

## PERFORMANCE COMPARISON BETWEEN PLANING MONOHULL AND CATAMARAN AT HIGH FROUDE NUMBERS\*

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**Abstract**– Conventional ships have been used for many years with usual body forms. But recent developments in high speed crafts have created many different alternatives. Therefore the selection of hull type becomes an important issue in the preliminary design stage. This selection should be based on performance comparisons and also other parameters such as building costs. Since planing monohulls and catamarans are very popular types of high speed crafts, in this paper their behaviors from resistance at high speeds are compared. The results may prove useful for designers at conceptual or preliminary design stages.

**Keywords** – High speed crafts, planing monohull, planing catamaran

### 1. INTRODUCTION

The ability to move marine vehicles at high speed has been at the forefront of naval engineering and hydrodynamic research since the days of the clipper vessels. However, perhaps the most significant advance occurred in 1896 by Charles Parsons around the British Fleet. His experimental vessel was capable of moving at 34.5 knots. During the latter part of the 19<sup>th</sup> century and the early 20<sup>th</sup> century, much thought was being given to alternative methods of moving ships quickly, with many concepts being patented. These concepts are planing craft, hydrofoil, air cushions, wing in grounds, etc [1]. In October 1964, a comprehensive paper which summarized previous experimental studies on the hydrodynamics of prismatic planing surfaces is presented by Savitsky. He presented a method for application of these results for the design of moving ships. Besides, many laboratories and research centers have conducted hydrodynamic studies on several fundamental planing hull phenomena [2].

The underlying principles of high speed planing craft resistance have been treated by DuCane, Clyaton and Bishop. Viscosity and free surface effects, including spray and overturning waves, play significant roles making both experimental and numerical predictions very difficult [3].

For predicting vessel performance, different methods are available, each with its own advantages and disadvantages. For example, a model test in a towing tank is a popular method. The idea of model testing is to perform experiments with a scaled model to extract information that can be scaled to the full size vessel. Despite continuing research and standardization efforts, certain empiricism is still necessary, particularly in the model to ship correlation, which is a method to enhance the prediction accuracy of ship resistance by empirical means. Although the procedures for predicting full scale resistance from model tests are well accepted, full scale data available for validation purposes are extremely limited and difficult to obtain.

For vessel resistance and powering, CFD has also become increasingly important and is now an indispensable part of the design process. But CFD is still considered by industry as too inaccurate for performance predictions. One of their reasons is that CFD codes often neglect wave making resistance and focus on the aft body or appendages.

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Design engineers need simple and reasonably accurate estimation for predicting ship performance. Common approaches combine a rather simple physical model and regression analysis to determine required coefficients either from one parent vessel or from a set of vessels. The coefficients may be given in the form of constants, formulae, or curves [4].

Since preliminary design is a very important stage in the design process of a vessel due to the fact that at this stage the type of hull should be specified, comparison between different hull types should be performed. Planing monohull and planing catamaran are both popular and have been used for different applications, thus evaluating their performance in the preliminary design stage and comparing their results will be very valuable for designers. Catamarans, and in general, multihull vessels, have better transverse stability and also because of their slender hulls, smaller wave making resistance. However monohulls have other advantages such as lower construction costs and better structural configuration [5].

Different studies are reported for comparison of monohulls and catamarans [6, 7], but many of the results are for low speeds and comparison at high speeds is still a research topic. In [8], results for a monohull and catamaran are presented. These results show that up to  $Fn_{\nabla} = 3.4$ , the monohull has higher resistance, but after this region, the monohull will have a lower resistance than the catamaran. A similar study was reported in [5] on the base of MICHLET software. This result indicates higher viscous resistance of catamarans for all speed regions, but total resistance of the catamaran has been lower than the monohull up to  $Fn_{\nabla} = 4.2$ .

In this paper a monohull and a catamaran with equal displacement are considered for comparison. The resistances of both vessels are compared for high speeds (planing mode). Furthermore, the effects of different hull form parameters are investigated on both vessels.

## 2. RESISTANCE OF PLANING CRAFTS

Resistance of a monohull or catamaran may be divided into the following components:

- 1) Skin or viscous resistance.
- 2) Wave making resistance.
- 3) Body form resistance which consists of pressure drag and spray of water.

In basic ship hydrodynamics, residuary resistance is also defined. This term means the difference of total resistance and viscous resistance. For high speed planing hulls, total resistance is usually divided into the following components [9]:

- 1) Viscous resistance, which is created on the wetted surface of the vessel, is shown by  $R_f$  and can be evaluated by the following formula [9]:

$$R_f = \frac{\rho V_m^2 \lambda b^2 C_F}{2 \cos \beta \cos \tau} \quad (1)$$

- 2) Pressure resistance is the horizontal component of hydrodynamic pressure created on the bottom of a vessel. This component is shown by  $R_p$  and is calculated by the following formula:

$$R_p = \Delta \tan \tau \quad (2)$$

Therefore, the total resistance for a high speed planing hull is

$$R = R_f + R_p = \frac{\rho V_m^2 \lambda b^2 C_F}{2 \cos \beta \cos \tau} + \Delta \tan \tau \quad (3)$$

Detailed explanation and calculation procedures are presented by [10 & 11]. Some parameters are also defined in Fig. 1.

### 3. MONOHULL AND CATAMARAN COMPARISON

Based on the Savitsky's method [9], a computer program is developed for resistance evaluation of planing hulls in calm water. The accuracy of software is verified through comparisons with available data and it has been employed for the present study [10, 11]. The Savitsky method is based on experiments on prismatic planing hulls. Typical forms for such vessels are shown in Fig. 2. Of course basic formulation was for planing monohulls, but as it is described in [12] it is possible to apply it to planing catamarans as well. Most high speed planing hulls can be assumed prismatic in high speed operation mode. In this case, the wetted surface would be similar to the area shown in Fig. 2.

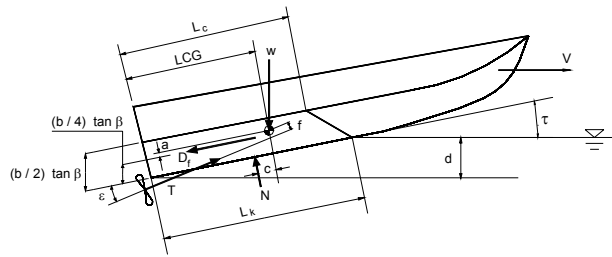


Fig. 1. Forces acting on a planing hull

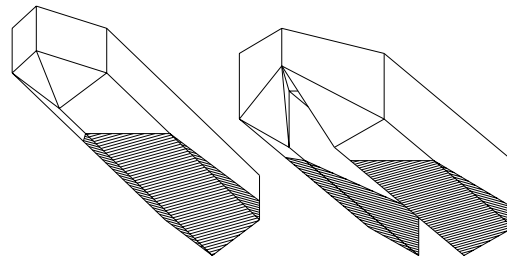


Fig. 2. Prismatic planing hulls

Figures 3 and 4 show the planing monohull and planing catamaran which are considered for comparison. Table 1 contains the main characteristics of these vessels. Since payload is an important design parameter, displacements of both vessels are assumed equal. Although payload is not equivalent to displacement, there is a good correlation between these parameters. The monohull has a typical body form of series 62 and detailed information for it is given in [13]. For both vessels the results of the developed computer program is compared with experimental data and good accuracy of the results was proven [10, 11].

Table 1. Main characteristic of both vessels

	Monohull	Catamaran
$\Delta$	18.7 ton	18.7 ton
$LGG/L$	0.375	0.375
$VGG$	0.87 m	0.87 m
$\beta$	13°	13°
$f$	0.038 m	0.038 m
$\varepsilon$	10°	10°
$\bar{b}$	4.325 m	4.325 m
$\bar{b}_1$	—	2.58 m

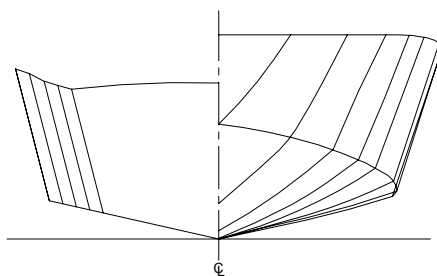


Fig. 3. Planing monohull body form

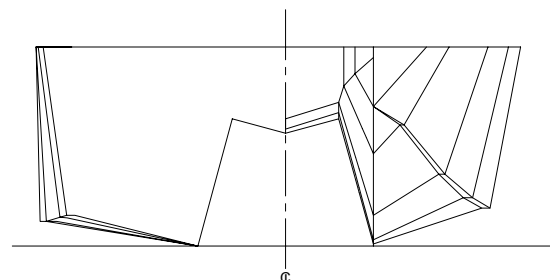


Fig. 4. Planing catamaran body form

Figure 5 shows the result for trim angle and resistance of both vessels. Trim angle is higher for the catamaran, which is due to the smaller LCG value. Since the length of the monohull is 15.57 m and the length of the catamaran is 14.5 m, for similar LCG/L of both vessels, the LCG of the catamaran is smaller than the monohull. The total resistance of the monohull is smaller than the catamaran in values

of  $F_{n_{\nabla}} > 3.4$ . Since the total resistance consists of two components, they are presented separately in Fig. 6. Viscous resistance for the monohull is slightly higher at very large  $F_{n_{\nabla}}$ , but pressure resistance is considerably lower. The total resistance represents these effects, and differences are shown clearly in Fig. 5.

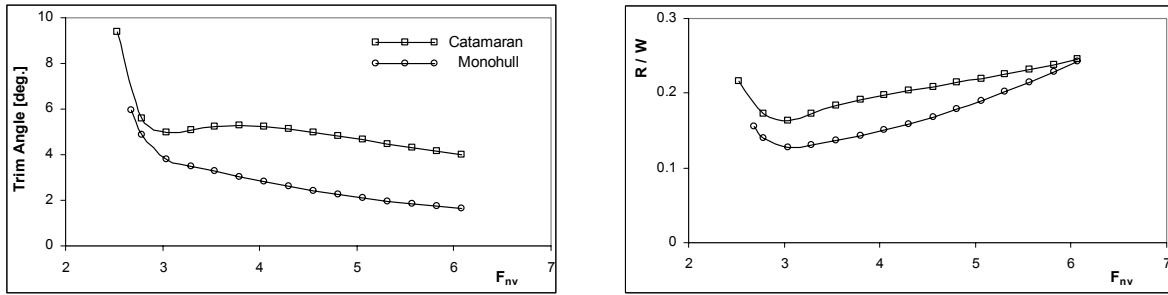


Fig. 5. Resistance and trim angle for planing monohull and catamaran

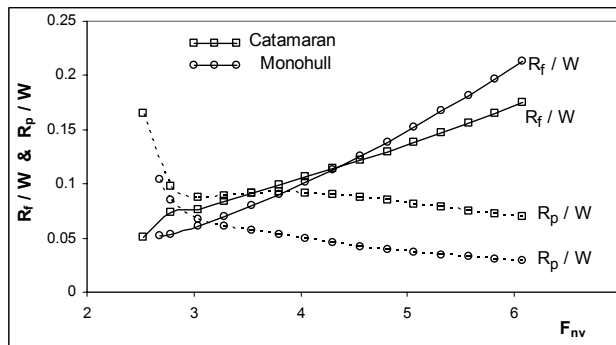


Fig. 6. Comparison between resistance components for both vessels

Figures 7 to 10 show effects of changes in main body form parameters on the performance of the vessels. From Fig. 7, it can be concluded that variation of displacement has a similar effect on resistance and the trim angle of both vessels. Of course catamaran seems to be more sensitive to the displacement changes.

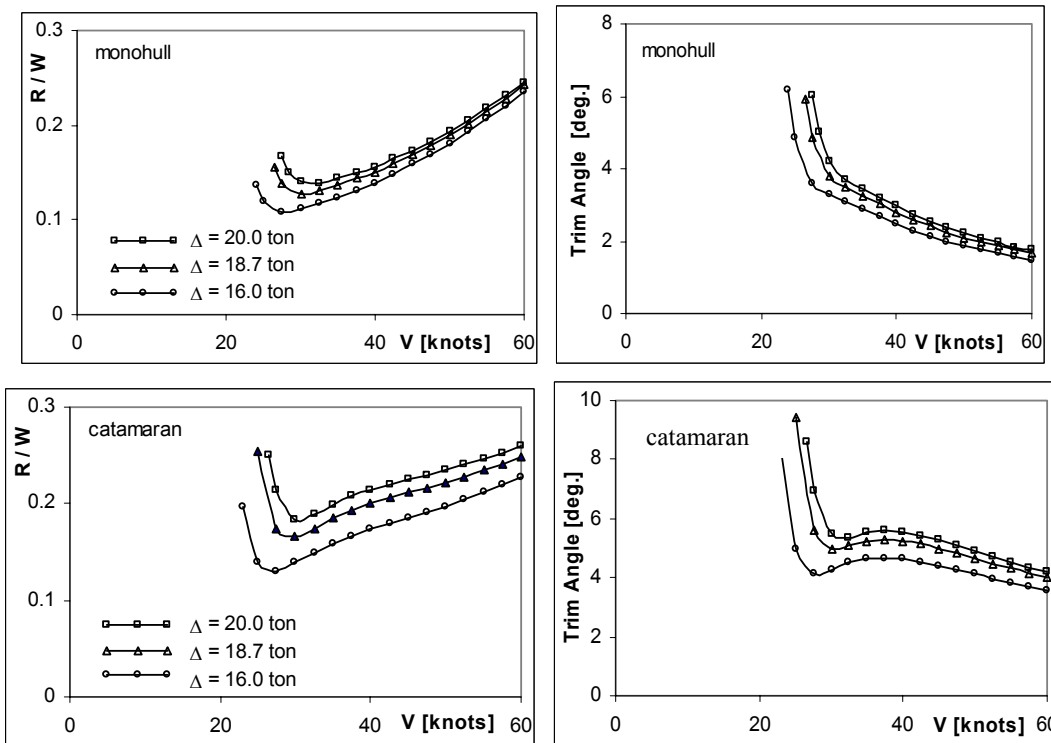


Fig. 7. Effect of changes in displacement on performance of both vessels

Figure 8 presents results for different longitudinal centers of gravity. According to the results, smaller LCG cause higher trim angles for both vessels, which are reasonable. On the other hand, a smaller LCG is equivalent to higher resistance at small values of  $Fn_{\nabla}$  and lower resistance at larger values of  $Fn_{\nabla}$ . The monohull shows this variation at lower values of  $Fn_{\nabla}$  and catamaran again seems to be more sensitive to the LCG variation.

Figure 9 shows the effect of changes in a deadrise angle on the performance of both vessels. A smaller deadrise angle causes reduction on the trim angle and resistance, but on the other hand, it would create possibility for higher slamming pressure in waves.

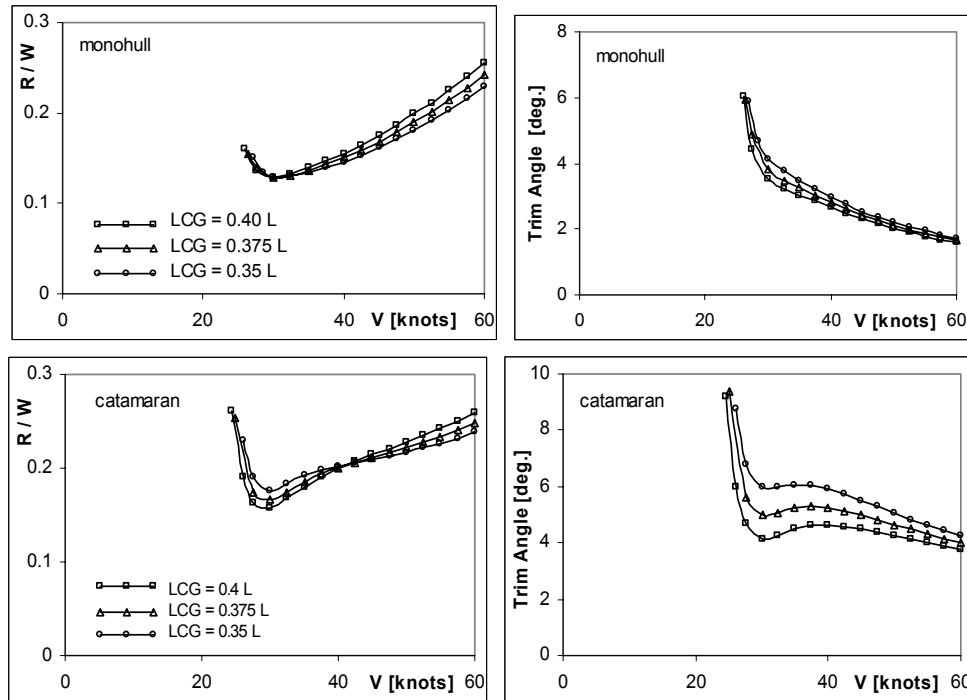


Fig. 8. Effect of changes on LCG on performance of the both vessels

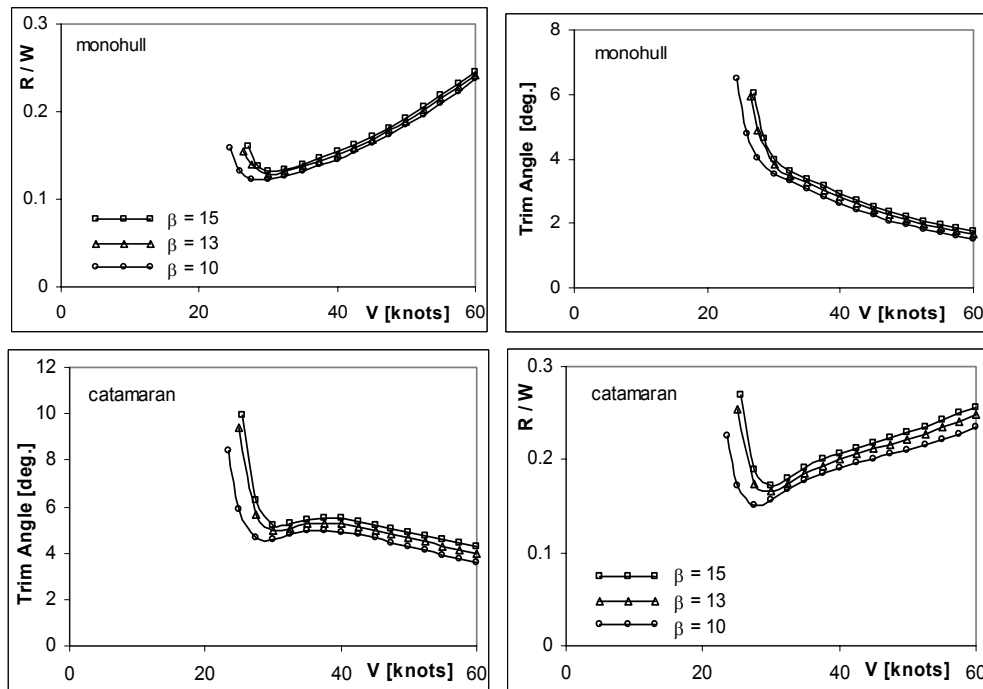


Fig. 9. Effects of changes in deadrise angle on performance of both vessels

Variation of length to beam ratio is also considered and results are shown in Fig. 10. For monohulls at speeds corresponding to the full planing mode, higher values of this ratio cause less resistance. For a catamaran, this effect would be completely similar.

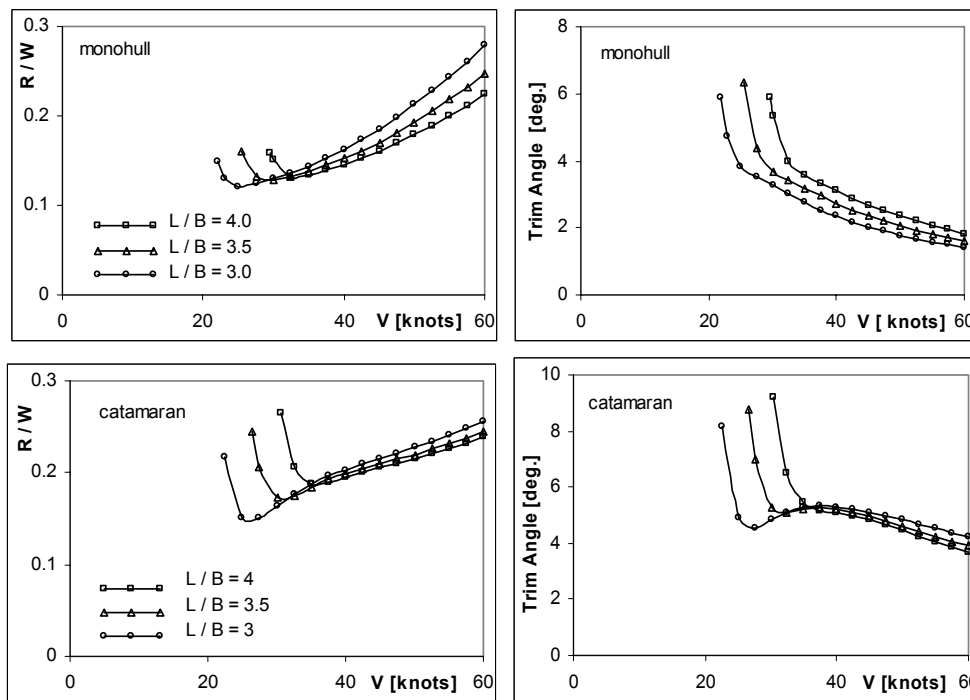


Fig. 10. Effect of changes in length to beam ratio on performance of both vessels

#### 4. CONCLUSION

In this paper a planing monohull and a planing catamaran are considered for comparison. These vessels are chosen of equal displacement and the different advantages and disadvantages of the vessels are reviewed from behavior in calm water. Results show a lower resistance of monohull at high speeds. Parametric study on body form is also performed and the results show some similarities and differences on the behavior of both vessels. These results can be used in the preliminary design stage for choosing the hull type. Of course the choice of hull type should be based on more detailed studies which should consider other parameters such as manufacturing costs, running costs, seakeeping and so on.

#### NOMENCLATURE

$\varepsilon$	angle between thrust and keel	R	total resistance
$\beta$	deadrise angle	$R_f$	frictional resistance
$\bar{b}$	mean breath of vessel	$R_p$	pressure resistance
$\bar{b}_1$	mean breath of two demihulls	$\lambda$	length to beam ratio
$C_F$	total frictional coefficient	$\rho$	water density
f	distance between thrust and center of gravity	$\tau$	trim angle
$Fn_{\nabla}$	Froude number- $\left(Fn_{\nabla} = \frac{V}{\sqrt{g \cdot \nabla^{1/3}}}\right)$	S	total wetted surface
g	gravity acceleration	$\nabla$	volumetric displacement of vessel
LCG	longitudinal position center of gravity	V	speed of the vessel
$\Delta$	displacement	VCG	vertical position center of gravity

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