Seakeeping Analysis of Hull Rounded Design With Multi-Chine Model on Fishing Vessel

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Abstract. This research is to find out the hydrodynamic characteristics of a ship, it presented in the form of the characteristics of the movements that are usually experienced by the ship when sailing. Therefore, testing the motion performance of 3 GT fishing vessels is done by calculating the ship's response to ocean waves, following the oceans and oceanic which cause oscillation movements in 3 degrees of freedom of ship compilation in the waters of the Malacca Strait. The object of the research model is 3 GT fishing vessel with a hull shape rounded by varying the amount of chine. The Rounded model and the Chine model are analyzed using motion to find out RAO ships such as heaving, rolling and pitching. RAO size for maximum heave motion occurs at a speed of 12 knots in the direction of 135° with a RAO value of 1.60 m/m with a frequency of 3.03 rad/s, the RC-2 Ship model with a frequency of 3,015 rad / s and a RH model ship and with a critical peak value of RAO heave 1,713 m with a frequency of 3.15 rad/s, the maximum roll value occurs wave angle 90° beam sea with RAO value ship model RC-3 is at the lowest point with a critical peak value of RAO roll 6.3048 deg/m with a frequency of 2.306 rad / s, the RC-2 Ship model with a frequency of 6,3048 rad / s and a RH model ship and with a critical peak value of RAO roll 6,405 m with a frequency of 3.092 rad/s. In RAO pict movements heading angle 180° head sea, RC-3 ship model is at the lowest point with a critical peak value of RAO roll 1.35 deg/m with a frequency of 2.93 rad / s, the RC-2 Ship model with a frequency of 1,45 rad/s with a frequency of 2.936 rad/s, and a RH model ship and with a critical peak value of RAO roll 1,843 m with a frequency of 3.015 rad/s. From the results of the study it can be concluded that the RC-3 type of fish has a good performance when used at sea.

Keywords : fishing vessel. rounded, chine, ecounter frequency, RAO, seakeeping

1. Introduction
Bengkalis Sub-district, Bantan and Pulau Rupat have great fishery potential. The potential of this great fishery must be pursued with the management of good fishery products in order to increase local revenue for Bengkalis Regency. In accordance with the data of the bengkalis district fishery service in 2004 alone the need for fishing vessel pompong reached 2,284 special units in Bengkalis Regency [6]
Based on survey, most of fishing vessels in the traditional port of Bengkalis and Bantan, the shape of the ship is still Conventional (rounded form). The ship is driven by one propeller with driven by a diesel engine with power 7-32 PK. The shape of the ship's body and the installation of propulsion such as this has became the tradition and inheritance of the ancestors and has not been developed much about ships with different shipbuilding shapes that can result in smaller obstacles than the rounded ships body shape in order to save the use of fuel and engine investment.

To be able to get a smaller ship resistance, one of the ways that can be used is by designing modifications of the ship's body shape from conventional ships (rounded shape) to multi-chine form. With smaller constraints, it is economically advantageous to reduce fuel consumption, and it may be possible to reduce the amount of propulsion used to achieve the same speed as a rounded vessel. This will certainly be very beneficial for fishermen because it can save expenses every time you sail.

2. Experiment Model

2.1 Fisheries Supervision Ship

In this research, the model of fishing vessel using a Maxsurf Software as for the dimension of fish vessels are as follows LOA: 10.17 Meter Breadth: 2.1 Meter Height: 1.65 Meter draft: 0.6 Vessel Speed: 8 Knot [3]

![Fishing Vessels model Bengkalis Island](image)

Figure 1. Fishing Vessels model Bengkalis Island

| Table 1. Model fish Ship |
|--------------------------|
| Model                  | Design Model |
| Rounded Hull (RH)      | ![Rounded Hull](image) |
| Double Chine (RC-2)    | ![Double Chine](image) |
| Multi Chine (RC-3)     | ![Multi Chine](image) |

2.2 Seakeeping Analysis

To find out the hydrodynamic characteristics of a ship, it will be explained in the form of the characteristics of the movements normally experienced by the ship while sailing. The characteristics of these movements will be presented in the form of heave, roll and pitch movements with varying speeds of 0 Knots, 6 Knots, and 12 Knots at heading angles 0°, 45°, 90°, 135°, and 180°. In this study sea
keeping analysis was performed with maxsurf software. For sea keeping analysis the numerical model is validated using the "Strip Theory" calculation. The next step is to analyze RAO (Response Amplitude Operator), added mass and damping on variations in ship speed and water depth. Further analysis is carried out by considering environmental conditions such as the Hs significant wave height parameter, so that the ship’s amplitude response is known for several Hs conditions. The final result of this research will be the selection of the best hull model based on the smallest response amplitude based on the incident wave angle in figure 2.

![Figure 2. Wave Angle Orientation](image)

1. Pitching Motion
Pitching motion is the motion of the ship which causes the trim of the ship both the bow and the stern which in turn and this movement can be analyzed with the following formula [1]:

\[ d\dot{\phi} + e\dot{\phi} + h\phi = M_0\cos\omega t \]  \hspace{1cm} (1)

When:
- Inertial Moment \( = d\frac{d^2\phi}{dt^2} \)
- Damping moment \( = e\frac{d\phi}{dt} \)
- Restoring moment \( = h\phi \)
- Exciting moment \( = M_0\cos\omega t \)

2. Heaving Motion
Heaving motion is the movement of ships up and down or vertically. To analyze the formula can be used as follows:

\[ a\ddot{z} + b\dot{z} + cz = F_0\cos\omega t \]  \hspace{1cm} (2)

When:
- Inertial Force \( F_a = a\ddot{z} \)
- Damping Force \( F_b = b\dot{z} \)
- Restoring Force \( F_c = cz \)
- Exciting Force \( = F_0\cos\omega t \)

3. Rolling Motion
Rolling motion is the movement of the ship that surrounds the axis, when there is rolling longitudinally on the right side of the ship moving to the left side of the ship which is repeated alternately. To analyze the rolling motion of the ship, the following formula can be used:

\[ a\frac{d^2\theta}{dt^2} + a\frac{d\theta}{dt} + c\theta = M_0\cos\omega \theta t \]  \hspace{1cm} (3)

Dimana:
- Inertial Moment \( a\frac{d^2\theta}{dt^2} \)
Damping moment $\frac{da}{dt}$
Restoring moment $c\ddot{\phi}$
Exciting moment $M_o\cos\omega t$

2.3 Wave Spectrum

When calculating the motion of a ship (seakeeping) that needs to be determined for a designer, must determine the spectrum of waves that are close to or in accordance with the waters in which this research is conducted, therefore researchers must be able to determine the spectrum of waves that are available in the Seakeeper program. Maxsurf based on the available wave spectrum, the authors determine the type of wave spectrum used is JONSWAP (Joint North Sea Wave Project). It is quite clear with this explanation, that the waters on Bengkalis Island are classified as closed waters, so before using the JONSWAP wave spectrum in analyzing the motion of the ship (seakeeping), resulting in the extent of motion pitch, motion heaving and motion rolling. From the results of the resulting motion area it can be concluded that the JONSWAP spectrum is better so that maximum vessel comfort is achieved with data records entered for ship motion analysis (seakeeping) equal or in accordance with the waters in Bengkalis Island.

![Figure 3. Location of waters on Bengkalis island.](image)

Based on the provisions of the sea state contained in the WOCE Upper Ocean Thermal Data June (2002) and the World Meteorological Organization (WMO) approved the standard sea state code, the waters associated with the crossing on Bengkalis Island are assumed to be classified as sea state code 2 with a wave height of 0.1 - 0.5 meters for more details, see Table II below:

| Sea State Code | Significant Wave height Meter | Description | Period (s) |
|---------------|-----------------------------|-------------|------------|
| 0             | 0                           | Calm (glassy) | 10         |
| 1             | 0.0 - 0.1                   | Calm (glassy) | 11         |
|               | 0.1                        | Smooth      | 12         |
| 2             | 0.5 - 1.25                  | Slight      | 13         |
| 3             | 1.25 - 2.5                  | Moderate    | 14         |
| 4             | 2.5 - 4.0                   | Rough       | 5          |
| 5             | 4.0 - 6.0                   | Very rough  | 6          |
| 6             | 6.0 - 9.0                   | High        | 7          |
| 7             | Over 14.0                   | Very high   | 8          |
| 8             | Over 14.0                   | Phenomenal  | 9          |
To determine the response of the motion of the ship, first determine the properties of the waters that are in Bengkalis Island, assuming the characteristics of the waters as follows:

Table 2. Wave characteristics

| Description   | Wind Velocity (Knot) | Heigh Wave (meter) | Periode Wave (s) |
|---------------|----------------------|--------------------|------------------|
| Moderate      | 10                   | 2.75               | 14               |

The source for wind speed is based on weather forecasts in Bengkalis 01 May 2018.

3. Result and Analysis

3.1 Dynamic Seakeeping

When a ship is sailing at sea, the ship will interact with waves, currents and air. As a result of the various circumstances at sea, it will affect the emergence of movements and a number of structural responses [2]. Furthermore, to find out information about the characteristics of the movement, it is given in the form of a graph with abscissa in the form of frequency parameters. While the ordinate is in the form of a ratio between the amplitude of certain movements such as heave, pitch, and roll with the amplitude of the wave which is called the Amplitude Response Operator (RAO). Characteristics evaluation will be carried out using the Maxsurf-Seakeeper program. To operate this program, input data must be prepared in advance. Some general input data are described in the following table:

Table 3. Date Input maxsurf program

| No | Input Data         | RH   | RC-2   | RC-3   |
|----|--------------------|------|--------|--------|
| 1  | Maksimum Draft     | 0.45 | 0.45   | 0.45   |
| 2  | Number of Mapped Section | 41   |        |        |
| 3  | Vesel Type         | Monohull |       |        |
|    | Specktra           | JOWSWAP 2.5 |    |        |
| 4  | a. Chair Height    | 0.245 m, - 0.745 m |     |        |
|    | b. Modal Priode    | 13.45 s   |       |        |
| 7  | Heading            | 0°, 45°, 90°, 135° dan 180° | | |
| 8  | Speed              | 0 Knot, 6 Knot, 12 Knot | | |

To see the response of the heave, roll, and pitch movements, the following will be presented in the form of an RAO curve with a heading angle of 135° at a speed of 12 Knots. The entry angle of 135° was chosen as one of the samples because the position of the direction of the incident angle of the wave was almost opposite to the direction of movement of the ship so that changes for every movement of the heave roll and pitch of the ship would be clearly visible.
Figure 4. Heave response model ship

In RAO heave movements at a speed of 12 knots heading angle of 135° can be seen on the curve that the RC-3 ship model is at the lowest point with a critical peak value of RAO heave 1.60 m with a frequency of 3.03 rad/s, the RC-2 Ship model with a frequency of 3.015 rad / s and a RH model ship and with a critical peak value of RAO heave 1.713 m with a frequency of 3.15 rad/s.

Figure 5. Roll response for model Ship

In RAO roll movements at a speed of 12 knots heading angle 90° beam sea, can be seen on the curve that the RC-3 ship model is at the lowest point with a critical peak value of RAO roll 6.3048 deg/m with a frequency of 2.306 rad / s, the RC-2 Ship model with a frequency of 6.3048 rad / s and a RH model ship and with a critical peak value of RAO roll 6.405 m with a frequency of 3.092 rad / s.
In RAO pict movements at a speed of 12 knots heading angle 180° head sea, can be seen on the curve that the RC-3 ship model is at the lowest point with a critical peak value of RAO roll 1.35 deg/m with a frequency of 2.93 rad/s, the RC-2 Ship model with a frequency of 1.45 rad/s with a frequency of 2.936 rad/s, and a RH model ship and with a critical peak value of RAO roll 1.843 m with a frequency of 3.015 rad/s.

3.2 Wave Spectrum

The fact, the ship moving in the sea wills random excitation (random), in accordance with the nature of ocean waves. Therefore, the analysis needs to be done by applying spectral distribution of Hs in Natuna waters into JONSWAP formula. The distribution of the wave peak period in the Bengkalis state waters has a range between 1.45 seconds to 10.45 seconds and Hs ranges between 0.245m to 2.745m Figure 11 shows the spectrum of wave energy in the Natuna waters Tp = 13.45 seconds by using a formula JONSWAP.

Figure 6. Pict respon for model Ship

Figure 7. Wave spectrum JONSWAP
3.3 Spektra Respon Wave Irregular

The irregular wave is in principle represented by the area under the spectra curve, \( S_r(\omega) \), which can be divided into pebbles based on their increasing frequency (Yuda, 2013). Whereas the sinusoidal response components are represented by the RAO curve. So it can be concluded that the response in a random wave will be obtained if RAO can be correlated in such a way that this correlation is substantially the same as transforming wave energy into response energy. Wave energy is the power value of the amplitude, \( \zeta_0^2 \), at each increase in frequency. By using an analogy, the response energy is the square value of the amplitude too, \( \zeta_r0^2 \). In this way a simple random wave response can be obtained by multiplying the \( S_r(\omega) \) wave energy spectrum value with RAO2. For the maximum Heave Response Spectra by each fishing boat model at a speed of 12 Knots heading 1800 is presented in Figure 8 as follows:

Figure 8. Spectra respon heave

Spectra Analysis Maximum roll response by each fishing vessel model at 12 knots heading 90° is presented in Figure 9 as follows:
Figure 9. Spectra respon roll

Spectra Analysis Maximum roll response by each fishing vessel model at 12 knots heading 180° is presented in Figure 10 as follow

Figure 10. Spectra respon pitch
Heave, roll and pitch motion response spectra which are calculated according to significant wave heights ranging from 0.245 m to 2.745 m. The change pattern of heave, roll and pitch response spectra curves in each fishing boat model is relatively similar to the wave spectra pattern, the position of each peak frequency spectrum of the three models is more or less the same. For the Heave Response Spectra, the RH model has a value of 1.12 m$^2$ (rad / s). The highest Frequency Encountering Frequency is 0.5 rad / s compared to the RC-2 and RC-3 models, 1.03 m$^2$ (rad / s), then the Response spectra Roll response of the three models has the same curve value, and for the response spectrum pitch the RH model has a value of 1.08 m$^2$ (rad / s). The highest frequency calculation is 0.5 rad/s compared to the RC-2 and RC-3, 0.96 and 0.92 m$^2$ (rad/s) on the Encountering Frequency of 0.5 rad/s. From the results of the study it can be concluded that the addition of the number of chines in fishing vessels can reduce the value of Heave and Pict in the motion of the ship, so based on analysis of response spectra RC-3 ship models have better response spectra compared to other models.

4. Conclusion
The results of the study can be concluded that RAO size for maximum heave motion occurs at a speed of 12 knots in the direction of 135° with an RAO value of 1.60 m/m with a frequency of 3.03 rad/s, the RC-2 Ship model with a frequency of 3.015 rad / s and a RH model ship and with a critical peak value of RAO heave 1.713 m with a frequency of 3.15 rad/s, the maximum roll value occurs wave angle 90° beam sea with RAO value ship model RC-3 is at the lowest point with a critical peak value of RAO roll 6.3048 deg/m with a frequency of 2.306 rad / s, the RC-2 Ship model with a frequency of 6.3048 rad / s and a RH model ship and with a critical peak value of RAO roll 6,405 m with a frequency of 3.092 rad/s. In RAO pict movements heading angle 180° head sea, RC-3 ship model is at the lowest point with a critical peak value of RAO roll 1.35 deg/m with a frequency of 2.93 rad / s, the RC-2 Ship model with a frequency of 1.45 rad/s with a frequency of 2.936 rad/s, and a RH model ship and with a critical peak value of RAO roll 1,843 m with a frequency of 3.015 rad/s The results of the Response Spectra analysis of the RH ship model have a value of 1.08 m2 (rad / s). The highest frequency calculation is 0.5 rad/s compared to the RC-2 and RC-3, 0.96 and 0.92 m$^2$ (rad/s) on the Encountering Frequency of 0.5 rad/s.

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