Resistance Prediction of Innovative Semi SWATH Design Concept in Shallow Water

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Abstract

Many analysis have been conducted to evaluate performance of High Speed Craft (HSC). One of the important analysis is resistance analysis of multihull in shallow water. Ship operating in shallow water experiences increasing of resistance due to change in potential flow and wave pattern. In this paper, shallow water performance has been studied for one type of HSC design concept, Semi SWATH hull form. The hulls are installed with fin stabilizers to reduce dynamic motion effect. Resistance component of the hull, trim and maximum wave amplitude around the hull are obtained from the calm water test in shallow water. These criteria are important in analysing pattern of Semi-SWATH resistance in shallow water flow around hull. The fore fin angle is fixed to zero degree while the aft fin angle is varied for 0, 5, 10 and 15 degree. For each configuration, the investigation is conducted with range of Depth Froude Number from 0.65 to 1.2. From the analysis, it is found that resistance, wave pattern and trim of Semi SWATH is affected by fin angle.

Keywords. Resistance; Semi SWATH; Shallow water; Fin stabilizers

1 Introduction

The research of High Speed Craft (HSC) is widely conducted in recent years due to development of inland waterways transportation. The design issue of this type of vessel strongly relate to coastal engineering point of view. One type of HSC vessel with innovative design is Semi SWATH, a combination of Small Waterplane Area Twin Hull (SWATH) and Catamaran. The concept of this design promise operation at coastal area with best seakeeping criteria.

It is important to determine hydrodynamic characteristic of Semi-SWATH in shallow water. The restriction of hull bottom and sea bed give increasing effect on resistance and changing of trim. [1] These two criteria are important in innovative catamaran design concept as it is a challenge to produce catamaran with both smaller resistance and good seakeeping criteria. Much catamaran vessels are installed with a pair of fin or foil to oppose roll and pitch motion. However, the design of fin require deep consideration because it will affect the resistance, lift and cavitation of twin hulls. [2]

Wave pattern is very critical in shallow water. This is because minimum water depth will cause the flow around the hull to achieve critical condition. The occurrence of wave in critical condition increases wave making resistance and consequently total resistance of the hull. There are many factors to minimize effect of flow around the hull including hull design and geometry and wetted surface area. [3]

The work presented in this study is performed to predict the resistance, changing of trim and wave pattern around hulls of Semi SWATH in shallow water. The shallow water experimental result can be a reference to further analysis of Semi SWATH operation in inland waterways and to validate numerical work in the future.

1.1 Wave Pattern at Shallow Water

Assessment of high speed performance at shallow water condition involves critical concern on the wave generated by the ship and wake wash. Wake wash is one of the effect contributed by wave energy around the hull. The assessment of wake wash involve many physical criteria including generated wave pattern during different operational speed and the wave propagation to the far field. The limited depth in shallow water makes the phenomena becomes critical with the influence of generated wave characteristic and dynamic behavior of the ship. [4] Wave characteristic of generated wave is strongly depends on Depth Froude Number, F*nh*. The formula of F*nh* is shown in Eq. 2.

$$F_{nh} = \frac{U}{\sqrt{gh}} \qquad (2)$$

where:
U is ship speed, g is acceleration due to gravity and h is water depth

The critical condition occurs when F*nh* approaches or equal to one. At this point, the ship waves are at critical point and the wave angle nearly become 0 degree and moving almost perpendicularly with ship array. Wave pattern when speed in sub critical (F*nh* <1.0), critical and supercritical (F*nh* >1.0) speed is shown in Fig. 1.

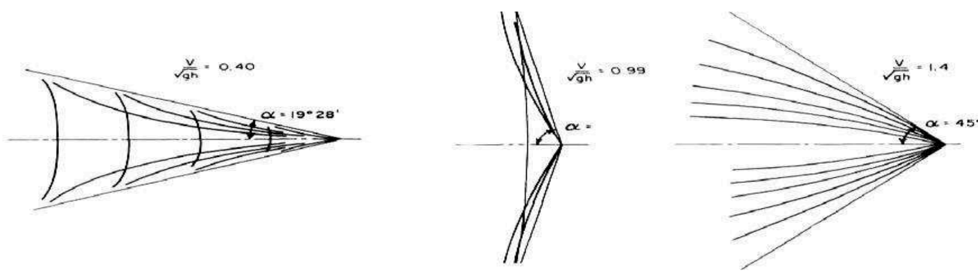


Figure 1. Effect on shallow water on wave pattern [1]

Faltinsen highlighted the ratio between shallow water and deep water wave resistance in comparison between the two condition and stated the ratio becomes larger than 15 for critical speed with small water depth over ship length, h/L. [2]

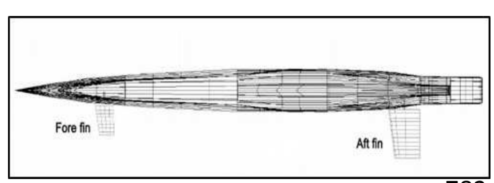
1.2 Effect of Trim in Resistance

Trim motion of high speed craft in shallow water is an important aspect. The restricted distance between hull bottom and sea bed changes the pressure around the hull and causes change in trim. This changing particulars influence the resistance component of the ship. The trim condition affect in wetted surface area and waterplane area and consequently change the wave resistance and friction resistance. Iakovatos [5] has performed analysis on trim effect to resistance of Semi-SWATH and found that wave resistance reduces more when the ship is trimmed by stern with small angle condition rather than at even keel condition. However, large trim angle causes the increasing of wetted surface area and increases frictional drag force and total resistance. It is important to remark that each hull form has specific response in term of resistance due to trim condition.

2 Methodology

2.1 Description of Model

The model which is used in this study is Semi SWATH as shown in Fig.2 with fixed fin at fore and adjustable fin at aft of the hull. The position of fin is shown in Fig. 3 while the particulars dimensions of the model are shown in Table 1. The displacement of hull is supported by submerged torpedo-like body below water surface.



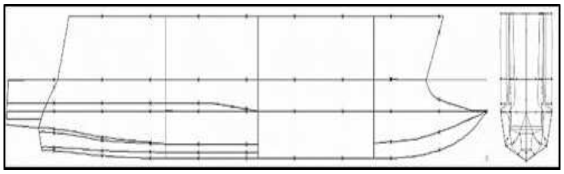


Figure 2. Hull form of Semi-SWATH model

Figure 3. Location of fore fin and aft fin on the model

2.2 Shallow Water Towing Tank

Semi SWATH model is tested in Marine Technology Center Universiti Teknologi Malaysia. (MTC UTM) The dimension of the towing tank is 120m x 4m x 2.5m. The shallow water platform is installed about the end of towing tank with length of 18.75m. This length allows the ship reach steady state condition. The model is tested at scaled speed based on water depth from about 1.8 to 4 knots with range of Depth Froude number, F_{nh} from 0.65 to 1.2. During the test, the separation distance between the models is remained constant with S/L value 0.28. The water depth, h in this test is 21.5cm based on the range of shallow water depth-to-draft ratio, h/T. The water depth is considered shallow when h/T value is from 1.2 to 1.5.

Table 1. Particular dimension of Semi SWATH

Dimensions	Full Scale	Model
Length over All (m)	23.90	2.39
Length of Waterline, L_{WL} (m)	18.30	1.83
Breadth over All	8.0	0.8
Hull spacing between centerlines (m)	6.4	0.64
Shallow Water Draft (m)	1.6	0.16

Wave height of Semi SWATH during running is recorded based on the method applied by Pauzi [6]. Resistance and trim were recorded by D.A.A.S at towing carriage. During the resistance test, wash generated by hull is measured. The longitudinal wave cuts was measured by 2 wave probes with specific y/L. Probe 1 indicates near field wave and probe 2 indicates far-field wave. Wave height recorded by LabView software which integrates with wave probes, signal conditioning unit and computer.

3 Results and Discussion

In this work, the angle of fin installation is varied to 0, 5, 10 and 15 degree. This value is based on the work by Rahimuddin [7] which considered effective fin angle for high speed to dynamic motion of tested Semi SWATH. The comparison of R_T for each condition is shown in Fig. 4. It appears that the fins give different resistance effect at different range of Froude number. At F_{nh} more than 1.0, the increasing of resistance is less obvious compare to F_{nh} less than 1.0. At Fnh more than 1.0, the wave is in super critical condition and no transverse wave exist.

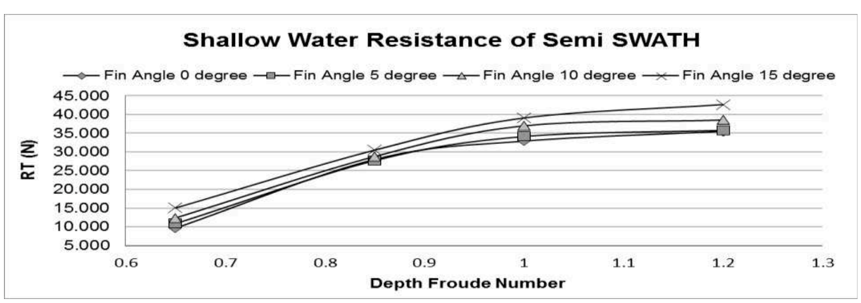


Figure 4. Resistance Curve of Semi SWATH in Shallow Water at Different Aft Fin Angle

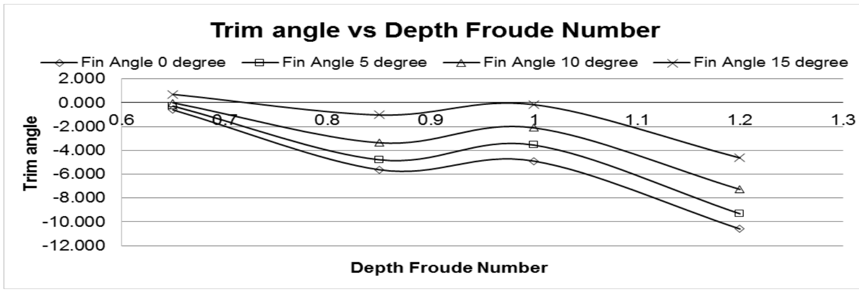


Figure 5. Trim Angle of Semi SWATH at Different Aft Fin Angle

From the above graph, it can be shown than the maximum total resistance is generated for condition fin angle 15 degree. This occurrence can be related to the trim condition during running the test in shallow water. Fig. 5 shows the variation of trim condition at different aft fin angle. It is shown that aft fin angle gives different effect on hull trim condition. Changing of trim during resistance test in calm water increases in negative direction with increasing of Depth Froude Number. This pattern shows the hull achieve surf riding at shallow water. The increasing of wetted surface area with reduction of negative trim angle causes the highest resistance at condition aft fin 15 degree.

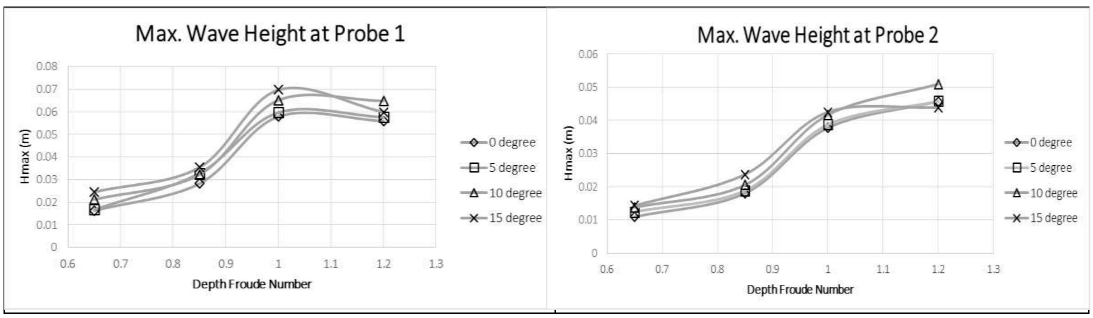


Figure 6. Comparison of Maximum Wave height at Near Field (Probe 1) and Far Field (Probe 2)

From data above, it can be described that there is relation between fin angle of hull and wave generated. In Fig 6, it is shown that maximum wave height (Hmax) is higher at near field than far field. Hmax is increasing until the speed achieve critical speed at Fnh=1.0. At condition of aft fin 15 degree, Hmax is at maximum value for both probe. This shows condition of hull affect the wave pattern generated around the hull.

4 Conclusion

The resistance test on the Semi SWATH model in shallow water was conducted to achieve the objective of the research. From the experiments, the effect of angle of fin towards resistance trim and wave profile of Semi SWATH was determined. There is a reduction in change in trim angle by increasing the fin angle. However, it was observed the small changes in trim may result in the resistance becomes large. Wave amplitude generated from the Semi-SWATH model increases with increase in fin angle. Whilst there are a number of factors contributing to the resistance of Semi SWATH in shallow water, however, the contributions mainly come due to the restricted water depth.

Further research on the fins stabilizer design need to be carried out in order to have better understanding on the wave interference phenomena between the fin and hull. This includes the prediction of wave interference factor to analyse its relation to wave height and at different h/T.

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