Numerical Analysis of Slamming Intensity of Warship in Territorial Water of Indonesia

Teguh Putranto,[a,*] and Aries Sulisetyono,[a]

[a)]*Naval Architecture, Institute of Technology Sepuluh Nopember, Indonesia*
*Corresponding author: theories_1990@yahoo.com

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ABSTRACT

Needs warships can certainly support the performance of the military to carry out military operations. The problem is that warship slamming behavior always occurs in high-speed vessels and can cause boat sunk. This research aims to predict the probability of slamming in operational areas where open water in Indonesia. The probability of slamming is provided from the response spectrum of heaving and pitching motion. The response spectrum is obtained from the multiple between Response Amplitude Operator (RAO) and wave spectrum which these values are determined by design of vessel and wave condition. This numerical analysis is carried out by using panel method. The output of this research is the probability of slamming which is important to determine the intensity of slamming during vessel operates. From the result of the numerical analysis, the intensity of slamming of warship is 1316 times per hour when the heading angle is 135 degrees and ship speed is 30 knots.

KEY WORDS: *warship, slamming, WAO, wave*

NOMENCLATURE

$S(\omega_w)$	Wave Spectrum
ω_w	Circular Frequency
$H_{1/3}$	Significant Wave Height
m	Mass of Ship
$a(\omega)$	Added Mass Coefficient
$b(\omega)$	Damping Coefficient
c	Restoring Coefficient
$F(\omega)$	External Force
RAO	Response Amplitude Operator
ς_a	Wave Amplitude
T	Ship Draft
m_{0s}	Energy Spectrum of Relative Motion
m_{2s}	Energy Spectrum of Relative Velocity

1.0 INTRODUCTION

Field of hydrodynamics which is discuss about the interaction between wave and elastic structure is hydroelasticity. In this time, hydroelasticity effect becomes the interest especially the ship having multi-hull, container ship, tanker, bulk carrier, and fast craft [1]. The hull design unique and light construction make flexibility of structure of ship when operate in wave. The considering of hull design becomes important when involving the hydroelasticity analysis. Therefore, the reaction is bigger at the elastic structure than the rigid structure [2]. So, it is no surprised that the hydroelasticity effect is important at fast craft using light and elastic material.

Advance technology in field of naval architecture, inovation of special material and hull design using fast speed patrol boat is interesting to be examined the characteristics of hydroelasticity. Determining of hull design can be reduced the slamming local and displacement of hull ship [3]. The intensity of slamming is definitely influenced by the draft of vessel. The low draft vessel is definitely reduced the total resistance where the next step is related to the main engine used and m fuel consumed [4]. But the lower draft vessel can cause the instability of ship motion. The other interesting phenomena is the problem of ship motion in wave that need to be fixed and evaluated the seakeeping characteristics [5].

2.0 SHIP MOTION THEORY

The ship motion can be affected by the shifting cargos, motion due to winds, water streams int he ocean, and possible effects due to shallow water. Furthermore, the deformation of the ship is not included in the current model. The ship hull is considered as rigid body [6].

When the ship operates in seaway, the motion of ship is affected by wave concerning to the hull. The motions are consisted of the transversal and rotational motion which are included surge, sway, heave, roll, pitch, and yaw. The description can be shown as Figure 1.

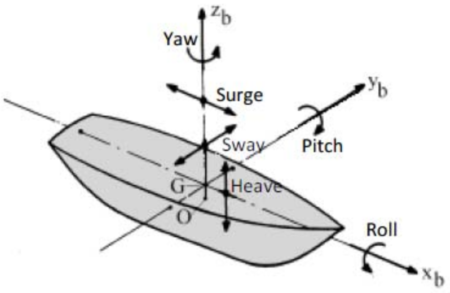

Figure 1. Six Degree of Freedom of Ship Motion

2.1Response Amplitude Operator (RAO)

The RAO curve indicates that the ratio between response of ship motion and wave amplitude. The magnitude of RAO is particularly determined by the design of ship. RAO is transfer function used to determine ship motion behaviour when it is experienced the regular wave. The RAO transfer motion is assumed to be linear in case of calculation of ship motion. The formula that used to determined the ship motion equation can be shown as Formula 1 [6].

$$[m + a(\omega)]\ddot{x} + b(\omega)\dot{x} + cx = F(\omega) \tag{1}$$

In condition of regular wave, the forces that concerning the hull ship are inclueded: (i) Froude Krylov force, pressure in wave concerning along hull ship immersed, (ii) Diffraction force, pressure occrued is affected by wave disturbance when operates. The RAO formula can be shown as Formula 2 [6].

$$RAO(\omega) = \frac{x}{\varsigma_a} = \frac{F_0}{C - [m + a(\omega)]\omega^2 + ib(\omega)\omega} \tag{2}$$

2.2 Wave Spectrum

The wave heights and the frequency can be differently occured at the irregular seaway. The statistical method is conducted to obtain the energy spectrum or wave spectrum in the irregular wave. The combination of regular wave produces the irregular wave [6].

When the wave spectrum of a particular sea is not available, International Towing Tank Conference (ITTC) spectral formulation should be used as Formula 3.

$$S(\omega_w) = \frac{A}{\omega_w^5} e^{-B/\omega_w^4} \tag{3}$$

Where, $A = 8.10x10^3 g^2$, $B = 3.11x10^4 / H_{1/3}^2$. the significant wave heeight affects the magnitude of wave spectrum [6].

2.3 Probability of Slamming

In case of dynamic effects due to ship motion, the vertical effect is affected by heaving and rolling motion. One of the vertical effects is slamming effect. Slamming is then defined as a hydrodynamic impact phenomenon, and it is associated with a sudden change in the acceleration of the ship [6].

The times of intensity slamming are definitely affected the strength construction of the ship. In case of slamming effects, if it is assumed that bow motion is statistically independent events, the slamming probability can be given as Formula 4.

$$\Pr ob\{slam\} = e^{\left(T^2 / 2m_{0s} + v_0^2 / 2m_{2s}\right)} \tag{4}$$

That formula relates to the energy spectrum that provided from the multiple between RAO and wave spectrum for heaving and pitching motion [6].

3.0 METHODOLOGY

Overall, the research is carried out with numerical analysis. This research is intended to examined clearly about the seakeeping of warship. The design of warship was provided from previous research. The methodology conducted in this research can be shown in Figure 2. After the hull design is obtained, the calculation of seakeeping in irregular wave is carried out numerically. Numerical method can be used to calculate the seakeeping. Ship model is devided in a thousand of elements or panels. Then the elements or panels model is integrated to obtain the response of ship because of wave [7].

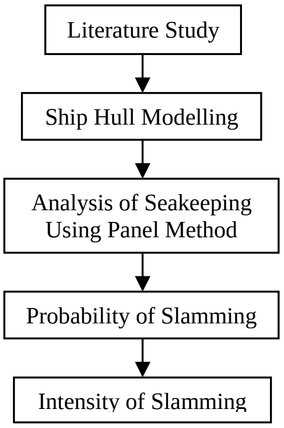

Figure 2. Flowchart of This Research

Theoritically, Response Amplitude Operator (RAO) is the ratio of the square of amplitude of ship motion to amplitude of wave [8]. Because ship never moves in regular wave, the data of wave in a region is needed. In a territorial water is always occured irregularly so the wave spectrum is approached with International Towing Tank Conference (ITTC) formula. To use that formula, significant wave height in this territorial water is needed as input in that formula.

The multiple between wave spectrum and RAO in each of six degrees of freedom will produce the response spectrum of warship in six degrees of freedom. The response spectrum is used to calculate the relative bow motion of warship. Because the goal of this research is to determine the probability and intensity of slamming, the energy of response spectrum is determined previously [9].

4.0 RESULT AND DISCUSSION

Main dimension of ship can be shown at Table 1 that it is used to this analysis. Figure 3 shows that the model ship used to calculate the slamming intensity.

Table 1.Main Dimension of Ship

Item	Value	Unit
Loa	106.00	m
B	14.00	m
T	3.70	m
H	8.75	m

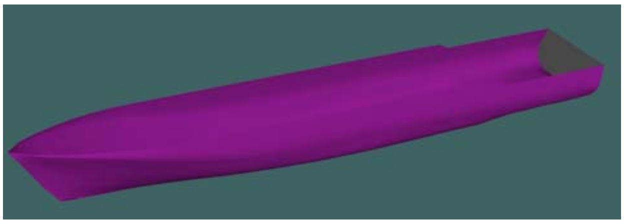

Figure 3. The Model of Ship

The numerical method produces the response spectrum of warship. Response spectrum is the density energy that occur when seakeeping. For slamming analysis, the seakeeping reviewed is the heaving and pitching motion because this motions affect the relative bow motion.

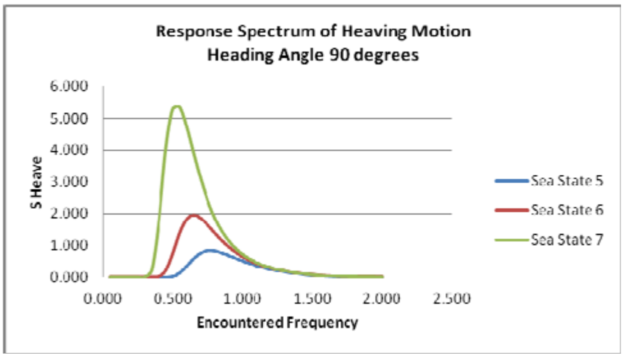

Figure 4. Response Spectrum of Heaving Motion at Heading Angle 90 Degree

The response spectrum graph is function of encountered frequency. The response spectrum is the multiple between wave spectrum from sea state 5 to 7 and RAO for heaving and pitching motion only. This research varies simulation based on the sea state and heading angle. For heading angle, it is taken 90, 135, and 180 degrees. The response spectrum with those variation can be shown in Figure 4 to 9.

This figures are shown that the sea state can influence the magnitude of response spectrum either heaving or pitching motion. The encountered frequency is obtained from the wave frequency, speed ship, and heading angle. Wave frequency can be marked from wave length. The longer of the wave length, the smaller of the wave frequency. So, the wave frequency is inversely to wave length.

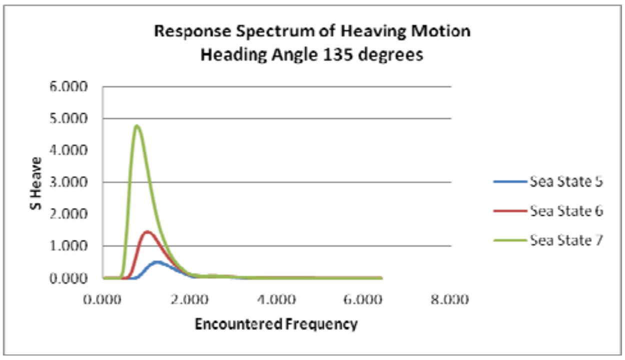

Figure 5. Response Spectrum of Heaving Motion at Heading Angle 135 Degree

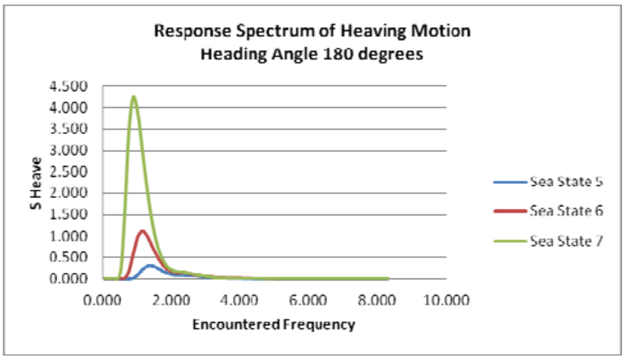

Figure 6. Response Spectrum of Heaving Motion at Heading Angle 180 Degree

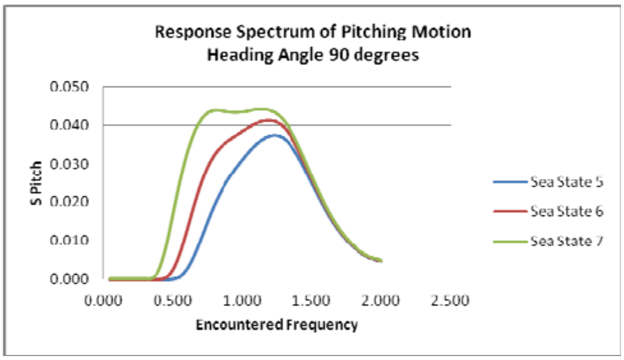

Figure 7. Response Spectrum of Pitching Motion at Heading Angle 90 Degree

From this figures, the response spectrum maximum is occured when sea state 7. Significant wave height of sea state 7 is about 5 metres. It is assumed that sea state 7 is the worst condition that may be happen in Indonesia. The warship is not always operated in calm condition so that the worst condition needs to be analyze to determine the survivability of warship in that condition.

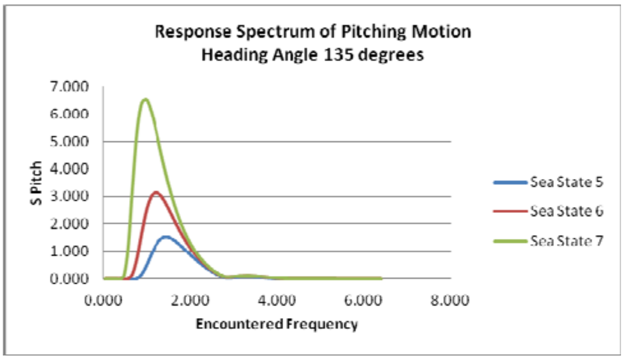

Figure 8. Response Spectrum of Pitching Motion at Heading Angle 135 Degree

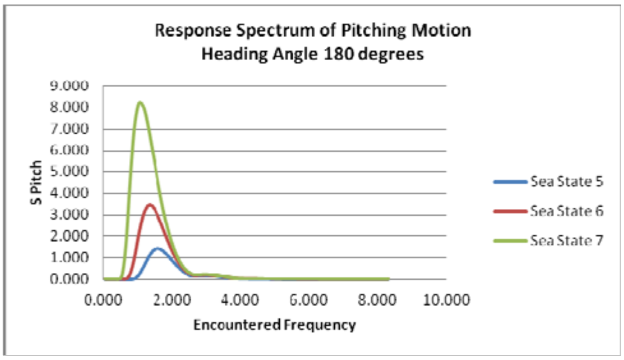

Figure 9. Response Spectrum of Pitching Motion at Heading Angle 180 Degree

The response spectrum is used to calculate the energy for calculation of probability slamming. Heaving and pitching motion give more contribution for relative bow motion. The heaving motion maximum is occured when sea state 7 and heading angle 90 degrees. The pitching motion maximum is occured when sea state 7 and heading angle 180 degrees. The information that can be gained about waves from a wave spectrum can similarly be obtained for motion from a motion spectrum.

By using the spectral method the spectral density of the relative bow motion in an irregular seaway can also be obtained from the spectral density of the heaving and pitching motions in an irregular seaway.

Table 2. Probability and Intensity Slamming at Heading Angle 180 Degree

Heading Angle 180					
Sea State	V	m_0	m_{2s}	P	N
Sea State 5	30 knot	13,557	158,438	0,620	1214
Sea State 6	30 knot	12,244	154,854	0,589	1200
Sea State 7	30 knot	9,204	150,213	0,495	1144

Table 3. Probability and Intensity Slamming at Heading Angle 135 Degree

Heading Angle 135					
Sea State	V	m_0	m_{2s}	P	N
Sea State 5	30 knot	20,253	196,250	0,726	1295
Sea State 6	30 knot	19,205	194,307	0,714	1300
Sea State 7	30 knot	16,738	191,668	0,679	1316

If it is assumed that bow emergence and relative bow velocity are statistically independent events, the combined probability (which is the product of the probability of bow emergence and the probability that the relative bow velocity exceeds the threshold velocity) then gives the slamming probability (Bhattacharyya, 1972) can be shown in Tabel 2 to 4.

Table 4. Probability and Intensity Slamming at Heading Angle 90 Degree

Heading Angle 90					
Sea State	V	m_0	m_{2s}	P	N
Sea State 5	30 knot	4,004	8,967	0,198	170
Sea State 6	30 knot	3,575	8,759	0,163	146
Sea State 7	30 knot	2,444	8,384	0,071	75

5.0 CONCLUSION

Conclusion of this research as follow:

1. Intensity of slamming maximum is occured at heading angle 135 degrees, ship speed 30 knots, and sea state 7 which the result of intensity of slamming is 1316 time per hour.
2. The faster of ship speed, the bigger of intensity of slamming.

6.0 ACKNOWLEDGEMENT

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