The Wake Wash Prediction on an Asymmetric Catamaran Hull Form

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Abstract: This paper presents results of wake wash prediction on an asymmetric catamaran hull form for leisure craft application. The study seeks to find the effect of hull form configuration and separation to length ratio on wave height produced. Computational Fluid Dynamics simulation was carried out and the results indicate that a novel 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

The wake wash from passing vessel could be regarded as a pollutant. Wake wash can erode the bank near the waterline, and can undercut the banks, leading to mass failure [1]. Many factors contribute to an individual wake wash pattern making. One of the major factors can be considered as vessel related i.e. hull form design [2]. One thing can be done to reduce wake wash is designing vessels with asymmetric catamaran hull form [3]. The earliest proposal of the concept of asymmetric catamaran with flat sides was proposed by Kustenko in 1926 and some non-systematic experiments conducted by Dubrovsky in 1978 [4].

Many ways to measure the wake wash; full scale measurement, model test in the towing tank, and numerical (Computational Fluid Dynamics). In this current study, potential flow method of Shipflow Computational Fluid Dynamics software code is used to predict the wake wash criteria.

2. Computational Fluids Dynamics

Computational Fluid Dynamics (CFD) has grown from a mathematical curiosity to become an essential tool in almost every branch of fluid dynamics. CFD is commonly accepted as referring to the broad topic encompassing the numerical solution, by computational methods, of the governing equations which describe fluid flow, the set of the Navier-Stokes equations, continuity and any additional conservation equations.

1) The Code

The CFD (Computational Fluid Dynamics) software Shipflow is developed by Flowtech International AB and Chalmers University of Technology. This software 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). Each of these methods is applied to a certain area of the flow domain as shown in Fig. 1.

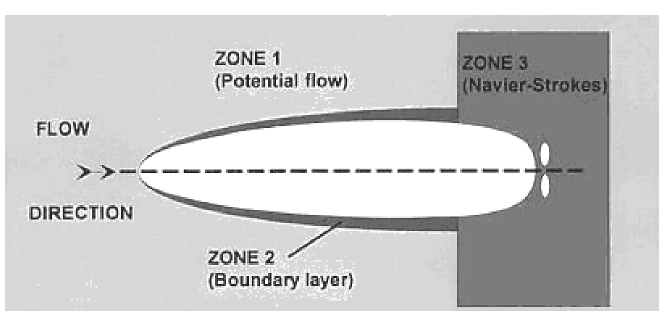

Figure 1: Shipflow methods of calculation

3. Basis Hull Form

The basis hull form was created from original hull form taken from ref. [5] 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 [6]. The modification of hull form also based on concept of a low wash catamaran using recommendations given by Zibell et. al [7]. 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. 2.

Table 1. Main Particulars of basis ship

Length Overall (LOA)	5.10	m.
Length Waterline (LWL)	5.02	m.
Breadth moulded of demihull	0.33	m.
Beam Overall	2.65	m.
Draught	0.50	m.
Passengers	4	Persons
Crew	1	Person
Service Speed	3	knots
Maximum Speed	6	knots

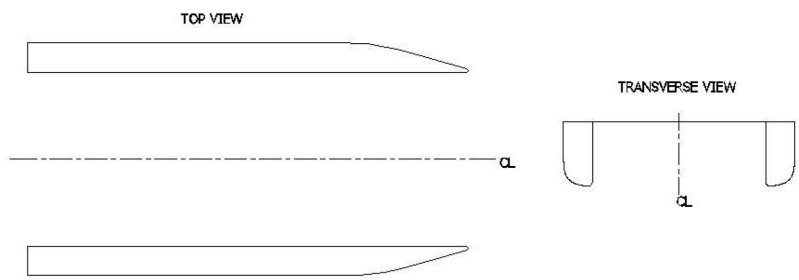

Figure 2. Hull form of basis ship, FSI

4. Case Study

1) Hull Form Configuration

The original configuration of the two demihulls of the basis catamaran was conventional where the asymmetric demihulls are arranged such that the flat sides faced inwards (FSI) see Fig. 2. A new configuration was introduced by arranging the hulls such that the flat sides of the demihulls face outwards. This new configuration, designated FSO (Flat Side faced Outward), is shown in Fig. 3.

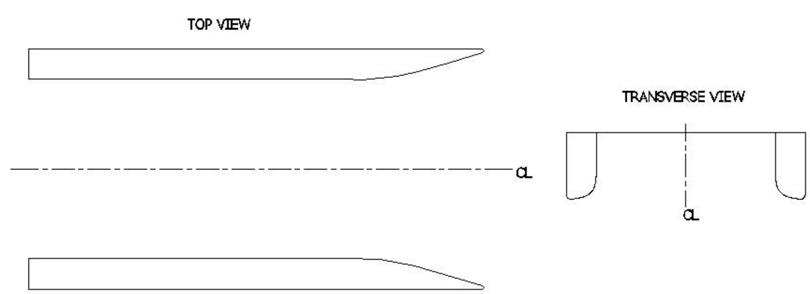

Figure 3. Hull form of designated ship, FSO

The wake-wash generated by the two catamarans was computed using SHIPFLOW and results as compared and discussed in Section 5. Potential flow methods were used to determine the wake-wash characteristics.

2) Hull Spacing

For FSO configuration, a study was carried out to determine the effect of hull spacing on the wake-wash phenomena. The analyses were carried out at the following spacing lengths and Froude numbers;

Separation to length ratio (S/L) : 0.2, 0.3, and 0.4
Froude number (Fn) : 0.2, 0.3, and 0.4

5. Results and Discussion

1) Result of catamaran configuration effect

The wave profiles at different location of longitudinal wave cuts were produced by FSI and FSO configuration with separation to length ratio 0.2 and Froude number 0.4 are given in Figs. 4a to 4d.

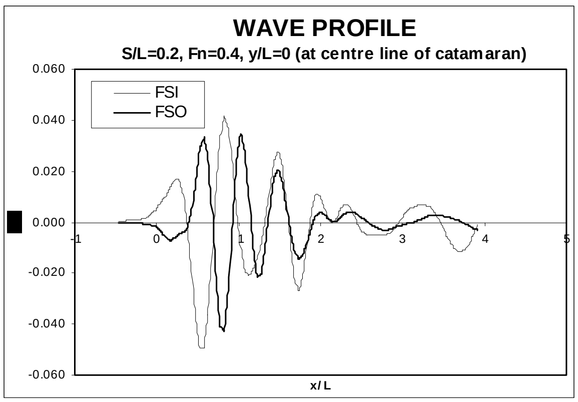

Figure 4a. Wave Profile of FSI vs FSO, with S/L = 0.4, Fn = 0.4 and y/L = 0

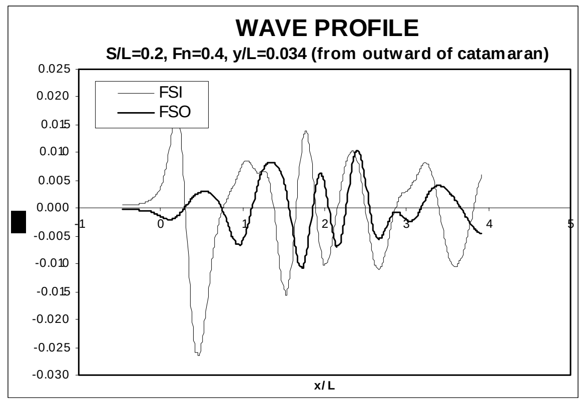

Figure 4b. Wave Profile of FSI vs FSO, with S/L = 0.4, Fn = 0.4 and y/L = 0.034

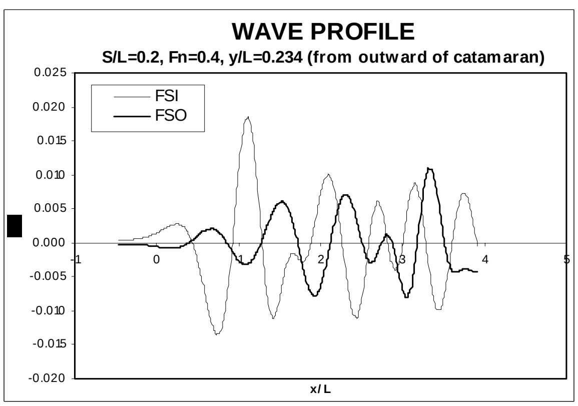

Figure 4c. Wave Profile of FSI vs FSO, with S/L = 0.4, Fn = 0.4 and y/L = 0.234

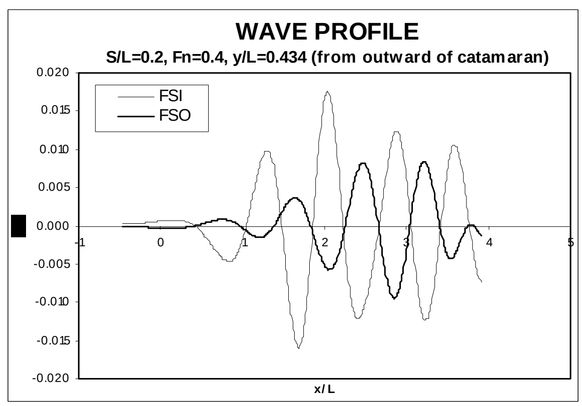

Figure 4d. Wave Profile of FSI vs FSO, with S/L = 0.4, Fn = 0.4 and y/L = 0.434

2) Result of separation to length ratio effect

The wave profiles at different location of longitudinal wave cuts were produced by FSO configuration in different separation to length ratio (i.e. S/L = 0.2, 0.3, and 0.4) with variation of Froude numbers (i.e. 0.2, 0.3, and 0.4) are given in Fig. 5 to 7.

Figs. 5a to 5d shows the wave profile of FSO configuration with variation of separation to length ratio at different location of longitudinal wave cuts with Fn = 0.2.

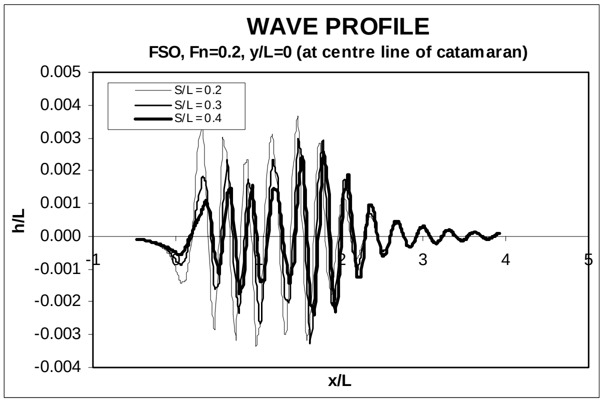

Figure 5a. Wave Profile, Fn = 0.2, y/L = 0

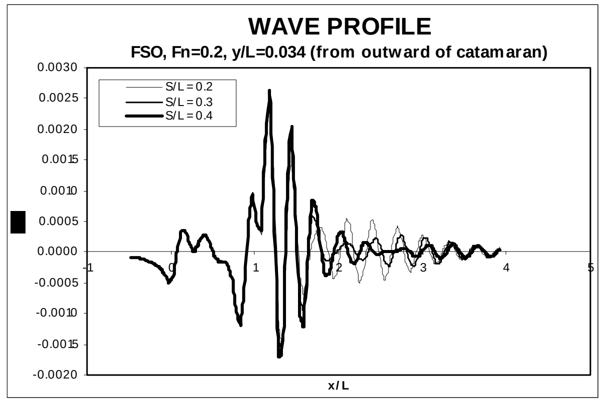

Figure 5b. Wave Profile, Fn = 0.2, y/L = 0.034

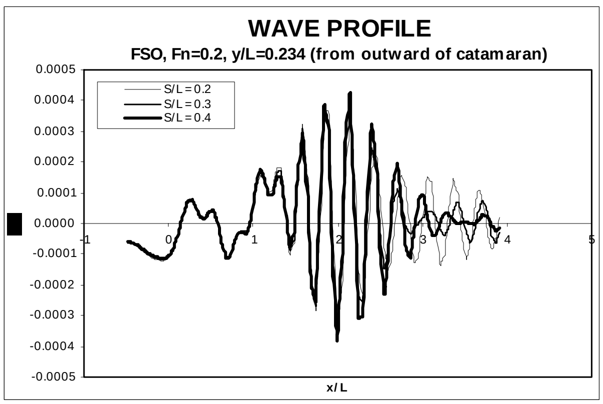

Figure 5c. Wave Profile, Fn = 0.2, y/L = 0.234

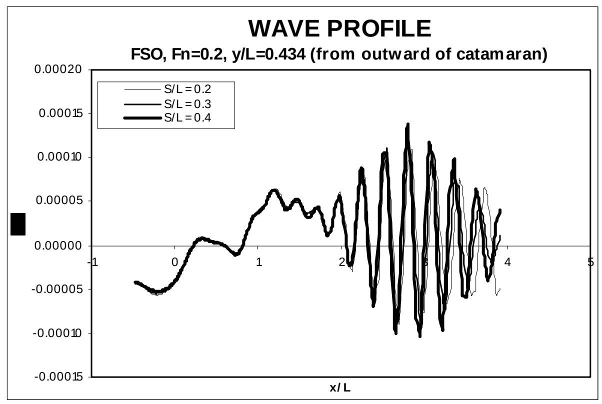

Figure 5d. Wave Profile, Fn = 0.2, y/L = 0.434

Figs. 6a to 6d shows the wave profile of FSO configuration with variation of separation to length ratio at different location of longitudinal wave cuts with Fn = 0.3.

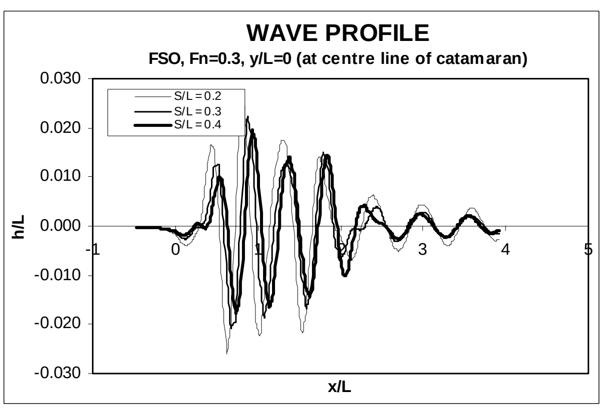

Figure 6a. Wave Profile, Fn = 0.2, y/L = 0

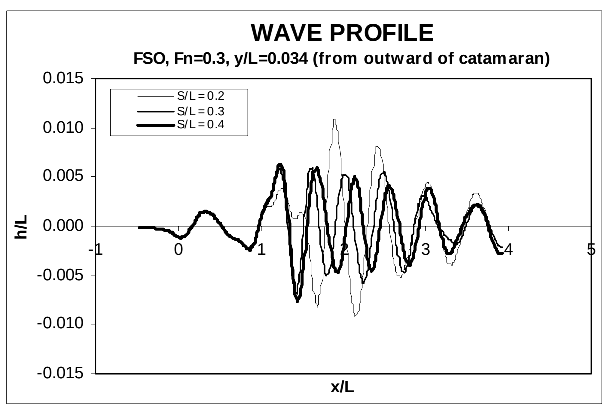

Figure 6b. Wave Profile, Fn = 0.2, y/L = 0.034

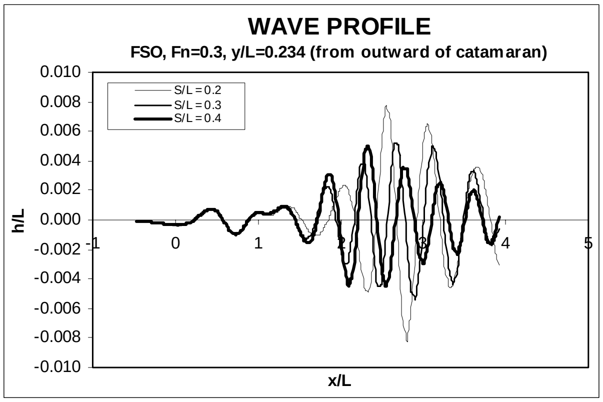

Figure 6c. Wave Profile, Fn = 0.2, y/L = 0.234

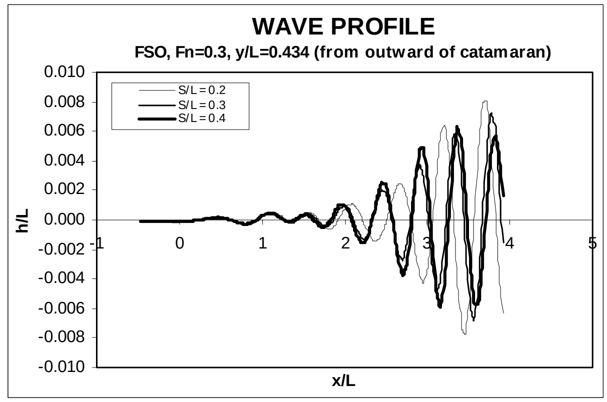

Figure 6d. Wave Profile, Fn = 0.2, y/L = 0.434

Figs. 7a to 7d shows the wave profile of FSO configuration with variation of separation to length ratio at different location of longitudinal wave cuts with Fn = 0.4.

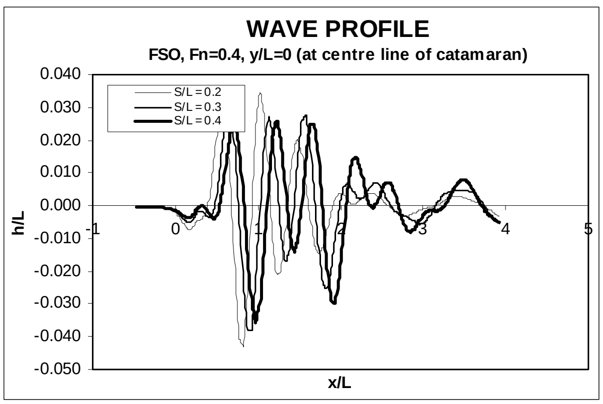

Figure 7a. Wave Profile, Fn = 0.2, y/L = 0

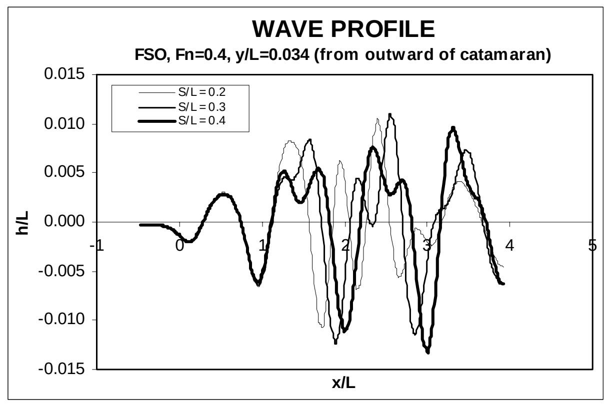

Figure 7b. Wave Profile, Fn = 0.2, y/L = 0.034

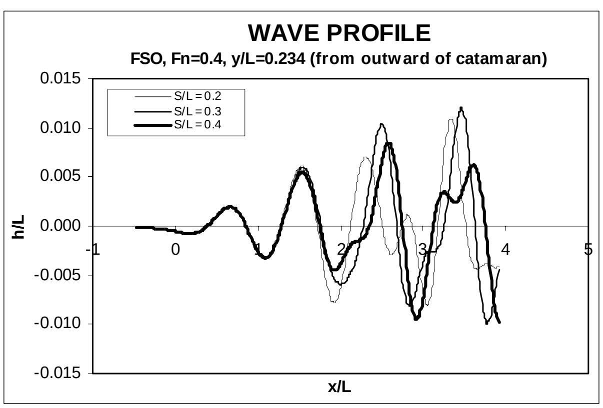

Figure 7c. Wave Profile, Fn = 0.2, y/L = 0.234

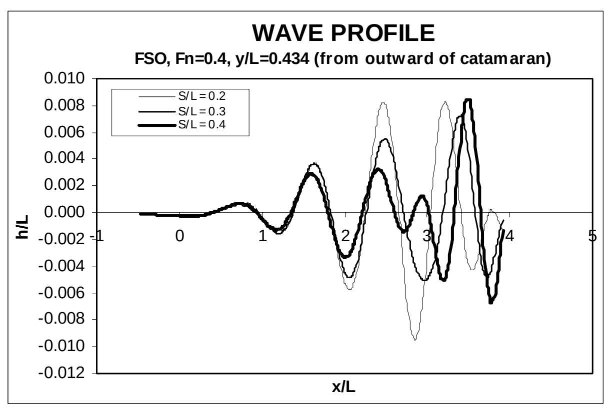

Figure 7d. Wave Profile, Fn = 0.2, y/L = 0.434

3) Discussions

Figs. 4a to 4d show that a new method of arrangement of the catamaran demihulls i.e. with Flat Side Outward (FSO) configuration produced lower wave height at all longitudinal wave cut location.

From Figs. 4b to 4c (i.e. longitudinal wave cut location, y/L = 0.034, 0.234, and 0.343 from outward of catamaran), it can be seen that demihull catamaran with curve shape will produce bigger wave height compared to flat shape. But, an interesting phenomenon happens with longitudinal wave cut at centreline of catamaran (Fig. 4a) which the curve shape of demihull place inward (FSO configuration), the interaction between waves created by the demihulls produce lower wave height compared to FSI configuration.

Figs. 5a, 6a, and 7a (i.e. wave profile at centre line of the catamaran) generally show that larger separation produces lower interaction wave height, but with Froude number 0.4 (Fig. 7a) at x/L more than 1.5, the wave height produced by larger separation to length ratio higher than smaller separation to length ratio.

Figs. 5 to 7 (b, c, and d) show that the waves created by the catamaran up to approximately x/L = 1 have the same wave profile with different separation to length ratio, it means that within this range of x/L the waves produced by demihulls independent by separation to length ratio. The differences of wave profile occurred at approximately x/L above 1.

At the farthest of longitudinal wave cut location, y/L = 0.434 from outward of catamaran (Figs. 5d and 7d) show that with Froude number 0.2 and 0.4 the wave height with separation to length ratio 0.3 has lower wave height compared to separation to length ratio 0.2 and 0.4. However, the wave height produced by catamaran at Froude number 0.3 (Fig. 6d) shows that larger separation to length ratio relatively produce lower wave height.

6. Conclusions

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) configuration.

The wave height produced by catamaran depends on separation to length ratio and Froude number. Separation to length ratio 0.2 and 0.4 will produce low wave height if the catamaran operated at Froude number 0.3, but if the catamaran operated at Froude number 0.2 and 0.4, separation to length ratio 0.3 will produce low wave height.

The next investigation is important to involve viscous flow to obtain more accurate wave height especially at x/L above 1, and also it is important to attempt with larger Froude Number range (0.1 – 1) to get more information the effect Froude number to wave height.

It should be stressed that the conclusions reached are based on simulation only, validation using model-experiments or full-scale measurements would be highly desirable.

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