Mechanical self-noise prediction of sonar parts based on equivalent excitation spectrum theory

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Abstract. The mechanical self-noise of the sonar is one of the important factors affecting the performance of the sonar. Therefore, studying the prediction of the mechanical self-noise of the sonar is of far-reaching significance for the effective performance of sonar detection. In this paper, the theoretical modeling of the propagation channel is carried out, and the transfer characteristics of the excitation of the vibration source device into the sonar platform region are numerically simulated. A method for predicting the mechanical self-noise of the sonar part based on the equivalent excitation spectrum analysis is proposed.

1. Introduction
To predict the mechanical self-noise of the sonar part, it is necessary to establish a mathematical theoretical model for calculating the mechanical self-noise of the sonar part according to the external excitation, and determine the external excitation method of the sonar matrix cavity, and then calculate the sonar matrix cavity according to the external excitation\textsuperscript{[1,2]}. Water sound field. In the case of "weak coupling", the change of the impedance characteristics of the sonar-based array has little effect on the excitation transmitted to the platform region. It can be considered that the excitation of the platform region remains substantially unchanged in the sonar chamber when it is filled with water or no water. This creates conditions for the estimation of platform area incentives\textsuperscript{[3-5]}. Therefore, the excitation of the platform region can be estimated by measuring the response of the sonar matrix region in the anhydrous state, and then the theoretical calculation mathematical model of the mechanical self-noise of the sonar is used to predict the background noise of the sonar.

2. Theoretical method calculation process
Perform vibrational modal analysis of the components of the sonar array cavity, the platform structure, the bulkhead and the fluid in the cavity to determine its main influence mode in the analysis frequency band\textsuperscript{[6]}. Applying the equivalent excitation spectrum theory, the measuring points are arranged in the platform area under the condition that the sonar matrix cavity is not filled with water, the vibration response of the platform area is measured, and the equivalent excitation spectrum is estimated according to the measured vibration response and the plateau vibration mode.
According to the weak coupling theory of the admittance analysis of the mechanical self-noise propagation mechanism of the sonar part, the mathematical model of the mechanical self-noise of the sonar part is simulated by the equivalent excitation of the plateau in the unfilled state, and the sound is calculated. Mechanical self-noise of the nano part.

Model establishment: As shown in Figure 1, it is a modeled description of the sonar array working space in the sonar shroud. Generally, the sonar cavity space has an irregular shape, and if there is a structural acoustic excitation $p(e, t)$ in some regions of the planar region, De is an excitation region, the excitation will form a hydroacoustic field in the sonar cavity. That is, the source of mechanical self-noise.

![Figure 1. Sonar cavity theory analysis model.](image)

For the water sound field in the sonar cavity, it satisfies the wave equation:

$$\nabla^2 p - (1/c_0^2) \frac{\partial^2 p}{\partial t^2} = 0$$

At the boundary D of the sonar, if the boundary is non-rigid, $\sigma \in D$

$$\frac{\partial p}{\partial n} = -\rho \omega (\sigma, t)$$

If there is a rigid wall area $D_s$, The boundary conditions are:

$$\frac{\partial p}{\partial n} = 0$$

Deriving the acoustic mode equation:

$$\ddot{p}_r + \left(\omega_r^2\right) p_r + \sum_i \frac{C_n p_i}{\left(\omega_i^2\right) M_i} = -\frac{1}{V} \sum_j L_{ij} q_j (r=0,1,2,\ldots)$$

Modal equation of elastic boundary:

$$\ddot{p}_r + \left(\omega_r^2\right) p_r + \sum_i \frac{C_n \dot{p}_i}{\left(\omega_i^2\right) M_i} = -\frac{1}{V} \sum_j L_{ij} \ddot{q}_j (j=1,2,\ldots)$$

The fluid-solid coupling modal equation is formed by equations (4) and (5).
3. Analysis on excitation transmission characteristics

In the model, the solid acoustic channels are respectively described as a lumped-parameter multi-stage elastic coupling structure system consisting of mass-spring-damping and a distributed parameter structure system (such as Figure 2 and Figure 3) connected by a four-sided simply-supported rectangular thin plate and platform interface. In this case, it is due to the limitations of the lumped parameter model, and also to avoid the contingency of parameter values in numerical calculations. As shown in Figure 2 and Figure 3, the vibration source device, the solid sound channel, and the receptor are respectively included. The main calculation process is as follows:

**Figure 2.** Theoretical analysis model of the mechanical self-noise propagation channel of the sonar part (concentrated parameters).
Firstly, according to the admittance analysis method used in the admittance analysis method of the mechanical self-noise propagation mechanism of the sonar part, the three parts of the vibration source equipment, the solid sound channel, and the receptor are connected by the admittance method to establish the vibration. The admittance relationship between the source and the sound field.

Then calculate the water sound field in the sonar cavity according to the following two methods: First, directly according to the propagation sequence of the solid sound, from the vibration source device to the receptor through the solid sound channel, using the vibration source device, the solid sound channel, the receptor three admittance relationship of each part is calculated for the excitation of the sonar cavity platform region, and then the calculated excitation is brought into the formula of the sound field solved by the modal method deduced in the literature to find the water sound field in the sonar cavity; The admittance analysis method firstly solves the vibration response of the sonar platform region structure, which is used to simulate the data measured under actual conditions, and then solves the equivalent excitation of the sonar platform region according to the equivalent excitation estimation method. Finally, the calculated excitation is brought into the formula of the modal method to solve the sound field, and the water sound field in the sonar cavity is obtained.

Figure 4 and Figure 5 show a comparison of the water acoustic fields in the sonar chamber obtained by the above two methods. Figure 4 is a centralized parameter structure system, and Figure 5 is a distributed parameter structure system.
By comparing the images, it can be found that the water sound field in the sonar cavity calculated by the equivalent excitation estimation method is basically consistent with the directly calculated water sound field, so that the vibration response data measured in the non-liquid-solid coupling environment can be confirmed. It is feasible to estimate the spectrum of the excitation of the platform region in its liquid-solid coupling environment.

4. Conclusions
The vibration response data measured in the non-liquid-solid coupling environment can be confirmed. It is feasible to estimate the spectrum of the excitation of the platform region in its liquid-solid coupling environment.

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