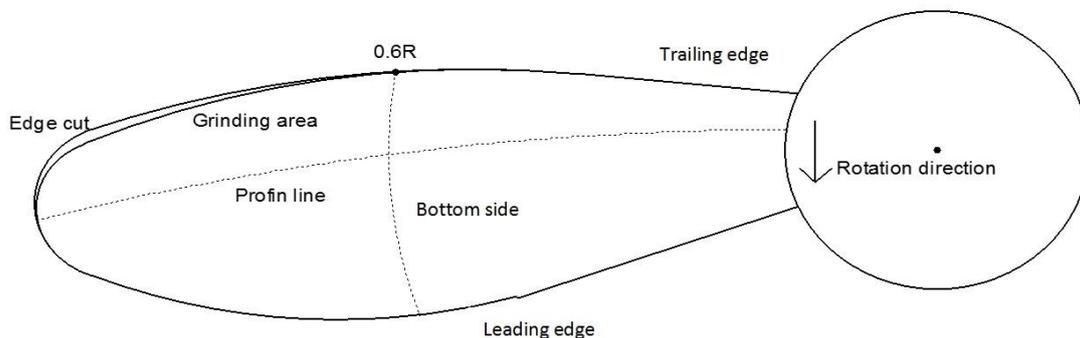
For the data after the survey, the research team decided to handle the technical alternatives:

- Aims to reduce the load for the propeller from 7 to 9%;
- Improve operating power of main engine from 6 to 7%, and to be able to achieve target from 12 to 15% compared to previously operation.

To reduce the propeller load, the research team agreed with the owners to carry out a treatment on blades of the propeller through reducing area of the blades as shown in Figure 10. Research team calculated the cutting location and an amount of cutting area of the blades very carefully. Finally, treatment method is as follows (starting from the first blade):

Cutting position is placed on external area; Cutting line (red color- cut edge) starts from 0.5R to 0.6R, along to top line shape. Edge (water vane edge) is not cut;

Depth of blade cut from 47 mm to 55 mm; No. 1 blade after cutting will be taken to deploy positive for the other side;



**Figure 10 Deploy the cutting line of boarder blade**

After taken off, thickness of cutting area from 8 mm to 10 mm (thick blades not the same), the next task is to identify and deploy profin or broth and grinding to create a new exit areas;

After making cuts and sharpen, propeller has checked static balancing with 2 kg determined weight. Sharpen aims to restore balance were conducted in opposite areas on the basis does not change the blades profin.

Measure the pitch after sharpen, determine pitch blade the average of 3,020.

### 5.2.2 Assessment after handling techniques

After completely technical processing, the vessel was put into operation with routes Jakarta

(Indonesia) - Singapore; Singapore - Saigon (Vietnam); Hon Gai - Vung Tau (Vietnam). In this voyage, the parameters of the main engines and the ship are fully and accurately recorded. Table 2 following bellows is the operating parameters before and after handling techniques.

**Table 2 Operating – Techniques parameters of engine before and after handling techniques**

Techniques parameters	Before	After
Ballast condition		
Fuel oil [T/24h]	17.09	14.37
Exhaust gas temperature [°C]	460	458
Fuel rack indicator [point out]	37.2	33.4
Ship speed [hl/h]	12.4	11.8
Charged pressure [kG/cm <sup>2</sup> ]	1.7	0.9
Tubo-charge revolution [v/p]	16,000	15,500
Full load condition		
Fuel oil [T/24h]	17,68	15,58
Exhaust gas temperature [°C]	466	464
Fuel rack indicator [point out]	39	34,2
Ship speed [hl/h]	11,4	11,8
Charged pressure [kG/cm <sup>2</sup> ]	1,9	1,2
Tubo-charge revolution [v/p]	19.000	18.000

Remarks:

- After processing, the operating parameters of the main engine are greatly improved in comparison with those pretreatment. The engine is no longer overloaded by torque;
- The amount of fuel consumed in a day of main diesel engine reduced approximately 2T/24h compared with before processing techniques;
- During the voyage from 5/7/2012 to 7/12/2012, the specifications of the propeller driven diesel engine, as well as the motivation of the whole system are stable.

## 6. Conclusion

Actually, fuel consumption management for vessels in Vietnam is still insufficient and causing huge losses. Therefore, fuel consumption management in general and for ships in particular is very urgent. To solve this problem in order to contribute to implementing the national target programme on saving the use of fuel, need to be urgently done :

- To change thought of shipping company leaders on the management of fuel on board ships, quickly moved from passive management to the active management;
- «Active method to manage the use of fuel on board of ships» is the modern method that has many countries effectively applied. For this method, the shipowners not only well manage fuel consumption but also increase the safety of the ship in bad weather and piracy;
- In addition to the radical of the ship owners, the government should have specific action plans, management issues put to use to save fuel on ships into national law is considered opinions and obligation force;

The research team of the Vietnam Maritime University are going to carry out research on active manage method the use of fuel oil, and do hope the method will be applied by companies, ship owners soon.

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