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STUDY ANALYSIS OF THE USE OF HDPE PLASTIC AS A SHELL ON CATAMARAN HULL

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ABSTRACT

This research will study the application of HDPE plastic as a substitute for boat shell on catamaran vessels. The boat was built by traditional vessel craftsmen from Kebondowo Banyubiru. The purpose of this research is to look at the performance of catamaran vessels that include resistances, stability and motion of the vessel. Apart from these technical factors, a strength analysis of the keel profile of HDPE plastic coated wood was also carried out using BKI standards.The method used in this research is to look at the performance of the vessel in question based on differences in the value of the ratio of the distance between demihull and length of the vessel (s / L). The stability value will be measured according to the IMO MSC 36 criteria (63) and the movement will be assessed according to NORDFORSK 1987. The results showed that the smallest resistance value was obtained under conditions of the ratio of demihull distance s / L = 0.42, which is 1.19 kN. The condition of the stability of the catamaran and the motion in all variations has met all the predetermined criteria. The biggest rolling deviation occurs at heading 90 ° at 1.11 ° for vessels variation 1 (S / L 0.32), the biggest pitching at heading 180 ° at 1.09 ° for all variations of demihull distances on the slight medium wave, and the biggest heaving at a 180 ° heading of 0.214 ° for all hull distances on the slight medium wave. The addition of a layer of HDPE material to wood gives an average strength increase of 17 % for a ratio of h/b 1.5 and 8 % for a ratio of h / b = 2. The results of these calculations meet the strength criteria according to Rules BKI.

Keywords: HDPE plastic, catamaran, traditional.

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1. INTRODUCTION

Wooden vessels or boats that are generally traditionally built are still pretty much scattered in various regions in Indonesia. Wooden vessels are identical to traditional vessels, where the vessels are generally built based on traditions and knowledge given from generation to generation. Wooden vessels are built for various purposes including transportation, fishing facilities, tourism and so on. There are several disadvantages of wood material as raw material for vessel construction, including the availability of materials that are increasingly reduced, relatively expensive prices and relatively low durability . This condition requires an alternative material that can replace it.

HDPE plastic from used drum packs can be considered as an alternative material for boat shell due to several advantages possessed by the material, including mechanical strength and durability. A HDPE plastic catamaran boat has been built in Rawa Pening Kebondowo, Banyubiru, Semarang district. The boat has a main size of the entire length, loa = 6.6 m, the width of the whole boa = 3 m, and deck height, d = 0.5 m. external drive engine used is an external engine (outboard) with a power of 6.5 pk. The catamaran boat in question is a two-hull boat. Catamaran boat hull as referred to in this study has a symmetrical shape. Boat making is expected to provide technical and economic benefits. The catamaran boat in question can be seen in Figure 1.

Figure 1 Catamaran Boat with Plastic HDPE which is used as a packaging drum produced by Kebondowo Banyubiru boat craftsmen.

HDPE plastic material used as packaging drum as an alternative material for substituting bark has several advantages including the availability of relatively abundant materials, low prices, easy to work on and has good technical characteristics. The technical characteristics referred to include the melting temperature ranging from 200 - 280 oC [1], and the tensile strength of 1200 - 2000 Psi [2], lighter to ± 30% compared to the hull skin of wood [3]. The type of HDPE plastic material used in drum packaging used as boat skin material, can be seen in Figure 2.

Figure 2 The use of HDPE plastic material used as a drum pack as a boat shell instead of wood.

This study aims to look at the characteristics of resistances, stability, and movement of catamarans produced by Kebondowo Banyubiru traditional vessel craftsmen. The catamaran was built with HDPE plastic material from used drum packs, with data as described above. There are a number of things that need to be considered in relation to the construction of the boat, among others, the construction is carried out according to traditional knowledge and the use of HDPE plastic materials that are not so popular. Shipbuilding traditionally means that vessels are built not referring to certain vessel design criteria as modern vessels have been built.

The method used in this study is to observe the construction of the catamaran in question, then conduct an evaluation based on the criteria given specifically for the design of the catamaran. The next step is to analyze the data to determine the stability characteristics, motion and resistance of the vessel by using the Maxsurf software. The standard used in the assessment of this criterion is the criteria provided by IMO MSC 36 (63) and NORDFORSK 1987. The expected benefit of this research is to look at the technical feasibility of the vessel that has been made, and provide correction if there are deficiencies in the design aspects.

2. STUDY METHODS

The method used in this study is to observe the construction of the catamaran in question, then conduct an evaluation based on the criteria given specifically for the design of the catamaran. The next step is to analyze the data to determine the stability characteristics, motion and resistance of the vessel by using the Maxsurf software. The standard used in the assessment of this criterion is the criteria given by IMO MSC 36 (63) and NORDFORSK 1987 for cargo vessels with L <100 m., While the wave criteria used follow the JONSWAP standard.

Table 1 1987 NORDFORSK Exercise Criteria

No.	Criteria	Prescribe Max. Value
1	RMS of Roll	6°
2	RMS of Vertical Acceleration at FP	0,275 g
3	RMS of Vertical Accelation at Bridge	0,15 g

Table 2 Characteristics of Waves according to JONSWAP

No.	Wave Height (m)	Wave Period	Description
1	0,5	7,5	Slight Low
2	0,75	7,5	Slight Medium

The results of observations on the size of catamaran vessels produced by Kebondowo Banyubiru boat craftsmen will be assessed based on design criteria provided by Insel and Molland (Table 3). Reference s / L value will use the assessment criteria based on the value of s / L in the condition of the wave value (Rw) is relatively small, ie s / L = 0.3 - 0.4 [4]. The selection of certain criteria can give consequences to the performance of the vessel.

There are several design characteristics as criteria for getting good catamaran performance. The design characteristics in this study refer to the following criteria:

Table 1 The Criteria of Catamaran Design [5]

Criteria		L/B1	B/H	s/L	s/B1	B1/T	Cb
Standard	Min	6	0,7	0,19	0,9	0,9	0,36
	Max	12	4,1	0,51	4,1	3,1	0,59

2.1. Modeling based on variations in S / L

The initial process of the analysis is carried out by first making a model based on variations in the distance between the hull of the catamaran and the length of the vessel s / L. Defined in this study three values of s / L are s / L = 0.32, s / L = 0.37 and s / L = 0.42 where the value of s / L = 0.37 is the s / L value of the vessel catamarans built in the field by craftsmen. The main sizes of the vessels in question can be seen in Table 3. Modeling results can be seen in Figures 3-5.

Table 3 Ship Particular of Catamaran

LOA	= 6,60	m
LWL	= 6,312	m
BOA	= 3,0	m
B	= 0,65	m
T	= 0,26	m
H	= 0,5	m
Cb	= 0,7	
Δ	= 1,407	ton
Vs	= 12	knot

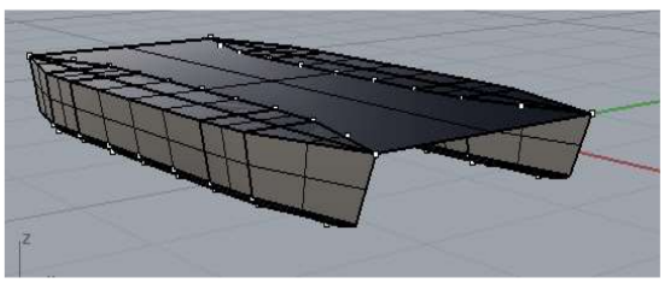

Figure 3 Variation 1 (S/L 0,32)

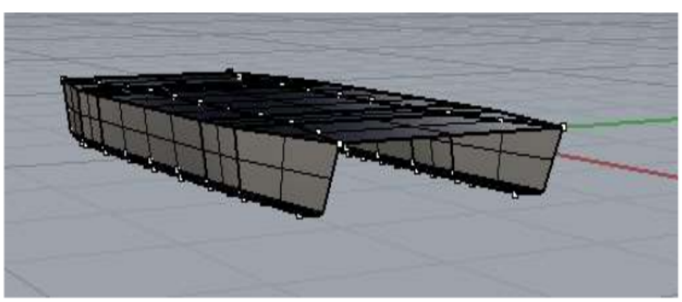

Figure 4 Variation 2 (S/L 0,35)

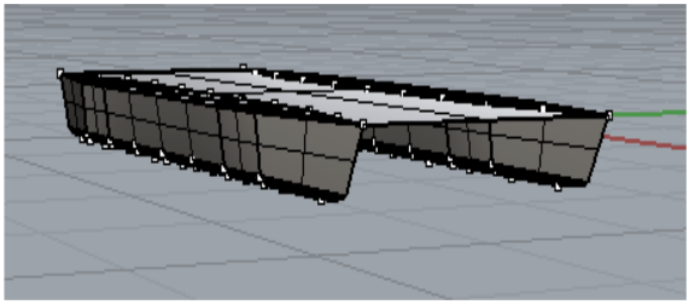

Figure 5 Variation 3 (S/L 0,42)

3. RESULTS AND DISCUSSION

3.1. Evaluation of Catamaran Design

A catamaran boat or vessel is a two-sided vessel. Such a hull shape will give effect to the performance of the vessel. The difference in the shape of the hull that affects the performance requires an evaluation of the traditional shape of the hull of the vessel. The results of measurements in the field and calculations obtained by comparison of the main size of the vessel being built. The comparison value in question will be compared according to the criteria given by Insel and Molland. Table 4 shows the evaluation based on the intended criteria.

Tabel 4. Characteristics of Catamaran

Size and Criteria	**K. HDPE**	**K. Insel & Molland**
Loa =	6,6	
Lwl=	6,3	
T =	0,26	
Lwl/B1 =	9,23	6 – 12
B1/D =	1,3	0,7 – 4,1
s/L =	0,37	0,19 – 0,51
s/B1 =	3,6	0,9 – 4,1
B1/T =	2,5	0,9 – 3,1
Cb	0,7	0,36 – 0,59

The results of the evaluation indicate that almost all of the criterion sizes that were evaluated were in accordance with the criteria, except the criteria for the value of the block coefficient (Cb). Relatively large block coefficient value will affect the value of relatively large resistances as well. For the same displacement, the value of wet surface area for catamarans is greater than 1.4 WSA compared to monohull vessels [6]. The results of the catamaran model test results, a decrease in the value of the ratio of the length of the vessel (L) to its displacement (V), L / V1 / 3, will have an effect on increasing the value of the resistance. While the value of the ratio of the centerline distance of the hull to the length of the vessel, s / L, there is a slight difference when there is an increase in the speed of the vessel [7]

3.2. Resistances of Catamaran Vessel

Computational results show that the difference in treatment by providing different distances between hulls does not provide a significant difference to the total resistance value of catamaran vessels. The computational results of calculating the total resistance of a vessel are shown in Figure 6. The insignificant difference is caused by the value of S / L only affecting the wave resistance. The magnitude of the wave resistance is more determined by the factor Froud Number Fn. The wave resistance will increase significantly if the concurrent value of s / L is obtained and the value of Fn is also relatively small. The influence of these two factors on the smallest wave resistance value Rw is in the value of Fn 0.3 - 0.4 for all conditions of the value of s / L [4].

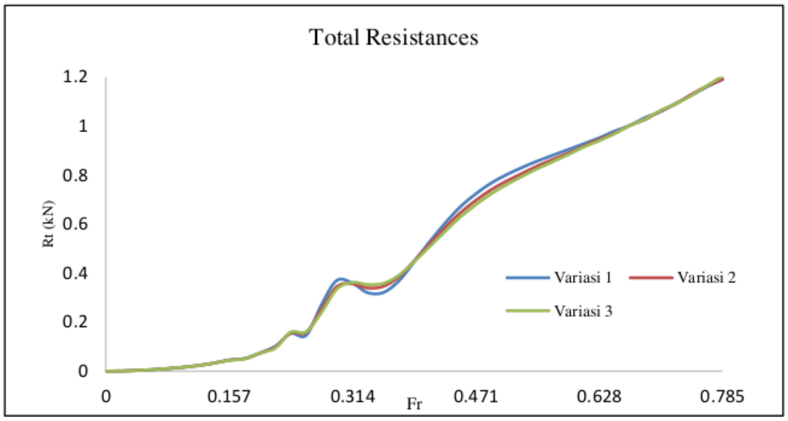

Figure 6. Running Results of vessel Resistances 3 Variations in Hull Distance Analysis Results of Maxsurf Resistance

This wave resistance is part of the remaining resistance component. The value of this remaining resistance can reach ± 30% of the total resistance, while the largest component of resistance is the friction resistance which can reach ± 70% of the total resistance of the vessel. Figure 6. shows that the largest hull distance variation or s / L 0.42 which has the smallest total resistance value, but not significantly different. Smaller wave interference will be obtained for the largest s / L value. The magnitude of the wave interference that affects the vessel's resistance can be proven by equation (1).

$$C_{T\,(cat)} = (1+\phi k)\,\sigma\,CF + \tau CW \qquad (\ldots\ldots\ldots\ldots\ldots$$

where σ is friction interference factor (friction) according to ITTC '57 method, ϕ is interference form factor (form), τ is the interference factor of the wave (wave) and $CT_{(cat)}$ coefficient of total resistance of catamaran vessels, CF coefficient of friction resistance, and CW is the wave resistance coefficient.

The use of certain types of material as the hull material will give consequences to the displacement weight of the vessel. The difference in displacement weight which causes the difference in maximum load will have an effect on the performance of the vessel. The results of previous studies indicate that the use of HDPE plastic material used as drum packs for boat hull shell, a substitute for bark, gives an influence on the change in resistance value of 60 N from 560 N to 510 N. The difference in the value of the resistance will give a difference in adequacy in the use of the amount of engine power . At a speed of 9 knots, an engine power of 5 PK is sufficient for the HDPE catamaran vessels as intended, but relatively small for wooden-shelled catamarans[8].

3.3. Calculation of Ship Stability

Stability analysis is carried out using software, based on two conditions, namely the condition of vessel s with empty loads and 100% consumable, and conditions of vessel s with full loads. The variation of demihull distance (s / L) condition I shows a maximum GZ value of 1.386 m. Calculation results will be analyzed using the IMO MSC criteria.36 (63). Calculation results can be seen in Table 4. and Figure 7.

Table 4 The stability value of the vessel condition I at the value of s / L = 0.32, s / L = 0.37, s / L = 0.42

s/L	Criteria	Value (m.deg)	Condition (m.deg)	Status
0,32	Area 0° - 30°	≥6,9329	9,3955	pass
	Angle of Max. GZ	10°	13,6°	pass
0,37	Area 0° - 30°	≥6,9329	10,958	pass
	Angle of Max. GZ	10°	13,6°	pass
0,42	Area 0° - 30°	≥6,9329	12,343	pass
	Angle of Max. GZ	10°	13,6°	pass

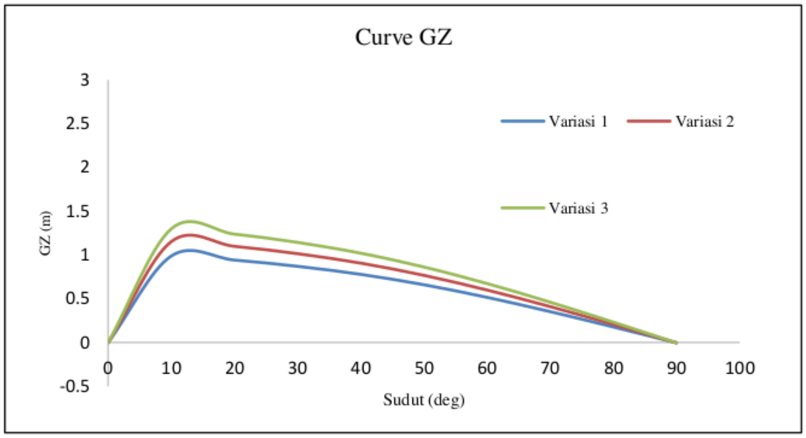

Figure 7. GZ Curve Condition I (Empty Vessel) 3 Variation of Hull Distance

Based on the results of the analysis in Table 2, condition I for demihull distance variation or S / L has fulfilled IMO criteria for the three variations that have been scenarios. All three variations of the vessel have a substantial return arm value. Variations I, II, and III of the vessel have a maximum GZ value respectively, namely, 1,055 m, 1,231 m, 1,386 m. These results indicate there is a difference in the value of GZ between Variation 1 with variation 2, amounting to 31.37%.

Calculation in condition II explains the change in the value of GZ due to the difference in the value of s / L at load load of 100% full load with empty consumables. Calculation results are shown in Table 5 and Figure 8.

Table 5 The stability value of condition II vessel s at the value of s / L = 0.32, s / L = 0.37, s / L = 0.42

s/L	Criteria	Value (m.deg)	Condition (m.deg)	Status
0,32	Area 0° - 30°	≥ 6,9329	8,8937	pass
	Angle of Max. GZ	10°	16,4°	pass
0,37	Area 0° - 30°	≥ 6,9329	10,958	pass
	Angle of Max. GZ	10°	13,6°	pass
0,42	Area 0° - 30°	≥ 6,9329	9,7844	pass
	Angle of Max. GZ	10°	12,7°	pass

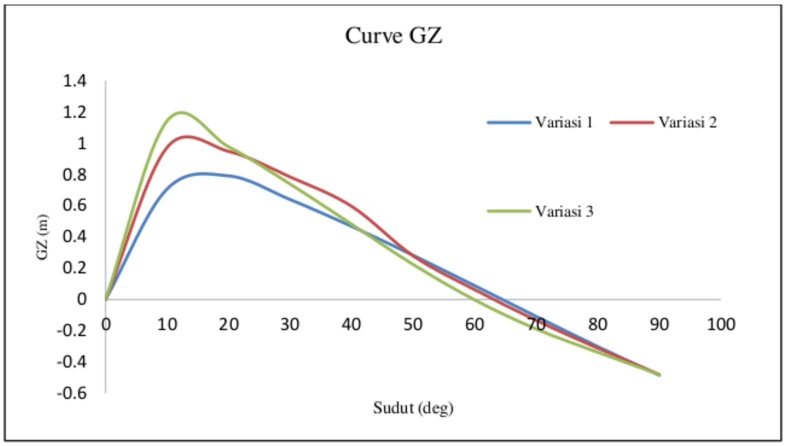

Figure 8 GZ Curve Condition II (Full vessel) 3 Variation of Hull Distances

Based on the analysis results in Table 5, condition II demihull distance variation or S / L meets IMO criteria for the three variations that have been scenarios. All three variations of the vessel have a substantial return arm value. Variations I, II, and III of the vessel have a maximum GZ value, respectively, 0.816 m, 1.051 m, 1.197 m. These results indicate there is a difference in the value of GZ between Variation 1 with variation 3, amounting to 46.7%.

3.4. Catamaran Ship Motion

The motion calculation is done by setting the heading 45 ° angle treatment (stern quarter sea), 90 ° (beam sea), 135 (bow quarter sea) and 180 ° (head sea). The angle treatment is applied to see the amplitude conditions of each heaving, rolling and pitching motion, for the condition of a full cargo vessel and empty supplies. Calculation of motion using the 12 knots service speed reference. Calculation results can be seen in Tables 6-11.

Table 6 RMS Ship Variation 1 (S / L 0.32) in the Slight Low Wave

No.	Head (deg)	Amplitude			VA (m/s^2)	
		Heave (m)	**Pitch (deg)**	**Roll (deg)**	**Bridge**	**FP**
1	45	0,124	0,46	0,47	0,051	0,042
2	90	0,128	0,27	0,74	0,259	0,142
3	135	0,138	0,48	0,53	0,475	0,513
4	180	0,143	0,73	0,00	0,906	0,880

Table 7. RMS Ship Variation 1 (S / L 0.32) in the *Slight Medium Wave*

No.	Head (deg)	Amplitude			VA (m/s^2)	
		Heave (m)	**Pitch (deg)**	**Roll (deg)**	**Bridge**	**FP**
1	45	0,185	0,69	0,70	0,077	0,063
2	90	0,193	0,41	1,11	0,389	0,212
3	135	0,206	0,72	0,79	0,713	0,770
4	180	0,214	1,09	0,00	1,359	1,320

Table 8. RMS Ship Variation 2 (S/L 0,37) in the *Slight Low Wave*

No.	Head (deg)	Amplitude			VA (m/s²)	
		Heave (m)	Pitch (deg)	Roll (deg)	Bridge	FP
1	45	0,124	0,46	0,47	0,051	0,042
2	90	0,128	0,27	0,73	0,260	0,142
3	135	0,138	0,48	0,52	0,476	0,514
4	180	0,143	0,73	0,00	0,908	0,881

Table 9. RMS Ship Variation 2 (S/L 0,37) in the *Slight Medium Wave*

No.	Head (deg)	Amplitude			VA (m/s²)	
		Heave (m)	Pitch (deg)	Roll (deg)	Bridge	FP
1	45	0,185	0,69	0,70	0,077	0,063
2	90	0,193	0,41	1,09	0,390	0,213
3	135	0,206	0,72	0,79	0,713	0,771
4	180	0,214	1,09	0,00	1,361	1,322

Table 10. RMS Ship Variation 3 (S/L 0,42) in the *Slight Low Wave*

No.	Head (deg)	Amplitude			VA (m/s²)	
		Heave (m)	Pitch (deg)	Roll (deg)	Bridge	
1	45	0,124	0,46	0,46	0,051	0,042
2	90	0,128	0,27	0,72	0,257	0,140
3	135	0,138	0,48	0,52	0,471	0,524
4	180	0,143	0,73	0,00	0,900	0,893

Table 11. RMS Ship Variation 3 (S/L 0,42) in the *Slight Medium Wave*

No.	Head (deg)	Amplitude			VA (m/s²)	
		Heave (m)	Pitch (deg)	Roll (deg)	Bridge	FP
1	45	0,185	0,69	0,70	0,076	0,064
2	90	0,193	0,41	1,07	0,385	0,210
3	135	0,206	0,72	0,78	0,707	0,785
4	180	0,214	1,09	0,00	1,350	1,339

The calculation results show that all conditions on the variation 2 vessel have increased response from slight low wave conditions to slight medium waves. Tables 6-11 show that all RMS are still below the maximum limit of the specified standard. The vessel's RMS starts to exceed the standard limits when slight medium wave conditions are applied, but only at vertical acceleration when headings are 135 ° and 180 °. An increase in vertical acceleration averaged by 33.3% for each increase in wave conditions.

The largest pitching deviation occurs at a 180 ° heading for all variations of the demihull distance on the Slight Medium Wave with a value of 1.09. This value has a difference of 33.03% greater when compared to the rolling deviation on the 180 ° heading for all variations of demihull distances on the Low Wave Slight. That is, variations in demihull distance do not affect pitching values. This also happened to heaving, where the value of heaving is not affected by variations in demihull distances. However, the value changes when a wave height changes.

The addition of medium wave variations in the above analysis is an additional variation to determine the response of the vessel in the event of extreme weather considering that the waters of Rawa Pening are in the slight category. There are many factors that influence the amount of deviation that occurs in the motion of the vessel such as determining the weight of the LCG, TCG, and VCG vessels. LCG, TCG values are respectively used to input the gyradius and roll gyradius pitch numbers. The greater the LCG point (calculated from midship), the higher the heaving and pitching deviations that occur. The greater the TCG point (away from the center line), the greater the rolling deviation that occurs. The shape of the bow which has a relatively small inclination also affects the movement of the vessel. A small bow angle can result in a relatively large vertical acceleration compared to a bow that tends to be straight. The vertical bow shape can cut waves so that vessels can pass waves with pitching that is smaller than the bow shape in general [9].

3.5. Added Strength from HDPE Plastic

The use of HDPE plastic as a substitute for wooden hull shells can have an effect on the longitudinal strength of the ship. The analysis of the strength calculation can use a simple calculation principle assuming the ship is a beam supported in the middle or at both ends. The principle of this calculation can be seen in Figure 9.

The purpose of the calculation of longitudinal strength is to determine the stress experienced by the ship's body as a unit in the longitudinal direction. It is caused by the condition where the weight of the ship at a point along the vessel is not supported by bouyancy to the same size. If the difference in longitudinal spread between gravity and compressive force is greater, the load that works on the ship is also greater. The longitudinal spread of the weight of the vessel is determined by the load state, while the spread of the upward pressure force is determined by the shape of the submerged part of the ship and the wave conditions. Generally, the calculation of longitudinal strength is made based on the static balance between gravity and bouyancy. The longitudinal flexure of the vessel is shown in Figure 2, and the cross section modulus expression is shown in Figure 3. Based on the description above, the amount of flexural stress (σ) can be calculated extending with the concept of technical mechanics in general, as follows [10] :

$$\sigma = \frac{M}{I}.y \quad . \qquad (1)$$

$$Z = \frac{I}{y} \quad /. \qquad (2)$$

$$\sigma = \frac{M}{Z} \qquad (3)$$

Di mana : M = longitudinal bending moment.
y = the distance of a point to the neutral axis.
I = moment of inertia cross section of the neutral axis.
Z = cross section modulus.

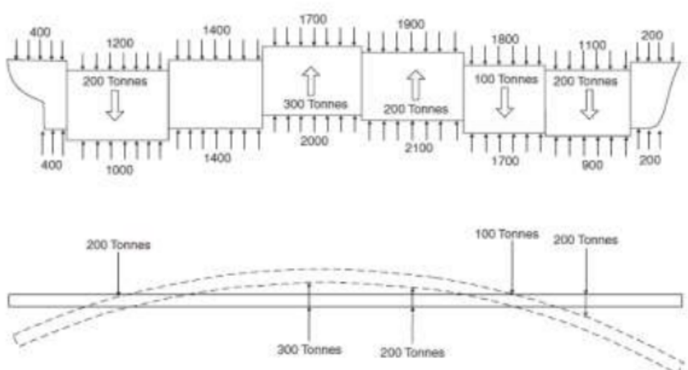

Figure 9 Longitudinal bending and vertical force in calm water conditions [10]

The calculation of the longitudinal strength as mentioned above also applies to calculating the parts of the ship's construction profile such as the keel. The keel has an important role in the structure of the hull of a ship which can be likened to the backbone of the human body. The strength of the keel, apart from being dependent on the support and loading system, is also influenced by the type and size of the material. In general, a high density material will have better strength, so that a profile with the same size will be obtained by a higher strength material, or for the same strength size of two different materials, the high density material will have a smaller size.

HDPE plastic coating on the keel profile aims to find better material quality both technically and economically. Referring to the BKI standard for Wooden Ship Construction Regulations [11], the ratio to the size of the keel is 1.5 (height / width). Meanwhile, HDPE plastic thickness ranges from 4 mm - 0.9 mm. The keel testing method can be seen in Figure 10.

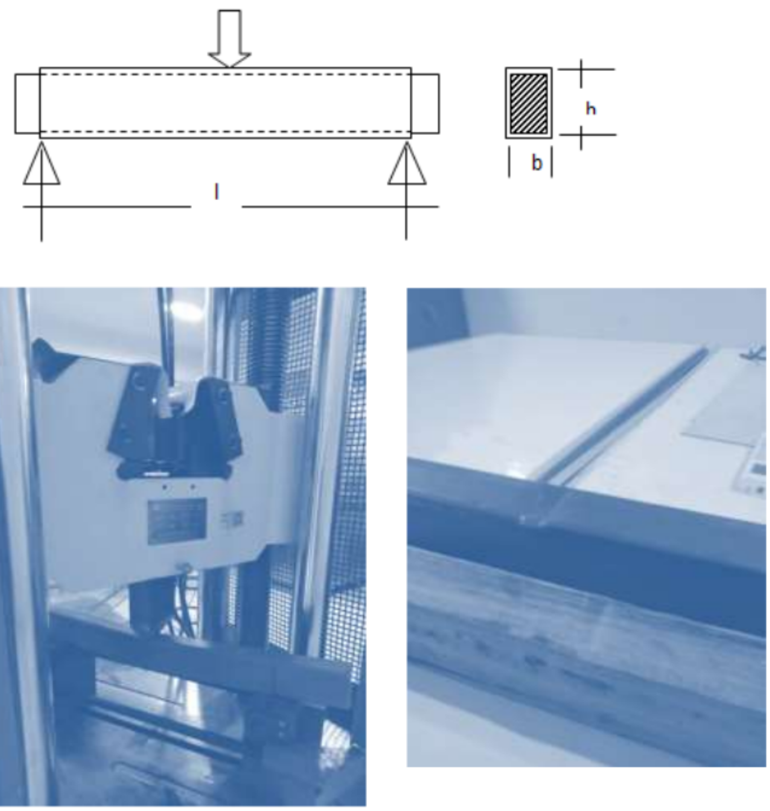

Figure 10 The keel testing method

Figure 11. Shows the test results with the treatment of wood coated with HDPE plastic and without coating, then the treatment is still distinguished by the ratio value between height and width, namely the ratio h / w = 1.5 da, h / w = 2. The support distance for the load bending l = 50 cm. The test results in Figure 11 can be explained as follows:

a. A change in the ratio that causes a change in modulus results in an increase in the load of 9 % for uncoated wood.

b. For the cross-sectional ratio of 1.5 between coated and uncoated HDPE wood there is a difference of 17 %

c. For the cross-sectional ratio of 2 between coated and uncoated wood with a 8 % difference and

d. The k factor states the amount of load change after HDPE coating, k = 0,9

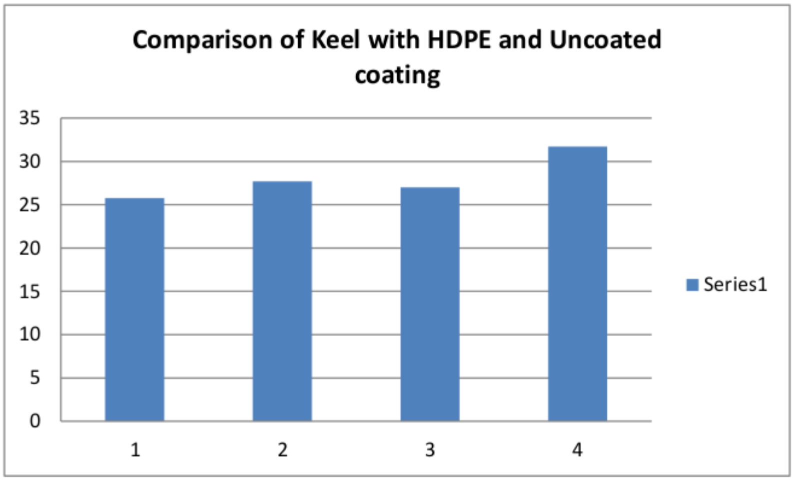

Figure 11. Comparison of Keel with HDPE and Uncoated coating

Based on the results of this study, the load change from the keel profile after coating with HDPE material can be multiplied by a factor of k

4. CONCLUSIONS

Based on the results of the analysis in the discussion section, the authors draw a number of conclusions including:

- The shape of production catamarans from traditional boat craftsmen has the appropriate design criteria based on the reference criteria of Insel and Molland, except for the relatively large Cb block coefficient.
- The smallest total resistance possessed by the shape of the vessel in Variation 3 (S / L 0.42) is 1.190 kN with a speed of 12 knots. An S / L ratio of 0.42 gives a relatively large distance between the stomach compared to other ratios in the treatment. The greater the distance between the hull, the value of the wave resistance caused by interference will be smaller.
- The results of the analysis of the stability criteria show that all variations of demihull distances in each vessel condition meet the IMO criteria MSC.36 (63). The largest GZ value is obtained by vessel in condition I (empty vessel with full supplies}, with Variation 3 ie s / L = 0.42, GZ = 1.386 m. A large GZ value indicates a good condition of vessel stability.
- Motion analysis of all variations fulfilled the 1987 NORDFORSK criteria. The maximum deviation value for all variations is obtained under slight medium wave conditions. The largest rolling deviation occurs at 90 ° heading at 1.11 ° The biggest pitching at 180 ° heading at 1.09 ° and the biggest heaving at 180 ° heading angle is 0.214 °. Demihull distance variation does not significantly influence rolling, pitching, and heaving but the value changes when wave height changes.

- Based on the results of this study, the load change from the keel profile after coating with HDPE material can be multiplied by a factor of k, where k = 0,9

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PAGE 1

PAGE 2

PAGE 3

PAGE 4

PAGE 5

PAGE 6

PAGE 7

PAGE 8

PAGE 9

PAGE 10

PAGE 11

PAGE 12

PAGE 13