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Model-Ship Correlation Study on the Powering Performance for a Large Container Carrier

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Abstract

Large container carriers are suffering from lack of knowledge on reliable correlation allowances between model tests and full-scale trials, especially at fully loaded condition. Careful full-scale sea trial with a full loading of containers both in holds and on decks was carried out to clarify it. Model test results were analyzed by different methods but with the same measuring data to figure out appropriated correlations factors for each analysis methods. Even if it is no doubt that model test technique is one of the most reliable tool to predict full scale powering performance, its assumptions and simplifications which have been applied on the course of data manipulation and analysis need a feedback from sea trial data for a fine tuning, so called correlation factor. It can be stated that the best correlation allowances at fully loaded condition for both 2-dimensional and 3-dimensional analysis methods are found through the careful sea trial results and relevant study on the large size container carriers.
Keywords: model test, powering performance, full-scale sea trial, 3-dimensional analysis method, 2-dimensional analysis method, model-ship correlation

1 Introduction

Recently many large container carriers, of which capacities go over 4,000 TEU and even more reach to almost 8,000 TEU, have been built and are also under construction. On the course of hull form and propeller design of the vessel, model testing have been regarded as the most reliable tool to predict full scale powering performance nevertheless its assumptions and simplifications on the data analysis and extrapolation to compensate a large gap of scale between model and actual full ship. Even if measured data were carefully manipulated and analyzed after model test by well-established methods, certain amount of correlation allowances is normally necessary to make a precise powering prediction in full-scale. So every model basins have their own correlation allowances based on the accumulated full-scale sea trial experiences for the final adjustment of the powering. But especially for the recent large container carriers, gathering the precise information on the full-scale trials at fully loaded drafts is very difficult and moreover even if full draft tests can be done during sea trial by loading some ballast water in the holds, the results still are very skeptical because test condition hardly coincides with actual container loading cases. It's believed that the correlation on the such a large container carrier should be fully reviewed and studied again although every model basin have a their own values on it, which may have been extrapolated from

Table 1: Main particulars of large container carrier

LOA	About 300.0 m
LBP	286.0 m
B	42.8 m
D	24.5 m
Loaded draft for Tests	12.5 m
No. of Container	About 6,800 TEU
Main Engine	12RTA96C
Max. Continuous Rating	65,880 kW X 100.0 RPM

their previous experience for smaller size of containers not comparable to the large size container carriers in main dimensions.

HHI designed some large container carriers of almost 7,000TEU container capacities and carried out model tests in HHI's towing tank. Hyundai Maritime Research Institute(HMRI) use ITTC78 method for the analysis of the tests data and the correlation between model and full scale is done in terms of powering correction factor(C_P). C_P variation and its influence on the powering was studied even HMRI have a standard C_P value for the container carriers developed through their previous experience. Furthermore the model test data was also analyzed through different method, so called traditional 2-dimensional method, that is used at some model basins such as HSVA, MARIN(partly), KRISO and SSMB etc. to figure out a comparable correlation allowance to the 3-dimensional ITTC78 method. So, simply, correspondent correlation factors between both methods can be found out in summarized table.

The vessel was also carefully carried out full-scale trial with actual container loading in holds and on decks up to the almost design draft after delivery of the vessel.

The paper will demonstrate the results of the full-scale sea trial and present what will be the best correlation between model and full-scale on this kind of large container carrier. Of course the correlation studies are expanded up to 2 different kinds of analysis methods such as aforementioned ITTC78 3-dimensional method and traditional 2-dimensional method based on the same measuring data during the model tests. Because the full-scale trial was performed in a very precise and careful manner, the values obtained through the trial are very reliable to make a fine adjustment of the correlation factor. Correspondingly it can be stated that the best correlation allowances can be respectively obtained for both analysis methods through this actual full-scale sea trial and relevant study for the loading condition.

Table 1 shows main particulars of the vessel to be studied and discussed in the paper.

2 Model test and its analysis methods

Every model basins have their own model test and analysis method but with the same physics of Froude Law. International Towing Tank Conference(ITTC) proposed one analysis method to standardize it in 1978, so called ITTC78 Method. But still many model basins are maintaining their traditional methods with their own special correlation allowances. So only typical analysis method, even it is 2-dimensional or 3-dimensional, can be described here. ITTC78 Method for the 3-dimensional and one typical method for the 2-dimensional are demonstrated herewith and utilized during this study. Figure 1 briefly demonstrates main difference between two methods in resistance analysis.

The model tests for the aforementioned vessel was performed in the scale ratio of 40.445 and length of the model was about 7.4 m. Because propeller load variation was done during the measurement in self-propulsion tests, ship self-propulsion points might be different in accordance with the different towing force calculated by two analyses methods. So the self propulsion factor and propulsive efficiencies for the 3-dimensional method and the 2-dimensional method will not be in line with each other.

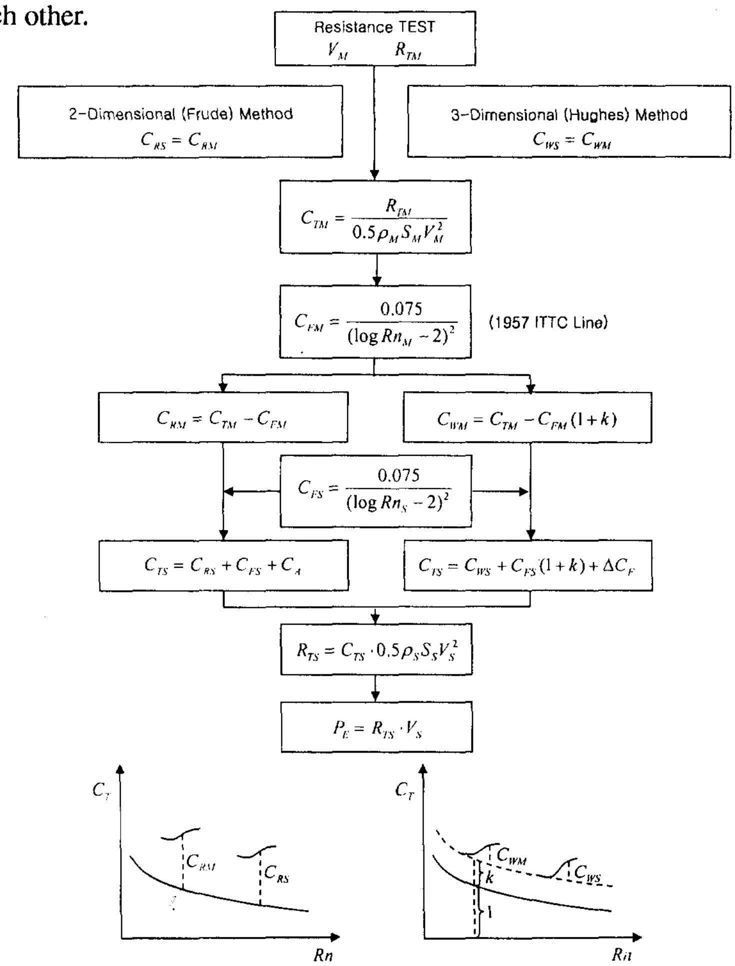

Figure 1: Model test analysis method in resistance

2.1 ITTC78 3-dimensional method

From the measured data of propulsion tests, self-propulsion factors in model-scale are assessed, and extended to full-scale values. Finally, rate of revolution(n_S)and delivered power(P_{DS})are predicted. Details are refered to "Report of Performance Committee",15th ITTC Proceeding,1978.

To make the prediction corresponding to trial conditions, the calculated rate of revolution(n_S)and delivered power(P_{DS})are corrected to each model basin's trial statistics.

$$n_T = C_N n_S, \qquad P_{DT} = C_P P_{DS}$$

HMRI has a standard C_P value of 0.95 and C_N of 1.0 for every type of merchant vessels such as tanker, bulk, gas carrier, etc. as well as container carrier and the values have already been confirmed by previous sea trials excepting large container carrier that have never been tried.

2.2 Traditional 2-dimensional method

(A) Resistance Test/Test method and Calculation

The total ship resistance coefficient(C_{TS})can be calculated as follows.

$$C_{TS} = \frac{S_S + S_{BK}}{S_S}[C_{FS} + C_A] + C_R + C_{AA}$$

C_A = model-ship correlation allowance

(B) Self-Propulsion Test/Test Method and Calculation

The test method and calculation are almost same, but some parameters concerning Resistance are different. In self propulsion test, The propeller rate of revolution is in general adjusted so that the towing force(F_D) will reach the value:

$$F_D = \frac{1}{2}\rho_m S_m V_m^2[C_{FM} - (C_{FS} + C_A)]$$

The remaining parts for calculating the rate of revolution and delivered power from the full scale propeller open water characteristics are same as 3-D Method.

3 Sea trial

The loaded sea trial was carried out at the sea area of Spain southern part(cabo de sta maria 15 miles) under the condition of 12.5 m draft by putting containers in holds and on decks. Especially on decks 5 tiers containers loading were made. To get a precise and reliable result, measurements for only one RPM, which is corresponding to about 85% MCR power, but with 2 double runs was done with at least 4 nautical mile distances for every run. Speed and power were respectively recorded by DGPS and torsion meter. It was estimated that the wind and wave condition was gentle and was within Beufort No. 3 and Sea State 2 during the measurements. So any correction on the results is unlikely necessary and all data of the full scale trial demonstrated in this paper remains in the raw.

Figure 2 shows the map for the full scale speed trial at the loaded condition of 12.5 m and its result for 4 speed runs is recorded in Table 2. Here in the table, the final averages of the speed, RPM and power are taken by means of means from every 4 runs.

4 Test results and correlation between model test and full trial

HMRI have carried out model tests for the mentioned vessel at the 12.5M loaded draft and performed analysis by two alternative methods described in previous chapter.

For ITTC78 3-dimensional method, the correlation factor C_P values, which is only one variable to correlate between model and full scale in the method, are systematically varied to find out

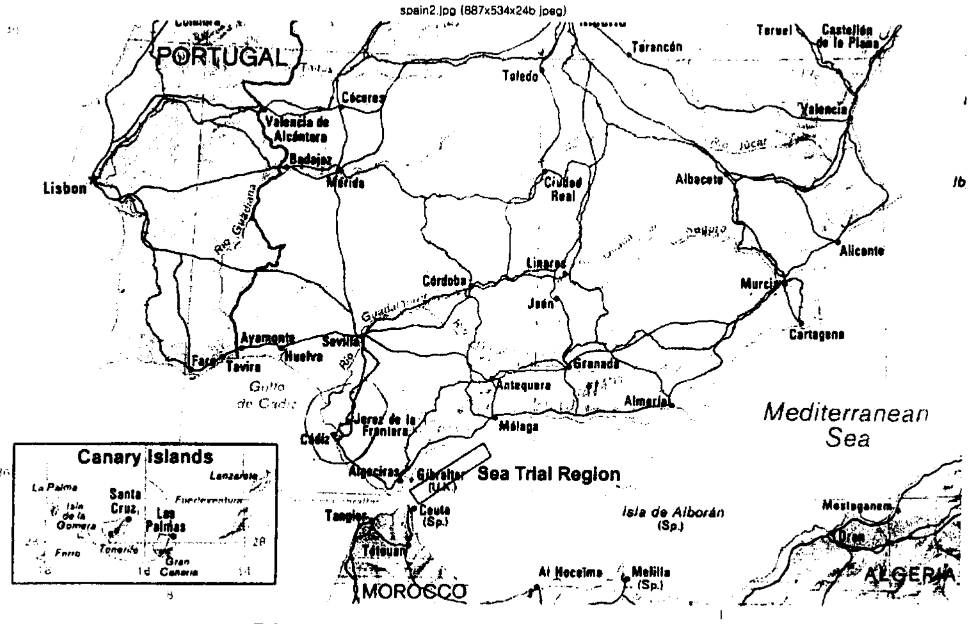

Figure 2: Map for full scale speed trial

Table 2: Result of full scale speed trial at 12.5 m draft

Engine Load	True Wind(m/sec)	Wave Height(m)	Speed kNots	Speed Average	Power kW	Power Average	RPM	RPM Average
85% MCR	3∼6	0.5∼1.0	26.32	25.91	55,350	55,741	100.9	100.9
			25.65		56,010		100.9	
			26.14		55,430		100.9	
			25.58		56,260		100.9	

appropriated factor coincided with the full scale speed trial result. Figure 3 presents relationship between variation of C_P values and predicted speeds. Furthermore the results from full-scale speed trial is also conglomerated in the figure together. It can be stated that the correlation factor C_P on the ITTC78 method will be about 0.95 to make a good match with actual full-scale trial result.

As pointed out in the previous chapter, the extension of C_P value of 0.95, which has been applied to all type of merchant vessels with a single screw at HMRI, up to the large container carrier is fully confirmed.

Figure 4 is showing variation of C_a values, which will be one correlation allowance in traditional 2-dimensional analysis method, and their corresponding predictable speeds. The full-scale trial result is also marked in the figure as the former case of ITTC78 3-dimensional method. By this comparison to the full-scale speed trial result, it can be esteemed that the C_a value of -0.032×10^{-3} is likely a good correlation allowance in the 2-dimensional method for this kind of large container carrier. It can be found from this figure that the difference of 0.1×10^{-3} in C_a value is roughly identical with 0.33knots in terms of ship's speed.

In Figure 5, the C_p value in 3-dimensional method and the comparable C_a value in 2-dimensional method are figured with the mark of full scale result.

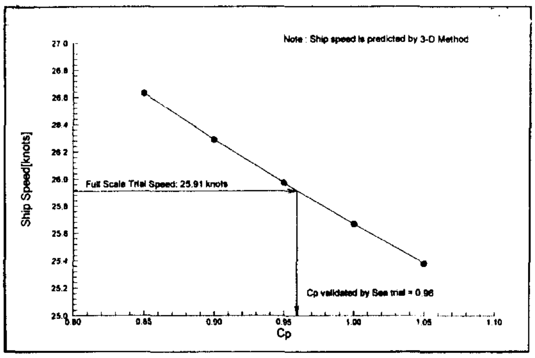

Figure 3: Relationship between Cp and Speed for ITTC78 3-dimensional method

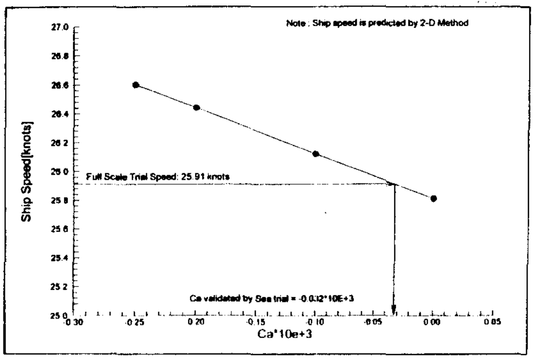

Figure 4: Relationship between Ca and Speed for 2-dimensional method

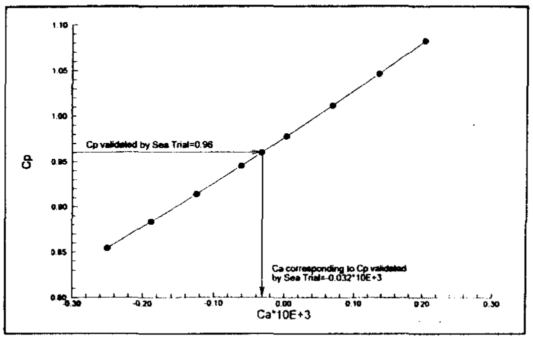

Figure 5: Identical Cp-Ca relationship for large container carrier

5 Conclusions

To find out the correlation factor at fully loaded condition on the large container carrier, some model test and relevant studies on different analysis methods and careful full-scale speed trial have been carried out. This study is believed very valuable to clarify correlation relationship between model tests and actual ship performance at the deeply loaded condition on very large container carriers that have never been built until some years before and furthermore it have been, so far, debatable due to lack of the precise data of full scale trial. Considering that some model basins use a certain figures without full confirmation on this, specially for the case of 2-dimensional analysis method, this kind of full scale sea trial should be carefully carried out.

Followings can be stated from these studies.

- Full load correlation factor C_p at the ITTC78 3-dimensional method should be around 0.95 to coincide with full-scale trial result.

- Correlation allowance C_a in the typical traditional 2-dimensional method should be around -0.05×10^{-3} to maintain the same condition to above.

- Because the difference of 0.1×10^{-3} in C_a value is identical with more than 0.3knots in terms of ship's speed, so the C_a value should be carefully used to avoid unrealistic performance prediction.

- Generally the ITTC78 3-dimensional method has been in good agreement with every type of vessels by C_p of 0.95 at HMRI. The study indicates even the large container carrier is also in line with same tendency to former experiences for normal merchant vessels and the extension of same correlation factors up to the large container carriers is fully acceptable. Robustness of physics of the 3-dimensional method may support stable correlations over every kinds and sizes of the vessels.

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