Dynamics study of proof jigging ship due to changes in hull geometry

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Abstract. Speedboats that serve the Bengkalis-Pekanbaru route continue to suffer losses because there are no passengers, so they have to stop operations. For this reason, development is carried out by changing the function of ships from passenger ships to cargo ships by modifying several ship hull geometries. changes made to the hull changed some dimensions and ratios of the ship. Dynamics study due to changes in the main size of the vessel uses seakeeper numerical simulation. The evaluated hull model has a size of 19.7 meters, width of 3.6 meters, height of 2.21 meters and draft of 1,135 meters. With a computer-based method to evaluate the motion of the ship, Evaluation results from hull model at 0 knots speed maximum RAO heave is in heading 90 degree with an amplitude of 1,206 m, RAO roll motion is heading 90 degree with an amplitude of 6.642 degree and RAO pitch motion heading 0 degree with an amplitude of 1.203 degree. At speed 20 knots the maximum RAO heave motion is heading 180 degree with an amplitude of 2.058 m, RAO roll is heading 90 degree with an amplitude of 6.684 degree and RAO pitch motion is heading 0 degree with an amplitude of 1.884 degree.

1. Introduction

Every object that floats in the water will experience oscillation. This oscillation motion is defined as the alternating motion of objects around the equilibrium point with the same trajectory and occurs periodically which is repeated in the same time span. Ship seakeeping operability refers to the quantification of motion performance in waves relative to mission requirements [1]. The design of the ship's hull is important in making the ship because it will affect the movement of the ship, ship speed, fuel consumption, draft needed in relation to the port waters that will be visited as well as the depth of the shipping path that is passed by the ship [2]. The seakeeping performance of the ship's design is very closely related to the type, size and shape of the ship's hull. Likewise, ships that are on the surface of water which the ship has criteria related to the principal dimension and the shape of the hull, then the speed and load of the ship greatly affect the performance of the ship when it is above the wave. Likewise, the characteristics of waves consisting of height and period and direction of wave propagation greatly determine the motion response of the ship. Several wave properties, such as various wavelengths and wave heights on heaving and pitching performances associated with different Froude number (Fr). increase of Fr was proportional with the increase the heaving and pitching motions. These led to the downgrade seakeeping performances presented in the form of high Response Amplitude Operators (RAO). In shorter wavelengths ($\lambda<1$), RAO of the heave and pitch motions were insignificant. However, the subsequent increase of wavelength ($\lambda>1$) was proportional with the increased RAO of the heave and pitch motions. The further increase in wavelength (>1.75) resulted in less RAO both of the heave and pitch motions. The increase in wave height had affected a proportionate increase in the heave and pitch motions that may possibly lead to degrade her seakeeping quality. It can be concluded that the effects of Fr and wavelength on the heave and pitch motions of the monotricat ship had more complex phenomenon as compared to the wave-height ones [3].

The evaluation of seakeeping performance of a ship largely depends on the environmental conditions and defined criteria and this is the main reason that any comparison related to the ship speeds, the influence of heading angles, loading conditions, etc. is a complex problem [4]. Response to motion such as roll, pitch and heave will ultimately affect the comfort and safety of passengers. The function of to shift ship from a passenger ship to a cargo ship by modifying its hull shape so that the performance will also change. A change in the shape stern of the speed boat can improve L / B in the amount of 1.2%, the increase in the L / B ratio can affect the ability to move and stability of the ship [5]. Recently, computer-based methods can be used to study the effects of variations in size, proportion and shape of the hull in the majority movement. Programmed design relies on two prerequisites. The first one is a product model with a variety of types large enough to face the modelling of any type of ship. The second one is a design language dedicated to create the product model [6].

Computational tools have been developed that can predict with a reasonable degree of accuracy the various levels of motion of ships in certain marine environments. In this study the evaluation was related to the performance of the ship that has been modified using the maxsurf seakeeper program to find out the value of ship's driving characteristics such as RAO heave motion, RAO roll and RAO pitch.

2. Hull

Hull form parameters have been classified into two groups: main dimensions (L, B and T) and secondary form parameters (LCB and CP) [7]. The shape of the hull is very influential on the pattern of water flow when operating. The hull provides buoyancy which prevents the ship from sinking, which is designed to be as small as possible to cause friction with water, especially for ships at high speed. The hull shape is widely used outside of the recreational boat industry by builders who want a fast and efficient hull. Ship building design is important in making the ship because it is the basis for calculating ship stability, the size of vessel resistance which certainly has an impact on the design ship speed, fuel consumption, engine power and load to calculate the depth needed in relation to port. In order to obtain a hull form which exhibits low resistance and highly-efficient energy-saving performance, the overall resistance should be calculated as the sum of wave-making and viscous resistance, in which the total resistance corresponds to the objective function whereas the hull geometry parameters correspond to design variables [8]. To modify an existing hull form shape, a boundary curve of the shape is selected as a design variable. A parametric piece wise polynomial curve satisfying new geometric requirements is constructed and super imposed on the top of the chosen boundary curve to yield the desired shape [9]. That will be visited as well as the depth of the shipping channel that is passed by the ship. The hull has dimensions so that it forms a planned ship model. The general dimensions or sizes on the ship consist of:

- The length of ship: Length over all is the overall length of the ship measured from the tip of the stern to the end of the bow. Length of water line is the horizontal distance between the end of the load line (water line), which is measured from the intersection with the stern height to the point of intersection with the bow and measured on the outer part of the stern and the bow. Length between perpendiculars is the size of the ship, the length between the two stern upright lines and the straight line measured on the load water line. Stern upright line (After perpendicular) the location is at the height of the rear steering wheel or on the axis of the steering shaft. Straight line (fore perpendicular) is the intersection between the height of the bow and the line of loading water.
- Ship width: Breadth (planned width) is the horizontal distance from the middle body measured on the outside of the body. (Not including hull plate thickness). Breadth of water line (width on the load water line) is the largest width measured on the ship's waterline. Breathing over all (maximum width)

is the largest width of the ship measured from the skin of the ship's hull beside the left to the skin of the hull of the right side of the ship.

- Ship Height (H) or Depth (D): Lowest height of the deck is the upright distance from the base line to the lowest deck line, generally measured in the middle of the length of the ship.
- Ship draft planned (T): It is the upright distance from the baseline to the load water line.
- Freeboard (Fb): It is a vertical distance from the full load line (full load water line) until the deck line on the hull emerges (free board deck line).
- Block coefficient (Cb): It is a comparison between the contents of the volume displacement with the contents of a beam that is limited by length L, width B and height laden T.
- Displacement: It is a term commonly used on ships to declare the weight of the ship in tons. Determination of displacement is very important in ship planning because it has a relationship with the shape and weight of the ship. Some terms that are often used on board include: the weight of the ship and all its contents (Displacement), the weight of an empty ship, which is the weight of a ship consisting of a ship's body, ship engines, equipment and a ship (Light Displacement), the weight of the ship as a whole when the ship sinks to the maximum draft allowed (Loaded Displacement), Load displacement = Light Displacement + DWT, The ability of ships to be loaded with loads such as cargo, fresh water, fuel, supplies, oil, passengers, crew and others (Dead Weight Tonnage (DWT)) and DWT = Operating Load + Cargo Operating load which is the weight of the equipment and tools to operate the ship in which without this tool the ship cannot sail.

3. Ship dynamics

3.1. Ships motion

Ship dynamics are the ability to respond to a ship's motion in waves. The dynamic behaviour of a damaged hull is a complex phenomenon involving the interaction of the flooded water and the ship motions [10]. In ship planning, the quality of the ship's performance is a part that explains the conditions in which the ship is tilted or sunk at each wave condition can be known for certain even in extreme conditions. Basically, a ship that is above sea level will always get an external force that causes the ship to move. The movement of the ship is due to the existence of 3 areas from the outside, mainly by waves. In obtaining treatment and waves the ship experiences 2 types of movements, namely rotation and translation movements. Rotational movements are rotational movements including rolling, pitching and yawing. Ship roll motion has been the subject of many studies, because of the complexities associated with this mode of ship motion, and its impact on operability, safety, and survivability. Estimation and prediction of the energy transfer and dissipation of the hydrodynamic components, added inertia and damping, is essential to accurately describe the roll motions of a ship. This is especially true for ship operations in moderate to extreme sea conditions. In these conditions, a complex process of energy transfer occurs, which alters the physical behaviour of the hydrodynamic components, and ultimately affects the amplitude of ship roll motion [11]. Roll and pitch criteria are most critical for seakeeping performance, and there is a significant influence of the transverse metacentric height, GMt, and the location of the reference checking points in the seakeeping performance [12]. Translation movement is a regular straight motion in accordance with its axis including surging, swaying and heaving.

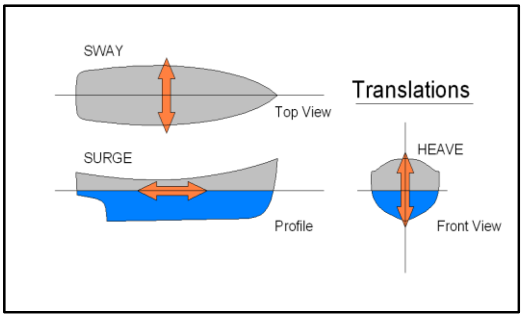

Figure 1. Rotation movement.

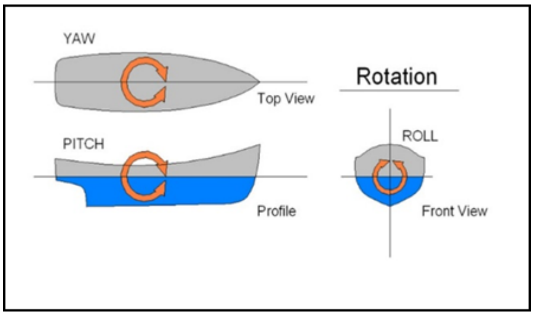

Figure 2. Translation movement.

3.1.1. Heave motion. Heave motion is a linear (up and down) motion of the ship in the direction of the Z axis, the general equation of the ship in heaving conditions [13]:

$$a\ddot{z} + b\dot{z} + cz = \dot{F}_o \cos\omega_e t \tag{1}$$

Inertial Force $F_a = -a\ddot{z}$
Damping Force $F_b = b\dot{z}$
Restoring Force $F_c = cz$
Exciting Force $F_a = F_o \cos\omega_e t$

3.1.2. Roll motion. The rolling movement is a movement of the ship left and right. General equation of the ship in rolling conditions [13]:

$$a\frac{d^2\emptyset}{dt^2} + a\frac{d\emptyset}{dt} + c\emptyset = M_o \cos \omega_e t \tag{2}$$

Inertial Moment $a\frac{d^2\emptyset}{dt^2}$
Damping Moment $a\frac{d\emptyset}{dt}$
Restoring moment $c\emptyset$
Exciting moment $M_o \cos \omega_e t$

3.1.3. Pitch motion. Pitch motion is movement that extends the ship with the direction of the Y axis, in the form of a nod from the stern to the bow or vice versa. The general equation of the ship in pitching conditions [13]

$$d\ddot{\theta} + e\dot{\theta} + h\theta = M_o \cos \omega_e t \tag{3}$$

Inertial Moment $d\frac{d^2\theta}{dt^2}$
Damping Moment $e\frac{d\theta}{dt}$
Restoring moment $h\theta$
Exciting moment $M_o \cos \omega_e t$

The ship's motion response to regular waves is expressed in RAO (Response Amplitude Operator), where RAO is the ratio between the amplitude of the ship's motion (both translation and rotation) to wave amplitude at a certain frequency. RAO for translational motion is a direct comparison between the amplitude of the ship's movement and the amplitude of the waves both in units of length. While the rotational motion is the ratio between the amplitude of the rotational motion (in radians) to the slope of the wave.

3.2. Wave spectrum
Wave statistics at sea can be used to determine the limits of wave height, periods and directions that might be encountered for a certain period of time. This is a way to determine how many days a year the

vessel is experiencing certain wave conditions and it can be represented by a wave spectrum that is approaching, for example by adopting the suggested formulation of the JONSWAP (Joint North Sea Wave Project). Wave conditions are indicated by significant wave height (Hs) and spectral peak period (Tp). The spectrum density of the process of increasing sea conditions can be represented by the JONSWAP spectrum. The spectrum suitable for shallow water, coastal waters and closed waters is the JONSWAP spectrum. The following is the JONSWAP formula [13]

$$S(\omega) = \alpha g^2.\omega^{-5}.exp\left\{-1{,}25\left[\frac{\omega}{\omega_o}\right]^{-4}\right\}.\gamma^{exp\left\{\frac{-(\omega-\omega_o)^2}{2\tau^2\omega_0^2}\right\}} \tag{4}$$

Where :

S(ω) = wave spectrum
= peak parameter
= shape parameter
for $\omega \leq \omega_o$ = 0, 07 and $\omega \geq \omega_o$ = 0,09.
α = 0.0076 $(X_o)^{-0{,}22}$, for X_0 unknown
α = 0.0081

4. Results and discussion

4.1. Ship model

The ship that was used as the object of research was the Proof Jigging vessel which operated in the Bengkalis waters area, the Proof jigging vessel was a vessel that switched functions from passenger ships to cargo ships by modifying the shape of the hull. During the process of building this ship, it has not predicted the performance of the ship so that this research is related to evaluating the movement of the ship so that it can be used as a reference for ship owners in the operation later. where the ship is carried out dimensional measurements and redrawing to get the shape of the ship's hull model. The main data size of the Jigging Proof vessel can be seen in Table 1.

Table 1. Principal dimension.

Item	Size	Unit
Length LPP	19.7	meter
Width (B)	3.6	meter
Deck Height(H)	2.21	meter
Draught (T)	1.13	meter

Based on the size of the ship as in Table 1, the process of drawing the hull model of the ship is similar to that of the original ship in the field. The results of the depiction of the ship's hull model can be seen in Figure 3. From the hull model that has been described then a shipbuilding evaluation is carried out to obtain the motion criteria for the hull model.

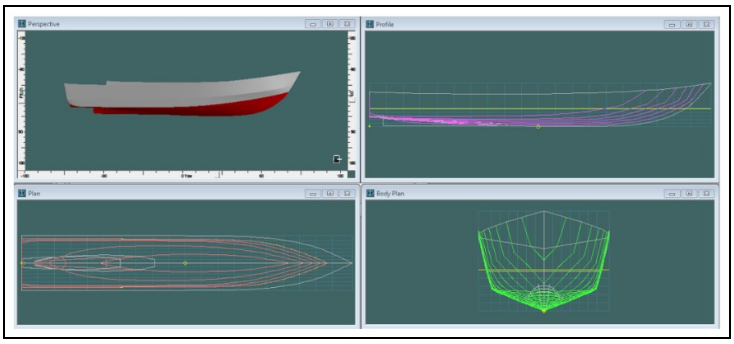

Figure 3. Ship's hull model.

4.2. Dynamic of the hull model

From the model of the ship's hull that was redrawn, a seakeeping simulation was carried out using seakeeper software with an operating area in Bengkalis waters so that the simulation waveforms were adjusted to the area of operation of the ship. The seakeeping evaluation on the jigging Proof hull model is carried out in a stationary condition, which is at a speed of 0 knots and the operating condition of the ship is at a speed of 20 knots. Evaluation of ship motion is done by using the maxsurf program, in evaluating the hull model of the ship required some input data, some data obtained from hydrostatic properties computation and field conditions. The input data needed is as follows.

Table 2. Input data program maxsurf-seakeeper.

No	Input Data	HPC
1	Maximum Draft	1.135
2	Number of mapped sections	91
3	Vessel type	Monohull
4	Spectra	JONSWAP
	a. Char. Height	0.5 m – 2 m
	b. Modal periodic	10 s
5	Heading	0°, 45°, 90°, 135°, and 180°
6	Speed	0 knot, 20 knots

To determine the height and period of the waves referring to the provisions of the sea state contained in the 2002 World Meteorological Organization (WMO) agree to the sea state standard code, the Riau Islands waters region has a range of 1.45 seconds to 16.45 seconds and the Hs range between 0.245 m to 5.745 m classified as Sea State 2 - 6 m. For more details, see Table 3:

Table 3. Sea state WMO, 2002.

Sea state code	Significant wave height	Description range (m)	Period (s)
0	0	Calm (glassy)	10
1	0.0 – 0.1	Calm (glassy)	11
2	0.1 – 0.5	Smooth (wavelest)	12
3	0.5 – 1.25	Slight	13
4	1.25 – 2.5	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

4.2.1. Motion evaluate at the speed 0 knots. After knowing the data input information, the ship's motion evaluation was carried out with the maxsurf-seakeeper program. The resulting output can be concluded with several comparisons of frequency variables, movement amplitude, speed and headings. As one of the outputs of RAO for each station one of the RAO tables was taken on the model at 0 Knots and angle headings 0°, 45°, 90°, 135° and 180°. From the results of the RAO table it was converted into an amplitude graph as shown in Figure 4 - 6.

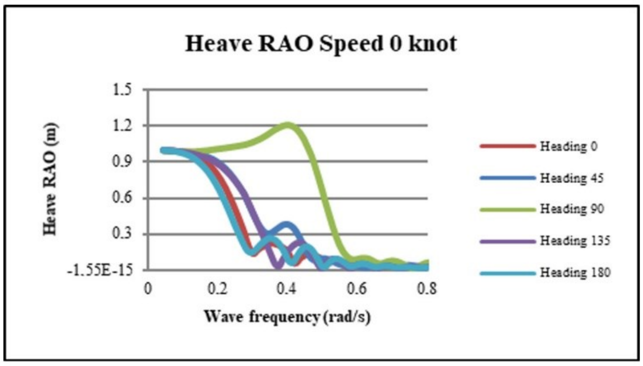

Figure 4. Heave RAO motion at speed 0 knot.

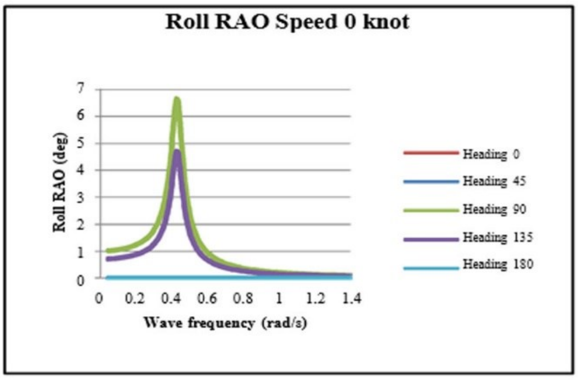

Figure 5. Roll RAO motion at speed 0 knot.

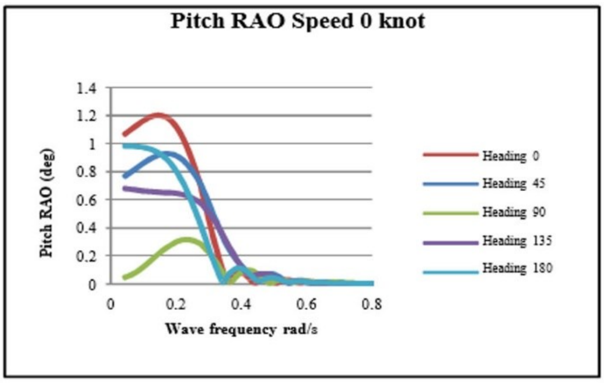

Figure 6. Pitch RAO motion at speed 0 knot.

In Figure 4-6 is a graph of the output of the motion of the ship model, namely the RAO heave movement, RAO roll and RAO pitch at a speed of 0 knots with 5 headings. At each movement the amplitude has the maximum value generated from the hull model that receives interference from outside in the form of waves that come towards the ship. from the evaluation results using the maxsurf-seakeeper program, the maximum value of the movement of the ship model amplitude at 0 knots is for the RAO heave movement in heading 90° with an amplitude of 1,206 m, the RAO roll is in heading 90° with an amplitude of 6.642 degree and RAO pitch movement is on heading 0° with an amplitude value of 1.203 degree. For more details the value of the amplitude of movement can be seen in Table 4.

Table 4. The maximum amplitude value of the ship model is at 0 knots.

Wave heading (deg)	Heave RAO (m)	Roll RAO (deg)	Pitch RAO (deg)
0	0.992	0	1.203
45	0.998	4.312	0.929
90	1.206	6.642	0.315
135	0.994	4.312	0.681
180	0.992	0	0.983

4.2.2. Motion evaluate at the speed 20 knots. Movement Evaluation at Speed of 20 knots at a speed of 20 knots, the output from RAO for each station is taken from one RAO table at angle headings 0°, 45°, 90°, 135° and 180°. Amplitude graphs for speeds of 20 knots can be seen in Figure 7-9.

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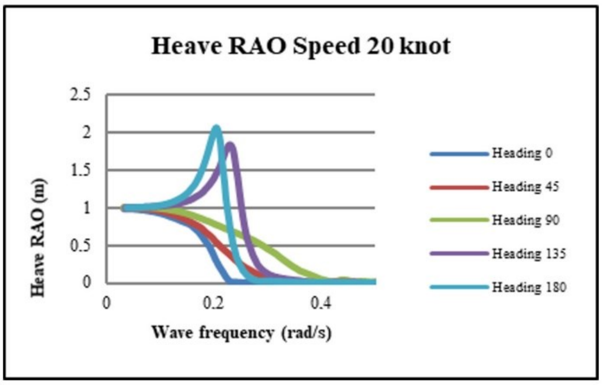

Figure 7. Heave RAO motion at speed 20 knot.

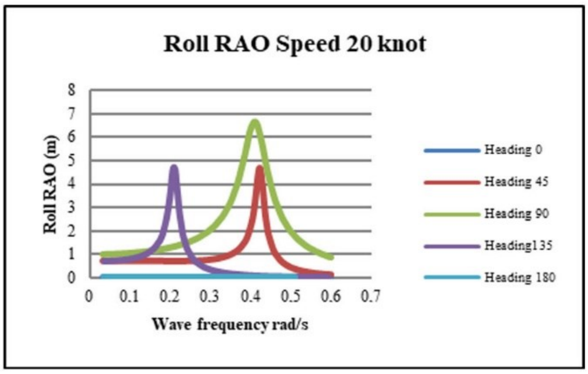

Figure 8. Roll RAO motion at speed 20 knot.

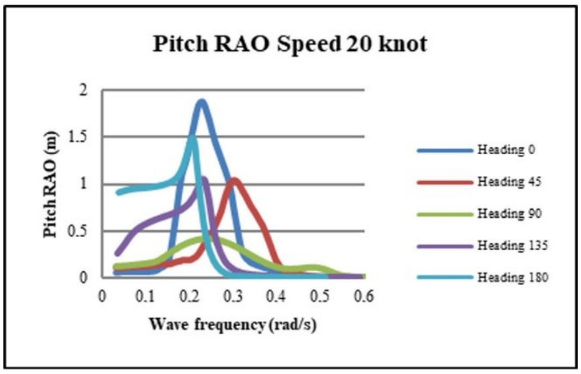

Figure 9. Pitch RAO motion at speed 20 knot.

In Figure 7-9 is a graph of the output of the motion of the ship model, namely the RAO heave movement, RAO roll and RAO pitch at a speed of 20 knots with 5 headings. At a speed of 20 knots, the maximum value of the motion amplitude of the ship model is for the RAO heave movement in heading 180° with an amplitude of 2.058 m, the RAO roll motion is in the heading 90° with an amplitude of 6.684 degree and a pitch RAO in heading 0 degree with a value amplitude of 1.884 degree. For more details the value of the amplitude of movement can be seen in Table 5.

Table 5. The amplitude value of the ship model at speed of 20 knots.

Wave heading (degree)	Heave RAO (m)	Roll RAO (degree)	Pitch RAO (degree)
0	1.003	0	1.884
45	1.003	4.716	1.038
90	1.033	6.684	0.42
135	1.838	4.606	1.146
180	2.058	0	1.502

4.3. Wave spectrum response

The shape of the ocean wave spectrum can be known through wave period data. By formulating wave frequency data that can be calculated from the wave period into each spectral density function, the peak period of the spectrum can be obtained. Through wave equations that give a relationship between wavelength and a wave period, the wavelength during the peak wave period is obtained. Evaluation of wave spectrum of ship models produces output from the spectrum for each station taken one of the wave spectrum tables at angle headings 0°, 45°, 90°, 135° and 180°. Based on the table obtained, the wave spectrum is converted into a graph as shown in Figure 10-11.

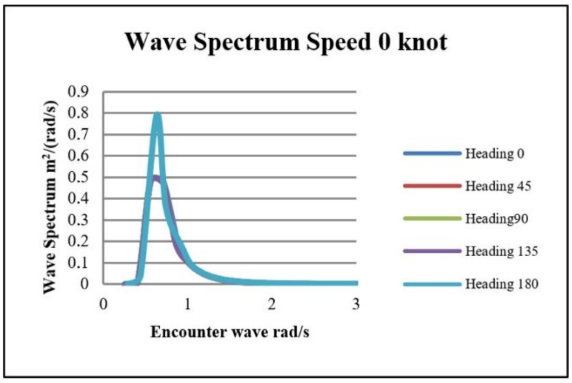

Figure 10. Wave spectrum at speed 0 knot.

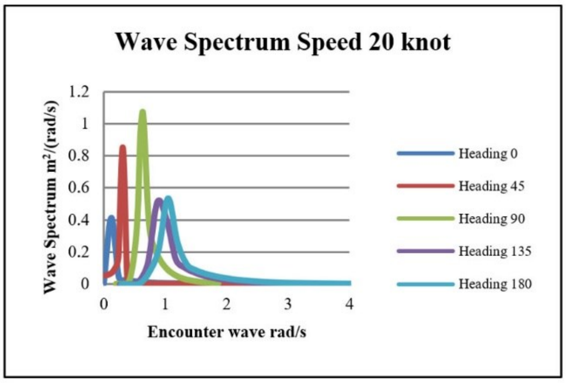

Figure 11. Wave spectrum at speed 20 knot.

Figures 10 and 11 are graphs of the wave spectrum output produced at speeds of 0 knots and 20 knots. The maximum wave spectrum at a speed of 0 knots is in heading 180° with a value of 0.79 m^2 / (rad/s), then for a speed of 20 knots the maximum wave spectrum is in heading 90° with a value of.

5. Conclusions

After analyse the proof jigging hull model, the conclusion produced by the proof jigging hull is at 0 knots speed and 90° wave angle, the ship will experience up and down movements of 1.206 m while at 20 knots speed and 180° wave angle, the ship will experience up and down movements of 2.058 m this will result in sea water can enter the deck of the ship and also can cause structural damage caused by pounding. For roll movements, at 0 knots speed and 90° wave angle the ship will experience a shaking motion of 6.642°, with an angle of this magnitude the ship is still in good condition because it is still in a small degree number. Whereas at the speed of 20 knots the greatest roll movement is found at 90° wave angle with an amplitude value of 6.684°, in this condition the ship is still in good condition because the tilt angle of the ship is still in a small degree number. At speed 0 knots the greatest pitch movement occurs at 0° wave angle with an amplitude value of 1.203°. In this condition the ship is still in safe condition because it is still in a small degree number. Whereas at the speed of 20 knots the greatest pitch movement occurs at 0° wave angle with an amplitude value of 1.884° under this condition the ship is still in safe condition because it is still in a good degree number.

6. References

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