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Development of Monohull Fish Processing Vessel Hullform to Support Domestic Fishing Activities in Indonesia

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Abstract*: *This research is focused on the development of the design and prototype of monohull fish processing vessel hullform to support fishing activities such as catching fish, collecting fish from the smaller boats and processing fish catches. The extensive on-board facilities in the fish processing vessel are maintaining the freshness of the catch and improving the quality of catch fish than traditional fishing boat. The initial stage of this study is determining the principal dimension and exploring of the configurations of monohull hull forms. Furthermore, the investigation of resistance characteristics, intact stability and seakeeping behavior was carried out using strip theory and computational fluid dynamic methods. Regarding the performance of the hulls resistance, the analysis indicates that the hull form with smaller block coefficients showed better resistance characteristics. In the case of intact stability, the results of the analysis showed that the model 2 of monohull hull form showed better intact stability characteristics compared to the other models.

Keywords* : *Monohull, Fish Processing Vessel, Domestic Fishing.

I. INTRODUCTION

Fishermen's income depends on the catch value and the sailing costs. Furthermore, the catch value is determined by the availability of fish stocks at sea, the efficiency of fishing technology, and the selling price of the fish. Meanwhile, the operational cost of fishing activities depends on the fuel consumption, the fuel price, and the provision cost which is depends on the size (weight) of the ship and the number of boat crew. In addition, the depreciation cost of the fishing vessel, the fishing equipment, and the supporting equipment must be included in the calculation of fishing operation costs. Based on those variables that affect the income of the fishermen, there are at least nine technical problems that make most of the fishermen still poor, [1].

The operation of fishing activities in overfishing areas is one of the nine factors which cause the low catch income. Many fishermen generally conduct fishing activities in the shallow waters with the distance to the land less than 12 nautical miles which is an area of overfishing waters. This problem arises because almost 95% of national fishermen adopted non-motorized fishing vessels or motor fishing boat below 30 gross tonnages (GT) which is equipped with traditional fishing gear. In addition, the handling operation of the catches not well organized that follow the standard procedures, due to the unavailability of cold storage facilities on ships. The unavailability of cold storage on board also reduces the quality of the catch which results in the low quality and the low selling price of catches.

Fig. 1.Fish Processing Vessel as Mother Ship

Based on these problems, the implementation of shipbuilding technology to fishing activities in Indonesia could provide a solution to the limitations of access to the potential fishing ground and the availability of catch management technology on board. One alternative solution is the use of a mother ship / fish processing vessel in fishing activities, see Fig. 1. Mother ship departs by involving small vessels to conduct fishing activities in the potential fishing ground areas that are located far from the mainland / fishing port. Mother ship becomes a base for small ships that spread and return after getting the catches to be unloaded in the middle of the sea and processed by the mother ship, so that the quality and freshness of the catches are maintained well.

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The proposed research is focused on developing a prototype design of a fully operational monohull hullform fish processing vessel above sea level with facilities for loading and unloading and management of fish catches, see Fig. 2. One of the challenges that must be anticipated in the hullform fish processing vessel design is the intact stability characteristics and station keeping of the ship. In this problem, the technique of cargo load distribution and selecting the right hullform type is expected to produce good station keeping characteristics even in the relatively large wave conditions. This research and development activity is ultimately intended as an integration of learning technology for the design of mother ship vessels in accomplishing the demand for an efficient exploration and utilization of marine resources in Indonesia.

Fig. 2.Monohull hullforms geometry of fish processing vessel

II. LITERATURE REVIEW

Fish Processing Vessel is a relatively large-sized vessel equipped with extensive on-board facilities for the management and freezing of fish catches. Initially this ship was a whaling boat which later evolved into a fishing vessel equipped with a catch management installation. Currently fish processing vessels are commonly used as mother ships in fishing operations.

The mother-ship vessel has a function as the main ship in the fishing operation fleet. Based on the functional and the fishing gear, the fish processing vessel consists of several types which are included:

1. Freezer trawler, Fig. 3a
2. Factory stern trawler, Fig. 3b
3. Factory bottom long liner
4. Factory purse seiner
5. Factory squid jigger
6. Factory barge

Based on the several fish processing vessel types, the freezer vessel and the factory barge vessel are appropriate to be used as mother-ship. In the study of fish processing vessel technology development, the articles reviewed were mostly related to fishing vessel technology. Sayli, et al, [2], identified the functional relationship between seakeeping characteristics and hull shape parameters on the fishing vessels at the Mediterranean region. The use of multiple regression analysis was carried out for quantitative assessments with a database based on the SQL server. The multiple regression models was developed using design parameters that are classified into two categories namely, displacement and principal dimension. The results show that the prediction of seakeeping at the design concept stage is very satisfying. In the next article, Sayli, et al, [3], developed a nonlinear meta model to predict the behavior of seakeeping fishing vessels. Seakeeping data of fishing vessels on regular head waves is used to develop meta models of the heave, pitch and vertical acceleration transfer functions using non-linear analysis. The results show a good agreement with the generated results of direct computation.

[a]

[b]

Fig. 3.[a] Freezer Trawler; [b] Factory Stern Trawler

Mantari, et al, [4], conducted a study of the intact stability of Portuguese and Peruvian fishing vessels which is operating in the Atlantic and Pacific seas by considering aspects of fishing gear, beam waves and wind. The computational results show that the moment heeling due to fishing gear is greater than the moment heeling caused by a rough weather scenario, the combination of the two moment heeling loads might reduce the intact stability performance even under the normal fishing conditions. The results also showed that the fishing vessels had excessive deck machinery and fishing gear that reduce the stability performance of the ship.

Gammon, et al, [5], optimized fish hull shape with Multi Objective Genetic Algorithm (MOGA), [5]. MOGA was developed in this study by allowing the automatic selection of Pareto optimal results. The optimization uses the three performance indexes for resistance, seakeeping and stability to modify the shape of the hull form to obtain an optimal hull offset, as well as the optimal value for the main parameters of length, width and draught. The results showed an improvement performance on the three objectives variables namely resistance, seakeeping and stability.

Gonzalez, et al, [6], developed a system that could assist the crew in providing information about the intact of stability performance and the magnitude of the given moment. The results show that the system is able to overcome the main problems of ship instability caused by loading conditions.

Tello, et al, [7], conducted a study of seakeeping performance on the fishing boat with the aim of identifying the seakeeping criteria and the vessel conditions that restricted the fishing boat operational capability under existing sea conditions. The results show that roll and pitch are the most critical motion for the boat seakeeping performance. There is a significant influence on the seakeeping performance due to the changes in the metacenter height and the location of the reference point that is used as the checking point on the fishing vessels.

Santullano, et al, [8], conducted a study of the relationship between stability performance, safety and operability level for the small fishing vessels. To achieve this goal, a data set of fishing vessels has been selected. Comparison of the stability and operability characteristics of such vessels has been carried out on the decommissioned vessels in order to build method, operated by the same crews, the same operation area and the same fishing gear. Comparisons of the stability rules between the sunken ships and previous vessels were also made. The results show that the more effort is needed to develop and to validate the more complex stability criteria that able to capture the dynamics of fishing vessel at sea.

III. RESEARCH METHODOLOGY

The research methods to develop the fish processing vessel monohull hull form, started with determining the principal dimension of the vessel, which is then followed by the exploration of the shape of monohull. The configuration of the hull form was made by considering the variation of block coefficient on the same displacement volume. The each hull forms were set in the lines plan as a description of each of the curved shape of the hulls. The assessment of hullform performances were conducted using holtrop method for the resistance performance, strip theory and panel method for intact stability and seakeeping behavior, respectively.

A. Determining Principal Dimension and Hullform

To determine the main dimension of the monohull hullform for the fish processing vessel, the linear regression was defined from the selected existing ship. The selected ships are the similar vessels that are already built and registered by the classification society. The vessels were collected to build the linear regression equation that would be used as a reference for determining the main dimension of the proposed design. Furthermore the obtained main dimension would be used to explore the hullform geometry. The selected existing vessel and the main dimension can be seen in Table 1 and Table 2, respectively. The linear regression approach is known as the comparison method.

Table 1. The selected existing fish processing vessel

No	TheName of Ship	LPP	B	H	T	VS	GT
1	Beagle F.I.	90.2	14.0	9.0	6.6	16.2	2849
2	Ljubica	75.2	14.4	9.4	6.8	18.0	2749
3	Egalabur	76.6	14.7	9.5	7.0	18.0	2863
4	Euskadi Alai	75.2	14.4	9.4	6.8	18.2	2788
5	Gran Roque	76.6	14.7	9.5	7.0	17.0	2860
6	Itsas Txori	82.3	14.7	9.3	6.5	18.0	2994
7	Izaro	75.2	14.4	9.4	6.8	18.2	2737
8	Jai Alai	75.2	14.4	9.4	6.7	18.2	2788
9	Jocay	76.6	14.7	9.5	7.0	17.0	2838
10	Mar de Sergio	72.0	15.0	9.6	7.0	15.8	2767
11	Montelucia	81.6	15.2	9.8	7.1	17.8	3005
12	Txori Gorri	82.3	14.7	9.3	6.8	18.0	2937
13	Astrid	90.3	14.5	9.0	6.0	15.6	3413
14	Galerna Ii	82.7	15.2	10.0	7.1	18.0	3445
15	Galerna Iii	82.7	15.2	10.0	7.1	18.0	3445

Table 2. The principal dimension of the proposed ship

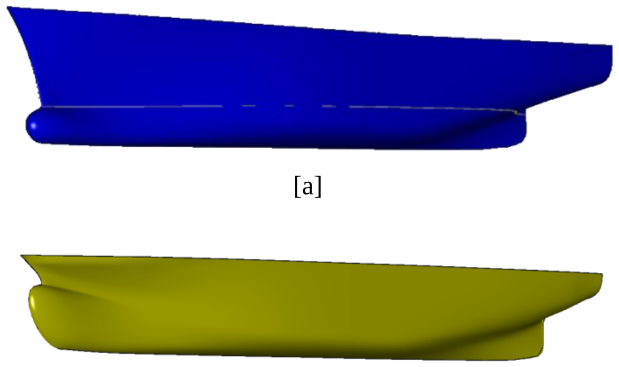
Length overall (LOA)	94.87 m
Length of perpendicular (LPP)	82.89 m
Length of waterline (LWL)	87.03 m
Breadth (B)	14.85 m
Height (H)	9.55 m
Draught (T)	6.76 m
Service Speed (Vs)	17.38 knot
Gross Tonnage (GT)	3200 Ton

Table 3. The configuration of the monohull geometry

NO	Hull series	Cb	LWL (m)	B (m)
1	Hull 1	0,539	90,049	15,544
2	Hull 2	0,549	89,673	15,401
3	Hull 3	0,558	89,264	15,262
4	Hull 4	0,568	88,443	15,126
5	Hull 5	0,578	87,807	14,993
6	Hull 6	0,585	87,118	14,844
7	Hull 7	0,598	86,094	14,740
8	Hull 8	0,614	85,861	14,652
9	Hull 9	0,628	85,245	14,562
10	Hull 10	0,637	84,727	14,481

The next step of the design procedure is exploring the shape of the monohull geometry through the modification of the parent hull form by configuring the block coefficient, the length of waterline, and the breadth of the hull.

The configuration of the hull forms can be seen in Table 3. The illustration of the parent hull form and the modified hullform can be seen on Fig. 4



[a]

[b]

Fig. 4.Illustration of: [a] the parent model hullform; [b] the modified hull form

B. Estimation of the resistance performance by Holtrop Method

The resistance behavior of the vessel is representation of the required force for towing or thrusting the vessel to move in the still water with the constant velocity. In the other words, the vessel needs the power that generates the thrust force as large as the resistance force in the specified service speed. The power that overcomes the resistance force is known as the effective power. The holtrop method was adopted to estimate the resistance of the each configuration of the developed monohull hullform. The formulation of the holtrop method was developed through the experiments study at the Netherland Ship Model Basin, [9]-[13]. The estimation of the resistance performance of the proposed monohull is determined with the maximum service speed of 17.4 knot.

C. Estimation of intact stability and seakeeping performance

The intact stability is the characteristics or ability to return to its initial position and original state when the external load is exerted or removed from the body of vessel. The immersed body of the ship has a buoyancy force as large as the weight of seawater displacement. The equilibrium is achieved when the weight of the ship is equal to the buoyancy force. Therefore the ship displacement is always be adjusted by shifting hull through heaving, trimming and heeling motion to achieved the equilibrium position.

The calculation of the intact stability characteristics is to estimate the ability of the proposed hullform to return to its original position while the external load is acted on the hull. The calculation was made to determine the righting lever arm of the hull which is known as length of GZ, see Fig. 5. The GZ length is influenced by the height of metacenter (the distance of point M to point G). The position of metacenter (point M) is determined by the moment inertia of water plane and the displacement of hull. Since the metacenter is influenced by the hull displacement, the load conditions that represent the deadweight and lightweight of the ship should be determined during the calculation of intact stability analysis. The full cargo load condition with 100% consumables was defined for the intact stability estimation of the proposed hulls.

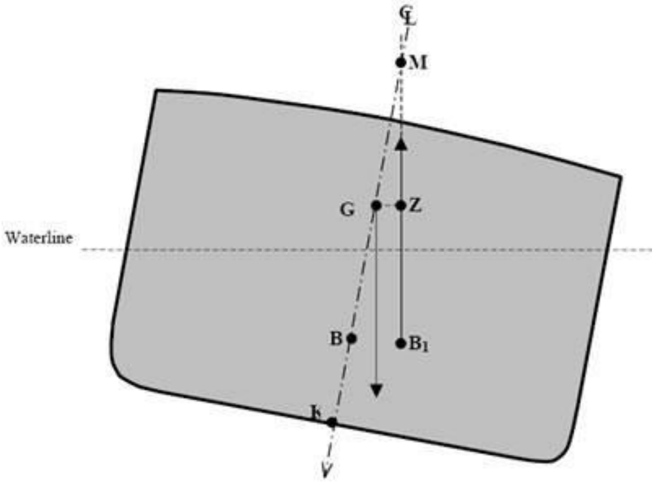


Fig. 5.Illustration of the righting lever arm of ship

In the case of seakeeping behavior, the calculation of the seakeeping performance of the proposed hull forms using the wave and wind characteristics of the fishing ground environment in Indonesia. According to the statistical characteristics, the maximum wave height of the Indonesia waterways which is located about 200 nautical miles from the shoreline is 6.65 m, [14]. However the domestic Indonesia waterways have been divided into the three regions as follow:

1. Region I: domestic waterways with significant wave height less than 1.0 m.
2. Region II: domestic waterways with significant wave height 1 m − 3.5 m.
3. Region III: domestic waterways with significant wave height larger than 3.5 m.

The estimation of the seakeeping behavior was made using the Region III environment. The ITTC wave spectrum was adopted, since the ITTC spectrum is suitable for the sea environment which is located in the inter-islands region. The numerical computation was made with the service speed 17.38 knot. The significant wave height was defined as large as 4 m with the zero crossing periods of 7 seconds. The angle of entrance of the wave is 90 degrees and 180 degrees which are known as Beam Sea and Head Sea condition, respectively.

IV. RESULTS AND DISCUSSION

A. Resistance Performances

Table 4. The proposed hull forms intact stability and IMO Criteria

Criteria	Required	Hull Forms Model									
		1	2	3	4	5	6	7	8	9	10
Area 0º to 30º	3,15 m.deg	25.00	24.63	24.43	23.93	23.60	23.38	22.95	23.04	23.05	23.06
Area 0º to 40º. or Downflooding point	5,16 m.deg	41.47	40.86	40.55	39.75	39.24	38.91	38.27	38.41	38.44	38.51
Area 30º to 40º. or Downflooding point	1,719 m.deg	16.47	16.23	16.13	15.82	15.64	15.54	15.32	15.37	15.39	15.45
GZ at 30º. or greater	0,2 m	2.00	1.98	1.97	1.94	1.92	1.92	1.90	1.90	1.89	1.90
Angle of GZ max	25 deg	62.7	62.7	63.2	63.6	64.1	64.5	64.5	64.1	63.6	63.6
Initial GM	0,15 m	3.58	3.53	3.47	3.42	3.37	3.33	3.27	3.26	3.24	3.22

Based on the results of resistance calculation of the proposed hull forms configurations in Fig. 6, the Hull 1 with block coefficient of 0.539 has shown a smaller resistance than the other hull forms. To reach the maximum service speed of 17.38 knot, the Hull 1 requires a thrust force of 301.534 kN. Otherwise the Hull 10 which have block coefficient of 0.637 has shown the largest resistance with the thrust force of 397.475 kN to generate the same maximum service speed. The wetted surface areas (WSA) have influenced on the resistance of the hulls. Therefore the Hull 1 with the WSA of 1784.97 m^2 has smaller resistance than the Hull 10 which have the WSA of 1839.10 m^2. The larger wetted surface area might generate larger frictional resistance. Instead of the wetted surface area, the hull form block coefficients which represent the slenderness of the hull also influence the resistance performance. The Hull 1 which have smaller block coefficient has shown a smaller drag force compare with the Hull 10. According to the computational results, it is indicated that the lower resistance performance can be achieved by the hull form with the smaller wetted surface area and the smaller block coefficient.

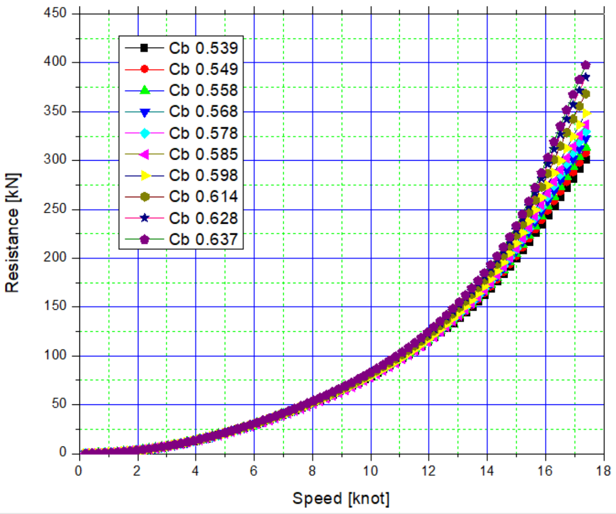


Fig. 6.Resistance characteristics of the proposed monohulls

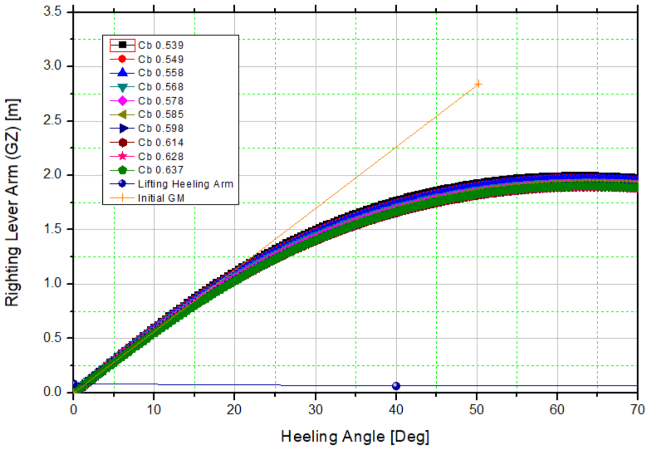


Fig. 7.The stability curves of the proposed monohulls

B. Intact Stability Performances

The intact stability performance is presented on the righting lever arm (GZ) with the variation of heeling angle. The graphics that show the variations of the righting lever arm at the each of heeling angle is known as GZ curve. Comparison of the intact stability performance of the each of proposed hull forms was made by plotting the GZ curves of each hull form models jointly, see Fig. 7.

According to the calculation result, the intact stability of the proposed hull forms have shown positive righting lever arm. In other words, all of the proposed designs have a good stability performance to support the fishing activities and the loading / unloading operation as a mother ship. In the full load condition, all of the proposed hull-forms have complied with the requirement of the IMO stability criteria. The stability characteristics of the proposed hull-forms and the IMO stability criteria can be seen in Table 4.

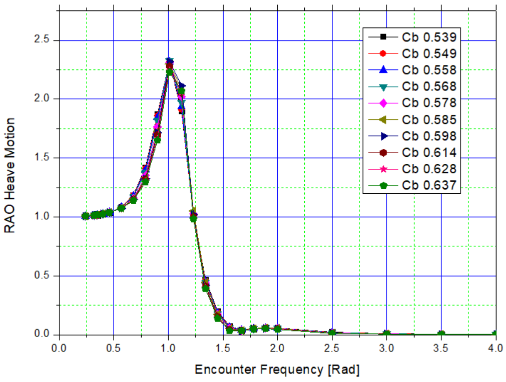
C. Seakeeping Performances

The evaluation of the seakeeping performance of the proposed mono hulls is made using strip theory method. The Response Amplitude Operator (RAO) of each motion of the vessel is the result of numerical computation.

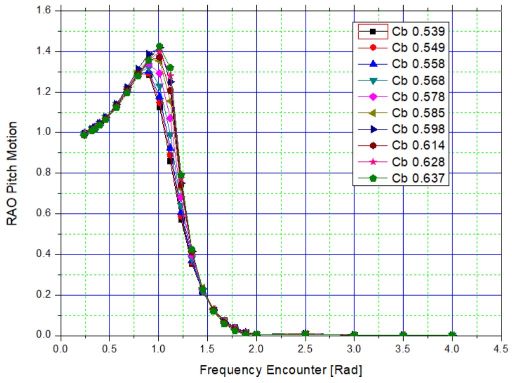
The RAO is the transfer functions which represent the relation of wave spectrums with the motion response of the vessel which is described as ship response spectrum. The characteristics of the motion response of the proposed mono hulls can be identified from the RAO of the each motion on the defined wave heading. The sensitivity of the motion response due to the environmental load as an excitation force can be recognized on the RAO diagram. The RAO of the proposed mono hulls in Head Sea and Beam Sea can be seen in Figure 8 and Figure 9.

According to the calculation results, it can be seen that the motion response of the all of proposed mono hulls is similar, Fig 8 and Fig. 9.

In the case of the wave heading angle of 180 degrees, it can be seen that the generated wave load do not have significant influence to the roll motion. It can be explained that the center of floatation and the center of buoyancy of the vessel is located exactly on the centerline of the symmetrical body of the ship hullform. Therefore the heave motion which is occurred as the response of the head wave was not able to generate the coupling of roll motion. Theoretically, the vertical and longitudinal excitation forces that are generated by the head wave do not have direct influence to the x-axis rotational motion (roll motion).

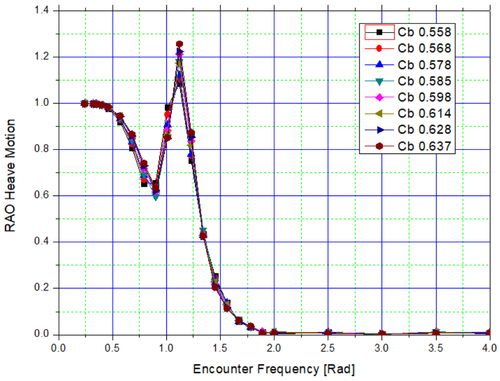


[a]



[b]

Fig. 8.RAO of the proposed monohulls: [a] heave in head sea; [b] pitch in head sea



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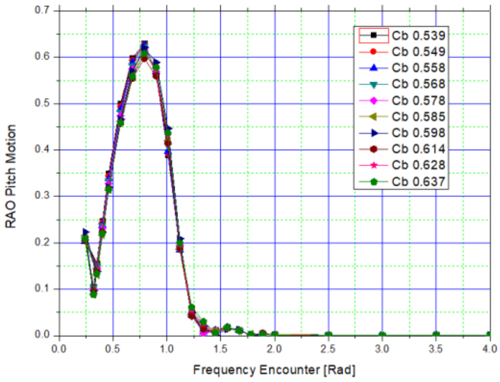

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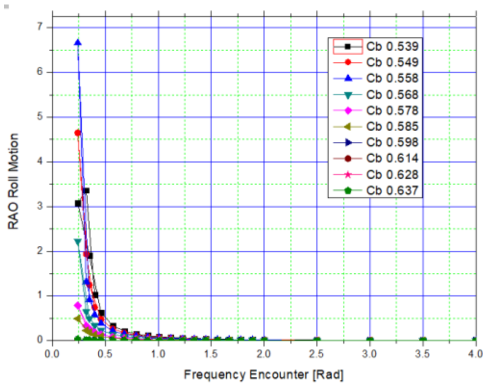

[c]

Fig. 9.RAO of the proposed monohulls: [a] heave in Beam Sea; [b] pitch in Beam Sea; [c] roll in Beam Sea

In the case of the wave heading angle of 90 degrees (Beam Sea), it can be seen that the large response have been shown on the RAO of the roll motion. Otherwise, the RAO diagram of heave and pitch motion have shown the smaller response than the roll motion for all of the proposed mono hulls. It also can be seen that the head wave sea have an influence on the heave and pitch motion. However, the effect of the beam wave on the pitch motion does not show a significant magnitude. Theoretically, it can be explained that the beam wave (the excitation force on the y-axis direction) does not have direct influence on the pitch motion (the y-axis rotational motion). The pitch motion is generated by the pitching lever arm that is appeared while the center of buoyancy is shifted in the heave motion. According to the calculation result, it can be conclude that all of the proposed mono hulls have a larger damping on the heave than the roll motion.

V. CONCLUSIONS

The design of the mono-hull for fish processing vessel was made. The comparison method using linear regression was adopted to determine the main dimension of the hulls. The configuration of hull forms was generated through the variation of the block coefficient and the modification of the hull parent model.

According to the calculation result, the hull forms with the smaller block coefficient have better resistance performance. It can be seen that the slender hull form have significant influence to reduce the hull resistance (drag force). Therefore the “Hull 1” has shown better resistance performance than the “Hull 10”.

On the intact stability performance, all of the proposed hull forms have shown a similar positive righting lever arm and fulfilled the requirements of IMO criteria. Although the “Hull 1” has shown a larger righting lever arm, however the other mono hulls design also acceptable to be adopted for the fish processing hull.

In the case of seakeeping characteristics, the calculation results show that the proposed mono hulls have similar response. The proposed hulls with the larger block coefficient have shown smaller heave motion response and larger pitch motion response, in the head sea condition. Furthermore the larger block coefficient hulls have shown smaller roll motion response and larger heave motion response on the beam sea. It is indicated that the larger block coefficient have shown better roll motion response which is suitable for the offshore loading / unloading activities.

Since the calculation results have shown similar performance, the experimental studies should be conducted for the validation of the calculation result, especially for the smallest block coefficient “Hull 1” and the largest block coefficient “Hull 10”.

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