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Numerical optimization and experimental research on listening environment of crew based on neural networks

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ABSTRACT

With greater noises in the cabin, a greater impact would be acted on the listening system of crew who lived in the cabin for a long time. The neural network and the listening environment of the cabin were optimized in the paper to improve the listening capacity of crew. Firstly, the periodic sound insulation package was proposed to make a comparison with the traditional sound insulation package to verify its advantage for sound insulation performance of the structure in mid-low frequency. Later, numerical simulation was applied to analyze the influence of duty cycle and periodic number on the transmission loss of the structure. In order to obtain the structure with an optimal transmission loss, the neural network was adopted to predict and optimize the periodic sound insulation package. In the meanwhile, boundary element method was adopted to predict the interior noise in the cabin. In order to analyze noises in the cabin, panel contribution analysis was conducted for the panel of the cabin. Finally, the periodic sound insulation package was applied on these panels to improve the noise in the cabin. It was found that the periodic sound insulation package can effectively control the vibration energy of these panels at these frequency points and reduce noise in the cabin. Finally, the noise in the improved cabin was tested to compare with the result of the numerical computation and obtain good consistency. It indicated that the numerical simulation was reliable. The low frequency noise in the cabin could really be reduced effectively through laying the periodic sound insulation package on the cabin panel. Finally, the listening capacity and environment of crew were obviously improved within the cabin.

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1. Introduction

With greater noise in the low frequency in the cabin, a greater impact would be acted on the listening system of crew who lived in the cabin for a long time. Therefore, learning about the characteristics of low frequency noise in the cabin and putting forward specific noise reduction measures are very important. Song laid viscoelastic damping materials on the floating floor structure of the cabin, conducted on numerical computation, predicted its structure-borne noise and studied the influence of damping's thickness, density and laying direction on the structure-borne noise of the floor [1]. However, its research was not verified by the corresponding experiment. Cha studied the influence of the floating floor on the vibration damping performance of the cabin, proposed two theory models including mass-spring model and wave model to compute the insertion loss of the floating floor and conducted tests in the typical cabin [2], but the vibration and noise was not reduced by applying some measures. Sung proposed the analytical procedures for the interior noise of a construction equipment cabin. The analytical method can also be used for the early design stage of the cabin or the investigation of air and structure-borne noise [3]. Desmet studied the insertion loss of an agricultural machinery cabin and combined finite element method with boundary element method for prediction and experimental verification. The research process could be taken as a reference for computing noises in the cabin, however, how to reduce noises in the cabin was not researched in his paper [4]. Xia adopted finite element/boundary element method and selected the cylindrical

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shell cabin applied to submarine structure to conduct the numerical computation of vibration and sound radiation and demonstrated numerical values aimed at different boundary conditions, sub cabin models, bulkhead structure parameters and so on [5]. Cho studied the problem of low frequency noises in the cabin through experimental tests and numerical analysis [6–8].

All the mentioned studies only laid big block damping materials on the cabin floor or conducting relatively complex design on the cabin floor structure [1,2,9]. In this way, the noise reduction effect would not be obvious in the low frequency band. Meantime, the design cycle and cost would increase. As a result, this paper proposed a kind of periodic sound insulation package. Referring to the principle of phononic crystals, the structure could effectively reduce the noise in the low frequency. The periodic structure was laid on the surface of the cabin panels which had the largest influence on the noise. Through tests and numerical simulation, it was verified that the structure had obviously reduced noises in the cabin.

2. The design of the periodic sound insulation package

Cabin panels could not satisfy the requirements for noises by only depending on its own structure. In this case, their surfaces were usually pasted with some other materials such as foam, fiber and sponge. Typical structures were usually composed of 4 layers including the cabin panel, the damping layer, the porous material layer and the covering layer, as shown in Fig. 1. Among them, porous materials were the main layer for absorbing sound. Through the friction between air and structure in porous materials, sound wave was converted into heat and the damping vibration of porous materials. It dissipated the energy of sound wave and achieved the goal of reducing noise.

Big block sound insulation package was usually laid on panels in noise control engineering, and it was obvious for reducing high frequency noise. The noise would not be improved in mid-low frequency bands, and certain negative effects might even be brought. With the constant development of the periodic structure band gap mechanism and theoretical studies on phononic crystals [10–12], the periodic sound insulation package was proposed to effectively reduce the noise in mid-low frequency bands and make up for the deficiencies of the traditional sound insulation package.

2.1. Periodic sound insulation packages

As shown in Fig. 2, it was a model of the periodic sound insulation package. The shaded area represented a crystal package in the periodic structure. L_a and L_b were lattice constants in the direction of x and y respectively. a and b were the length and width of sound insulation packages. Duty cycle was represented by $ab/(L_aL_b)$. The periodic sound insulation package was a two-dimensional structure for saving the space of the objective. Structures in Fig. 1 were only a crystal package in the periodic structure.

The geometric model of the periodic structure in Fig. 2 was built, imported into HYPERMESH to divide meshes and endowed with corresponding structural materials. Then, the finite element

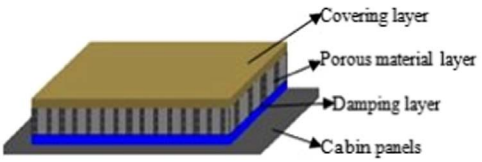

Fig. 1. Composition of the sound insulation package.

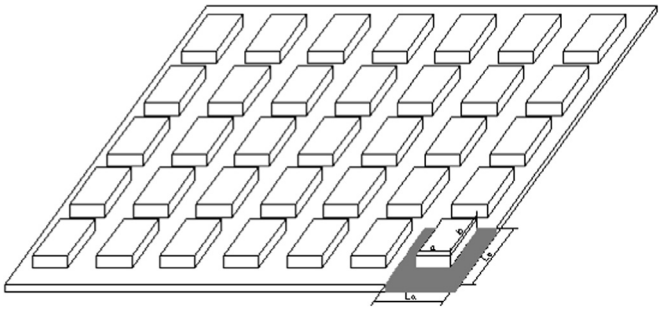

Fig. 2. Model of the periodic sound insulation package.

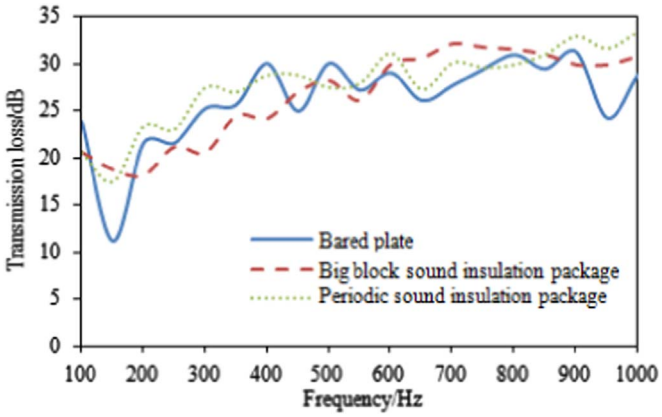

Fig. 3. Comparison of transmission loss under different sound insulation packages.

model was imported to the virtual-lab to compute the transmission loss. In addition, the transmission loss of bared plates with the same size and the plate with the traditional sound insulation package was also computed to make a comparison. The result was shown in Fig. 3 in which only the transmission loss less than 1000 Hz was computed. For the plate, the computational frequency was only in mid-low frequency bands. Additionally, it could be seen from Fig. 3 that the transmission loss of the plate with the traditional sound insulation package was lower than that of the bared plate at most of frequency points. It had a negative effect on noises. The transmission loss was improved at most of frequency points to some extent due to the periodic sound insulation package. The maximal transmission loss of the periodic sound insulation package in the analyzed frequency was 33.2 dB, while the bared plate was 29.1 dB and the traditional sound insulation package was 28.6 dB. Therefore, it showed that the periodic sound insulation package proposed by this paper had significant advantages in improving the sound insulation performance in mid-low frequency bands.

2.2. Analysis on the influence of duty cycle

The period number of sound insulation packages in Fig. 4 was remained unchanged in the direction of x and y. The duty cycle of the periodic structure was changed to observe the change of the transmission loss. The result was shown in Fig. 4. It could be seen from Fig. 4 that the transmission loss of the structure increased with the increase of duty cycle. The reason was that the change of duty cycle would lead to the change of integral rigidity and transmission loss mainly depended on the structural rigidity in the mid-low frequency bands. Thus, appropriately increased duty cycle of the periodic sound insulation package had an obvious effect on reducing structural radiation noise.

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