論 文

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On the Characteristics of Form Factors

(Series 60, $C_B=0.60$)

by

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Series 60, $C_B=0.60$ 선형의 형상계수의 특성고찰

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Abstract

The Resistance Committee of the Korea Towing Tank Conference extended the Cooperative Experimental Study Program(1985) [1] to perform the geosim tests by exchanging the five different scaled Series 60, $C_B=0.60$ models between the participating organizations and 13 sets of resistance data have been obtained. The test results are compared among the participating towing tanks and also with the results given in the report of the Resistance and Flow Com-identify the mittee of 18th ITTC.

The form factor of each model is derived by Prohaska's method to investigate its dependency on R_n. On the other hand, at each F_n, form factors are also derived by Telfer's method to relation between F_n and form factor.

For this hull form, form factors show relatively weak dependency on R_n and strong dependency on F_n. And it is also found that dependencies on both have a cross relation. It seems that further study should be continued to understand more clearly the physical phenomena involved in this problem.

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요 약

국제선형시험수조회의의 저항시험에 관한 표준선형인 Series 60, C_B=0.60에 대하여 서로 크기가 다른 5척의 모형선을 국내의 선형시험수조 보유기관(한국기계연구소 선박분소, 현대선박해양연구소, 서울대학교, 인하대학교)에서 제작, 교환하여 상사모형시험을 수행하였다.

이 결과를 Hughes 및 Telfer의 방법에 따라 해석하여 형상계수와 모형선 크기 및 예인속도와의 관계를 파악하고자 하였다.

이 선형에 대해서 형상계수는 Reynolds 수 뿐 아니라 Froude 수에 따라서도 변화하는 것을 확인하였다. 또한 현행의 형상계수를 이용한 실선저항추정법이 공학적 유용성을 가지고 있음을 재확인하였다.

선형특성이 다른 여러 선형에 대해서 상사모형시험을 실시하므로서 보편적인 원리를 파악하는 것이 필요하다고 판단된다.

1. Introduction

About a century ago, W. Froude had proposed the model and ship similarity. After his time, modernized towing tanks were constructed and experimental techniques were developed and improved very much. But, up to the present, the extrapolation of model test results to full scale is based on Froude's method even it is well known that physically unreasonable factors are included in Froude's assumption. Though the concept of form factor proposed by Hughes can take the three dimensional effect into account, but basically it is also confined to Froude's assumption.

Hughes' method known as three dimensional extrapolation was proposed at the 10th ITTC, 1963. But the physical interpretation of form factor is not clearly described until now. Hughes defined that form factor depends only on the geometric characteristics of hull form, but according to the geosim test results, it depends not only on model sizes (R_n) but also on F_n. To confirm this fact, Resistance Committee of KTTC of SNAK extended the Cooperative Study with Series 60, C_B=0.60 model to the second year(1986). Exchanging the models among the participating organizations, 13 sets of resistance test results were obtained.

An analysis of the results reveals that the form factor varies with the model sizes and speeds, and is not same for a given hull form with different sizes contrary to Hughes' assumption.

The scale effects are strongly related to the speed effects on form factors. The procedure for full scate resistance prediction with form factor is investigated for an engineering application.

2. Results of Resistance Test

The Ship Research Station of Korea Institute of Machinery and Metals(SRS, KIMM), Hyundai Maritime Research Institute(HMRI), Seoul National

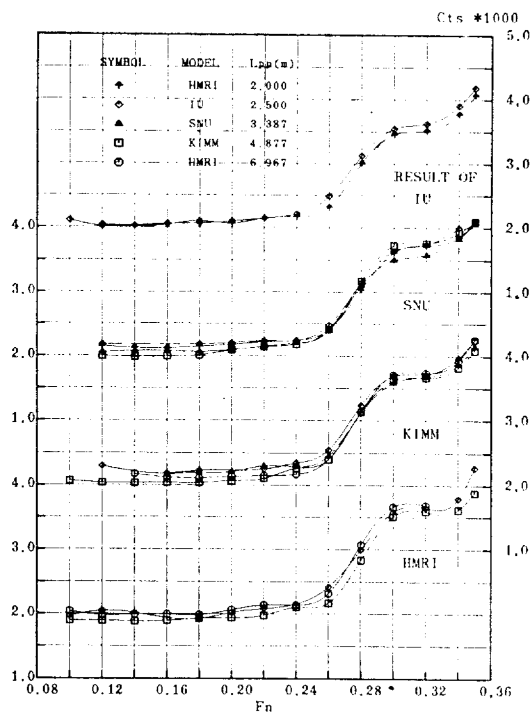

Fig. 1 Comparison of total resistance coefficients

Table 1 Model size and towing tank dimension

KTTC Organi.	Towing Tank $L\times W\times D$(m)	Model		Resistance Test
		scale	L_{pp}(m)	
KIMM	223×16×7	25	4.877	KIMM, HMRI, SNU
HMRI	232×14×6	17.5	6.967	HMRI, KIMM
		60.96	2.0	SNU, IU
SNU	117×8×3.5	36	3.387	SNU, KIMM
IU	79×5×3	48.77	2.5	IU, KIMM, HMRI, SNU

University(SNU) and Inha University(IU) have participated in the Cooperative Experimental Study on Series 60, $C_B=0.60$ model, performed in 1985 by preparing their own models.

Continued to the first year plan[1], the study is extended to the geosim test by exchanging the models among four organizations and the results of the second year are summarized in Table 1.

The resistance tests are performed with the same conditions as those of the first year, and the model-scale results are extrapolated to the predesignated ship length of 121.92m(400ft) and standard temperature of 15°C using the "ITTC 1957 Model-Ship Correlation Line," and total resistance coefficients are plotted in Fig. 1. Test methods and measuring accuracy were confirmed through the first year study, it is believed that the results are reliable, though some inherent characteristics of each organization may be included in the results. The differences in residuary resistance coefficients should be explained by the fact that the form factor is changed due to

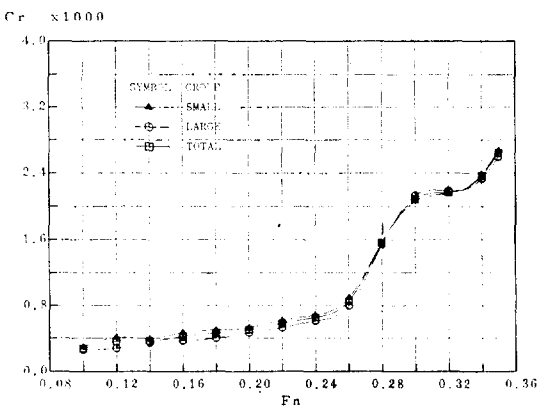

Fig. 2 Comparison of mean resisduary resitance coefficients

the model sizes and the speeds. To confirm the fact, the models are classified into the small(2, 2.5 and 3.387m in L_{pp}) and the large(4.877 and 6.967m in L_{pp}) groups. The arithmetic mean values of C_r for each group are compared in Fig. 2. In the range of $F_n\leq 0.28$, mean value of C_r for the small group is greater than that for the large group, and the differences are greater as F_n becomes smaller. To obtain the same full-scale values from these two curves, there should be a parallel adjustment of C_r curves due to the variation of form factor dependency on the model sizes and rotational adjustment

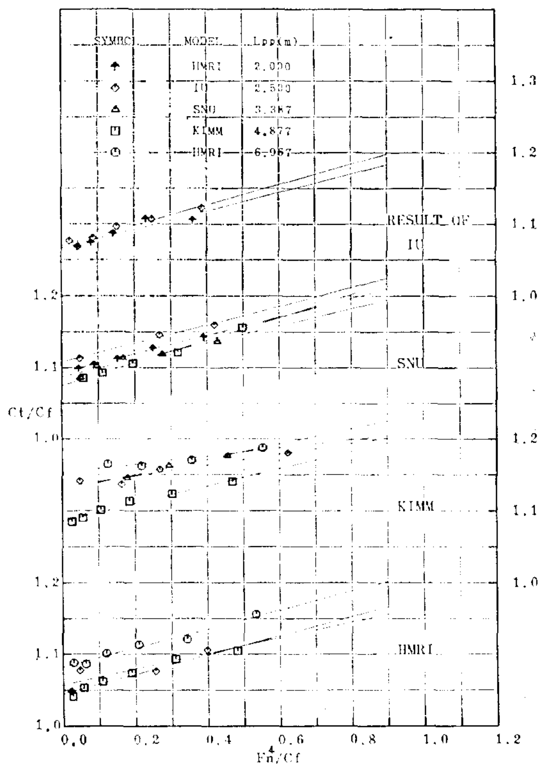

Fig. 3 Form factors by prohaska's method

due to the variation of form factor dependency upon the speeds.

3. Scale Effect on Form Factor

To investigate the scale effect on form factor, the form factor for each data set was calculated by Prohaska's method ($n=4$) as shown in Fig. 3. The results for each model are summarized according to the model length in Fig. 4. The form factor kequals 0.1 approximately and includes the varying components for the changes of the model size. If Hughes' assumption is correct and experiments are performed accurately, these values should be constant and coincide with that from mean values of total data set. But form factor is composed of the linearly varying component and fluctuating component with the model sizes as shown in Fig. 4. In this method, the form factors are obtained based on same range of F_n but with different R_n due to the differences of

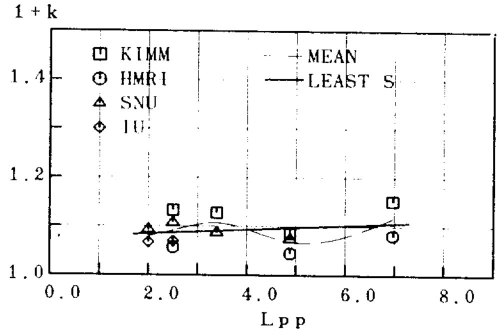

Fig. 4 Scale effect on form factor

model sizes. It is evident that the form factor changes for different model sizes of geometrically similar hull forms.

4. Speed Effect on Form Factor

All the results with 5 different models are sum-

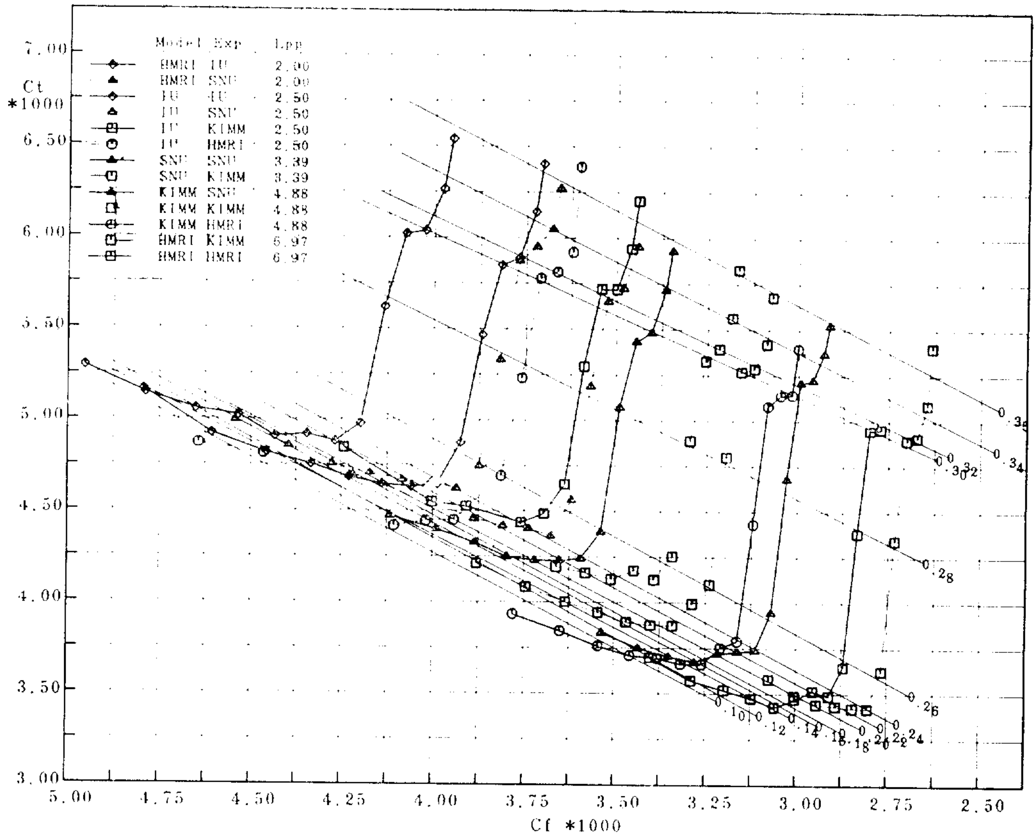

Fig. 5 Evaluation of form facors by Telfer's method

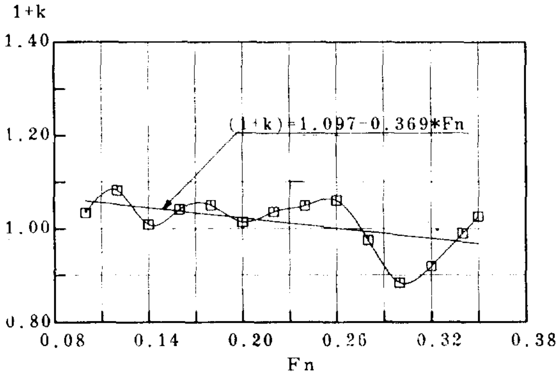

Fig. 6 Effect of Froude number on form factors

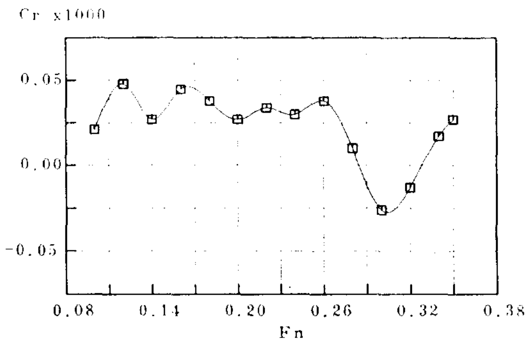

Fig. 7 Difference of mean residuary resistance between large and small models

marized by Telfer's method as shown in Fig. 5. Form factors at the same F_n can be obtained by least square approximation, and show the dependency on F_n as in Fig. 6. Form factor curve shows humps at $F_n=0.12$, 0.17, 0.25 and hollows at $F_n=0.14$, 0.20, 0.30. The C_r curve in Fig. 2 obtained from the mean of total data set also shows humps at $F_n=0.14$, 0.20, 0.30 and hollows at $F_n=0.17$, 0.25. This fact denotes that the form factor changes due to F_n and has strong relation with the wave system generated by a ship. Differences between mean C_r curve of the small models ($L_{pp}<3.5$m) and the large models($L_{pp}>4.9$m) can be plotted as in Fig. 7. The trend of the curve agrees well with that of Fig. 6. It can be concluded that there is an evident relation between the change of residuary resistance and the form factor due to themodel sizes.

5. Form Factor for Engineering Application

It is confirmed that the form factor depends on F_n as well as R_n, and this fact is not consistent with the Hughes' assumption. Extrapolation method currently being in use with the concept of form factor is not correct in physical sense. However this method is in use for a practical engineering application.

For evaluation of form factors in application, it is recommended to use the ITTC method. The full scale resistances in Fig. 8 can be obtained with the assumption that the form factor changes linearly with respect to the model sizes as shown in Fig. 4 with solid line. This procedure gives almost same results from the model tests of different sizes. The full scale resistances based on the geosim test with the assumption that the form factors vary linearly with respect to F_n are also plotted in Fig. 8 with

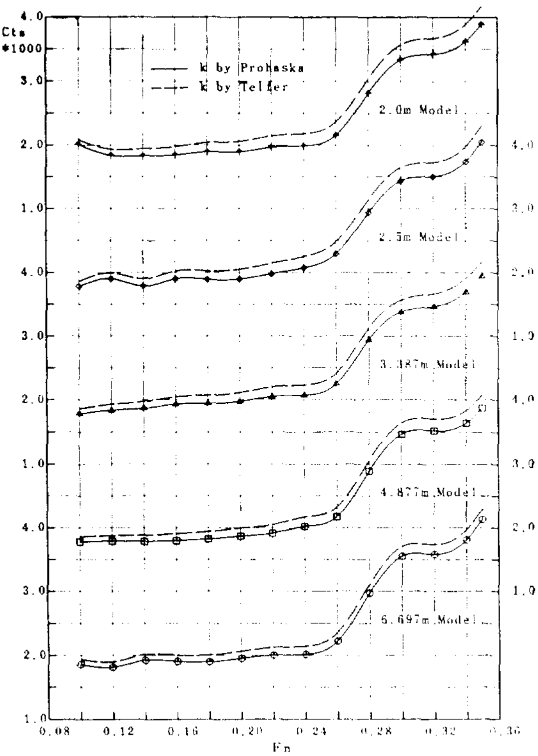

Fig. 8 Effect of form factor selection

broken line.

The results with the former are smaller than those of the latter and the differences between them are approximately $0.15 \sim 0.25 \times 10^{-3}$ in the tested range of speed. Considering that the model ship correlation allowance is not necessary when the geosim test result is available including the sufficiently large model, the difference between solid and broken line can be interpreted as model ship correlation allowance.

Present extrapolation method based on a single model test can be reliably applied to a practical engineering problem, provided that the measurements in model test are made accurately and proper correlation allowance is adopted, even though it is not consistent with the physical phenomena.

If the geosim test can be made, it gives more useful results by taking into account the changes of form factor with the assumption that it varies linearly with the F_n. Though this additional correction can not fully reflect the physical phenomena, more appropriate analysis can be made similar to the definition of form factor.

6. Conclusion

It is confirmed that form factor is affected not only by R_n but also by F_n because it is changed due to model sizes and speeds as shown in the analysis of present geosim test. It reveals that Hughes' assumption based on Froude's method that the form effect appears only on frictional resistance and is same for geometrically similar ships is not correct.

In the scope of the present investigations, the effect of R_n and F_n can not be separated quantitatively. However further experimental as well as theoretical studies should be made for a better way of decomposition of resistance components.

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