



The Prediction of Hydrodynamic Performance of Pinisi Ship

Muhammad Akbar Asis^{1*)}, A. Dian Eka Anggriani¹⁾, Fadhil Rahmat Ramadhan¹⁾

¹⁾Department of Naval Architecture, Universitas Hasanuddin, Gowa 92171, Indonesia

* Corresponding Author : akbar.a@eng.unhas.ac.id

Article Info	Abstract
<p>Keywords: Pinisi; Hydrodynamic; Hydrostatic; Resistance; Stability;</p> <p>Article history: Received: 22/10/2022 Last revised: 03/03/2023 Accepted: 04/03/2023 Available online: 04/03/2023 Published: 14/06/2023</p> <p>DOI: https://doi.org/10.14710/kapal.v20i2.49749</p>	<p>Pinisi ships are famous for their toughness across the ocean. The uniqueness of Pinisi is shipbuilding methods that are different without design engineering. The conditions present pinisi for tourist ships, problems have arisen recently, namely the number of Pinisi ship accidents. The main cause is bad water and technical factors. To improve safety and comfort, the aspect that needs to be studied hydrodynamic characteristics. The subject ship uses three samples of Pinisi ships produced by the Tanah Beru traditional shipyard. The hydrodynamic performance to be analyzed is hydrostatics, stability, resistance and ship motion, with several methods according to the respective standard to be analyzed. The shape of the pinisi hull is a rounded hull small coefficient block, and the largest change in hydrostatic parameters occurs at a draft of 0 meters to 0.25 meters. The resistance at a speed of 0-7 knots is relatively the same at every speed increase, but at speeds > 7 knots there is a change. RAO analysis for roll motion at a wave frequency of 1.5 – 1.75 rad/s for heading 90 degrees and for 45 degrees 3.65-3.80 rad/s. Heave motion occurs at a frequency of 4.25 rad/s – 4.4 rad/s with a wave direction of 0 degrees and a heading of 90 degrees smaller than the direction of the wave of 0 degrees. Evaluation of the stability arm, for variation KG critical, failed in 5/4H dan 1H in with B/T 3.43 to B/ T 5.00, while for the initial metacentric height parameter, all conditions still passed the criteria.</p> <p>Copyright © 2023 KAPAL : Jurnal Ilmu Pengetahuan dan Teknologi Kelautan. This is an open access article under the CC BY-SA license (https://creativecommons.org/licenses/by-sa/4.0/).</p>

1. Introduction

The Pinisi is a famous type of traditional 'Sulawesi schooner' sailing ship [1]. And the original ship of the Bugis and Makassar tribes of the South Sulawesi Province. The Pinisi generally has two masts and seven sails, consisting of three at the front end, two in the front, and three in the rear. The arrangement has a meaning in that the ancestors of the Indonesian nation were able to sail over the seven large oceans in the world [2]. The uniqueness of wooden boats is influenced by local wisdom and environmental characteristics, the shape of the hull and shipbuilding methods that are different from conventional shipbuilding. The knowledge of craftsmen/panrita lopi is passed down from generation to generation without any written records from the foreman/punggawa.

The problem faced by traditional ships today is the application of safety that has not been complied with according to shipping safety procedures. One example of a traditional ship accident occurred in Lake Toba due to the addition of superstructures and loads that were not in accordance with the procedure, thereby reducing the performance of the ship based on the results of research conducted by Abdy Kurniawan [3] and the Pinisi ship accident in Labuan Bajo, this was because the construction of traditional ships was not carried out properly. Strict and special regulations for traditional ships are still lacking and the current trend is that pinisi ships have transformed their function from ships transporting goods to cruise ships. Faced is the request of the ship owner to add a building on two or more decks to accommodate passengers because the number of passengers determines the profit if this is allowed to happen, it will be repeated like the ship on Lake Toba.

Pinisi safety could not be assessed in the initial design stage because the ships were built without preliminary design based solely on the builder's experience [4]. The shape of the hull and the size of the ship are based on the arrangement of boards or skins according to their rules, then installed frame on a wooden boat construction is made from a single frame, and it's continuously constructed from starboard to portside according to the body curvature, but they are attached and connected through wooden keel [5], This uniqueness is the difference between conventional and traditional development in Tanah Beru.

The difference between constructing a pinisi boat using a design and based on hereditary knowledge will also affect the ship body balance when lowered. The characteristics of the hull shape and size of the finished ship are usually very different

from the previous design, and these differences greatly affect hydrodynamic performance such as hydrostatics, stability, resistance and ship motion. The ship's performance must be known so that the ship's safety can be guaranteed in accordance with the conditions of the voyage. To ensure the ship's safety, panrita's knowledge must be aligned with the expertise of naval architecture.

The conditions of the past and present are very different in their designation used to function to transport goods and passengers. Now Pinisi ships in Labuan Bajo, Raja Ampat and other tourist destinations are widely used as tourist ships, but problems have arisen recently, namely the number of Pinisi ship accidents. Based on data from the National Transportation Safety Committee of Indonesia (KNKT) in the year of 2013, the number is larger than the other types of accidents. The main cause is bad water and technical factors. To improve safety and comfort, the aspect that needs to be studied hydrodynamic characteristics [6].

Previous research on the hydrodynamic aspects of pinisi has been carried out by F. Mahmuddin et al. By studying the motion analysis of pinisi ship hull with the new strip method, it was found that the total hydrodynamic force obtained by the resonance of the hood of the pinisi ship which was analyzed shifted to a lower frequency as the speed increased [7]. In this study, the code analysis strip theory developed by the Australian Maritime Engineering Cooperative Research (AMECRC) provided a windows platform that was easy to use compared to the new strip method created by F. Mahmuddin. A study of the roll motion of the pinisi ship with bilge keel was also investigated by A. Dainiswara. It was found that the application of the bilge keel on the pinisi made the roll motion performance of the pinisi ship better and could reduce the roll motion of 26% - 56% [8] Using the three-dimensional linear radiation and diffraction analysis method on ansys aqwa software, roll motion can also be analyzed on maxsurf motion, such as roll decay and faster response amplitude operators (RAOs). An experimental approach has been studied by Asis focusing on bilge keel positions [9]. Maxsurf motion has been validated against a variety of data from various independent sources including model tests, full-scale trials, and other numerical methods. The aspect of ship resistance and ship motions also done by A. Bahatmaka used computational fluid dynamic (CFD) by OpenFOAM was used to predict the resistance and motion analysis using strip theory [10].

2. Methods

The subject ship uses three samples of Pinisi ships produced by the Tanah Beru traditional shipyard in Bulukumba regency, South Sulawesi, as shown in Figure 1. From the figure below, the main dimensions of the ship and hull offset measurements are taken.



Figure 1. Measurement of the main dimensions and offset of the pinisi hull.

Shown in Table 1. A sampling of ships based on the class interval method from all data on length, breadth and height of ships in the field with different geometric characteristics in breadth-to-height. Technical data in the form of hull specification and body plan can be seen in Table 1 and Figure 2 (a) breadth-to-height 3.00, (b) breadth-to-height 3.77, (c) breadth-to-height 2.09, On the ratio of width-to-height that can be taken in the field because other sizes such as the draft of the ship have not been determined previously by the Panrita, the draft of the Pinisi ship can be known if the ship is already floating in the water This ship's load becomes a variable that greatly affects the hydrostatic characteristics.

Table 1. Pinisi Hull Specification

Dimension	Notation	Pinisi A	Pinisi B	Pinisi C
		Value (m)	Value (m)	Value (m)
Length Overall	LoA	26	22.8	25
Length Between Perpendicular	L _{BP}	25.3	21.7	24.5
Overall Breadth	W	5.71	4.8	5.73
Height	H	2.73	1.6	1.04
Depth	D	2.09	3.00	3.77

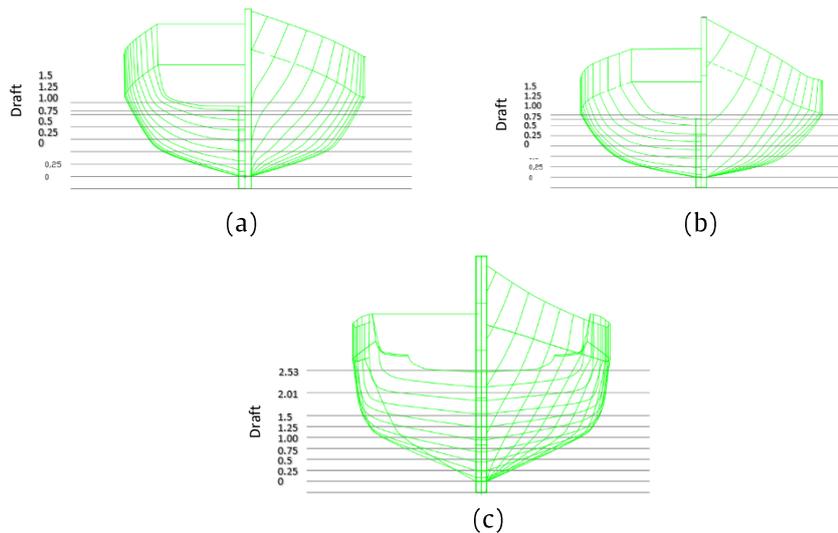


Figure 2. Body plan Pinisi (a) Pinisi A, (b) Pinisi B, (c) Pinisi C.

In this research hydrodynamic performance analyzing with numerical methods according to design standards. The aspect that will be predicting such is hydrostatic, ship resistance, ship stability and ship motion. The calculation of hydrostatic needed for known change hydrostatic hull ship Pinisi characteristic in underwater with approach empirical while stability aspect is calculated with Benyamin spance approach and the righting arm evolutions based general criterion in intact stability code, ship resistance approach Holtrop method and ship motion approach with strip theory.

Ship resistance for this use study Holtrop method; this algorithm is designed for predicting the resistance of tanker, general cargo ships, fishing vessels, tugs, container ships and frigates. Resistance calculation Fundamentals breakdown Total resistance = Wave + Viscous = Residuary + Friction. Total resistance is normally broken down into Froude number dependent component-wave resistance (residuary resistance) and a Reynolds number dependent component-viscous resistance (friction resistance). The total resistance as in (1) of a ship has been subdivided into:

$$R_{Total} = R_F(1+k) + R_{APP} + R_W + R_B + R_{TR} + R_A \quad (1)$$

where

- R_F : Frictional resistance according to ITTC 1957 friction formula (kN).
- $(1+k)$: Form factor describing the viscous resistance of the hull form in relation to R_F .
- R_{APP} : Resistance of Appendage (kN)
- R_B : Additional pressure resistance of bulbous bow near the water surface (kN).
- R_W : wave-making and wave breaking resistance (kN).
- R_{TR} : Additional pressure resistance of immersed transom stren (kN).
- R_A : Model- ship correlation allowance resistance (kN).

Ship stability for the analysis is of large angle stability, displacement and center of gravity are specified in the load case. A range of heel angles are specified and stability calculates the righting lever and other hydrostatic data at each of these heel angle balancing the load case displacement against the hull buoyancy and if the model is free to-trim, the center of gravity against the center of buoyancy such that the trimming moment is zero. The righting lever, GZ as in (2) may be calculated from the KN cross curves of stability (at the desired displacement) for any specified KG using the following equation:

$$GZ = KN - KG \sin(\phi) \quad (2)$$

where GZ is the righting lever measured transversely between the center of buoyancy and the center of gravity in meter, and KG is the distance from the baseline to the vessel's effective vertical centre of gravity in meter, An illustration of the displacement of the stability points, namely the metacentre (M), the centre of gravity (G), the centre of buoyancy (B) and Keel (K) when the ship is tilted and the arm of the return moment that occurs can be seen in Figure 3.

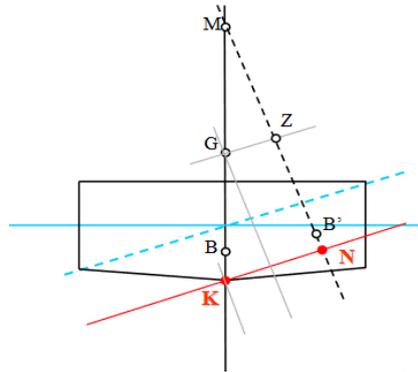


Figure 3. Point of stability of the ship [11].

Ship motions is the seakeeping analysis to calculate the response of the vessel to user-defined sea conditions. Two methods to calculate the vessels response: a linear strip theory method and a panel method. The linear strip theory method is based on the work of Salvesen et al, it is used to calculate the coupled heave and pitch response of the vessel. The roll response is calculated using linear roll damping theory. In addition to graphical and tabular output of numerical results data

Heave and pitch motion of a vessel is a seaway. The ship motions of heave, pitch, and roll are oscillatory in nature, this is due to the restoring force created by changes in buoyancy involved in these motions. The motions of a ship in response to waves, may be considered as forced damped-spring-mass system. Ship motion currently only deals with the coupled motions of pitch and heave. The relevant equations of motions are for heave in (3) as follows.

$$(M + A_{33})\ddot{\eta}_3 + B_{33}\dot{\eta}_3 + C_{33}\eta_3 + A_{35}\ddot{\eta}_5 + B_{35}\dot{\eta}_5 + C_{35}\eta_5 = F_3e^{i\omega t} \tag{3}$$

and for the pitch calculation is shown in (4) as follows.

$$(I_5 + A_{55})\ddot{\eta}_5 + B_{55}\dot{\eta}_5 + C_{55}\eta_5 + A_{53}\ddot{\eta}_3 + B_{53}\dot{\eta}_3 + C_{53}\eta_3 = F_5e^{i\omega t} \tag{4}$$

Where the variables are defined as follows: M is the mass of the vessel, I₅ is the moment of inertia for pitch, A₃₃, A₃₅ is the added mass coefficient for heave due to heave and due to pitch, A₅₅ is added mass coefficient for pitch due to pitch, A₅₃ is the added mass coefficient for pitch due to pitch and due to heave, B₃₃, B₃₅ is the damping coefficient for heave due to heave and due to pitch, B₅₅ and B₅₃ damping coefficient pitch due to pitch and due to heave, C₃₃, C₃₅ is the hydrostatic restoring coefficient for heave due to heave and due to pitch, C₅₅, C₅₃ is the hydrostatic restoring coefficient for pitch due to pitch and due to heave, F₃ is the heave exciting force, F₅ is the pitch exciting moment, η₃ is the instantaneous heave displacement, $\dot{\eta}_3$ is the instantaneous heave velocity, $\ddot{\eta}_3$ is the instantaneous heave acceleration, η₅ is the instantaneous pitch displacement, $\dot{\eta}_5$ is the instantaneous pitch velocity, $\ddot{\eta}_5$ is the instantaneous pitch acceleration.

The vessel' s roll motions may be represented by a second order differential equation in (5), such as that describing a forced spring, mass and damper system.

$$(I_4 + A_{44})\ddot{\eta}_4 + B_{44}\dot{\eta}_4 + C_{44}\eta_4 = F_4e^{i\omega t} \tag{5}$$

Where the variables are defined I₄ moment of inertia for roll, A₄₄ is the added inertia coefficient for roll, B₄₄ is the damping coefficient for roll, C₄₄ hydrostatic restoring coefficient for roll, F₄₄ is the roll exciting moment at the encounter frequency, η₄ is the instantaneous roll displacement, $\dot{\eta}_4$ is the instantaneous roll velocity, $\ddot{\eta}_4$ is the instantaneous roll acceleration.

3. Results and Discussion

3.1. Hydrostatic parameter analysis

Hydrostatic parameters are important to study because they closely relate to hydrodynamic performance during operation. One of the hydrostatic parameters such as displacement, wetted area, LCB, LCF, KM, KB, TPc, MTc and the coefficient of the ship. The ship's performance in question is ship resistance, stability and motion.

Hydrostatic parameters related to ship resistance, stability and motion, namely displacement and ship draft, changes in ship draft affect its hydrodynamic characteristics, such as a floating-point shift (LCB and KB). Highly dependent on hydrostatic parameters such as the volume of the submerged hull, which will greatly depend on variations in the draft height of the ship. At each height variation, the characteristics of the hull in the water will change based on the actual draft condition of the ship; geometric characteristics (main dimension, block coefficients and prismatic coefficients can be seen in Figure 4

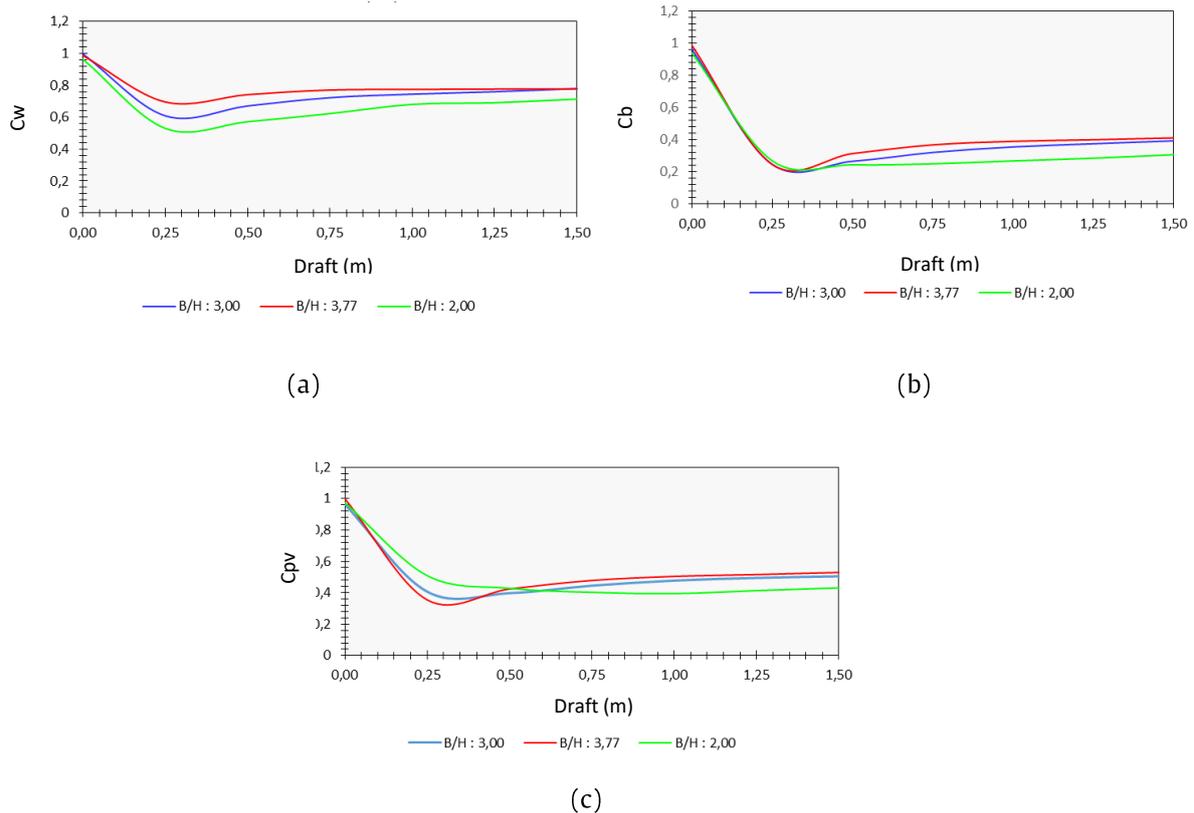


Figure 4. Pinisi main coefficient (a) Waterline coefficient (b) Block coefficient (c) Prismatic coefficient

Figure 4 (a) is the curve of each draft's change in the waterline coefficient. The waterline coefficient for the Pinisi ship is between 0.50 – 0.80. It can be seen that the waterline coefficient decreases significantly at the 0 meter to 0.25 meter draft, of all samples of the Pinisi C breath-to-height 2.09 vessel has an extreme change. This occurs because the area of the waterline is smaller than the rectangular area of the length and width of the waterline, the area of the small waterline will have an impact on the location and shift of the floating point of the ship which affects the ship's stability, the waterline coefficient will increase with an increasing draft due to changes in the width of the ship, so the waterline area will also be large, based on the initial evaluation of the three samples, the Pinisi C breath-to-height 2.09 vessel will have a small stability arm area, the ship's motion response will be small, and ship resistance will also be small. Figure 4 (b) is the curve of the block coefficient change for each draft, the decrease in the block coefficient is also significant at 0 meter to 0.25 meter draft, at 0 meter draft the block coefficient is 1 because this happens because of the keel beam installed on the pinisi ship, The decreasing trend of the coefficient is almost the same in all samples of the ship, the block coefficient on the draft of the pinisi ship is 0.75 meters to 1.50 meters which is between 0.20 – 0.40. Figure 4 (c) is a vertical prismatic coefficient change curve; the prismatic coefficient of the pinisi ship is between 0.40 – 0.60, the breath-to-height 3.00 and 3.77 have the same change, namely breath-to-height 2.09, the relative decrease is not significant changes with increase in the ship's draft.

3.2. Resistance analysis

The calculation of the resistance is carried out according to the conditions that the even keel conditions have determined. The method used to get the ship's resistance is the Holtrop method according to the characteristics of the hull shape of the pinisi ship, the overall efficiency used is 65% this is because at generally, Pinisi ships have an internal propulsion system with a shaft length of approximately 3–5 meters and the average speed of the ship that can be achieved by pinisi ships is 7–15 knots and will be adjusted to the conditions of the shipping lane according to the experience of the Panrita. Therefore it needs to be analyzed based on standard on ship design, the results of the analysis can be seen in Figure 5.

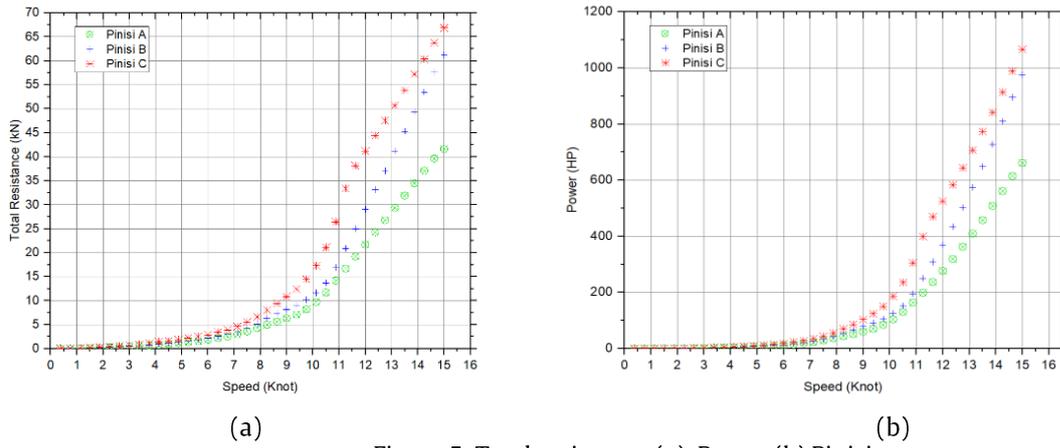


Figure 5. Total resistance (a), Power (b) Pinisi.

In Figure 5 the ship's resistance for the three samples was used at a speed of 0 - 7 knots. The addition of resistance is relatively the same for every increase in speed, but at speeds > 7 knots, the ship's resistance has a large change between Pinisi A, B and C whereas Pinisi C has a large change due to the characteristics of different hull shape and main dimension. The power required for a speed of 0 – 7 knots, which is below 100 HP, to reach a maximum speed of 15 knots for the three samples of Pinisi A is smaller than Pinisi B and C with 661, 974 and 1065 HP, respectively, based on the committee's statement that usually they install an engine with a power of 150 HP - 600 HP and is very dependent on the length of the speed boat. The contract for the construction of a Pinisi ship between the ship's owner and the Panrita generally does not exist for the ship's speed, but the Panrita Lopi usually determines the installed engine power.

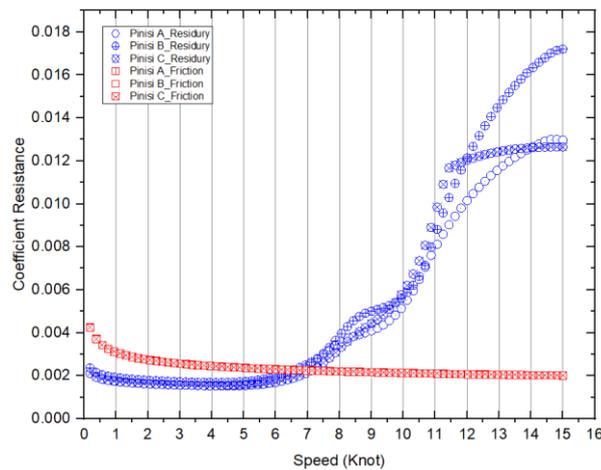


Figure 6. Ship resistance coefficient

Changes in ship resistance are strongly influenced by the coefficient of ship resistance, residual and frictional resistance. Based on Figure 6, the coefficient of residual resistance with changes in the speed at 0 - 7 knots tend to be constant, and the same for the three sample ships and at speeds > 7 knots, the coefficient changes are large with significant changes big. Meanwhile, the coefficient of friction is greater than the coefficient of residual at speeds of 0-7 knots and then smaller than the coefficient of residual resistance at speeds above 7 knots.

3.3. Motion analysis

Analysis of the ship's motion was carried out according to the conditions of the cruise. In this study, the waters data were taken, namely the waters of the Flores sea, because, in general, the Pinisi operates for marine tourism ships in Labuan Bajo, West Manggarai. Wave distribution data for the Flores Sea is presented in Figure 7.

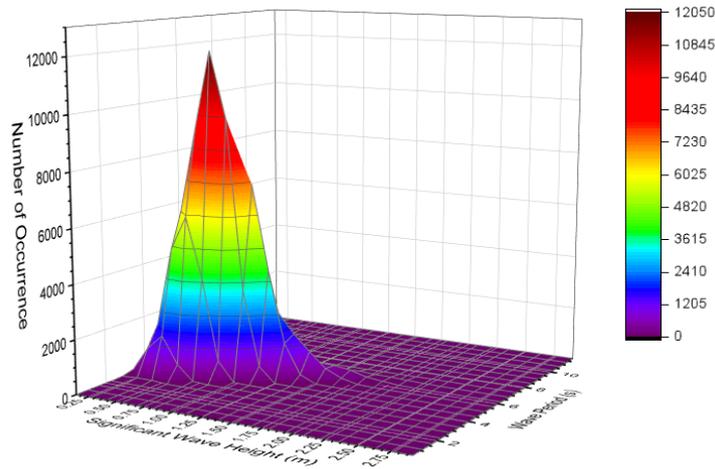


Figure 7. Spread of waves in the Flores Sea [3].

In Figure 7 is the data of the Flores Sea waves for 10 years that have been recorded. The number of occurrences for each combination of significant wave height and wave period. This operating area's maximum significant wave height is 1-1.5 meters and the maximum average wave period is 4 - 6 seconds. The method used in analyzing ship motion uses strip theory. This theory predicts a ship's hydrodynamic characteristics using potential fluid flow theory [6]. In theory, the ship's strip is divided into two-dimensional strips. From here, a hydrodynamic coefficient is calculated to obtain the ship's response to various conditions. Get the response with the help of maxsuft motion results can be seen in Figure 8.

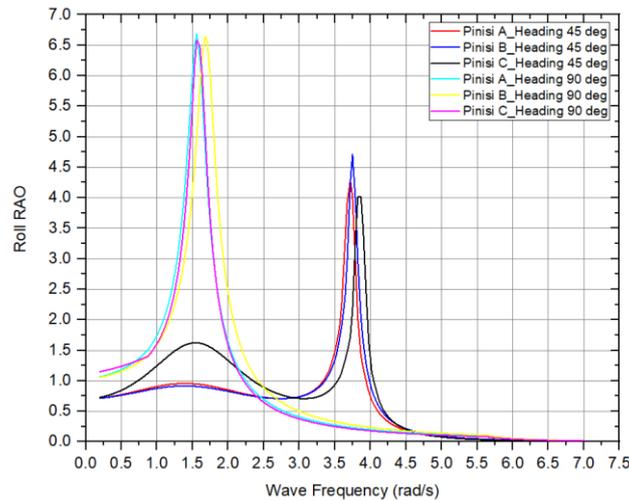


Figure 8. Respon Amplitude Operator Roll

Based on the results of the RAO analysis for roll motion only occurs at a heading angle of 45 and 90 degrees, the amplitude response of the operator at a wave frequency of 1.5 – 1.75 rad/s for heading 90 degrees. And for 45 degrees 3.65-3.8 rad/s, where the position of the ship's response will be greater if the ship's frequency is the same as the wave frequency, this condition must be avoided, not only needs to be avoided, but it also needs to be analyzed more deeply in the condition of second-generation intact stability, specifically for wooden ships in Indonesia, according to the results of D. Paroka's research [12].

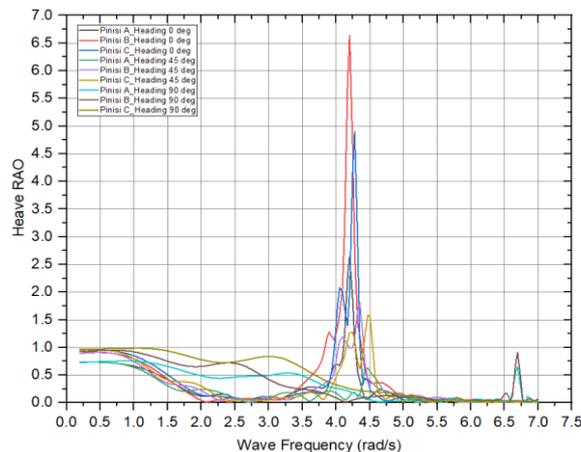


Figure 9. Respon Amplitude Operator Heave

The largest RAO heave motion occurs at a frequency of 4.25 rad/s – 4.4 rad/s with a wave direction of 0 degrees. The heave response at an angle of 90 degrees is smaller than the direction of the wave of 0 degrees, and the heaving response has very little effect on the direction of the incoming wave of 45 degrees.

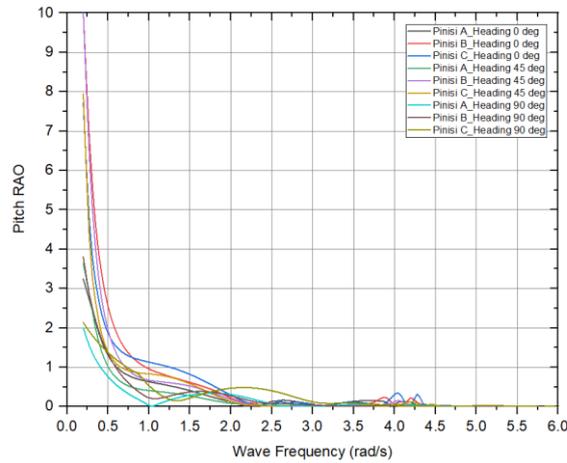


Figure 10. Respon Amplitude operator Pitch

As for the pitching motion, the ship's response will be large at low frequencies because the wavelength is close to the ship's length so the pitching response will be greater than the frequency of 1.0 rad/s, with the highest response at an angle of 0 degrees.

3.4. Stability analysis

The stability analysis in question is the analysis of geometric characteristics based on the ratio of the main size of the wooden ship to the characteristics of the stability arm. Determination of the main size of traditional wooden ships in Bulukumba is still based on the experience of the Panrita, and until now, no literature can explain the determination of the size of traditional ships in the area, one of the main dimensions that are difficult to determine is the ship's draft. The difference in the type of wood and the characteristics of the building provide a full charge. Loads can be seen after the ship has been floated. This is different from the construction of conventional ships.

Determining the draft of the ship is important because it is the draft that will determine the characteristics of the shape of the ship's hull in the water, so it is necessary to analyze several draft heights and the main size ratio parameters. The load is determined based on the ratio of the width to the draft of the ship, the ratio of the width to the draft width of the deck is constant, and the draft varies according to the draft height of the wooden ship. After the ship's draft is known, the height of the hull will also be known so that in several variations of the ship's draft.

Table 2. Variations in the ratio of the ship's width-to-draft and freeboard-to-width

Pinisi A (B/H 3.00)				Pinisi B (B/H 3.77)				Pinisi C (B/H 2.09)			
Draft	Fb	B/T	Fb/B	Draft	Fb	B/T	Fb/B	Draft	Fb	B/T	Fb/B
0.80	0.80	6	0.17	0.96	0.57	6	0.1	0.95	1.78	6	0.31
0.87	0.73	5.5	0.15	1.04	0.48	5.5	0.08	1.04	1.69	5.5	0.3
0.96	0.64	5	0.13	1.15	0.37	5	0.07	1.14	1.59	5	0.28
1.07	0.53	4.5	0.11	1.27	0.25	4.5	0.04	1.27	1.46	4.5	0.26
1.20	0.40	4	0.08	1.32*	0.20	4.34	0.03	1.43	1.30	4	0.23
1.37	0.23	3.5	0.05					1.63	1.10	3.5	0.19
1.40	0.20*	3.43	0.04					1.90	0.83	3	0.14
								2.28	0.45	2.5	0.08
								2.53*	0.20	2.26	0.04

Note: the sign (*) is loaded with an embossed hull of 0.2 m. This height is based on researchers' observations of several operating conditions of wooden ships.

The stability arm curve for each width to draft ratio for each center of gravity variation and the variation of the hull ratio and ship width for each Centre of gravity variation is also calculated using the same method, the variation of the Centre of gravity used in the range of 1/2H to 5/4H according to point the weight of the Pinisi ship, Where, H is the Depth ship.

Table 3. Variations center of gravity

Centre of gravity	Pinisi A (B/H 3.00)	Pinisi B (B/H 3.77)	Pinisi C (B/H 2.09)
	KG (m)	KG (m)	KG (m)
1/2 H	0.80	0.76	1.37
2/3 H	1.07	1.01	1.82

H	1.60	1.52	2.73
5/4 H	2.00	1.90	3.41

After knowing B/T and Fb/B, and KG, it is necessary to observe changes in the stability arm that occur, such as the area under the curve of the stability arm, the angle of the maximum stability arm and the slope angle of the stability arm equal to zero according to the general criteria in the Intact stability code 2008 [13]. Changes in the stability arm due to differences in B/T can be seen in Figure 11. The reduction in the area of the curve under the large stability arm occurs in small B/T. This phenomenon occurs due to changes in ship draft and hull height. The smaller the draft of the ship, the larger the hull of the ship, so the angle of inclination until the edge of the deck sinks into the water will also be greater. The width of the ship's waterline will increase with increasing the angle of inclination until the angle of inclination where the edge of the deck is immersed in the water. As a result of this phenomenon, the metacentric radius (MB) is getting bigger, so the stability arm is also getting bigger with the increasing B/T ratio. At small B/T ratios or relatively large ship drafts, the angle at which maximum arm stability occurs is greatly affected by hull rise.

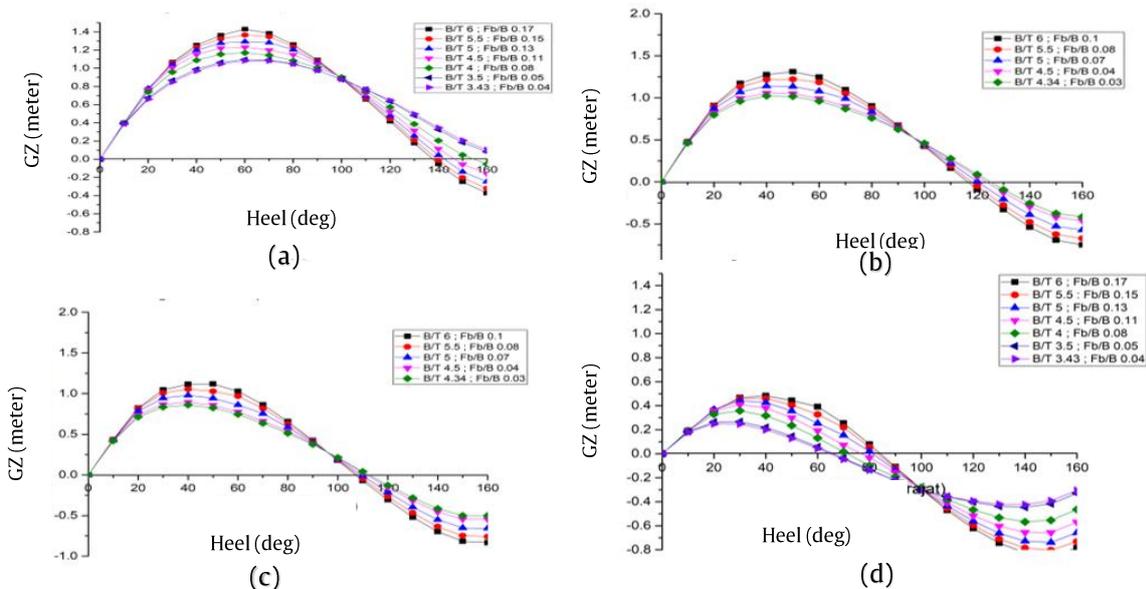


Figure 11. Stability arm characteristics KG 1/4H(a), KG 1/2H (b), KG 2/3H (c) and KG 1H (d)

When the ship's draft is reduced, or the B/T ratio is large, the angle of inclination where the bottom of the ship appears above the water surface also affects the angle of inclination at which the maximum stability arm occurs [14]. From the angle where the bottom of the ship appears above the water surface, the decrease in the moment of inertia of the waterline causes the radius of the centring to decrease so that the stability arm is also smaller. Therefore, the change in inclination angle where the maximum stability arm occurs is smaller at a large ratio of width to height of the ship. Based on these data, it can be concluded that the effect of B/T decreases with increasing the ratio.

The angle of inclination with zero stability arm (angle of vanishing stability) increases with increasing the B/T of the ship. Changes in the angle of vanishing stability due to changes in the ship's B/T are also caused by changes in the characteristics of the waterline when the angle of inclination is greater than the angle of inclination where the ship's deck is submerged in the water and the angle of inclination where the bottom of the ship appears above the water surface. The results of the analysis of changes in the angle of the slope with the zero stability arm (angle of vanishing stability).

The increase in the magnitude of the KG centre of gravity reduces the return moment can be seen in Figure 9. The results show that with the increase in the centre of gravity, the return moment, in this case, the GZ value decreases in Figure 9a the stability arm is greater than the 9a-d stability arm. The return arm is highly dependent on the position of the metacentre of gravity. The increase in the magnitude of the KG centre of gravity reduces the return moment. The results show that with the increase in the centre of gravity, the return moment, in this case, the GZ value decreases. The return arm is highly dependent on the position of the metacentre of gravity.

Evaluation of stability arm characteristics against general criteria of International Stability rules intact stability code edition 2008 resolution MSC.267 (85). The rules consist of part A mandatory criteria and part B recommendations for certain types of ships and additional instructions (IMO 2008). General criteria include the characteristics of the stability arm, such as the area under a certain slope, the angle of the maximum stability arm and the initial metacentric height, the evaluation of the stability arm based on the wooden hull can be seen in Table 4– 6 based on the variable B/T ratio.

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