International Journal of Marine Engineering Innovation and Research, Vol. 9(1), March. 2024. 200-207
(pISSN: 2541-5972, eISSN: 2548-1479)

The Impact of B/D Ratio on the Technical Performance of Outrigger Fishing Vessels at PPN Palabuhanratu

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(Received: 21 March 2024 / Revised: 26 March 2024 /Accepted: 27 March 2024)

***Abstract*— Small and slender boats are usually installed with outrigger as additional construction to enhance its stabilities. The same practices are found in Palabuhanratu fishing port. The massive use of outrigger in most fishing ports, including Palabuhanratu, have led to berthing problems due to limited area of the port basin, hence boat or outrigger modification is required to overcome the problem. Adjusting the hull slenderness by defining the proper breadth and depth (B/D) ratio can be potential approach to eliminate the outrigger. Therefore, this research is designed to define ideal B/D ratio for boat without outrigger based on its stability, resistance and seakeeping in accordance with operational purpose. The study was conducted by simulating three different B values with constant D, each of which experiencing two different operational conditions, half and full loads. The quality of boat stability was evaluated in five parameters defined by IMO, whilst the resistance performance was evaluated using comparison analysis, and the seakeeping performance was evaluated using wave height and wave arrival angle. The result showed that according to its operational purposes, the boat with B/D ratio of 1,71 has the best performance to be operated without outrigger.**
Keywords— *Outrigger, resistance,slender boats, stability.*

I. INTRODUCTION

Outrigger construction is used by fishermen on their boats to increase the stability of the boat so that it does not easily capsize when operated [1]. This is done by Palabuhanratu fishermen who own vessels ≤ 5 GT with a slender hull shape. The negative impact of using boat construction is the non-optimal use of the harbor pool area. The addition of fishing boat moorings is caused by the construction of outrigger on the right and left sides of fishing boats. This condition results in non-optimal utilization of the port dock [2].

Several studies have been conducted in an effort to replace the outrigger construction, namely varying the length and width of the outrigger construction on a 3 GT fishing boat [3]. Variations in the size of the outrigger still affect the resistance of the ship and the area of the fishing port, although it is considered useful in increasing the stability of the ship. Another alternative to eliminate the use of outrigger construction is to use a gyroscope. Based on the results of research that has been conducted, gyroscope technology has the performance and influence in maintaining the stability of slender ships [4]. However, the disadvantage of using a gyroscope stabilizer is that the price is quite expensive considering that gyroscope ships are generally used by small fishermen.

Outrigger construction can be eliminated if the ratio of ship width to ship height (B/D) is well known. The comparison of the main dimensions of the ship consists of a length to height ratio (L/D), a length to width ratio (L/B), and a width to height ratio (B/D). Comparison of L / B values is used to analyze ship maneuverability and ship speed, comparison of L/D values is used to analyze ship longitudinal strength, and comparison of B/D values is used to analyze ship stability values. The comparison of the B/D ratio affects the stability of the ship [5]. The greater the B/D value of the ship, the better the quality of the ship. Therefore, it is necessary to conduct research to obtain the appropriate B/D value for ships ≤ 5 GT. This research will be conducted on ships anchored at PPN Palabuhanratu as a case example and carried out through numerical simulations.

II. METHOD

A. Data Types and Sources

The data collection method in this study was carried out through direct measurement or observation in the field and interviews with fishermen. The types of data collected are the main dimensions of the ship, data on the curvature of the ship's shape and the cargo of the fishing vessel. The source of the data collected comes from outrigger fishing vessels anchored at the port dock. Measurement of outrigger fishing vessels is carried out when there is no activity on board and the ship is anchored at the dock.

B. Sample Data Collection Technique

The data collection method in this study was through direct measurement methods on outrigger fishing vessels and interviews with Palabuhanratu fishermen. The sampling technique was carried out using purvosive sampling technique.

The purvosive sampling method is applied to obtain a sample of vessels that are the object of observation with a sample size of 10% of the total number of outrigger fishing vessels. The next stage, from 10% of the total

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number of outrigger fishing vessels sample units, then 1 unit of the dominant outrigger fishing vessels is selected for further measurements, namely in the form of measuring the curvature of the ship's body, and the size of the outrigger.

C. Data analysis

Data processing in the calculation of ship stability using the formula [6]. Stability analysis using criteria presented in Table 1 [7].

$$GZ = BR - BT \tag{1}$$

The BR and BT values can be found using the equation:

$$BR = \frac{v \: x \: hh_1}{\nabla} \tag{2}$$

$$BT = BG \sin\theta \tag{3}$$

where: GZ = Return arm, BR = Horizontal displacement of the center of buoyancy, v = Volume of the ship's parts, hh_1 = Displacement of the ship's parts. Processing resistance data using calculations [8]. Resistance analysis uses comparative descriptive analysis.

$$R_{total} = R_F(1 + k_1) + R_{APP} + R_W + R_B + R_{TR} + R_A \tag{4}$$

where R_F is the friction resistance; $1+k_1$ is the hull factor; R_{APP} is the additional prisoners; R_W is the wave resistance; R_B is the additional pressure from Bulbous; R_{TR} is the additional resistance from the transom tension; and R_A is the correlation of actual ship resistance.

Calculation of wave spectrum for seakeeping analysis using the JONSWAP method [9].

$$S(\omega) = \frac{\alpha g^2}{\omega^5} exp\left[-\beta \frac{\omega_p^4}{\omega^4}\right] \gamma^{\alpha} \tag{5}$$

where α is 0,07 if $\omega \le \omega_p$, and 0,09 if $\omega > \omega_p$; β is 5/4; α are constants related to wind speed and retrieval length; ω is the wave frequency; and ω_p is the peak frequency wave.

The analysis of a vessel seakeeping using the criteria in Table 2, the analysis of vessel stability data follows the IMO standard shown in Table 1. The comparison of the ship's height (D) and width (B) is treated to see how it affects the vessel's captain, seakepping, and ship stability [10]

The vessel width additions are presented in Table 3. The calculation of the vessels' captain value, sekeeping and stability using the two vessel loading conditions presented at Table 4. The main dimensions of the supporting vessel are shown at Table 5 and the image of the lines plan are shown in Figure 1 and the general arrangement are shown in Figur 2

TABLE 1.
IMO CRITERIA

Criteria	Value	Units
Area 0 to 30	>3,15	m.deg
Area 0 to 40	>5,16	m.deg
Area 30 to 40	>1,72	m.deg
Max GZ at 30 or greater	>0,2	m
Angle of maximum GZ	>25	deg

TABLE 2.
SEAKEEPING CRITERIA

Criteria	*Prescribe maximum value*
Roll motion	6 *deg*
Pitch motion	3 *deg*

TABLE 3.
SEAKEEPING CRITERIA

Variation	LOA	B	D	B/D
Redesigned fishing boat 1	10,79	1,673	1,13	1,48
Redesigned fishing boat 2	10,79	1,801	1,13	1,59
Redesigned fishing boat 3	10,79	1,928	1,13	1,71

TABLE 4.
CONDITION OF CARGO OF FISHING VESSELS

Load type	*Fishing ground* (M1)	*Fishing base* (M2)
Fuel	100%	50%
Ice	100%	100%
Supplies	100%	50%
Catch	0	100%
Fishing equipment	100%	100%
Machine	100%	100%

TABLE 5.
THE MAIN DIMENSION OF THE FISHING VESSEL.

Item	Unit	Value
Total length of the ship (LOA)	m	11,241
Ship width (B)	m	1,31
Ship height (D)	m	1,13
Outriger float	m	3,3
Outriger boom)	m	5,3
Outrigger arm).	m	0,24

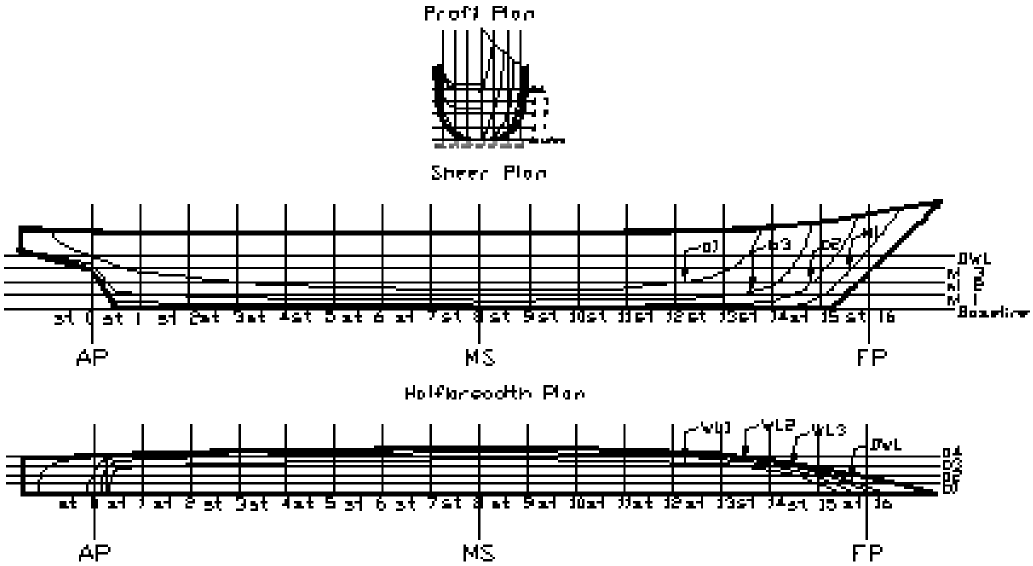

Figure 1. Lines Plan of a Outrigger Fishing Vessels.

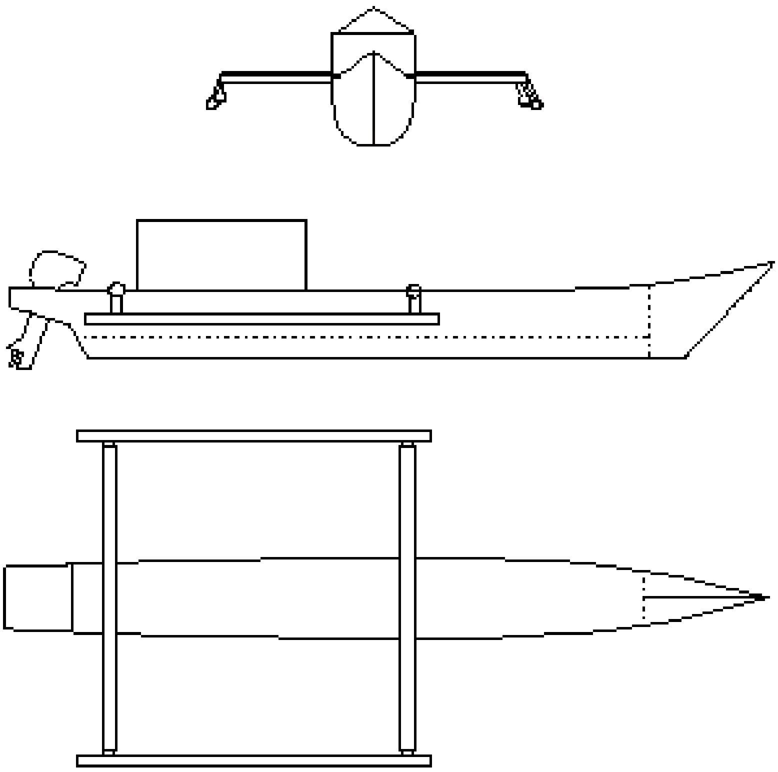

Figure 2. General Arrangement of a Outrigger Fishing Vessels.

III. RESULTS AND DISCUSSION

A. Effect of Increased Ship Width (B) on Ship Stability

Static stability is the stability of a ship when the ship is in an unstable place and after the ship curves due to external factors. The static stability parameter used as the stability value is the armforcement value (GZ) which is usually displayed in a graphical form that will then be compared with the IMO criteria value.

Redesign 3 has the best stability rating than any other redesign.

The good quality of ship stability can be seen from the value of GZmax and the angle of inclination of the ship at the value of GZmax (αGZmax), so that the greater the GZmax and inclination, the better the stability of the ship. The safe limit of the ship's inclination angle is when the inclination is at the point

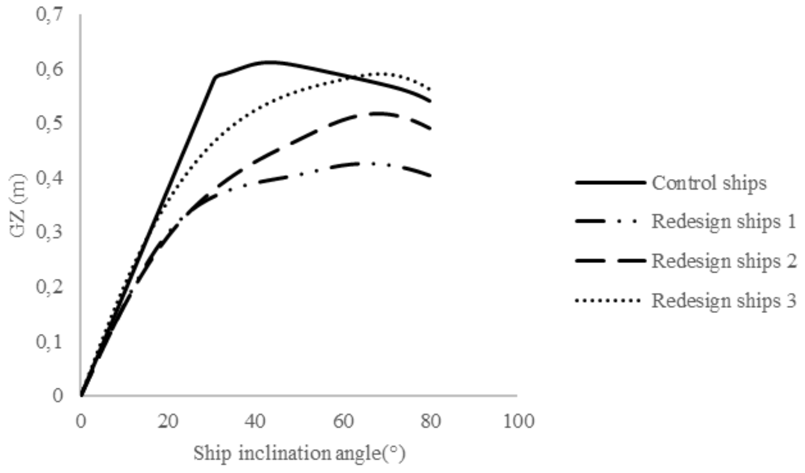

Figure 3. Ship stability curve with load condition 1 (M1).

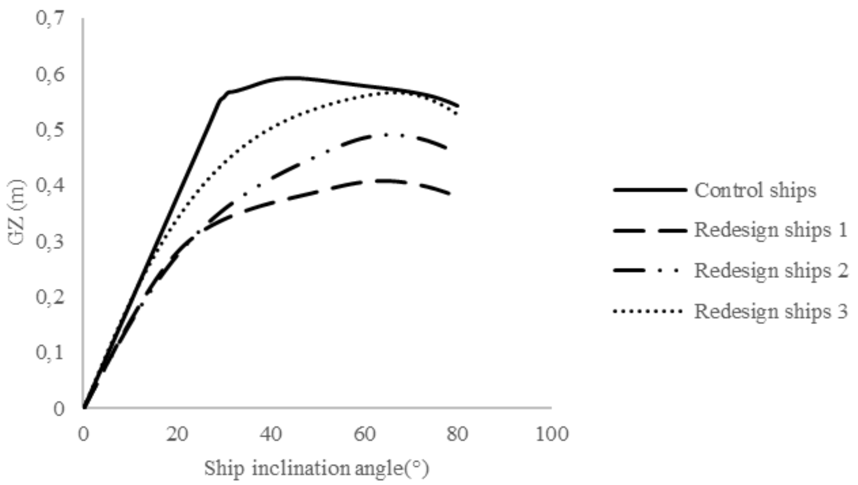

Figure 4. Ship stability curve with load condition 2 (M2).

The processing done to increase the B/D ratio value is by increasing the value of the vessel's width (B) and not changing the values of the ship's height (D) as in Table 3. Based on Figure 3 and 4, it can be seen that the three redesigned fishing vessels have good stability.

value GZmax. Apart from the value of the ship's tilt angle and GZmax, there is also the ship's rotational energy, where this energy functions to return the ship to an upright position after heeling occurs

TABLE 6.
VALUE OF STABILITY OF THE CONTROL VESSEL AND THE RESTORED VESSEL IN LOAD CONDITIONS 1

Criteria	Unit	IMO	Condition of Ship Load 1				Status
			Control fishing vessels	Redesign 1	Redesign 2	Redesign 3	
Area 0 to 30	m.deg	>3,15	6,92	4,152	6,55	8,03	Pass
Area 0 to 40	m.deg	>5,16	14,24	6,97	10,59	12,99	Pass
Area 30 to 40	m.deg	>1,72	7,32	2,82	4,04	4,96	Pass
Max GZ at 30 or greater	m	>0,2	0,76	0,43	0,52	0,59	Pass
Angle of maximum GZ	deg	>25	40,90	65,5	68,20	69,1	Pass

TABLE 7.
VALUE OF STABILITY OF THE CONTROL VESSEL AND THE RESTORED VESSEL IN LOAD CONDITIONS 2

Criteria	Unit	IMO	Condition of Ship Load 1				Status
			Control fishing vessels	Redesign 1	Redesign 2	Redesign 3	
Area 0 to 30	m.deg	>3,15	6,93	3,83	6,13	7,62	Pass
Area 0 to 40	m.deg	>5,16	13,62	6,50	9,98	12,36	Pass
Area 30 to 40	m.deg	>1,72	6,69	2,66	3,85	4,74	Pass
Max GZ at 30 or greater	m	>0,2	0,69	0,45	0,49	0,57	Pass
Angle of maximum GZ	deg	>25	45,50	60,0	65,5	66,4	Pass

The condition of a ship whose angle exceeds the angle at point GZmax means that the ship will have difficulty returning to an upright position and has the potential for the ship to capsize. Detailed values for each condition based on IMO criteria are presented in Table 6 and Table 7. Based on IMO criteria, the stability value of each redesigned ship has met the minimum limits given by IMO, meaning the ship is suitable for operation. The redesign of three boats is the ship with the best stability compared to the redesign of one and two fishing boats.

B. Effect of boat width increase (B) on ship resistance

The resistance value of a ship is influenced by the shape of the ship's hull underwater, and the shape of the ship's hull can influence the fluid flow characteristics which will result in the size of the resistance. The use of outrigger can cause inefficiencies in the form of additional investment costs, operational costs, and an increase in the total weight of the ship, resulting in greater resistance values, as well as increasing engine thrust and fuel requirements [11]. The total resistance of a ship is the sum of the ship's frictional resistance (Rf) and the residual resistance (Rr) that occurs on the ship [12]. The results of the calculation of the resistance of the control fishing vessel and the redesigned fishing vessel in each load condition are shown in Figure 5 and Figure 6.

The vessel with the smallest resistance value is the vessel resulting from one redesign in each condition, whereas for the vessel resulting from the redesign the smallest resistance value is redesigned ship 1 at each load condition. Redesign period 3 has the greatest resistance value. This shows that the comparison value between B/D can influence the value of the ship's resistance. The resistance value of the redesign 3 ship is still smaller compared to the resistance value of the control fishing vessel, namely the outrigger fishing vessels. This is because the wet surface area (WSA) of control fishing vessels is greater, this is due to the use of outrigger construction. The surface area of the wet area can influence the total resistance value of the ship [13].

C. Effect of boat width increase (B) on ship seakeeping

The seaworthiness of a ship (seaworthiness) can be influenced by the movement of the ship itself when operating in the waters. A ship can be declared seaworthy if the ship has good hydrodynamic qualities. Good hydrodynamics can prevent accidents at sea so that they do not cause material losses and casualties [14].

Some examples of ship movements due to sea waves are rolling movements and pitching movements. Rolling movement is the movement of the ship around the X axis. When rolling occurs, the right side of the ship moves to the left side and repeats this alternately. Pitching movement is the movement of the ship around the Y axis, when pitching occurs the ship will experience alternating changes in bow and stern trim. Rolling and pitching movements are the most dominant movements in ships sailing in waves [15].

The calculation of the ship's roll motion and pitch motion is carried out in two loading conditions: condition one (M1) towards fishing ground and condition two (M2) towards the fishing base and the wave direction of 90° from the side of the boat (beam seas) for the rolling movement of the vessel, and the direction of the 180° wave from the head seas for the pitching movement of a vessel. Based on Tables 8 and 9, roll motion and pitching motion values were obtained for the control vessel and the vessel was redesigned in each condition. In Table 8 is the pitch motion value of all ships at any load conditions, there are ships that have is the roll motion value of all vessels in any load condition, under these conditions the roll-motion value of each vessel is different. Redesigned ships 3 at the time of rolling conditions, ships are able to operate well at heights of less than 2.5 meters due to the RMS of Roll at a height of more than 2,5 meters above the standard, whereas redesigner ships 1 and 2 are only capable of operating well at wave heights less than 2 meters. Based on the results of the study, it can be concluded that changes in the size of the vessel's width can affect the seakeeping of the ship. The redesigned ship 3 is the ship that has the largest size of the ship's width and the ship

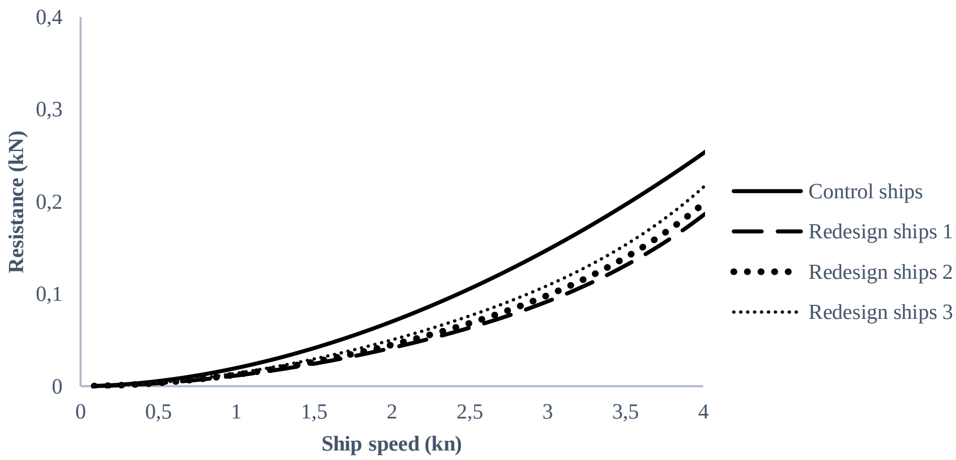

Figure 5. Curve Resistance Ship Load Condition 1.

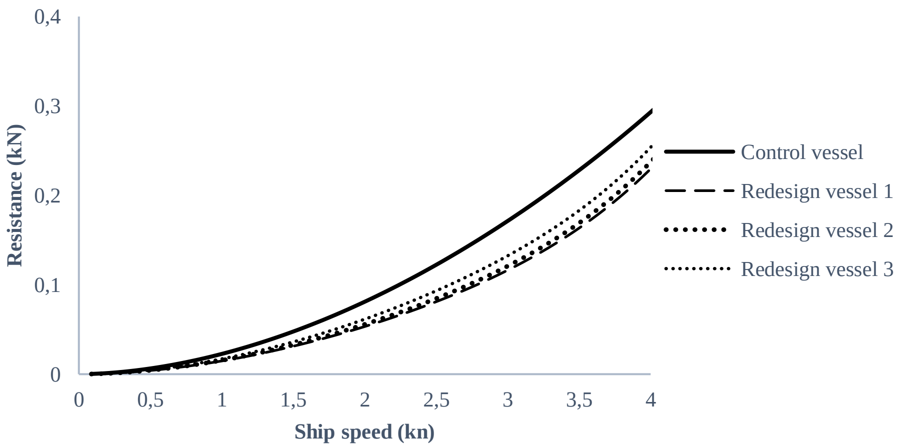

Figure 6. Curve Resistance Ship Load Condition 2.

differences in ability to face waves. In conditions of pitching movement with the direction of the 180º (head seas) waves, all ships are redesigned to be able to operate only well at wave heights below 2.5 meters because the RMS of Pitch at heights of more than 2.5 metres. Table 9 which has the best motion response during rolling and pitching among the other redesigning vessels. A good quality seakeeping ship can support fishing operations at sea and can reduce accidents at sea.

TABLE 8.
TABLE 8 SEAKEEPING SHIPS CONTROL AND REDESIGN ON HEAD SEAS

Ship loading condition	Wave height (m)	*Pitch motion* (deg)(RMS)				Reference value (deg)
		Control ships	Redesigned ship 1	Redesigned ship 2	Redesigned ship 3	
M1	0,5	0,67	0,5	0,43	0,38	3
	1	1,29	1,01	0,94	0,85	3
	1,5	1,89	1,51	1,44	1,35	3
	2	2,6	2,02	1,94	1,85	3
	2,5	3,25	2,6	2,53	2,43	3
	3	3,87	3,21	3,15	3,07	3
M2	0,5	0,74	0,52	0,45	0,4	3
	1	1,34	1,15	1,05	0,95	3
	1,5	1,99	1,75	1,65	1,55	3
	2	2,69	2,31	2,2	2,09	3
	2,5	3,4	2,9	2,76	2,68	3
	3	4,3	3,56	3,4	3,2	3

TABLE 9.
TABLE 9 SEAKEEPING SHIPS CONTROL AND REDESIGN ON BEAM SEAS

Ship loading condition	Wave height (m)	*Roll motion* (deg)(RMS)				Reference value (deg)
		Control ships	Redesigned ship 1	Redesigned ship	Redesigned ship 3	
M1	0,5	0,54	1,29	1,15	0,97	6
	1	1,82	2,58	2,45	2,25	6
	1,5	3,11	3,91	3,79	3,6	6
	2	4,35	5,16	5,01	4,85	6
	2,5	5,45	6,37	6,25	5,85	6
	3	6,4	7,41	7,32	7,12	6
M2	0,5	0,62	1,41	1,25	1,11	6
	1	1,87	2,67	2,54	2,37	6
	1,5	2,99	3,92	3,76	3,63	6
	2	4,18	5,25	5,11	4,89	6
	2,5	5,43	6,49	6,31	5,88	6
	3	6,45	7,59	7,46	7,31	6

Based on the results of the stability, resistance, and seakeeping studies of the redesigned vessel, it is recommended that the B/D of the control vessel be changed to the redesigned 3 vessel with a value of 1.71, although the resistance value of the 3 redesigns is greater than that of the 1 and 2 redeigns. The condition is due to the control ships used by fishermen in the PPN Palabuhanratu operate gillnet and handline catch devices whose method of operation is static gear. However, although the resistance values of re-designed vessels 3 are greater than those of redesigned 1 and 2, the resistance value is still smaller when compared to the resistances generated by the control vessel.

IV. CONCLUSION

Berdasarkan hasil pengolahan dan analisis data didapatkan kesimpulan sebagai berikut:

1) The best stability value of fishing vessels according to IMO criteria is a redesigned vessel 3 with a B/D ratio value of 1,71
2. The best resistance value of the vessel is the redesigned vessel 1 with a B/D ratio value of 1,48.
3. Good quality seakeeping of fishing vessels at rolling and pitching movements is a redesigned vessel 3. The redesigned vessel 3 has the ability to operate at wave heights below 2.5 meters.
4. The control vessels used by fishermen at Palabuhanratu operate gillnet and handline capture devices whose operating method is static gear. Therefore, the recommendation for a B/D value that can replace a rowing boat is a redesigned ship 3 with a B / D ratio of 1.71.

The suggestion of this research, the addition of the size of the vessel's width to the redesigned vessel, requires social and economic analysis. Boundary construction is a fisherman's habit that is difficult to change. Adding the size of a ship's width also requires calculating the amount of cost to find out the cost of changing the width of the ship.

ACKNOWLEDGEMENTS

The author expresses his gratitude to the Governor of Palabuhanratu Fishing Harbour who has allowed the research to be carried out as well as to the parents, families, lecturers and friends who have helped during the research process.

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