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RESEARCH ARTICLE

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The Development of Monomaran Fishing Boat Hullform to Improve Ship Stability Performance in Supporting the Safety Improvement of Fishing Activity

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The safety of fishing vessels is the interaction of complex factors, such as human factors (ship's crews), machines (ships and safety equipment) and the environment (weather and fisheries resource management scheme). Safety or accident issues will arise if at least one element of the human factor, machines or environmental factor is not working properly. Although the efforts to prevent and mitigate the risk of accidents through safety regulations have been done. It is also necessary to assess and study the shipbuilding technology that may improve the performance of the fishing boats, especially in the improvement of the safety and reduce the risk of sea accidents. One technology that offers a better level of safety is the monomaran hull form

The main purpose of this study is expected to provide and produce the fishing boat hull form design using monomaran technology that may improve the safety level of fishing activities. In this research, the development of monomaran hull form design is made. The assessment of the intact stability and the seakeeping characteristics of monomaran hull form are done using strip theory method. The results of this study are expected to provide the alternatives design recommendation to improve the safety of fishing activities.

Keywords: Monomaran Hull Form, Fishing boat, Intact Stability, Seakeeping Analysis.

1. INTRODUCTION

Sea fishing is the most dangerous job in the world. The fishing vessel's seafarers professions have the characteristics of "3D" work that are: dangerous, dirty and difficult, [1]. By the three properties of the work plus the relatively small ship size factor in severely weather and wave conditions, the rate of ship fishing accidents is getting higher.

The high rate of fatal accidents of fishing vessels in the world has generated the attention of international agencies such as IMO, FAO and the ILO on the importance of improving the safety and employment of fishing vessels. These world bodies have involved some parties, namely the government, boat owners and seafarers to adopt a decent work-related convention.

In Indonesia, the collected data on fishing vessel accidents has not yet been well organized systematically. The results of research on PPP Tegalsari, PPN Pekalongan and PPS Cilacap in the last three years (2006-2008) there have been 61 fatal accidents (causing the crew died / missing) as much as 68 fishermen from 58,919 active fishermen. The fatal accident rate at these three sites is equivalent to 115 deaths per 100,000 active fishermen per year. The accident rate is higher than the average fatal accident of world-class fishing vessels which is about 80 people per 100,000 fishermen died. The loss of property in the form of vessels and equipment and fishing gear lost

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in the sea was recorded as many as 22 units. The illustration of a fishing boat accident can be seen in **Fig. 1**.

Fig. 1. The illustration of a fishing boat accident

The number of fishing boat crews including the traditional fishermen in Indonesia is approximately 2.78 million people as many as 555,940 units of fishing vessels, [2]. The number of fishing boat crews in Indonesia is about 10% of the population of fishermen around the world.

The high rate of fishing vessel crews accidents requires more serious attention through the awareness of fulfilling the standards of knowledge and skills of seafarers, the standard of design fishing vessels, the standard of fishing gear, The standard of fishing vessel crews, The standard of fishing operation, The standard of labor on fishing vessels. Those standards should be tailored to the size of the vessel, the main engine power of the vessel, the shipping area and the adopted fish catch technology.

The safety of fishing vessels is the interaction of complex factors, i.e. human factors (the captain and crews), machines (ships and safety equipment) and the environment (weather and fisheries resource management scheme). The safety or accident issues will arise if at least one element of the human factor, machines or environmental factor is not working, [3].

2. LITERATURE RIVIEWS

In the study of the development of monomaran fishing vessel technology, the reviewed articles mostly related to the technology of fishing vessels. This is due to the shape of the monomaran was the newly adopted hull form for the fishing boat. Therefore the number of studies on monomaran is still very limited. Sayli, A., [4] has identified the functional relationship between seakeeping characteristics and hull form parameters on fishing vessels in the Mediterranean region. The use of multiple regression analysis is done for quantitative assessment with SQL server-based database. Multiple regression models were developed using design parameters classified into two categories: displacement and principal dimension. The results show that the seakeeping prediction at the design concept stage is very satisfactory. In the next article, Sayli, A. [5], has developed a nonlinear Meta model to predict seawater fishing seakeeping behavior. The fishing boat seakeeping data on regular head waves (regular head waves) were used to develop the Meta models of heave motion transfer functions, pitch and vertical acceleration using non-linear analysis. The results indicate a good agreement with the results that produced by direct computation.

Mantari, J. L., [6] studied the intact stability of Portuguese and Peruvian fishing boats that operating in Atlantic and Pacific seas taking into account the aspects of fishing gear, beam waves and wind. The calculation results show that the heeling moment due to the fishing gear is greater than the heeling moment caused by the rough weather scenario, the combination of these two loads can result in total stability even in the normal fishing conditions. The results also show that some fishing vessels have excessive deck and the fishing gear machinery may reduce the ship stability.

Gammon, M. A., [7], optimized the fishing boat hull form with Multi Objective Genetic Algorithm (MOGA). MOGA was developed in this study by allowing for automatic selection of optimal Pareto results. Optimization uses three performance indexes for barriers, seakeeping and stability to modify the shape of the hull form to obtain the optimal hull offset, as well as the optimal values for the main parameters of length, width and weight. The results show an improvement in the three objectives of the ship resistance, seakeeping and stability.

Gonzalez, M. M., [8], developed a system that could assist the crew in providing information about the degree of intact stability and the magnitude of the given heeling moment. The results show that the system is able to overcome the main cause of ship instability caused by the loading conditions.

Tello, M., [9], conducted a study of seakeeping performance on fishing vessels with the aim of identifying seakeeping criteria and ship conditions that limit the fishing vessel's operating abilities under sea conditions. The results show that the motion of roll and pitch is the most critical movement for seakeeping performance. There is a significant influence on seakeeping performance due to the height of metacenter and the location of the reference point used as the checking point on the fishing boat.

Santullano, F. M. A., [10], conducted a study of the relationship between stability, safety and operability for fishing vessels. To achieve this goal, a set of fishing boat data has been selected. Comparisons to the manufacturing process have been carried out on capsized ships and safe vessels. A comparison of the stability rules between capsized vessels and previous vessels is also done. The results show that there is no consistent relationship between safety and operability.

Based on the review of the above articles, this research intends to develop a fishing boat design that has a better level of safety and comfort, by applying the hull form of Monomaran. The proposed monomaran hullform design will be developed as an improvement effort against traditional fishing boat designs that have been commonly used by the traditional fishermen.

3. THE PRINCIPAL DIMENSION OF MONOMARAN FISHING BOAT HULLFORM

Generally, in fishing boat design planning, the requirements is provided by the traditional culture of the fishermen fishing habits such as the type of fishing gear, the duration of fish catch activities, and the crew numbers. In addition to the requirements usually some item is considered as related to the safety, comfort, and beauty. The mission requirements became the consideration factors that used as references by the boat planners to determine the principal dimensions of the boat which is compatible for technical and economic aspects.

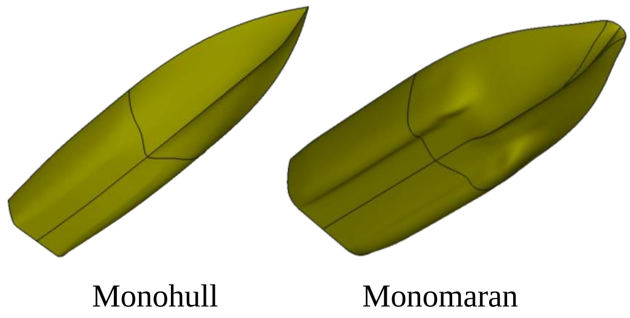

Fig. 2. The comparison of monohull and the proposed monomaran hullform

In determining the principal dimension of the monomaran fishing boat, it was chosen the traditional boat with the length perpendicular (LPP) of 30.7 m, the draught of 2.35 m, and the breadth of 21.3m. Furthermore, the estimated displacement of the design configurations was used as a reference for the modification to have the monomaran hullform for the fishing boat.

Since the principal dimension of the fishing boat was determined, moreover the shape of the monomaran hull form is determined by the exploration of geometry parameters which is include the radius of bilge, and the height of the centerline bottom. The comparison of the shapes of the proposed monomaran and monohull are presented in **Fig. 2**.

4. RESULTS AND DISCUSSION

4.1. Intact Stability Performances

The comparison of the stability curves of the proposed monomaran and monohull hull form are presented in **Fig. 3**. Regarding the stability curves calculated for the full load conditions, it is indicated that the monomaran hullform have a better intact stability than the monohull hullform.

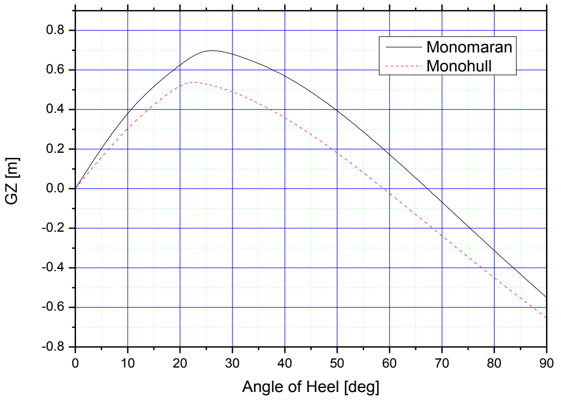

Fig. 3. The comparison of stability curves of the monomaran and the monohull hull form

Table 1. The intact stability and IMO criteria

The Comparison of the Fishing Boat Hull Form			
Criteria	Required	Monomaran	Monohull
Area 0º to 30º	3.15 m.deg	14.8156	11.4183
Area 0º to 40º. or Downflooding point	5.16 m.deg	21.2262	15.7919
Area 30º to 40º. or Downflooding point	1.719 m.deg	6.4106	4.3736
GZ at 30º. or greater	0.2 m	0.688	0.500
Angle of GZ max	25 deg	24.5	22.7
Initial GMt	0.15 m	2.347	1.825
Initial GMt for fishing vessel ≥24 m in length	0.35 m	2.347	1.825
Initial GMt for fishing vessel ≥70 m in length	0.15 m	2.347	1.825

According to the analysis results it is indicated that the monomaran and monohull hullform has intact stability comply with the IMO stability criteria, see **Table 1**. However the monomaran hullform shows a better performance than monohull. In the case of area 0° to 40°, the monomaran hull form has a larger area than the monohull. It is shows that the monomaran hullform has a larger righting moment about 29.77% than monohull, amongst the heel interval from 0° to 40°. During the heel angle 30° to 40°, the monomaran hullform also have better performance about 35.51%. In the criterion of GZ at 30°, the monomaran hullform has the GZ length of 0.688m and the monohull hullform has the GZ length of 0.50m. Regarding the numerical results, it may be shown that the monomaran hullform has improved the intact stability performance of the monohull hull form.

4.2. The Seakeeping Performances

In ship design, it is important to pre-determine the behavior of the ship or floating structure when it is subjected to waves. It can be calculated, found through physical model testing and ultimately measured on board the vessel. The calculations can be performed analytically for simple shapes like rectangular barges, but need to be calculated by a computer for any realistically shaped ship. The results of some of these calculations or model tests are transfer functions called Response Amplitude Operators (RAO).

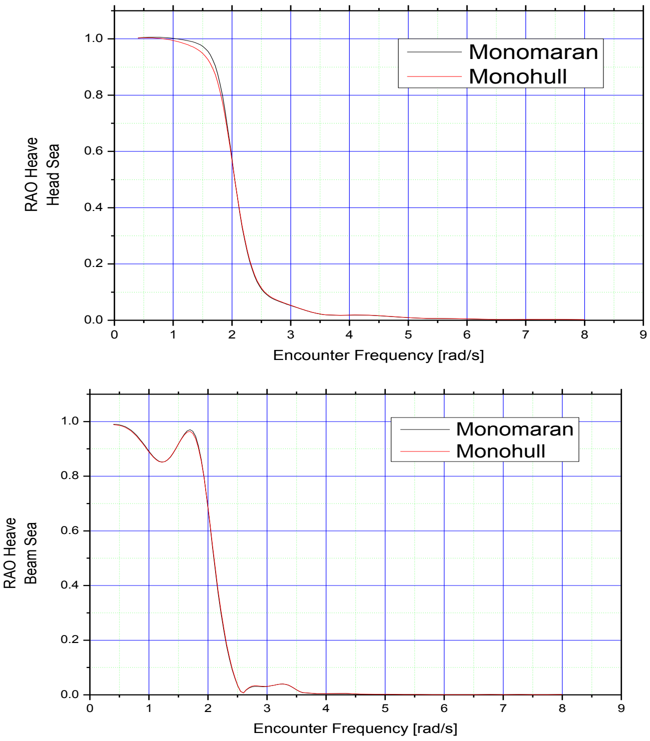

Fig. 4. RAO of heave motion in head sea and beam sea

Seakeeping analysis is performed using the wave and wind characteristic of the Java Sea which is defined as the operational conditions. The operational conditions have been assumed with the sea state of moderate and the significant wave height of 2.5m. Considering the Java Sea characteristics, the JONSWAP spectra were chosen for the seakeeping analysis. Calculations were made at 11.5 knots for the fishing boat service speed, Head Sea, Beam Sea and the JONSWAP wave spectrum with significant wave height of the operational conditions.

Seakeeping analysis is calculated by using commercial software with frequency domain strip theory. The result of the analysis is Response Amplitude Operator (RAO). RAO is the transfer function expressing the relation between wave spectrums in response to movement of the vessel (ship response spectrum). The response characteristics of the movement of the proposed hull form can be seen from RAO. On the RAO diagram, the magnitude of the response sensitivity of the fishing boat against the excitation force caused by ocean waves might be seen. The RAO on the heave, pitch and roll motion of the developed monomaran hull form in the Head Sea and Beam Sea might be seen in **Fig. 4**. Furthermore, the comparison of the motion response of the monomaran to the monohull hullforms is shown in **Table 2**.

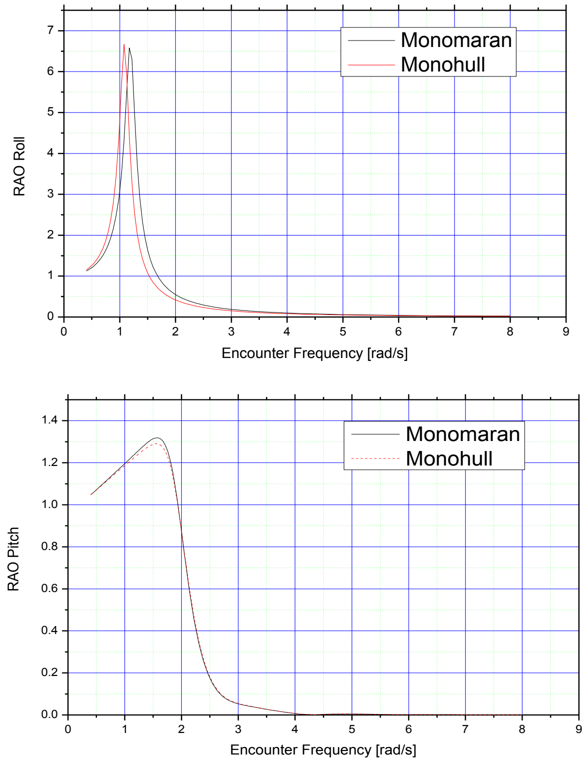

Fig. 5. RAO of roll motion in Beam Sea and pitch motion in Head Sea

Based on the numerical results obtained from the calculation (**Fig. 5** and **Table 2**), it is indicated that the heave motion response of the both hull forms was similar. The amplitude of the heave of the monomaran hull form is 0.592m-0.602m and the monohull hull form is 0.596m-0.597m. In the case of heave motion, it may be described that the monomaran hullform is more sensitive than the monohull. Although commonly the large bottom area has a damping effect to the heave motion, however the monomaran do not change the heave performance significantly. Furthermore, the heave velocity and acceleration response of monomaran appeared in the range of 0.453m/s-0.618m/s and 0.432-0.743m/s2, respectively. Otherwise the monohull have shown 0.452-0.610m/s and 0.431-0.732m/s2 for the heave velocity and acceleration, respectively. Although the monohull have a smaller heave velocity and acceleration however the heave motion performance is not significantly different with the monomaran.

In the case of pitch and roll motion, it appears that the amplitude of pitch and roll motion of monomaran is similar with the monohull. The pitch and roll motion velocity and acceleration also have the similar characteristic with the monohull. It may be explained that the modification from the monohull to the monomaran do not change the pitch motion characteristics, because the water plane area of the fishing boat does not change significantly. Accordingly, it may be concluded that the proposed monomaran does not change the seakeeping performance of the monohull, since the modification do not change the water plane inertia of the fishing boat.

Table 2. The fishing boat motion behavior in head and beam sea

H significant 2.5m (Sea State 4 – Moderate) Head Sea		
	Monomaran	Monohull
Heave motion (m)	0.602	0.597
Pitch motion (deg)	2.44	2.41
Heave velocity (m/s)	0.618	0.610
Pitch velocity (rad/s)	0.059	0.058
Heave acceleration (m/s2)	0.743	0.732
Pitch acceleration (rad/s2)	0.094	0.093

H significant 2.5m (Sea State 4 – Moderate) Beam Sea		
	Monomaran	Monohull
Heave motion (m)	0.598	0.596
Roll motion (deg)	7.80	7.56
Pitch motion (deg)	1.06	1.04
Heave velocity (m/s)	0.453	0.452
Roll velocity (rad/s)	0.160	0.142
Pitch velocity (rad/s)	0.022	0.022
Heave acceleration (m/s2)	0.432	0.431
Roll acceleration (rad/s2)	0.204	0.167
Pitch acceleration (rad/s2)	0.030	0.030

5. CONCLUSIONS

The alternative monomaran hullform for the fishing boat was developed by considering the waterways characteristics of Indonesia. The modification of an existing monohull was made to generate the monomaran hullform. It was determined the principal dimension of the proposed monomaran have the length perpendicular (LPP) of 30.7 m, the draught of 2.35 m, and the breadth of 21.3m

Based on the results of numerical analysis, it is indicated that the monomaran and monohull model was accepted by the IMO Criteria. However, the model monomaran hull form has shown a better intact stability performance than the monohull hull form. The monomaran bilge may improve the intact stability performance for the fishing boat hull form. In the case of seakeeping analysis, the monomaran shows the similar seakeeping performance with the monohull.

Although the numerical analyses have shown that the monomaran models were reliable for the fishing boat on the intact stability and seakeeping performance, however, the experimental studies should be for the validation process of the development of the new fishing boat hull form.

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