HULL FORM CONFIGURATION STUDY OF A LOW WAKE WASH CATAMARAN LEISURE BOAT

Omar Yaakob, Mohd. Afifi Abd. Mukti, Ahmad Nasirudin, Mohd. Arizam Abdul Wahab
Faculty of Mechanical Engineering
Universiti Teknologi Malaysia,
81310 UTM Skudai,
MALAYSIA
omar@fkm.utm.my

SUMMARY

This paper presents the development on an asymmetric catamaran hull form for leisure craft application. The study is part of an effort to develop an environmental friendly boat having an appropriate hull form configuration to minimize bank erosion, and propulsion system to prevent air and water pollution. An asymmetric catamaran hull form configuration was selected and an electric motor with solar cell system was chosen as propulsion system. Model experiments were carried out to validate a CFD software and the software was used to find the effect of hull form configurations and separation to length ratios on the wake wash heights produced. The results indicate that a new method of arrangement of the catamaran demihulls as well as their spacing improves the wake-wash characteristics significantly.

Keywords: wake wash, asymmetric catamaran.

1. INTRODUCTION

Inland-waterways has been developed in Malaysia for leisure and transport of goods. Leisure crafts are widely used in lakes, dams and man made waterways such as the one in the new Malaysian government administrative capital Putrajaya. In some states such as Sarawak there already exists relatively good network of river transportation while, in the Peninsular Malaysia, the government has identified Kedah River and Muar River sites for inland-waterways development. Currently, most of the inland-waterway vessels are not environmental friendly. Studies have shown these that vessels cause pollution on the environment [1], [2]. These vessels pollute the three component of the environment that is water, land and air.

A study was made to design a more environmental friendly vessel to incorporate solar electric powwr and low wake wash technology. An overview of the design methodology and vessel specifications is given in ref [1]. An asymmetric catamaran hull form configuration was selected and an electric motor with solar cell system was chosen as propulsion system.

This paper describes an experimental study conducted to validate results obtained from a CFD application, SHIPFLOW. Using the software, further studies were carried out to determine configurations of the catamaran which will give the better wake wash characteristics.

2. THE BASIS HULL FORM

The basis hull form was created from original hull form taken from ref. [3] i.e. a flat bottom shape of asymmetric catamaran with flat side hull form faced inward. To obtain better wash characteristic the hull form was modified based on the assumption that the hull form with rounded bottom and smooth transition to the stern profile will produce lower wash compared to flat bottom vessel [4]. The modification of hull form also based on concept of a low wash catamaran using recommendations given by Zibell et. al [5]. The hull form then scaled down to the specification similar to the main particulars of the gondola leisure boats of Putrajaya. The new main particulars of this basis ship, designated FSI (Flat Side faced Inward), are given in Table 1 and the hull form is shown in Fig. 1.

<table>
<thead>
<tr>
<th>Table 1 Main Particulars of basis ship</th>
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<tbody>
<tr>
<td>Length Overall (LOA)</td>
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<tr>
<td>Length Waterline (LWL)</td>
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<tr>
<td>Breadth moulded of demihull</td>
</tr>
<tr>
<td>Beam Overall</td>
</tr>
<tr>
<td>Draught</td>
</tr>
<tr>
<td>Passengers</td>
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<tr>
<td>Crew</td>
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<tr>
<td>Service Speed</td>
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<td>Maximum Speed</td>
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</table>
3. SIMULATION

3.1 HULLFORM DESIGN

The aim of the simulation is to investigate the wake wash generated by the asymmetric catamaran hull form. The simulation program used in this research is a commercial package of Computational Fluid Dynamic (CFD) software, SHIPFLOW version 2.8.

The hull form of the asymmetric catamaran was designed with Computer Aided Design ship design software, PROSURF 3. It was developed by New Wave Systems, Inc. USA. The 3-dimensional design of the asymmetric catamaran hull form produced by PROSURF 3 was then transferred to Computer Aided Design software, AutoCAD 2000 to get a complete set of offset data for simulation process. The offset data of the asymmetric catamaran obtained from AutoCAD contains 100 stations with around 27 points each.

3.2 SIMULATION SOFTWARE

The simulation was carried out using Computational Fluid Dynamics (CFD) software SHIPFLOW. The software developed by Flowtech International AB and Chalmers University of Technology is a special purpose software for investigating the hydrodynamic properties of ships and other marine vessels. It makes use of three different methods to compute the resistance of a ship; a potential flow method, a boundary layer method and the Reynolds Average Navier-Stokes equations (RANS). Amongst the many capabilities of this software is prediction of wave profile.

4. MODEL EXPERIMENT

In order to validate Computational Fluid Dynamics simulation results, a model experiment was conducted in the towing tank of Marine Technology Laboratory. The tank is 120m long by 4m wide with waterdepth of 2.5m.

Two kinds of data were taken, resistance data and wave height data generated by the model.

4.1 MODEL EXPERIMENT PREPARATION

The asymmetric basis hull-form was scaled down for model experiment using a scale of 1:2.5, giving a 2m long model weighing 80.64kg weight. The detail particulars of the model can be seen in Table 2 below.

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<table>
<thead>
<tr>
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<tbody>
<tr>
<td>Length Overall (LOA)</td>
<td>2.04 m.</td>
</tr>
<tr>
<td>Length Waterline (LWL)</td>
<td>2.00 m.</td>
</tr>
<tr>
<td>Breadth moulded of demi hull</td>
<td>0.13 m.</td>
</tr>
<tr>
<td>Draught</td>
<td>0.20 m.</td>
</tr>
<tr>
<td>Displacement</td>
<td>80.64 kg</td>
</tr>
</tbody>
</table>

4.2 EXPERIMENTAL SET-UP

The investigation was conducted with no-motion condition (fixed) of the model. The investigation was conducted for flat side of hull form place inward (FSI) with length to beam ratio of hull 15.2. The investigation was conducted with Foude number 0.3 corresponding to a speed of 3 knots.

At each run, wave heights were measured at three points using resistance type wave probes. Two wave probes were placed 40 cm distance from the outer side of asymmetric catamaran hull form model corresponding to y/L ratio of 0.2. Another wave probe was placed at the centre line of the catamaran. The longitudinal locations of the wave probes were varied along the length of the boat at every experimental run.

5. WAVE PROFILE COMPARISON

Figures 2 and 3 shows the wave profile in three dimensional views of the simulation and the model experiment result respectively.

The wave profile data from simulation and model experiment are presented as wave height to length ratio (h/L). The comparison of wave profile obtained from simulation and wave height values obtained from model experiment can be seen in Figure 4 and 5.

The results indicate that the simulation results are very closely correlated to experimental results. For y/L=0.2, the correlation is very good except for a slight phase shift. The comparison at the centreline is not as good but SHIPFLOW results are not too far out from the experimental data, particularly in order of magnitude. The covariance between the datasets are positive and the correlation coefficients for y/L =0.2 and the centreline are found to be 0.76 and 0.68 respectively.
6. PARAMETRIC STUDY

The previous Section has shown that CFD simulation is a valid tool for prediction of wave profiles. In this chapter, parametric study of the asymmetric catamaran hull form using simulation is applied. The parametric study covers hull-form configuration of the asymmetric catamaran and separation to length ratio variation.

6.1 SIMULATION SET-UP

The investigation was conducted on an asymmetric catamaran hull form in deep water with no-motion condition of ship. The investigation was conducted in two configurations of hull forms i.e. Flat side of hull form place inward (FSI) and another placed outward (FSO) with length to beam ratio fixed at 15.2. The investigation was conducted with Froude number 0.1, 0.2, and 0.3 and separation to length ratio 0.2, 0.3, and 0.4.

The calculation used in SHIPFLOW was limited on potential flow and boundary layer calculation, this being the software limitation for multihull case i.e. catamaran.

Domain of the area investigated is five times of ship length in breadth of area and the length of area as far as eight times of ship length. The body of catamaran was divided by two parts. Left side are 31 stations and seven points. The right side was divided with the same condition as the left one.
6.2 PARAMETRIC VARIATION

The parametric study of asymmetric catamaran hull-form in this case is related to hull-form configuration i.e. the position of flat side or curve side of asymmetric catamaran hull-form. The configurations are Flat Side Inward (FSI) and Flat Side Outward (FSO). In addition, the variations of Length to Beam ratio (L/B) and Separation to Length ratio (S/L) with variations of Froude Number (Fn) are also considered. At L/B of 15.2, the configurations are changed with S/L variations of 0.2, 0.3, and 0.4. Each was tested at Froude Number (Fn) of 0.1, 0.2, and 0.3. A summary of the parametric variations is given in Table 3.

Table 3  Parametric Variation of Asymmetric Catamaran Hull-Form

<table>
<thead>
<tr>
<th>L/B</th>
<th>S/L</th>
<th>Fn</th>
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<tbody>
<tr>
<td>15.2</td>
<td>0.2</td>
<td>0.1</td>
</tr>
<tr>
<td></td>
<td>0.2</td>
<td>0.2</td>
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<td></td>
<td>0.3</td>
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<td>0.3</td>
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</table>

6.3 EFFECT OF HULL-FORM CONFIGURATION ON WAVE PROFILE

The aim of this section is to determine the effect of configuration to wave profile created by hull-form. Comparisons will be made between the FSI and FSO hull form configurations.

Figures 6, 7, and 8 show the comparison of wave profiles of FSI and FSO configurations with L/B 15.2, S/L 0.4, and Fn 0.3. The wave profiles are taken at the centre line, y/L= 0.2 and y/L= 2.0 longitudinal wave cut from the outer side of hull form.

The results have shown that FSO configuration produced smaller wave profile than FSI. This occurs at all positions of longitudinal wave cut.
6.4 SEPARATION TO LENGTH RATIO (S/L) EFFECT ON WAVE PROFILE

Results from the previous Section have shown that FSO configuration produces lower wave profiles. Thus further work will only concentrate on FSO configuration.

The aim of this part is to know the effect of separation to length ratio (S/L) on the wave profiles created by hull-form with FSO hull form configuration.

Figures 9, 10, and 11 show the comparison of wave profiles at S/L 0.2, 0.3, and 0.4 with FSO configuration, L/B 15.2, and Fn 0.3. The wave profile is taken at centre line, y/L=0.2 and y/L = 2.0 longitudinal wave cuts from the outer side of hull form.

The results above show that regardless of the transverse positions of longitudinal cuts, larger separation to length ratio leads to smaller wave heights of wave profiles produced by the FSO configuration.

6.5 TOTAL RESISTANCE FROM MODEL EXPERIMENT

The wave heights in the previous section resulted from predictions of simulation program i.e. Computation Fluid Dynamics. The resistance of the asymmetric catamaran hull-form in this section is taken from model experiment.

Resistance was measured in two cases. First drag of only one demihull was measured. Secondly, the resistance of actual catamaran of various S/L ratios are measured. The experimental results are shown in Figures 12, 13 and 14. The 2Demihull curve show results of doubling the one demihull resistance values, assuming no interaction between the hulls.

As seen in Figures 12 and 13, the total resistance of the catamaran is more than twice the demihull values which do not take into account the hull interaction. For S/L=0.3, FSO configuration shows slightly lower resistance compared to FSI. On the other hand, for S/L=0.4, FSI shows lower drag values. Nevertheless, the difference in resistance between FSO and FSI is not very significant. The effect of S/L on FSO configuration is shown in Figure 14 and it indicates that increasing S/L leads to a slight increase in resistance.
6.6 DISCUSSIONS

The comparison between simulation and experimental wave profile results has shown satisfactory results. Figures 6 to 8 indicate that the Flat Side Outward (FSO) configuration has better result with respect to reduction of wake wash. Obviously the flat side of the asymmetric catamaran facing outwards has significantly contributed to this low wake. An interesting phenomenon could be observed with wave profile when the longitudinal wave cut was made at centre line of the catamaran. Since the FSO configuration has curved surfaces facing inwards, it was expected to produce higher wave heights along the centreline compared to the FSI, but actually the FSO configuration produced lower wave height as shown in Figure 5. This may be due to wave interaction and superposition which led to a a cancellation process.

With respect to to separation to length ratio, the results indicate that the further the separation the lower the wave profile. It is important to note that there is a slight but not much appreciable additional resistance penalty for the new hull form configurations. From hull resistance viewpoint, experimental measurement indicates that differences in resistance values are not significant.

7. CONCLUDING REMARKS

The new configuration of asymmetric catamaran hull form, i.e. flat side placed outward (FSO) has better wake wash characteristic than flat side inward (FSI) configurations.

The wake wash produced by catamaran also depends on separation to length ratio.

Based on the result above the prototype of this boat is produced i.e. Prototype with Flat Side Outward (FSO) configuration, length to beam ratio (L/B) 15.2, and separation to length ratio (S/L) 0.4. The prototype has been built. Although visually the wake wash seems to be diminished, actual measurement on the full scale vessel must be carried out to actually confirm the expectation.

ACKNOWLEDGEMENT

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REFERENCES


