Design and research on impact resistance characteristics of vector hydrophone application platform

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Abstract. On the basis of the analysis of the impact resistance of the application platform of the vector hydrophone is analysed, this paper designed single-stage and two-stage vibration isolation system based on rubber damper by using its characteristics of large viscous damping coefficient, low mass and easy installation and disassembly. By comparing the output signal of vector hydrophones in the state of rigid connection and with single-stage vibration isolation system, it can be seen that under different connection conditions, the signal amplitude of the impact response of the hydrophone are also different. The results of the experiment verified the effect of vibration isolation system on impact signal and the accuracy of theoretical analysis results.

1 Introduction

Vector hydrophone and its matrix are occasionally disturbed by sudden and narrow band impact during transportation and the progress of using[1]. For example, during the process of sonar throwing, the sea surface will cause a great impact on sonar, as shown in Fig.1. For example, when the hydrophone array is operating at sea, it will occasionally collide with the hull during drag and drop, as shown in Fig.2(a)[2]. Once these shocks are too large, they will cause damage and damage such as the loss of mass blocks in the accelerometer and the overload of amplifying circuit.

Fig. 1. Throwing process of sonar.

In conclusion, when designing the vibration damping structure of vibration absorber, it is necessary to consider the above impact interference problems, and determine the parameters of each part of the vibration damping structure in combination with the actual environment and conditions. The rubber shock absorber has the characteristics of large viscous damping coefficient, small mass and easy to install and disassemble. This paper makes use of these characteristics of rubber shock absorber and makes theoretical and experimental research on its impact resistance.

(a) Hydrophone matrix array dragging process

(b) Hydrophone output signal

Fig. 2. Shock effect on sensor array.

2 Research on shock resistance characteristics of vibration isolation system

When a vector hydrophone is connected to a working platform by a single rubber damper, the hydrophone and damper and platform constitute a single-stage damping system[3], and its physical model is shown in Fig.3. The shock signal received by the single-stage damping system can be simplified to the half-sine pulse signal shown in Fig.4.

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According to the kinetic law, the dynamic equation of the hydrophone $m$ is as follows:

$$m\ddot{x} + c\dot{x} + kx = ky + cy$$  \hspace{1cm} (1)

Using damping ratio $\zeta$ and system resonance frequency $\omega_0$ as parameters, the above equation is written as follows

$$\ddot{x} + 2\zeta\omega_0\dot{x} + \omega_0^2 x = \omega_0^2 y + 2\zeta\omega_0 y$$  \hspace{1cm} (2)

To solve the acceleration response $\ddot{x}$ of the damping system, we need to integrate $\dot{y}$ once and twice to get $y$ and $\ddot{y}$, and then substitute them into equation (2) to solve the problem.

$$\ddot{y} = \int \dot{y} dt = \int a_0 \sin(\omega t) dt = -\frac{a_0}{\omega} \cos(\omega t) + C_1$$  \hspace{1cm} (3)

Using initial conditions $\dot{y}(0) = 0$, we get $C_1 = a_0 / \omega$.

So we get that

$$\dot{y} = -\frac{a_0}{\omega} \cos(\omega t) + \frac{a_0}{\omega}$$  \hspace{1cm} (4)

And by the same logic, we can get that

$$y = -\frac{a_0}{\omega^2} \sin(\omega t) + \frac{a_0}{\omega} t$$  \hspace{1cm} (5)

By substituting the above two equations into equation (2), it can be obtained that the force balance equation of the single-stage damping system under the excitation of semi-sinusoidal pulse is

$$\ddot{x} + 2\zeta\omega_0\dot{x} + \omega_0^2 x = \omega_0^2(-\frac{a_0}{\omega^2} \sin(\omega t) + \frac{a_0}{\omega} t)$$

$$+ 2\zeta\omega_0(-\frac{a_0}{\omega^2} \cos(\omega t) + \frac{a_0}{\omega})$$  \hspace{1cm} (6)

The acceleration response $\ddot{x}$ of a single-stage vibration damping system can be obtained by taking two derivatives of the solution $x$ of this differential equation. If the rubber shock absorber damping ratio is 0.08, known as the assumption of half sine shock value is $a_0 = 1$, the natural frequency $\omega_0$ of the system is 100Hz, we can calculate the system response $\ddot{x}$ under different frequencies of the results are shown in Fig.5.
3 Design and experiment of vibration reduction system

According to the rules obtained in the previous section, this paper designs a single-stage vibration damping system that matches the vector hydrophone as shown in Fig.11.

Fig. 11. Material object of vibration isolation system.

In this paper, the impact experiment is designed to investigate the impact resistance of the damping system. The experimental setup is shown in Fig.12. The mass of the pendulum is about 1kg, and the length of the lanyard is about 1m.

Fig. 12. Impact experiment by using a swing ball.

During the experiment, the opening angle of each lanyard is controlled to be as constant as possible, so that the impulse caused by the pendulum ball to the application platform of the vibrator is kept constant. The comparison of the time domain waveforms of the hydrophone output signals in the three connected states is shown in Fig.13-14.

Fig. 13. Time domain signal waveform of vector channel in rigid connection.

Fig. 14. Time domain signal waveform of vector channel in vibration isolation system of single stage.

It can be seen that when the weight falls from the same height and impacts the vibration damping system, the smaller the rigidity of the system, the smaller the output, which means the single-stage vibration damping system has certain impact resistance.
4 Conclusions

Based on the dynamic equations, the impact resistance of single-stage vibration reduction systems are analysed. Through experimental research, it is found that the vibration damping system constructed by rubber damper can restrain the impact signal, and the impact resistance is basically consistent with the theoretical analysis. The above results are helpful for improve the vector hydrophone’s adaptability of the engineering application by optimize the design of the vector hydrophone application platform.

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