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Stability Study of Water Ambulance in East Kalimantan Inland Waterways

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ABSTRACT

This paper discusses the prediction of ship stability before sailing. This study aims to determine the stability value of the water ambulance in specific operating scenarios. The method used in this study is the B-splines mathematical equation and the optimization method using Maxurf software, which varies ship loading by 100% DWT, 50% DWT, and 25% DWT. The results of the study showed that 100% DWT had a maximum GZ value of 40 degrees and an initial GM of 1.240 meters; 50% DWT conditions had a maximum GZ value of 41.8 degrees and an initial GM of 0.711 meters; and 25% DWT conditions had a maximum GZ value of 43.2 degrees and an initial GM of 0.653 meters. The initial GM value increases with an increasing DWT value. Meanwhile, the maximum GZ value decreased as the DWT value increased. All operational scenarios are determined to meet HSC 2000 Annex 8 monohull criteria.

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INTRODUCTION

Sea transportation has a much greater risk of accidents than other transportation means. Dynamic movement is implicated in comfort. Boats are preferred in shallow water, short sailing routes, and calm water conditions. Hydroplane-type ships are widely used as fast boats and in the health sector as water ambulances. The development of the need for ships with high speeds has implications for technological breakthroughs in ship hull design that can accommodate this (Febrian et al., 2018).

Awwalin et al. (2022) conducted a conceptual study on planning sea transportation facilities as a water bus to increase the ease of access to the economic activities of the archipelago community (Awwalin et al., 2022). Water ambulances transport critical patients who live on the river's banks far from the hospital (Alifantio, 2020). A study approach has been carried out regarding the design and construction of water ambulances operated in the waters of the Mahakam Hulu River (Alamsyah et al., 2019).

It was found that the water ambulance made the patient uncomfortable while being evacuated. An in-depth study of rolling motion behaviour is required when operating in river waters. Several similar studies have been conducted regarding the ship's stability, which is affected by the primary size of the ship (Alamsyah et al., 2020). The size of the angle of inclination of the ship when receiving force is influenced by the width and height of the draft (Paroka, 2018). The ship's stability is affected by the arrangement of the location of goods in the ship's cabin (Alamsyah et al., 2021). Stability is the ability of a ship to straighten up when the ship is tugged because the ship gets external influences, such as wind, waves, and so on. In general, things that affect the balance of the ship can be grouped into two major groups, namely: Internal actors, namely the layout of the goods or cargo, the size of the ship, leakage due to grounding or collision; and External factors, namely wind, waves, currents, and storms.

According to many research findings, ships with low drafts or a wide ratio with a large draft do not meet one of the International Maritime Organization's (IMO) stability criteria, particularly when heeling, where the maximum stability arm occurs (IMO, 2008). This is also influenced by the relatively small freeboard or the ratio between the freeboard and the small width of the ship. The comparison of the maximum ship width and draft that meets the ship stability criteria is influenced by the value of the block coefficient (Cb) on the ship. The lower the Cb value, the higher the minimum width and draft ratio required to achieve IMO stability criteria (Fadillah et al., 2019).

Research on the balance (stability) of ships is very much carried out, including the influence of the KG value (the vertical distance of the centre of gravity from the bottom of the ship) on the size of the ship's cargo, where the KG value has an impact on the stability of the ship. Following the theory, the crucial points in the analysis of ship stability are the centre of gravity (G), floating point (B), and metacentre (M). If the ship is in a heeling condition and cannot return to its original position but continues to tilt (negative GZ), it is in an unstable equilibrium condition. To determine the value of ship stability, static and dynamic stability analyses of the ship are carried out. Static stability is indicated by the value of the GZ fixing arm, while dynamic stability is the area of and below the static stability curve. Based on the results of studies on ship accidents while sailing, it was found that most of them involved capsizing the ship. This condition is due to the ship experiencing overload and the laying of excessive goods on the ship's main deck. Cargo placed below the ship's deck can improve the ship's stability; ideally, the cargo is placed below the ship's deck, where overload conditions on board should be avoided.

The ship's capsized condition is a fatal event caused by the ship's instability, which does not meet when operating (Krata, 2008). When sailing, the tendency of the ship's roll angle at heeling 30^{o}, which results in a heeling period of 4.5 to 6 seconds, is extremely dangerous.

Innovations have been implemented regarding improving ship stability by paying more attention to ship roll events. Dianiswara et al. (2020) examined the effect of the bilge keel on the roll motion of the ship, which proved that the application of the bilge keel design and technology showed satisfactory results on several ships and that the performance of the ship's roll motion was getting better. Alamsyah et al. (2019) examined the effect of adding a longitudinal bulkhead to the maximum GZ value and initial GM, as stated in the stability arm curve. Alamsyah & Setiawan (2021) studied commercial ships' transverse and longitudinal stability using the Benjamin Spence method. Alamsyah et al. (2020) applied primary data and optimization methods using Maxsurf software to study the transverse stability of catamaran hull ships. The results were evaluated using IMO regulation criteria A. 749 part 3 and High-Speed Craft 2000 Annex 7 Multihull. Paroka et al. (2022) demonstrated that the second-generation stability criteria could be used to assess the stability of traditional Indonesian wooden vessels.

With that, Azis et al. (2020) conducted a study on applying weather criteria according to IMO standards on traditional wooden ships in Indonesia. Paroka et al. (2019) investigated the operating limits of traditional wooden vessels from the viewpoint of second-generation integral stability standards. Paroka (2020) studied the yaw motion stability of Ro-Ro ferries on stormy weather voyages using numerical analysis. Woo & Im (2022) evaluate the safety of passenger ships using the index for the Intact Stability Appraisal Module (IPSAM). Im & Choe (2021) evaluated ship stability using a particular marine ship instant stability assessment model index. Shin, et al. (2021) discovered that in order for the ship design to meet the second-generation IMO intact stability criteria, a ship mass of 10% of the design mass must be added. This research will focus on analyzing the stability of water ambulances that are operated on the Mahakam River.

METHOD

Table 1. Main dimension of water ambulance
(Alamsyah et al., 2019)

Particular		
L_{WL}	9.170	*m*
T	0.438	*m*
H	1.230	*m*
B	2.660	*m*
∇	3.350	m^3
C_B	0.300	-
C_M	0.599	-
C_P	0.5009	-
C_{WP}	0.4715	-
KG	4.389	*m*
LCG	-2.652	*from midship*
LCB	4.075	*from AP*

The particular dimension of the water ambulance ship from previous research can be seen in Table 1. The drawings for the water ambulance ship design in CAD obtained from previous research can be seen in Figure 1. Then, for the water ambulance boat design drawings on Maxsurf software, see Figure 2. The next stage is the manufacture of tanks for the ship. This helps manage the operational load when the water ambulance is operating. The design of the tanks is shown in Figure 3.

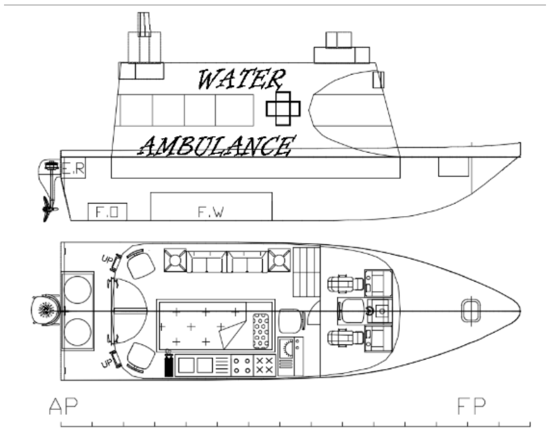

Figure 1. General arrangement of water ambulance

Figure 2. 3D of water ambulance

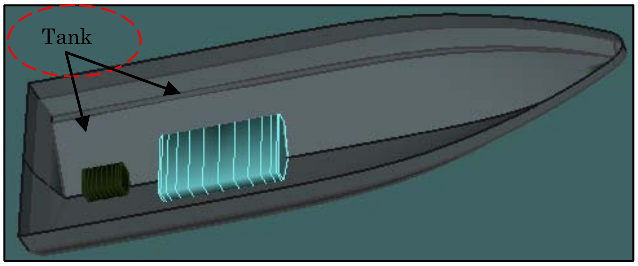

Figure 3. Tank of water ambulance

Figure 3 shows the location of the tank in the water ambulance. It consists of a fuel oil tank (green) and a freshwater tank (blue). After the tanks have been made, the next step is to make the load case. This study had three load case conditions, including load cases with 100%, 50%, and 25% DWT loads. The constant value is the ship's LWT weight. The dynamic value is the weight percentage of the fluid in the tanks and the payload percentage. This study's load case 1 consisted of 100% DWT, totalling seven people, with all tanks at 100%. Load case 2 is 50% DWT, with four people and all tanks at 50%. Load case 3 consists of 25% DWT, totalling two people with 25% tank conditions. The following is a recapitulation of load cases 1, 2, and 3 shown in Table 2.

Table 2. Loadcase operational of water ambulance

Initial	100% DWT	50% DWT	25% DWT
Fuel Oil Tank	0.075 m^3	0.038 m^3	0.019 m^3
Fresh Water Tank	0.561 m^3	0.281 m^3	0.140 m^3
Passenger	7	4	2
Draft at Mid Ship	0.438 m	0.401 m	0.378 m

Before analysing the ship's stability, it must first determine the standard criteria that apply according to the provisions. In this study, because the Water Ambulance ship is fast, the standard used is the HSC 2000 Annex 8 monohull (high-speed craft) (IMO, 2000). HSC 2000 is used as a standard in evaluating the stability of a water ambulance because it is included in the criteria for a V-hull fast boat. In addition, it is included in the hull plan ship category.

RESULTS AND DISCUSSION

After the running process is complete, some analysis results will be obtained, which include the graphs shown in Figure 4 to Figure 6. Figure 4 shows the maximum GZ value on the green line at an angle of 40°. The initial GM Figure 6 shows the maximum GZ value on the green line at an angle of 43.2°. The initial GM value is shown on the pink line at 0.653 m. The simulation results of three operational load cases matched the HSC 2000 Annex 8 monohull (high-speed craft) criteria in Table 3 to Table 5.

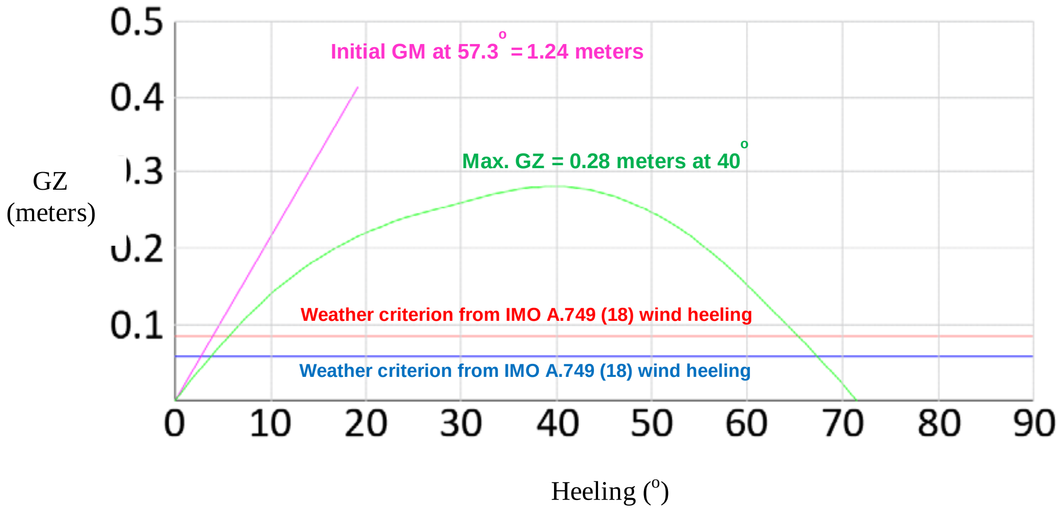

Figure 4. GZ curve of loadcase 1

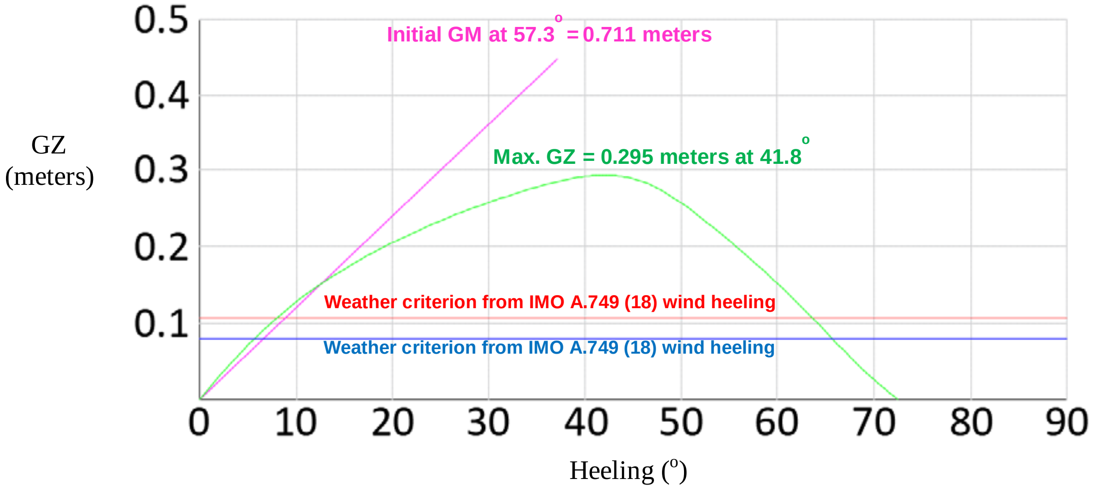

Figure 5. GZ curve of loadcase 2

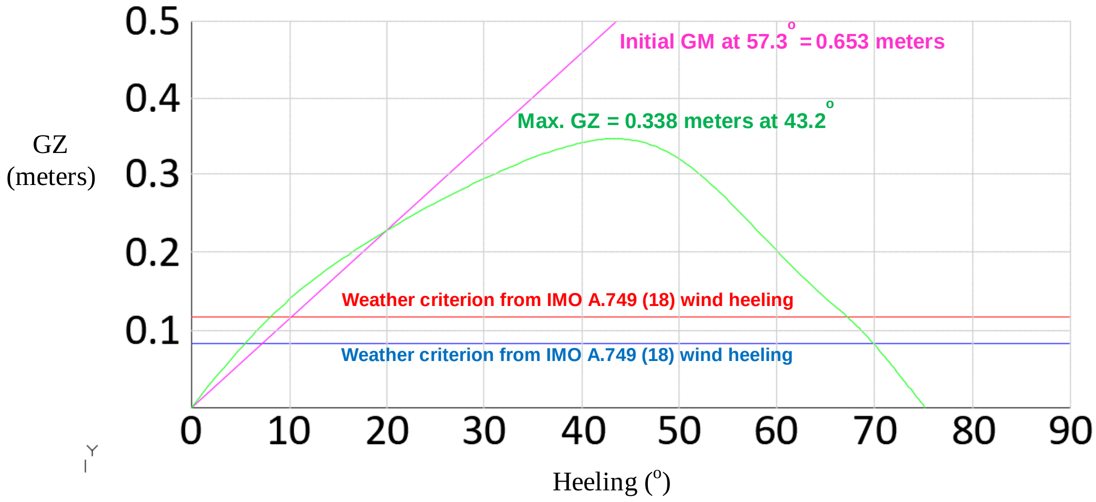

Figure 6. GZ curve of load case 3

Table 3. Simulation result of loadase 1 vs criteria HSC 2000 Annex 8 monohull

Criteria	Value	Units	Actual	Status
1.1Angle of steady heel shall not be greater than	≤16	deg	3.10	Pass
Angle of steady heel / margin line immersion angle shall be less than	<80	%	9.27	Pass
Area1 / Area2 shall not be less than ≥	≥100	%	132.08	Pass
1.2 Area 0 to 30 or GZmax	≥3.15	m.deg	5.02	Pass
1.3 Area 30 to 40	≥1.71	m.deg	2.71	Pass
1.4 Max GZ at 30 or greater	≥0.20	m	0.28	Pass
1.5 Angle of maximum GZ	≥15	deg	40	Pass
1.6 Initial GMt	≥0.15	m	1.24	Pass

Table 4. Simulation result of loadase 2 vs criteria HSC 2000 Annex 8 monohull

Criteria	Value	Units	Actual	Status
1.1Angle of steady heel shall not be greater than	≤16	deg	4.70	Pass
Angle of steady heel / margin line immersion angle shall be less than	<80	%	13.62	Pass
Area1 / Area2 shall not be less than ≥	≥100	%	116.53	Pass
1.2 Area 0 to 30 or GZmax	≥3.15	m.deg	4.88	Pass
1.3 Area 30 to 40	≥1.71	m.deg	2.80	Pass
1.4 Max GZ at 30 or greater	≥0.20	m	0.29	Pass
1.5 Angle of maximum GZ	≥15	deg	41.80	Pass
1.6 Initial GMt	≥0.15	m	0.71	Pass

Tables 3 to Table 5 show the simulation results for the three load cases. Significantly, the simulation value in criterion 1.1, "Angle of the steady heel," shall not be greater than the increase in angle along with the reduced load on the water ambulance. The value for the steady heel/margin line immersion angle criterion must be less than the percentage value found to increase as the load decreases. Area 1 and Area 2 criteria must be greater than 100 and in the 132-116% range. The area 0 to 30 or GZ max for criterion 1.2 was found to be in the range

Table 5. Simulation result of loadase 3 vs criteria HSC 2000 Annex 8 monohull

Criteria	Value	Units	Actual	Status
1.1Angle of steady heel shall not be greater than	≤16	deg	6.00	Pass
Angle of steady heel / margin line immersion angle shall be less than	<80	%	16.61	Pass
Area1 / Area2 shall not be less than ≥	≥100	%	120.19	Pass
1.2 Area 0 to 30 or GZmax	≥3.15	m.deg	5.13	Pass
1.3 Area 30 to 40	≥1.71	m.deg	3.16	Pass
1.4 Max GZ at 30 or greater	≥0.20	m	0.33	Pass
1.5 Angle of maximum GZ	≥15	deg	43.20	Pass
1.6 Initial GMt	≥0.15	m	0.65	Pass

4.88-5.13 m.deg. Criterion 1.3 Area 30 to 40 has increased along with the reduced load on the water ambulance. Criterion 1.4 Max GZ at 30 or greater increases with decreasing load.

While the criterion of 1.5 angular degrees of maximum GZ also increases when the load decreases. The last criterion, 1.6 Initial GMt, shows results directly proportional to the decrease in water ambulance loads.

CONCLUSION

After conducting simulations for the three operational load cases, it was found that load case 1 showed the safest standard, followed by load case 2 and then load case 3. Even though the results of all operational load cases for water ambulances met the standards, the research results proved that the water ambulance would be more vulnerable to load case 3, where the remaining 25% DWT with two passengers. It can be seen from the initial GM value that it is close to the minimum standard, which has implications for other variables listed in the HSC 2000 Annex 8 monohull criteria. The vulnerability of load case 3 can be overcome by placing ballast tanks on top of the water ambulance to create the safest ship load case.

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