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The Effect of Damping Treatment for Noise Control on Offshore Platforms Using Statistical Energy Analysis

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Abstract**—**Structure-borne noise is an important aspect of offshore platform sound field. It can be generated either directly by vibrating machineries induced mechanical force, indirectly by the excitation of structure or excitation by incident airborne noise. Therefore, limiting of the transmission of vibration energy throughout the offshore platform is the key to control the structure-borne noise. This is usually done by introducing damping treatment to the steel structures. Two types of damping treatment using on-board are presented. By conducting a Statistical Energy Analysis (SEA) simulation on a jack-up rig, the noise level in the source room, the neighboring rooms, and remote living quarter cabins are compared before and after the damping treatments been applied. The results demonstrated that, in the source neighboring room and living quarter area, there is a significant noise reduction with the damping treatment applied, whereas in the source room where air-borne sound predominates that of structure-borne sound, the impact is not obvious. The conclusion on effective damping treatment in the offshore platform is made which enable acoustic professionals to implement noise control during the design stage for offshore crews' hearing protection and habitant comfortability.

Keywords**—**Statistical energy analysis, damping treatment, noise control, offshore platform.

I. INTRODUCTION

PEOPLE are more concerned about the habitability nowadays. As the deepening of understanding and the testing technique becoming better and approaching perfection day by day, all kinds of pollutions such as water pollution, air pollution, light pollution, noise pollution and etc. are getting seriously attention and requesting for strict control. An offshore platform has facilities for oil drilling, processing and storage or subsequent refining on shore. In many cases, the platform is integrated with facilities of housing the work crew as well. In recent years, offshore platform owners are not only concern about the operational efficiency and safety during offshore operation, but also crew habitability. Noise is known to be one significant factor that affects the health of offshore personnel. Adverse effects of noise on people have been reviewed in the past few decades [1]. Long hour's noise exposure influences hearing and emotion, subsequently leads to the potential risk of safety hazard during drilling operation.

Structure-borne noise is an important component of offshore platform sound field. It can be generated on offshore platform either directly by vibrating machineries induced mechanical force, or indirectly by the excitation of structure excitation or by incident airborne noise. The structure vibrates at lower frequencies whereas at high frequencies, the large number of resonant modes of structure generates noise and radiates into rooms. The structure-borne noises propagated into the control rooms, radio rooms, offices and the living quarters through steel structures. The attenuation of structure-borne sound transmission tends to be rather small because the internal loss factor of metallic materials is relatively low, and steel structure's resonant behavior promotes sound radiation.

Two methods are commonly used control the transmission of vibration energy. By adding resilient mount to the typical vibrating machineries, transmission of vibration energy from the machines to the hull structures can be effectively reduced. Subsequently, the vibration energy received by hull structure can be further dissipated through a highly damped, dynamically stiff material in contact with the structure. Typically, damping materials are applied on the decks and bulkheads of the room. The commonly used damping treatments onboard are damping tiles and floating floors/room system. The tile product is a constrained damping layer and it is typically installed to the middle of un-stiffened steel plating. In practice, it is mainly applied to the source room or its adjacent room to reduce the vibration level of the steel plates. On the other hand, floating floor/room system is mainly applied in the superstructure for providing both flooring and vibration/noise reduction purposes. The floating floor/room system has several configurations depending on the purpose of the room. Examples are system for wet area, dry area and control rooms.

In this study, software VA-One Statistical energy analysis (SEA) module is utilized to investigate the effect of damping layer on noise reduction of a jack-up rig. The SEA model of a complete jack-up rig is developed. The paper is structured as follows: (a) configurations of damping tile and floating floor/room are briefly described; (b) SEA model of the jack-up rig and damping treatments are introduced; (c) damping tiles are applied at different surface area coverage in engine rooms and mud pump room and the impact in the relevant rooms are studied; and (d) room noise level comparison is made before and after the floating floor/room system been installed to the superstructure; and (e) conclusion on effective damping treatment in the offshore platform is presented.

II. DAMPING TREATMENT USED ABOARD

As mentioned in previous section, the most commonly used damping treatment on-board offshore platforms are tile product and the floating system.

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A. Tile Product

Applying the tile product is a simple and traditional way for attenuating noise and vibration levels [2]. The vibration damping tiles used on-board is mainly the constrained damping layer type, which is suitable for harsh environment and not subject to abrasion or deterioration. As shown in Fig. 1, damping tile is a 'sandwich' formation which laminates the base structure to the thin visco-elastic damping layer and adding a third constraining layer. When the base structure flexes during vibration, shear strains develop in the damping layer and energy is lost through shear deformation. The maximum shear deformation in the middle layer is a function of the modulus and the thickness of the constraining layer [3]. In general, the performance of a constraint layer construction is depending on the constraint layer thickness, damping layer material and thickness, and the room temperature. At constant temperature, thicker or stiffer constraint layer warrants better damping and increases the resonance frequencies, but will increase the tile weight and may be harder to adhere; increasing the damping layer creates more damping but this is not always the case when the constraint layer exceeds a certain thickness. Therefore, damping tile product should provide an optimum combination of constraint layer and damping layer. The installed damping tiles increase structure mass and therefore increase the sound transmission loss according to mass law.

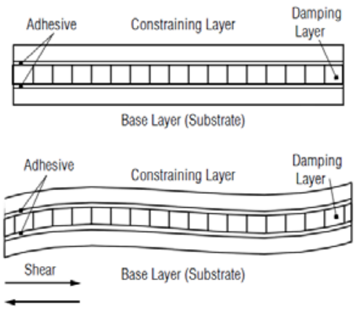

Fig. 1 Constrained-layer construction (top) and under flex condition (below) [3]

B. Floating Floor/Room

In the living quarters, airborne noise is less dominant than structure-borne noise, isolating the rooms from vibrating steel structures can effectively reduce the noise level in the room. Rooms under such condition are usually called 'floating rooms'. A floating room consists of deck covering system, lining panels, and ceiling panel.

Deck covering system provides adequate flooring, meanwhile, it reduces the structure-borne noise radiated from the steel decks, lowers the vibration energy transmitted to bulkheads connecting to the deck, and increases the sound transmission loss of the deck [4]. One form of deck covering system is a combination of various layers, such as visco-elastic layer, underlayment, and the finishing surface. The visco-elastic layer is made of resilient material and direct in contact with steel deck to give dampening effect. The underlayments are materials that are placed to level and smooth the surface so that the surface can receive further covering. Concrete is a common material for underlayment which acts as constraint on the visco-elastic layer. Their combination forms the constrained damping layer on top of steel deck. Selection of finishing surfaces material is mainly depending on the room functions. For example, vinyl sheet is installed in the dry area like cabins whereas the epoxy is applied to the wet area. Another form of deck covering system is raised floor usually installed in the control rooms to allow access of massive cables. Other than that, the raised floor panel is made from two welded steel plate with light cement core material, which exhibits airborne noise isolation and damping effect. The panels are rigidly connected to the deck by bolted stringers ensure the stability of the raised access floor system.

The lining panels are mounted on top of the floating floor and connected with ceiling to form the entire floating system/room. The lining and ceiling panels are general sandwich structure with core material of mineral wool and surface panel of galvanize steel. A resilient anti-vibration device is added to the interconnection between panel and bulkhead to isolate the panel from vibrating steel structures.

The floating system/room has several configurations which are designed for specific areas. In this study, the performance of three actual configurations for dry areas, wet areas, and wheelhouse deck (raised access floor) of the prototype rig are investigated. Their construction details are shown in Fig. 2.

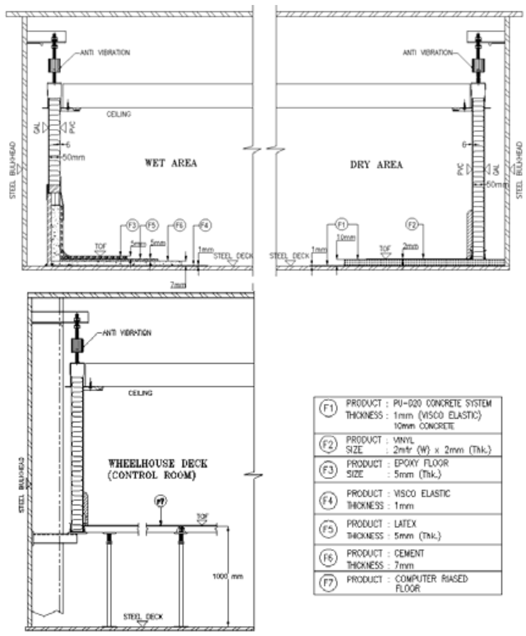

Fig. 2 Typical construction of deck covering system for dry areas, wet areas, and control rooms

III. SEA Model Description

The SEA is mainly used in the occasions where the system under the stochastic environment excitations. The SEA has long been a favorite method for analyzing the flow of acoustic and vibration energy in complex structures [5]. Based on the energy conservation principle, SEA deals with the frequency-averaged value of energy response function of subsystems and relates the time-averaged power flow between subsystems to their steady-state energies. For a subsystem i connected to many subsystems j, with j varying, the power balance equation is written as:

$$P_{in}^{i} = P_{diss}^{i} + \sum_{j\neq i} P_{coup}^{ij} \quad (1)$$

where P_{in}^{i} is the power input to the subsystem from external excitation, P_{diss}^{i} is the power dissipated within the subsystem i by the internal damping and P_{coup}^{ij} is the net power transferred from subsystem i to the subsystem j through dynamic coupling. All the power components mentioned are time-averaged quantities, and the structure is considered under steady-state conditions.

This study is conducted on a jack-up rig with the hull dimension of 88.8m (L) x 115.1m (Breadth) x 12m (Depth). It has five tiers living quarter locates at the forward hull. The full-size SEA model the study involved rooms which are shown in Fig. 3. The major noise sources rooms such as engine rooms, mud pump room etc. are arranged at the aft which is far from the living quarter; the receiver rooms are include engine control room (ECR) which is next to corridor connecting to the port engine room; store room is next port engine room and mud pump room, which is under double influence; cabin D08A is located on the D deck; and operation control room is on the wheelhouse deck.

Steel structures of the rig are modeled in accordance with structure drawings and general arrangements of the rig. Bulkheads and decks are represented by ribbed plates; air medium are represented by the room cavity. Acoustic absorptive material on the bulkheads and decks are not implemented for better illustrating the damping layer performance. The noise and vibration sources throughout the rig are described by means of its sound power level and vibration level. These data are obtained from suppliers or existing noise and vibration database.

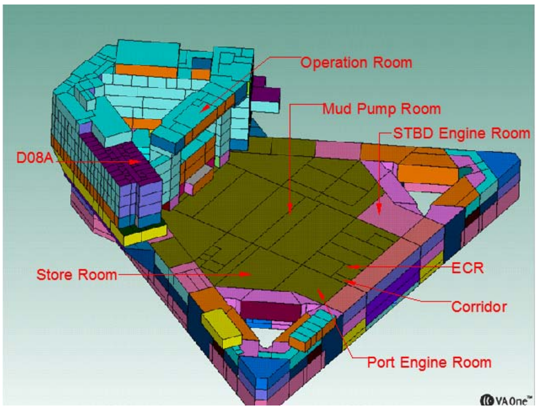

Fig. 3 Jack-up rig full-size SEA model

The damping tile products of 9mm thickness are modeled using 6mm damping layer and 3mm constraint layer. The damping tile, ceiling panel, lining panel and the deck covering systems for dry and wet areas in Fig. 2 are modeled using the available noise control treatment package of VA-One software; the raised floor panels in Fig. 2 are modeled using steel-concrete-steel sandwich plates which are constrained by stiff line and point junctions to the deck. The thicknesses of the sandwich layers used in this study are: 0.005m-0.028m-0.005m. The actual isotropic, visco-elastic and fiber materials, their representation in the software and their predefined physical properties are listed in the Table I.

TABLE I
MATERIALS INVOLVED, THEIR REPRESENTATION AND PHYSICAL PROPERTIES

Isotropic/Visco-elastic Material	Representation	Density kg/m3	Tensile Modulus Pa	Shear Modulus Pa	Poisson's Ratio	Loss Factor
Steel	Steel	7800	2,E+11	8,E+10	0,31	
Visco-elastic	Visco-elastic Polymer	1000		1,E+05	0,90	50%
VNYL	Plywood	700	6,E+09	2,E+09	0,25	
Concrete/Cement	Concrete	2300	3,E+10	1,E+10	0,25	
Latex	Hard Rubber	1100	2,E+09	8,E+08	0,49	
Fiber Material	Representation	Density kg/m3	Flow Resistivity N.s/m4	Porosity	Tortuosity	Viscous c.l. m
Mineral Wool	Mineral Wool	50	6,E+04	0,95	3,2	5,E-05

SEA provides a basis for prediction of average noise and vibration level particularly in high frequency region where modal densities are high (minimum three modes in the bandwidth) so that the average modal densities can be accurately captured. The valid frequency range of the rig model is determined by computing the number of modes in octave bands. By checking the mode counts in each band for each of the model subsystem, the frequency range of 125 ~ 8000 Hz is determined.

IV. ANALYSIS MODELS AND RESULTS

To understand the effect of noise treatment in the source room, the engine rooms and mud pump room which contain the major noises and vibration sources are treated by the damping tiles. Subsequently, their influences in the adjacent store room, ECR room, room in remote living quarter area (D08A) and operation control room are investigated. Furthermore, three selected floating systems/room are applied to the cabin and operation control room in turns to compare their noise reduction performance. In summary, the following configurations have been investigated:

- R0 - Bare steel model
- R1 – 9mm damping tiles applied to all boundaries of engine rooms and mud pump room
- R2 – 9mm damping tiles applied to half bulkheads and bottom deck of engine rooms and mud pump room
- R3 – 9mm damping tiles applied to the bottom deck of engine rooms and mud pump room
- R4 – Install the dry area type (Fig. 2) to all cabins
- R5 – Install the wet area type (Fig. 2) to all cabins
- R6 – Install the raised access floor (Fig. 2) in the operation control room

A. Damping Tiles Applied in the Source Rooms

Figs. 4-9 present sound pressure level (SPL) spectra in the port engine room, mud pump room, ECR, store room, cabin D08A, and operation control room in the case of R0 to R3; and Table II tabulates the equivalent noise level before and after the damping tiles been applied. As shown, sound field of the source rooms in Figs. 4 and 5 are not sensitive to the applied damping tile, and there is little improvement on the equivalent noise levels. In contrast, the adjacent rooms (Figs. 6 and 7) have good responses to the applied damping tiles, particularly at higher frequencies. The effects of attached damping tiles are reflected on both structure-borne and airborne noise reduction in these rooms. From the condition of R1 to R3, with varying coverage area, the noise reduction effects are different. Although condition R1 has the best performance with 4 dB noise reduction, the condition R2 with slightly lower noise reduction effect may be preferred in real practice when economical perspective is taken into consideration. Apply damping tiles on the deck only (condition R3) seems not reducing the noise level in the adjacent room efficiently.

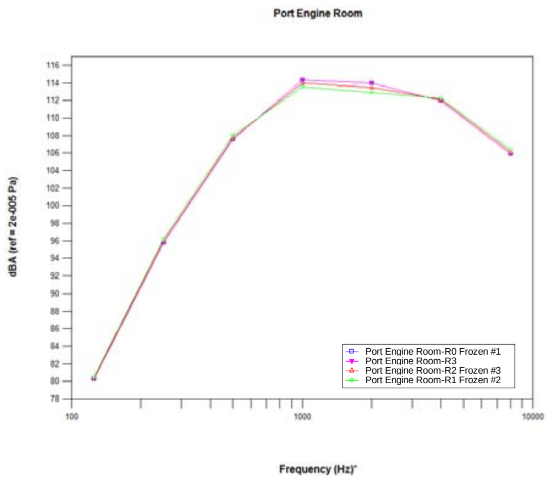

Fig. 4 SPL of port engine room under the condition of R0 to R3

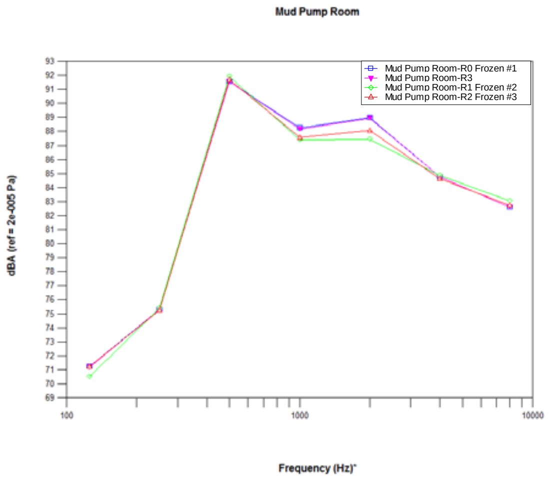

Fig. 5 SPL of mud pump room under the condition of R0 to R3

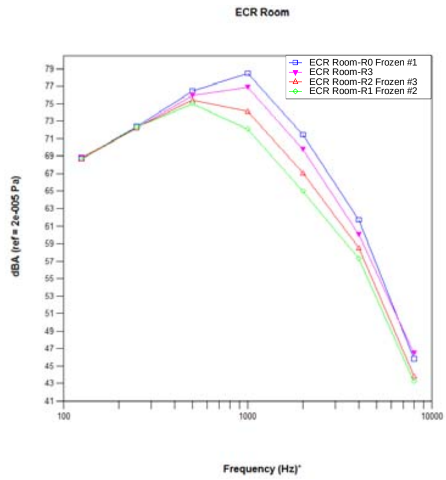

Fig. 6 SPL of the ECR under the condition of R0 to R3

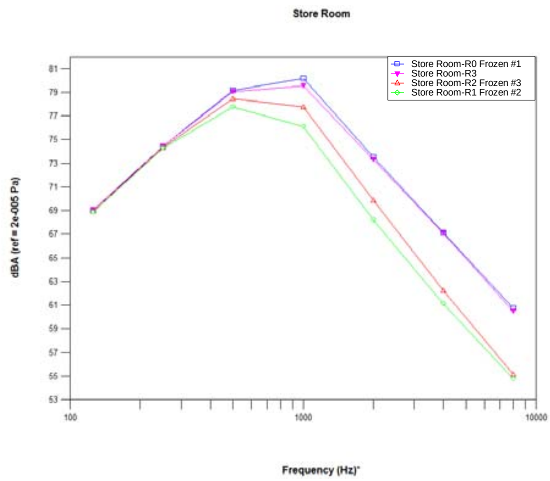

Fig. 7 SPL of the store room under the condition of R0 to R3

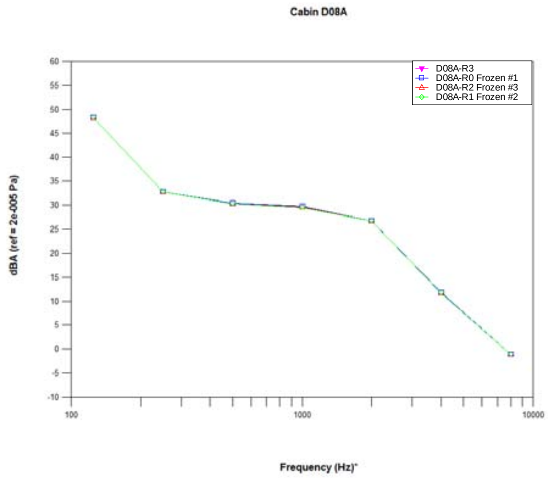

Fig. 8 SPL of cabin D08A under the condition of R0 to R3

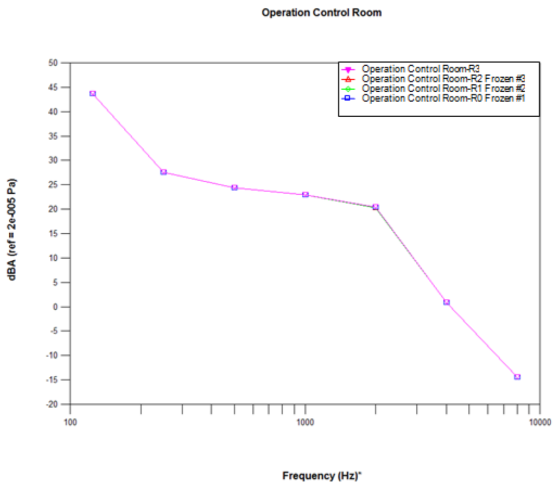

Fig. 9 SPL of operation control room under the condition of R0 to R3

Installing damping tiles in the engine rooms and mud pump room seems not benefiting in noise control of the remote cabin (Fig. 8) and operation control room (Fig. 9). This is because engine rooms and mud pump room are located far remote from living quarter; the vibration energy dissipates along the junctions before reaching it. Moreover, vibration energy in the superstructure is the combination from all sources and transmission paths. The damping treatment applied in the engine rooms and mud pump at far end seems not contributing to the structure-borne sound pressure level.

TABLE II
EQUIVALENT SPL COMPARISON FOR THE FIRST FOUR CONDITIONS

Rooms	Equivalent Noise Level (dBA)			
	R0	R1	R2	R3
Port Engine Room	107,75	107,7	107,71	107,74
Mud Pump Room	95,3	95,06	95,07	95,28
Store Room	82,81	79,2	80,23	82,23
ECR	80,68	75,53	77,41	79,1
Cabin D08A	51,17	51,17	51,17	51,17
Operation Control Room	43,83	43,83	43,83	43,83

B. Floating System/Room Applied in the Living Quarter

As comparing to the damping treatment applied to the source room, the installation of local floating system/room shows high effectiveness in reducing the structure-borne sound pressure level in the accommodation. Figs. 10 and 11 compared the cabin and operation control room noise level before and after the floating system been installed. It can be seen that with the effect of floating system/room, noises across whole range of frequencies have been improved. As shown in Table III, the performance of the three types of floating system/room with approximately 4 dB noise reduction.

TABLE III
EQUIVALENT SPL COMPARISON FOR CONDITION R0, R4, R5 AND R6

Rooms	Equivalent Noise Level (dBA)			
	R0	R4	R5	R6
Cabin D08A	51,17	47,2	47,15	
Operation Control Room	43,83			38,76

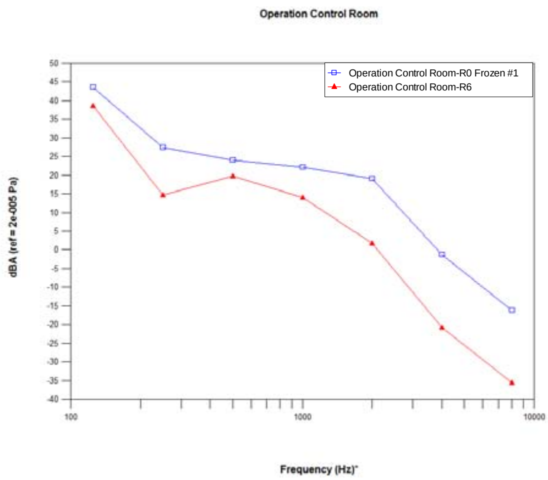

Fig. 10 SPL of cabin D08A under the conditions of R0, R4, and R5

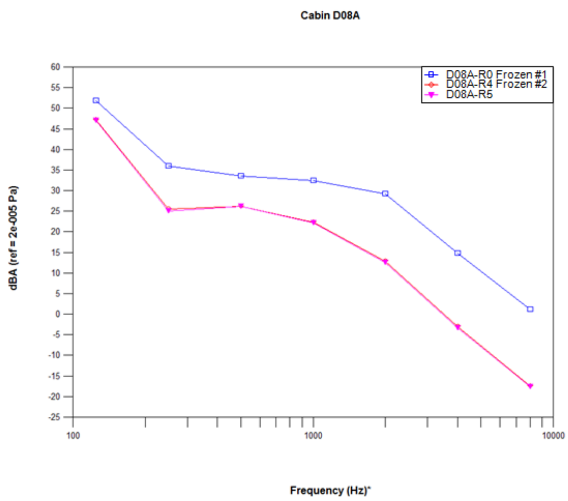

Fig. 11 SPL of operation control room under the conditions of R0 and R6

V. CONCLUSION

Apply damping treatment is a conventional way to control noise and vibration onboard offshore platform. Base on the simulation results, applying the damping tiles on the source room boundaries will attenuate the noise level in its adjacent non-source rooms. However, full boundary coverage is not recommended as it is not economical and offers very little noise reduction than the bottom deck and partial bulkheads coverage condition. Unfortunately, damping tile attached to the source room boundaries only limited improvement in the source room itself and the remote accommodation area. Instead, for the airborne noise dominated source rooms, installing highly absorbent materials on the boundaries can largely reduce the energy from reflections and thus reduce the room noise level; for cabins and control rooms in the living quarter which are dominated by the structure-borne sound, local floating system/room seems to isolate the structure-borne noise from radiating into the room.

In this study, the performance of the specified damping tile and floating system configurations are discussed. With different thickness and materials been used in the real practice, the results may vary. However, the noise effects on different configurations are studied and could help engineers to develop more efficient and economical noise control solutions for the rig design.

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