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Study of Purse Seine Fishing Ship Trimaran Seakeeping with Axe-Bow and Without Axe-Bow Using Computational Fluids Dynamic in regular wave

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Abstract

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Maluku waters are dominated by extreme weather conditions with wave heights up to 3 meters. Purse seine fishing vessel is one type of fishing vessel that has very poor transverse stability. One way to improve the stability of the ship is to change the shape of the monohull ship to a ship with a trimaran hull type. This research was focused on examining the movement characteristics of purse seine fishing vessels with trimaran hull type with Axe-Bow modification on the bow and without Axe-bow, through computational fluid dynamics with the panel method approach. The analysis was carried out at the fishing ground location in regular wave height 0.5 m conditions. The use of Axe-bow on trimaran is able to significantly reduce RMS Pitch, which is an average of 13.35% smaller when compared to Trimaran without Axe-bow. On the RMS Heave Trimaran Axe-bow can reduce an average of 5.27% if the Trimaran is without Axe-bow. Furthermore, the Trimaran Axe-bow is also able to reduce the RMS Roll by an average of 3.98% compared to the Trimaran without Axe-bow. The results of this study can provide an initial description of the advantages of using the Axe-Bow on the Purse seine fishing trimaran ship.

1. Introduction

The fishing sector, as well as the management of marine fisheries, is an industry that is susceptible to the negative impacts of severe weather at sea [1]. The upwelling process has an effect on the lifestyle and ecosystem of marine biota, including pelagic fish, which is one of the largest foreign exchange earners from the fisheries sector. The effects of global warming and the impact of El-nino and La-nina are very influential on the upwelling process. This has an impact on the lifestyle and ecosystem of marine biota [2].

The purse seine is mostly utilised for fishing for kinds of fish that travel in vast populations close to the surface of the water [3]. A purse seine is a type of fishing net that is used to catch fish by floating the top of the net at the surface of the water and attaching weights to the bottom of the net to drag the walls of the net downward. The fish are secured inside the net by pulling on a wire that is threaded through the bottom of the net. This creates the effect of a purse being pulled tighter around the fish. After that, the boat will begin to bring the net closer to it, at which point the catch will either be pumped out or hoisted out using smaller nets, or the entire net will be carried onboard. The width of purse seine nets may be adjusted to catch a variety of different species, and the size of the net can vary [4].

Fishing using a purse seine is a very selective process since it typically only pursues a single species at a time [5]. This means that other marine species are little affected by purse seine fishing. As purse seine nets are only deployed on the water's surface and never reach the sea floor, they have minimal effect on the marine ecosystem. It is common practice in some regions to encircle ocean garbage or other floatable with purse seine nets as shown Figure 1.

In severe sea conditions, the majority of fishermen opt not to go to sea, not because there are no fish on the fishing grounds, but to prevent marine mishaps in extreme weather conditions has an effect on the income and well-being of fishermen in extreme sea conditions. As an alternative to using a purse seine vessel with a monohull, a trimaran hull might be utilised. Based on the fact that the people of Maluku have always been familiar with the form of a ship with a simple type 3 hull in the form of a "semang ship" [6]. Ships with multiple hull types, such as catamarans (ships with two hulls) and trimarans (ships with three hulls), are increasingly utilised as a result of advances in maritime technology [7].

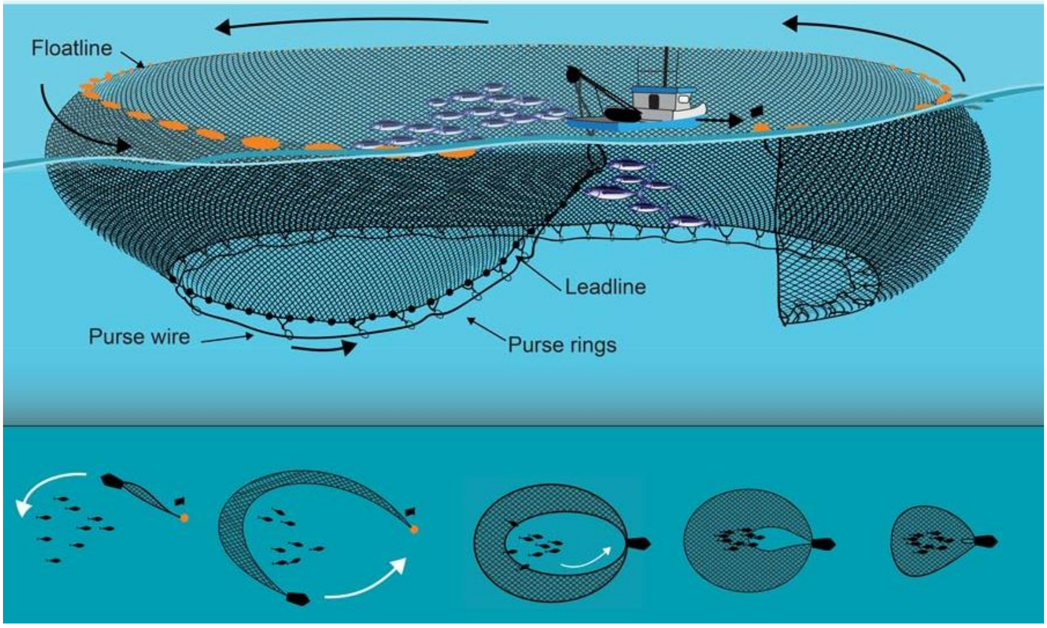


Figure 1. Purse Seine perform ground fishing operations [8]

The Axe-Bow has better seakeeping than the Enlarged Ship, which already has 50 percent less vertical acceleration than a typical monohull, and it has better resistance at speeds up to 35 knots [9]. The AXE bow design may improve fast patrol boat seakeeping and operability in a seaway. The AXE bow reduces head seas vertical acceleration peaks by 40% [10] Trimaran motions in relation to wave pressures indicate that an axe bow trimaran hull operating near shorelines has unique motions and wave loadings when it encounters waves impacted by nearshore reflections [11]. The seakeeping analysis was estimated using the panel method, while the stability study was based on static stability. From the stability assessment, both multihulls (catamaran and trimaran) have greater values of BM, GM, and GZ, making them more stable than monohulls and giving them superior heeling and listing characteristics. The trimaran models have improved heave, pitch, and roll seakeeping [12].

The trimaran due to ships with several hulls are more stable and efficient than those with a single hull. In the application of a fishing vessel, the critical issue is related to the seakeeping performances in at sea water of Maluku. However, more study of the hydrodynamic characteristics such as the seakeeping/motion performances are also critical. Up to date, there are still a few numbers of the development of trimaran fishing vessels to deal with such issues by using Axe-Bow.

In this paper, we aim to study the seakeeping performances of a trimaran fishing vessel in comparison to a trimaran without Axe-bow fishing vessel at the initial design stages in operational condition at fishing ground with 3 knot. The seakeeping computation using Panel Method was described in this paper. The RAOs and response motion of each variation of trimaran fishing vessel were described for heading angle (90^0), bow quartering seas (135^0) and Head seas (180^0). Every direction of the wave provides a precise response to the ship's motion in the kind of heave and pitch, allowing the fishing vessel's behaviour to be predicted. This will greatly aid the engineers in designing a better purse-seine ship.

2. Methods

The seakeeping performance analysis of the trimaran with and withour Axe-Bow at main hull models was carried out using CFD. The investigation is carried out at several ship operating speeds (v=3 knot). The use of the regular wave spectrum adapted to the conditions of the waters in costal area of Maluku Island of Indonesia is used to predict the wave energy that occurs in the waters where ships operate with 0.5 m wave heigh.The simulation used to solve this problem is the panel method approach.

2.1 Panel Method

This approach is appropriate for finding solutions associated with a variety of specialized subjects, such as wave impacts on offshore platforms, ship motions in the time domain, and ship interactions in a channel [13-15]. Based on an investigation of inviscid flow, the approach as presented here is confined to the resulting surface pressure forces. It is assuming potential flow, the flow field's governing equation being the Laplace of the velocity potential, as shown Equation 1:

$$\nabla^2\phi = 0 \tag{1}$$

The boundary condition at an impermeable surface, where the velocity normal to the surface is zero, as follows (Equation 2)

$$\nabla\phi \cdot n = 0 \tag{2}$$

The fluid flow may approach the object by providing a frame of reference for it. Since the surface is inviscid, there may be a non-zero velocity component tangent to the surface. Then, the pressure can then be integrated over the surface to find the force by the fluid flow. it can be shown that the following defines the velocity potential at any point P in the flow field, by following Equation 3:

$$\phi(P) = \frac{1}{4\pi}\int\left(\frac{\nabla\phi}{r} - \phi\nabla\frac{1}{r}\right)\cdot n dS \tag{3}$$

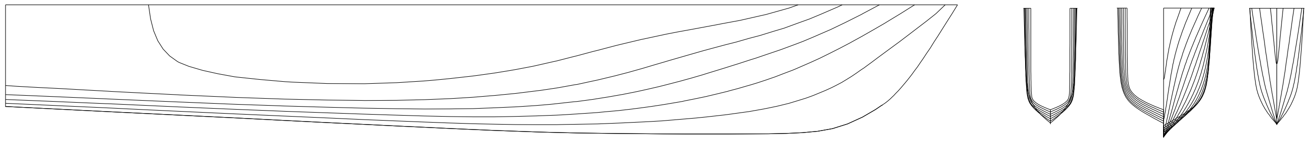
Where the integral is over the surface area of the flow (assuming that it is a flow in two dimensions), S. According to this equation, in order to get a solution for the velocity potential, we need to do an integral calculation on the flow boundaries (both the solid surface and infinitely far away).

2.2 Ship Model

CFD solver three-dimensional method uses for seakeeping analysis. The tow hull models are discretized so that they are arranged into small grid that compose the shape of the hull. The Purse seine trimaran hull, i.e with Axe-bow and without Axe-bow as shown at Table 1 and Figure 2 will analyses with CFD method.

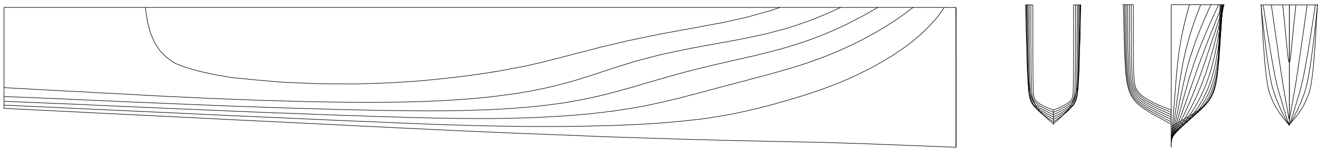
Tabel 1. Particular Dimension of Trimaran Purse Seine

Parameter	Unit	Mainhull NPL 4a without Axe-bow	Mainhull NPL 4a dengan Axe-bow	Sidehull NPL 4a
L_{OA}	m	18	18	9
L_{WL}	m	17.51	18	8.42
B	m	2.41	2.41	1.21
T	m	0.96	1.38	1.35
Wetted Surface Area	m^2	35.13	39.27	12.24
Displacement	kg	9268.72	9268.72	1860.27
Block Coefficient (C_B)		0.397	0.194	0.397



(i) side view (ii) front view

(a) Hull Model 1 (Trimaran without Axe-bow for mainhull)



(i) side view (ii) front view

(b) Hull Model 2 (Trimaran with Axe-bow for mainhull)

Figure 2. Lineplan of Trimaran Models

2.3 Response Amplitude Operator

Response Amplitude Operator (RAO) is called the transfer function. It is a response function that transfers the wave force into a dynamic response to the structure in the frequency range. The RAO graph contains the frequency parameter in its abscissa and the ratio between the amplitudes of the motion of a particular mode in its ordinate. RAO in translational motion in formulated as follows:

$$RAO\ (\omega) = \frac{\zeta_{k0}(\omega)}{\zeta_0\ (\omega)}\ (m/m) \tag{4}$$

Where $\zeta_{k0}(\omega)$ is structure amplitude in meter and $\zeta_0\ (\omega)$ is wave amplitude in meter.

Meanwhile, RAO on rotational motion which is the ratio between the amplitude of the rotational motion and the slope of the wave, namely the multiplication of the wave number and the wave amplitude ($k_w = w^2 / g$) is formulated as follows:

$$RAO\ (\omega) = \frac{\zeta_{k0}(\omega)}{\zeta_0\ (\omega)}\ (rad/m) \tag{5}$$

$$RAO\ (\omega) = \frac{\zeta_{k0}(\omega)}{\left(\frac{\omega^2}{g}\right)\zeta_0}\ (rad/m) \tag{6}$$

2.4 Response Spectra

Effect of hydrodynamic interaction on the added mass, damping potential, and the external force in analyzing the response of buildings floating on a regular wave. The response of marine buildings to random waves is to transform the wave spectrum into a response spectrum. The response spectrum is the energy density response to the structure due to wave loads. it can be formulated as follows:

$$S_{\zeta r}(\omega) = [RAO\ (\omega)]^2 x\ S_\zeta(\omega) \tag{7}$$

Where $S_{\zeta r}(\omega)$response spectra in m2/s is, $S_\zeta(\omega)$ is wave spectra in m^2/s and ω is wave frequency in rad/s.

2.5 Response Motion

Motion response is obtained by using equation 12, namely by multiplying the RAO square with the wave spectrum to get the motion spectrum response from the ship. Then statistical analysis was performed to obtain the Root Mean Square (RMS) motion of each ship's motion mode, the ship's heave, roll, and pitch. Ship motion RMS is obtained using Equation 8 below:

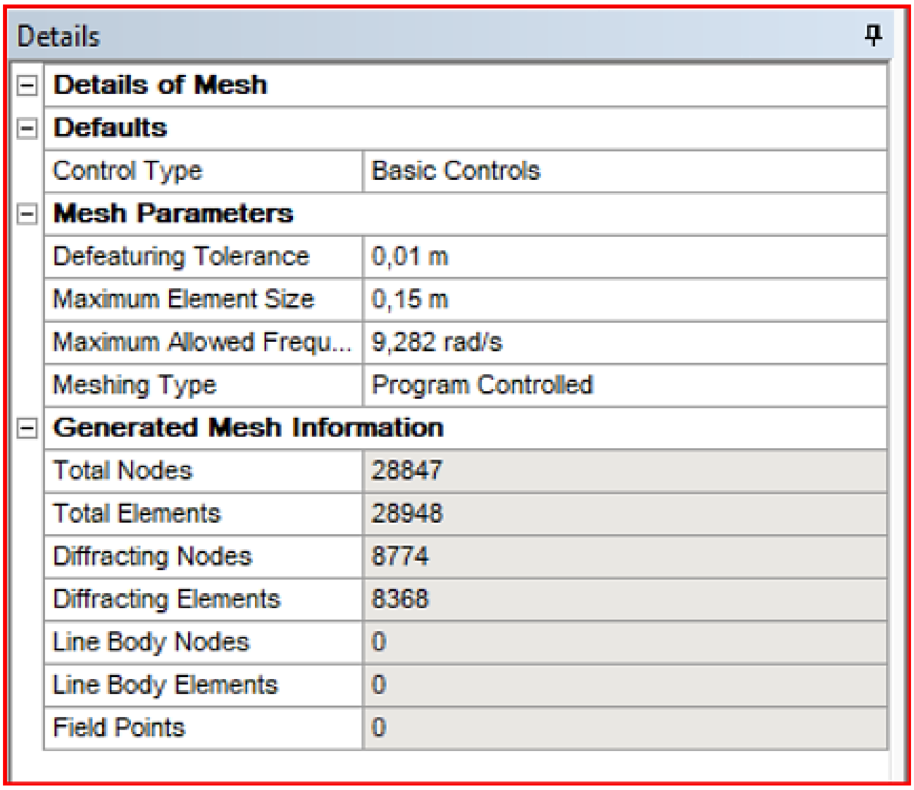
$$RMS = \sqrt{m_0} \tag{8}$$

Where m_0 is the area under the spectrum response curve obtained using numerical calculations. The area under the curve can be formulated in the following Equation 9 below:

$$m_0 = \int_0^\infty {\omega_e}^0\ S_\zeta\ d\omega \tag{9}$$

2.6 Numerical Simulation

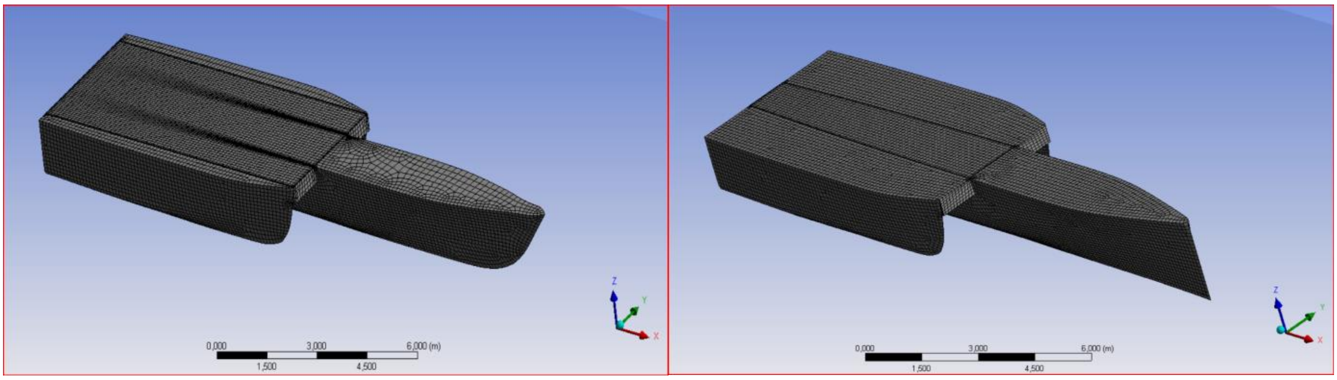
It is important to mesh first in order to carry out a simulation of a ship that is a trimaran. In numerical simulation, the process of meshing is used to evaluate whether the model represents how a ship reacts when it encounters waves. Figure 3 illustrates the specified meshing, which has a maximum element size of 0.15 metres, a wave frequency range of up to 9,282 rad/s, and a total of 28948 elements. The figure also includes a legend. Figure 4 is an illustration of this idea for better understanding.



Details

Details of Mesh	
Defaults	
Control Type	Basic Controls
Mesh Parameters	
Defeaturing Tolerance	0,01 m
Maximum Element Size	0,15 m
Maximum Allowed Frequ...	9,282 rad/s
Meshing Type	Program Controlled
Generated Mesh Information	
Total Nodes	28847
Total Elements	28948
Diffracting Nodes	8774
Diffracting Elements	8368
Line Body Nodes	0
Line Body Elements	0
Field Points	0

Figure 3. Meshing model setting



(a) Trimaran without Axe-bow (b) Trimaran with Axe-Bow

Figure 4. Meshing of Trimaran Models

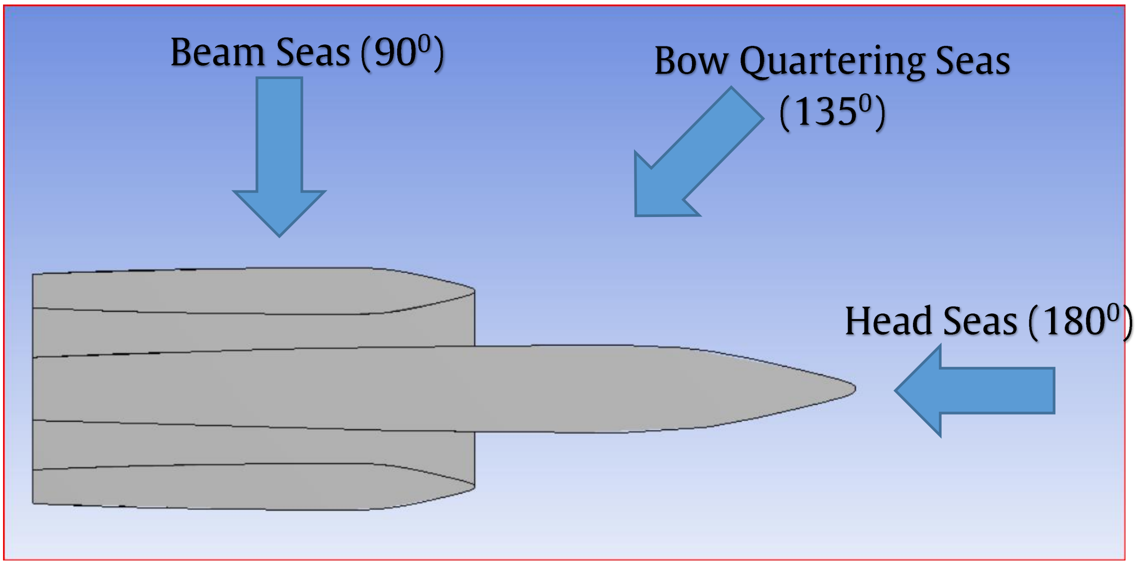


Figure 5. Wave Heading Angle

CFD was utilised to analyse the seakeeping performance of trimaran models with and without an Axe-Bow at the main hull. The experiment is conducted at a variety of ship operating speeds (v = 3 knots). Using the regular wave spectrum suited to the characteristics of the seas in the coastal area of the Indonesian island of Maluku, the wave energy that happens in the waters where ships operate at a wave height of 0.5 metres is predicted. with wave direction angles of 90^0, 135^0, and 180^0 as seen in Figure 5.

3. Results and Discussion

3.1 RAO of Trimaran

CFD Salculation demonstrates that the employment of the Axe-bow results in a reduction in the RAO Heave, its can be seen in Figure 6. At a wave frequency of 2.15 rad per second, the location that exhibits the greatest RAO Heave value may be found in the direction of the beam seas. The continuation of this outcome occurs when the Axe-bow is used excessively on the RAO heave in conjunction with other wave-direction angles. Nevertheless, the RAO heave with Axe-bow and without the Axe-bow has practically having similar result for the following angles.

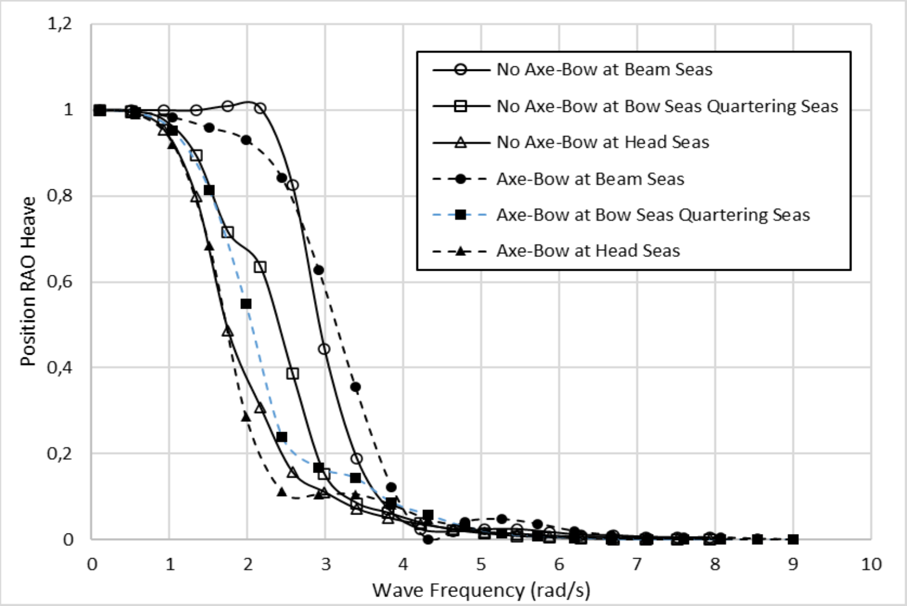


Figure 6. Heave RAOs of the trimaran and trimaran without Axe-bow at velocity = 3 knot in following seas

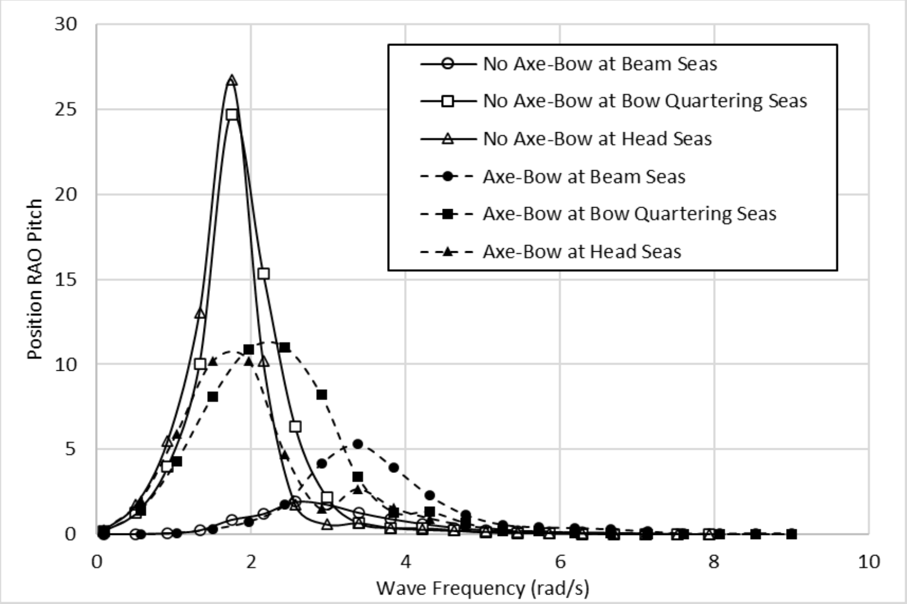


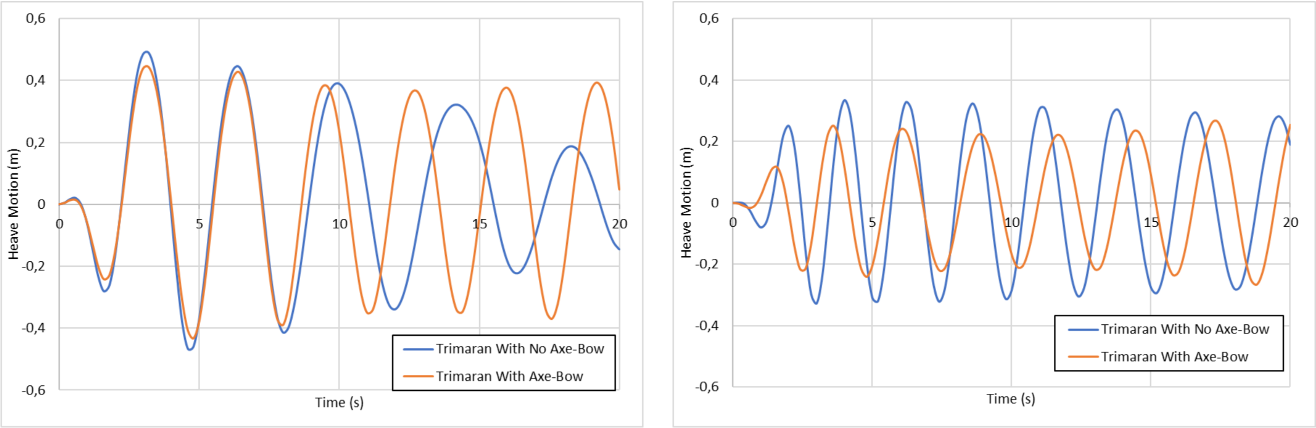
Figure 7. Pitch RAOs of the trimaran and trimaran without Axe-bow at velocity = 3 knot in quarter, beam and bow seas

The CFD simulation showed a significant difference in the RAO Pitch on the Axe-bow and without axe-bow trimaran purse seine vessels, as shown at Figure 7. Purse seine trimaran Axe-bow vessels have a smaller RAO pitch when compared to purse seine trimarans without Axe-bow, which in general the difference is around 61.5%. this, is very likely to occur from the use of the Axe-bow which is functioning effectively. A detailed explanation of the magnitude of the effect due to the use of the Axe-bow on the trimaran main hull is presented in sub-chapter 3.2 Response Motion.

3.2 Response Motion

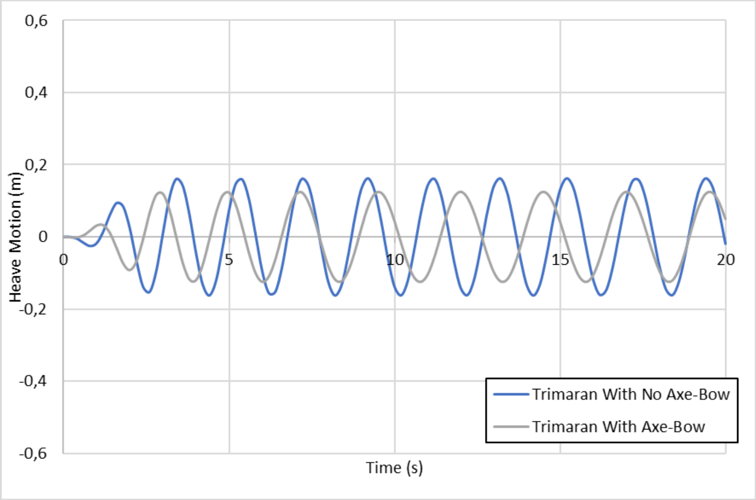
Figure 8 shows the response motion of the Heave variable. As can be seen in Figure 8(a) ship that is applied to waves coming from a direction of 90^0 degrees experiences the highest heave ship response, which is approximately 0.47 m in height. A ship subjected to waves coming from a direction of 90 degrees experiences a response that is simultaneously lower, measuring approximately 0.43 m in height. This demonstrates that ships with ax-bow versions offer an advantage of reduced ship reaction by roughly 4% compared to those without Axe-bow.

Furthermore, the response motion heave of about 0.36 m occurs on the purse siene trimaran with a wave direction of 135^0 as shown in Figure 8(b). The wave response is about 7% lower than the purse seine trimaran with no ax-bow in the same direction. This gives the advantage that the purse seine trimaran has a better motion response than the purse seine trimaran with no Axe-bow.



(a) Wave Heading Angle 90^0

(b) Heading Angle 135^0



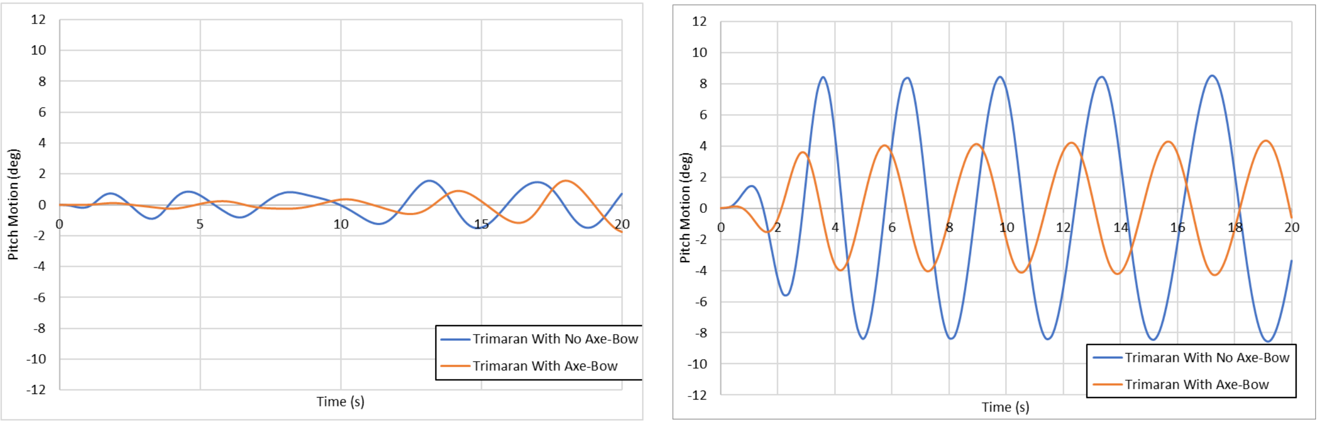
(c) Wave Heading Angle 180^0

Figure 8. Ship Response Heave Motion

The response of heave motion with a wave direction of 180^0 reveals that ships with a dominating Axeg-bow are lower than those without Axe-bow, as shown at Figure 8(c), which have a response of roughly 0.16 m. This is because ships without Axe-bow have a response of approximately 0.16 m. When compared to a vessel that does not have an Axe-bow and has a heave motion reaction of 0.18 metres, this one has a heave response that is approximately 2% less.

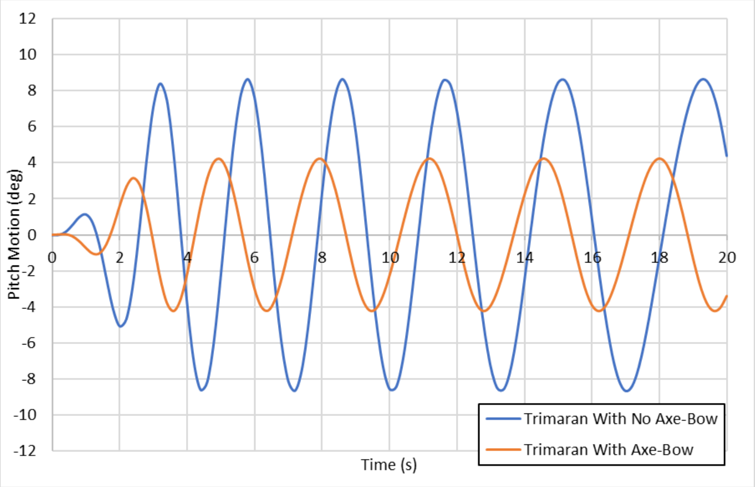
In addition, the response of the pitch motion on the purse seine trimaran is demonstrated in figure 9. The purse seine trimaran vessel with Axe-bow has a lower motion than the purse seine without Axe-bow in the 90^0 wave direction (beam seas), which is where the lowest pitch response occurs, as shown at Figure 9(a). A difference of 35 percent on average can be seen between the trimaran with Axe-bow and without Axe-bow in the first second to 17th second. Nevertheless, from this second forward until the 20th second, the ship's response of pitch motion is same relatively.

In Figure 9 (b), there is a significant difference in pitch response, where the purse seine trimaran with Axe-bow have an average difference of 57% lower than the purse seine trimaran without Axe-bow. As shown in the Figure 9 (b), the purse seine trimaran with Axe-bow has a pitch motion response of 3.75 deg, while purse seine trimaran with Axe-bow has an average pitch motion response of 8.27 deg.



(a) Wave Heading Angle 90^0

(b) Wave Heading Angle 135^0



(c) Heading Angle 180^0

Figure 9. Ship Response Pitch Motion

Purse seine trimaran with Axe-bow gives a fairly good response to pitch motion with a wave direction of 180^0 as shown in Figure 9 (c) which has a response value of 67% lower than Purse seine trimaran without Axe-bow. The response of the pitch movement on the Purse seine trimaran ship with an Axe-bow has an average value of 8.21^0 and 3.72^0 on the Purse seine trimaran ship without Axe-bow.

In the identical technique that was mentioned previously. A purse seine trimaran equipped with an Axe-bow offers the benefit of a reduced motion response in heave and pitch in comparison to a trimaran that does not have an Axe-bow. This is due to the Axe-bow, which acts as a breakwater while the ship is moving forward, has a role in the motion of the ship. Since of the way the bow Axe-bow is designed, it is capable of adapting to waves crashing from the front of the ship in the form of breaking waves. This ensures that the waves already don't apply a significant amount of external force on the hull of the ship, particularly with regard to its pitch motion. However, the direction of the waves from the side (beam seas) is still able to provide external force to the ship so that the pitch and heave responses are still relatively large and are not affected by variations in the shape of the ship's bow. The same phenomenon was mentioned in the investigation [9] and [10] carried out about the use of the axe-bow on vessels.

4. Conclusion

The panel method of CFD modeling provides a reasonably accurate description of the RAO and motion response pada the trimaran purse-seine without and with Axe-bow. The results of the study are shown in two different ways so that the RAO of heave and pitch motion can be found. In addition, the motion responses were calculated at forward speed of 3 knots in regular wave with a height of 0.5 meters. The use of Axe-bow on trimaran is able to reduce RAO Heave, which is an average of 7.35% smaller when compared to Trimaran without Axe-bow. On the RAO Pitch, the Trimaran Axe-bow can reduce an average of 61.57% if the Trimaran is without Axe-bow. Furthermore, the simulation of ship's motion response results show the Trimaran Axe-bow is also able to reduce the Heave Motion by an average of 4.98% compared to the Trimaran without Axe-bow. Furthermore, the reduction in pitch motion occurs significantly, which is 67.1% with the use of the Axe-bow than without the Axe-bow. The ship's motion depends on the Axe-bow, which functions as a breakwater while going forward. Breaking waves from the ship's bow may be absorbed by the Axe-bow.The results of this study can provide an initial description of the advantages of using the Axe-Bow on the Purse seine trimaran.

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