TRANSNAV
http://www.transnav.eu
the International Journal
on Marine Navigation
and Safety of Sea Transportation
Volume 19
Number 2
June 2025
DOI: 10.12716/1001.19.02.09

Numerical Analysis of the Effect of Passive Free Surface Tank on Rolling Motion of Batang-Type Traditional Fishing Vessel

D. Chrismianto, H. Yudo, B. Arswendo Adietya, A. Firdhaus & A. Abel Salassella
Diponegoro University, Semarang, Central Java, Indonesia

ABSTRACT: Ship accidents are caused by various factors, one of which is excessive roll motion that can lead to capsizing. To address excessive rolling, the passive free surface tank device is a potential solution that can be applied. In order to ensure good performance of the passive free surface tank, it is necessary to investigate the effect of the tank's dimensional configuration on the damping it generates. By identifying the best tank configuration, it is hoped that this study can provide useful references for the design of passive free surface tanks, especially for traditional fishing vessels. The analysis begins by creating several tank specimens with variations in length and fluid height. The performance of the passive free surface tank is evaluated based on the RMS values generated by the ship with the tank, which are then compared to the RMS values of the ship without a tank. In the analysis, FEM-based software is used to assist in the calculations. The results show that the ship with the addition of passive free surface tank type C1 produces the highest roll damping, with a damping percentage of 20.01% at empty load, 25.12% at half load, and 24.37% at full load.

1 INTRODUCTION

As with other modes of transportation, ships are also at risk of accidents. Ship accidents can be caused by adverse natural conditions or human factors. Such incidents can be highly detrimental, leading to property losses and even fatalities. Notably, between 2003 and 2019, there were 120 recorded ship accidents in Indonesia, with 41% involving grounding and sinking incidents. Motorized vessels accounted for the majority of these accidents, comprising 89% of the total cases. The majority of these accidents occurred in the Java Sea, with 44 reported cases. This situation warrants special attention, especially since the Java Sea holds significant fishery potential and is a hub of intensive fishing activities.

Fishing vessels play a crucial role in supporting fishing operations and represent one of the most commonly operated types of ships in Indonesia. This is further underscored by the fact that Indonesia has the world's second-longest coastline, exceeding 90,000 km. Consequently, the fisheries sector, particularly capture fishing, has become a viable profession for coastal communities. According to data from the Ministry of Marine Affairs and Fisheries (KKP), in 2021, there were approximately 900,000 marine fishing vessels, predominantly consisting of motorized boats and motorized canoes, with over 2.4 million. However, most fishing vessels in Indonesia are still traditional, and be built using conventional methods [1].

When operating at sea, fishing vessels require reliable seakeeping capabilities. This is based on the fact that fishing activities are inherently hazardous, as these vessels often encounter relatively high waves [2]. Good seakeeping performance not only ensures passenger safety but also enhances the efficiency of crew operations. Conversely, excessive motion amplitudes indicative of poor seakeeping performance can disrupt the functionality of fishing gear, adversely impacting the fishing process [3].

One critical aspect of seakeeping is the rolling motion, which is the rotational movement of a vessel about its longitudinal axis in response to wave action. Rolling causes the vessel's sides to alternately tilt from right to left in a repetitive manner [4]. Excessive rolling can negatively affect vessel stability, posing a risk to the crew and even leading to dangerous situations such as capsizing [5], [6]. Large rolling amplitudes increase the likelihood of vessel instability, which can result in accidents or sinking.

Various methods can be employed to mitigate rolling and its negative effects, including the addition of bilge keels, active fins, or anti-roll tanks. An anti-roll tank functions by creating a counteracting moment induced by the oscillatory flow of fluid within the tank [7], which gradually dampens the rolling motion caused by incoming waves.

Anti-roll tanks are categorized into two types: active anti-roll tanks and passive anti-roll tanks. Although passive anti-roll tanks are less effective than active systems, they are more economical in terms of operational costs. Moreover, passive systems are simpler, relying solely on the movement of fluid within the tank without the need for pump systems. There are various types of passive anti-roll tanks, with the simplest being the free-surface tank (or flume tank) and the U-tube tank. The free-surface tank consists of a single tank structure, while the U-tube tank comprises a dual-tank configuration connected at the bottom by a channel.

Previous studies have investigated the effects of applying anti-roll systems on ships, including bilge keels, passive U-tube tanks, and active fins. The use of bilge keels has been shown to reduce rolling motion by 1–3%. Active fins provide a rolling reduction effect of 75%, while U-tube anti-roll tanks achieve a reduction of 26.5% [8]. Meanwhile, passive free-surface tanks offer a rolling reduction effect 50% greater than that of U-tube tanks [9].

Among fishing vessels, bilge keels are the most commonly used anti-roll systems. However, their performance is inferior to that of passive anti-roll tanks. The main drawback of bilge keels is that they increase the vessel's resistance [10]. On the other hand, while active fins deliver optimal rolling reduction performance, their application involves significantly higher costs compared to passive anti-roll tanks. Thus, the adoption of passive anti-roll tanks offers an advantage in terms of cost-effectiveness, outperforming bilge keels in efficiency while remaining affordable.

Based on these considerations, designing an anti-roll system for fishing vessels is necessary to mitigate rolling motion. The selected system is a passive anti-roll tank of the free-surface tank type, chosen for its simple geometry, which makes it particularly easy to implement, especially for fishermen operating fishing vessels.

However, further research is needed to determine the effects of tank dimensions and fluid fill levels within passive free-surface tanks. Such studies would identify the optimal tank dimensions and fluid height configurations that achieve the best rolling reduction performance. By determining the most effective configuration, this research is expected to serve as a reference for developing anti-roll systems, specifically passive free-surface tanks.

2 METHOD

2.1 *Research Object*

The sample used in this study is a traditional vessel from the Batang region operating in the Java Sea. The vessel, as shown in Figure 1, has the main dimensions listed in Table 1.

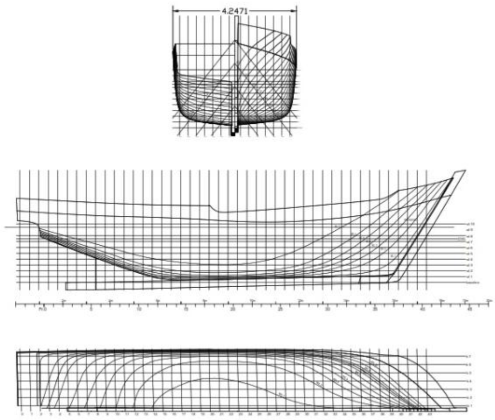


Figure 1. Linesplan of KM Barokah Rezeki

Table 1. Vessel Data of KM Barokah Rezeki

Size	Value	Unit
Length Waterline (LWL)	13,00	m
Length Over All (LOA)	15,45	m
Breadth (B)	4,25	m
Height (H)	2,40	m
Draft (T)	1,50	m
Gross Tonnage (GT)	30,0	tons
Service Speed (Vs)	7,00	knot
GMT	0,75	m

2.2 *Research Parameters*

This study aimed to investigate changes in rolling amplitude, expressed as Root Mean Square (RMS), after the application of a passive free-surface tank on a fishing vessel. The RMS values of the rolling motion of the vessel with the passive free-surface tank were compared to those without the tank to determine the reduction in RMS, which reflects the damping effect.

The research variables are categorized into fixed and independent variables, as described below.

Fixed Variables

1. Placement of the passive free-surface tank on the vessel, as illustrated in Figure 3.
2. Wave parameters, including a significant wave height (Hs) of 1 meter and an average peak period (Tp) of 5 seconds.
3. Fluid used to fill the passive free-surface tank.
4. The main dimensions of the passive free-surface tank, based on previous studies, as detailed in Table 2.

Table 2. Main Dimension of the passive tank

Size	Value	Unit
Tank Width (BT)	3.50	m
Tank Height (HT)	1.60	m

Independent Variables are include:

1. Length of the Passive Free Surface Tank, as shown in Table 3 and illustrated in Figure 2.
2. Fluid Height in the Passive Free Surface Tank, as detailed in Table 4.
3. Vessel Loading Conditions, varied into three states as listed in Table 5.

Table 3. Variations in Passive Tank Length

Type	Length	Unit
A	0.5	m
B	1.0	m
C	1.5	m

Table 4. Variations in Fluid Height

Type	Fluid Height	Unit
1	0.3	m
2	0.6	m
3	0.9	m

Table 5. Variations in Vessel Loading Conditions

Condition	Loading Condition	Description
K	0 %	Empty
S	50 %	Half-load
P	97 %	Fully-load

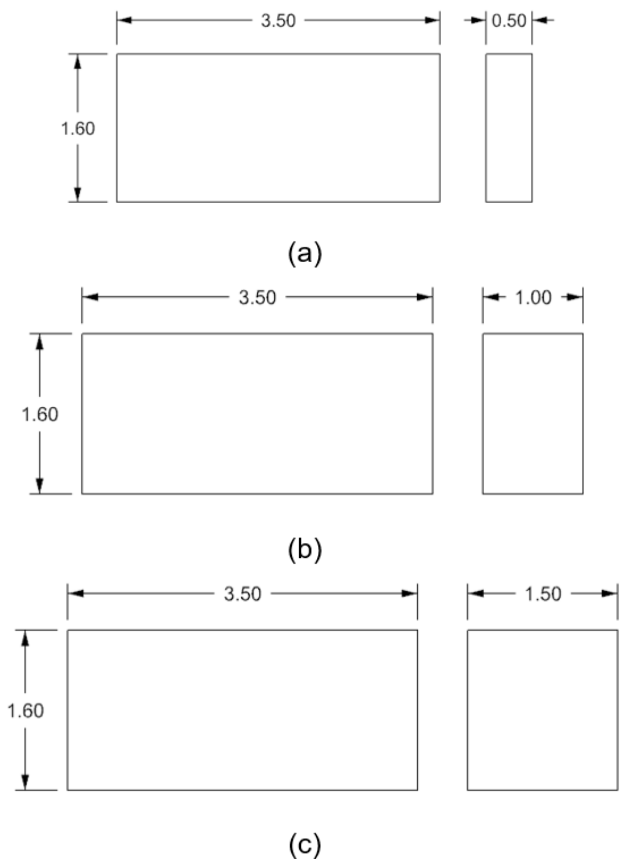


Figure 2. Front and side view geometries of the passive tank for (a) Type A, (b) Type B, (c) Type C

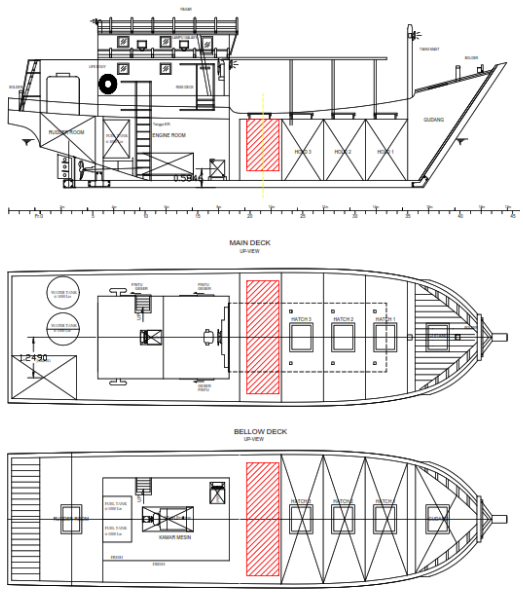


Figure 3. Illustration of Passive Free Surface Tank Placement on KM Barokah Rezeki

2.3 *Data Analysis*

Data analysis was conducted to identify the tank variation that achieves the highest percentage of rolling reduction. This involved evaluating the influence of fluid height and tank length of the passive free-surface tank on the vessel's rolling motion, expressed in terms of RMS. The steps involved in the analysis are as follows:

1. Analyzing the Vessel’s Rolling Motion Without a Tank The results from this analysis serve as a baseline for comparing the damping effects of the tank variations, expressed as a percentage reduction in rolling.
2. Analyzing the Vessel's Center of Gravity and Draft for Different Loading Conditions The values obtained are used as input for the rolling motion analysis.
3. Performing Rolling Motion Analysis for Each Tank and Loading Variation Using Numerical Computation Software Fluid height within the tank is a key input for this stage.
4. Processing Rolling Motion Analysis Results (RAO to RMS)
5. Validating the RMS of the Vessel Without a Tank by calculating the percentage difference in RMS.
6. Comparing Results for Vessels With and Without Passive Free-Surface Tanks By calculating the percentage rolling reduction for each tank variation based on the comparative analysis.
7. Interpreting the Rolling Reduction Percentages achieved by each passive free-surface tank variation.

3 RESULT AND DISCUSSION

3.1 *3D Modeling of the Vessel and Tank*

To conduct analysis using FEM-based software, the vessel geometry and passive free-surface tank must be modeled in three dimensions. The 3D representation of the vessel and the tank placement is shown in Figure 4.

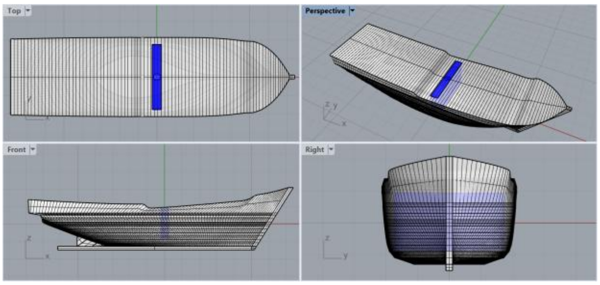


Figure 4. 3D Model of the Modified Vessel With the Addition of a Tank

3.2 *Determination of Center of Gravity, Displacement, and Draft*

The center of gravity and displacement are essential inputs for analyzing the vessel's rolling motion and must be determined for each tank variation. Additionally, the draft is critical as it serves as a boundary for the submerged area of the vessel in the rolling motion analysis. The data for the center of gravity, draft, and displacement are presented in Table 5 for empty load condition (0%), Table 6 for half-full load condition (50%), and Table 7 for fully loaded condition (97%).

Table 6. Data on Center of Gravity, Displacement, and Draft under 0% load

Type	Draft (m)	LCG (m)	VCG (m)	TCG(m)	Disp(kg)
A1-K	0.93	4.73	1.19	0.003	21459
A2-K	0.95	4.76	1.19	0.003	21916
A3-K	0.96	4.78	1.19	0.003	23895
B1-K	0.95	4.76	1.26	0.003	21916
B2-K	0.98	4.81	1.25	0.003	22830
B3-K	1.00	4.86	1.25	0.003	23744
C1-K	0.96	4.78	1.33	0.003	22373
C2-K	1.00	4.86	1.32	0.003	23744
C3-K	1.05	4.92	1.31	0.003	25115

Table 7. Data on Center of Gravity, Displacement, and Draft under 50% load

Type	Draft (m)	LCG (m)	VCG (m)	TCG (m)	Disp (kg)
A1-S	1.14	5.57	1.49	0.01	26648
A2-S	1.15	5.58	1.48	0.01	27105
A3-S	1.16	5.58	1.48	0.01	27562
B1-S	1.15	5.58	1.55	0.01	27105
B2-S	1.18	5.59	1.53	0.01	28019
B3-S	1.20	5.60	1.52	0.01	28933
C1-S	1.15	5.57	1.59	0.01	27243
C2-S	1.19	5.59	1.56	0.01	28614
C3-S	1.23	5.61	1.55	0.01	29986

Table 8. Data on Center of Gravity, Displacement, and Draft under 97% load

Type	Draft (m)	LCG (m)	VCG (m)	TCG (m)	Disp (kg)
A1-P	1.22	6.09	1.49	0.01	31661
A2-P	1.31	6.09	1.48	0.01	32118
A3-P	1.32	6.09	1.48	0.01	32575
B1-P	1.31	6.09	1.54	0.01	32118
B2-P	1.33	6.08	1.52	0.01	33032
B3-P	1.35	6.08	1.52	0.01	33946
C1-P	1.30	6.07	1.58	0.01	31956
C2-P	1.34	6.07	1.55	0.01	33327
C3-P	1.37	6.07	1.54	0.01	34699

3.3 *Vessel Motion Analysis*

The motion analysis focuses on the rolling motion experienced by the vessel. A wave heading angle of 90 degrees was chosen, as it produces the largest response to rolling [11]. FEM-based software was utilized to facilitate numerical computations. The output of the analysis is in the form of a Response Amplitude Operator (RAO), which represents the vessel's response to regular waves.

In this study, the RAO values for rolling with and without the passive free-surface tank are presented as graphs. Figure 5 displays RAO rolling comparison for the vessel at 0% load (Condition K), while figure 6 displays RAO rolling comparison for the vessel at 50% load (Condition S), and figure 7 displays RAO rolling comparison for the vessel at 97% load (Condition P).

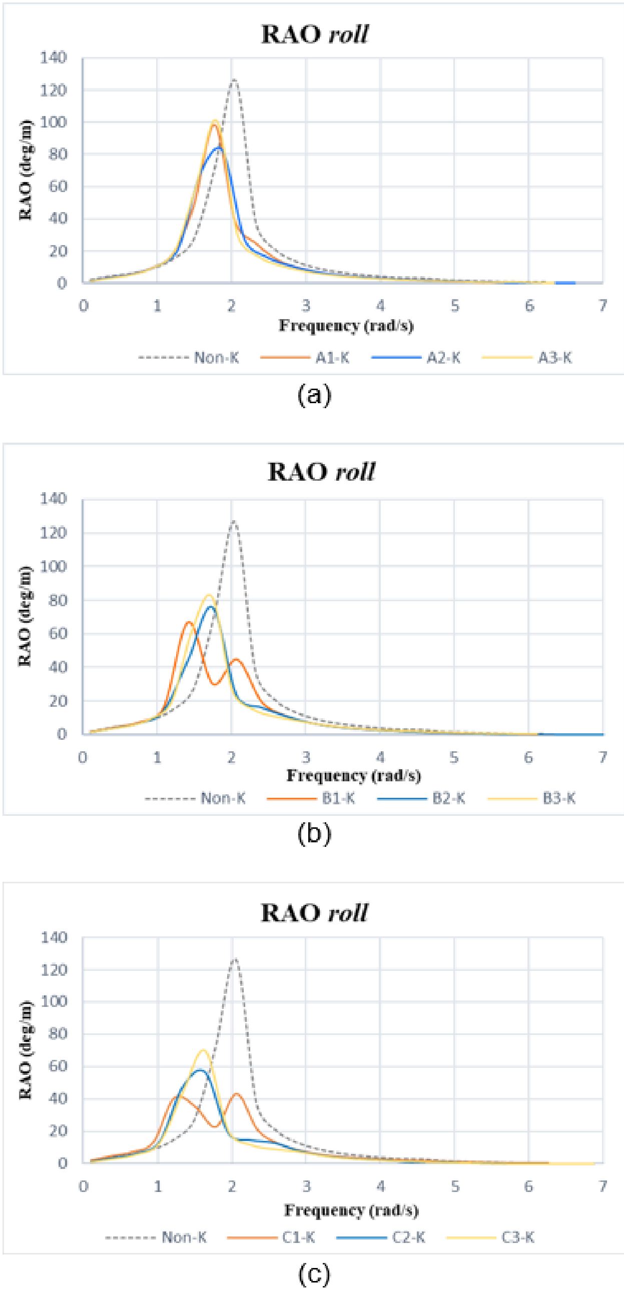
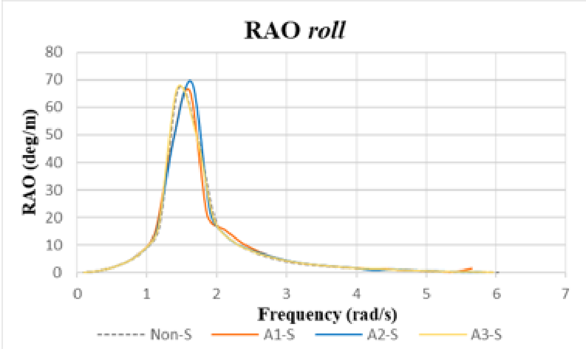
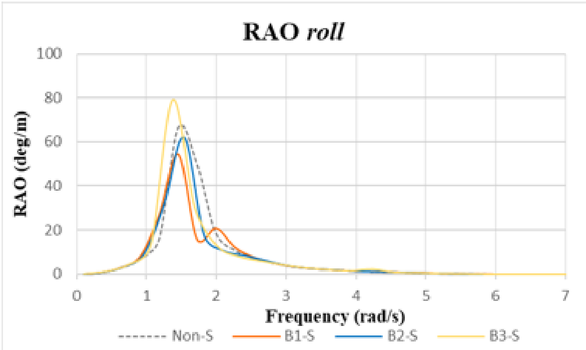


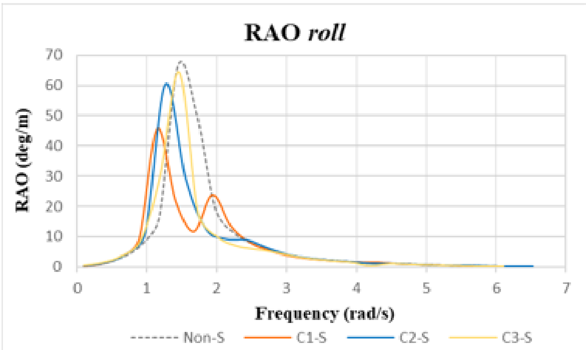
Figure 5. RAO rolling comparison for the vessel at 0% load (a) Tye A, (b) Type B, (c) Type C



(a)

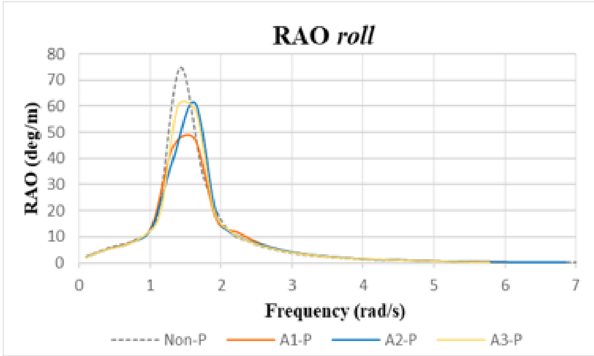


(b)

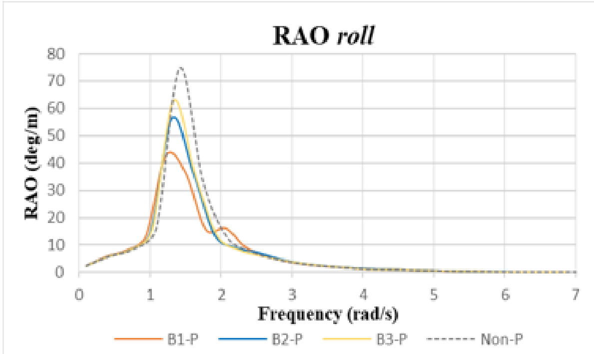


(c)

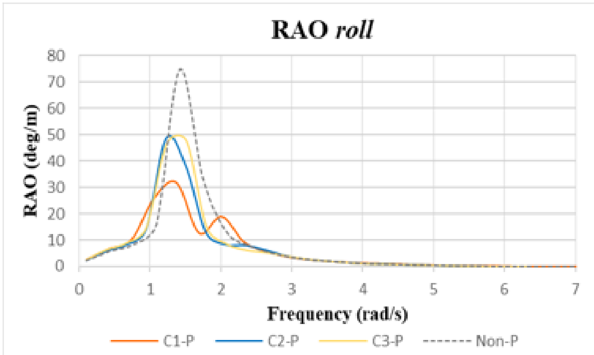
Figure 6. RAO rolling comparison for the vessel at 50% load (a) Type A, (b) Type B, (c) Type C



(a)



(b)



(c)

Figure 7. RAO rolling comparison for the vessel at 97% load (Condition P) (a) Type A, (b) Type B, (c) Type C

Based on Figures 5, 6, and 7, it can be observed that the implementation of the passive free-surface tank on the fishing vessel has a varying impact on the peak RAO rolling values. The dominant effect is the reduction in the peak RAO rolling value. This occurs because the peak RAO at the center is damped by the passive free-surface tank [12]. The lowest peak RAO rolling values for all loading conditions are observed for the vessel with the passive free-surface tank, which has a length of 1.5 meters (Type C) and a fluid height of 0.3 meters (Variation 1).

In reality, ocean waves are always irregular (random), so the RAO values do not fully represent the actual vessel response. To determine the vessel's response under real conditions at sea, the RAO needs to be converted into a response spectrum by multiplying the square of the RAO values with the wave spectrum (Sζ) [13].

To convert RAO into the response spectrum, wave parameters must be defined, namely the significant wave height (HS) and the peak period (TP), corresponding to the conditions in the Java Sea. In this study, a significant wave height (HS) of 1 meter and a peak period (TP) of 5 seconds were established.

These wave parameters are used to calculate the wave spectrum (Sζ) by inserting them into Equations 1 to 4. For the wave spectrum calculation, the ITTC formula is used due to the lack of a specific spectrum for the Java Sea waters [14].

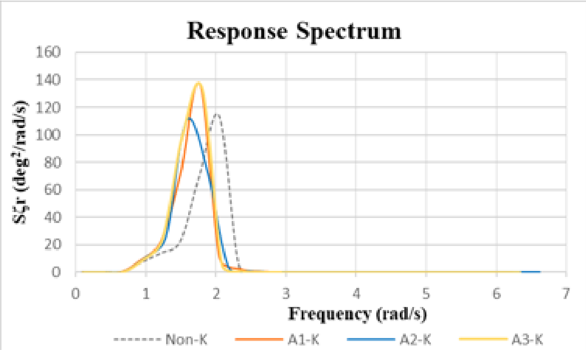
$$S_{ITTC\zeta}(\omega_e) = S_{ITTC\zeta}(\omega_w)\frac{1}{1-\left(\dfrac{2\omega_w V}{g}\right)\cos\mu} \tag{1}$$

$$S_{ITTC\zeta}(\omega_w) = \frac{A}{\omega_w^5} e^{-B/\omega_w^4} \tag{2}$$

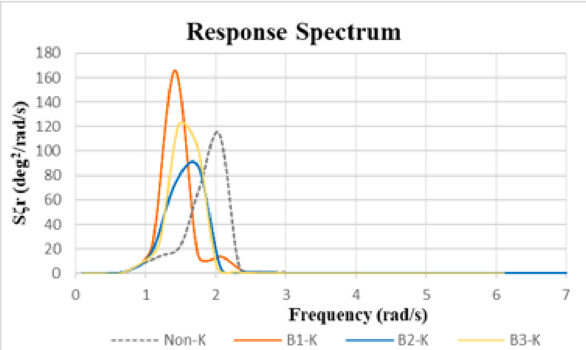
$$A = 483,5 \times \frac{H_s^2}{T_p^4} \quad \left(m^2 / s^{-4}\right) \tag{3}$$

$$B = \frac{1944,5}{T_p^4} \quad \left(s^{-4}\right) \tag{4}$$

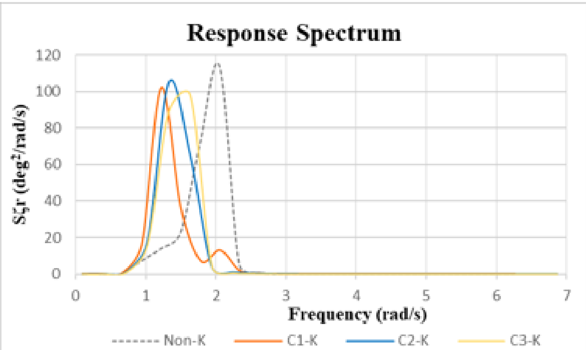
where ω_w is the wave frequency (rad/s), ω_w is the encountering frequency (rad/s), V is the vessel velocity (m/s), g is the gravitational acceleration (9.8 m/s²), μ is the wave heading (degrees), HS is the significant wave height (m), and TP is the peak period (seconds).



(a)



(b)

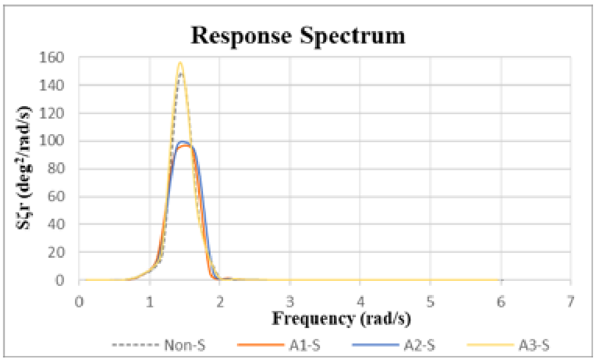


(c)

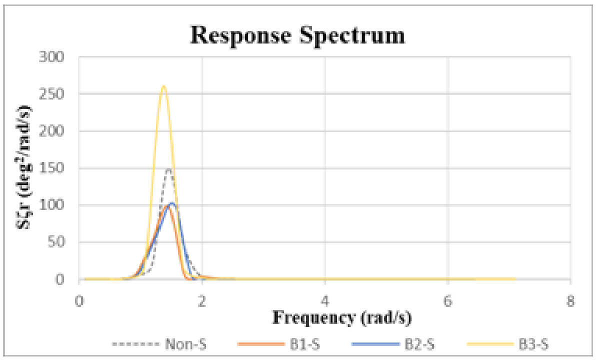
Figure 8. Response spectrum for the vessel at 0% load (Condition K): (a) Type A, (b) Type B, (c) Type C

In this study, the response spectrum for the vessel with and without the passive free-surface tank is shown in graphical form for each loading condition. Figures 8 display the response spectrum for the vessel at 0% load (Condition K), Figure 9 display the response spectrum for the vessel at 50% load (Condition S), and Figure 10 display the response spectrum for the vessel at 97% load (Condition P).

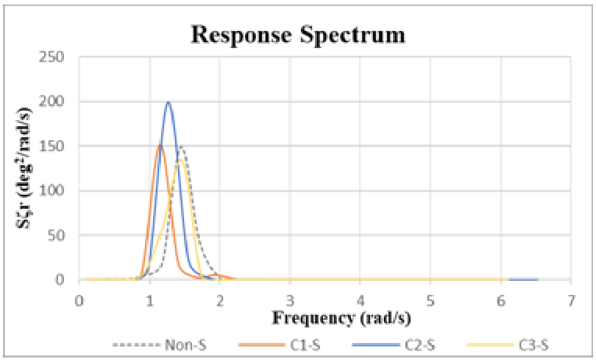
The effect of the passive free-surface tank can be observed in Figures 8, 9, and 10. The effect generated mostly reduces the peak values and the area under the response spectrum curve. The reduction in the area under the curve indicates the damping effect produced by the passive free-surface tank.



(a)



(b)

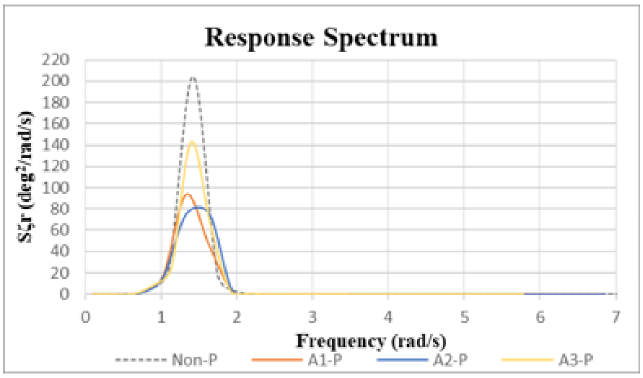


(c)

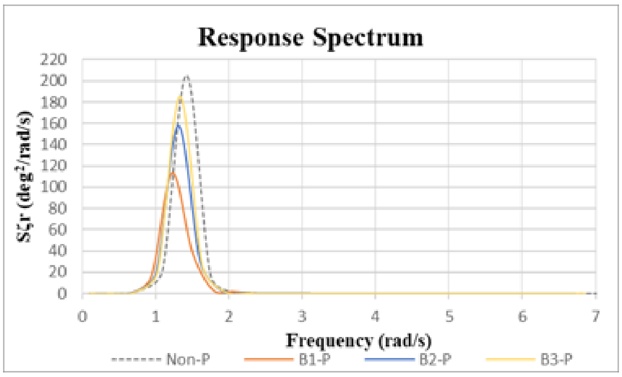
Figure 9. Response spectrum for the vessel at 50% load (Condition S) (a) TYpe A, (b) Type B, (c) Type C

The response spectrum needs to be processed into the root mean square (RMS) to assess the amplitude of the rolling experienced by the vessel. The rolling amplitude serves as a parameter to measure the magnitude of the damping effect generated by the passive free-surface tank on the vessel. Larger movement amplitudes indicate a poor vessel response to incoming waves. RMS is obtained by taking the square root of the equivalent value of the area under the response spectrum curve.

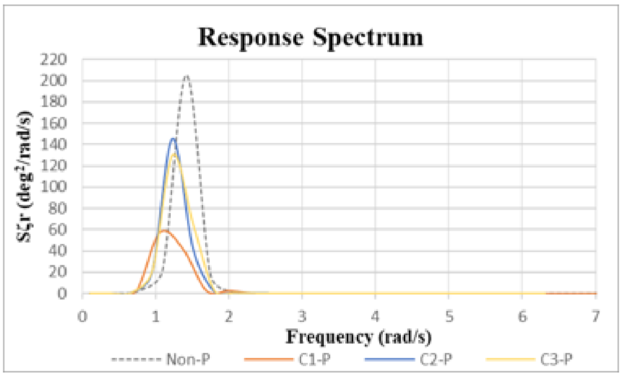
Figure 11 shows the RMS for each loading condition, grouped by the same tank length. Figures 11a, 11b, and 11c shows RMS for the vessel with a passive free-surface tank of 0.5 meters (Type A), 1 meter (Type B), and 1.5 meters (Type C), respectively



(a)



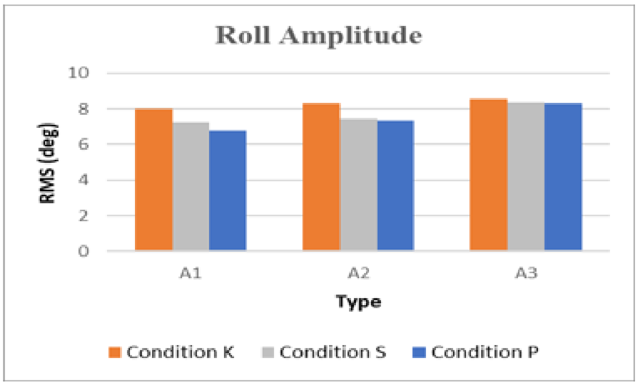
(b)



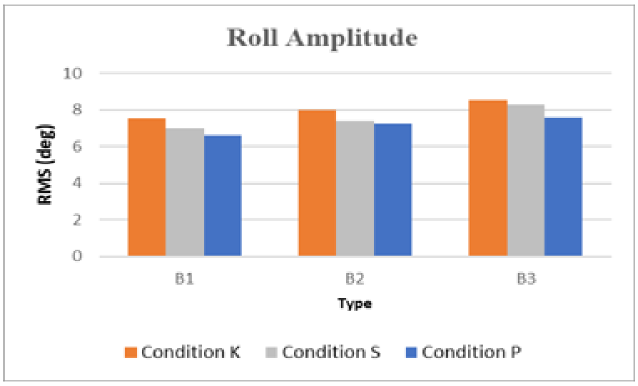
(c)

Figure 10. Response spectrum for the vessel at 97% load (Condition P) (a) Type A, (b) Type B, (c) Type C

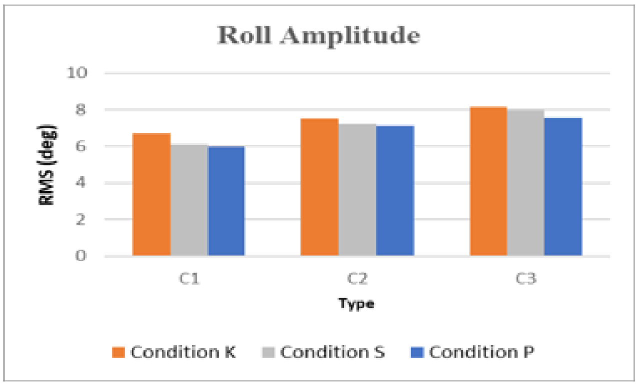
In Figures 11a, 11b, and 11c, the lowest RMS value is shown by the tank with a fluid height of 0.3 meters (height variation 1) in all loading conditions. On the other hand, the highest RMS values are shown by the tank with a fluid height of 0.9 meters (height variation 3) across all loading conditions. This indicates that the tank's fluid filling condition, specifically the fluid height, affects the rolling amplitude experienced by the vessel. This is related to the damping effect produced by each tank variation.



(a)



(b)

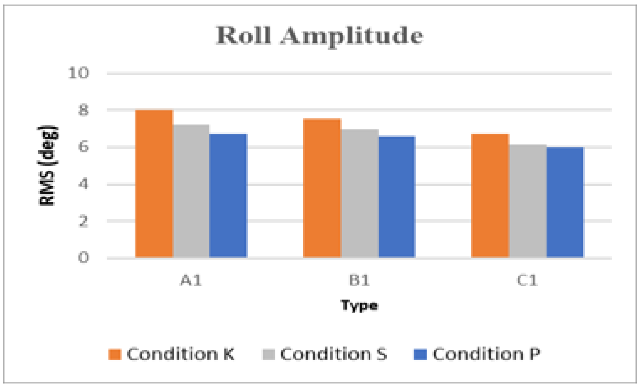


(c)

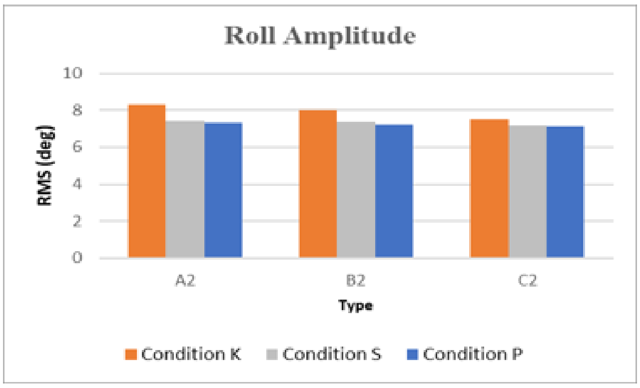
Figure 11. RMS rolling for the vessel with a passive free-surface tank in terms: (a) Type A, (b) Type B, dan (c) Type C

In Figure 11, it can generally be observed that there is a correlation between the fluid height and the RMS rolling of the vessel: RMS rolling increases as the fluid height increases. This suggests a reduction in the performance of the passive free-surface tank. This finding supports the theory related to passive free-surface tanks, where the damping effect generated by the fluid oscillation inside the tank decreases when the fluid's movement space is limited.

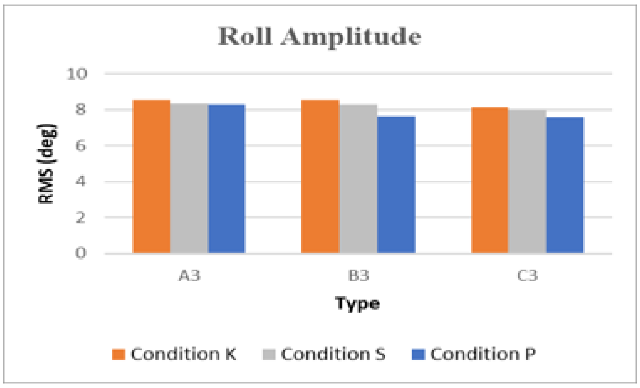
Based on Figure 11, it can be concluded that the highest damping effect is generated by the passive free-surface tank with a fluid height of 0.3 meters (height variation 1) in all tank length variations. For variation A1, the average damping value is 10.41%, for variation B1 it is 13.98%, and for variation C1 it is 23.17%.



(a)



(b)



(c)

Figure 12. RMS rolling RMSof the Vessel with Passive Free Surface Tank Evaluated at the Same Fluid Height: (a) variation 1, (b) variation 2, and (c) variation 3.

Figure 12 shows the RMS results for each loading condition grouped by fluid height, which is used as the parameter for assessment. Figures 12a, 12b, and 12c show RMS rolling for the vessel with a passive free-surface tank filled with fluid at a height of 0.3 meters, 0.6 meters, and 0.9 meters, respectively.

In Figures 12a, 12b, and 12c, it can be observed that the lowest RMS value of the rolling motion is shown by the passive free surface tank with a length of 1.5 meters (Type C) under all loading conditions. Meanwhile, the highest RMS value is shown by the passive free surface tank with a length of 0.5 meters (Type A) under all loading conditions. This review indicates that the length of the passive free surface tank influences the rolling motion experienced by the vessel. This is related to the damping effect provided by the passive free surface tank, where, based on Figure 12, the damping value produced by the tank is directly proportional to its length. Other studies explain that increasing the tank length longitudinally can be an option to enhance the damping effect, as it increases the mass of water and the moment of the tank [15].

Based on Figure 12, it can be concluded that the highest damping value for rolling is produced by the passive free surface tank with a length of 1.5 meters (Type C) across all variations of fluid height. Variation C1 results in an average damping value of 23.17%, Variation C2 produces a damping of 10.86%, and Variation C3 results in an average damping of 3.40%.

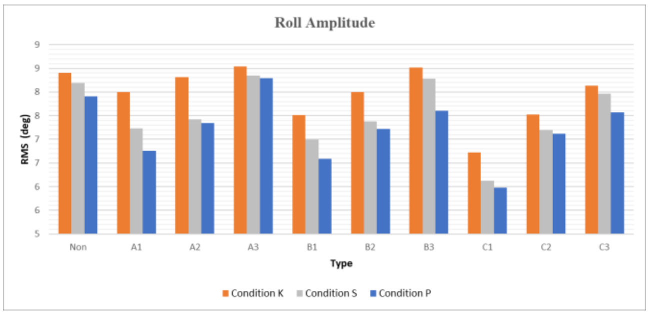


Figure 13. RMS Rolling of the Fishing Vessel Before and After the Addition of the Passive Free Surface Tank

Table 9. RMS values of the Vessel Before and After the Application of the Passive Free Surface Tank Along with the Damping Percentage for Each Specimen

Type	Condition K		Condition S		Condition P		Average	
	RMS	% damping	RMS	% damping	RMS	% damping	RMS	% damping
Non	8.41	0.00	8.19	0.00	7.91	0.00	8.17	0.00
A1	7.99	-4.91	7.23	-11.73	6.76	-14.58	7.33	-10.41
A2	8.32	-1.05	7.42	-9.38	7.34	-7.22	7.69	-5.88
A3	8.54	1.63	8.35	2.05	8.29	4.77	8.40	2.82
B1	7.51	-10.64	7.00	-14.51	6.58	-16.78	7.03	-13.98
B2	7.99	-4.90	7.38	-9.88	7.22	-8.71	7.53	-7.83
B3	8.52	1.32	8.28	1.19	7.60	-3.91	8.13	-0.47
C1	6.72	-20.01	6.13	-25.12	5.98	-24.37	6.28	-23.17
C2	7.52	-10.52	7.20	-12.09	7.12	-9.98	7.28	-10.86
C3	8.13	-3.26	7.97	-2.66	7.57	-4.29	7.89	-3.40

Figures 13 and Table 9 present the RMS values of the vessel's rolling motion, both before and after the application of the passive free surface tank under each loading condition. The negative values for the damping percentages indicate the damping effect generated by the passive free surface tank. It can be observed that most of the specimens have a positive impact, as they result in lower RMS values compared to the vessel without the passive free surface tank. However, there are some variations that do not reduce the rolling motion experienced by the vessel, namely variations A3-K, A3-S, A3-P, B3-K, and B3-S. Meanwhile, the vessel response that results in the smallest RMS values is the variation with a tank length of 1.5 meters and a fluid height of 0.3 meters (Variation C1), both under the 0% load condition (6.725°), 50% load condition (6.130°), and 97% load condition (5.983°). The average damping percentage generated by tank variation C1 is 23.17%.

3.4 *Validation of Ship Motion Analysis*

The validation process was carried out by comparing the RMS results from the ship motion analysis obtained through numerical calculations with analytical calculations. The numerical calculations were performed using FEM-based software, along with data processing software, while the analytical calculations were conducted using a different software tool.

The vessel used for validation was the one without the tank, under all loading conditions, namely 0% load (condition K), 50% load (condition S), and 97% load (condition P). The maximum allowable discrepancy was set to 10%.

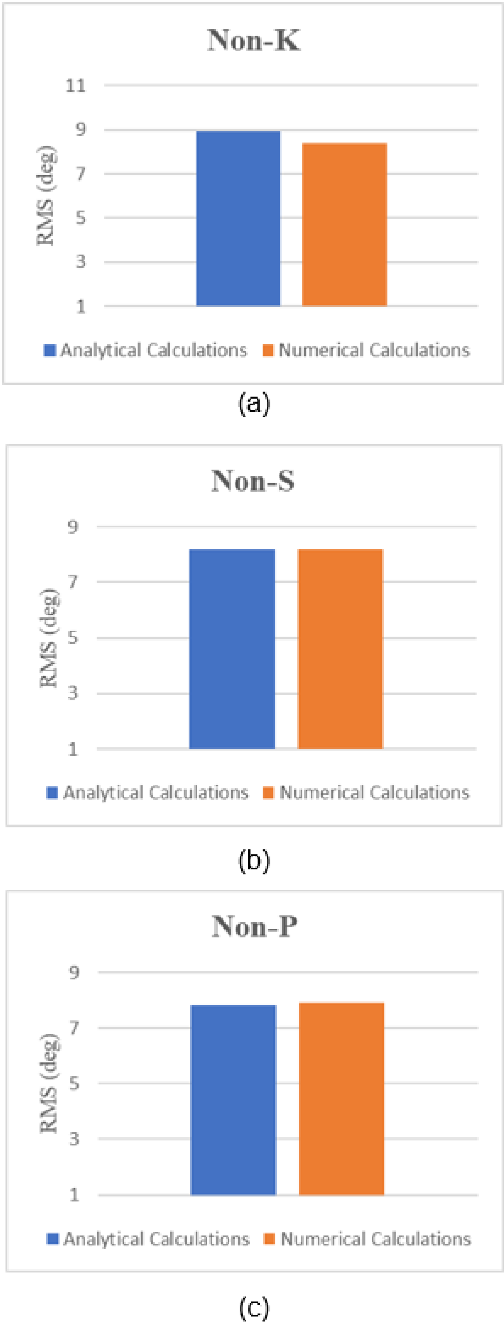


Figure 14. The comparison of RMS rolling results for the vessel at each loading condition: (a) 0% load, (b) 50% load, and (c) 97% load.

In this study, the calculation for the ship with 0% load (Non-K) resulted in an RMS value of 8.91° in the numerical calculation, while the analytical calculation gave a value of 8.41° as shown in Figure 14a. The difference in RMS values for the empty load condition is -5.65%.

Figure 14b (Non-S) shows the comparison of RMS for the vessel with 50% load (half load). The numerical calculation resulted in 8.19°, while the analytical calculation showed 8.18°. The percentage difference in RMS is 0.07%.

Figure 14c (Non-P) illustrates the comparison of RMS rolling for the vessel with 97% load (full load). The numerical calculation yielded a value of 7.91°, while the analytical calculation showed 7.83°. The percentage difference in RMS is 1.04%.

4 CONCLUSION

Based on the research conducted, it was found that the application of passive free surface tanks on fishing vessels has a positive effect on the ship's motion. The dominant effect observed is the reduction in the rolling amplitude experienced by the fishing vessel. This is indicated by the decrease in the RMS value of the modified ship relative to the original ship. However, there are some variations that result in an increase in the rolling amplitude under certain conditions.

In general, the damping effect provided by the passive free surface tank increases as the length of the tank increases. Additionally, in relation to the fluid height, the damping effect decreases as the fluid height increases. Therefore, the variation with the largest damping effect that can be applied to the fishing vessel is the one with the longest tank dimensions (Type C) and the lowest fluid height (variation 1), namely variation C1, with an average damping percentage of 23.17%.

ACKNOWLEDGMENT

This research is funded by Directorate General of Higher Education, Research, and Technology in schema Penelitian Fundamental with Contract No: 601-72/UN7.D2/PP/VI/2024.

REFERENCES

[1] N. Zarma, A. F. Zakki, and A. Trimulyono, "Studi Karakteristik Seakeeping Kapal Ikan Tradisional dan Modern," Jurnal Teknik Perkapalan, vol. 3, no. 1, 2015.
[2] N. Im and S. Lee, “Effects of Forward Speed and Wave Height on the Seakeeping Performance of a Small Fishing Vessel,” Journal of Marine Science and Engineering, vol. 10, 1936, 2022, doi: 10.3390/jmse10121936.
[3] O. Yaakob, F. E. Hashim, M. R. Jalal, and A. Mustapa, “Stability, Seakeeping and Safety Assessment of Small Fishing Boats Operating in Southern Coast of Peninsular Malaysia,” Journal of Sustainability Science and Management, vol. 10(1), pp. 50-65, 2015.
[4] A. Widyatmoko, S. Samuel, P. Manik, and A. Trimulyono, “Analisis Pengaruh Jumlah Bilge Keel terhadap Gerakan Rolling pada Kapal Patroli 14 m,” Warta Penelitian Perhubungan, vol. 33, no. 1, 2021, doi: 10.25104/warlit.v33i1.1667.
[5] A. Herbowo, D. Chrismianto, and M. Iqbal, "Analisa Fin Stabilizer Terhadap Rolling Pada Kapal Ferry Ro-Ro 500 GT Dengan Metode CFD (Computational Fluid Dynamic)," Jurnal Teknik Perkapalan, vol. 5, no. 1, 2017.
[6] O. A. Marzouk and A. H. Nayfeh, “Control of ship roll using passive and active anti-roll tanks,” Ocean Engineering, vol. 36, no. 9–10, pp. 661–671, 2009, doi: 10.1016/j.oceaneng.2009.03.005.
[7] R. Subramanian and P. Jyothish, “Genetic algorithm based design optimization of a passive anti-roll tank in a

sea going vessel," Ocean Engineering, vol. 203, p. 107216, 2020.

[8] F. A. Karim, A. F. Zakki, and M. Iqbal, "Desain Passive U-Tube Tank pada Kapal Ikan Tradisional Tipe Kragan Guna Menurunkan Rolling Kapal," Kapal, vol. 15, no. 3, pp. 95–101, 2019, doi: 10.14710/kapal.v15i3.17897.

[9] G. Kapsenberg and N. Carette, "A consistent method to design and evaluate the performance of Anti-Roll Tanks for ships," Ship Technology Research, vol. 70, no. 2, pp. 117–145, 2023, doi: 10.1080/09377255.2022.2117496.

[10] A. Lloyd, "Seakeeping: ship behaviour in rough weather," Admiralty Research Establishment, Haslar, Gosport, Publisher Ellis Horwood Ltd, John Wiley & Sons, ISBN: 0 7458 0230 3, 1989.

[11] M. Iqbal, M. Terziev, T. Tezdogan, and A. Incecik, "Operability analysis of traditional small fishing boats in Indonesia with different loading conditions," Ships and Offshore Structures, vol. 18, no. 7, pp. 1060–1079, 2023, doi: 10.1080/17445302.2022.2107300.

[12] N. Carette, R. P. Dallinga, and G. Kapsenberg, "On the design of anti-roll tanks" Conference: 13th International Symposium on Practical Design of Ships, Copenhagen, Denmark, September 2016.

[13] M. A. Zahril, P. Manik, and K. Kiryanto, "Analisa Pengaruh Penambahan Hull Fixed Bow Fin Terhadap Gerak Pitching dan Heaving Pada Kapal Tanker 112 Meter," Jurnal Teknik Perkapalan, vol. 9, no. 3, 2021.

[14] R. Bhattacharyya, "Dynamics of marine vehicles", John Wiley & Sons Incorporated, 1978.

[15] C. S. Nielsen and U. D. Nielsen, "Reducing Roll Motion by Passive Free Surface Tanks," Proceedings of the ASME 2014 33rd International Conference on Ocean, Offshore and Arctic Engineering, San Francisco, California, USA, June 8-13, 2014, doi: 10.1115/OMAE2014-23299.