ANALYSIS OF RESISTANCE AND STABILITY IN THE MODIFICATION OF OUTRIGGED FISHING BOAT DESIGN IN THE PUGER WATER, JEMBER

ANALISIS HAMBATAN DAN STABILITAS PADA MODIFIKASI DESAIN KAPAL IKAN BERCADIK DI PERAIRAN PUGER, JEMBER

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(Received April 19, 2024; Revised October 5, 2024; Accepted January 9, 2025)

ABSTRACT

Fishing boats are one of the essential means of transportation for fishers. In Puger, fishing boats are crafted by traditional boat builders who have passed down their skills through generations. However, the effectiveness of the bow stem design of these fishing boats remains unknown. This research aims to analyze the impact of the bow stem shape on the resistance and stability values of the boat. This research utilized an outrigger fishing boat design with the following dimensions: a length overall (LOA) of 11 m, a beam (B) of 1.5 m, a height (H) of 1.5 m, and a draft (T) of 0.5 m. We compared the boat's original design and its modified bow design. The results of this study indicate that the modified design has a 16.327% lower resistance. Regarding stability, the modified design shows a 12.7% greater GZ (upholding arm value) and a 2.1% smaller heel compared to the initial design. Additionally, the modified design has a rolling period that is 5.8% faster than the original design. The modified design has better resistance and stability than the initial design.

Keywords: outrigged fishing boat, resistance, stability

ABSTRAK

Kapal ikan merupakan salah satu alat transportasi yang penting untuk profesi nelayan. Kapal ikan di Perairan Puger dibuat oleh pengrajin kapal tradisional secara turun temurun. Desain linggi haluan kapal ikan tersebut belum diketahui efektivitasnya. Tujuan dari penelitian ini adalah untuk menganalisis pengaruh bentuk linggi haluan terhadap nilai hambatan dan stabilitas kapal. Penelitian ini menggunakan kapal ikan bercadik dengan panjang (LOA) 11 m, lebar (B) 1,5 m, tinggi (H) 1,5 m, dan sarat (T) 0,5 m. Penelitian dilakukan dengan membandingkan desain awal kapal ikan dan desain modifikasi haluannya. Perbandingan menggunakan nilai hambatan dan stabilitas sebagai acuan. Hasil dari penelitian ini didapatkan bahwa desain modifikasi mempunyai hambatan lebih kecil sebesar 16,327%. Pada aspek stabilitas, desain modifikasi mempunyai nilai GZ lebih besar yaitu 12,7% dan sudut oleng lebih kecil 2,1% dari desain awal. Desain modifikasi mempunyai periode oleng 5,8% lebih cepat daripada desain awal. Desain modifikasi mempunyai nilai hambatan dan stabilitas yang lebih baik daripada desain awal.

Kata kunci: hambatan, kapal ikan bercadik, stabilitas

INTRODUCTION

Boats are a means of transportation used by people in water areas. Boats can also be used as a means of earning a living, one of which is the profession of fishers. Outrigger fishing boats are one of the characteristics of fishing boats that are often used by fishers. Boat builders or craftsmen of traditional fishing boats, especially outrigger fishing boats, do not use knowledge about boat design (Simanjuntak *et al.* 2018). The craftsmen of traditional fishing boats in Puger also do not use knowledge but are only equipped with hereditary habits. The role of the development of naval architects can be used to obtain optimal designs for fishers.

Outrigger fishing boats are a form of fishing boat that is safe for fishers in sailing (Kiryanto and Samuel 2014). Outriggers are used to balance the ship when sailing. However, the addition of these outriggers increases the area of the ship that is submerged in water, thus increasing the resistance value.

The parameters of the hydrodynamic values of the traditional fishing boat design made by the craftsmen of the fishing boat are not yet known. An analysis of this needs to be done because if the design of the fishing boat does not consider the resistance value, it will cause the craftsmen not to know how much power is needed to propel the boat. In theory, the greater the resistance value of the boat, the greater engine power is needed (Theotokatos and Tzelepis 2015). Ignorance of the resistance value will result in the engine power not being in accordance with the required speed. In addition to resistance, the stability value is also important because it will affect the ability of the boat to return to its original position when it is tilted (Yulianti *et al.* 2017). This is the background that the design of the outrigger fishing boat should be designed in such a way as to be more effective and efficient.

Based on the description, a study was conducted to modify the shape of the bow of an outrigger fishing vessel because the shape of the bow can affect the hydrodynamic characteristics of the vessel. This study aims to compare the resistance and stability values of the original design bow (spoon bow) with the raked bow shape. Syahril and Nabawi (2019) stated that the raked bow shape has the advantage of tending to have lower resistance when applied to a vessel. However, the study did not test the effect of the bow shape on the resistance and stability values of outrigger fishing boats.

METHODS

This study focuses on the analysis of the resistance and stability of outrigger fishing boats. The stages of the work steps include data collection, drawing of outrigger fishing boat models, resistance evaluation, stability evaluation, and comparative analysis. The following is a description of the work steps.

Data collection

The data collection process was carried out by measuring one of the outrigger fishing boats owned by fishers in Puger Waters, Jember, in July 2023 for 2 days. Outrigger fishing boats that have similarities with each other, then only one boat was taken. Measurements were made by getting the distance and offside of each frame from the stern to the bow of the ship, while for outrigger measurements, the length and width of the centerline of the ship's hull were measured. The process of collecting ship size data is shown in Figure 1.

Figure 1. The process of collecting data on the size of outrigger fishing boats in Puger.

Depiction of a model of an outrigger fishing boat

The depiction of the ship model in this study uses Maxsurf software. Surface modeling is carried out with control points that will be given an offside value for each frame so that the ship's hull is formed. The process of making the ship model uses the original values obtained so that it uses the original scale in the process. Furthermore, a modification design is made to improve its hydrodynamics with a raked bow shape. The shape of the bow is adjusted to research that has been done (Syahril and Nabawi 2019). The striking difference is that the shape of the bow after being modified becomes more pointed at the end.

Resistance analysis

Ship resistance test simulation is used to determine the resistance value at each speed. Resistance occurs due to the interaction between the ship and the fluid or seawater when the ship is sailing (Harvald 1983). Resistance consists of wave resistance, viscous resistance, and frictional resistance. This study uses the Van Ootmersen calculation method because the formula is used for small ships such as fishing boats (Prayitno 2012).

The magnitude of the total resistance force is the sum of the types of resistance. Total resistance can be used to find the engine power needed when sailing at a certain speed. The following is a formulation for calculating the total resistance produced by a ship (Molland *et al.* 2011):

$$R_T = 0.5 \times \rho \times C_T \times S \times V_s^2$$

Where:
ρ = Density of sea water (1.025 ton/m^3)
C_T = Total drag coefficient
S = Wet surface area (m^2)
V_S = Boat speed (knot)

Stability analysis

Boat stability analysis can determine at what angle the ship can maintain its position. In general, ship stability is influenced by 2 factors, namely internal factors and external factors. Internal factors, for example, are ships experiencing leaks or loads that exceed capacity. External factors, for example, are waves, currents, and wind. Stability is also closely related to the shape of the boat, cargo, ship draft, and GM value (metacenter height). Therefore, stability can also be influenced by the main dimensions of the boat.

The study was conducted using simulations in ship stability data processing software. The software uses the A.N. Krylof formula as follows (Fadillah *et al.* 2019):

$$F_B = g\Delta = \rho g \nabla$$

Where:
F_B = Buoyancy
g = Gravity
Δ = Boat displacement
ρ = Density

$$GZ = y_{B\varphi} \cos\varphi + Z_{B\varphi} - KG \sin\varphi$$

Where:
GZ = The value of the upholding arm
$y_{B\varphi}$, $Z_{B\varphi}$ = Coordinates of the center of buoyancy
KG = The value of the metacentric point above the keel minus the metacentric height

Boat stability analysis uses stability data processing applications to obtain calculation results. Stability analysis uses IMO criteria to determine whether a ship has good stability. In this case, the criteria used are IMO regulation A. 749 (18) (IMO 1993), including:

1. Area under the GZ curve at a pitch angle of 0-30 deg ≥ 0.055 m.rad or 3.151 m.deg.
2. Area under the GZ curve at a pitch angle of 0-40 deg ≥ 0.03 m.rad or 5.157 m.deg.
3. Area under the GZ curve at a pitch angle of 30-40 deg ≥ 0.09 m.rad or 1.719 m.deg
4. Maximum GZ value at a pitch angle of 30 deg or greater ≥ 0.2 m.
5. Maximum GZ value must not be more than a pitch angle of 25 deg.
6. GM0 height must not be less than 0.15 m.

Comparative analysis

The initial design and the modified design are then compared to determine which design is best in terms of ship resistance and stability, and can also provide recommendations regarding the design as a development of the outrigger fishing boat design in Puger.

RESULTS AND DISCUSSION

Model depiction

Model drawing using ship modeler software by combining several surfaces and adding control points to get its shape. The main dimensions of the ship are obtained in Table 1, then the bow height is modified to become a raked bow as in Figure 2.

A comparison of the bow height shape can be seen in Figure 3. The shape of the raked bow is adjusted to the research that has been conducted by Syahril and Nabawi (2019). After completing the model, the hydrodynamic values were obtained and compared in Table 2.

Resistance analysis

The results of the resistance evaluation on outrigger fishing boats in Puger using the formulation from Van Ootmerssen. Table 3 shows the resistance values of various speeds from both designs, namely the initial design with the modified design. It was found that the resistance value in the modified boat model design was smaller than the resistance value of the initial boat model design.

The analysis of the resistance value uses speed variations ranging from 10.5 knots to 15 knots. This is based on the results of interviews with several fisher using outrigger fishing boats, that the average speed of outrigger fishing boats in Puger is 12 knots. Based on Figure 4, it is found that the resistance curve graph of the modified design is smaller than the initial design, so a decrease in the resistance value of 16.327% is obtained. In this case, the shape of the bow greatly affects the resistance value; this is in line with the research of Firmansyah and Riyadi (2019).

Table 1. Main sizes of outrigger boats in the Puger waters, Jember.

Data	Sizes	Units
Length (L)	11	m
Width (B)	1.5	m
Height (H)	1.5	m
Loaded (T)	0.5	m
Machine	54	HP
Types of fishing gear	Gill net	

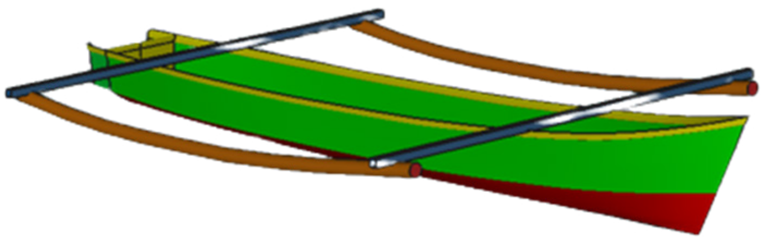
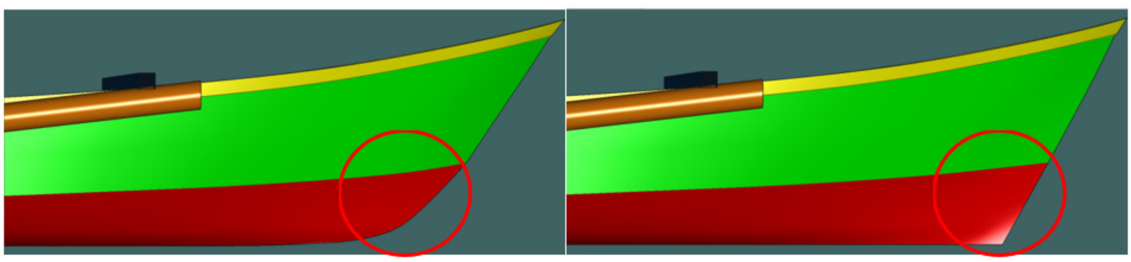


Figure 2. 3D design of an outrigger fishing boat in the Puger waters, Jember.



(a) (b)

Figure 3. The shape of the bow of an outrigger ship: (a) Before modification, (b) After modification.

Table 2. Comparison of hydrostatic values of the initial boat model design and the modified boat model design.

Parameters	First Design	Modified Design
Displacement	6.519 ton	6.539 ton
LWL	10.395 m	10.511 m
WSA	23.421 m^2	23.761 m^2
CP	0.749	0.743
CB	0.158	0.156
CM	0.212	0.212
CWp	0.232	0.23
LCB	0.252 m	0.283 m
LCF	0.253 m	0.291 m

Table 3. Comparison of the resistance values of the initial boat model design and the modified boat model design at different speeds.

Speed	First Design	Modified Design
10.5 knot	1.4 KN	1.2 KN
11.25 knot	1.6 KN	1.2 KN
12 knot	2.1 KN	1.6 KN
13.5 knot	3.4 KN	2.7 KN
14.25 knot	4.2 KN	3.4 KN
15 knot	4.9 KN	4.1 KN

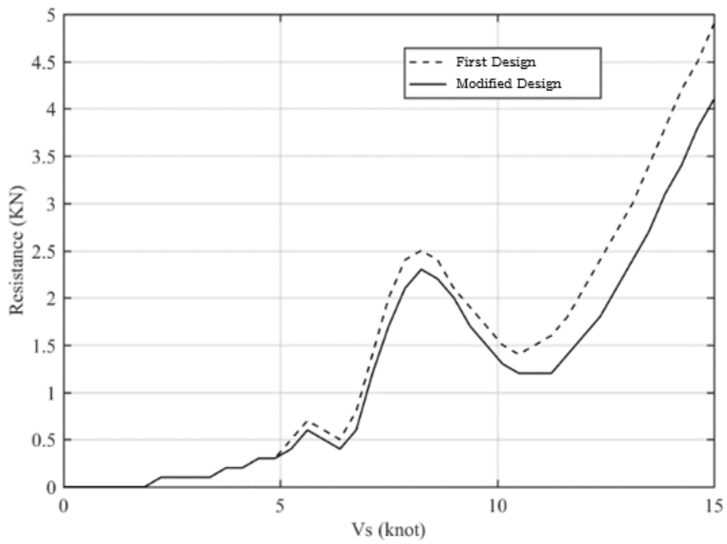


Figure 4. Comparison of resistance value curves between the initial boat model design and the modified boat model design.

This resistance value will affect the power required by the outrigger fishing boat to be able to propel the boat. Based on Figure 5, when the modified design is traveling at a speed of 15 knots, the power required is 52.979 HP, while in the first design, the power required is 63.352 HP. Meanwhile, for an average speed of 12 knots, the modified design requires a power of 16.082 HP, while the initial design requires 21.323 HP. The modified design is effective in reducing power so that fishers can save costs for the main propulsion engine and fuel consumption.

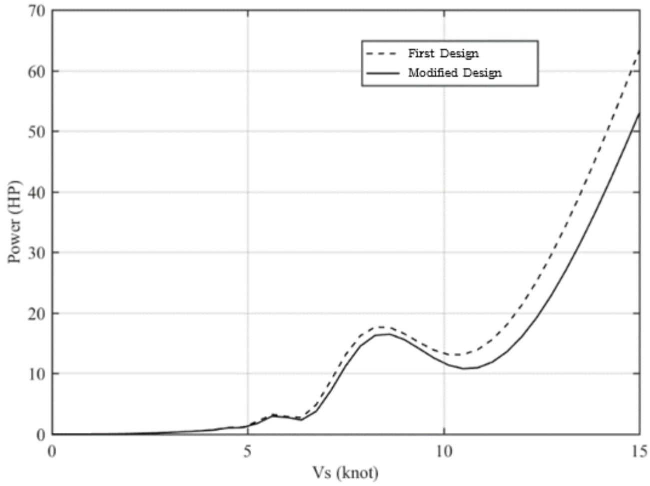


Figure 5. Comparison of power requirements between the initial boat model design and the modified boat model design.

Stability analysis

Stability analysis using ship stability data processing software. The calculation used is intact stability, or complete stability, where stability is not affected by leaks and others. The GZ value graph is obtained at each angle of roll as shown in Figure 6.

Figure 6 shows a comparison of the GZ values between the first/initial design and the modified design. It was found that the maximum GZ value of the initial design, which is 0.244 m, is smaller than the modified design, which is 0.275 m. The bow design also affects the maximum angle of the outrigger fishing boat in the initial design, the maximum boat's heeling angle is 41.8 deg, while the modified design is at a heeling angle of 40.9 deg. In this case, the healing period can also be calculated. When the boat experiences a heeling angle of 40 deg, the heeling period of the initial design is 2.147 seconds, while the modified design is 2.022 seconds. It can be concluded that the greater the GZ value, the smaller the healing period (Alamsyah *et al.* 2021).

Based on the intact stability criteria of IMO in Table 4, the initial design and modified design values meet the six IMO criteria, so that outrigger fishing boats can sail safely and stably.

The modified design has a smaller resistance value than the initial design, this can increase the efficiency of the power produced by the engine. In terms of stability, the modified design has a shorter rolling period. The modified boat design needs to be further researched on the boat's movement when facing waves in Jember waters.

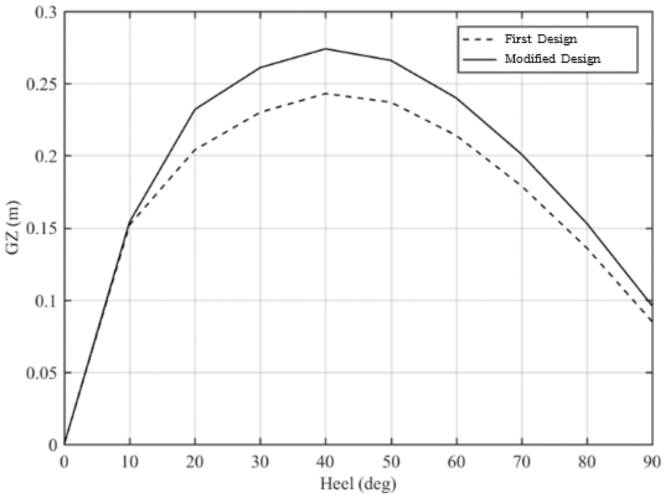


Figure 6. Comparison of the resistance stability value curves between the first boat model design and the modified boat model design.

Table 4. Comparison between IMO stability criteria of first/initial boat model design and modified boat model design.

Criteria	Values	Units	First Design	Modified Design
Area 0 to 30	3.1513	m.deg	4.8327	5.2862
Area 0 to 40	5.1566	m.deg	7.2126	7.9764
Area 30 to 40	1.7189	m.deg	2.38	2.6902
Max GZ at 30 or greater	0.2	M	0.244	0.275
Angle of maximum GZ	25	Deg	41.8	40.9
Initial GMt	0.15	M	0.182	0.179

CONCLUSION

In the study, it can be concluded that outrigger fishing boats with modified designs have better resistance values, which are reduced by 16.327% (4.1 KN). In terms of boat stability, both designs meet the IMO criteria. The modified boat model design has a larger GZ value of 12.7% and a smaller heeling angle of 2.1% than the initial boat model design. The modified boat model design has a healing period of 5.8% faster than the initial boat model design.

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