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INFLUENCE OF FLOATING FLOOR COVERING ON THE VIBRATIONS OF A STIFFENED DECK PANEL

ВПЛИВ ЗАЛИВНОЇ ПІДЛОГИ НА ВІБРАЦІЇ ПІДКРІПЛЕНОЇ ПАЛУБНОЇ ПАНЕЛІ

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Abstract. *Purpose.* Dynamic analysis of ship structures made by finite element method (FEM) usually includes dissipation of excitation energy only in metal structures following the approach that damping is very low in ship structures and actually measured vibration values during sea trials are similar or less than the predictions. Non-structural coverings such as floating floors, insulations are widely used to limit the distribution of vibration energy and avoid its exceedance in living compartments. In general, structural damping increases with the increasing of frequency. This article is aimed to represent the role of non-structural deck covering in vibration amplitudes of stiffened deck panel since this has direct relation to comfort requirements and safe human being onboard.
Method. FEM as a part of numerical methods is used to solve current complex task since analytical solution is not possible due to large amount of variables. In general, FEM uses partial differential equations to describe certain physical phenomena and discretization algorithms to obtain approximate solution.
Results. The results of the study show the comparison between usage of non-structural mass objects which are in-built into the FEM software and real materials modelled by volume finite elements with respect to influence on natural frequencies and amplitudes of vibro-velocities. Based on the results of dynamic response analysis it is possible to estimate influence of damping across the excitation range.
Scientific novelty. Class Rules [1–3] widely used for the dynamic analysis of ships contain fragmentary information about non-structural damping (NSD) or neglect it at all. This article is aimed to show quantitative indicators of NSD versus frequency for different orders of natural frequencies.
Practical importance. The results of this study can be used during design stage for the stiffening of deck panels to avoid potential vibration problems or reducing vibration levels when the ship is already been built.
Key words: non-structural damping; finite element method; forced response analysis; stiffened deck panel.

Анотація. *Мета.* Динамічний аналіз суднових конструкцій, виконаних методом скінченних елементів (МСЕ), зазвичай включає розсіювання енергії збудження лише в металевих конструкціях, дотримуючись підходу, що демпфування в суднових конструкціях дуже низьке, а фактично виміряні значення вібрації під час ходових випробувань подібні або менші за прогнозовані. Неконструкційні покриття, такі як заливні підлоги, ізоляція, широко використовуються для обмеження розподілу енергії вібрації та запобігання її перевищенню в житлових відсіках. Загалом, структурне демпфування збільшується зі збільшенням частоти. Ця стаття має на меті представити вплив неконструкційного покриття палуби на амплітуді вібрацій підкріпленої палубної панелі, оскільки це має прямий зв'язок з вимогами до комфорту та безпечного знаходження людей на борту.
Метод. МСЕ як частина чисельних методів використовується для вирішення поточної складної задачі, оскільки аналітичне рішення неможливе через велику кількість змінних. Загалом, МСЕ використовує диференціальні рівняння з частинними похідними для опису певних фізичних явищ та алгоритми дискретизації для отримання наближеного рішення.
Результати. Результати дослідження показують порівняння між використанням неструктурних масових об'єктів, вбудованих у програмне забезпечення МСЕ, та реальних матеріалів, змодельованих об'ємними скін-

ченними елементами, щодо впливу на власні частоти та амплітуди віброшвидкостей. На основі результатів аналізу динамічного відгуку можна оцінити вплив демпфування в діапазоні збудження.
Наукова новизна. Правила Морських Класифікаційних Спілок [1–3], що широко використовуються для динамічного аналізу суден, містять фрагментарну інформацію про неструктурне демпфування (NSD) або взагалі не враховують його. Ця стаття має на меті показати кількісні показники NSD в залежності від частоти для різних порядків власних частот.
Практичне значення. Результати цього дослідження можуть бути використані на стадії проектування для посилення палубних панелей, щоб уникнути потенційних проблем з вібрацією або зменшити рівень вібрації, коли судно вже побудоване.
Ключові слова: неструктурне демпфування; метод скінченних елементів; аналіз вимушеної реакції; підкріплена палубна панель.

PROBLEM STATEMENT

Dynamic analysis at the initial design stages includes only metal structures and corresponding damping coefficient. However, it can not represent in global FE model all complexity of damping phenomena related to structures mentioned in [1, App. D. p. 24]. This can lead to the overestimation of actual vibrations obtained by finite element analysis and as result to additional modifications, which in reality are not needed. The purpose of the article is to show how to include damping of non-structural deck covering additionally to the available information from Class Rules, i.e. [2, p. 7] and perform calculation in more accurate way.

ANALYSIS OF THE LATEST RESEARCHES AND PUBLICATIONS

Structural engineers are facing with the two problems during the dynamic analysis of ship structures. One of them corresponds to the definition of pressure fluctuation induced by propeller as main excitor on board. Holden et al. method [4] is widely used for the definition of pulsing pressure on the aft part of the ship. However, the statistics based on experimental data from 72 ships is collected for conventional hull shapes and approximation formulas give overestimated cavitating and non-cavitating pressures for modern offshore vessels and yachts with open shaft lines supported by brackets or azimuth/tunnel thrusters.

Since more accurate analytical model for the definition of pulsing pressures is absent another problem with damping is rising when Holden's method is used as it is without any corrections related to geometry of the aft part of the ship and propeller but validation of FE model with sea trial measurements is performed by tunning of damping factor. Such damping coefficients are unrealistic and has no physical sense, [5].

Therefore, both input parameters are to be clarified to orders acceptable for engineering usage.

SEPARATION OF PREVIOUSLY UNRESOLVED PARTS OF THE OVERALL PROBLEM

In general designers have the statistics about non-structural mass of floating floors, decorative coverings and systems underneath the deck. Therefore it is possible to calculate approximately amount of mass in kg/m^2 needed for natural frequency and dynamic response analyses. This information is needed to set up non-structural mass (NSM) objects in FEM software coupled to deck panel. However, each deck covering has its own combination of stiffness, mass and damping, which will have certain influence on vibration amplitudes. The peculiarity of this study is that the floating floor is modelled by volume finite elements with real physical properties and obtained vibrations are compared with the ones calculated with NSM.

PURPOSE OF THE STUDY

The purpose of the study is to show quantitative results of the influence of floating floor covering modelled using volume finite elements with real physical properties on natural frequencies and vibration amplitudes of deck stiffened panel.

METHODS, OBJECT AND SUBJECT OF THE STUDY

Finite element **method** is used in this study due to complexity of the task and post-processing purposes. Modal frequency response analysis allows to take into account functional dependency of damping coefficient versus frequency.

Object of the investigation is stiffened deck panel extracted from global FE model of the offshore vessel [6].

Subject of the study is damping coefficient which is derived from frequency response functions obtained for respective natural frequencies.

MAIN CONTENT

The object of the study is a deck stiffened panel with the following parameters:

- Material: Steel Grade A, Yield strength is 235 MPa, Young's modulus is 206 GPa, Poisson's ratio is 0.3, density is 7850 kg/m^3;
- Plate thickness: 8 mm;
- Primary girders: T300×8/100×10, frame space is 2.4 m;
- Secondary stiffeners: EN 10067, Holland profile (HP) 100×7, frame space is 0.6 m.

The Weber Marine dB A-60 floating floor system [7] includes multiple layers, four of which are included into the FE model:

- 1st layer: 1.5 mm visco-elastic layer;

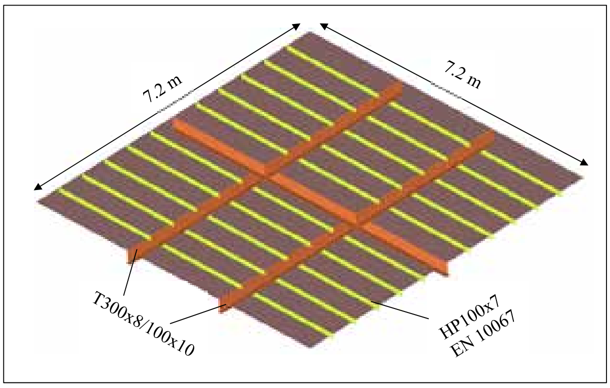

Fig. 1. Object of the investigation – deck stiffened panel

- 2^{nd} layer: 15 mm cement based, fibre reinforced levelling compound with nominal density of 1.7 kg/m^2/mm;
- 3^{rd} layer: 50 mm non-combustible mineral wool;
- 4^{th} layer: Interglass woven glass fabric with weight 100–300 g/m^2;
- 5^{th} layer: Steel reinforcement net Ø 5 mm, grid 150 x 150 mm;
- 6^{th} layer: 25 mm cement based, fibre reinforced levelling compound with nominal density of 1.7 kg/m^2/mm.

A detailed view of the multilayer floor modeled by finite elements is shown in Fig. 2. The first and the fourth layers are excluded from the model, as they are technological layers and their influence on the results can be neglected.

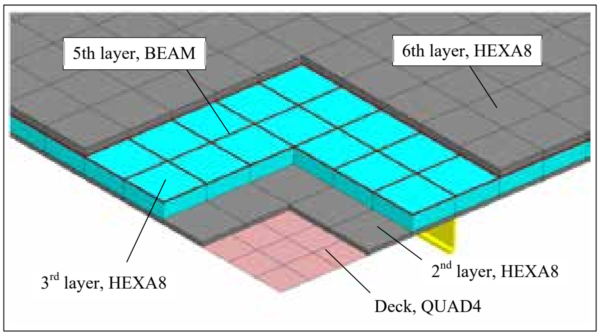

Fig. 2. Weber Marine dB A-60 floating floor modelled by finite elements

FE model parameters:

- Mesh size of structure is 100×100 mm; mesh size of floor is 150×150 mm;
- Meshes of floating floor are merged node-to-node; this multilayered package is glued to structure using inbuilt software tool;
- Software: Siemens NX with Nastran solver;
- Analysis: SOL111 Modal Frequency Response;
- Boundary conditions: All translational degrees of freedom are constrained around the perimeter;
- Excitation load: 1 Pa normal pressure;
- Measurement point: Center of the panel;
- Damping: Functional dependency of critical damping versus frequency from [2, p. 7];
- Frequency range: 0–100 Hz, step 0.1 Hz.

DISCUSSION OF THE RESULTS

The vibration velocity amplitudes along the vertical axis in the graph in Fig. 3 are indicative and are used solely for evaluating the damping coefficient and identifying the most significant vibration modes.

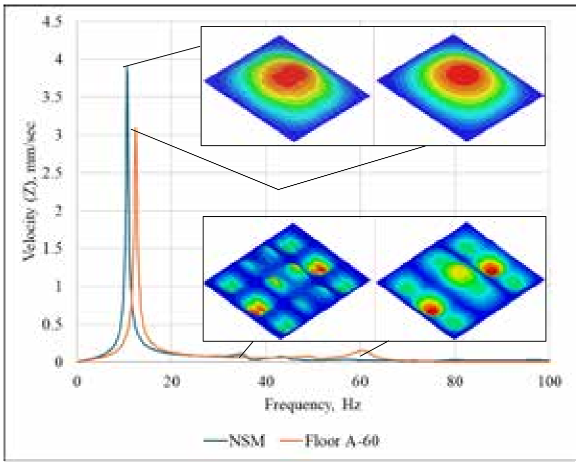

Fig. 3. Vertical vibration velocity versus frequency depending on the modelling approach of non-structural covering

The method for evaluating the energy dissipation coefficient is taken from [1, App. D, p. 29], see Fig. 4.

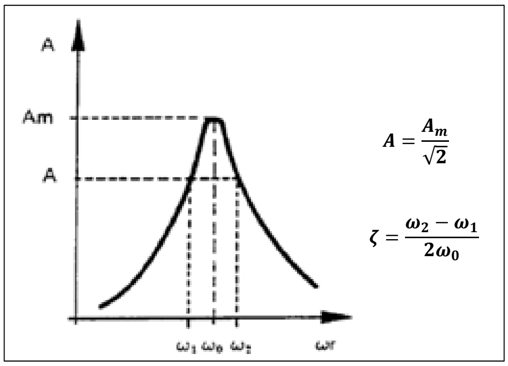

Fig. 4. Method used for the evaluation of damping coefficient

The results are presented in Table 1.

Table 1. Structural damping coefficient [%] versus mode shape and frequency

Modelling approach of Non-Structural Covering	1st Mode	7th Mode
NSM	3.7	5.15
Floor A-60	4.0 (+8,1 %)	6.2 (+20,3 %)

Fig. 5 represents initial and modified function of damping based on the results from Table 1. Following approach is used to build modified curve:

- Range from 0 to 5 Hz remains the same since influence of structural damping here can be neglected.
- Inclined part starts from 2 % of structural damping at 5 Hz. Second point can be found if first natural frequency falls into the range from 5 to 20 Hz.

• Horizontal part above 20 Hz remains the same but is to be increased by percentage found for natural frequencies with higher order.

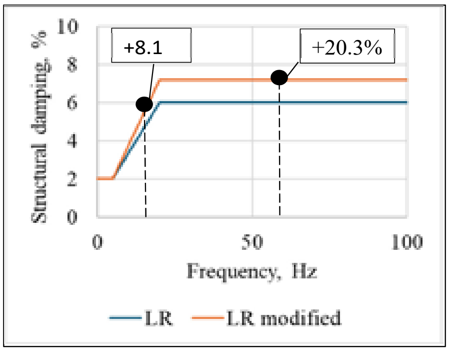

Fig. 5. Initial and modified Lloyd's Register structural damping dependencies versus frequency

CONCLUSIONS

• Both methods of applying non-structural covering show good agreement with the results only for the first fundamental vibration mode with the highest response.

• The derivation of the damping versus frequency function depends on the type of covering and deck structure and clearly requires analysis of a larger number of typical deck panels to generalize the results.

• Damping correction from [2, p. 7] can be applied based on this example, as shown in Fig. 5, but it does not solve the issue of the large number of vibration modes when the non-structural covering is applied using the NSM inbuilt tool directly to the deck plates. Therefore, the search for the optimal ratio of sizes and types of elements will be addressed in future publications.

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