Study on vibration reduction of crane monitoring system

Wang Jian¹, Zhang Yong Kui² and Yan Xin³

¹Safety and Production Dept, State Power Investment Co. Ltd Tibet Branch, Lhasa 850000, Tibet China
²Planning and Development Dept, State Power Investment Co. Ltd Tibet Branch
³Electrical Manager, Safety and Production Dept, State Power Investment Co. Ltd Tibet Branch

Abstract. Based on the analysis of the vibration factors of the hoist and the vibration control theory, the BS composite anti-vibration suspension structure based on the hoist monitoring system is designed. The vibration damping test of the designed structure is carried out. The experimental results show that the anti-vibration structure designed in this paper is universal and has good effect on vibration isolation.

1. Introduction

The monitoring system of medium and large hoist is the key guarantee for stable and efficient operation of equipment. However, the phenomenon of shaking and vibration is inevitably accompanied by the daily operation of the crane, so that the image collected by the monitor on the hanger is blurred and distorted by the uncertain vibration, which greatly affects the work efficiency and the safety of the work. Therefore, optimizing the link structure between the monitor and the hanger is of great significance for ensuring the stability and efficiency of the monitor and improving the monitoring level of the equipment.

Since 1965, Stewart's earliest article has solved the problem of motion coupling using the 6-DOF active vibration isolation device developed by Stewart. And researchers achieved certain results in the field of vibration isolation control. W.S.M. Lau, K.H. Low et al. analyzed the movement of the suspension mass attached to the crane and studied the vibration of the crane hanger. Sun Wei et al. used the finite element software ANSYS to build a model of the damping spring anti-vibration hammer-transmission line, and used the breeze excitation force to load it, and optimized the structural parameters of the damping anti-vibration hammer. Zhao Pengrui applied the TRIZ theory to analyze the vibration generated by the agricultural locomotive seat, innovated the seat suspension structure design, and simulated and analyzed the vibration reduction design of the agricultural locomotive seat. 

Li Jingchun et al. used the finite element analysis software to analyze the aircraft cabin of the aircraft. Without changing aircraft gun bay main dimensions, the researchers innovatively designed the damping vibration damping device applied to the structure. Starting from the vibration source, the vibration damping effect of the aircraft gun cabin structure was obtained. The dynamic response stress value was reduced to about 70% of the original value, and a great achievement was achieved in the structural dynamics of the aircraft.
The vibration damping structure adopted in the above research results is mainly based on the supported vibration damping structure. Based on the vibration control principle and the application of crane in actual engineering, this paper develops a suspension damping structure based on the crane monitoring system. A number of experimental data show that the suspension-type anti-vibration structure developed in this paper has good vibration-damping and anti-vibration effect, and it is ideal in the application of the actual crane monitoring system.

2. Vibration characteristics of medium and large hoist

Medium and large hoisting machines are mainly composed of a number of complex mechanical structures. Most of the vibrations are nonlinear vibrations caused by the power system and the transmission system, and are also multi-degree-of-freedom system vibrations. The actions of the large hoist include the change of the pitch angle of the elephant nose frame and the rotation of the fuselage, and the movement of the nose frame, the hanger, and the hook. When the lifting machine is rotating or the boom is telescopic, the hanger mainly swings in the horizontal plane; when it is carrying out the lifting operation, the hanger mainly generates vibration in the vertical direction, and multiple generalized coordinates are required at any instant to fully determine their position. Therefore, the vibration of a large hoist is a combination of various vibration types, and the vibration law is difficult to describe, and the vibration is complicated. The monitoring device is suspended and mounted on the hanger of the hoist through the vibration damping structure. The vibration damping device camera is actually installed in the crane as shown in Fig. 1.

![Fig.1 Damping structure installation position](image)

3. Design and analysis of vibration damping device structure

3.1 Vibration isolation design principle

Vibration isolation is used to prevent vibration of the monitoring system of the lifting equipment. Vibration isolation, referred to as vibration isolation, according to the direction of transmission, vibration isolation measures can be divided into two categories [6]:

① Active vibration isolation: to reduce the vibration caused by the disturbance of the object. The purpose is to isolate the source of vibration, the machine itself that is the source of vibration, and to isolate it from the entire foundation in order to reduce its impact on surrounding equipment.

② Passive Vibration Isolation: to reduce the vibration caused by the movement of the pedestal. The goal is to isolate the response, that is, to isolate the entire foundation from the precision instruments and machinery that allow the vibration to be small, in order to influence the surrounding source.

Obviously, passive vibration isolation measures should be used in this project to isolate the vibration of the rack and prevent the vibration of the monitoring equipment installed on the rack.

For the monitoring device installed on the hanger of the medium and large hoist crane, it is subjected to the exciting force in several directions, so the vibration isolation design needs to be based
on the multi-degree of freedom system. The vibration isolation device and the base are simplified into a rigid body of mass, and the origin is the coordinate of the center of gravity. The three central principal axes of the rigid body are the x-axis, the y-axis, and the z-axis, as shown in Figure 2. The installation of the vibration isolating device is usually symmetrical in the xOz and yOz planes, and the arrangement of all the vibration isolating devices on the same is the same.

![Fig.2 Multi-degree of freedom vibration isolation system](image)

3.2 Damping structure design

Combined with the location and use requirements of the monitoring system installation, the system of Fig.2 can adopt the multi-dimensional form of vibration isolation, damping and vibration reduction to adopt the vibration isolation and vibration isolation design. In this paper, BS (Buffer-Spring) combined anti-vibration suspension structure is proposed. The specific combination of spring, hydraulic buffer and ball hinge is used to isolate the vibration generated by the hanger during the working. The specific structure is shown in Fig.3:

![Fig.3 BS combination anti-vibration suspension structure](image)

The main advantages of this structure are as follows:

1. The combination of springs, hydraulic shock absorbers and ball hinges is highly feasible and can effectively reduce vibrations in six main directional dimensions.
2. The main structure is connected by a ball hinge, which occupies a small installation space.
3. Reasonable use of the spring-symmetric structure makes the main structure balanced in three directions and is easy to maintain steady state.

4. Experimental study on vibration of vibration-damping structure

4.1 Experimental equipment and installation plan

In this paper, the QLVC-ZSA1 vibration signal analyzer is selected for the vibration test, as shown in Fig.4:
Fig.4 QLVC-ZSA1 vibration signal analyzer

The sensor of the QLVC-ZSA1 vibration signal analyzer is a piezoelectric acceleration sensor whose main principle is the piezoelectric effect: when a force proportional to the vibration acceleration acts on the sensitive core, the surface of the piezoelectric material will generate this pressure. Piezoelectric accelerometers are widely used because of their simple structure, light weight, small size and long service life [7]. The installation and connection of the test equipment are mainly divided into the following steps.

1. Operators lower the hanger of the hydraulic lift truck to the appropriate height.
2. Testers install the BS combined anti-vibration suspension structure on the hanger of the hydraulic lifting transport vehicle as required.
3. Testers fix the sensor on the analyzer channel A to the hanger and connect the signal output to the No. 1 end of the analyzer.
4. Testers fix the sensor on the analyzer channel B to the hanger, and connect the signal output to the No. 2 end of the analyzer.

The vibration isolation test of the vibration isolation device designed and prototyped in this paper is shown in Fig.5:

In order to vibrate the entire hanger, it is necessary to excite the cantilever connected to the hanger during the test. At this time, the amplitude of the vibration generated by the monitor fixed to the base is almost the same as the frequency and the vibration generated by the hanger. Therefore, the vibration characteristics of the monitor without the vibration-damping structure on the hanger can be reflected by the vibration characteristics of the hanger itself. Under the premise of ensuring the feasibility and reliability of the test, the percussive method is used to sequentially sample the vibration acceleration signal in several vertical excitation experiments in the vertical direction and the horizontal direction. The sampling frequency is 4000 Hz, and the sampling duration is 2.20 s.

4.2 Test results time-domain analysis

The vibration acceleration curve of the hanger and the monitor under continuous vertical excitation is shown in Fig. 6. It can be seen that the vibration acceleration of the hanger fluctuates greatly under the force condition, the maximum value is 1937.14 mm/s², and the effective value is 294.20 mm/s²; After the combination of the anti-vibration structure of the BS, the vibration acceleration signal of the monitor tends to be gentle, with a maximum value of 104.10 mm/s² and an effective value of 59.62
mm/s$^2$. The vibration in the vertical direction is efficiently isolated by the combined structure. In the same way, under the continuous horizontal excitation, the vibration acceleration signal of the hanger fluctuates greatly, the maximum value is 463.03 mm/s$^2$, and the effective value is 38.02 mm/s$^2$; after the BS combined anti-vibration structure, the vibration acceleration of the monitor. The signal fluctuations also tend to be flat, with a maximum value of 67.98 mm/s$^2$ and an effective value of 7.52 mm/s$^2$. It can be seen that the vibration in the horizontal direction can also be effectively isolated.

4.3 Frequency domain analysis

The amplitude spectrum of the vibration signal of the hanger and monitor under continuous horizontal excitation is shown in Fig.7.
The maximum spectral value of the pylon is 5.21, and its corresponding vibration frequency is 489.26 Hz. The maximum spectral value of the monitor is 1.95, and its corresponding vibration frequency is 72.69 Hz. The results show that the frequency corresponding to the peak vibration of the two is quite different. Combined with the spectrogram under continuous horizontal excitation, the frequency corresponding to the peak vibration of the hanger under vertical excitation is mainly concentrated at about 520 Hz. The peak corresponding to the peak vibration of the monitor under vertical excitation is about 175 Hz. Therefore, when the amplitude and the vibration frequency are both large, the frequency corresponding to the lifting device hanger is between 400-600 Hz, and the corresponding frequency of the camera mounted on the vibration-damping structure is between 72-175 Hz, both of which occur. The frequency corresponding to the peak vibration and the natural frequency differ greatly, so the two basically do not resonate. Under the experimental conditions, the BS combined anti-vibration suspension structure can effectively reduce the vibration in the frequency range where the hanger generates vibration, which proves the rationality of the structure again.

In addition, due to the limitations of the test conditions, we only use the QLVC-ZSA1 vibration signal analyzer and its own piezoelectric sensor as the test and analysis instrument; taking into account the test safety and other factors, this test uses the height adjustable hydraulic lift. The transport vehicle and its hangers replace the large lifting equipment and its hangers, which is still different from the actual working conditions of the equipment.

5. Conclusion

With the popularization of medium and large lifting equipment, anti-vibration and vibration reduction technology has been paid more and more attention by engineers. The current damping structure is mostly supported vibration damping structure. Based on the actual working environment and vibration control principle of the crane, this paper designs a BS combined anti-vibration suspension damping structure based on the crane monitoring system and conducts corresponding vibration analysis test on the structural sample. Based on the actual working environment and vibration control principle of the crane, this paper designs a BS combined anti-vibration suspension damping structure based on the crane monitoring system and conducts corresponding vibration analysis test on the structural sample.

References

[1] STEWART D. A platform with six degrees of freedom [J]. Proceedings of the Institution of Mechanical Engineers, 1965,180(1): 371-386.
[2] W.S.M. Lau, K.H. Low, “Motion analysis of a suspended mass attached to a crane”, Computers & Structures, Vol. 52, pp. 169–178, 1993.
[3] K.W, Hu kunzhi, Study on the Vibration Suppression Performance of Damping Spring Damper [J]. Shaanxi Electric Power,2013,17(6): 40-42
[4] Zhao pengrui. Vibration damping structure design of agricultural vehicle seat based on TRIZ theory [J]. Journal of Chinese Agricultural Mechanization, 2014,35(4): 161-164

[5] Li jingchun, Chen zhongming, He lianzhong. Structure design and study of the plane gun bay’s vibration reduction [J]. JOURNAL OF SHENYANG INSTITUTE OF AERONAUTICAL ENGINEERING, 2003,20(2): 5-8

[6] Wu Tianhang, Hua Hong Xing. Mechanical vibration [M]. Beijing: Tsinghua University press, 2014

[7] Liu Pan, Model turbine and aqueduct vibration test and analysis [D]. Baoding: Hebei University of Engineering, 2013