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Evaluation of Motion Dynamics Characteristics of Fishing Boats in Bengkalis Island

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ABSTRACT

Fishermen in Bengkalis Island tend to choose alternative materials such as fiberglass instead of wooden materials for constructing their ship. The fiberglass is always available, the price is affordable and it is not require many equipments in the process of ship construction. As the fiberglass is lighter than wood, the design of fiberglass fishing boat is need to be evaluated, especially the dynamics of motion of the vessel that determine whether the vessel meets the criteria for the comfort sailing. Prior to the evaluation, the vessel was redrawn and the dynamic motion parameters that were evaluated include the motions of the heave, pitch and roll. There were 4 types of ship that have same capacity (3GT), but they have different main size. Based on the value of heave motion acceleration, it can be concluded that the heave motion meets its criteria because the acceleration of vertical motion is less than 0,315 m/s^2 (< 0.315 m/s^2) and it is categorized as *Not Uncomfortable*. For the roll motion, not all of ships meet the criteria. The value of the roll periods based on the result of evaluation, the closest criteria is vessel-2 because it is in the range of 5.5 to 7.0 seconds. The size of this ship is of 10.23 meters length, 2 meters width, 1.33 meters height and 0.44 meters draft.

Keywords: *Fiberglass, Fishing, Vessel, Wood*

INTRODUCTION

Bengkalis Island consists of two subdistricts which have a great potential in the field of fisheries. Based on the information from the public official website of Bengkalis Regency, according to the Local Medium-Term Development Plan (RPJMD) Bengkalis Regency of 2010-2015 that the two subdistricts in Bengkalis Island will be made as the center of the development of marine fisheries. One of the developments intended is the change of raw material for making the fishing boat from wood to fiberglass. The Fishing boats consist of several types differentiated by *Gross Tonnage* (GT), the capacity of 1GT to 7GT. One vessel with the largest type has the capacity of 3GT with the total number of 160 units (Marine and Fisheries Department of Bengkalis Regency, 2013). The number, may be in several years forward, will be reduced.

There are two influential factors: it is difficult to get the wood base material or there is no longer a development of fishing boat 3GT because the fishermen can't afford to build a fishing boat with other raw materials because it was feared that the price is more expensive. The raw material expected has the greatest likelihood to be applied as a substitute for wood is *Fiberglass Reinforced Plastic* (FRP). The nature of fiberglass that is lighter than wood can be a strong reason why this material is chosen for alternative (Scott, 1996). The weight ratio of wood and fiberglass: for the hull the wood has weight of 20 kg/m^2, while the FRP has weight of 14 kg/m^2 (Fyson, 1985).

With the weight ratio, then viewed from the side of ship displacement it will be more advantageous so that it will also affect the ship barriers that may be smaller and will be useful in the selection of the ship's main engine power. To see the effect more clearly, it is essentially evaluated to the wood ship 3GT available at this time in advance in order that it may be obtained the characteristic comparison of the wood-based fishing boat to the FRP-based fishing boat. The characteristics include displacement, barriers, as well as the ship stability and the ship motion dynamics. The evaluation of these characteristics is to get the 3GT-type fishing boat with the size fulfilling the criteria to obtain the primary size of 3GT fishing boat that can be input in the construction of fiberglass fishing boat in the future.

MATERIALS AND METHODS

When the ship is sailing, it will interact with the wave, current and air. As a result of the various sea states, they will affect the emergence of motions and a number of structural responses (Djatmiko, 2012). In order find out some information on the characteristics of motions, it is provided graphically with the abscissa in the form of frequency parameter. While the ordinate is in the form of the ratio of the certain motion amplitude such as heave, pitch, and roll to the wave amplitude called *Response Amplitude Operator* (RAO). The ship to be seen characteristically consists of 4 types with the same capacity of 3GT but with the different main sizes. As for the data of the ships are as follows:

Table 1. Main dimension of ship to be evaluated

No	Name of Ship	Length (m)	Breadth (m)	Depth (m)	Draft (m)
1	Ship-1	10,20	2,20	1,76	0,40
2	Ship-2	10,23	2,00	1,33	0,44
3	Ship-3	10,97	1,93	1,69	0,49
4	Ship-4	10,62	2,10	2,00	0,37

Evaluations of characteristics will be conducted using the software with the following several data inputs:

Determinations of height and wave period refer to the provisions of sea state contained in the World Meteorological Organization (WMO) of 2002 have approved the code standard of sea state, then the waters region of Bengkalis Island is categorized in the Sea State 2 with Significant Wave Height of 0.1 to 0.5 with the period of 12 Sec.

After knowing the information concerning the data inputs above, each vessel models will be tested in *seakeeping* by using software Maxsurf-Seakeeper. The resulting output can be concluded with several comparisons of frequency variable, motion amplitude, speed and heading. The motions to be seen are *heave, pitch* and *roll*.

Table 2. Data inputs

No	Data Input	Ship-1		Ship-2		Ship-3		Ship-4	
		Wood	FRP	Wood	FRP	Wood	FRP	Wood	FRP
1	Maxsimum draft (meter)	4,21	0,45	4,71	0,46	4,42	0,56	4,45	0,56
2	Number of mapped sections	41							
3	Vessel type	Monohull							
4	Environment	1025 Tonne/m^3							
5	Spectra	ITTC							
	a. Char height	0,5 meter							
	b. Modal periode	12 Second							
6	Headings	0^0, 45^0, 90^0, 135^0, 180^0							
7	Speed	0 Knot, 7 Knot, 12 Knot							

Table 3. Sea state WMO, 2002

Sea state code	Significant wave height Range (m)	Description	Periode (s)
0	0	Calm (glassy)	10
1	0,0 - 0,1	Calm (glassy)	11
2	0,1 - 0,5	Smooth (wavelets)	12
3	0,5 - 1,25	Sligth	13
4	1,25 - 4,0	Moderate	14
5	2,5 - 4,0	Rough	5
6	4,0 - 6,0	Very rough	6
7	6,0 9,0	High	7
8	9,0 - 14,0	Very high	8
9	Over 14,0	Phenomenal	9

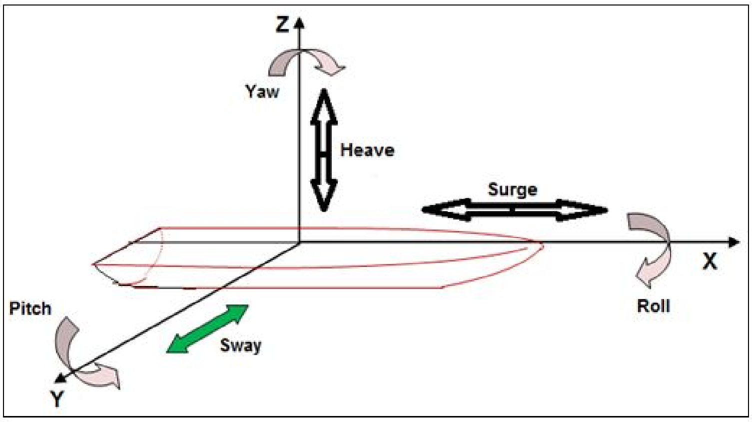

Figure 1: Direction of vessel motion viewed from the axis

Equation of motion dynamics can be described through the pressure on the whole hull integrated, and then it will be obtained a hydrodynamic force on the hull. Based on the hydrodynamic force, the linear motion in six degrees of freedom will be obtained in the form of *response amplitude operator* (RAO). RAO is calculated first by solving the equation of motion at each frequency and then displayed in the diagram of functional transfer. The equation of RAO in the functional frequency is:

$$RAO(\omega) = \left(\frac{\xi_a}{\zeta_a}\right)^2$$

Where;

ξ_a : Structural amplitude

ζ_a : Wave amplitude

The general equation in calculating the vessel motion is the following:

$$a\ddot{z} + b\dot{z} + cz = F_0 Cos\omega_e t$$

The explanation of equation above is the *heaving* motion and called as *forced heaving motion*. Whereas for other translational motions, the equation can be applied to alter the motion axis to *x* or *y* where *a* is *virtual mass* (vessel period coupled with *added mass*), *b* is *damping* coefficient (a force against the motion direction), *c* is coefficient of *restoring force* (a force returning to the point of balance) and *Fo* is *existing force* or *encountering* force or external force acting on an object when the vessel is in the calm water condition, so the value of *Fo* is zero (Bhattacharyya, 1978). For another motion, that is rotational motion, the basic equation used remains the same but only changing the translational motion variable, the distance to be angle and the force to be moment as written in the pitching equation below. The *rolling* equation is also the same, but because its rotational axis is different from the *pitching*, the angle *θ* is replaced by ϕ.

$$a\frac{d^2\theta}{dt^2} + b\frac{d\theta}{dt} + c\theta = M_0 \mathrm{Cos}\omega_e t$$

where:

a	: inertial moment	b	: damping moment
c	: restoring moment	Mo	: existing moment

In order to determine a vessel's RAO, then it will use *software maxsurf-Seakeeper*. At this *software*, in order to influence the motion response, the vessel will be divided into several stations or strips. The response occurring at each station will integrated to the vessel's longitudinal direction to obtain an overall output and this method may be called a strip theory (Kornev, 2012). The strip theory method is very suitable to be used for the 3GT fishing boat, because principally this theory can be used to the vessel in the form of *slender body*, *monohull* with the ratio of the length to width is L/B>3 (Kornev, 2011). The seakeeping has the comfort criteria aiming to establish the favorable conditions for those who are on board where there are various motions when sailing. As described by Riola & Garcia de Arboleya (2006) concerning the instructions on the ability of personnel activities associated with the acceleration of vertical motion.

Table 4. The relationships of vertical acceleration and comfort (*Source: Riola & Garcia de Arboleya, 2006*)

Velocity	*Remarks*
< 0.315 m/sec^2	*Not Uncomfortable*
0.315 – 0.63	*A little Uncomfortable*
0.5 – 1.0	*Fairly Uncomfortable*
0.8 – 1.6	*Uncomfortable*
1.25 – 2.5	*Very Uncomfortable*
> 2.0 m/sec^2	*Extremely Uncomfortable*

In order to identify the comfort level for those who were on the ship to the seakeeping of a ship it can be determined based on the acceleration of the motions of *heave, roll* and *pitch*. The acceleration of the 3GT-type vessel's motion consists of *Heave* (m/s^2), *Roll* (rad/s), and *Pitch* (rad/s). It is essentially to note that in this research the comfort criteria the seakeeping for *heave* motion it refers to the criteria of Riola & Garcia de Arboleya (2006) where the criteria for the vertical motion acceleration. Whereas for the *seakeeping* comfort criteria of *roll* motion that has been established by Bhattacharyya (1978), where it has been recommended the *roll periods* for the fishing boat is 5.5 to 7.0. While for the seakeeping comfort criteria of *pitch* motion it has been not yet found a recommendation on the appropriate criteria for the type of fishing boat. The table 5.6 below is displayed the value of heave motion acceleration for each vessel obtained from the result of *maxsurf-Seakeeper*.

Table 5. The Periode of Rolling Motion (Bhattacharyya, 1978)

Types of Ships	T (second)
Passenger	20 – 25
Cargo-Passenger	10.5 – 14.5
Cargo	9 – 13
Tanker	9 – 10
Fishing Boat	5.5 – 7.0
Whale Boat	9 – 11.5
Battleship	14.5 – 17.0
Cruiser	12.0 – 13.0
Destroyer	9 – 9.5
Torpedo Boat	7 – 7.5

Based on the value of heave motion acceleration as shown above, it can be concluded that the heave motion meets the criteria of Riola & Garcia de Arboleya (2006) because the acceleration of vertical motion is in the condition of less than 0.315 m/s^2 (< 0.315 m/s^2) with status *Not Uncomfortable*. However, it should be seen further, whether this 3GT-type fishing boat categorized in the type of comfortable vessel (*Not Uncomfortable*) or uncomfortable. This needs to be clarified again because the conclusion that this 3GT fishing boat meets the criteria of heave motion when the fishing boat has been categorized in the type of *Not Uncomfortable* vessel. In order to identify whether the *roll* motion meets the criteria or not, then the following will be displayed in Table.7 the value of roll motion period in seconds based on the results of calculation for *maxsurf-Seakeeper*.

Table 6. The Ship's Heave Motion Acceleration

No	Ship	Speed (Knot)	Draft (m)	0^0	45^0	90^0	135^0	180^0
1	Ship-1	0	0,36	0,082 m/s^2	0,088 m/s^2	0,106 m/s^2	0,086 m/s^2	0,081 m/s^2
			0,45	0,081 m/s^2	0,086 m/s^2	0,105 m/s^2	0,085 m/s^2	0,08 m/s^2
		8	0,36	0,028 m/s^2	0,037 m/s^2	0,093 m/s^2	0,212 m/s^2	0,261 m/s^2
			0,45	0,028 m/s^2	0,037 m/s^2	0,092 m/s^2	0,21 m/s^2	0,257 m/s^2
2	Ship-2	0	0,38	0,08 m/s^2	0,087 m/s^2	0,109 m/s^2	0,084 m/s^2	0,077 m/s^2
			0,46	0,08 m/s^2	0,086 m/s^2	0,109 m/s^2	0,084 m/s^2	0,077 m/s^2
		8	0,38	0,029 m/s^2	0,037 m/s^2	0,093 m/s^2	0,197 m/s^2	0,235 m/s^2
			0,46	0,029 m/s^2	0,037 m/s^2	0,094 m/s^2	0,196 m/s^2	0,235 m/s^2
3	Ship-3	0	0,45	0,082 m/s^2	0,089 m/s^2	0,11 m/s^2	0,086 m/s^2	0,08 m/s^2
			0,56	0,08 m/s^2	0,086 m/s^2	0,109 m/s^2	0,085 m/s^2	0,079 m/s^2
		8	0,45	0,028 m/s^2	0,037 m/s^2	0,1 m/s^2	0.226 m/s^2	0,275 m/s^2
			0,56	0,027 m/s^2	0,037 m/s^2	0,098 m/s^2	0.226 m/s^2	0,275 m/s^2
4	Ship-4	0	0,45	0,087 m/s^2	0,092 m/s^2	0,109 m/s^2	0,088 m/s^2	0,083 m/s^2
			0,56	0,082 m/s^2	0,08 m/s^2	0,106 m/s^2	0,086 m/s^2	0,081 m/s^2
		8	0,45	0,028 m/s^2	0,037 m/s^2	0,098 m/s^2	0,229 m/s^2	0,282 m/s^2
			0,56	0,028 m/s^2	0,037 m/s^2	0,097 m/s^2	0,229 m/s^2	0,282 m/s^2

Based on Table 7, it appears that not all of the vessel-1, vessel-2, vessel-3 and vessel-4 meet the criteria for the comfort of roll motion. Based on the criteria of roll periods, it is known that the comfortable vessel viewed from the roll motion is in the range of 5.5 to 7.0 seconds. For the value of *roll periods* based Table.7 the closest to the criteria is vessel-2. So, it can be concluded that the most comfortable vessel among all 3GT-type vessels evaluated in this study is the vessel-2. In the previous studies on the effects of changes in payload on the vessel stability, the vessel-2 is the largest vessel being able to increase the payload as compared to other 3 vessels (Nurhasanah, 2014).

Table 7. Rolling Periode

No	Name of Ship	Speed	Draft	0^0	45^0	90^0	135^0	180^0
1	Ship-1	0	0,36	6,87 Sec	7,36 Sec	7,72 Sec	7,96 Sec	7,32 Sec
			0,45	6,75 Sec	6,97 Sec	7,25 Sec	7,58 Sec	7,21 Sec
		8	0,36	6,95 Sec	7,18 Sec	7,99 Sec	8,32 Sec	7,93 Sec
			0,45	6,64 Sec	7,03 Sec	8,36 Sec	8,87 Sec	8,66 Sec
2	Ship-2	0	0,38	6,18 Sec	6,70 Sec	7,01 Sec	7,33 Sec	6,57 Sec
			0,46	5,06 Sec	5,33 Sec	6,84 Sec	6,32 Sec	5,97 Sec
		8	0,38	6,65 Sec	6,93 Sec	7,21 Sec	7,04 Sec	7,48 Sec
			0,46	6,87 Sec	7,07 Sec	7,48 Sec	7,51 Sec	6,95 Sec
3	Ship-3	0	0,45	7,61 Sec	7,86 Sec	8,31 Sec	8,57 Sec	8,22 Sec
			0,56	7,44 Sec	7,77 Sec	8,08 Sec	8,26 Sec	8,68 Sec
		8	0,45	7,93 Sec	8,32 Sec	8,81 Sec	8,89 Sec	9,43 Sec
			0,56	7,61 Sec	7,96 Sec	8,67 Sec	8,89 Sec	8,69 Sec
4	Ship-4	0	0,45	7,06 Sec	7,44 Sec	7,93 Sec	8,07 Sec	7,97 Sec
			0,56	6,82 Sec	7,08 Sec	7,54 Sec	7,87 Sec	7,51 Sec
		8	0,45	7,19 Sec	7,57 Sec	8,65 Sec	8,99 Sec	8,54 Sec
			0,56	7,43 Sec	7,43 Sec	8,41 Sec	8,66 Sec	8,06 Sec

CONSLUSION AND RECOMENDATION

Based on the comfort criteria of motion dynamics by Riola & Garcia de Arboleya (2006) because the acceleration of vertical motion in a state of less than 0.315 m/s^2 for *heave* motions and the criteria by Bhattacharyya (1978) in which it has been recommended that the *roll periods* for the fishing boats are in the range of 5.5 to 7.0 seconds, it can be concluded that the vessels fulfilling the criteria of *heave* and *roll* motions are vessel-2 with the length of 10.23 meters, the width of 2 meters, the height of 1.33 meters and the loaded of 0.44 meters. However, it is essentially recommended that in order to choose which the vessel design is most proper to be made a reference in the manufacture of fishing boat FRP 3GT, then it can reconsider the total of payload, obstacles, and the dynamics of each vessel's motion.

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