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The Analysis of Engine Room Vibration of Tugboat 24 M

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Abstract

A tugboat is a ship that guides large ships to dock, helps escort coal barges over bridges and also helps carry out rescues if needed. Some Tugboats had to experience increased engine power because they followed ministerial regulations. When in operation, the tugboat's engine generates the power necessary to move the ship, but on the other hand the engine also produces vibrations. Vibrations that occur on the ship have a side effect that damages the structural resistance of the ship's own construction. The purpose of this study is to find out the value of vibration and noise that occurs on the deck above the engine room due to increased engine power on the Tugboat. The method used is Finite Element Analysis using Ansys software. The results showed that the excitation frequency of the parent machine based on successive rpms was 14.99 Hz, 16.65 Hz, and 18.32 Hz. Based on the calculation of system amplitude, obtained value ranges of 8.73 x 10^{-10} to 8.25 x 10^{-10} for 1 machine and 1.14 x 10^{-9} to 5.65 x 10^{-10} for 2 machines. Then the standard vibration value is in the range of values 0.00012 to 0.00017 for 1 engine and 0.000652 to 0.000479 for 2 machines. Furthermore, the noise value obtained is in the range of 140.53 dB to 130.88 dB for 1 engine, and 140.68 to 130.75 for 2 engines. All results from calculations regarding vibration standards on the 2 deck models above the engine room get results according to standards, but the resulting noise value exceeds the limit, so it can be concluded that the construction of the engine room and deck is safe from vibration but has excessive noise.

Keywords: Tugboat, Engine Room, Vibration, Natural Frequency, Noise

1. Introduction

A tugboat is a ship that can be used to maneuver / move, mainly towing or pushing other ships in ports, high seas or through rivers or canals. Tugboats are also used to towing barges, damaged ships, and other equipment. Tugboats generally serve in water areas where a ship requires pilotage services or when another ship requires assistance in terms of maneuvers that must be assisted. Tugboats vary in size, but in general they are 20-32 meters long, 11-12 meters wide, and have an engine power of 2,000-4,000 kW The ship has Lpp of 24.26 meters, a width of 8 meters, a height of 1.6 meters and has an engine power of 2000 hp [1]. The engine is capable of moving the ship at a speed of 8-10 knots depending on the load. The size of this machine is quite large for the size of a tugboat, considering that the task is quite heavy. The engine is generally located in the engine room section on the double bottom, including for tugboats. When operating, the engine produces the power needed to move the ship, but on the other hand the engine also produces vibrations [2].

Vibration that occurs on the ship has a side effect of damaging the structural resistance of the ship's construction itself. The greatest vibrations occur in the engine room, but all parts of the ship can also be affected by vibrations because vibrations propagate. Vibration can be minimized, for example by installing an engine bed, but the resulting damping does not completely eliminate the effects of the vibration. The strength of the ship's construction needs to be considered. Because

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the data shows that ship vibrations that are not analyzed properly result in structural failure on the ship including the engine room and can affect the health of crew members when exposed to noise due to vibrations that are not up to standard [3].

Due to the relatively small size of the tugboat for a large engine size, the resulting vibration is also large. It is necessary to do calculations to analyze the vibrations generated that exceed the limit or not [4]. FEM is one of the methods used to find the value of the natural frequency (natural frequency) in an object, then used to obtain the value of the amplitude and standard of vibration. 3D modeling of engine rooms and decks on finite element-based software is one way to simulate actual conditions so that research results are expected to be accurate [3].

2. Materials and Methods

Tugboat is a ship that can be used to maneuver or move, mainly towing or pushing other ships in ports, high seas or through rivers or canals. Tugboats function to tow or push other ships. In addition, tugboats are a type of guide ship that is commonly used to pull and push large ships to exit or dock to the dock, guide large ships on dangerous paths, carry out water rescues such as extinguishing fires [5].

The terrain that is traversed is usually quite difficult, such as small winding rivers and shallow rocky seas to the wide seas between large islands, so tugboats must perform good maneuver [5]. Based on the location and performance, there are 3 types of tugboats, namely Seagoing Tug, Escort Tug, and Harbour Tug. For the clearer sight can be seen in Figure 1 below.

Fig. 1. Tugboat

Vibration is a mechanical movement that occurs back and forth due to a force that acts from one point and propagates to another point. In the world of shipping, vibration is a common thing. Vibration in a ship's engine is the result of periodic or random oscillations caused around the equilibrium point. One of the causes of vibration on ships is caused by the propulsion system [6]. When vibration occurs in a larger engine, operating under heavy load (2 stroke marine diesel) the intensity of the vibration level will increase due to the large rotational mass and the force of the combustible gas inside the engine. If the vibration level increases beyond the minimum level i.e. when the mechanical system has one or more frequencies, it can cause deformation or damage to machine components. It is therefore important to dampen vibrations by some external arrangement. When working, this system produces a forced vibration on the ship. Vibration that occurs excessively can cause damage to the structure and can also cause noise and interfere with passenger comfort [4].

Natural frequency or natural frequency is the frequency at which the system vibrates by instantaneous stimulation of impulses from the equilibrium position. All objects that have mass and stiffness/elasticity have a natural frequency. Natural frequency is a frequency that affects the occurrence of resonance. To avoid resonance, the natural frequency and the excitation frequency should not have the same value, therefore it is necessary to know the value of the natural frequency in the hull. While the frequency of excitation is a quantity value that can be calculated. So that the natural frequency of the hull needs to be determined so that it is not the same value as the excitation frequency. Natural frequencies can be determined by various methods such as the Euler-Bernoulli Beam Theory method and the mode shapes method [4]

The research method uses the finite element method (FEA), in which the object of research is the

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engine room and the deck of the tugboat. To obtain the standard values for vibration and noise in this study, several stages were carried out, namely the first stage of literature study, identification, problem formulation and data collection. The construction that is used as the object of research is frame 15-20 on the tugboat in the engine room. The design of the engine room and the construction of the transverse profiles are shown in Figure 2.

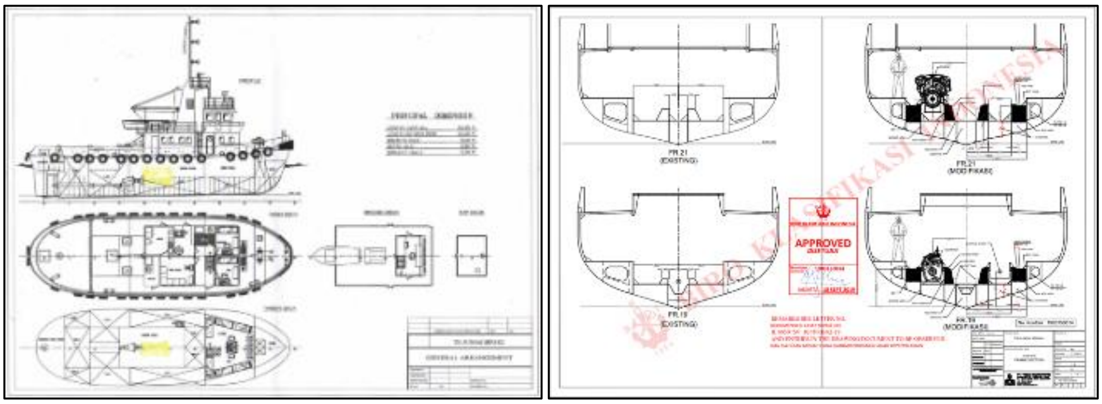

Fig. 2. (a) General Plan Design; (b) Cross Construction

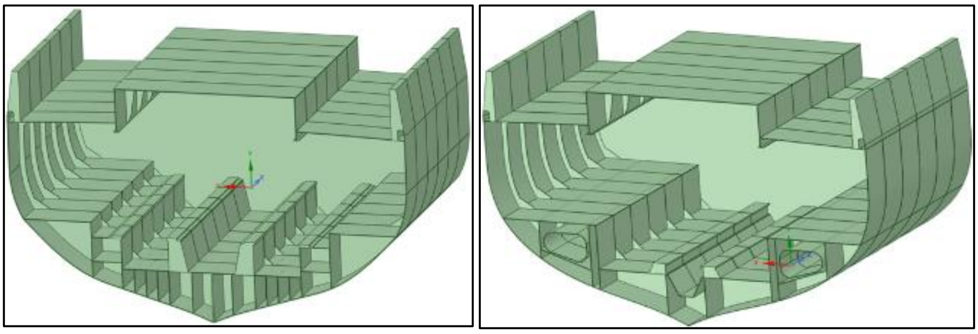

Fig. 3. (a) Engine room 3D modeling (1 engine); (b) Engine room 3D modeling (2 engines).

Figure 3 shows the main dimensions of the ship, with width (b) = 8 m, height (h) = 3.3 m, and length (lpp) = 24 m. The second stage is to design it in 2 dimensions and then develop it into 3 dimensions. The image below is the result of modeling the tubgoat engine room on frame 15 – frame 20, and 2 3D models are produced. in Figure 3 below is the engine room for a tugboat with 1 engine, and Figure 4 is a modeling engine room for a tugboat with 2 engines, where the X axis is the width of the ship, Y is the height of the ship and the Z axis is the length of the ship

After doing the modeling, the next step is to do meshing. Meshing is a method or process in FEA to divide a system into smaller elements in order to obtain detailed analysis results on the system. The results of the meshing can be seen in Figure 4 below.

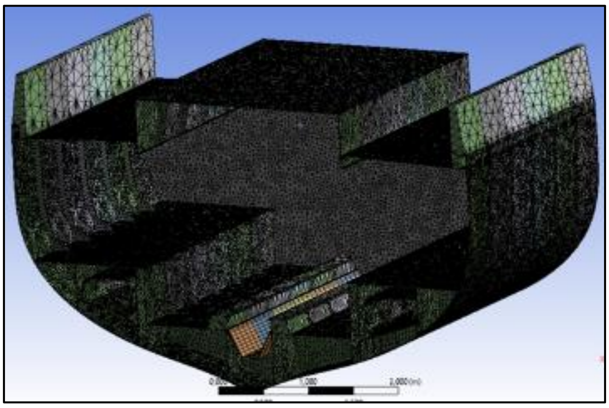

Fig. 4. The result of meshing the engine room model

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Next step is the process of assigning boundary conditions to the pedestal. If there are no boundary conditions, the FEA program cannot run properly and the results will not be valid. In the analysis of natural frequency and ship mode shapes, basically no boundary conditions are needed. However, because the program cannot run if it is not given a boundary condition, then in this analysis a minimal boundary condition is given. Referring to (DNV-GL, 2015), it is stated that the boundary conditions for ships can be used using the 3-2-1 Minimal Supports method. This method is a method commonly used in finite element analysis, especially static linear analysis to get realistic results. For a clearer picture can be seen in Figure 5 below.

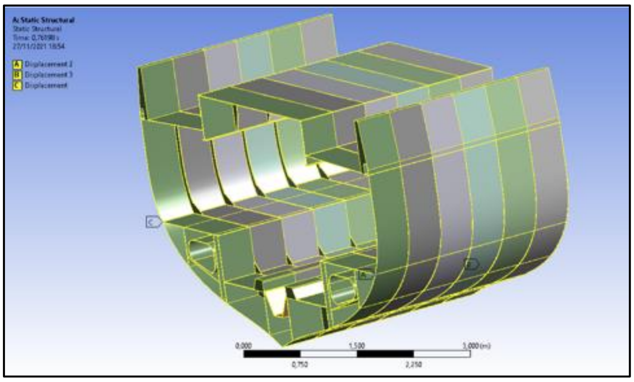

Figure 5. Model Boundary Condition

After giving the model support boundary conditions, then the running/rendering process is carried out to get the natural frequency value of the model.

3. Results

3.1 Finite Element Analysis Results 1 Engine and 2 Engine Tugboat Models

Based on the results of the settlement that has been carried out, the natural frequency of the 1 engine tugboat engine room model is obtained. In the analysis of this global model, the first 200 frequencies are sought. The natural frequency values for each mode analyzed using FEA Software can be seen in Figure 6 below.

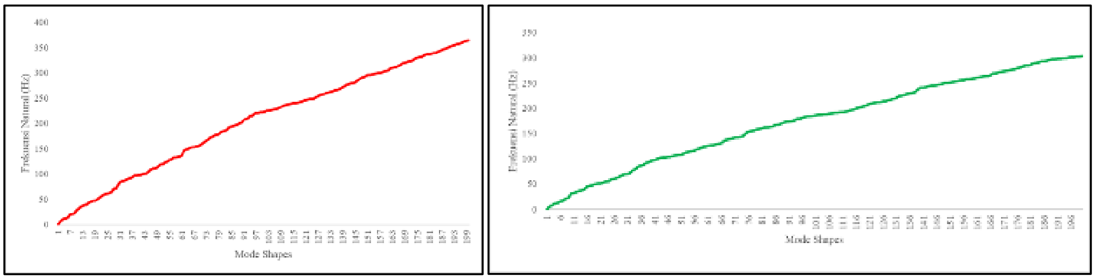

Fig. 6. (a) Natural Frequency (1 engine); (b) Natural Frequency (2 engines).

3.2 Discussion of Standard Analysis, Vibration and Noise of Tugboat (1 Engine)

After all the analysis on the FEA Software has been completed, then an analysis of the vibration standards is carried out on each resulting value using the help of spreadsheet software. At this stage the next step is to calculate the value of the excitation frequency. Furthermore, the determination of the value of the system's amplitude for each mode shapes. When the system amplitude value has been obtained, it can then be determined whether the construction meets the specified vibration standard value or not. From the data obtained, it is known that the main engine RPM used on this tugboat is 900 rpm, 1000 rpm, and 1100 rpm under service speed conditions. So that the excitation frequency can be calculated using equation (1) and the results are obtained as shown in Table 1 below:

$$f = \sqrt{\frac{E.I}{\rho.A}}.\frac{1}{2\pi}.(\frac{\beta n}{L})^2 \quad (1)$$

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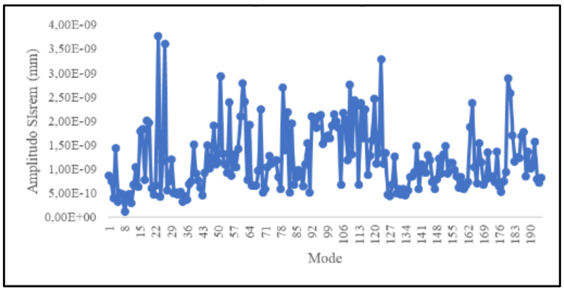
Table 1. Engine Excitation Frequency

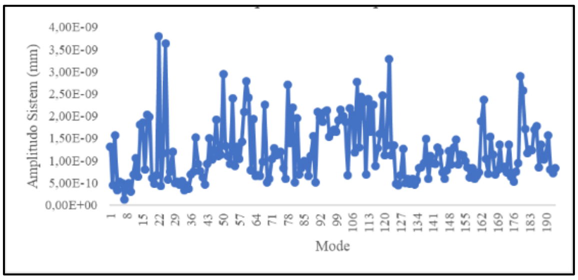
No.	RPM	Rad/s	Hz
1	900	94.2	14.99
2	1000	104.66	16.65
3	1100	115.33	18.32

From the analysis above, it is known that the excitation frequency value is slightly close to the natural frequency value, so there is a potential for resonance to occur. Then after that, the process of calculating the value of the vibration amplitude of the system is carried out with equation (2). From the natural frequency value that has been obtained in the previous stage, a graph curve is obtained as shown in Figure 7 below.

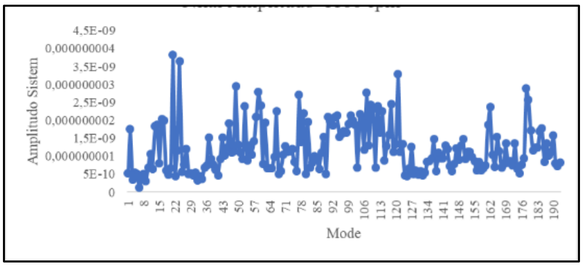
$$f = \frac{2\,.\pi\,.RPM}{60} \qquad (2)$$



(a)



(b)



(c)

Fig. 7. (a) Amplitude System 900 rpm ; (b) Amplitude System 1000 rpm ; (c) Amplitude System 1100 rpm

Furthermore, the calculation of the standard value of vibration is carried out. Referring to the ABS standard, it is known that the longitudinal vibration of the propulsion system is considered excessive if the Root Mean Square (RMS) acceleration amplitude is greater than 0.25 * g. For example, to find Arms from the vibration amplitude in a system with the 100th mode, it can be obtained using equation (3), which is as follows:

$$A_{RMS} = \left[\frac{900\,.2\pi\,.4}{60}\right]^2 2{,}10\,.\,10^{-9} \qquad (3)$$

A_{RMS} = 0.000297522

The amount of Arms for the propulsion system for vibration on the 100th mode shapes is 0.000297522.

From the calculation results, it is known that

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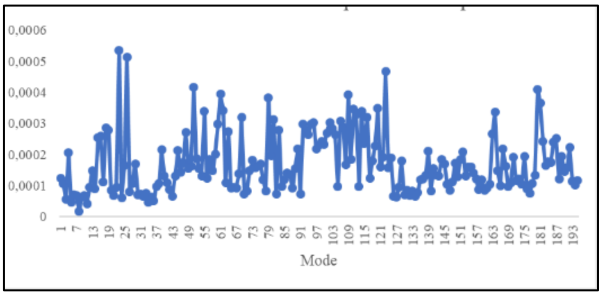
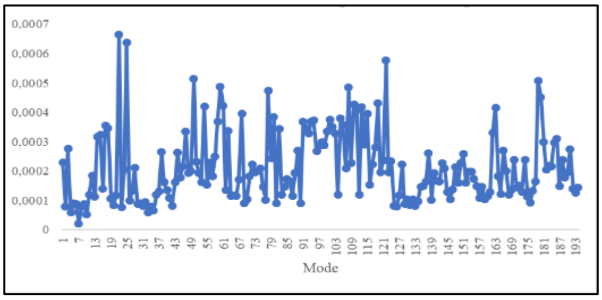
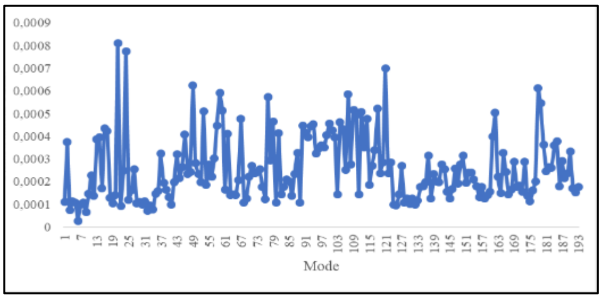
based on the ABS specifications the vibrations that occur in the 100th mode meet the standard. The rest have been calculated and analyzed for ARMS vibration standards for all 200 mode shapes as a result of FEA Software analysis and obtained value data as shown, which forms a curve of the natural frequency value against the vibration standard in Figure 8 below.



(a)



(b)



(c)

Fig. 8. (a) Arms Standard Value 900 rpm ; (b) Arms Standard Value 1000 rpm ; (c) Arms Standard Value 1100 rpm

Then after getting the standard value for vibration, noise standard analysis is carried out according to IMO standards. Because the natural frequency value obtained from the first 200 forms of the FEA Software analysis is less than 1kHz, the value of the noise radiation level can be determined using the following equation (4), so that the noise value is obtained:

$$SL = 135 - 1.66\, log10\, [\frac{FHz}{1Hz}] \quad (4)$$

SL = 131.24 dB

For example, the value of the SL noise level on the 100th mode shapes is 131.24 dB. In this case, the SL value is > 110 dB so that based on the radiation standard the noise level by IMO that occurs in the 100th mode does not meet the permissible threshold. In addition, the calculation and analysis of noise level standards has also been carried out on all 200 mode shapes resulting from the FEA Software analysis and obtained value data as shown in Figure 9 below.

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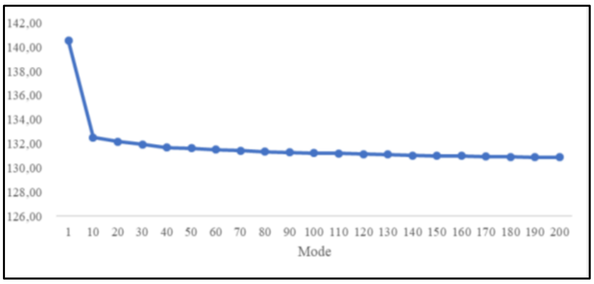
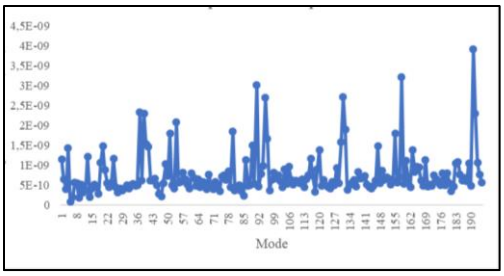


Fig. 9. Noise Standard Curve

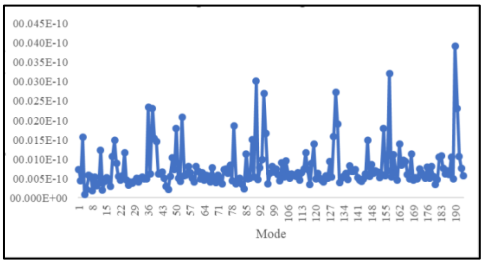
3.3 Discussion of Standard Analysis, Vibration and Noise of Tugboat (2 Engine)

After all the analysis on the FEA Software has been completed, then an analysis of the vibration standards is carried out on each resulting value using the help of spreadsheet software. At this stage the next step is to calculate the value of the excitation frequency. Furthermore, the determination of the value of the system's amplitude for each mode shapes. When the system amplitude value has been obtained, it can then be determined whether the construction meets the specified vibration standard value or not. From the data obtained, it is known that the main engine RPM used on this tugboat is 900 rpm, 1000 rpm, and 1100 rpm under service speed conditions. So that the excitation frequency can be calculated using equation (1) and the results are obtained as shown in Table 1.

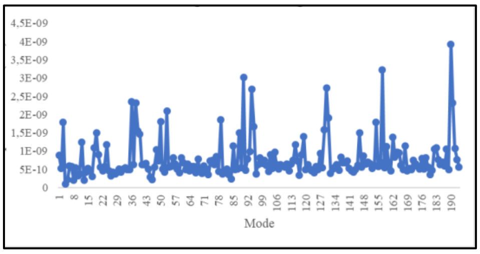
From the analysis above, it is known that the excitation frequency value is slightly close to the natural frequency value, so there is a potential for resonance to occur. Then after that, the process of calculating the value of the vibration amplitude of the system is carried out with equation (2). From the natural frequency value that has been obtained in the previous stage, a graph curve is obtained as shown in Figure 10 below:



(a)



(b)



(c)

Fig. 10. (a) Amplitude System 900 rpm ; (b) Amplitude System 1000 rpm ; (c) Amplitude System 1100 rpm

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Furthermore, the calculation of the standard value of vibration is carried out. Referring to the ABS standard, it is known that the longitudinal vibration of the propulsion system is considered excessive if the Root Mean Square (RMS) acceleration amplitude is greater than 0.25 * g. For example, to find Arms from the vibration amplitude in a system with the 100th mode, it can be obtained using equation (3), which is as follows:

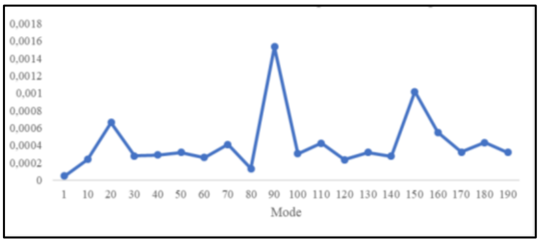
A_{RMS} = 0.00153328

The amount of Arms for the propulsion system for vibration on the 100th mode shapes is 0.00153328.

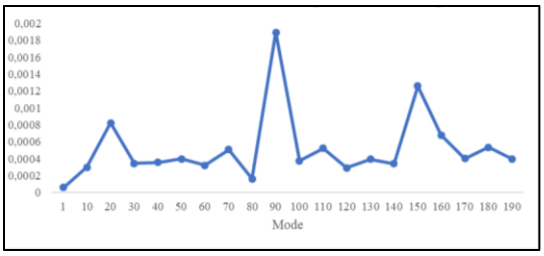
= A_{RMS} < 0,25 . g

= 0.00153328< 0,25 . g

From the calculation results, it is known that based on the ABS specifications the vibrations that occur in the 100th mode meet the standard. The rest have been calculated and analyzed for A_{RMS} vibration standards for all 200 mode shapes as a result of the FEA Software analysis and obtained value data as shown, which forms a curve of the natural frequency value against the vibration standard in Figure 11 below.



(a)



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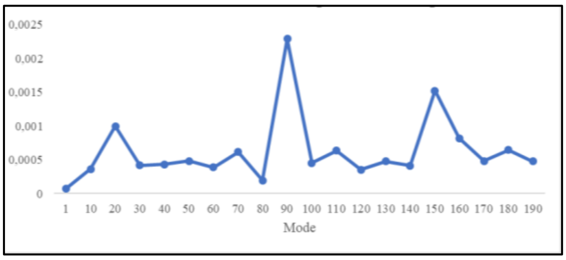

(c)

Fig. 11. (a) Arms Standard Value 900 rpm ; (b) Arms Standard Value 1000 rpm ; (c) Arms Standard Value 1100 rpm

Then after getting the standard value for vibration, noise standard analysis is carried out according to IMO standards. Since the natural frequency value obtained from the first 200 forms of the FEA Software analysis is less than 1kHz, the value of the noise radiation level can be determined using the following equation (4), so that the noise value is obtained:

SL = 131.11 dB

For example, the value of the SL noise level on the 100th mode shapes is 131.11 dB. In this case, the SL value is > 110 dB so that based on the radiation standard the noise level by IMO that occurs in the 100th mode does not meet the permissible threshold. In addition, the calculation and analysis of noise level standards for all 200

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mode shapes has also been carried out as a result of the FEA Software analysis and obtained value data as shown in Figure 12 below.

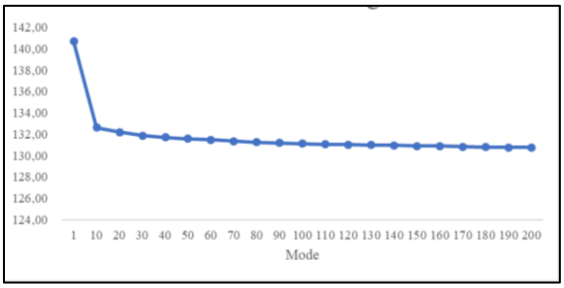

Fig. 12. Noise Standard Curve

4. Conclusions

The results showed that the excitation frequency of the main engine based on rpm was 14.99 Hz, 16.65 Hz, and 18.32 Hz, respectively. Based on the system's amplitude calculation, the values range from 8.73 x 10^{-10} to 8.25 x 10^{-10} for 1 machine and 1.14 x 10^{-9} to 5.65 x 10^{-10} for 2 machines. Then the standard vibration values are in the range of 0.00012 to 0.00017 for 1 machine and 0.000652 to 0.000479 for 2 machines. Furthermore, the noise values obtained are in the range of 140.53 dB to 130.88 dB for 1 machine, and 140.68 to 130.75 for 2 machines. All the results from the calculation of the vibration standards on the 2 deck models above the engine room get the results according to the standard, but the value of the noise generated exceeds the predetermined limit, so it can be concluded that the construction of the engine room and deck is safe from vibration but has excessive noise.

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