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Motion Response on The Water Ambulance Ship

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***Abstract*- In designing a ship, it is necessary to know the response of the ship's motion before sailing. The purpose of this research is to determine the ship's motion response to waves as well as ship speed in ship loading operational conditions. The method used in this study is the B-spiline mathematical equation and the strip theory method, with the help of ship motion software, which varies the ship's load by 100% DWT, 50% DWT, and 25% DWT. While the highest significant amplitude heave value occurs on a ship with 100% DWT conditions with a speed of 18 knots and a wave direction of 90^0, which is 2.70 meters, the highest significant value of amplitude pitch occurs on a ship with a condition of 25% DWT with a speed of 6 knots and a wave arrival direction of 180^0, namely 1.10 degrees, and the highest significant value of roll amplitude occurs in ships with 25% DWT conditions with speeds of 18 knots with a wave arrival direction of 90^0, which is 3.42 deg. The research results detected at a speed of 18 knots for the significant amplitude heave value, the significant amplitude pitch value, and the maximum RAO value still meet the Nordforsk criteria.**

Keywords-Water Ambulance, RAO, following sea, beam sea, nordforsk

I. INTRODUCTION

Hydroplanes are the most widely used type of ship for various needs, such as racing purposes, military applications, recreation in tourism, and even health facilities, namely water ambulances. The increasing demand for high-speed marine vehicles has led to the development of several sophisticated hull shape designs to increase speed performance and efficiency of use. [1]. A water ambulance is a ship that functions as a floating hospital or can also be used to deliver patients who are in critical condition to riverbank areas far from the hospital [2]. On the one hand, sea transportation has a much greater risk of accidents than other means of transportation. This is because the plane of motion tends to be dynamic, causing many movements that are difficult to predict and disturb comfort. Based on the area of operation, boats are mostly used in waters that tend to be shallower with not too far sailing distances and less extreme water conditions [3].

In previous research, a general plan for water ambulance was designed for the waters of the Upper Mahakam River [4]. A water ambulance has the potential to make patients experience excessive shocks or vibrations. In-depth studies are needed regarding the behavior of hydrodynamic motion when operating in river waters. Several similar studies were carried out related to hydrodynamics, including ship stability in determining the main size of the ship design [5]. Paroka (2008) states that the size of the angle of inclination of the ship when receiving forces from outside or from the ship itself depends on the width and height of the ship's draft in the transverse direction and depends on the length and height of the draft in the longitudinal direction [6]. In addition, the ship's maneuvering behavior to remain stable is also influenced by the placement of goods on board the ship's cabin [7]. Heaving motion is the ups and downs of the ship vertically caused by changes in the magnitude of the buoyancy and weight of objects due to changes in momentum in a wave spectrum [8]. Meanwhile, swaying motion is a side-to-side movement experienced by objects due to translational impulses from waves. In contrast to swaying, yawing has the opposite direction of motion between the bow and stern of the object [9]. When operating in water, there are five general directions that represent the direction of waves that hit the ship's hull [10]. Waves with directions of 120° and 150° are referred to as complete bow oblique waves, or bow waves for short [11].

Several theories are used in analyzing the ship's motion response at sea. For different types of ships, seakeeping forecasts based on strip theory and the panel technique on maxsurf movements are possible to be made with a considerable amount of accuracy. The quickness of analysis and the incorporation of Maxsurf features make Maxsurf motions very useful at the initial design stage [9]. Nasar et al. (2013) studied ship maneuvering due to sloshing behavior that occurred in ship tanks [12]. The prediction of ship response under real-world sailing conditions is very important to ensure effective ship design. Most ships prefer a slanted wave for less resistance and greater propulsion when at sea, and they rarely sail in severe swell conditions. Using the commercially-based potential flow breaker (PF), HydroSTAR, Rahaman et al. (2017) give tilted wave modeling results for container ships, tankers, and bulk carriers to provide comparative comparisons in trends in

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drag and ship motion at various heading angles for three models of boat [13].

Typically, investigations on wave-induced ship motion and load response are conducted assuming that the incident wave is long-crested. On the other hand, realistic ocean waves are short-crested irregular waves. Real-world experience demonstrates that short-crested waves cause the ship to move and respond to loads differently than long-crested waves. Jiao et al. 2019 conducted a comprehensive study of ship movements and loads in various wave fields [14]. Adhitama et al. 2019 analyze exercises using the CFD method [15].

Using the computational fluid dynamics (CFD) approach and the 3-D linear potential method, Hizir et al. 2019 performed numerical simulations to forecast the additional resistance of KVLCC2 with variable wave steepness, followed by the nonlinearity of the additional resistance and ship motion. Regular long and short waves were examined [16]. Hao et al. (2022) used the recurrent neural network (RNN) model to predict container ship maneuvers. The sequence of rudder angles and their variations, the ship's speed, and the recursive output speeds of surge, sway, and yaw make up the input model [17]. Oh et al. 2021 compared the results of the model tests and discovered that the proposed hybrid radiation technique-adopting three-dimensional Rankine source approach is more accurate and stable numerically, as well as in obtaining seakeeping solutions [18]. Using the Seakeeper computational application, Romadhoni investigates the motion of an ax bow type ship under the influence of regular waves [19].

The Tasai approach was utilized by Arslan et al. (2021) to determine a container ship's two-dimensional hydrodynamic added mass and damping coefficient. The Ikeda method can be used to determine the damping value for the roll motion under various loading circumstances. Using the head-seas method, the Froude-Krylov terms and diffraction for pitch and heave motions are determined [20]. For one type of ship, Erselcan 2010 forecasts sway, roll, and yaw movements. Even though the calculations produced findings that were extremely similar to the experimental data, more calculations had to be done using other hull shapes [21].

II. METHOD

3D modeling is done using B-Spiline-based software. Likewise, with the analysis of calculations using the help of Maxurf Motion software [22]. Basically, the software adopts one of the Frequency Domain Method or Strip Theory methods. Nordforsk 1987 became the control for the results of the analysis of motion [23]. This study focuses on a comparative analysis of three seakeeping codes based on the commercial MaxSurf code, which is the standard strip approach. RAO heave and pitch were compared and calculated whenever possible with and without the transom term activated [24]. The "Strip Theory" is used to estimate how the ship would move when there are regular waves, arbitrary directions, and a constant forward speed for the ship as well as to compute the horizontal and vertical shear forces caused by the waves, as well as bending moments and twisting moments. Unlike more sophisticated techniques, this theory, which was first devised by Salvesen et al. in the 1970s, is relatively simple to utilize and computationally simple. In the frequency domain, strip theory is mathematically stated. The theory states that the two-dimensional ship's equation of motion's coefficients are computed, integrated throughout the whole length of the ship, and then transformed into three-dimensional global coefficients. The technique created by Salvesen et al. can be used to calculate the global additional mass and damping coefficient [25].

Another method can also be used where the additional two-dimensional hydrodynamic mass and the damping coefficient are calculated by using Ursell [26] and [27][28] multipolar expansion theory and conformal mapping from Tasai. The hydrodynamic coefficient is calculated using the Lewis conformal mapping method. Using the head-seas method, the excitation terms for the pitch and heave movements were estimated. Operator Amplitude Responses for hull motion are plotted at different velocity increases under the influence of head waves [29].

The body-exact strip theory shows significant results that have been proven to provide good predictions, taking into account the interactions between parts when the ship's speed increases [30]. In this study, operational loadcase settings were also carried out, namely 100% DWT, 50% DWT, and 25% DWT, with variations in wave entry angles of 180° (head sea) and 90° (beam sea) and by varying the ship's speed, namely 18 knots [31]. The results of the motion analysis will be controlled using seakeeping criteria [32].

III. RESULTS AND DISCUSSION

At this stage, the process and results of the work will be described in detail in analyzing the ship's motion on the Water Ambulance ship.

A. Scantling Model Water Ambulance

Before being able to analyze the stability and maneuverability of the ship, it must first have a design for the ship itself. In previous research, the design of the ship's shape has been made in CAD and MaxSurf forms. The main size values on the water ambulance ship from previous studies are as follows Figure 1. Here are the main dimensions of the ship as designed:

LWL = 9.17 m
B= 2.66 m
H= 1.23 m
T= 0.43 m

B. Operational loadcase conditioning

Proses This process is carried out by entering loading data (the distribution of ship weight and equipment located on all parts of the ship, including the deck), as well as the use of tanks in each shipping condition (depaerture, ballast, and lightship). The Loadcase function is used to add an input factor in the form of a load, which will be used as the basis for calculating the stability and strength of the ship. Some supporting data include: weight distribution of empty ships; machine weight distribution; and weight distribution of equipment, crew, and provision. In this study, there were 3 loadcase conditions, namely loadcases with 100%, 50%, and 25% DWT loads.

TABLE 1.
LOADCASE

The arragement loadcase data are:

Initial/loadcase	100% DWT	75% DWT	25% DWT
F.O. T	0.075 m^3	0.038 m^3	0.019 m^3
FWT	0.561 m^3	0.281 m^3	0.140 m^3
Crew	7	4	2
Draf	0.438 m	0.401 m	0.378 m

In addition to carrying out operational loadcase conditioning at a speed of 18 knots, which will be used in the RAO analysis process.

C. Ship Motion Analysis

The maxurf motion software is used to analyze wave entry angles of 180° (head sea) and 90° (beam sea) as well as speed variations. The main ship sizes are LWL, T, and H, which are 9.17 m, 0.43 m, 1.23 m, and 2.66 m, respectively.

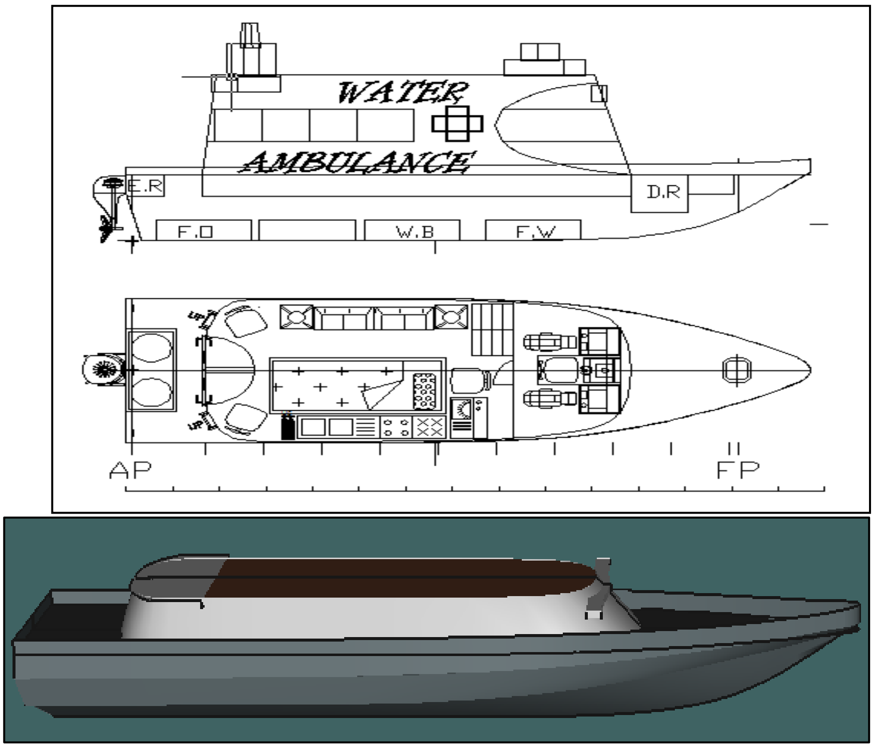

Figure 1. Water ambukance [4]

RAO for ships with a DWT loadcase of 100% with the direction of the wave coming from the front of the ship (head sea) and from the side of the ship (beam sea) can be shown in Figures 2 and 3. Meanwhile, the RAO for ships with a loadcase DWT of 50% and the direction of the waves coming from the front of the ship (head sea) and from the side of the ship (beam sea) can be shown in Figures 4 and 5. In the RAO for ships with a 25% DWT loadcase, the direction of the wave coming from the front of the ship (head sea) and from the side of the ship (beam sea) can be shown in Figures 6 and 7.

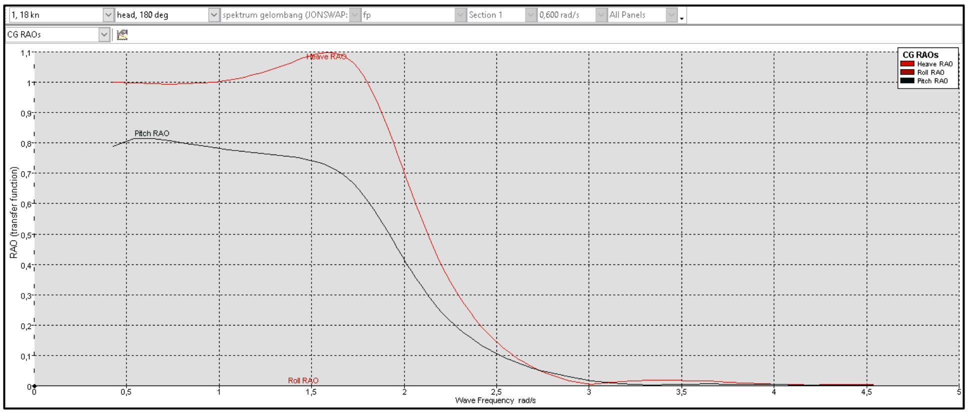

Figure 2. RAO under head sea loadcase 100% DWT

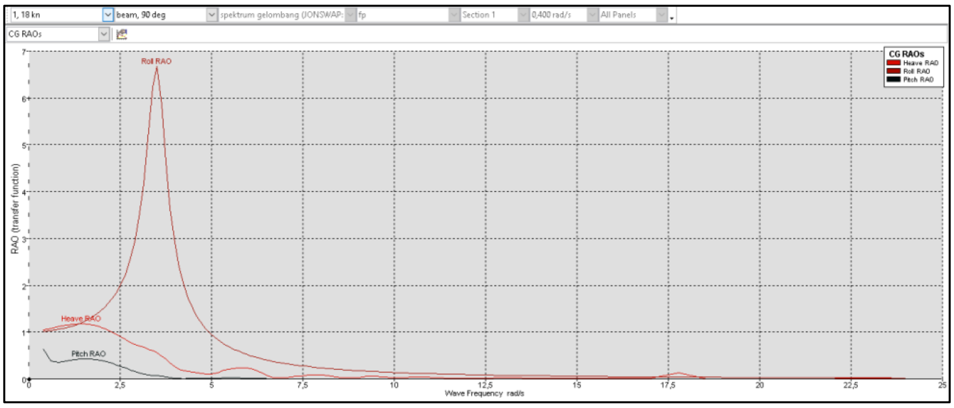

Figure 3. RAO under beam sea loadcase 100% DWT

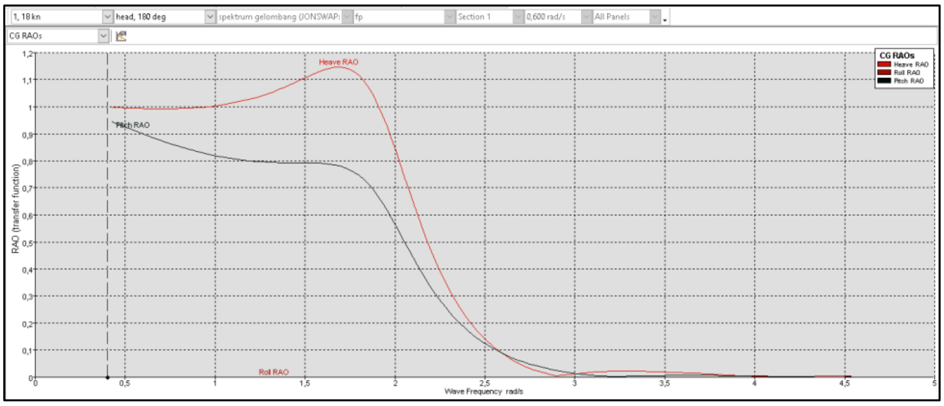

Figure 4. RAO under head sea loadcase 50% DWT

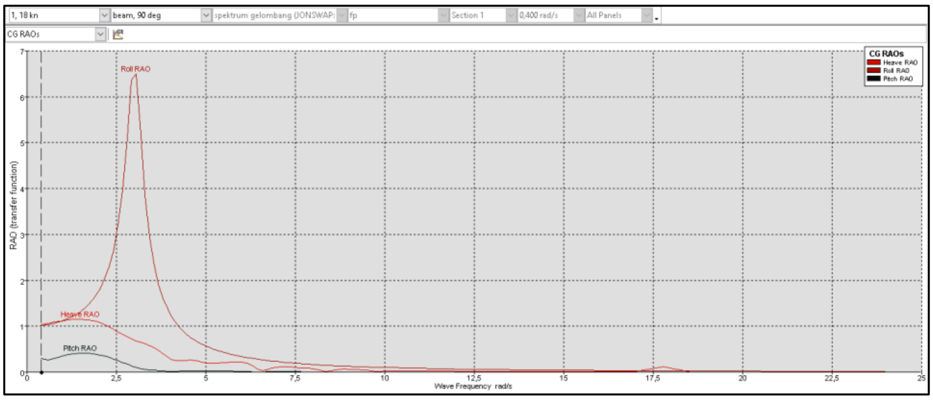

Figure 5. RAO under beam sea loadcase 50% DWT

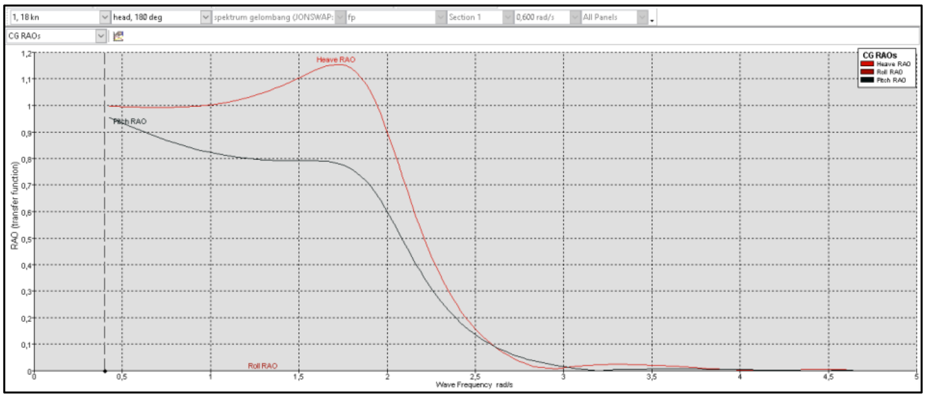
1, 18 kn
head, 180 deg
spektrum gelombang (JONSWAP:
fp
Section 1
0,600 rad/s
All Panels
CG RAOs

Figure 6. RAO under head sea loadcase 25% DWT

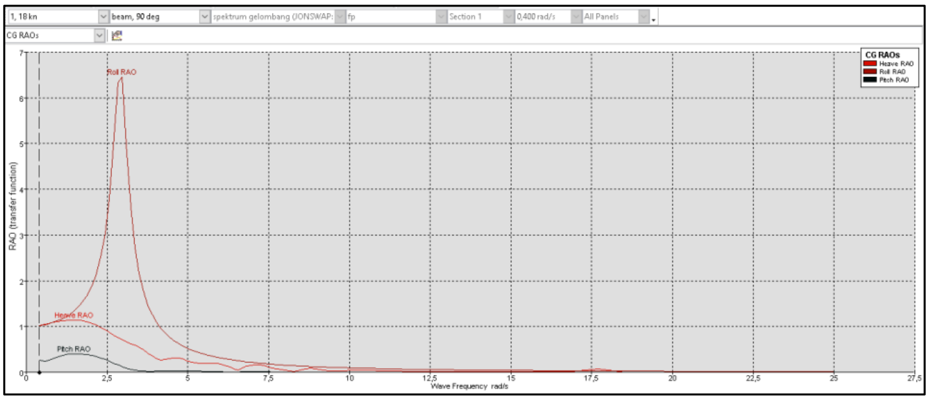
1, 18 kn
beam, 90 deg
spektrum gelombang (JONSWAP:
fp
Section 1
0,400 rad/s
All Panels
CG RAOs

Figure 7. RAO under beam sea loadcase 25% DWT

TABLE 2.
MOTION OF SUMMARY

Laodcase & wave direction angle		**Criteria Nordforsk 1987**	**Value**	**Units**	**Actual**	**Status**
100% DWT	head sea	At FP, vertical acceleration (RMS)	≤ 0.275	g	0.067	accepted
		Bridge Vertical Acceleration (RMS)	≤ 0.2	g	0.055	accepted
		Bridge Lateral Acceleration (RMS)	≤ 0.1	g	0	accepted
		Roll (RMS)	≤ 4.0	deg	0	accepted
	beam sea	At FP, vertical acceleration (RMS)	≤ 0.275	g	0.014	accepted
		Bridge Vertical Acceleration (RMS)	≤ 0.2	g	0.012	accepted
		Bridge Lateral Acceleration (RMS)	≤ 0.1	g	0.03	accepted
		Roll (RMS)	≤ 4.0	deg	1.63	accepted
50% DWT	head sea	At FP, vertical acceleration (RMS)	≤ 0.275	g	0.072	accepted
		Bridge Vertical Acceleration (RMS)	≤ 0.2	g	0.058	accepted
		Bridge Lateral Acceleration (RMS)	≤ 0.1	g	0	accepted
		Roll (RMS)	≤ 4.0	deg	0	accepted
	beam sea	At FP, vertical acceleration (RMS)	≤ 0.275	g	0.013	accepted
		Bridge Vertical Acceleration (RMS)	≤ 0.2	g	0.012	accepted
		Bridge Lateral Acceleration (RMS)	≤ 0.1	g	0.025	accepted
		Roll (RMS)	≤ 4.0	deg	1.71	accepted
25% DWT	head sea	At FP, vertical acceleration (RMS)	≤ 0.275	g	0.074	accepted
		Bridge Vertical Acceleration (RMS)	≤ 0.2	g	0.059	accepted
		Bridge Lateral Acceleration (RMS)	≤ 0.1	g	0	accepted
		Roll (RMS)	≤ 4.0	deg	0	accepted
	beam sea	At FP, vertical acceleration (RMS)	≤ 0.275	g	0.013	accepted
		Bridge Vertical Acceleration (RMS)	≤ 0.2	g	0.025	accepted
		Bridge Lateral Acceleration (RMS)	≤ 0.1	g	0.025	accepted
		Roll (RMS)	≤ 4.0	deg	1.71	accepted

1. RAO loadcase 100% DWT under heading sea
   Show in Figure 2, when the ship is against the waves, namely at 180° (head sea) at a speed of 18 knots, the ship experiences the largest heave movement at a frequency of 0.252 rad/s, the largest pitch movement at a frequency of 0.086 rad/s, and no roll movement occurs. Then we obtained a heave value of 0.249 m, a pitch of 0.82 deg, an RMS for vertical acceleration at FP of 0.0667 g, an RMS for vertical acceleration at bridge of 0.0550 g, an RMS for lateral acceleration at bridge of 0 g, and an RMS roll of 0 deg.
2. RAO loadcase 100% DWT under beam sea
   From Figure 3, when the ship gets a wave of 90° (beam sea) at a speed of 18 knots, the ship experiences the largest heave movement at a frequency of 0.230 rad/s, the largest pitch movement at a frequency of 0.064 rad/s, and the largest roll movement at a frequency of 0.558 rad/s. Then we obtained a heave value of 0.276 m, a pitch of 0.47 deg, an RMS for vertical acceleration at FP of 0.0143 g, an RMS for vertical acceleration at bridge of 0.0129 g, an RMS for lateral acceleration at bridge of 0.03 g, and an RMS roll of 1.63 deg.
3. RAO loadcase 50% DWT under heading sea
   From Figure 4, when the ship is against the waves, namely at 180° (head sea) at a speed of 18 knots, the ship experiences the largest heave movement at a frequency of 0.269 rad/s, the largest pitch movement at a frequency of 0.095 rad/s, and no roll movement occurs. Then we obtained a heave value of 0.249 m, a pitch of 0.90 deg, an RMS for vertical acceleration at FP of 0.0727 g, an RMS for vertical acceleration at bridge of 0.0585 g, an RMS for lateral acceleration at bridge of 0 g, and an RMS roll of 0 deg.
4. RAO loadcase 50% DWT under beam sea
   From Figure 5, when the ship gets a wave of 90° (beam sea) at a speed of 18 knots, the ship experiences the largest heave movement at a frequency of 0.238 rad/s, the largest pitch movement at a frequency of 0.064 rad/s, and the largest roll movement at a frequency of 0.486 rad/s. Then we obtained a heave value of 0.270 m, a pitch of 0.44 deg, an RMS for vertical acceleration at FP of 0.0138 g, an RMS for vertical acceleration at bridge of 0.0126 g, an RMS for lateral acceleration at bridge of 0.0259 g, and an RMS roll of 1.71 deg.
5. RAO loadcase 25% DWT under heading sea
   From Figure 6, when the ship is against the waves, namely at 180° (head sea) at a speed of 18 knots, the ship experiences the largest heave movement at a frequency of 0.273 rad/s, the largest pitch movement at a frequency of 0.095 rad/s, and no roll movement occurs. Then we obtained a heave value of 0.249 m, a pitch of 0.91 deg, an RMS for vertical acceleration at FP of 0.0748 g, an RMS for vertical acceleration at bridge of 0.0598 g, an RMS for lateral acceleration at bridge of 0 g, and an RMS roll of 0 deg.
6. RAO loadcase 25% DWT under beam sea
   From Figure 7, when the ship gets a wave of 90° (beam sea) at a speed of 18 knots, the ship experiences the largest heave movement at a frequency of 0.238 rad/s, the largest pitch movement at a frequency of 0.238 rad/s, and the largest roll movement at a frequency of 0.473 rad/s. Then we obtained a heave value of 0.268 m, a pitch of 0.42 deg, an RMS for vertical acceleration at FP of 0.0136 g, an RMS for vertical acceleration at bridge of 0.0125 g, an RMS for lateral acceleration at bridge of 0.0251 g, and an RMS roll of 1.71 deg.

From several analyses of the ship's motion consisting of two wave incident angles and three loadcases, it was found that all of them still met the Nordforsk criteria, namely vertical acceleration at the FP (RMS) 0.275g, vertical acceleration at the bridge (RMS) 0.2g, lateral acceleration at the bridge (RMS) 0.1g, and roll (RMS) 4.0 degree.

IV. Conclusion

While the highest significant amplitude heave value occurs on a ship with 100% DWT conditions with a speed of 18 knots and a wave direction of 90^0, which is 2.70 meters, the highest significant value of amplitude pitch occurs on a ship with a condition of 25% DWT with a speed of 6 knots and a wave arrival direction of 180^0, namely 1.10 degrees, and the highest significant value of roll amplitude occurs in ships with 25% DWT conditions with speeds of 18 knots with a wave arrival direction of 90^0, which is 3.42 deg. The results of the analysis show that all conditions still meet the Nordforsk criteria. in the future work, it is suggested to use panel method (CFD), since some aspects are more detail in panel method.

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