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Hull Form Optimization of a Small Trimaran by Model Testing

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Abstract

A 12 m long G/T 4.99 Class Trimaran is now under development at the Center for Transportation System of the Yellow Sea (CTYS) before deployed as a pleasure fishing boat along the west coast of Korean peninsula. The boats will be made of fiber reinforced plastics and equipped with a 360 hp diesel engine and a water jet propulsion system to propel the ship to reach maximum speed of 25knots after fully loaded.
Model tests for hull form development of the Trimaran have been done at the towing tank of the Inha University. The influence of the spacing between main hull and outriggers and the longitudinal location of the outriggers have been carefully examined to find the optimal size and locations of the outriggers to improve both the resistance characteristics, and the results are reported in the present paper.
Keywords: trimaran, hull form, outrigger, FRP, leisure boat, resistance, model test

1 Introduction

It has been reported recently that public interests in marine leisure are rapidly increasing in Korea with enhancement in family incomes and wide spreads of 5 days a week working system. Especially, the fact that Saturday is an off-work day encourages Korean young generation pursuing various kinds of leisure activities not only on land but also at sea and in air. Among those, marine leisure activities are the most rapidly growing one since Korea is located at a peninsula and beaches and seas are within a foot from almost everywhere in the country. It is worthy to mention here that demands for pleasure fishing boats are also increasing since fishing is one of the simplest marine activities even safe for the old and weak unacquainted to the sea.

Design of a ship such as a pleasure fishing boats may necessitate different aspects of design concepts or goals; the ship may require comfortability rather than high propulsive efficiency, stability than noble function, good appearance than better sea worthiness and so on. In addition, pleasure fishing usually takes place in such coastal areas as on-shore or near-shore regions and it will necessarily evoke environmental problems such as pollution, coastal erosion, sediment transport, wake wash, and etc, and proper measures to prevent or minimize those impacts on the environment. A trimaran which consists of a main hull and two outriggers at the both sides has several advantages over other hull forms, such as good resistance characteristics at high speed ranges, wider deck adequate for various marine leisure activities including pleasure fishing, among others. All the more the outriggers at the sides can produce considerable extra restoring moments against roll motions and hence offering more comfort and safety to the customers most of whom may not be familiar with marine environment. Trimarans also suffer from disadvantages. One of the examples is that the resistance of a Trimaran experiencing during navigation is larger than that of a mono-hull ship at low speed ranges because of its comparatively larger wetted surface area and difficulties in maneuvering at wavy and stormy seas.

In the present paper, a study for the design of a G/T 4.99 Class Trimaran for pleasure fishing is reported. Model tests are preformed on various arrangements of main hull and side outrigger configurations to minimize ship-born waves and so as to reduce the total.

2 Principal dimensions

Wide deck of a trimaran is one of the big advantages over mono hull ships, especially when it is to be used for a platform of various leisure activities. The relative positions of the outriggers play a significant role in determining hydrodynamic performance of a trimaran and have crucial influence on the properties such as wave resistance, roll periods and so on.

A hull form of a ship is designed to improve both the motion and resistance characteristics. In the context, key parameters in Trimaran design will include main hull length to beam ratios, draft and block coefficient (C_b) and so on as in usual ship designs, and in addition, characteristic of side hulls and their relative lengths and positions to the main hull.

Table 1: Principal parameters of main hulls, outriggers of trimarans

Item (unit)		Hull 1	Hull 2
LBP(m)	Main Hull	12.00	12.00
	Side Hull	5.40	6.4
Beam at W.L (m)	Main Hull	2.00	2.00
	Side Hull	0.40	0.40
Depth (m)	Main Hull	1.20	1.20
	Side Hull	1.05	1.05
Draft (m)	Main Hull	0.50	0.50
	Side Hull	0.35	0.35
Displacement (Ton)	Main Hull	7.40	7.4
	Side Hull	0.80	0.80
L/B	Main Hull	6	6
	Side Hull	13.5	16
B/T	Main Hull	4	4
	Side Hull	1.14	1.14
Slenderness ($L/\nabla 1/3$)	Main Hull	6.2	6.20
	Side Hull	5.87	6.89
C_b	Main Hull	0.61	0.61
	Side Hull	0.52	0.44

Principal Dimensions of Trimaran

L.O.A (m)	14.3
L.B.P (m)	12.0
Breadth (m)	5.0
Displacement (Ton)	8.2
Design speed (knots)	25.0

Principal dimensions and important parameters in design of a preliminary hull form can be deduced from existing ship data. But in case of a small leisure boat, straightforward adaptation of such empirical parameters may not be possible. For an example, length over beam ratios of high speed trimarans are mostly distributed in the range of 12~19 for the main hull and 18~35 for outriggers. Maintaining such slenderness in a small trimaran design may be impractical since it may be impossible to fit in machineries such as main engines, and extra crew space if possible, inside the main hull. Hence the length over beam ratios for a small trimaran boat will become considerably less than those of existing large ones.

The principal particulars of the hull forms designed for a G/T 4.99 Class trimaran are shown in Table 1, which are decided from a conceptual design process in which machinery and general arrangements appropriate for a leisure trimaran are considered as a priority.

3 Hull form design

Main Hull

It can be easily understood that the resistance of the main hull dominates the total resistance of a trimaran Therefore, it is very important at the initial design stage to find out a shape of the main hull with good resistance performance. In the present study, it has been decided to use a semi-planning hull form which has a very fine stem and a box type stern for accommodation of a water jet propulsion system. Figure 1 shows the body plan of the main hull of the trimaran and Figure 2 shows the curve for cross sectional area distribution of the main hull.

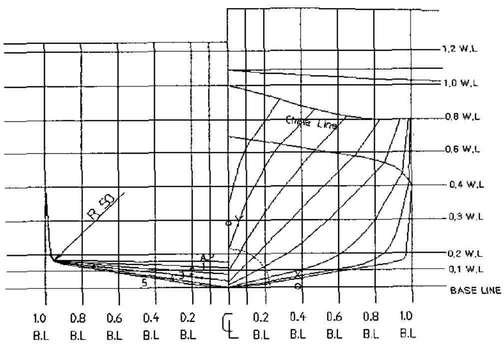


Figure 1: Body Plan of the Main Hull of Trimaran

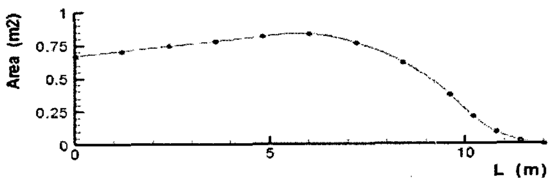


Figure 2: Sectional Area Curve of Main Hull

Side Hull

The configurations of the side outriggers of the trimaran should be designed to provide sufficient restoring force while maintaining minimum displacement to prevent excessive increase in resistance. Hence the outriggers designed usually have simple and thin shapes.

Two types of side hulls are designed in the present paper. In the first design, a simple Wigley hull form was cut into two identical pieces along the centerline and altered to have constant cross section behind the midship as shown in Figure 3 (hereafter called as Wigley type) while second one has been modified to have thinner V type bow as shown in Figure 4 (hereafter called as V type) for the purpose of reducing wave resistance. Then, the outriggers were attached on the both sides of the main hull.

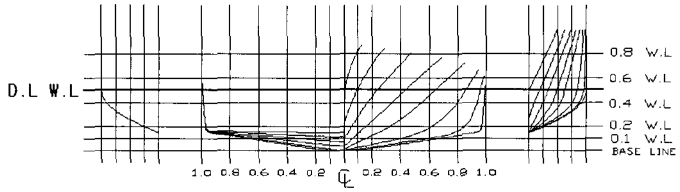


Figure 3: Body plan of Wigley type outriggers

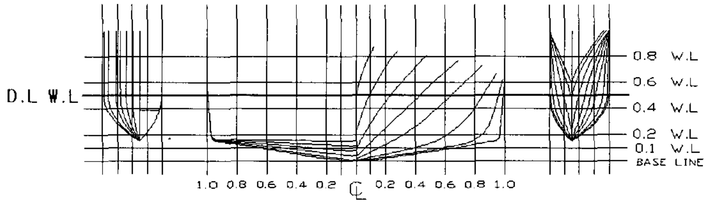
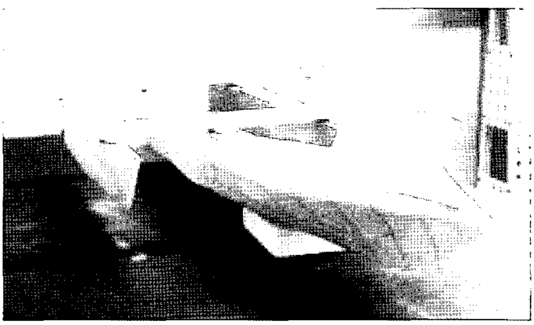


Figure 4: Body plan of V type side hull (modified)

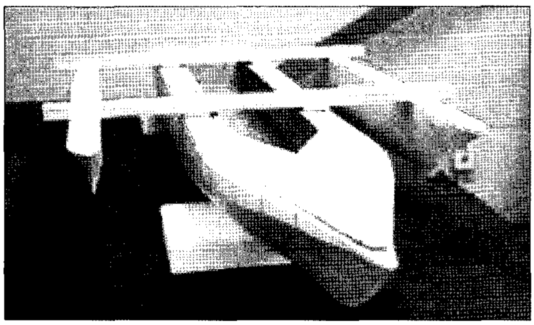
4 Model test

A 1/8 scale model of the main hull and two types of outriggers are made of polyurethane foam on a three axes NC machine at the model shop of Inha University and used in the towing tests.(Figure 5)

A series of tests have been conducted at the towing tank of Inha University to study the influences of shapes as well as longitudinal and transverse locations of the outriggers upon the resistance characteristics of the trimaran.



(a) Wigley type



(b) V type

Figure 5: Photograph of the models with Wigley type outriggers and the one with V type outriggers

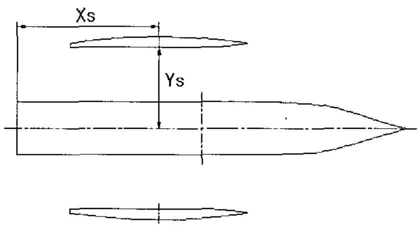
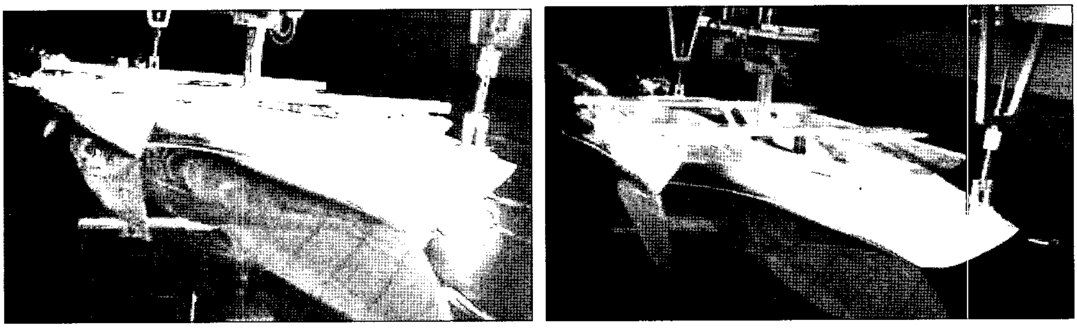


Figure 6: Definition for relative location of the main hull and outriggers

Figure 6 shows definitions for side hull positions relative to the main in which *Xs* denotes the distance between AP of the main hull and LCB of the outriggers and *Ys* the distance between centerline of the main hull and inner wall of the outriggers.

Longitudinal and transverse locations of the Wigley type outriggers were tested in advance, and the modified V type later, to find their influence on the resistance performance of the trimaran. Model tests were carried out for the outrigger positions of *Ys/LBP* = 0.133, 0.175 and 0.217 in transverse and *Xs/LBP* = 0.3, 0.4 and 0.47 in longitudinal directions.

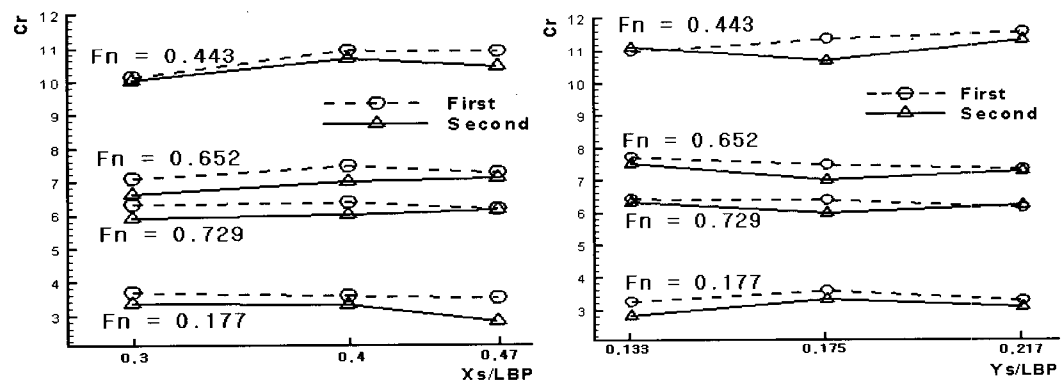


(a) Wigley type: Fn = 0.729 (b) V type: Fn = 0.729

Figure 7: Photograph of the model test at the Froude number 0.729

Figure 7 shows the photographs taken during trimaran with the model tests of the Wigley type (a) and V type outriggers (b) at Fn = 0.729. In both figures, however, it is apparent that bow sprays which should not be so severe in full scales may considerably disrupt the measured resistances. Measured resistances are extrapolated to the full-scale values based on the 1957 ITTC model-ship correlation method. In the process, C_F values for the main hull and the outriggers have been extrapolated separately to avoid underestimations of C_F in the extrapolation process.

The resistances of the two types of outrigger configurations (Wigley and V types) attached at various positions were measured to study the relation between the relative position and resistance.

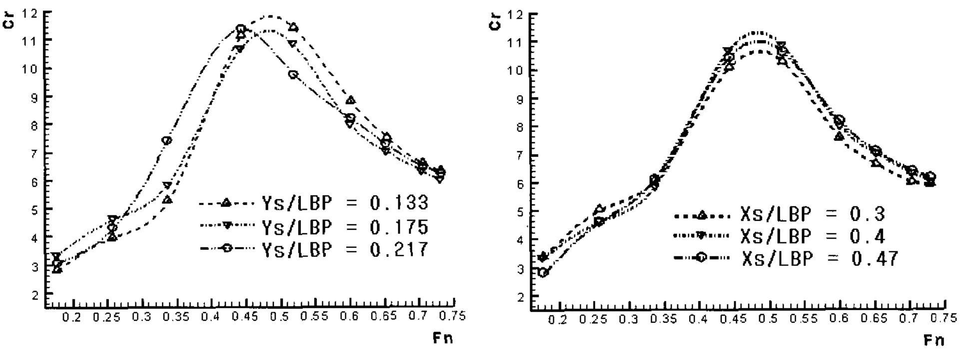


(a) *Ys* = 0.175 (b) *Xs* = 0.4

Figure 8: C_R Curves for outriggers at the various speed and transverse and longitudinal locations

Figure 8 shows the residuary resistance coefficients C_R of the trimaran at the various locations and speeds and compare changes in C_R values due to the different configurations of outriggers. It can be concluded from the figures that the V type outrigger model has the better resistance characteristics than the Wigley type model at almost all positions of the outriggers and speeds tested in the present study.

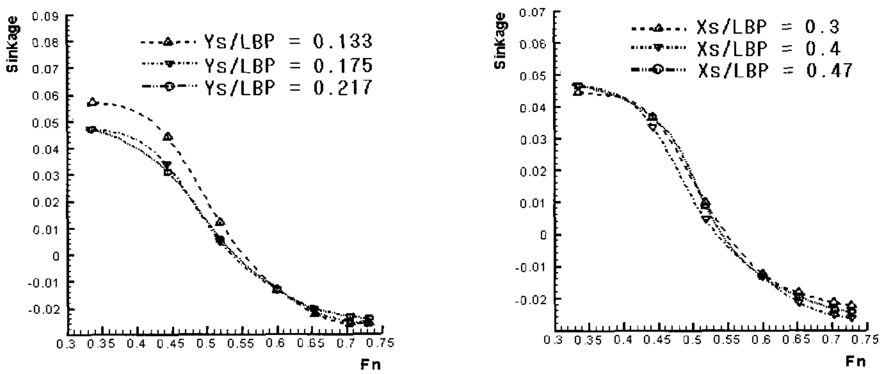
The V type outriggers are chosen and model tests were carried out for the purpose of investigating the influence of the outrigger positions on the resistance in detail. Model tests were carried out for various outrigger location of *Ys/LBP* = 0.133, 0.175 and 0.217 and *Xs/LBP* = 0.3, 0.4 and 0.47.



(a) *Xs/LBP* = 0.4 (b) *Ys/LBP* = 0.175

Figure 9: C_R curves at the various locations of *Xs* and *Ys*

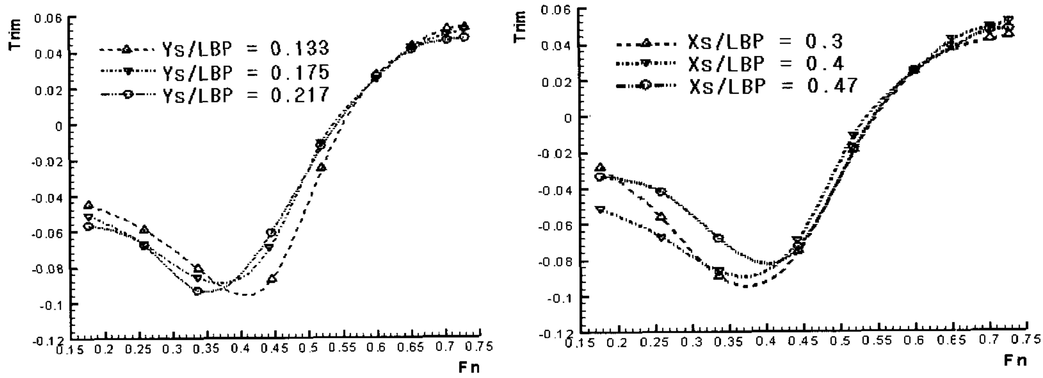
Figure 9(a) shows the residuary resistance coefficient curves at the outrigger positions of *Ys/LBP* = 0.133, 0.175 and 0.217 when *Xs/LBP* is fixed at 0.4. The figure shows that C_R curves tend to merge but the minimum resistance occurs at *Ys/LBP* = 0.175 for the range of Fn larger than 0.6. Then transverse position of the outriggers are fixed at *Ys/LBP* = 0.175 and changes in the residuary resistance are measured for the longitudinal positions of the outriggers of *Xs/LBP* = 0.3, 0.4 and 0.47. Figure 9(b) shows the results where residuary resistance at *Xs/LBP* = 0.3 is the minimum for the regions of Fn larger than 0.4. Therefore, the best position of the outriggers found in the present study has been decided to be *(Xs, Ys)/LBP* = (0.3, 0.175).



(a) *Xs/LBP* = 0.4 (b) *Ys/LBP* = 0.175

Figure 10: Sinkage Curves for various locations of *Xs* and *Ys*

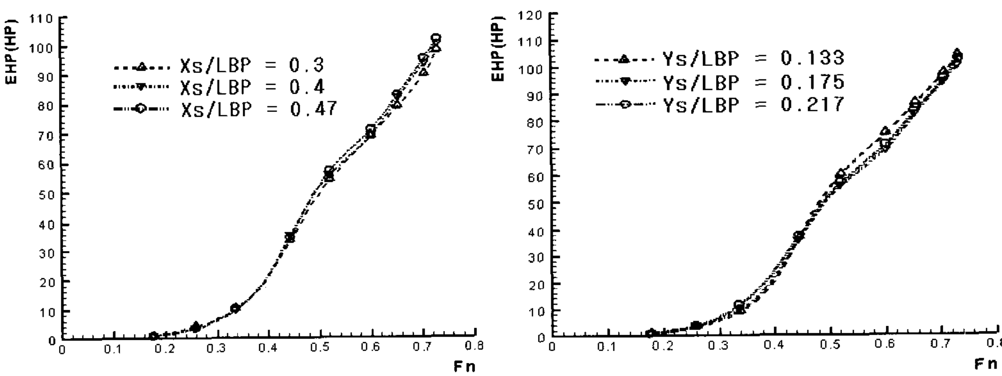
Figures 10~11 show the model test results for trim and sinkage characteristics of the trimaran consists of the main hull and V type outriggers attached at the various locations. Figure 10 shows that the longitudinal and transverse positions of the outriggers affect sinkage of the trimaran considerably at the low Fn but not significant at the high Fn ranges. Figure 11 shows changes in trims of the trimaran in which both the transverse and longitudinal positions of the outriggers do not significantly affect the trim of the trimaran, especially when the ship speed is high.



(a) *Xs/LBP* = 0.4 (b) *Ys/LBP* = 0.175

Figure 11: Trim curves for various *Xs* and *Ys*

Figures 12(a) and (b) show the EHP curves of the trimaran for various values of *Xs* and *Ys*, respectively.



(a) *Xs/LBP* = 0.4 (b) *Ys/LBP* = 0.175

Figure 12: EHP curves for various *Xs* and *Ys*

The figures show that EHP of the trimaran is not very sensitive to the locations of the outriggers but as already shown in Figure 9, the outrigger position of *Ys/LBP* = 0.175, *Xs/LBP* = 0.3 gives the lowest EHP values among tested.

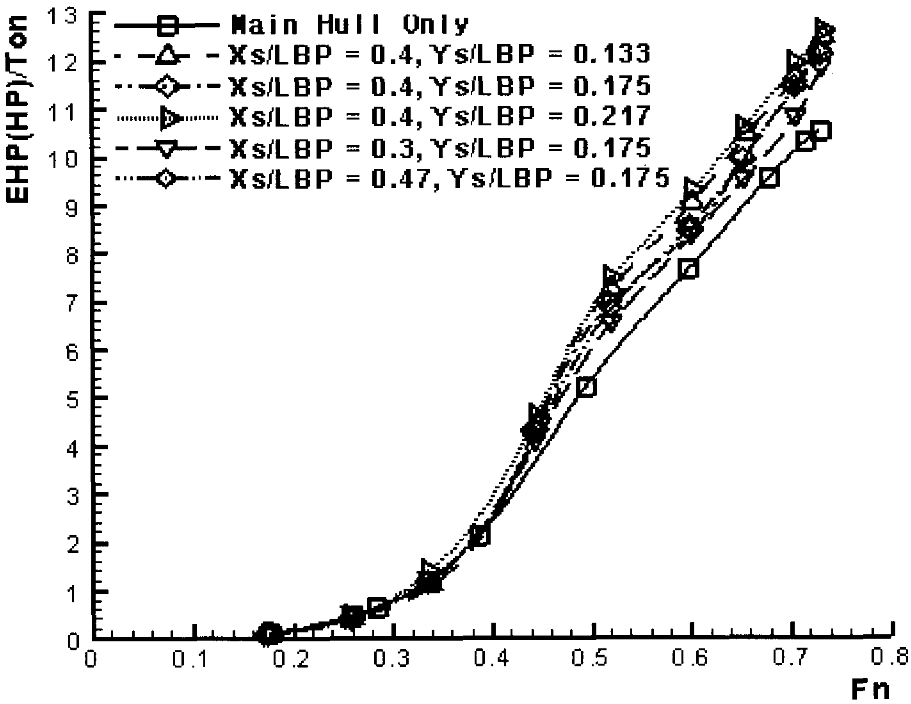


Figure 13: EHP/Ton curves of the trimaran with various positions of the outriggers

Figure 13 shows EHP per unit displacement found from the model tests. The EHP curve of the main hull only case yields the lowest values as expected and the presence of the outriggers increase the EHP for all the position of outriggers in transverse and longitudinal direction. The increase in EHP may be explained by the frictional resistance increase due to the added wetted surface areas. However, the differences among the EHP's grow up with the increase of the Froude numbers and indicating that the amplification of interference among the wave systems generated by the main hull and outriggers become severe with the increase of the ship velocity.

5 Discussions and conclusions

A 12 m long G/T 4.99 Class Trimaran is now under development at the Center for Transportation System of the Yellow Sea (CTYS) before deployed as a pleasure fishing boat along the west coast of Korean peninsula. The boats will be made of fiber reinforced plastics and equipped with a 360 hp diesel engine and a water jet propulsion system to propel the ship to reach maximum speed of 25knots after fully loaded.

Model tests for hull forms development of the Trimaran have been done at the towing tank of the Inha University. The influence of the spacing between main hull and outriggers and the longitudinal location of the outriggers have been carefully examined to find the optimal size and locations of the outriggers to improve both the hull attitudes and resistance characteristics, and the results are reported in the present paper.

The result of the model tests indicate that the V type side hull has better resistance performance than the Wigley type and that the optimal location of the side hull is *Ys/LBP* = 0.175, *Xs/LBP* = 0.4. The estimated EHP of the final hull form at the speed of 15knots, which is the speed limit for the 1.5m model at the towing tank, is found to be 98HP. The test results have been extrapolated empirically to found that the 360HP class engine is not sufficient to achieve design speed of 25 knots.

Further study for hull form refinement to improve the propulsive efficiency of the trimaran boat is planned. In the process, *L/B* of the main hull will be increased and the displacement will be reduced. A preliminary estimation indicates that the design speed of 25 knots can be reached with such modifications. After confirming the performance of the modified hull form experimentally, a full scale test ship will be built and powering performance and motion characteristics of the ship will be verified through extensive sea trials.

Acknowledgement

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