REDUCE FUEL OIL CONSUMPTION BY MODIFICATION OF PROPELLER

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ABSTRACT

After a certain time of operation, the conflict between Main engine, Propeller and Hull of ships has occurred, which causes decreasing of engine output and increasing the fuel consumption. In order to solve this problem, researches have been conducted in Japan. The best solution to reduce fuel consumption of the aged ships proved to be modification of propeller. The modification of propeller of ship can be made in several ways: Diameter cut, Twisted blade and Edge cut or Modification of edge.

According to current situation of Vietnam, Maritime Research Institute (MRI) – Vietnam Maritime University (VIMARU) found that Edge cut method would be the most applicable method. This Edge cut method was applied to the merchant ship Glory Star (16.800 MT) in Ho Chi Minh City (Vietnam) from October 24th to December 24th 2012. As a result, calculating method of the edge cutting amount of propeller's blades upon the actual conflict situation of Main engine, Propeller, Hull and the experiment have been studied, developed and obtained.

Keywords: *Main engine, propeller, hull, output, fuel rack index, fuel consumption, confliction, blade, edge, pitch.*

1. RELATION SHIP OF MAIN ENGINE - PROPELLER - HULL

1.1 Design point

Design problems for a ship begin from defining the most basic features, which consists of water occupied volume (equivalent to the cargoes loaded) and its speed. Based on its foundation, a designer starts to draw the curve of hull, calculate resistant, choose engine, propeller and operating modes.

M.E is chosen to assure the suitability between its effective output and thrusted power of propeller, overcoming the resistance and keep the speed of ship. Turning speed of M.E has to be compatible with turning speed of propeller at which the thrusted output reaches largest.

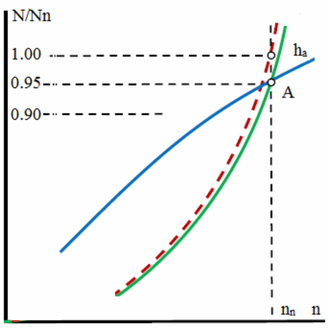

Figure 1 Combined point between Main Engine - Propeller in designing

On the power curve particularity N-n, a design point A will normally satisfy following conditions [1]:

- Full loaded ship sailing in normal marine condition;
- At the norm revolution speed n_n Output of M.E reaches at $N = 0.95N_n$
- Speed of the ship will reach the designed value and some other features.

At the design point A, operating mode of M.E (diesel engine) is correlatively at the revolution n_n and fuel rack index (see figure 1).

During the actual operating period, there are many factors affected which make the operating point between Diesel engine and Propeller be not the point A. Combination as initial design does not keep stable and becomes 'confliction'.

1.2 The loss of M.E's output

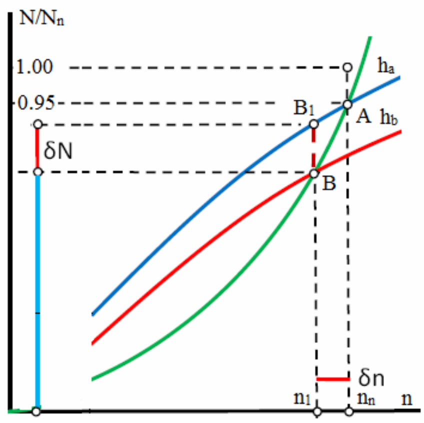

Figure 2 The loss of M.E output

Since the technical condition of M.E is decreased, the operating output will be lowered, which means that at the normal operating condition, while keeping the fuel rack index, the engine's output will be decreased. On the graph of figure 2, while keeping the fuel rack index h_a (point A) unchanged, since the output decreased, it makes the turning speed of Propeller be decreased from n_n to n_1 (point B). This fact is described in figure 2: at point B, the output of M.E provided to the propeller N_b correlatively at the revolution speed n_1. However, at the turning speed n_1 the actual fuel rack index of M.E is not h_b but h_a (point B_1). So, the amount of loss of output is δN (see figure 2). The amount of fuel correlatively with the difference between h_a and h_b (at turning speed n_1) may be understood as the loss of fuel consumption increased [4].

Instead of operating, correlative to the fuel rack index, engine may generate the output lower due to the inner leakage of Fuel Injection pump and quality of Fuel valve (Nozzle). Therefore, before performing an experiment of evaluating the decrease of output, the quality of Fuel Injection pump and Nozzle should be maintained in advance).

1.3 Heavy Propeller – Hull

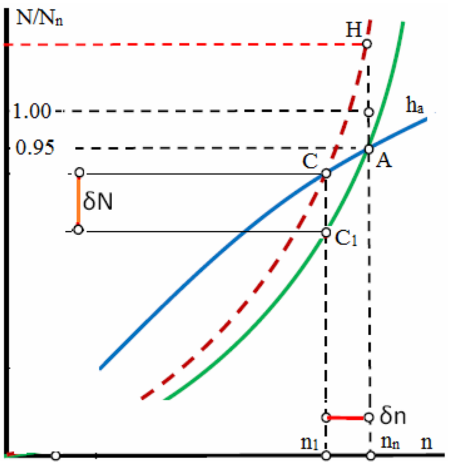

Figure 3 Operating main engine in heavy load or torque rich condition

The state of confliction may happen due to the bad weather condition, the resistance of Hull of the ship increases or Propeller becomes heavier. In these conditions, if M.E is kept operating at the fuel rack index h_a, its turning speed cannot reach the value n_n but can only reach the value n_2 (see figure 3). Comparing to the standard of Propeller's particularity (state of sea trial), the output of engine becomes larger in addition of δN (turning speed decreased around δn).

Operating main engine in this condition is very critical, if the operating revolution is increased, the output and especially the rotating torque will be increased very much (point H, figure 3). In some cases the crankshafts were broken, the gears of gearbox were damaged and the fuel consumption was increased rather much.

2. MARINE DIESEL ENGINE OPERATION IN VIETNAM

Diesel engines installed on marine ships consist of two types: Propeller driven by Main Engine and Generating Engine driven by Auxiliary Engines. M.E is designed to drive directly or indirectly the Propeller (Fixed Propeller Pitch - F.P.P or Controllable Propeller Pitch - C.P.P). On Vietnam's ships, about 95% M.Es drive the fix Propellers directly. From the beginning of 2000, the medium speed engines driving the Propellers via Gearboxes have been installed on significant numbers of medium and small newly built ships [3].

The basic feature of M.E is that it operates according to curve of the Propeller, where the output used on Propeller is rated by power of three with the turning speed: $N = C.n^x$ $(x = 3)$ and using heavy fuel oils (HFO). The most important parameters used to evaluate the operating condition of M.E are the turning speed and the fuel rack index (load indicator).

Most Diesel engines installed on ships in service for more than 5 years are all operated in both decreased and incurred the confliction to Propeller-Hull technical conditions [3].

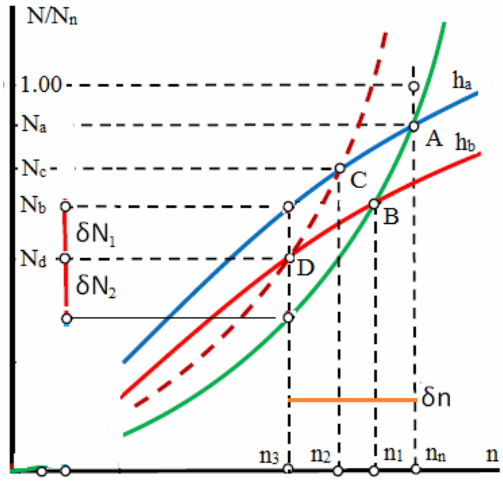

Figure 4 M.E is under output loss and confliction

The impacts concurrently by two factors as described above in figure 4 will move the operating co-operated point to point D (output N_d and turning speed n_3). Moreover, the effect of the fuel consumption is significantly reduced.

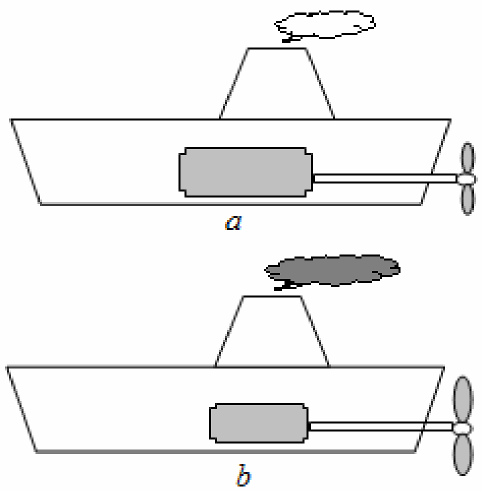

Figure 5 The relation between M.E - Propeller - Hull: a - at design and b - while operating

Phenomena relating to the heavy load (or torque rich) on M.E originated by Propeller - Hull is called the confliction between M.E - Propeller - Hull. If compare this to the initial design, M.E seems to be smaller while the propeller and hull seem to be larger and larger (see figure 5). To protect the engine, the operator often reduces the fuel control handle, therefore the revolution speed and output is decreased.

According to technical reports of some Vietnam shipowners, from 2007, there is rather much confliction happening right after launching or after operating in very short time [3].

3. RESEARCH ON CONFLICTION OF M.E - PROPELLER - HULL

3.1 Research in Japan

Researches which targeted to resist the phenomena of confliction between diesel engine-propeller-hull by Kawasaki Heavy Industries Maker, Kobelco Marine Eng., Kamome propeller Co. Ltd., [5] consist of:

- Diameter cut: this method is aimed at avoiding the torque rich by reducing the Propeller diameter. Due to cut off large amount of blade, it alters the Propeller moment of inertia so widely that it may affect on the Main Engine torsional vibration and it may decrease the Propeller efficiency largely.
- Twisted blade: twisting the blade at each blade root to reduce pitch, by using special equipment upon heat up at the workshop, had also been taken. This method has disadvantage of possible residual stress caused by heat given to the material and complicated work to take off Propeller for measurement of blade pitch after the correction.
- Edge cut: with the point aimed at the alternation of Propeller performance caused by the variable shapes on the trailing edge, it has been developed to reduce the Propeller absorbing torque as said the 'Edge cut' or 'Modification of edge'. In this case, it is required to carry out the complicated calculation for the hydrodynamic estimation on the alternation of Propeller performance. Nowadays, such complicated calculation is undertaken by computer within short time and the edge cut method has been undertaken widely.

All results of researches are approved by quality from Class offices such as Nippon Kaiji Kyokai, American Bureau of Shipping, Lloyd's Register, Germanischer Lloyd [5].

3.2 Research in MRI – VIMARU

From year 2003, in the program developed in co-operation with Japan (JICA), the officers of Vietnam Maritime University (VIMARU) have approached all the results studied by Japan and got the first step of research relating to the actual matters when operating ships in Vietnam.

Researches of Marine Research Institute (MRI) of VIMARU concentrate on the following targets [3]:

- Overcome the confliction among M.E - Propeller - Hull;
- Minimize the loss of output of M.E by technical conditions;

MRI builds up steps to target on inspecting and defining the amount of loss of M.E output and degree of heavy load toward the Propeller - Hull. The standard data referred in 'sea trial' document is used to compare and evaluate to the actual data. Moreover, the data used to evaluate and calculate is chosen to not have used the complicated measuring equipments. For example: to determine the amount of fuel oil injected in a cylinder in one cycle or fuel rack index instead of measuring the effective output of M.E.

Based on the data measured and calculated above, MRI builds up the below projects:

- Cutting and grinding the edge of propeller's blades based on the confliction degree;
- Repairing the M.E to restore the output;

4. THE RESULT EXPERIMENTED SIGNIFICANTLY

In August 2012, shipowner K. Marine suggested to MRI research team to build up the plan to resolve the matter of loss output of M.E and confliction M.E - Propeller - Hull for the M/T Glory Star.

All the major works related to the science project consist of:

- Approaching, handling documents and checking the actual condition of M.E of M/T Glory Star;
- Calculating the amount of loss of M.E output;
- Calculating the degree of confliction M.E - Propeller - Hull;
- Measuring all parameters of actual Propeller;
- Calculating the dimension needed cutting at edges and grinding blades of Propeller;
- Build up the repair project to restore the M.E output.

The contract was done at Hochiminh city (Vietnam) from October 24th to December 24th, 2012 with all related data as below:

4.1 Degree of confliction & amount of loss of M.E output

In fact, operating at turning speed from 470 to 472 rpm, M.E of M/T Glory Star has to be operated under the overload of output ranging from 12% to 15%, include:

- Degree of confliction M.E - Propeller - Hull in range from 7 - 9%
- Amount of loss of M.E output in range from 6 - 7%

4.2 The Propeller of G.S ship

The Propeller of M/T Glory Star (figure 7) is made by the drawing P-1030-G22 with specifications below:

- Diameter: 4,382 mm;
- Pitch ratio: 0.691;
- Number of blade: 5;
- Material: BRONZE GRASS 4;
- Total weight: 7,327 kg;
- Average pitch: 3,026 mm;

However, after inspecting actual specification of Propeller of M/T Glory Star at SG S.M factory on October 27th, 2012, some differences were found as below:

- The actual weight is more than 8,000 kg if compared to design 7,327 kg
- The actual average pitch blade measured is 3,080 compared to design 3,026

4.3 Modification on propeller

All blades of propeller described in figure 6, with the data relating to the degree of modification defined as follows (see figure 6):

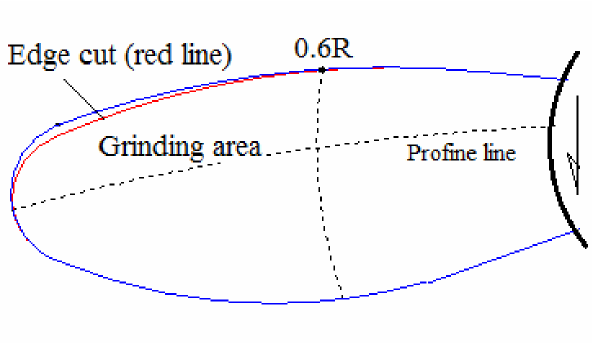

Figure 6 Deploy cutting the edge of propeller's blades

4.3.1 Cutting edge of blade:

- Blade is cut at the area of escape edge (red line), start from 0.6R;
- The cut area got the maximum depth from 47 to 55 mm;

4.3.2 Grinding the blade:

- The area grinded defines at face side, limited by the profile line and cutting edge;
- Deploy grinding from deepest toward cut edge to line profile;

4.4 Running test

After complete repairing, ship G.S was running test in ballast condition from Sai Gon to Dung Quat and in status of 13.000T from Dung Quat to Sai Gon. Measuring to define all parameters, the below results were found:

- The fuel rack index of H.P Pump reduced 4 - 5 (before: 37 - 39; after : 33 - 34);
- Fuel consumption per day reduced 2.0 - 2.5 MT (before: 17.09 - 17.69 MT; after: 14.37 - 15.16 MT);
- Speed of the ship changed slightly; other features of this ship are normal.

5. CONCLUSIONS

MRI was on its first steps to complete as below:

- Built up the method to calculate the amount of edge cut (cutting, grinding) of propeller's blades depending on the degree of confliction M.E - Propeller - Hull.
- The results of qualitative (before) and quantitative (present) is quite suitable with the experiment.
- Modification of propeller's blades for old ships could improve the operating mode of M.E; reduce the fuel consumption but not decrease or slightly decrease the speed of ships.

6. REFERENCES

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Figure 7 M/T Glory Star 16,800 T (K. Marine)