The influence of foil-shaped center bulb geometry into catamaran fishing vessels resistance

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Abstract. This paper discusses the use of foil-shaped center bulb in catamaran fishing vessels, where the length, width, and height of the center bulb were configured into six variations. This study aims to get the best configuration that can most reduce the total resistance of catamaran fishing vessels. Ship resistance was tested at Fr 0.15 to Fr 0.35 using the CFD method. The results showed that the best model was found in Model 6, where the length of the center bulb was 15% greater while the width and height were smaller by 10% from the original one. Model 6 can reduce resistance by 10.68%.

Keywords: catamaran, foil-shaped, center bulb, resistance

1. Introduction
The catamaran is a ship with a double hull that has many advantages over single-hull ships with the same displacement. Among these advantages is the catamaran has a broad deck so that designers are more flexible in arranging the ship's accommodation space. Besides, the catamaran has excellent stability, so that catamarans are safer and more comfortable for passengers [1,2].

Because catamaran has two hulls, the interference between them is a very popular topic to be discussed on catamarans. Errors in designing the hull form and determining the distance between the hull will increase the interference that causes ship resistance to catamaran vessels increase [3].

Some researchers conduct some research to reduce catamaran resistance due to interference. Iqbal and Samuel [4] has researched to overcome the resistance of catamaran fishing vessels by modifying the shape of the ship's demi hull using the Luckenby method. The Curve of Sectional Area of the vessel was changed to form a new hull. This method succeeded in reducing the total resistance by 6.5%, which has also been used successfully by Iqbal and Rindo [5] to improve catamarans' seakeeping quality.

The use of the bulbous bow on catamaran fishing vessels has also been carried out by Samuel et al. [6] to reduce ship resistance. The results show that ship resistance can be reduced and can also increase depending on the type of bulbous bow used. In that case, the type used to reduce the resistance is the nabra type, where the total resistance was decreased by 10%. 
Other studies conducted to reduce catamaran's resistances have been carried out using the concept of a center bulb, which is bulbous that is installed between the hulls of the catamaran [7], [8]. Center bulb applications can also improve the quality of catamaran's seakeeping [9-11].

Danisman [8] optimized the position and geometry of the ellipsoidal center bulb. The research has succeeded in reducing ship wave resistance by 15% based on numerical calculation results and 13% based on experimental test results in towing tanks. The elliptical center bulb from Danisman has also been applied to catamarans by Samuel et al. [12] and can reduce the resistance by up to 25.76%.

The using a center bulb on a catamaran is still relatively new and still requires a lot of studies. Therefore, in this study, the ellipsoidal center bulb's shape will be replaced by a foil. This shape is expected to reduce ship resistance further because the tapered back shape of the foil will make the flow pattern become streamlined and will not cause vortex shading like when the water flow passes through a circle or ellipsoid.

Optimization of the size of the elliptical center bulb on the NPL hull catamaran has been carried out by Iqbal et al. [13] using the response surface method (RSM). The center bulb's optimal model can reduce wave resistance by 11.11% compared to the center bulb model without optimization and can reduce the wave resistance by 5.36% compared to the model without the center bulb.

In addition to the elliptical shape, the optimization of the center bulb size in the form of foil on the NPL hull catamaran has been investigated by Hadi et al. [14] with the same method, namely RSM. The center bulb's optimal size reduces wave resistance, RW by 11.74% from the initial center bulb model (center bulb form that has not been optimized) and can reduce by 4.72% compared to not using center bulb.

When compared, the difference in the reduction of the wave resistance between the ellipse and the foil shape is only slightly, where the ellipse shape is 0.64% better. However, the two optimizations only use two parameters: the length and diameter of the center bulb. Both cases were not considering the difference in width and height and position of the center bulb.

Therefore, this study aims to examine the three parameters of the foil-shaped center bulb: length, width, and height to determine which parameters significantly affect the total resistance of catamarans. Besides, knowing which parameters are very significant to the ship's resistance will help the ship's designers more quickly determine the size of the foil-shaped center bulb.

2. Methods

The ship used in this study was one of the traditional fishing catamarans in Cilacap Region, Central Java - Indonesia, whose name FV. Laganbar. The figure and 3D model of a vessel are shown in Figure 1 and Figure 2. For the computational simulation, the vessel was scaled with 1:10. The main dimensions of the ship and the size of the ship scale model are shown in Table 1. Dimension, 3D modeling, and the figure of center bulb installation used in this study are shown in Table 2, Figure 3 and Figure 4, respectively. The length, width, and height of the center bulb were modified into six models with the same surface area, which is 0.001671 m², as shown in Table 3.

Vessel resistance was tested at five-speed, which is between Fr 0.15 - Fr 0.35 or equivalent from 1.4 to 3.37 m s⁻¹ in actual size. The CFD software used is Tdyn version 12.2.3.0. The size of the fluid domain is shown in Figure 5. Hadi et al. [15] as well as Iqbal and Utama [16] proved that the Tdyn software simulation results had results similar to experimental testing in towing tanks. K omega SST was used as the turbulent model. The mesh size used is 0.01 for the underwater area of the ship, 0.05 for free surface, 0.1 for all remaining components except Centerbulb 0.005. The meshing result is shown in Figure 6.
Figure 1. F.V. Laganbar

Figure 2. 3D hull modelling of F.V. Laganbar

Table 1. Full scale and model scale of vessel

| Dimension     | Full Scale | Model Scale |
|---------------|------------|-------------|
| Lwl           | 8.90 m     | 0.89 m      |
| B demi hull    | 1.10 m     | 0.11 m      |
| BOA           | 3.40 m     | 0.34 m      |
| T             | 0.50 m     | 0.05 m      |

Table 2. Dimension of center bulb

| Parameter      | Value     |
|----------------|-----------|
| Length (m)     | 0.50 m    |
| Width (m)      | 0.26 m    |
| Height (m)     | 0.12 m    |
Figure 3. 3D modelling of center bulb

Figure 4. Center bulb installation with the vessel

Table 3. Ratio and dimension of center bulb

| Model | Ratio (%) | Dimension (m) |          |
|-------|-----------|---------------|----------|
|       | Length    | Width | Height | Length | Width | Height |
| Original Without Center Bulb | | | | | | |
| 1     | 100       | 100   | 100    | 0.500  | 0.260 | 0.120  |
| 2     | 100       | 90    | 110    | 0.500  | 0.234 | 0.132  |
| 3     | 100       | 80    | 120    | 0.500  | 0.208 | 0.144  |
| 4     | 100       | 110   | 90     | 0.500  | 0.286 | 0.108  |
| 5     | 100       | 120   | 80     | 0.500  | 0.312 | 0.096  |
| 6     | 115       | 90    | 90     | 0.575  | 0.234 | 0.108  |
3. Results and discussion

The results of CFD simulations of Catamaran ship resistance without using a center bulb were validated using the Empirical Formula, as found in Jamaluddin et al. [17]. The results of this validation have errors below 5%, as shown in Table 4. The same set-up is used to simulate the six catamaran models that use the center bulb whose results are presented in Table 5.

| Fr  | $v$ (m s$^{-1}$) | Total Resistance Based on Empirical Equation (KN) | Total Resistance based on CFD (KN) | Error (%) |
|-----|-----------------|--------------------------------------------------|-----------------------------------|-----------|
| 0.15| 1.40            | 0.24                                             | 0.24                              | -1        |
| 0.20| 1.87            | 0.54                                             | 0.56                              | 2         |
| 0.25| 2.33            | 1.01                                             | 0.98                              | -3        |
| 0.30| 2.80            | 1.39                                             | 1.37                              | -1        |
| 0.35| 3.37            | 1.98                                             | 1.89                              | 4         |

Based on Table 5, the smallest resistance at Fr 0.35 is found in Model 6. This model has a slender shape, where the length is 15% larger and width and 10% smaller (from its original form). Similar results were also found by Hadi et al. [14], in which the optimal dimensions of the foil-shaped center bulb were slender as well. The length of the center bulb has 15% larger, and its diameter is 34% smaller than the original one. Both of these results prove that the shape of a slender foil-shaped center bulb can reduce catamaran vessels' resistance.

Furthermore, the resistance of Model 6 is compared with the original model (without the center bulb), whose results are presented in Table 6. The configuration of model 6 still increases
the total resistance of the original model at Fr 0.20 to Fr 0.30 but reduces at Fr 0.35. The results of
the wave contour from the CFD calculation are presented in Figure 7.

Table 5. Results of ship resistance

| Model     | Fr 0.15 (N) | Fr 0.20 (KN) | Fr 0.25 (KN) | Fr 0.30 (KN) | Fr 0.35 (KN) |
|-----------|-------------|--------------|--------------|--------------|--------------|
| Original  | 0.24        | 0.56         | 0.98         | 1.37         | 1.89         |
| 1         | 0.23        | 0.77         | 1.28         | 1.74         | 1.82         |
| 2         | 0.24        | 0.61         | 1.02         | 1.46         | 1.85         |
| 3         | 0.26        | 0.60         | 1.05         | 1.51         | 1.89         |
| 4         | 0.24        | 0.63         | 1.01         | 1.47         | 1.85         |
| 5         | 0.26        | 0.60         | 0.98         | 1.43         | 1.87         |
| 6         | 0.24        | 0.60         | 1.02         | 1.47         | 1.77         |

Table 6. Comparison of ship resistance between original model and Model 6

| Fr  | \( v \) (m s\(^{-1}\)) | Total Resistance of Original Model (KN) | Total Resistance of Model 6 (KN) | Difference (%) |
|-----|------------------------|----------------------------------------|---------------------------------|----------------|
| 0.15| 0.44                   | 0.24                                   | 0.24                            | 0.00           |
| 0.20| 1.09                   | 0.56                                   | 0.60                            | 7.14           |
| 0.25| 0.74                   | 0.98                                   | 1.02                            | 4.08           |
| 0.30| 1.65                   | 1.37                                   | 1.47                            | 7.29           |
| 0.35| 1.04                   | 1.89                                   | 1.77                            | -6.35          |

**Figure 7.** Comparison of wave elevation contour between original model (top) and model 6 (bottom) at Fr 0.35

**Figure 7** explains the wave elevation produced by the original model and Model 6 when operating
at Fr 0.35. The picture shows that Model 6 has a lower wave elevation compared to the Original
Model. The difference in wave elevation can be called as one of the indicators of wave resistance.
The lower elevation generated, the lower wave resistance occurred.
4. Conclusion
The best form of foil-shaped center bulb from various configurations that have been conducted in this study is Model 6. The center bulb's length is extended by 15%, while the width and height of the center bulb are reduced by 10% from the original one. This model can reduce the total resistance by 10.68% at Fr 0.35.

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