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Research Paper

Analysis of vibrations in finite elements in the SAP2000 software on the structure of a main deck of a fluvial pusher of the Amazon region

Accepted

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ABSTRACT

To foster academic learning, the present study was conducted to evaluate and analyse the vibration on the main deck of a pusher using finite elements. The modeling and analysis in software made in this work can be applied by students of the area of Naval Engineering and other related areas in the discipline of Applied Computational Methods. We have at our disposal several finite element programs capable of correctly characterizing structures. In this article we used a commercial program called SAP2000. The pusher chosen as the standard for the calculations was a typical pusher built in the Amazon region. With the study it is possible to verify the applicability of the program, variation of the structural behavior, as well as help in the understanding of the subject.

Key-words: Vibration, finite elements, main deck, fluvial pusher, SAP2000.

INTRODUCTION

Pusher

A river pusher is a boat designed to push and maneuver large trains made up of several barges (flat, reinforced bottom vessel used to carry large quantities of cargo).

The pushers are characterized by being small, but have powerful motors and high maneuverability. They are generally seen on waterways where they can be identified by carrying many barges tied or tied together by steel cables.

Trains must always be in continuous navigation without interruption. It is of great responsibility of the crew or on-board personnel, personnel of the workshops and of the preventive maintenance to acquire the movement and the transport of continuous form.

Deck

The deck of a vessel is any part that serves as a roof or roof of its own hull, which reinforces it and serves as the main working structure or surface. It can also be described as any floor or deck of a vessel. The plating of the deck and the roofs divides the space inside the hull in certain floors, allowing the adequate use of these spaces. In addition, they contribute to the vessel's durable structure in the longitudinal direction.

MODELING SOFTWARE

In the definition of structures considered complex in the field of engineering, it is convenient to study numerical methods, especially the MEF - Finite Element Method, which is able to refine the structure to generate more precise results. One of the programs responsible for finite element analysis is SAP2000. In the MEF the whole structure to be analyzed is replaced by elements that behave in such a way that they are connected by us. An approximate result is obtained for the elements. With simulations, it is possible to determine if the analyzed structure meets the requirements by its norms.

The SAP name has been synonymous with state-of-the-art analytical methods since its emergence more than 30 years ago. SAP2000 follows the same tradition with a sophisticated, intuitive and versatile interface provided by a structural analysis system and project aids for engineers who work with transport, works, industrial, public infrastructure, facilities, power generation, etc.

THEORETICAL FOUNDATION

The boat in general is subject to several external and internal efforts, we consider from the waves that influence in its stability of the vibrations caused by its motor.

The vessels present unique characteristics compared to other large constructions made by man, since besides being complex and large structures, they still need to navigate the waters, also suffering with dynamic loads.

In this way, random loads act on the structure, making it difficult to identify the external forces acting on the vessel, and how they are transferred internally between the various structural components (Rawson and Tupper, 2001).

Therefore, the choice of a structural arrangement that satisfies well its function and also presents the least weight of possible material becomes a great challenge. Several combinations of different components can serve as a solution for the same project, however, we always seek the arrangement that presents the greatest relation between load capacity and material weight (Moretto, 2016).

It is important to know that vibrations and noise are always present on boats. The result is serious when it comes to influencing health problems in passengers and / or crew. However, not only health problems but associated structural problems in vessels.

These phenomena are the result of the structural excitation that comes from the dynamic making of the propeller, propeller shaft, motors or turbines and auxiliary machines. Of all of these, propellers and main combustion engines are the most prevalent sources of vibration problems on board.

During the development phase of any vessel, a finite element analysis of pavements, structural profiles, sheets, etc. is convenient in order to predict future fatigue and other adverse effects that may arise in the future.

One of the most used methods in naval engineering is to divide the structure and the tensions into primary, secondary and tertiary structure (Rawson and Tupper, 2001). Each part of the structure presents a level of hierarchy and corresponding tensions. In the end the above-mentioned tensions are then composed to discover the total voltage acting on each part of the vessel. Table 1 shows a summary of the elements that make up each level of a ship's structure, and the supports for each level.

Analyzing Table 1 we can see that the study structure of this work is at the tertiary structural level.

Tertiary structure

According to Moretto (2016), this comprises a smaller portion of plating that is limited by reinforcers. In the plating of the bottom and the side of the vessel, there are efforts caused by the hydrostatic of the water. On the main deck there are the weights of the equipment, passengers and loads. Longitudinal or transverse reinforcers are considered as indescribable supports with rigidity superior to that of the plate (Augusto, 2007).

According to Augusto (2007), the theory of plates in small deflections is used in the calculation of tertiary tensions:

$$\sigma 3 = K.p.\left(\frac{b}{t}\right)^2 \quad (1)$$

Where $\sigma 3$: - bending stress in the plate; k - Constant depending on the ratio between the sides of the plate and the boundary conditions; p - Normal pressure on the plate; b - Measurement of the smallest side of the plate; t - Sheet thickness.

Linear dynamic analysis

The dynamic analysis of structures uses computational methods that allow to take into account some dynamic effects, which is of great interest for deck plate.

The formula that represents the equilibrium in a given period of time t between the external forces, which are that of mass, damping and elastic. It presents the formula that can be represented in matrix form and vectors, depending on their degrees of freedom.

$$Mat + Cvt + Kt.dt = ft \quad (2)$$

Where: M - Mass matrix; C - Damping matrix; Kt - Stiffness matrix; ft - Vector of time-dependent external forces; (at, vt, dt) - Vector acceleration, velocity and displacement.

Vibration n degrees of freedom

The existence of a system with n degrees of freedom has n natural frequencies, which are associated with its modal forms. The general equation of motion can be described in matrix form as:

$$[m]\ddot{x} + [c]\dot{x} + [k] = F(vetor) \quad (3)$$

Considering m being a matrix corresponding to mass, c is a matrix corresponding to damping, and k is a stiffness matrix. We have:

$$[m] = \begin{bmatrix} m_1 & 0 & 0 & \cdots & 0 & 0 \\ 0 & m_2 & 0 & \cdots & 0 & 0 \\ 0 & 0 & m_3 & \cdots & 0 & 0 \\ \vdots & & & & & \\ 0 & 0 & 0 & \cdots & 0 & m_n \end{bmatrix} \quad (4)$$

Table 1: Structural levels.

Structural Level	Elements		Support
Primary structure	Beam-ship	Plating of the deck, side and bottom, longitudinal bulkheads, sicordas, longitudinal crossbars	Free Tips
Secondary structure	Reinforced panels	Reinforced deck panels, side and bottom, reinforced bulkheads	Transverse bulkheads longitudías and crow's feet
Tertiary structure	Plating units	Plates	Longitudinal, goos, sicordas, hastilhas

Source: MORETTO (2016).

$$[c] = \begin{bmatrix} (c_1 + c_2) & -c_2 & 0 & \cdots & 0 & 0 \\ -c_2 & (c_2 + c_3) & -c_3 & \cdots & 0 & 0 \\ 0 & -c_3 & (c_3 + c_4) & \cdots & 0 & 0 \\ \cdot & \cdot & \cdot & \cdots & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdots & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdots & \cdot & \cdot \\ 0 & 0 & 0 & \cdots & -c_n & (c_n + c_{n+1}) \end{bmatrix} \quad (5)$$

$$[k] = \begin{bmatrix} (k_1 + k_2) & -k_2 & 0 & \cdots & 0 & 0 \\ -k_2 & (k_2 + k_3) & -k_3 & \cdots & 0 & 0 \\ 0 & -k_3 & (k_3 + k_4) & \cdots & 0 & 0 \\ \cdot & & & & & \\ \cdot & & & & & \\ \cdot & & & & & \\ 0 & 0 & 0 & \cdots & -k_n & (k_n + k_{n+1}) \end{bmatrix} \quad (6)$$

Where, $\ddot{x}$, $\dot{x}$, x, and F (vector) are respectively vectors representing the displacement, velocity, acceleration and force, which can be represented by:

$$\vec{x} = \begin{Bmatrix} x_1(t) \\ x_2(t) \\ \cdot \\ \cdot \\ \cdot \\ x_n(t) \end{Bmatrix}, \dot{\vec{x}} = \begin{Bmatrix} \dot{x}_1(t) \\ \dot{x}_2(t) \\ \cdot \\ \cdot \\ \cdot \\ \dot{x}_n(t) \end{Bmatrix} \ddot{\vec{x}} = \begin{Bmatrix} \ddot{x}_1(t) \\ \ddot{x}_2(t) \\ \cdot \\ \cdot \\ \cdot \\ \ddot{x}_n(t) \end{Bmatrix}, \vec{F} = \begin{Bmatrix} F_1(t) \\ F_2(t) \\ \cdot \\ \cdot \\ \cdot \\ F_n(t) \end{Bmatrix} \quad (7)$$

It is fundamentally important to determine the natural frequencies of a ship or any vessel on a project, so as to avoid the phenomenon of resonance, which is responsible for causing defects and structural damage to the vessel.

As a result, a study was conducted to determine the natural frequencies of the first four modes of vibration of a fluvial pusher of Amazonian standard characteristics.

NUMERICAL APPLICATION AND DISCUSSION OF RESULTS

The study began from the analysis of the main deck structure of a two-machine pusher (propeller bi-propeller). The plate in analysis has 23 × 7 m. Figure 1 shows the view of the modeled deck.

The analysis began by modeling the main deck plate in the SAP2000, so that the coordinates (deck reference points) could be created in the modeling software. The top view was used to remove points from the AUTOCAD software to construct the finite element mesh.

A comparative study of the vibration frequencies of the plate was sought. The comparison was made from two models: the first one with longitudinal reinforcers, contours and transversal supports the deck plate, the second without longitudinal reinforcers, remaining the others. The modeling and refinement of the main deck meshes in SAP2000 can be seen in Figure 2.

Note that the model does not correspond exactly to the geometry of the main deck of the fluvial pusher analyzed, mainly in the part of the geometry modeling of the structural details (longitudinal profiles), that make the connection with the deck, in order to reinforce it. The real geometry also has radii of curvature at its ends, whereas in the modeling it was used of the division into small rectangles.

It was necessary to make an approximation of the points and the size of the plate at the moment of the modeling, because it has curves, that is, it was chosen to approach in such a way that three rectangular shapes were constructed.

Second gender supports were used to replace the longitudinal reinforcements and set supports to replace the others (contours and transverse reinforcers). Later it was possible to obtain the first four modes and frequencies of vibrations of the plate. Figures 3 to 6 show the displacements and stresses of the modes.

The displacement of all the vibration modes performed with the modeling of the plate is shown in Figures 3-6. The frequencies and periods associated with each mode are shown in Table 2 for a better understanding.

By removing the longitudinal reinforcers of the shaped plate, or better, by removing the supports of second genus, it was possible to obtain the first four modes and frequencies of vibrations. Figures 7-10 show the displacements and stresses of the modes.

The frequencies and periods associated with each mode

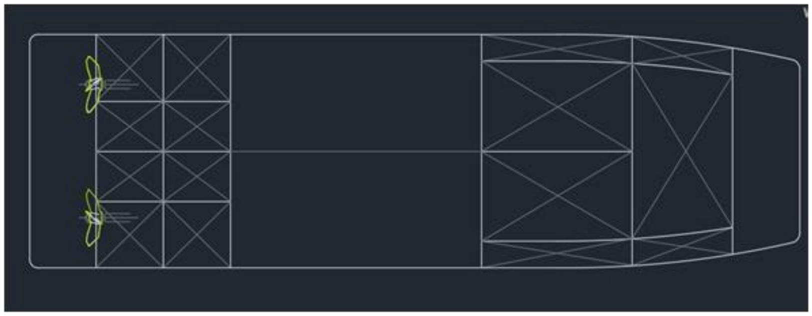

Figure 1: Top view of the boat deck.
Source: The author (2016).

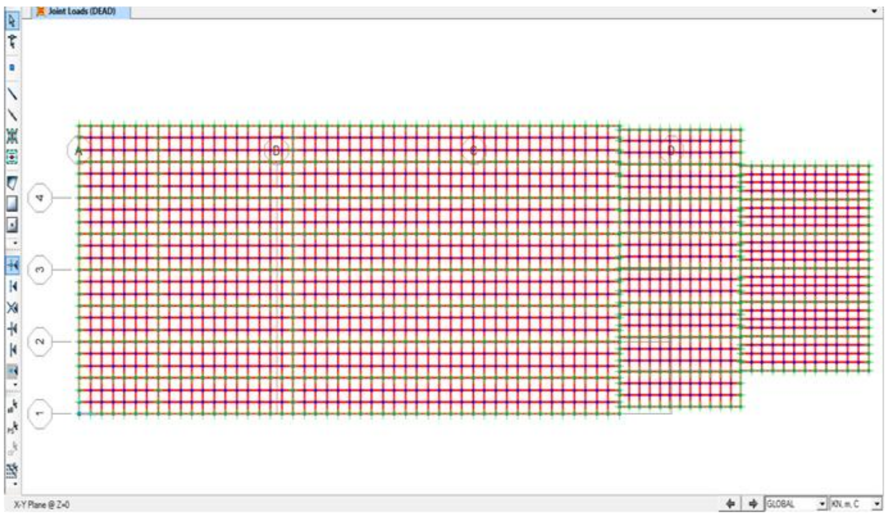

Figure 2: Construction of the finite element mesh.
Source: The author (2016).

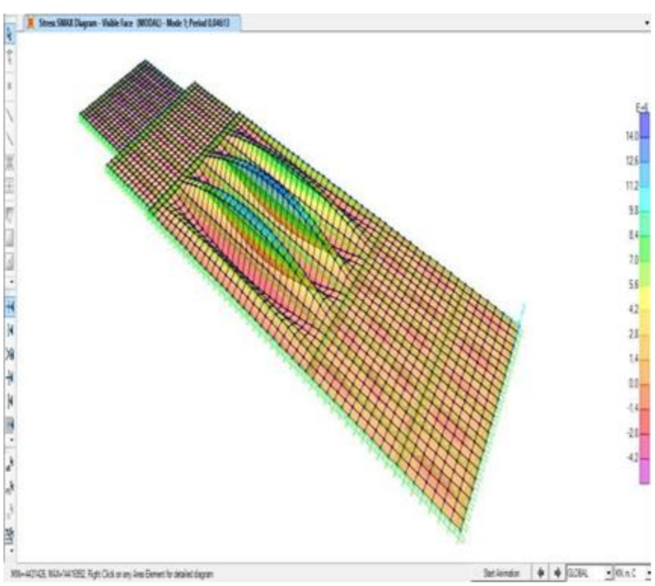

Figure 3: Vibration Mode 1.
Source: The author (2016).

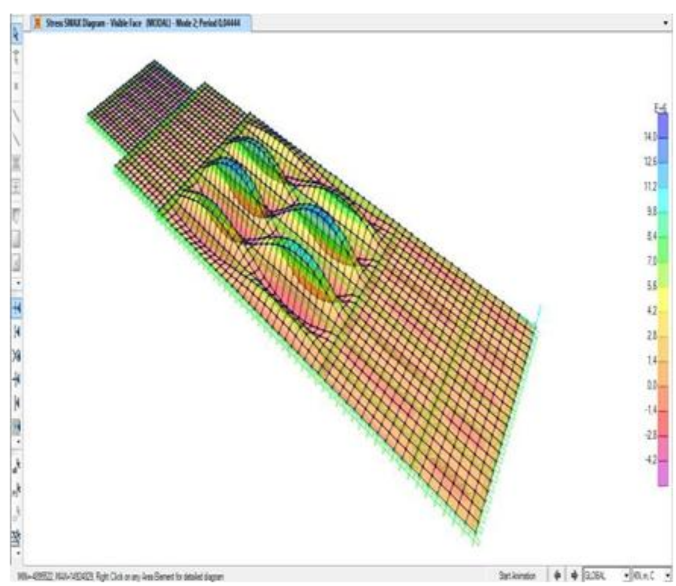

Figure 4: Vibration Mode 1.
Source: The author (2016).

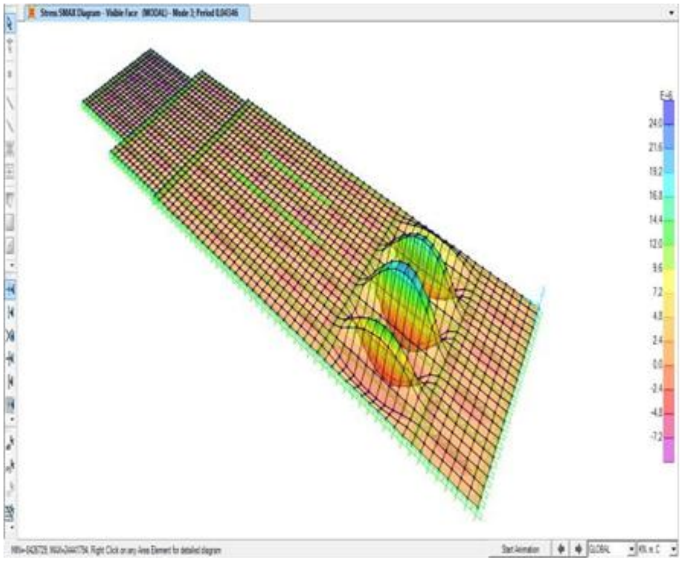

Figure 5: Vibration mode 3.
Source: The author (2016).

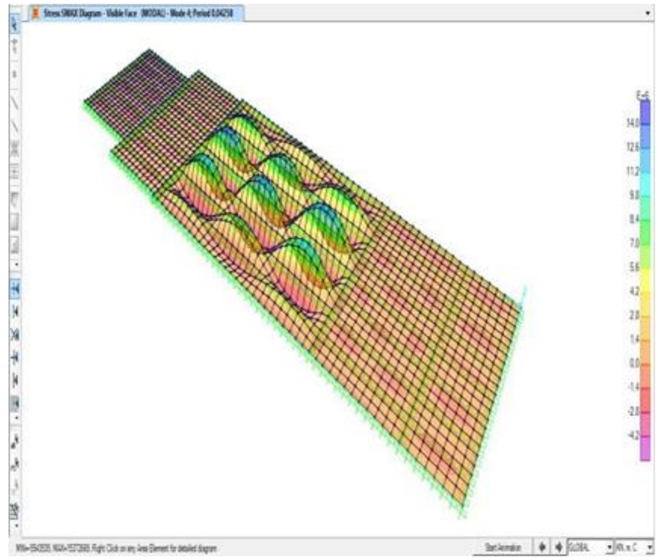

Figure 6: Vibration mode 4.
Source: The author (2016).

Table 2: Frequencies (1-4) of vibration.

	Frequency (Hz)	Period (s)
Modo 1	21.68	0.047
Modo 2	22.51	0.045
Modo 3	23.01	0.044
Modo 4	23.49	0.043

Source: The author (2016).

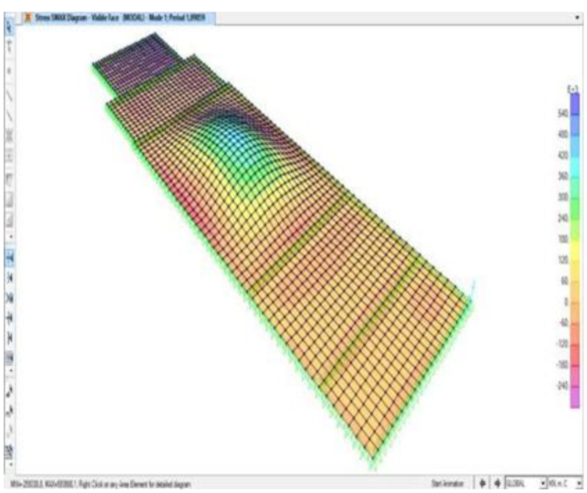

Figure 7: Vibration mode 1 without longitudinal reinforcers.
Source: The author (2016).

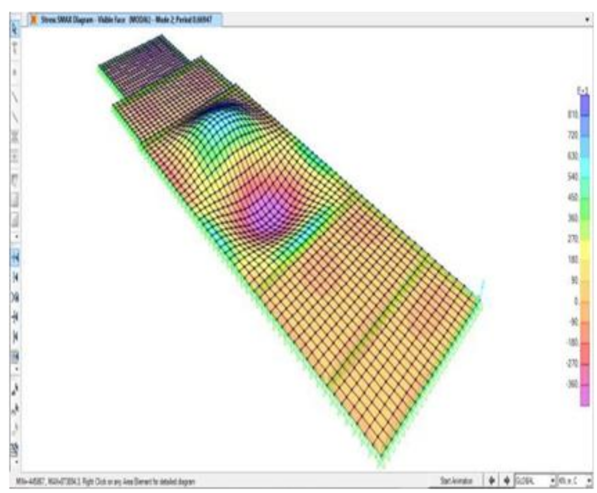

Figure 8: Vibration mode 2 without longitudinal reinforcers.
Source: The author (2016).

are shown in Table 3. For better visualization and comparison, the results obtained with the two analyzes are presented in Figure 11.

In the first analysis we can observe a relatively high frequency as compared with the second analysis. From this we can say that the results are satisfactory due to what was

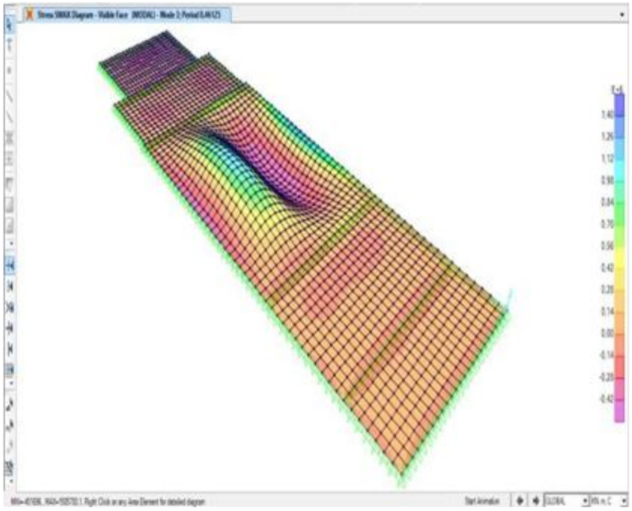

Figure 9: Vibration mode 3 without longitudinal reinforcers.
Source: The author (2016).

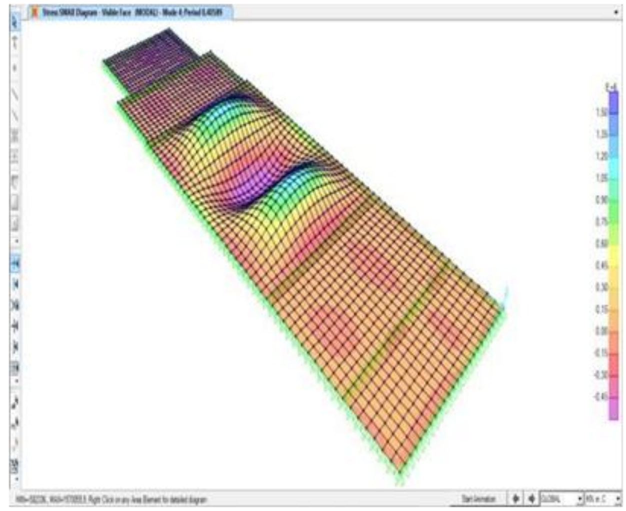

Figure 10: Vibration mode 4 without longitudinal reinforcers.
Source: The author (2016).

Table 3: Frequency (1-4) of vibration without longitudinal reinforcers.

	Frequency (Hz)	Period (s)
Modo 1	0.92	1.10
Modo 2	1.50	0.67
Modo 3	2.17	0.47
Modo 4	2.47	0.41

Source: The author (2016).

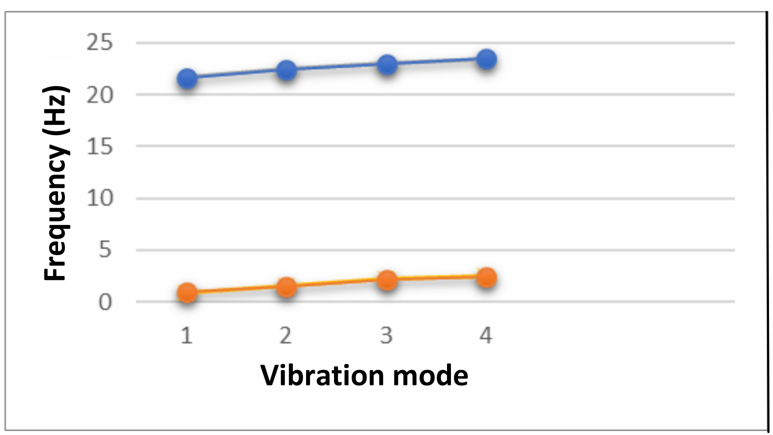

Figure 11: Comparison of vibration analyzes.
Source: The author (2016).

expected, because in the first analysis we have a structure of the main deck plate more rigid, set and safe because all the profiles and reinforcers necessary for a firm structure are present.

In the second analysis, we can see a very low frequency so as to observe that the vibration oscillation period is high, yet it is less rigid and more unstable as compared with the first analysis. It is known from the analysis of the results that it is essential the structure of the deck contains the longitudinal, transverse reinforcers and that it is well supported in its contours. Any element of this removed can cause over time fatigue and structure failure due to vibrations caused by motors and other components already mentioned above.

FINAL CONSIDERATIONS

The development of this work allowed the study and understanding of the interference that the frequency of the operation of the equipment of the vessel can cause in its structure. Any movement in a certain period of time is called vibration or oscillation, it is known that the importance of this phenomenon must be taken into account, because this excess causes noise, discomfort in the crew and structural failures.

When comparing the results obtained with the development of the analysis, it can be concluded that each element of support, reinforcers, among other means of fixation and safety of the structure are important to keep everything in balance, in order to reduce forces and / or phenomena caused by other external agents.

The use of softwares allows a real-time interaction with the study under analysis, this provides the prediction of possible faults or unforeseen future in the boats and their structure in general. If there are imperfections, it is possible through it to know if there should be changes in the project before its actual application.

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