Advanced education and research on marine propulsion – new method for analyzing propulsion performance in service

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Abstract

The most important subject of logistics is to make an effective transportation of cargo and people. Seafarers who are involved in sea-transportation take responsibility not only for safety of operations but also for economical and environmentally friendly operations. It is very important to grasp the knowledge of real-time ship propulsion performance on board in order to optimize operation and maintenance planning. Ship propulsion performance deteriorates in service because of increase in the hull resistance and deterioration of the propeller performance caused by the adhesion of sessile organisms on its surface. However, only the relationship between the ship velocity and the shaft power can be directly detected on board. It is impossible to divide the propulsion performance into the influence of hull resistance and propeller performance by the conventional analysis method. The authors, by carrying out model experiments in ship model basin and actual ship experiments on the Fukae-maru which is installed with a shaft torque meter and a shaft thrust meter, have developed and proposed a new analyzing method, which by numerical calculations can estimate, in service, the hull resistance and the propeller performance individually.

According to this proposed method of analyzing ship propulsion performance in service, the hull resistance performance and the propeller performance can be grasped individually; therefore, the prevailing surface condition of hull and propeller can be estimated correctly. The proposed method can be useful in making an effective maintenance plan, and to achieving an economical and an environmentally friendly operation.

Keywords: propulsion performance, hull resistance, propeller performance, propeller thrust, shaft torque, aged deterioration.

1 Introduction

Propeller and hull surface of actual ships are fouled and their roughness increase in service, due to various causes such as deterioration of painting, adhesion of sessile organism, cavitation erosion, etc. The increase of roughness induces increase of hull resistance and deterioration of propeller performance. Both of them lead to same result such as increase of power and decrease of ship speed. Therefore, the deterioration of propulsion performance cannot be divided conventionally into effects of hull and propeller from logbook data analysis.

A new analyzing method has been developed paying attention to the relation between propeller torque and thrust characteristics. The new method can divide the propulsion performance into the hull performance and the propeller performance by the analysis utilizing logbook data, sea-trial data, propeller open characteristics and self-propulsion factors.

2 Proposed analysis method

2.1 Typical conventional method

The propeller shaft torque can be usually measured through the torsional strain or can be estimated from the specific fuel consumption and the shaft revolution speed in actual ships at sea. On the other hand, the propeller shaft thrust is not measured in normal merchant ships because the compressive rigidity of propeller shaft is extremely larger than the torsional rigidity and it is difficult to measure the propeller shaft thrust.

The propulsion performance of actual ship at sea deteriorates due to various factors, such as weather, sea condition, hull fouling, propeller fouling and so on. The monitoring method of propulsion performance has basically been by the analysis of Log-data for relationship between the M/E power and the ship velocity, as shown in Figure 1. It is impossible to investigate the effects of the hull resistance and the propeller performance individually.

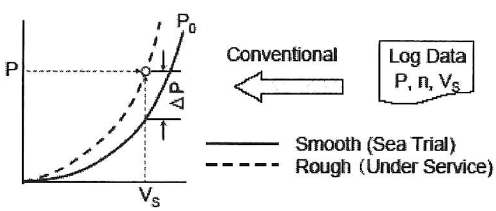

Figure 1: Typical conventional analysis.

2.2 Outline of proposed method

A certain relationship should exist between the deviation of the shaft torque and the shaft thrust of a fouled propeller from clean propeller performance. If the relation between them could be detected properly, the shaft thrust can be estimated from the measured shaft torque in service and the propeller performance in clean condition, and then the variation of propeller performance due to the surface fouling can be estimated. Therefore, the variation of hull resistance is also estimated from the propeller thrust by taking into account of the thrust deduction coefficient.

The estimation method for the change of torque and thrust through the change of drag caused by the propeller surface fouling was proposed by Kaizu [1]. The method was based on the evaluation method for the scale effect of propellers proposed by ITTC 1978 [2]. SR233 [3] also carried out development of an advanced monitoring method for ship performance by use of the ITTC 1978 method. The estimated results of propeller surface roughness by both methods agree qualitatively with actual measurements that the torque increases and the thrust decreases caused by the surface roughness, but there are large differences quantitatively between the actual and the estimation results.

The new analyzing method for propulsion performance of actual ship has been developed and proposed by the authors [4] by carrying out of model propeller experiments with various artificial roughness, numerical calculations based on hydrodynamic theory and actual ship experiments on a training ship equipped with thrust measuring device. The outline of the proposed method is as follows and as shown in Figure 2.

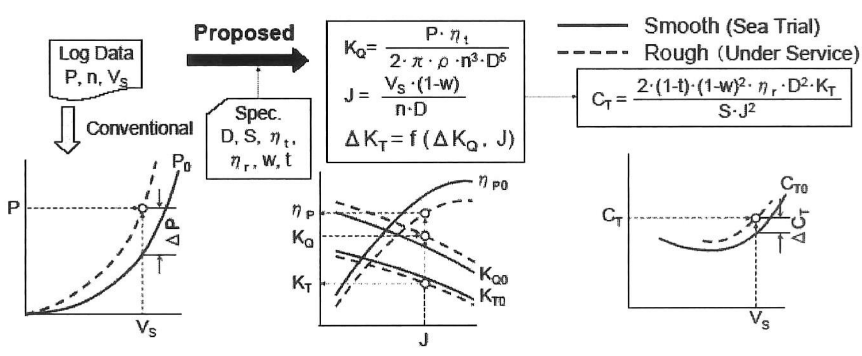

Figure 2: Concept of proposed analysis.

Step 1. To grasp certain relationship between the deviations of the torque and the thrust:
Propeller performance is estimated under clean and several fouled conditions by model experiments or numerical calculations and the relation between the deviation of the torque and the thrust is grasped in advance.

Step 2. To estimate the propeller performance in service:
The present torque coefficient is calculated from measured torque in service, and the present thrust coefficient is estimated by using of the

relation obtained in the step 1. The present propeller performance in service can be estimated.

Step 3. To estimate the hull resistance in service:
The present hull resistance can be estimated from the propeller thrust by taking into account of the thrust deduction coefficient.

2.3 Estimation of roughness effects on propeller performance

The procedure for estimation of roughness effects on propeller performance consists of two steps. In the first step, the boundary layer calculation is done for two dimensional blade section. The propeller blade section is regarded to be deformed due to the surface roughness, apparently by the growth of a thickness of the boundary layer. In the second step, the vortex lattice model, based on lifting surface theory, is adopted for the calculation of a three-dimensional propeller performance.

2.3.1 Boundary layer calculation for two dimensional blade section

Yamaguchi [5] has developed a prediction model for the viscosity effects on hydrodynamic characteristics of 2D hydrofoil and the FORTRAN77 program package has been opened as a freeware. The boundary layer displacement thickness can be estimated by this model. The estimation of roughness effect on 2D blade section can also be carried out by the program with minor modification. The principles of modelling and calculation process are described in [5] and the author's paper [6].

2.3.2 Three dimensional propeller performance calculation

The three dimensional vortex lattice model is used for the calculation of the propeller performance. Each blade section of propeller is considered to be deformed by the boundary layer displacement thickness due to the surface roughness. The effects of surface roughness are taken into account as the change of camber curve and blade thickness.

2.3.3 The relation between deviations of propeller thrust and propeller torque

The relation between the deviations of the propeller thrust coefficient and the propeller torque coefficient can be grasped by several calculations described above at a certain number of surface roughness conditions.

The validity of the prediction method is confirmed by a comparison with model experiments in the author's previous paper [6]. The principle of calculation process is described in the paper.

3 Results and discussion

The calculation and experiment results of a propeller open performance under several fouled conditions are shown in Figure 3. The relation between deviations of fouled propeller performance from that of the clean propeller performance is shown in Figure 4 with results of simplified method by Nishikawa and Liu [7] and ITTC 1978 method. It can be said in general that the proposed estimation method for propeller roughness effect is pretty accurate.

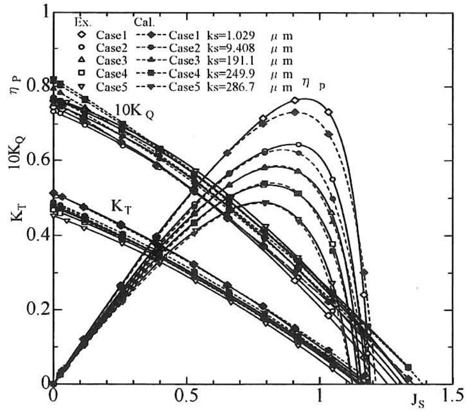

Figure 3: Experiment results of fouled propeller performance.

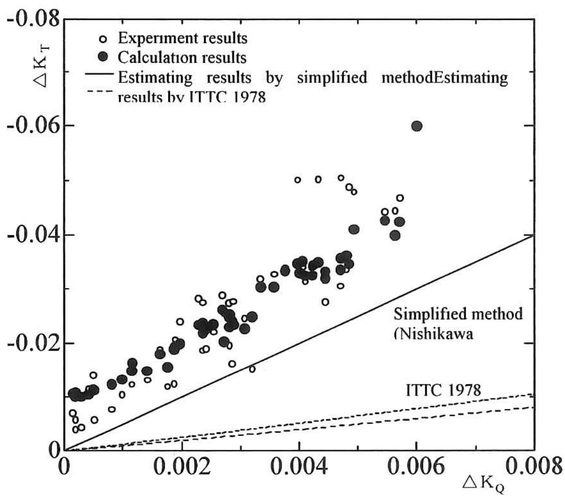

Figure 4: Relation between ΔK_T and ΔK_Q.

The proposed method for analysis was applied to training ship "Fukaemaru" in actual service. She is equipped with torque meter as well as thrust meter. A series of speed tests were carried out in order to investigate the effects of hull and propeller surface fouling on propulsion performance. The experiment results and estimation results obtained by the proposed method are shown in Figures 5 and 6. As seen, it can be said that the estimation results explain very well the deterioration of propeller performance and hull resistance.

In order to investigate its application for general ships, an analysis of Ab-Log data of an ocean going vessel was carried out according to this proposed analysis method. The estimation results of propulsion performance are shown in Figures 7and 8. Figure 7 shows time history for 6 years, with two dry-dockings.

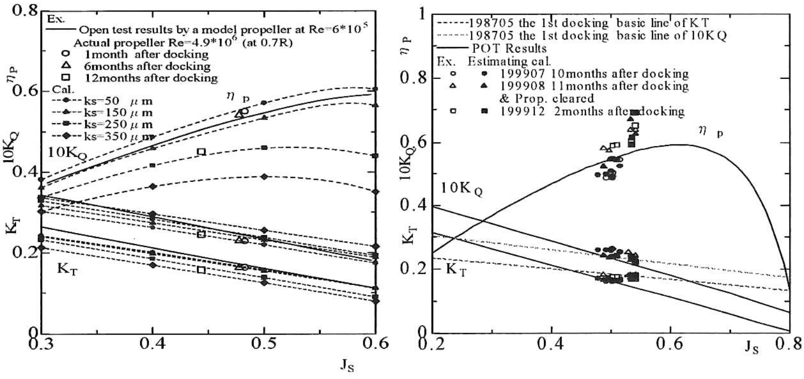

Figure 5: Propeller performance of "Fukaemaru" in service.

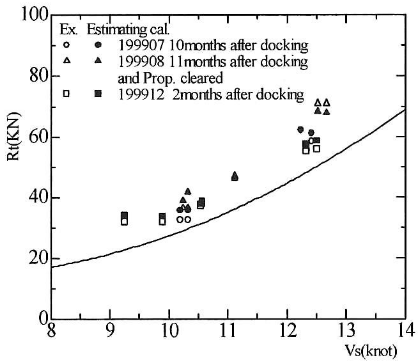

Figure 6: Hull resistance of "Fukaemaru" in service.

The propeller performance tends to deteriorate reasonably as the time passes from the previous docking and tends to recover due to cleaning works at dry-dock. But, it is difficult to see a certain trend of changes in the hull resistance performance. Figure 8 shows all the data of propeller open characteristics and the hull resistance coefficient respectively during first service term, i.e. in clean condition between the start of service and the first docking. The estimation results spread on both the figures. However, there is a specific distribution pattern, i.e. the advanced ratio especially extends to a wide value although the measured torque does not change widely. The value of the data of ship speed is wondered about the accuracy. If the ship speeds data would include a certain error, the analysis results are affected as shown in Figure 9. An error in ship speed data has a great influence on the estimation of results, especially of hull resistance, because the present thrust performance is estimated from the present torque coefficient and the performance of clean propeller, and the hull resistance is obtained from the propeller thrust. It should be stressed that a ship speed measurement device is not generally disputable, however it is pointed out that there is an ample scope for improvement of recording method of ship speed in a logbook. In an ordinary way average ship speed during a watch period is obtained from the running distance for 4 hours. Attention must be paid to the fact that a ship speed data of logbook includes a substantial error for propulsion performance analysis.

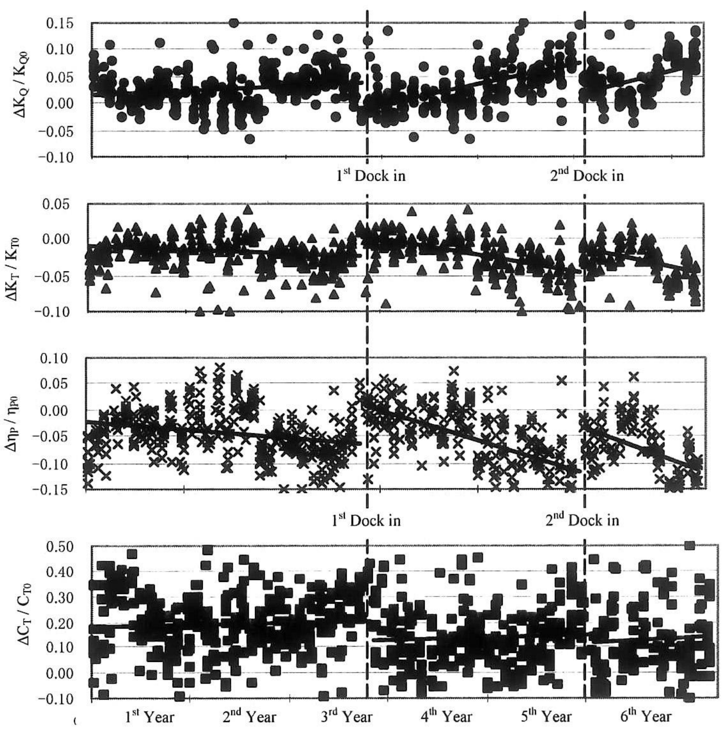

Figure 7: Time history of propulsion performance of an ocean going vessel.

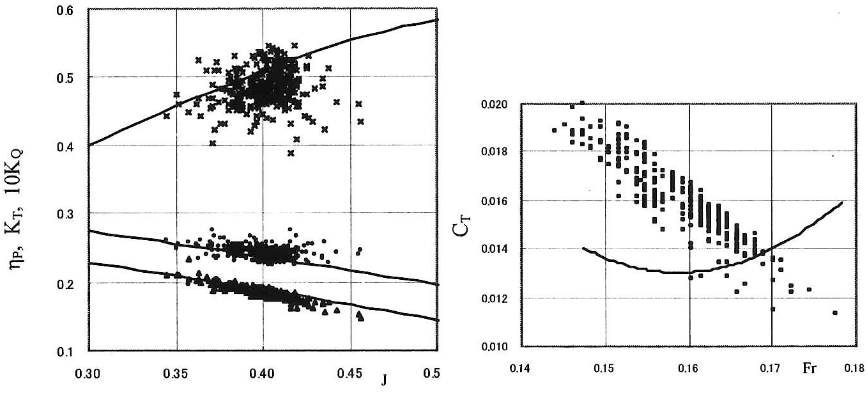

Figure 8: Propeller performance and hull resistance coefficient of an ocean going vessel.

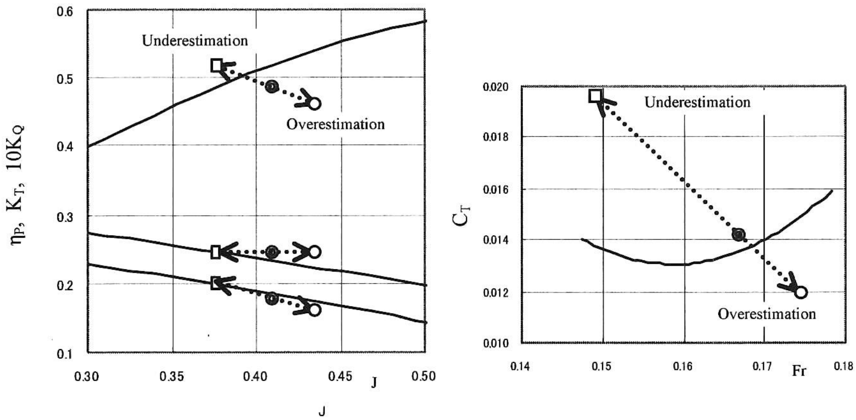

Figure 9: Influence of ship speed error on propeller performance and hull resistance coefficient.

4 Concluding remarks

The new method for analyzing propulsion performance, which in actual service can analyze the aged deterioration of propeller performance and hull resistance individually, has been described. The method is based on the relationship, grasped in advance, between the deviations of the torque and the thrust of fouled propeller from the clean propeller performance. It has been confirmed, through speed tests on "Fukaemaru" in actual service, that this method is able to estimate the roughness effects of propellers by comparison of experimental results of model propeller with artificial roughness, and to divide reasonably the propulsion performance into propeller performance and hull resistance. The method was also applied for Ab-Log data analysis of an ocean going vessel. The estimation results are influenced significantly by the error of ship speed data. In order to investigate the application of this method for ships in general, it is essential to collect actual data of various kinds of ship, such as Log-data, sea-trial data, specifications, self-propulsion factors, etc. Since it is confirmed that the proposed method is valid basically, authors would like to improve the method.

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