Seakeeping performance assessment of planing hulls
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Abstract

A new systematic series of planing hull forms, with good characteristics with respect to both resistance and seakeeping is under development at the Laboratory for Ship and Marine Hydrodynamics of the National Technical University of Athens. Before the selection of the parent hull, five “equivalent” models with the same main particulars and different hull forms have been designed and tested for resistance and seakeeping. The seakeeping performance of three of these models, both in regular and random waves, is presented and discussed in the paper.

1 Introduction

The seakeeping performance of any sea-going vessel should be assessed with respect to the sea states its mission requires to be able to operate in. Hence, describing, comparing and assessing the seakeeping characteristics of a ship on the basis of limited-range regular wave results can be misleading and/or inadequate and the same is true when trying to decide if analytical results can be useful for prediction purposes. Thus, appropriate random wave testing is necessary for prediction purposes, either per se or for validation of analytical prediction methods.

Planing hull forms possess some additional characteristics, which make their seakeeping testing more difficult: they move at high Froude numbers and their kinematic responses are known to be non-linear with respect to the wave
amplitude, at least in some wavelength ranges. In addition, they experience
dynamic lift underway, which makes their underwater displaced volume to vary
with respect to speed and, hence, further complicates any attempt for analytical
prediction of their seakeeping responses.

In view of the above, the title of this paper is certainly overambitious and
only some interesting, we hope, pieces of information with respect to the
seakeeping performance of planing hull forms are going to be presented in the
sequel.

2 Description of the hull forms

The five “equivalent” hull forms used for the selection of the parent hull form of
the new series have been described in Grigoropoulos and Loukakis [1]. In the
present paper, part of the test results in both regular and random waves for
three of these hull forms will be presented. Two of the hull forms have narrow
transom, the first being a normal L/B=5.5, Series 62 hull form (Clement and
Blount [2]) and the second a deep-V single chine variant of the above (Keuning
and Gerritsma [3]). The third hull form is a wide transom, same L/B, double
chine hull form (Savitsky et al. [4]). The body plans of the three hull forms are
shown in Figures 1a to 1c. All tests have been conducted with the models at the
same displacement (29.7 kp), the same static trim (nearly even-keel) and the
same radius of gyration (0.25 LWL). All models were wooden, had an overall
length of 2.2 m, were appended with appropriate spray rails and have been
tested in various wave conditions for model speeds up to 4.5 m/s or Froude
number 1.032.

3 Some results of the testing program

As it is very well known in the seakeeping community, seakeeping results have a
sinister way to vary, even when all test conditions are kept constant, see for
example the Seakeeping Committee Report of the 18th I.T.T.C. [5]. This real
life phenomenon is demonstrated in Figure 2, where the regular wave results for
the deep-V hull form are shown. The response shown is the vertical acceleration
at the C.G. and at Froude No. = 1.032 and at each wavelength, the experiment
was performed three times. In the context just mentioned, the results are
pronounced very satisfactory and, after testing in a similar manner for all
responses, the rest of the testing program was performed with single runs.

The linearity test for the same model, the same response and the same
Fr.No. is shown in Figure 3. The results are substantially non-linear about the
peak of the R.A.O. and less so for the lower frequencies of encounter (longer
wavelengths).
As it will be discussed shortly, strip theory predictions for the responses of planing hull forms are substantially higher than the experimental values, especially near resonance. The situation is better for long wavelengths (e.g. high sea states with large peak spectral periods). This fact is demonstrated in Figure 4 for the same hull form, ship response and speed and again in Figures 13 to 16.

Nevertheless, the fact that strip theory [6], which is a high frequency theory, with the hull forms at their static waterline, gives reasonable results at the lower frequencies, with the hulls at the planing condition, is yet another curiosity associated with this theory. The predictions might even become better if an older version of the strip theory is used [7]! Unfortunately no theoretical prediction method exists for the seakeeping behaviour of planing hull forms at any Froude number of practical interest. In this context, the theory of Martin [8] is valid for Froude Nos above 1.3 and at these speeds the operability of a vessel is in doubt for any sea state of serious magnitude.

In Figures 5 to 8 and 9 to 12 the experimental response amplitude operators of pitch, bow acceleration, stern acceleration and added resistance are shown, for model speeds 3.0 m/s (Fr.No.=0.688) and 4.5 m/s (Fr.No.=1.032) respectively and for the three hull forms. The theoretical predictions for the double chine hull form are also shown in all cases, with the added resistance computed as in [9].

Two conclusions can be drawn from these figures: that the theoretical predictions are much higher near resonance and the seakeeping behaviour of the double chine hull form is overall better than that of the two others. This is an interesting result if one takes into account that the calm water resistance of the double-chine hull form is overall lower than the resistance of both the deep-Vee and the series 62 hull forms.

However, to the experience of the authors, carefully conducted random wave experiments are a much better yardstick for the comparative study of seakeeping behaviour. Thus, in Figures 13 to 16, the rms values for pitch, bow acceleration and stern acceleration and the mean added resistance of the three hull forms are shown at Froude No =0.688 and for sea states with modal periods 6 to 10 sec. These results correspond to ships of 22 m length overall (scale ratio of 10) and the full scale testing was about 16 min.

From these figures, the overall superiority of the double chine hull form is verified.

4 Conclusions

The conclusions from the results presented can be summarized very briefly as follows:

o Testing for seakeeping in regular waves for planing hull forms is not very meaningful.
On the contrary, testing in sea states and at speeds where the vessel can operate can provide really useful information. However, the cost of conducting the great number of runs, necessary to get sufficient testing time for statistically reliable results, can be excessive. In this respect, a systematic series of hull forms tested for both resistance and (random waves) seakeeping, could be useful. The up to now results of our investigation point out that the double chine, wide transom hull form with warp is appropriate to be the parent hull for the series to be created.

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References

a. Series 62 model

b. DeepVee model

c. Double-chine model

Figure 1: Body plans of the models tested.

Figure 2: Experimental repeatability test

Figure 3: Experimental linearity test

Figure 4: Analytical and experimental results for the Deep-Vee model.
Figure 5: Experimental pitch R.A.O.'s for the three models and analytical predictions for the double-chine model at 3.0 m/s.

Figure 6: Experimental bow vertical acceleration R.A.O.'s for the three models and analytical predictions for the double-chine model at 3.0 m/s.

Figure 7: Experimental stern vertical acceleration R.A.O.'s for the three models and analytical predictions for the double-chine model at 3.0 m/s.

Figure 8: Experimental added resistance R.A.O.'s for the three models and analytical predictions for the double-chine model at 3.0 m/s.
Figure 9: Experimental pitch R.A.O.'s for the three models and analytical predictions for the double-chine model at 4.5 m/s.

Figure 10: Experimental bow vertical acceleration R.A.O.'s for the three models and analytical predictions for the double-chine model at 4.5 m/s.

Figure 11: Experimental stern vertical acceleration R.A.O.'s for the three models and analytical predictions for the double-chine model at 4.5 m/s.

Figure 12: Experimental added resistance R.A.O.'s for the three models and analytical predictions for the double-chine model at 4.5 m/s.
Figure 13: Experimental r.m.s. pitch response for the three models and analytical predictions for the double-chine model at 3.0 m/s.

Figure 14: Experimental r.m.s. bow vert. acceleration response for the three models and analytical predictions for the double-chine model at 3.0 m/s.

Figure 15: Experimental r.m.s. stern vert. acceleration response for the three models and analytical predictions for the double-chine model at 3.0 m/s.

Figure 16: Experimental mean added resistance for the three models and analytical predictions for the double-chine model at 3.0 m/s.