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Development of Low Wake Wash Hull Form

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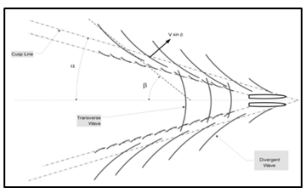
Graphical abstract



Abstract

Wake wash has become a significant issue in the ship design industry due to its impact on the environment in terms of erosion of natural shoreline wetlands. Many ideas for reducing wake wash have been introduced. This research work presents the development of a low wake wash catamaran hull form. In particular, the study is focused on the effectiveness of specially designed fin in order to reduce the wake wash produced by the ship. The fin was attached vertically along the centerline of the catamaran model and the model was tested in the towing tank of Marine Technology Center (MTC) to assess its wake wash. The fin was located at three different positions, which are at bow, center and stern of the ship. The results based on wave height measurements at the various fin locations showed that the fin located at the stern position produces lower wake wash compared to other positions.

Keywords: Wake wash; catamaran; fin; wave height

1.0 INTRODUCTION

Nowadays, water transportation has become an important way of transportation. In shipping business the important part is to deliver the passenger or cargo to the right destination on time and that would mean it should have ship with high speed capability and safety. The past decade has witnessed a rapid growth of interest in development of fast marine vehicles for various applications [1]. Conventional high speed vessel naturally will produce high wake wash and will affect the environment in term of erosion that occurs to natural shorelines and wetlands [2]. Generally, the ship wake is due to three principal [3, 4]:

(a) The frictional drag of the hull causes a following current which increases in velocity and volume towards the stern, and produces there a wake having a considerable forward velocity relative to the surrounding water.
(b) The streamline flow past the hull causes an increased pressure around the stern, where the stream lines are closing in. This means that in this region the relative velocity of the water past the hull will be less than the ship's speed and will appear as a forward or positive wake augmenting that due to friction.
(c) The ship forms a wave pattern on the surface of the water, and the water particles in the crests have a forward velocity due to their orbital motion, while in the troughs the orbital velocity is sternward. This orbital velocity will give rise to a wake component which will be positive or negative according to whether there is a crest or a trough of the wave system in the vicinity of the propeller.

Low-wash catamarans designs are needed to prevent the environmental failures. Stumbo. *et al.* [5] predicted the wash for various speeds of high-speed aluminum catamarans by using computational fluid dynamics. Kirkegaard *et al.* [6] studied the coastal erosion potential, the simulation of sediment transport showed that the long periodic ship-generated waves give rise to beach accretion and steepening of the cross-shore profile. Macfarlane and Renilson [7] carried out experimental work for over 80 different hull form configurations to measure the vessel generated waves. As a result, they determined whether a multihull is preferable to a monohull for a specific purpose. Yaakob *et al.* [8] proposed the improvements on an asymmetric catamaran hull configuration form for luxury craft applications to minimize erosion and prevent air and water pollution. Ghani *et al.* [9] Carried out model test of a high speed patrol and validated with theoretical prediction of wake wash. Yaakob *et al.* [10] presented parametric study of catamaran hull form to obtain low wake wash hull form configurations or low speed inland waterway boats by using a Computational Fluid Dynamics (CFD) simulation, and model experiments were carried out for validation of the CFD results. The study interested on the asymmetric catamaran hull form. Furthermore, Suprayogi *et al.* [11] carried out a full-scale experimental work to measure wave heights and wave angle direction on boat generated waves.

In this study, a special fin was attached to a catamaran ship at different locations along the ship centerline. The fin was located at bow, center and stern of the ship. The catamaran model was tested in the towing tank of Marine Technology Center (MTC) to assess the effectiveness of the fin on the wake wash of the ship model.

■2.0 SELECTION OF LOW WAKE WASH HULL TYPES

For selecting the low wash hull form for this study, displacement, planning, hydrofoils and foil assisted hulls were considered in this study. Different factors were accounted for selection such as cost and facilities. Displacement catamaran vehicle (MTL050) which was used in a previous study [10], was chosen for this research work. The hull form particulars are given in Table 1 and the hull form is shown in Figure 1.

Table 1 Main particulars of catamaran hull [10]

Scale Factor	**2.5**
Length Overall (LOA)	5.1m
Length Waterline (LWL)	5.02m
Breadth Moulded of demi-hull	0.33m
Depth Moulded	0.74m
Beam	2.65m
Draught	0.43m
Displacement	997.6kg

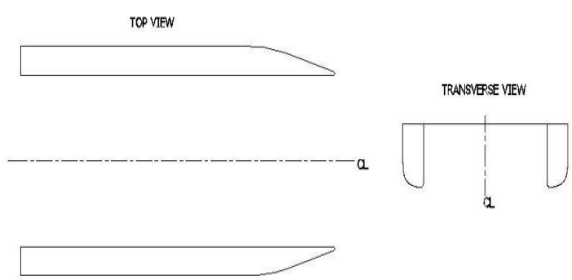


Figure 1 Catamaran hull form

The hull is provided with a vertical fin Figure 2a of special design at its centerline as shown in Figure 2b to increase its stability, reduce hull wave making resistance and to reduce the wake wash. The fine generates waves which interact with the wave system that are generated by the catamaran demi-hulls and lead usually to reduce ship wave making resistance [12].

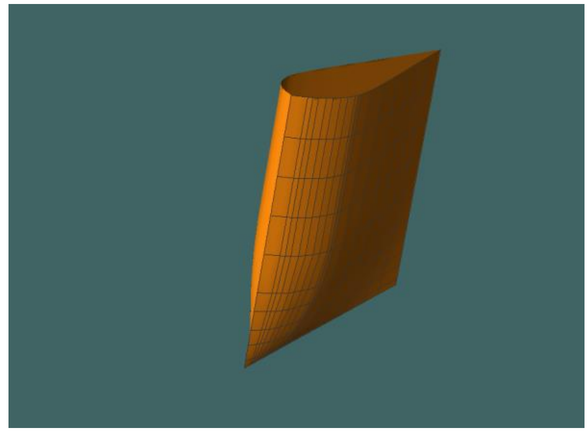


Figure 2a Surface of the catamaran fin

Figure 2b Fin attached to the catamaran hull at centerline

■3.0 LABORATORY TEST

The catamaran model (MTL050) was checked first to ensure that it is in good condition and ready for the experiments in the Marine Technology Center (MTC). The wave probe and fin locations were specified on the right position and on the centerline respectively. The catamaran wake was measured in terms of wave height. The measurements were conducted at two different longitudinal wave cut locations (y/L). The locations were the centerline (longitudinal cut) of the catamaran and y/L = 0.2 (Figure 3).

First, the test run was performed without the fin at *Fn* = 0.3 (1.342 m/s of the carriage speed), and after that the location of the wave probe was changed to a new position (Figure 4) for every run. After finishing the runs without fin, the tests were conducted with fin at positions 1, 2 and 3. The total runs for this research work was 31.

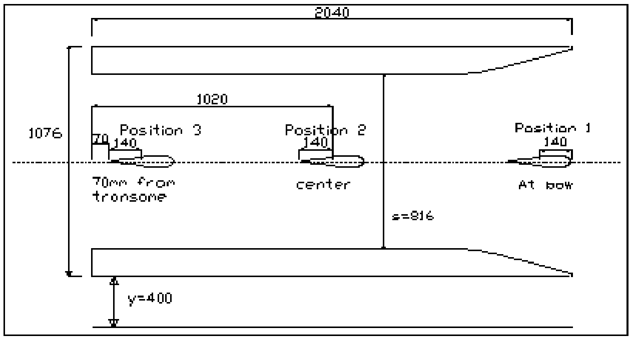


Figure 3 Model and fin arrangement

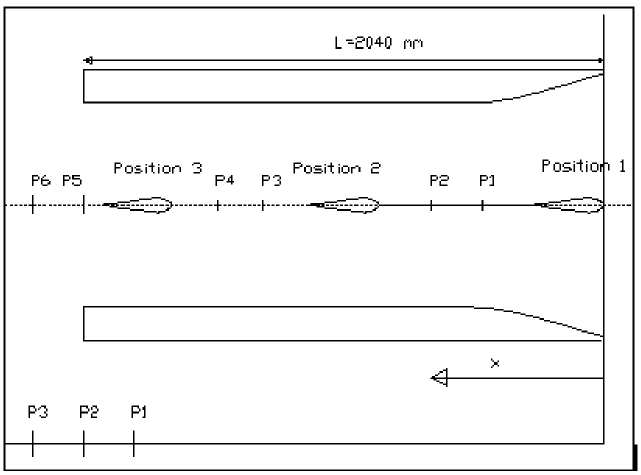


Figure 4 Wave probe locations

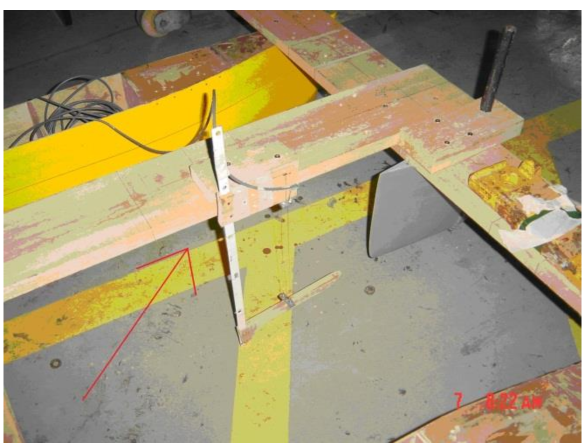


Figure 4(b) Wave probe location (P1) at centerline

4.0 RESULTS AND DISCUSSION

Figure 5 shows the wave dispersion along the center longitudinal cut. The numerical results in the last figure were obtained using Computational Fluid Dynamics (CFD) [10]. The effectiveness of the fin was seen clearly in terms of the wave height in the previous figure. Furthermore, Figure 5, shows that fin at position 3 has produced the lowest wave height compared to results without the fin. This fact is strongly supported by the results in Table 2. Wave probe P1 to P4 didn't show any changes when the fin at position 3 (the stern of the ship). However, starting with wave probe P5, wave height decrease nearly by 160% of the value without fin and the decreasing rate continued until wave probe P9. The wave height in case of fin in position 3, was nearly reduced by 36%, as shown in Table 2. Finally, the results in Figure 5 and Table 2 show the important rule of the fin for reducing the wave height that was generated by the catamaran. However, the fin at positions 1 and 2 showed the increase of wave height. These two locations will contribute to the most horrible result in terms of wave height with 90% and 23% of increase respectively.

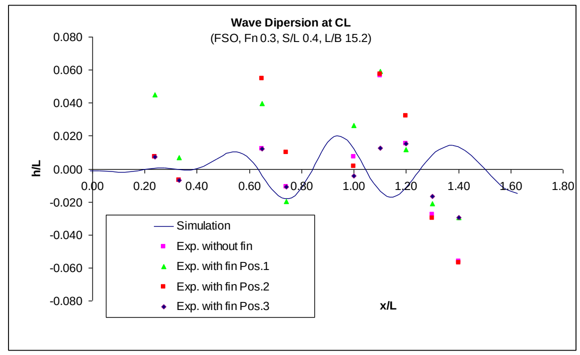


Figure 5 Wave dispersion along center longitudinal cut

Table 2 Experimental results with and without fin at the center longitudinal cut

Long. Cut at Centerline								
x/L	Wave Probe	Without Fin	With Fin					
			Position 1		Position 2		Position 3	
		(*h/L*)	(*h/L*)	% increase/ decrease	(*h/L*)	% increase/ decrease	(*h/L*)	% increase/ decrease
0.24	P1	0.0072	0.0451	527	0.0072	0	0.0072	0
0.33	P2	-0.0071	0.0067	-195	-0.0071	0	-0.0071	0
0.65	P3	0.0122	0.0398	226	0.0550	350	0.0122	0
0.74	P4	-0.0108	-0.0198	82	0.0098	-190	-0.0108	0
1.00	P5	0.0073	0.0264	264	0.0018	-76	-0.0044	-160
1.10	P6	0.0567	0.0591	4	0.0575	2	0.0127	-78
1.20	P7	0.0152	0.0116	-24	0.0322	111	0.0152	0
1.30	P8	-0.0276	-0.0211	-24	-0.0299	8	-0.0165	-40
1.40	P9	-0.0559	-0.0294	-47	-0.0571	2	-0.0296	-47
			Average % =	90	Average % =	23	Average % =	-36

The results at y/L=0.2 for wave dispersion are shown in Figure 6. The results show noticeable differences in comparison with the previous results if Figure 5, due to the relatively larger distance of this section and the vessel centerline. Furthermore, the catamaran model has flat side outward (FSO), which helps in generating low wake wash. The results in Table 3, display noticeable reduction in wave height in comparison with that at the center of longitudinal cut. Fin showed an average reduction of 5% at position 1, 25% at position 2 and 17% at position 3, which give an indication about the importance of replacing the fin at position 2 to reduce the wake wash of the vessel in this case. Finally, the numerical results showed obvious differences with the experimental results at the centerline and the longitudinal cut of y/L = 0.2, which means the need for improving the CFD simulations.

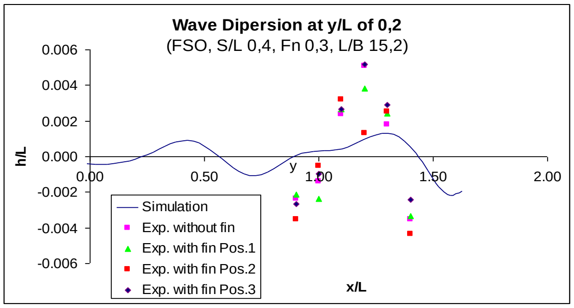


Figure 6 Wave dispersion along longitudinal cut y/L = 0.2

Table 3 Experimental results with and without fin at y/L = 0.2 longitudinal cut

Long. Cut at y/L 0.2								
x/L	Wave Probe	Without Fin	With Fin					
			Position 1		Position 2		Position 3	
		(h/L)	(h/L)	% increase/ decrease	(h/L)	% increase/ decrease	(h/L)	% increase/ decrease
0,90	P1	0,0264	-0,0021	-108	-0,0035	-113	-0,0026	-110
1,00	P2	-0,0014	-0,0024	66	-0,0005	-62	-0,0010	-31
1,10	P3	0,0024	0,0026	13	0,0032	35	0,0026	13
1,20	P4	0,0051	0,0038	-25	0,0013	-74	0,0052	2
1,30	P5	0,0018	0,0024	32	0,0025	38	0,0029	59
1,40	P6	-0,0035	-0,0033	-6	-0,0044	24	-0,0024	-32
			Average % =	-5	Average % =	-25	Average % =	-17

5.0 CONCLUSION

The effects of changing the position of specially designed fin along the ship centerline on the produced near field wake wash by the catamaran model has been studied experimentally in this study. The wave height measurements were taken at different positions along the ship centerline and on the longitudinal cut of y/L = 0.2. The results show that the fin at position 3 on the centerline produced the lower wake (36% reduction), while at position 2 on the longitudinal cut of y/L = 0.2 on the reduction has reached to 25%. The experimental results were compared with the available numerical results, which show the need for more investigations for improving these results. The study showed the ability of the fin in improving the wake wash of the catamaran ship model. Finally, position 3 has been found the best location for the fin to reduce the wake wash of the vessel.

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