# Reliability Analysis of Passenger Ship Structure Conversion in Bali Straits

Rizky Chandra Ariesta[1], Aries Sulisetyono[2], Totok Yulianto[3], Elwas Cahya Wahyu Pribadi[4]

***Abstract*— LCT conversion passenger ships have been widely operated in the waters of the Bali Strait. Ship operations in the Bali Strait result in repeated loads on the structure. Repeated loading produces vertical and horizontal bending moments that act randomly due to waves. Based on this, it is necessary to analyze the structure of the ship. The purpose of this study was to analyze the reliability value of the ship structure operating in undulating waters. Wave analysis is performed using the spectral method to determine the value of the load acting on the ship, while the reliability calculation uses the Mean Value First Order Second Moment (MVFOSM) method to determine the reliability value. The analysis was carried out on a full load and an empty load. The value of the reliability of the structure at full load is 0.913615 and at empty load is 0.88948.**

*Keywords*— Mean Value First Order Second Moment (MVFOSM), Reliability, Ship structure, Spectal

## I. INTRODUCTION

Ships operating in certain waters will experience random loading due to wave height and period. The continuous operation of the ship causes repeated loads to occur on the ship's structure. This loading causes stress to occur in the ship structure. The stress needs to be analyzed whether it is still allowed and how long it can withstand repeated wave loads. One of the methods to determine the load acting on the ship is using the spectral method to determine the stresses that occur in the ship structure. In addition, designing the ship structure needs to be analyzed because of the uncertainty of several parameters in designing the ship, such as wave loads, materials, and manufacturing. This uncertainty needs to be anticipated by considering the safety factor.

Because of this, a design requirement approach and analysis method that considers random conditions, both loading and structural conditions need to be carried out to estimate the risk of a response that exceeds the safety factor. This analysis will make the ship structure design tend to be more rational and lead to a probability-based design procedure that refers to the limit states design, which is based on a reliability-based design.

The theory of structural reliability considers the uncertainties and methods of clarification and rationalization in the design process to obtain a probability value of the structure meets the design criteria in its operation [1].

One of the methods used is MVFOSM which is used to estimate the reliability of a structure, the reliability of a structure is not obtained by reliability life-testing but can be calculated directly by considering the probability function that occurs and results in random variables that govern the failure behavior of a structure. This method is suitable for use in structural reliability analysis [2].

First Order Reliability Method (FORM) is another method that is almost the same as MVFOSM. Both have a first-order use function of the Taylor series. While the difference between these methods is in the location of the linearization of the boundary function. In the FORM method linearization is carried out at any one place at the failure limit while in MVFOSM linearization is carried out at the average value of the variables [3].

Honarmandi has optimized the cantilever beam based on reliability by using the MVFOSM and FORM methods. The use of MVFOSM and FORM shows almost the same results. There is only a slight difference between the two for high reliability [4].

Liu also uses the MVFOSM and FORM methods in optimizing the missile suspension structure with a reliability-based approach [5].

The aim of this study is to analyze the reliability of the LCT Convertible Passenger Vessel operating in the Bali Strait.

## II. METHOD

### A. Literature Review

This research is based on a case study conducted on an LCT conversion vessel operating in the waters of the Bali Strait. The dimensions of the ship are 54.90 m long, 2.57 m draft, 14.40 m breadth, and 3.50 m high.

A ship floating on the sea in a state of sagging can be assumed to be a beam with supports at the ends [6], while the hogging condition is assumed to be a beam supported in the middle. The maximum vertical bending moment occurs due to these two conditions.

This bending moment results in the maximum stress that occurs in parts of the structure that are far from the neutral axis, in this case the deck plate and base plate. Tensile stress on the base plate occurs in the sagging condition while compressive stress occurs in the deck plate. Then the hogging condition resulted in tensile

Rizky Chandra Ariesta, is with Department of Naval Architecture, Sepuluh Nopember Institute of Technology, Surabaya, 60111, Indonesia. E-mail: chandra@its.ac.id

Aries Sulisetyono is with Department of Naval Architecture, Sepuluh Nopember Institute of Technology, Surabaya, 60111, Indonesia. E-mail: chandra@its.ac.id

Totok Yulianto is with Department of Naval Architecture, Sepuluh Nopember Institute of Technology, Surabaya, 60111, Indonesia. E-mail: chandra@its.ac.id

Elwas Cahya Wahyu Pribadi is with Department of Marine Engineering, Sepuluh Nopember Institute of Technology, Surabaya, 60111, Indonesia. E-mail: elwascahyawahyupribadi@gmail.com

stress on the deck plate and compressive stress on the base plate. Potentially serious failures of the base and deck, which include failure due to fatigue.

In this study, the transfer function is calculated on the longitudinal section of the ship's keel to get the stress response acting on the ship. The stress response is obtained by calculating the random waves acting on the ship structure.

Random calculation analysis is done by modeling the wave spectrum, the response of the structure to the waves and the stress of the point of view in this case is the longitude on the bottom structure of the ship or on the keel to be precise. The calculation is carried out by using the spectral analysis method which uses a statistical approach factor.

Tensile and compressive stresses are calculated based on wave conditions that occur in the waters of the Bali Strait. The data used is the monthly average wave height data for one year taken from data from the Meteorological, Climatological, And Geophysical Agency (BMKG) Indonesia. Wave height is considered as a probabilistic variable, while the condition of the ship is assumed to remain even keel at empty draft and full load. Based on this calculation analysis, it will be known how big the ship structure reliability index is.

### B. *Wave Modeling*

According to Bhattacharrya [7] Three components can cause bending moments in the structure of the ship, namely the difference in the distribution of weight and upward compressive force when stationary in calm water, waves formed due to the motion of the ship in calm water, and because the ship is in a bumpy sea. There are two kinds of waves, namely sinusoidal waves and trichoidal waves. The wave which is a random variable requires an approach to calculate it which can be calculated using the approach can be seen in equation (1) to determine the zero up crossing period.

$$T_z = 2\pi \sqrt{\frac{m_0}{m_2}} \tag{1}$$

Where $T_Z$ is the value of zero ip crossing(s); $m_0$ is the 1 order moment spectral and $m_2$ is the 2nd order moment spectral. Then a wave scatter diagram table is arranged to correlate the significant wave height ($H_S$) with the period ($T_Z$) which shows the number of wave events, where each 1 table can be interpreted as 1 short-term wave analysis [8].

The waveform data obtained are represented in the form of a wave spectrum for further analysis. The wave spectrum is shown in each sea-state. The wave spectrum used has two parameters, namely significant wave height ($H_S$) and period ($T_Z$). Spectrum representation using the Pierson-Moskowitz spectrum approach which can be obtained by equation (2).

$$S_{(PM)} = \frac{H_s}{4\pi}\left(\frac{2\pi}{T_z}\right)\omega^{-5} \exp\left[-\frac{1}{\pi}\left(\frac{2\pi}{T_z}\right)^4 \omega^{-4}\right] \tag{2}$$

Where $S_{(PM)}$ = Pierson Moscowitz wave spectrum, Hs value = significant wave height (m), Tz = zero period *up crossing (s), and* ω = *wave frequency (rad/s).*

Hasselmann et al. found that there are factors addition to the spectrum that had previously been developed by Pierson-Moskowitz. So, JONSWAP spectrum is the Pierson-Moskowitz spectrum multiplied with peak enhancement factor γr [9]. Until the spectrum waveform can be converted into equation (3).

$$S_{(JWP)} = S_{(PM)}\,\gamma^r \tag{3}$$

Where, the value of S(JWP) = JONSWAP wave spectrum, γ = peak enhancement, which is 2.5, and r = peak factor *enhancements.*

### C. *Stress*

Stress is caused by various kinds of waves. The stress due to waves can be calculated in the bending moment conditions that occur on the ship horizontally and vertically which are calculated based on equations (4) to (6).

$$\sigma_H = \frac{M_Z}{I_{CL}}\, y \tag{4}$$

$$\sigma_V = \frac{M_y}{I_{NA}}\, z \tag{5}$$

$$\sigma_T = \sqrt{{\sigma_H}^2 + {\sigma_v}^2} \tag{6}$$

Where the value of σ = stress ($N/m^2$), M = bending moment (Nm), I = moment of inertia of the section ($m^3$), and z,y = distance point of view from the neutral axis or centerline (m).

Previously, stress analysis was carried out on strength checks. Strength checking is carried out on conditions, namely overall and one point review.

Previously by Misbah, an analysis of the longitudinal strength of this ship was carried out and verified by rules. The analysis was carried out on 4 loading cases where (1) is the load loadempty on sagging condition, (2) empty load on hogging condition, (3) full load at sagging condition and (4) full load at condition hogging. Calculations are carried out with the FEA software for stress value. The results show that the stress at each condition is (1) 72,393 MPa, (2) 74,792 MPa, (3) 129.92 MPa and (4) 132.4 Mpa [10].

Meanwhile, the local analysis was carried out by Ardianus who performed a stress analysis on the transverse bulkhead between the corrugated bulkhead and the transverse bulkhead. The results showed that the stress and weight were more effective with the use of corrugated bulkhead with a stress value of 76.6 N/mm2 at an angle of 45 degrees and a deformation of 2.48 mm [11].

### D. *Response Amplitude Operator*

To statistically determine the behavior of the structure due to waves, it is necessary to translate it into spectral moment, before further analysis is carried out, it is necessary to calculate the response amplitude operator (RAO) and the response spectrum for irregular waves. RAO is a function of the amplitude of the movement of the structure with respect to the amplitude of the wave [12]. The calculation of RAO is obtained from equation (7).

$$RAO_M = \frac{M}{Z_a} \quad (7)$$

Where the value of RAOM = response amplitude operator (Nm/m), M = bending moment (Nm), and Za = wave amplitude.

*E. Structural Reliability Analysis*

Structural reliability is defined as the probability that a structure will fulfill its design objectives under certain conditions [1]. To estimate the reliability of a structure requires attention to every form of failure that may occur. There are many modes of failure that may occur in a structure, for example material failure, structural stability, deflection, fatigue, and we can determine the reliability of the structure separately for each failure mode.

The method used in this study is the method of mean value first order second moment. This method is commonly used in structural reliability analysis [2]. The loading and structural strength effects expressed in a component performance function are treated as random variables.

In this method the input required in the calculation is the average value (mean value or first moment) and standard deviation (standard deviation or second moment) of these random variables. So the distribution or probability density function of these variables is not needed directly.

If Z is a random variable representing the working load and S is a random variable representing the strength of the material then the safety margin (M) is determined as M = S -Z [3]:

Failure will occur if the working load Z exceeds the ultimate capacity S,

$$P_f = P\,[M \leq 0] = F_m(0) \quad (7)$$

If the load Z and the power of S is the independent variable, then the average price($\mu_m$) and variant ($\sigma_m^2$) of the safety margin (M) is:

$$\mu_m = \mu_s - \mu_z \quad (8)$$

$$\sigma_m^2 = \sigma_s^2 - \sigma_z^2 \quad (9)$$

The standardized G, which has a mean of zero and a standard deviation, can be written as

$$G = \frac{M - \mu_m}{\sigma_m} \quad (10)$$

Failure occurs when $M \leq 0$. Therefore, the above equation can be written according to Equation 10.

$$Pf = P_m(0) = F_G\left[\frac{-\mu_m}{\sigma_m}\right] = F_G(-\beta) \quad (11)$$

and Equation 9 can be written

$$G = \frac{-\mu_m}{\sigma_m} = -\frac{\mu_s - \mu_z}{\sqrt{\sigma_s^2 + \sigma_z^2}} \quad (12)$$

where $\beta = \mu_m/\sigma$ is the index safety, which is the inverse of the coefficient of variation of the safety margin. From the previous results, it can be generalized by determining the boundary state function g(x) first:

$$M = g(x_1, x_2, \dots, x_n) \quad (13)$$

where $x_i$ is a random variable. The allowable limit states for failure to occur are:

$$M = g(x_1, x_2, \dots, x_n) \leq 0 \quad (14)$$

This boundary state function can be developed using Taylor's series, and if we take only the first order we get:

$$g(x_1, x_2, \dots, x_n) = g(x_1^*, x_2^*, \dots, x_n^*) + \sum_i (x_i - x_i^*)\left[\frac{\delta g}{\delta x_i}\right] \quad (15)$$

where $x_i^*$ is the linearization point, and the partial derivative is evaluated at this point. In the MVFOSM method the linearization point is determined at the mean value (x1, x2, ..., xn). The mean and variance of M are approximated by:

$$\mu_m \cong g(\bar{x}_1, \bar{x}_2, \dots, \bar{x}_n) \quad (16)$$

$$\sigma_m^2 \cong \sum_i \left(\frac{\delta g}{\delta x_i}\right)^2_{\bar{x}_i} \sigma_{x_i}^2 + \sum_i \sum_j \left(\frac{\delta g}{\delta x_i}\right)_{\bar{x}_i} \left(\frac{\delta g}{\delta x_j}\right)_{x_j} \rho(x_i, x_j)\sigma_{x_i}\sigma_{x_j} \quad (17)$$

where $\rho(x_i, x_j)$ is the correlation coefficient of the variable and $\bar{x}_i$, $\bar{x}_j$ is the mean of each variable.

$$\rho(x_i, x_j) = \frac{COV(x_i, x_j)}{\sigma_{x_i}\sigma_{x_j}} \qquad i \neq j \quad (18)$$

To assess whether the spread is large or small will be very difficult, it will be more objective if it is measured relative to its central value, namely the coefficient of variation (COV), and is given by the following equation [13].

$$COV\,x = \frac{\sigma_x}{\mu_x} \quad (19)$$

where $\mu_x$ is the average value (mean) of each variable, and $\sigma_x$ is the standard deviation of each variable, and is formulated as follows:

$$\mu = \frac{\sum_i^N x_i}{N} \quad (20)$$

$$\sigma = \sqrt{\frac{\sum_i^N (x_i - \mu)^2}{N}} \quad (21)$$

The accuracy of the above equation depends on the effect of the higher order beheading of the equation. If the variable $x_i$ is the independent variable, then:

$$\sigma_m^2 \cong \sum_i \left(\frac{\delta g}{\delta x_i}\right)_{\bar{x}_i}^2 \sigma x_i^2 \quad (22)$$

For example, if the limit M is expressed by the two variables S and Z then:

$$M = g(x_1, x_2) = g(s, z) = S - Z \quad (23)$$

This method is called MVFOSM because the linearization of the boundary function uses a place on the mean value and only the first order of the tailor's series and which is taken only until the second moment of the random variables (mean and variance) is used to calculate reliability, not using the entire probability distribution.

Geometric interpretation can be done by determining the safety margin M=S-Z, where S is the strength of the material and Z is the working load. S and Z are independent random variables which are normally distributed and can be written in standard form

$$S' = \frac{S - \mu_s}{\sigma_s} \quad (24)$$

$$Z' = \frac{Z - \mu_z}{\sigma_z} \quad (25)$$

If the specified safety margin M = 0 then M can be written as

$$M = \sigma_s S' - \sigma_z Z' + \mu_s - \mu_z = 0 \quad (26)$$

The distance between point 0 and the line M=0 can be used as a measure of reliability.

$$\beta = \frac{\mu_m}{\sigma_m} = \frac{\mu_s - \mu_z}{\sqrt{\sigma_s^2 + \sigma_z^2}} \quad (27)$$

and the probability of failure is:

$$P_f = \Phi(-\beta) \quad (28)$$

where Φ is the cumulative distribution function of the standard normal distribution (mean = 0, standard deviation = 1). This transformation is usually called standardization. and price

$$\beta = \Phi^{-1}(1 - P_f) \quad (29)$$

given in the standard normal distribution table.

## III. RESULTS AND DISCUSSION

Determination of the value of reliability in this study has several stages, namely:

### *A. Data Analysis*

There are two data components, namely the stress data that occurs on the ship and the stress used as a standard requirement for acceptance of the applicable rules.

The initial stage to get the stress is modeling the hull structure to get the RAO bending moment with the help of CFD software. Can be seen in Figure.1.

This modeling is carried out in two conditions, namely on a full load and an empty load. This condition is determined in accordance with ship operations in the Bali Strait.

Then determine the frequency and heading of the wave to get the RAO bending moment response to the structure. The frequency of the waves used is taken based on [8] normally 0.1 rad/second and bending moment is taken at head seas, quartering seas and beam seas.

**Figure. 1.** Hull Modeling

### *B. Cross-sectional Modulus*

The cross section analyzed in this study is at the bottom of the ship by calculating the vertical and horizontal moments of inertia and the ship's neutral axis distance in Table 1.

TABLE 1.
THE VERTICAL AND HORIZONTAL MOMENTS OF INERTIA

| Parameter | Big |
|---|---|
| INA | 142196979.6 |
| Z1 | 1,705 |
| ICL | 1460805765 |
| Y1 | 0 |

### *C. Transfer Function*

The transfer function or load transfer function is carried out after the moment of inertia and the point of view are known, the magnitude of the transfer of the load into stress is obtained by the value of the transfer function for the vertical bending moment. This analysis is carried out on the midship of the ship in the longitudinal section of the bottom structure of the ship. The cross section of the ship can be seen in Figure 2.

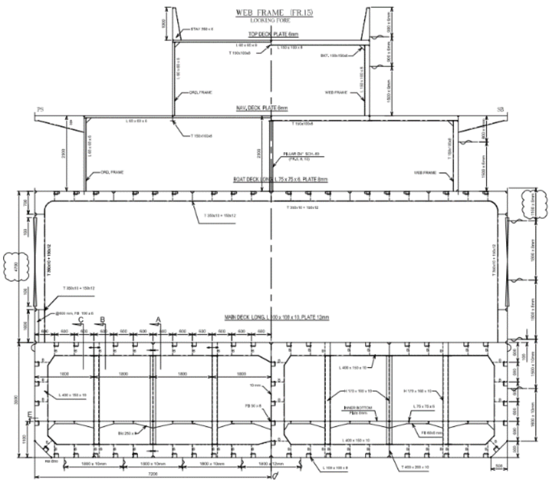
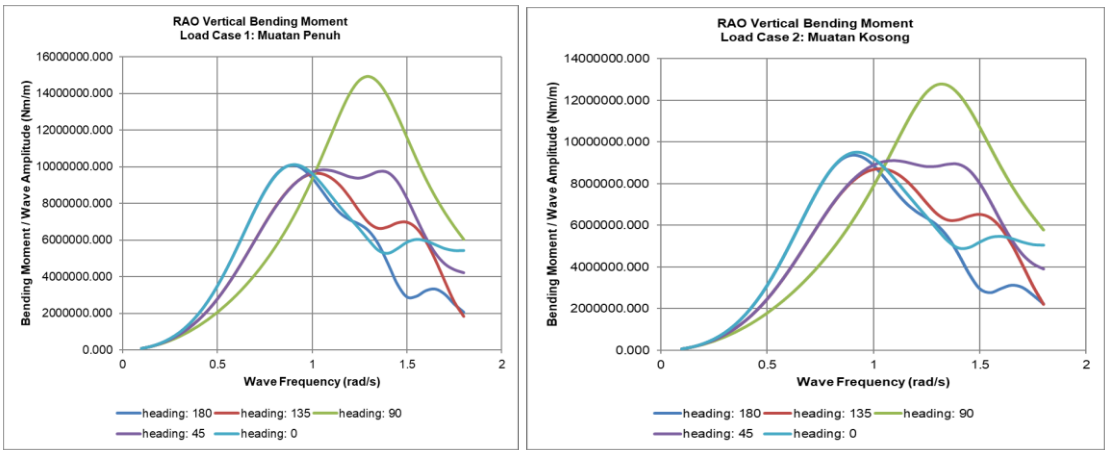


**Figure. 2.** Cross-section of the ship

### *D. Stress Determination*

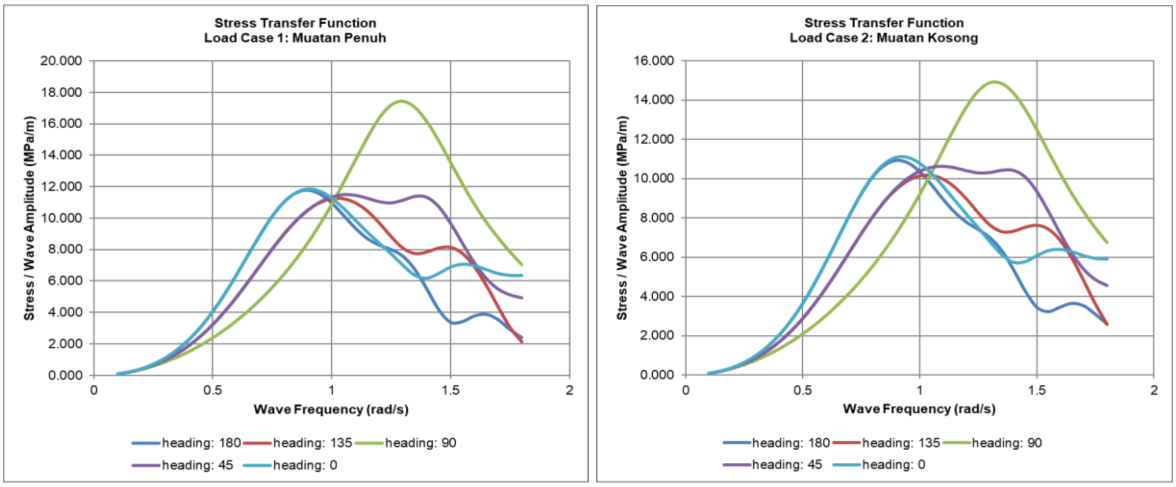
Determination of stress is carried out by transfer function on the response amplitude operator (RAO) of vertical bending moment with the point of view on this structure is at the bottom. RAO bending moment that occurs on the ship is obtained with the help of finite element analysis software. It can be seen in Figure 3.




**(a)** **(b)**

**Figure. 3.** RAO vertical bending moment a) full load b) empty load

Then the transfer function is carried out on the structure under review to get the RAO value of the stress which can be seen in the full load table in Figure 4 (a) and the empty load in Figure 4 (b). The maximum value at full state is 17,426 MPa/m. As for the empty load is 14,886 MPa/m




**(a)** **(b)**

**Figure. 4.** ROA stress a) full load b) empty load

*E. Reliability Analysis*

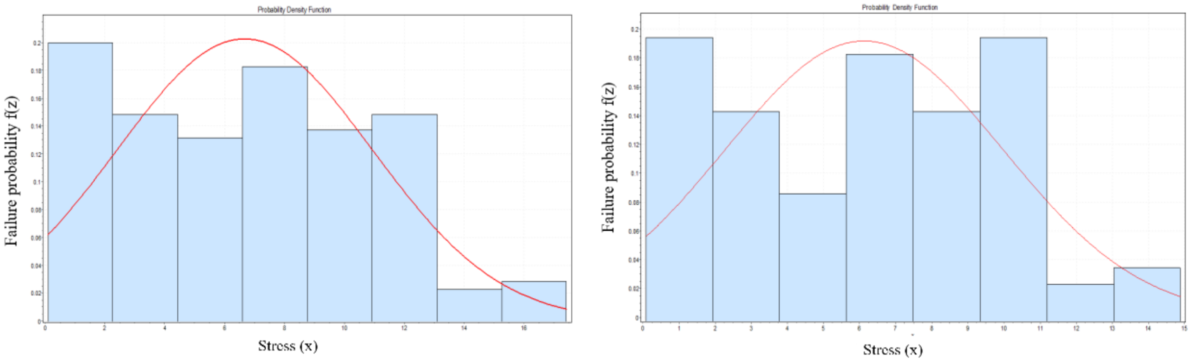
The value of the stress on the RAO stress is in Table 2. full load conditions. used to obtain the probability density function (PDF) of the stress in the statistical process using the statistical packages software.

TABLE 2.
RAO VALUE OF FULL LOAD STRESS

| rad/s | stress/wave amplitude (MPa/m) heading 180 | 135 | 90 | 45 | 0 |
|---|---|---|---|---|---|
| 0.1 | 0.087 | 0.085 | 0.082 | 0.085 | 0.087 |
| 0.15 | 0.202 | 0.194 | 0.186 | 0.194 | 0.202 |
| 0.2 | 0.380 | 0.355 | 0.330 | 0.355 | 0.380 |
| 0.25 | 0.635 | 0.576 | 0.517 | 0.576 | 0.635 |
| 0.3 | 0.983 | 0.864 | 0.745 | 0.864 | 0.983 |
| 0.35 | 1.444 | 1.230 | 1.015 | 1.230 | 1.444 |
| 0.4 | 2.031 | 1.682 | 1.328 | 1.682 | 2.031 |
| 0.45 | 2.759 | 2.227 | 1.685 | 2.227 | 2.759 |
| 0.5 | 3.630 | 2.868 | 2.086 | 2.868 | 3.630 |
| 0.55 | 4.636 | 3.606 | 2.532 | 3.606 | 4.636 |
| 0.6 | 5.755 | 4.431 | 3.027 | 4.430 | 5.754 |
| 0.65 | 6.939 | 5.325 | 3.572 | 5.324 | 6.938 |
| 0.7 | 8.120 | 6.259 | 4.171 | 6.257 | 8.121 |
| 0.75 | 9.207 | 7.190 | 4.830 | 7.189 | 9.212 |
| 0.8 | 10.097 | 8.069 | 5.553 | 8.072 | 10.118 |
| 0.85 | 10.694 | 8.843 | 6.346 | 8.861 | 10.754 |
| 0.9 | 10.939 | 9.467 | 7.214 | 9.520 | 11.072 |
| 0.95 | 10.816 | 9.909 | 8.162 | 10.030 | 11.067 |
| 1 | 10.373 | 10.149 | 9.192 | 10.384 | 10.774 |
| 1.05 | 9.709 | 10.176 | 10.296 | 10.585 | 10.258 |
| 1.1 | 8.966 | 9.985 | 11.453 | 10.636 | 9.600 |
| 1.15 | 8.295 | 9.576 | 12.606 | 10.560 | 8.886 |
| 1.2 | 7.792 | 8.976 | 13.655 | 10.414 | 8.181 |
| 1.25 | 7.422 | 8.275 | 14.461 | 10.301 | 7.493 |
| 1.3 | 7.007 | 7.651 | 14.886 | 10.318 | 6.793 |
| 1.35 | 6.352 | 7.313 | 14.850 | 10.430 | 6.136 |
| 1.4 | 5.394 | 7.329 | 14.371 | 10.431 | 5.737 |
| 1.45 | 4.300 | 7.529 | 13.544 | 10.098 | 5.767 |
| 1.5 | 3.462 | 7.634 | 12.501 | 9.362 | 6.069 |
| 1.55 | 3.240 | 7.437 | 11.371 | 8.336 | 6.331 |
| 1.6 | 3.465 | 6.866 | 10.262 | 7.221 | 6.392 |
| 1.65 | 3.654 | 5.958 | 9.237 | 6.200 | 6.270 |
| 1.7 | 3.533 | 4.823 | 8.317 | 5.394 | 6.076 |
| 1.75 | 3.105 | 3.624 | 7.492 | 4.863 | 5.932 |
| 1.8 | 2.606 | 2.583 | 6.746 | 4.565 | 5.900 |

The PDF distribution graphs of the stresses are obtained in Figure 5 (a) and Figure 5 (b). The distribution used is normal from the input stress data.

Determination of S or strength is determined by looking at the allowable stress of the material based on the applicable classifications in Table 3.




**(a)** **(b)**

**Figure. 5.** PDF a) full load stress b) empty load stress

TABLE 3
MATERIAL ALLOWABLE STRESS BASED ON CLASSIFICATION RULES

| ReH (MPa) | k | Yield Stress (MPa) | Class Rules |
|---|---|---|---|
| 235 | 1 | 235 | |
| 265 | 0.91 | 241.15 | |
| 315 | 0.78 | 245.7 | BKI |
| 355 | 0.72 | 255.6 | |
| 390 | 0.66 | 257.4 | |
| 235 | 1 | 235 | |
| 315 | 0.78 | 245.7 | BV Class |
| 355 | 0.72 | 255.6 | |
| 390 | 0.7 | 273 | |

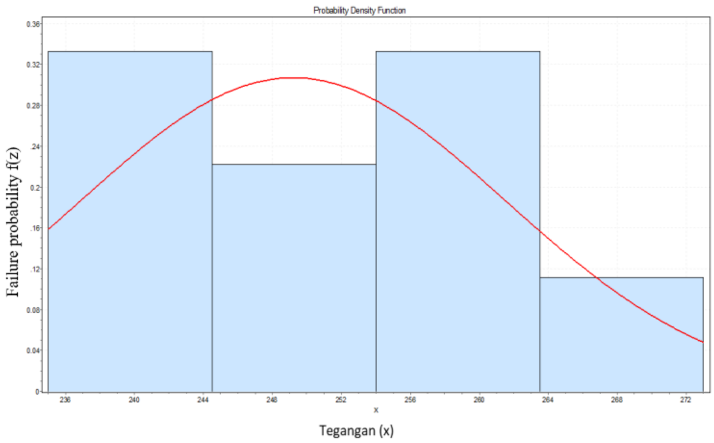



**Figure. 6.** PDF power

Then obtained the value of the probability density function (PDF) of the strength for reliability calculations in Figure 6. Calculation of reliability using the mean value of first order second moment is done by calculating the value of the safety index to determine the probability of failure (Pf) based on equation (27). The Safety Index value is calculated based on the ship calculated based on the area being visited using [14]:

$$\beta = \frac{b}{t}\sqrt{\frac{\sigma_{yield}}{E}}$$

Where b is the tusk distance, t is the thickness and E is the modulus of elasticity of the material and the yield function of the material. So that the safety index and reliability values obtained from the conditions of full load and empty load with the strength of the material used in Table 4.

TABLE 4.
RELIABILITY VALUES UNDER LOADING CONDITIONS

| Loading Condition | Minimum Safety Index | Safety Index | Reliability Value |
|---|---|---|---|
| Full Load | 2.007 | 19.64 | 0.913615 |
| Empty Payload | 2.007 | 18.12 | 0.88948 |

## IV. CONCLUSION

Based on the results of the analysis, it is known that the reliability value of the LCT Vessel Conversion operation has a safety index value of 19.64 and 18.12 with a minimum safety of 2.007 and has a reliability of 0.913615 on a full load condition and 0.88948 on an empty load condition.

## REFERENCES

[1] P. Thoft-Christensen and Y. Murotsu, 1986, Berlin: Springer-Verlag, Application of Structural System Realibility Theory.

[2] D. Rosyid and Mukhtasor, Introduction to Reliability Engineering, Surabaya: ITS Press, 2002.

[3] SSC-351, An Introduction to Structural Realibility Theory, New York: Ship Structure Committee, 1990.

[4] P. Honarmandi, "Reliability Based Structural Optimization with Fatigue Crack Initiation Constraint," Dissertation Publishing, Toronto, 2007.

[5] Z. Liu, Y. Zhang and W. Wang, "Fatigue Life Reliability Based Design Optimization for The Missile Suspension Structure," Multidiscipline Modeling in Materials and Structure, vol. 8, no. 1, pp. 120-129, 2012.

[6] O. Hughes, Ship Structural Analysis Design, New Jersey: The Society of Naval Architechts and Marine Engineers, 2010.

[7] R. Bhattacharyya, Dynamics of Marine Vehicles, New York: John Wiley & Son, 1978.

[8] AB o. S. (ABS), “Spectral-Based Fatigue Analysis for Vessels,”, Houston: ABS, 2016.

[9] EK Hasselmann, T. Barnett, H. Bouws, DE Carlson, K. Cartwright, JA Enke, DEGH Ewing, P. Hasselmann, A. Kruseman, P. Meerburg, DJ Mller, K. Olbers, WS Richter and H. Walde, "Measurements of wind-wave growth and swell decay during the joint North Sea Wave Project (JONSWAP)," Ergnzungsh. zur Dtsch. Hydrogr. Zeitschrift R, vol. 8, no. 12, p. 95, 1973.

[10] M. Mohammad Nurul, S. Dony and WM Dananjaya, "Construction strength analysis of landing craft tank conversion to passenger ship using finite element method," Journal of Physics: Conference Series, vol. 924, pp. 2-9, 2018.

[11] SH Ardianus and DS Sujiatanti, Analysis of the Strength of Transverse Bulkhead Construction for Tankers Using the Finite Element Method, Surabaya: ITS, 2017.

[12] S. Chakrabart, Hydrodynamic of Offshore Structures, Boston, 1987.

[13] A. Rumiati, Concepts of Opportunity and Statistics in Engineering, Surabaya: ITS Press, 1998.

[14] AE Mansour, "Approximate Formula for Preliminary Design of Stiffened Plates," in Fifth International Symposium and Exhibition on Offshore Mechanics and Arctic Engineering, Tokyo, 1986.

[15] J. Barsom and S. Rofle, Fracture and Fatigue Control in Structure, 1987.

[16] RAR Ramadhani, M. Misbah and SH Sujiatanti, Fatigue Life Analysis on LCT Conversion Using Spectral Fatigue Method, Surabaya: Department of Marine Engineering ITS, 2018.