ITTC Quality System Manual

Recommended Procedures and Guidelines

Procedure

Performance Prediction Method for Triple Shaft Vessels

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Extension for Triple Shaft Vessels

1. PURPOSE OF PROCEDURE

The procedure gives a general description of an analytical method to predict delivered power and rate of revolutions for triple screw ships from model test results.

2. DESCRIPTION OF PROCEDURE

2.1 Introduction

The method is generally based on that for single or twin screw ships. This appendix describes only the difference from the original ITTC1978 procedure for single or twin screw ships.

The method requires respective results of a resistance test, a self-propulsion test and the characteristics of the model propellers used during the self-propulsion test. Note that the characteristics of side propellers may be averaged, since the two side propellers are used in a pair and we don't need to distinguish them.

As for self-propulsion test, load variation test (LVT) results are also required to decide the self-propulsion point and the load ratio between centre and side propellers. The details are described in section 2.3 of this appendix.

2.2 Definition of Variables

The symbols not defined in the original ITTC1978 procedure are listed below:

ΔF additional towing force in load variation test

ΔT additional thrust in load variation test

Δt additional thrust deduction factor in load variation test

τ thrust deduction under propulsion condition

γ_i resistance fraction for one shaft

Subscript "*i*" is to distinguish propellers. (*i*=1,2,3 corresponds to center, port and starboard)

2.3 Model Tests

How to conduct model test is not covered by ITTC1978 method but the required data is mentioned here.

In case of triple shaft vessel, thrust of centre propeller and side propellers can be different and controlled independently. Therefore the load ratio of centre and side propellers is not unique for one self-propulsion point. Finally one design point is decided in design process.

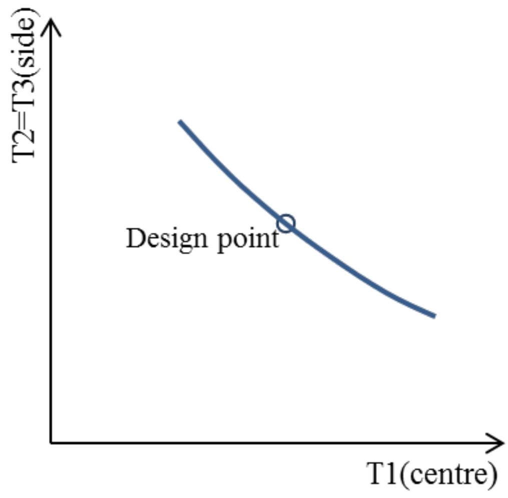

Fig.1 Thrust combination curve which represents self-propulsion points

The load variation test for triple shaft vessel can be classified as this:

Table 1: Classification of load variation test

	Centre	Side
LVT for all prop.	Variable	Variable
LVT for centre prop.	Variable	Constant
LVT for side prop.	Constant	Variable

To draw a thrust combination curve for one ship speed, three series of load variation tests are required. A self-propulsion point should be included within the measured range of each series.

In case of LVT for all propellers, the power ratio is to be decided firstly and then the power variation of each shaft can be set to the same percentage of the maximum power of each shaft. Tests can be done also with the optimum power distribution for each speed which have to be determined in separate tests.

Fig.2 is a schematic sketch of test planning example. Considering that the thrust is not test parameter actually, the diagram is to be based on the power characteristics (i. e. number of rotation).

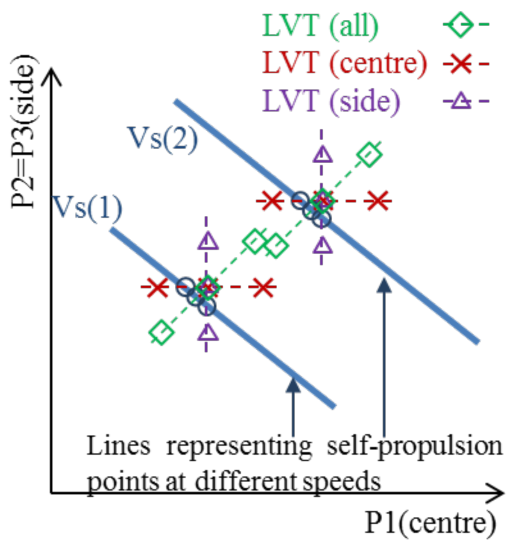

Fig.2 Schematic sketch of LVT planning

2.4 Analysis of the Model Test Results

The analysis methods of resistance and propeller open test are the same as the original procedure. As for the self-propulsion test, self-propulsion point and factors for each shaft are obtained afterwards by interpolation. Thrust deduction factor of each shaft is required in wake scaling calculation.

The thrust deduction from a LVT is obtained from original ITTC1978 description

$$1-t=1-\frac{T_{\mathrm{M}}+F_{\mathrm{D}}-R_{\mathrm{C}}}{T_{\mathrm{M}}}=\frac{-F_{\mathrm{D}}+R_{\mathrm{C}}}{T_{\mathrm{M}}} \quad (1)$$

The thrust, thrust deduction and additional towing force slightly change by ΔT, Δt and ΔF in load variation test and the relation is

$$1-(t+\Delta t)=\frac{-(F_{\mathrm{D}}+\Delta F)+R_{\mathrm{C}}}{T_{\mathrm{M}}+\Delta T} \quad (2)$$

Applying eq. (1) to eq. (2)

$$\frac{-F_{\mathrm{D}}+R_{\mathrm{C}}}{T_{\mathrm{M}}}-\Delta t=\frac{-(F_{\mathrm{D}}+\Delta F)+R_{\mathrm{C}}}{T_{\mathrm{M}}+\Delta T} \quad (3)$$

Then eq. (3) can be deformed to

$$1-\left(\frac{(t+\Delta t)\Delta T+\Delta t T_{\mathrm{M}}}{\Delta T}\right)=\frac{\Delta F}{\Delta T} \quad (4)$$

which can be written as

$$1-\tau=-\frac{\Delta F}{\Delta T} \quad (5)$$

Where

$$\tau=t+\Delta t\frac{T_{\mathrm{M}}+\Delta T}{\Delta T} \quad (6)$$

Note that eq. (2) and following equations can be simplified under the assumption that Δt is negligibly small. Then eq. (6) is no use anymore and eq. (5) becomes the only equation to describe the thrust deduction.

τ for each propeller (τ_i) is derived from LVT for *i*-th propeller and is used to determine the resistance fraction which each propeller to overcome. Then the load fraction of *i*-th propeller at a certain load condition γ_i is derived,

$$\gamma_i = \frac{T_i\left(1-\tau_i\right)}{\sum_{j=1}^{3} T_j\left(1-\tau_j\right)} \tag{7}$$

$$\sum_{i=1}^{3}\gamma_i = 1 \tag{8}$$

After the analysis of LVTs, self-propulsion points are calculated. Relation between total resistance and thrust is written as

$$\begin{aligned} R_{\mathrm{TS}} &= T_1\left(1-t_1\right)+T_2\left(1-t_2\right)+T_3\left(1-t_3\right) \\ &= T_1\left(1-t_1\right)+2T_2\left(1-t_2\right) \end{aligned} \tag{9}$$

Usually τ is a function of load factor of each propeller, therefore a number of self-propulsion points should be calculated by interpolation of LVT results and then a curve representing the self-propulsion points can be obtained by curve fitting.

The thrust deduction factor for *i*-th propeller at one self-propulsion point t_i is calculated from the result of LVT for *i*-th propeller by interpolation. At the same time, total thrust deduction factor t is also obtained.

$$1-t_i = \gamma_i \frac{R_{\mathrm{TM}}-F_{\mathrm{D}}}{T_i} \tag{10}$$

$$t = -\frac{R_{\mathrm{TM}}-F_{\mathrm{D}}-\sum_{i=1}^{3}T_i}{\sum_{i=1}^{3}T_i} \tag{11}$$

The effective wake ratio for each propeller is obtained by thrust-identification (or torque-identification) method using propeller open characteristics. Then the relative rotative efficiency is calculated.

2.5 Full Scale Predictions

As described in the following sections, no full scale data is disclosed up to now and this section only shows the principle idea of extrapolation.

2.5.1 Total resistance of ship

Extrapolation method for the resistance is the same as the original procedure.

$$\begin{aligned} C_{\mathrm{TS}} = \frac{S_{\mathrm{S}}+S_{\mathrm{BK}}}{S_{\mathrm{S}}}\left[\left(1+k\right)C_{\mathrm{FS}}+\Delta C_{\mathrm{F}}+C_{\mathrm{A}}\right]+ \\ +C_{\mathrm{R}}+C_{\mathrm{AAS}}+C_{\mathrm{APPS}} \end{aligned} \tag{12}$$

2.5.2 Scale effect corrections for propeller characteristics

The prediction method for characteristics of the full-scale propeller is also the same as the original procedure. Correction should be done for each propeller.

$$K_{TS} = K_{TM} - \Delta K_T \tag{13}$$

$$K_{QS} = K_{QM} - \Delta K_Q \tag{14}$$

where

$$\Delta K_T = -\Delta C_D \cdot 0.3 \cdot \frac{P}{D} \cdot \frac{c \cdot Z}{D} \tag{15}$$

$$\Delta K_Q = \Delta C_D \cdot 0.25 \cdot \frac{c \cdot Z}{D} \tag{16}$$

The difference in drag coefficient ΔC_D is

$$\Delta C_D = C_{DM} - C_{DS} \tag{17}$$

where

$$C_{DM} = 2\left(1 + 2\frac{t}{c}\right)\left[\frac{0.044}{\left(Re_{c0}\right)^{\frac{1}{6}}} - \frac{5}{\left(Re_{c0}\right)^{\frac{2}{3}}}\right] \tag{18}$$

and

$$C_{DS} = 2\left(1 + 2\frac{t}{c}\right)\left(1.89 + 1.62 \cdot \log\frac{c}{k_{\rm P}}\right)^{-2.5} \tag{19}$$

Details are described in the original procedure.

2.5.3 Full scale wake and operating condition of propeller

The full-scale wake is calculated by the ITTC1978 formula using the model wake fraction and the thrust deduction fraction for each propeller. The number and position of rudder, type of side shaft support (brackets or split stern) should be considered for each propeller. Formulas for correction are the same as the original procedure.

$$w_{TS\_i} = (t_i + w_{{\rm R}\_i}) + \\ +(w_{TM\_i} - t_i - w_{{\rm R}\_i})\frac{(1+k)C_{\rm FS} + \Delta C_{\rm F}}{(1+k)C_{\rm FM}} \tag{20}$$

where w_{R_i} is set to zero when rudder is not located after i-th propeller.

Firstly the load ratio for the centre and side propellers at self-propulsion point should be decided. Secondary self-propulsion factors in full scale are calculated for each propeller and finally total power is obtained.

The load of the full-scale is obtained by the same procedure, however the operating conditions of centre and side propellers are different.

$$\frac{K_{TS\_i}}{J_i^2} = \frac{S_{\rm S}}{2D_{\rm S}^2}\frac{C_{\rm TS}\gamma_i}{(1-t_i)(1-w_{TS\_i})^2} \tag{21}$$

$$n_{{\rm S}\_i} = \frac{(1-w_{TS\_i})V_{\rm S}}{J_{{\rm TS}\_i}D_{\rm S}} \tag{22}$$

Finally the delivered power, thrust and torque of each propeller are

$$P_{{\rm DS}\_i} = 2\pi\rho_{\rm S}D_{\rm S}^5 n_{{\rm S}\_i}^3 \frac{K_{QTS\_i}}{\eta_{{\rm R}\_i}} \cdot 10^{-3} \tag{23}$$

$$T_{{\rm S}\_i} = \left(\frac{K_{TS\_i}}{J_i^2}\right) \cdot J_{TS\_i}^2 \rho_{\rm S} D_{\rm S}^4 n_{{\rm S}\_i}^2 \tag{24}$$

$$Q_{{\rm S}\_i} = \frac{K_{QTS\_i}}{\eta_{{\rm R}\_i}} \cdot \rho_{\rm S} D_{\rm S}^5 n_{{\rm S}\_i}^2 \tag{25}$$

2.5.4 Model-ship correlation factor

The model-ship correlation factor should be based on systematic comparison between full scale trial results and predictions from model scale tests. Thus, correlation factor for triple shaft vessels may differ from that of single/twin shaft vessels. However no recommended value exists at present, since there are not enough data for triple shaft vessels.

3. VALIDATION

3.1 Uncertainty Analysis

General uncertainty analysis procedure for self-propulsion test will be applied.

3.2 Comparison with Full Scale Results

Not yet available

4. REFERENCES

Not yet available