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Operability and Sea worthiness Analysis of Passenger Ship using Motion Simulation

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Abstract:
The disturbance of external forces such as wave force will affect the comfort and safety of the crew and the passengers of a vessel. The ship's motion response is a paramount parameter that must be considered to be considered during the ship feasibility design. This paper provides an analysis of three responses of ship motions namely heaving, rolling and pitching. The operational scenarios include full **load with three ship speeds of 8, 10, 12 knots and three headings of 0°, 90°, and 180°.**The variation of the wave height is significant and the zero up crossing wave period is based on the shipping data and the route of the vessel in accordance with the sea state. The simulations were performed using the MaxSurf Motions Advance software. The simulation results show that the percentage of ship operability based on seakeeping criteria is 86.58% operable and 13.42% downtime. The comfort level on the passenger vessel presented by the value of Motion Sickness Incidence and found to be less than 10 SM for the operational wave height permitted and safe sailing vessels in the waters of Java Island.

I. Introduction

Passenger ships have an oscillating motion caused by external forces. The motions of ship generated by the disturbances of currents, winds, and waves will cause symptoms of seasickness for passengers and crew. The safety and comfort of passenger is affected by the motion response due to the external disturbances impactingon the ship, especially the disturbance of wave force. The motion response is analyzed from the seakeeping calculation. A passenger ship should have the ability of being operated on various ocean conditions.

Therefore, a seakeeping and seaworthiness analysis is needed to determine the level of operability. In this paper, seakeeping quality of 1200 GT passenger ship is analyzed using MaxSurf Motion Advanced software with related variables of wave height on the Java Island shipping route. The results obtained from this seakeeping analysis are safety, comfortable, and operability level. Regression model is developed to predict the maximum wave height of vessel to fulfil the seakeeping and seaworthiness criteria.

II. Literature Review

Seakeeping performance of the vessel is dependent on the heading angle of the wave, its amplitude, and spectrum. The ship motions will raise the level of motion sickness incidents and the ship operability.

The definition of seakeeping, response amplitude operator, wave spectrum, motion sickness incidence and operability of ship is described below.

A. Seakeeping

The ship motions are influenced by external excitation in the form of current, wind, and wave which plays the most significant role. The seakeeping performance of vessel is determined by ability of ship to keep its condition in the acceptable operability and seaworthiness criteria. The motions of ship considered in seakeeping analysis are heaving, pitching, and rolling. Heaving is the translation motion of a ship parallel to the Z axis. Heavingmotion will change the drift of ship periodically due to the ship moving up and down.Pitching is the motions of the ship that rotates around the Y-axis. Pitching motion ship changes trim by the bow and stern in turn.Rolling is the motions of the ship towards the X axis. The coordinate system of 6-DF ship motions is shown in figure 1.

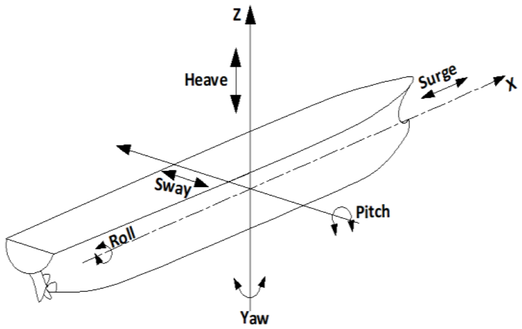

Figure 1. The 6-DF of Ship Motions

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The research on seakeeping criteria has been widely practiced by the US Navy, as stated in the paper from Olson [1] and listed in table 1.

Table 1
Seakeeping Criteria [1]

No.	General Criteria
1.	12˚ single amplitude average roll
2.	3˚ single amplitude average pitch
3.	Significant heave acceleration ≤0.4g (no people working on deck)
4.	Significant heave acceleration ≤0.2g (people working on deck)

B. Heading Angle

The heading angle of wave (μ) is the angle at which the forward direction of the wave and the arrival direction of the vessel is counted clockwise from the direction of the wave. There are 3 types of heading on seakeeping analysis and are:

a. Head Sea (180°)
b. Following Sea (0°)
c. Beam Sea (90°)

C. Response Amplitude Operator (RAO)

The ship motions response in regular waves is expressed in the RAO. The RAO is ratio between ship's amplitude of motion, either translation or rotation, to the amplitude of the wave at a particular frequency. The RAO or often referred to as the transfer function is a response function that occurs due to waves in the frequency range of the ship.

The RAO is an instrument to transfer the external load in response to a structure. The general form of the RAO equation in the frequency function is presented in equation (1).

$$\text{Response}(\omega) = (\text{RAO})\eta(\omega) \quad (1)$$

where, η = wave amplitude, m or ft

The RAO for translational motion is a direct comparison between the amplitude of the ship's motions and the wave amplitude both in length units as described by equation(2). The RAO for rotational motion is the ratio between the amplitude of rotational motion, in radians, to the wave inclination which is the multiplication of the wave number, $kw = \omega^2 /g$ with wave amplitude, as shown by equation (3).

$$RAO = \frac{Z_0}{\zeta_0} \text{ (m/m)} \quad (2)$$

$$RAO = \frac{\theta_0}{kw\zeta_0} = \frac{\theta_0}{(\frac{\omega^2}{g})\zeta_0} \text{ (rad/rad)} \quad (3)$$

The waves in the ocean are random waves, therefore the ship's response to the regular waves expressed in the RAO cannot describe the ship's response to the real state of the ocean. According to Bhattacharyya [2], to get a response of ship motions against random wave the RAO can be described with response spectrum. The response spectrum is obtained by multiplying the wave spectrum (Sζ) with RAO^2as given by equation(4).

$$S_{\zeta r}(\omega) = RAO^2 \times S_{\zeta}(\omega) \quad (4)$$

D. Wave Spectrum

The wave spectrum in North Jawa Sea can be represented by the JONSWAP wave spectrum [4]. This spectrum is a refinement of the Pierson-Moscowits spectrum, because the North Sea has extreme environmental conditions and is bordered by islands and continents which result in fetch in this area quite short but has large waves. The wave spectrum is shown by equation (5).

$$S(\omega) = \alpha g^2 \omega^{-5} \exp\left[-1.25\left(\frac{\omega}{\omega_0}\right)^{-4}\right] \gamma^{\exp\left[\frac{(\omega_0-\omega)}{2r2\omega_0{}^2}\right]} \quad (5)$$

where,

γ is peakedness parameter = 3.3
τ isshape parameter = 0.07, if ω ≤ ωz
= 0.09, if ω >ωz
α = $0.076\ (x_0)^{-0.22}$
= 0.00819 (when x is unknown)
ω_0 = $2\pi\,(g / U\omega_0)\,(x_0)^{-0.33}$
x_0 = $gx/U\omega^2$
$\omega_0{}^2$ = 0.161g/HS

E. Motion Sickness Incidence (MSI)

Motion sickness incident on a ship also known as seasickness is commnly used for assessing possible occurrence of the illness [5]. The symptom of illness is the result from the motions of the ship resulting in uncomfortable physical symptoms characterized by difficulty breathing, dizziness, nausea, pale and vomiting.

The International Standard ISO 2631 [6] defines a method for estimating the percentage of passengers experiencing motion sickness symptoms at various positions on the ship for various criteria:

1. 10% MSI after 2 hours
2. 10% MSI after 8 hours
3. 10% MSI after 30 hours

The MSI assessment can also be based on the MSI value range based on the existing index as presented in table 2.

Table 2
MSI Index Range

Range	Status
0 – 5 SM	Moderate
5 – 10 SM	Serious
10 – 15 SM	Severe
10 – 15 SM	Hazardouse
>20 SM	intolerable

F. Operability

Operability can be interpreted as a descriptionof the ability of structures to operate by comparing the chances of structures working with operating area wave data. The ability of the operating structure is determined on the basis of those aspects according to the experts deemed to be representative enough in keeping a structure in good order. Operability is calculated using equations(6) and (7).

$$Down\ Time = \left[\frac{\Sigma Hs\ upper\ \ significant\ \ \ wave\ \ height}{\Sigma Hs\ Total}\right] \quad (6)$$

$$Operable = 100\% - \%\ Down\ Time \quad (7)$$

III. Methodology

Seakeeping and seaworthiness analysis on passenger ship require the actual ship's data consisting of key plan and stability booklet and also the ocean data where the vessel is sailing [3]. Furthermore, the passenger ship is re-modeled with a level of accuracy. The result of the modeling will be the basis of seakeeping analysis using Maxsurf Motion Advanced software. The study can be described the flowchart, figure 2.

IV. Results and Discussion

The model of a passenger ship to be analyzed in this study is modelled in MaxSurf software. The model is developed using the criteria of maximum 5% error on the displacement of the real ship. The main dimensions of the vessel is presented in table 3.

Table3
Validation of Ship Model

Δ (ton)	Cb	Lwl (m)	B (m)	H (m)	T (m)
1318	0.676	58.79 4	12.00	4.00	2.70

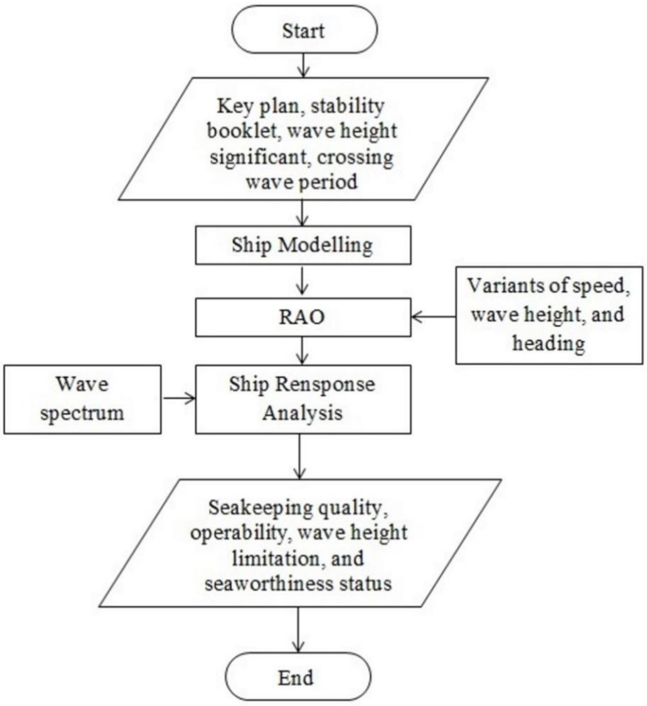

Figure 2. Flowchart of the Study

Table 4
Ship Operating Condition

Speed (Knots)	Heading (°)			Wave Height(meter)		
12						
10	0	90	180	1.8	2.5	3.2
8						

A. Operating Condition

The seakeeping analysis for the passenger ship uses three variables as operating condition, i.e. speed, heading and the significant wave height. The analysis is related to the three ship motionsofheaving, pitching, and rolling. The variables are shown in table 4.

Ship motion analysis using JONSWAP wave spectrum with wave height significant (Hs) in **West Jawa Sea**is 1.8 meters and maximum height (H max) is 3.2 meters with the zero up crossing wave period of 7 s.

B. Seakeeping Performance

The seakeeping analysis produced 9 (nine) graphs showing motion response parameters as a function of significant wave height at variations in ship speed and heading angle. Furthermore, by comparing the parameters, one graph is selected which shows the greatest value for each motion type. Seakeeping performance of the vessel by the operating condition of the simulation is shown in figures 3 to 5 for rolling, pitching, and heaving motions, respectively. The limit of acceptable criteria are plotted on the figures.

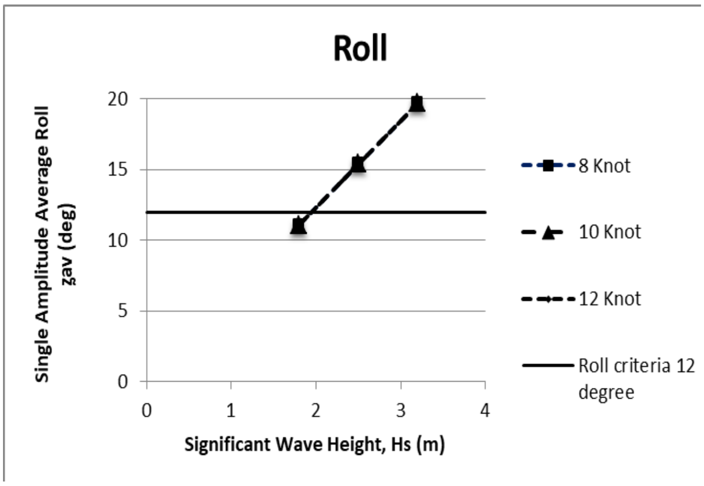

Figure 3. Rolling Performance by Ship Speed vs Wave Height

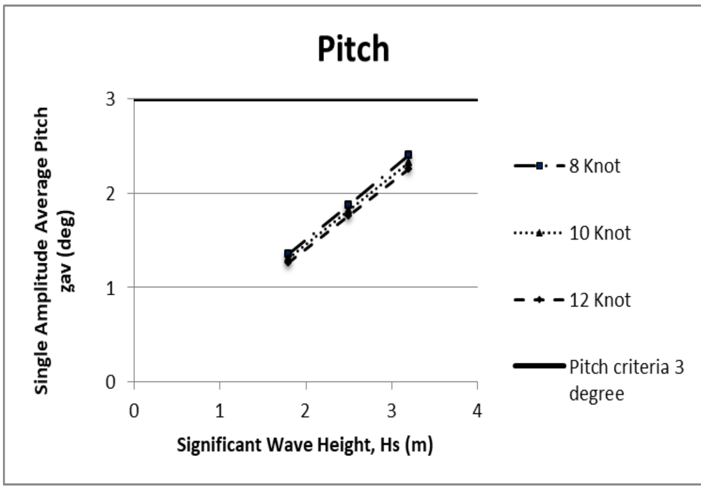

Figure 4. Pitching Performance by Ship Speed vs. Wave Height

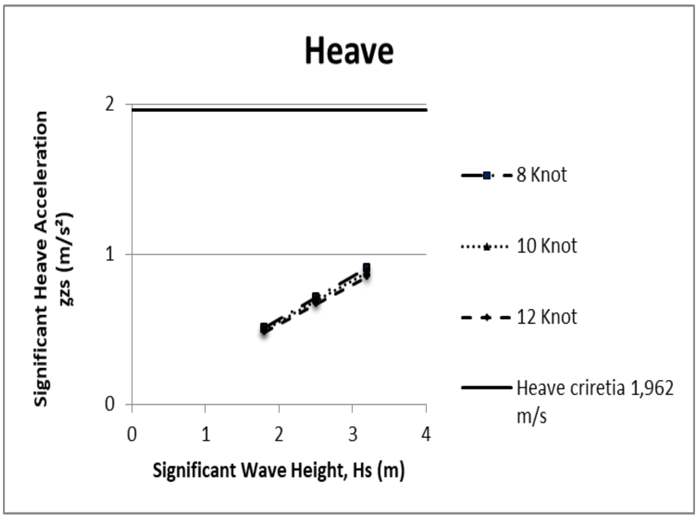

Figure 5. Heaving Performance by Ship Speed vs Wave Height

The figures show that rolling is the most factor that affect motion and the limitation of wave height to fulfil the criteria is 1.95 m.

C. Operability

Vessel operability and downtime values representing the percentage of vessels may be operated and vessels not operable are shown in figure6. The limitation of wave height average for passanger ship in full load condition with following sea, beam sea, and head sea heading is 1.95 meters. The calculation using wave scatter diagram or **wave distribution of Java Sea**with wave height limitation 1.5 meters, the operability 1200 GT passanger ship is 86.58% an 13.42% down time.

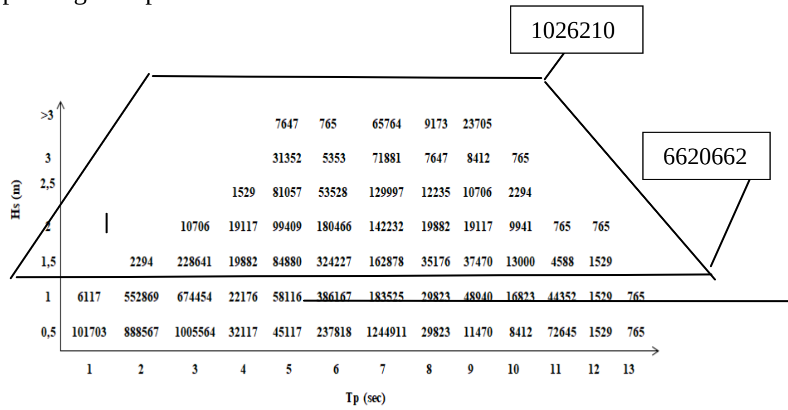

Figure 6. Ship operability plot[7]

D. Motion Sickness Incidence (MSI) Index

The simulation resultonMSI index is presented by table 5.

Table 5

Motion Sickness Incidence (MSI) Index

Speed (knots)	Hs	Following Sea		Beam Sea		Head Sea	
		MSI	Satus	MSI	Satus	MSI	Satus
8	1.8	0.109	Moderate	2.476	Moderate	1.069	Moderate
	2.5	0.174	Moderate	3.961	Moderate	1.710	Moderate
	3.2	0.248	Moderate	5.367	Serious	2.435	Moderate
10	1.8	0.124	Moderate	2.361	Moderate	1.486	Moderate
	2.5	0.198	Moderate	3.777	Moderate	2.377	Moderate
	3.2	0.282	Moderate	5.376	Serious	3.384	Moderate
12	1.8	0.196	Moderate	2.250	Moderate	1.939	Moderate
	2.5	0.313	Moderate	3.600	Moderate	3.101	Moderate
	3.2	0.445	Moderate	5.124	Serious	4.414	Moderate

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V. Conclusions

Based on the analysis of results conducted using software of Maxsurf Motion, the conclusions are:

a) The maximum wave height allowed for passenger ship sailing in the waters of Java Island is not more than 1.95 meters.
b) Referring to the data of wave scatter diagram assumed to represent the operating area of the 1200 GT passenger ship the result is 86.58% operable and 13.42% downtime.
c) The severity of the MSI index will be occur if the wave height is 3.2 meters, but based on the criteria of rolling motion the allowable wave height is 1.95 meters.

VI. References

[1] Olson S 1978 An Evaluation of the Seakeeping Qualities of Naval Combatants *Naval Engineers Journal ASNE* 901 23-40
[2] Bhattacharyya R 1972 Dynamics of Marine Vehicles Annapolis, Maryland: John Wiley& Sons New York.
[3] Djatmiko E B 2012 Perilaku Dan OperabilitasBangunanLaut Di atasGelombangAcak Surabaya: ITS Press (in Indonesian)
[4] Hasswlmann K, Barnett T P, Bouws E, Carlson H, et. al. 1973 *Measurements of Wind-Wave Growth and Swell Decay during the Joint North Sea Wave Project* (JONSWAP)
[5] Cepowski T 2012 The prediction of the Motion Sickness Incidence index at the initial design stage *Scientific Journal* 31 103 45-48
[6] The International Standard ISO 2631–1 1997 *Mechanical vibration and shock – Evaluation of human exposure to wholebody vibration*
[7] Peters and David J H 2010 *Summary OfMetoceanCriteria* Conoco Phillips