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Directional Effects on
Sinkage, Trim, and Resistance

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Abstract

The influence of fore-and-aft asymmetry of a ship is known to be ignored in the classic thin-ship theory for resistance. In the current work, a more sophisticated approach is utilized in which the sinkage and trim are accounted for within the framework of the same theory. It is shown that the enhanced computer program correctly predicts that vessels with the centre of buoyancy forward of midships suffer a greater sinkage. In addition, the trim is relatively more by the bow. Finally, it is demonstrated that the inclusion of the effects of sinkage and trim in the analysis results in a slightly increased resistance for vessels with the centre of buoyancy forward of midships, in keeping with the experimental evidence.

1 Introduction

Previous work on the subject of prediction of resistance of marine vehicles, such as monohulls and catamarans, has shown that the *trends* in the curve of total resistance with respect to speed can be predicted with excellent accuracy, using the traditional Michell (1898) wave-resistance theory.

These principles were advanced in the research of Doctors and Day (1997) and Doctors (1998 and 1999). There, transom-stern effects were included in the theory by accounting for the hollow in the water behind the vessel in an approximate manner. The wave resistance was assumed to be simply that of the vessel plus its hollow in the water behind the transom. To this drag they added the so-called hydrostatic resistance, which represents the drag associated with the transom stern not being wetted. A good level of correlation between the predictions and the experimental data for a large set of conditions for the tests on a towing-tank catamaran model was demonstrated.

Following that effort, Doctors and Day (2000a and 2000b) extended the research by performing a detailed analysis of the actual near-field water flow past the vessel, using the rather more complicated formulas presented by Wehausen and Laitone (1960). This permitted the estimation of the sinkage and trim and provided a more intellectually-satisfying determination of the resistance — utilizing a pressure integration over the wetted hull surface — without the need to resort to the use of the concept of the so-called hydrostatic drag.

In the current work, this theory has been applied to a series of vessels which do not possess fore-and-aft symmetry. The purpose of this project was to investigate to what extent fore-and-aft asymmetry plays a role. To this end, it should be noted that the Michell formula itself (which ignores sinkage and trim) is insensitive to this geometric effect.

2 Formulation of the Problem

Figures 1(a) and 1(b) show the main geometric features of the two most extreme of the five test models. These models have been named the Duplo series (because of the way the fore-, aft- and mid-body sections connect to each other for flexibility in shape). In all, there are five models, in which Model 5 is the reverse of Model 1 and Model 4 is the reverse of Model 2. Model 3 is the standard Wigley (1934) model.

Tables 1 and 2 list the principal dimensions and features of the models.

For the purpose of the numerical calculations, the models were represented by a computational grid with 40 panels longitudinally and 8 panels vertically. This computational grid has

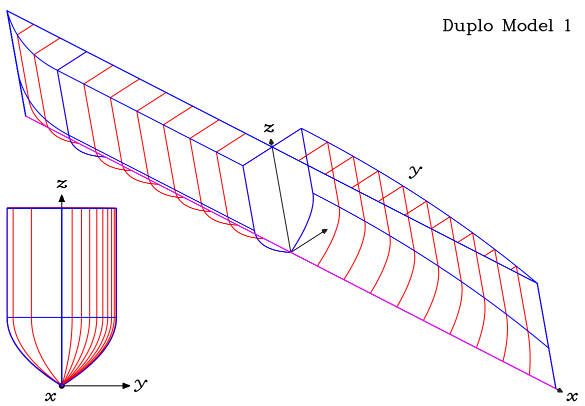

Figure 1: Definition of the Problem
(a) Duplo Model 1

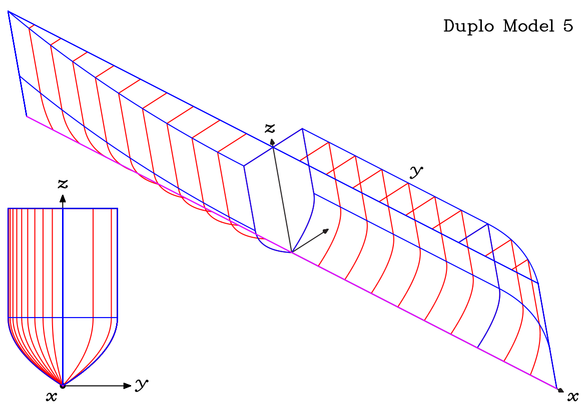

Figure 1: Definition of the Problem
(b) Duplo Model 5

Table 1: Common Vessel Particulars

Item	Symbol	Value
Length	L	1500 mm
Beam	B	150 mm
Draft	T	93.75 mm
Maximum section coefficient	C_M	0.6777

been found to be sufficiently fine for most practical purposes. The form factors for the viscous resistance were calculated on the basis of the work of Holtrop (1984). These formulas will provide different estimates for the frictional resistance, depending on the direction of travel of the ship model, thus complementing the calculations of the wave resistance noted earlier.

3 Towing-tank Experiments

The five models were all tested in the towing tank at the Australian Maritime College during 2000 by the two student authors. The models were tested over a large range of speeds in two conditions. These were the fixed condition and the free-to-sink-and-trim condition. The vertical movements were measured in the usual fashion at the two towing posts in order to compute the sinkage s at the centre of the vessel and the trim by the stern t. The steady-state resistance was recorded in the usual manner.

Table 2: Non-Common Vessel Particulars

Model Number	Length of Run L_R (mm)	Length of Parallel Middle Body L_M (mm)	Length of Entrance L_E (mm)	Prismatic Coef-ficient C_P	Dis-place-ment Δ (kg)	Longitudinal Centre of Buoyancy LCB (mm)
1	225	525	750	0.7833	11.016	−75.40
2	450	300	750	0.7333	10.313	−40.91
3	750	0	750	0.6667	9.375	0.00
4	750	300	450	0.7333	10.313	40.91
5	750	525	225	0.7833	11.016	75.40

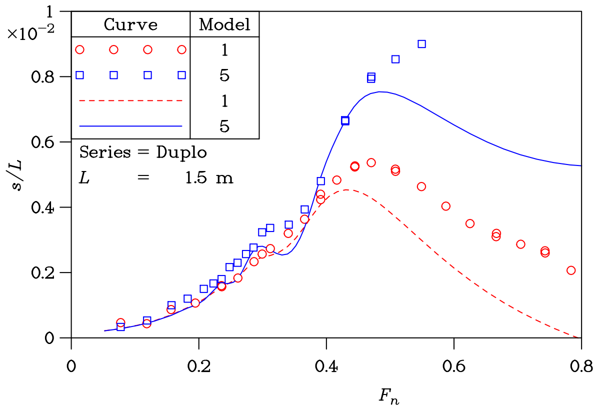

Figure 2: Sinkage
(a) Model 1 and Model 5

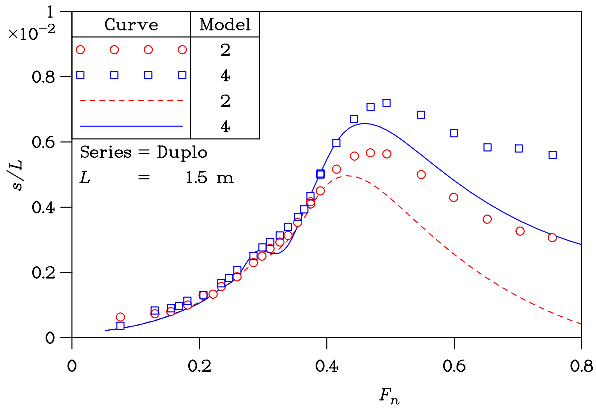

Figure 2: Sinkage
(b) Model 2 and Model 4

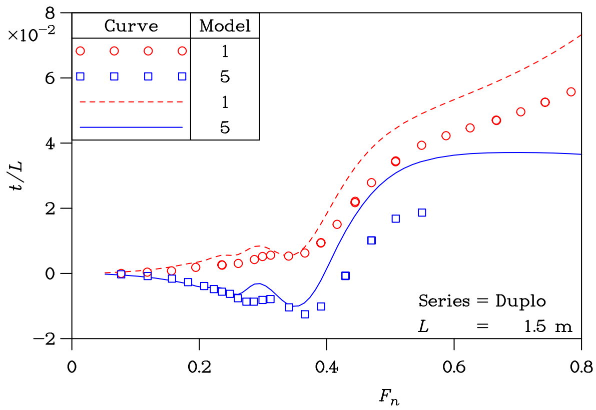

Figure 3: Trim
(a) Model 1 and Model 5

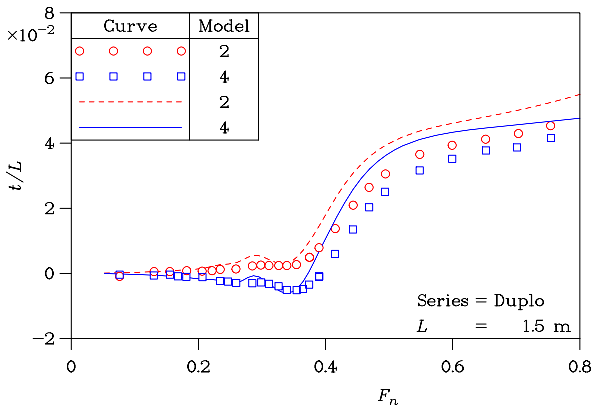

Figure 3: Trim
(b) Model 2 and Model 4

The experiments are described in the thesis of Loadman (2000), where the results of this investigation can be found in greater detail.

4 Numerical Results

Figure 2(a) shows the sinkage-to-length ratio s/L as a function of the length Froude number F for Model 1 and Model 4. It can be seen that the theory predicts the sinkage in an adequate fashion up to a Froude number of 0.45. Beyond that speed, the theoretical results are low; however, they still correctly predict that Model 5 (LCB forward of midships) undergoes a greater sinkage. Similar comments can be made about the comparison between Model 2 and Model 4 in Figure 2(b).

The trim by the stern t is made dimensionless with respect to the vessel length in Figure 3. In Figure 3(a), it is seen that the theory provides an accurate prediction up to a Froude number of 0.4. Indeed, Model 1 (LCB aft of midships) trims by the stern while Model 5 (LCB forward of midships) trims by the bow. At greater speeds, the absolute predictions are low but the relative predictions are still correct. Similar comments are true for the comparison between the behaviour of Model 2 and Model 4 in Figure 3(b), where it can be noted that the trim is now less for these two models.

Finally, the total specific resistance is plotted in Figure 4. The total specific resistance

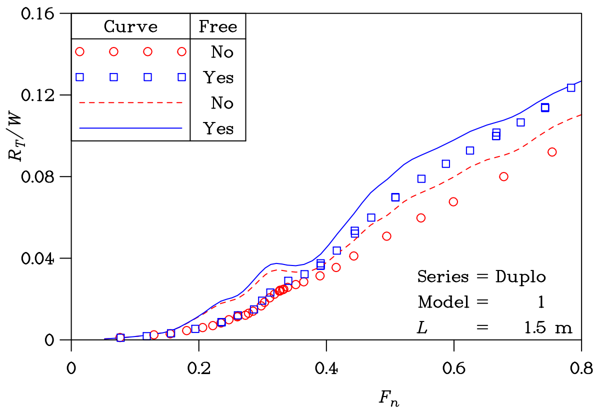

Figure 4: Resistance
(a) Model 1

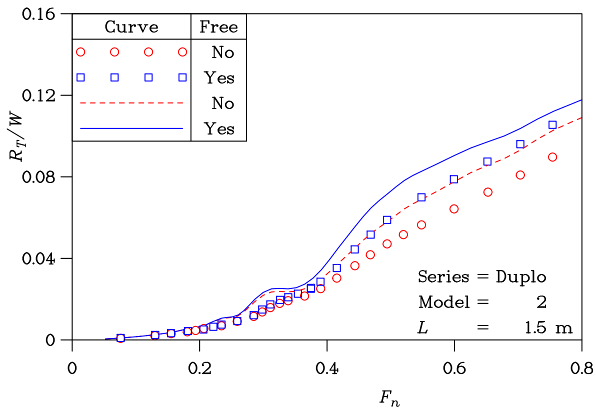

Figure 4: Resistance
(b) Model 2

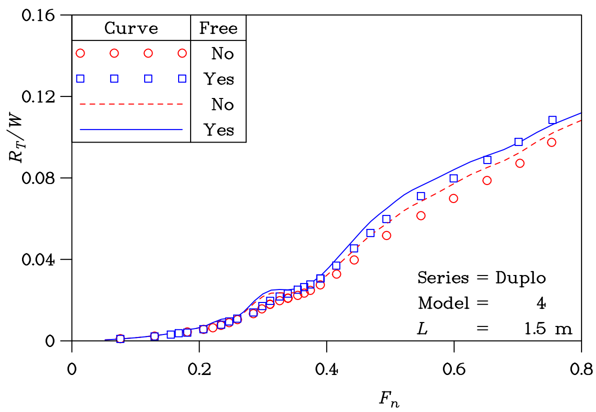

Figure 4: Resistance
(c) Model 4

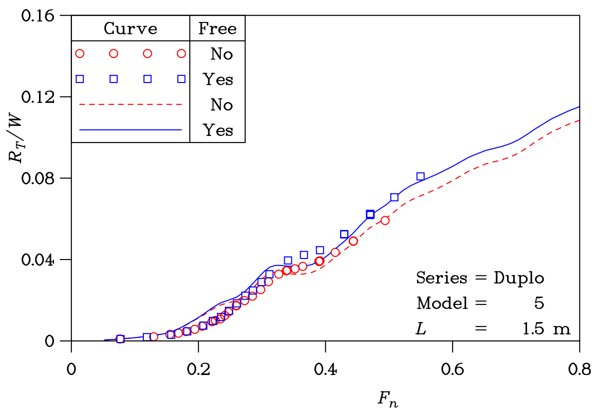

Figure 4: Resistance
(d) Model 5

is the ratio of the total resistance R_T to the weight W of the vessel. It is noteworthy that the theory correctly predicts that the resistance is greater when the vessel is permitted to sink and trim in the proper manner.

5 Conclusions

Future research should be directed toward a continuation of this work by increasing the number of towing-tank models, these being a more realistic representation of ships. In particular, it would be worthwhile to study the applicability of the theory to catamarans.

6 Acknowledgments

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