Analysis of Maintenance Methods and Process Improvement of Vacuum Laser Collimation System for Dams

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Abstract: The method and process of vacuum laser collimation system maintenance is one of the key technologies directly related to the accuracy of dam vacuum laser collimation system measurement value. Taking the maintenance methods and processes of vacuum laser collimation system in Lianlu and Xiacheng as the background, a new set of dam vacuum laser collimation system maintenance methods and processes are proposed, aiming to make up for the gaps in the maintenance of vacuum laser collimation system. It was found that the vacuum pipeline operates at vacuum values between 400 Pa and 900 Pa. The influence of light on the vacuum laser is avoided by correcting the system and shading the transmitting end as well as the connecting part of the receiving end and the vacuum pipeline with a rubber sheet. This new maintenance method and process also provides a useful reference for the safety monitoring of similar projects.

Keywords: Dam Monitoring; Vacuum Laser Collimation System; Maintenance Methods; Maintenance Process

1. Introduction

Vacuum laser collimation system, as a key deformation monitoring method in the field of safety monitoring in recent years, has attracted much attention for its unique advantages. When applied to the deformation monitoring of dams, the system has demonstrated its high practical value. The fully automated laser dam deformation monitoring system is a master of this technology, which not only realizes the automated monitoring of deformation parameters of each dam section, but also automatically completes the data acquisition, processing, library compilation and process line drawing, greatly improving the monitoring efficiency and accuracy.

At present, the application of dam vacuum laser collimation system in the field of engineering safety monitoring [1-4] has made significant progress. The system not only plays an important role in the deformation monitoring of dams, but also has been widely used in the safety monitoring of key projects such as hydropower plants [5]. The data acquired by the vacuum laser collimation system can deeply analyze the deformation of different dam sections and time periods in the upstream and downstream directions and vertical directions of the dam crest [6-9]. This kind of refined monitoring helps to grasp the deformation law of the dam more accurately, so that corresponding maintenance measures can be taken in time to ensure the safe and stable operation of the dam. On this basis, automated and synchronized monitoring of horizontal displacement and vertical displacement is also realized [10], which greatly improves the efficiency and accuracy of monitoring. At the same time, the effects of environmental factors such as time duration, temperature, rainfall and reservoir level on the monitoring data during the operation period of the vacuum laser collimation system were also investigated [11-12], and these studies provide an important basis for a better understanding of the deformation mechanism of dams. For concrete dams in severe cold regions [13], the stability of vacuum laser collimation data was specifically studied, and the degree of

influence of factors such as water level, temperature, and aging on the deformation of dams was deeply analyzed. These studies provide new ideas and methods to ensure dam safety in extreme environments. However, vacuum laser collimation system maintenance methods and processes are still one of the difficulties in analyzing dam deformation data.

Based on the maintenance experience and process of the vacuum laser collimation system in Lianlu and Xiacheng, a set of optimized maintenance methods and processes for the vacuum laser collimation system of the dam is innovatively proposed. This new set of methods mainly focuses on key aspects such as reducing the vacuum level of the vacuum pipeline, optimizing light avoidance measures, strengthening the internal cleaning of the pipeline, maintenance of the wave band plate lifting system, and fine adjustment of software parameters. Through careful design and implementation of these maintenance means, the accuracy of the measured value of the vacuum collimation system is improved, making the deformation monitoring data of Lianlu and Xiacheng dams more reliable and stable. The implementation of this new maintenance method and process has improved the performance of the vacuum laser collimation system of Lianlu and Xiacheng dams.

2. Project Overview and Problems

2.1 Project Overview

As an important water conservancy facility, the safety monitoring of the Lianlu Hydropower Station is of paramount importance. In order to ensure that the deformation of the dam can be accurately monitored, two sets of vacuum laser collimation systems have been installed at the hydropower plant. One set is installed in the corridor area, covering five measurement points to monitor the deformation of the corridor section; the other set is installed on the top of the dam, with seven measurement points to fully grasp the deformation dynamics of the top of the dam. These two systems together constitute the core network for monitoring the deformation of the dam at Lianlu Hydropower Station.

The Xiacheng Hydropower Station also emphasizes the safety monitoring of the dam. This hydropower plant has a set of vacuum laser collimation system installed at the top of the dam, with a total of 8 measurement points from the right to the left of the dam. These points are reasonably distributed and can fully cover all key areas of the dam top to ensure the accuracy and comprehensiveness of the deformation monitoring.

The vacuum laser collimation systems at the Lianlu and Xiacheng dams have not been fully maintained during the six years that the vacuum measurement systems have been in operation. With the passage of time, the systems may be affected by a variety of factors, such as the external environment and aging of the equipment, resulting in a decrease in measurement accuracy or malfunction. Therefore, comprehensive maintenance of the two systems is imperative.

2.2 Problems

In recent years, the vacuum laser collimation systems of the Lianlu and Xiacheng dams have frequently experienced problems during operation. These problems not only affect the accuracy and reliability of dam deformation monitoring, but also pose a potential threat to the safe operation of the dams. Through in-depth research and analysis, the main reasons are found as follows:

(1) Poor sealing of the vacuum tube. Due to the aging of the sealing material, improper installation or erosion of the external environment, the vacuum tube has a leakage phenomenon, making the leakage rate far more than the prescribed 120 Pa/h. This not only affects the stability of the laser transmission, but also may lead to the distortion of the measurement data.

(2) Poor light avoidance. Light avoidance facilities are not reasonably designed, aging damage or improper maintenance, so that the external light can interfere with the laser beam, resulting in beam dispersion, measurement value disorder.

(3) Optical components and laser propagation environment is not clean enough. Dust and impurities accumulated on the surface of the optical components, as well as obstacles in the laser propagation path, so that the light diffraction, affecting the accuracy of the measurement.

(4) There are a large number of uncleared iron filings, debris and other construction remnants inside the vacuum tube, which seriously affects

the propagation of the internal beam and the normal operation of the transmission components.

(5) Sluggish start-stop flip of the wave band plate is another common problem. This may be due to wear and tear of mechanical parts, insufficient lubrication or control system failure.

(6) Measuring software controls timing errors. This can be caused by software programming errors, clock synchronization problems, or hardware failures. Control time errors can lead to interruptions in the measurement process, loss of data, or inaccurate measurement results.

Therefore, in order to ensure the accuracy of the measured values of the dam vacuum laser collimation system, the maintenance methods and processes of the three existing vacuum laser collimation systems of Lianlu and Xiacheng hydropower stations have been thoroughly studied. Based on the full understanding of the system principle, operation characteristics and existing problems, a new set of dam vacuum laser collimation system maintenance methods and processes is innovatively proposed.

3 Maintenance Method and Process Analysis

Aiming at the disease status of vacuum laser collimation system of Lianlu and Xiacheng dams, a new set of maintenance method and process of vacuum laser collimation system of dams is proposed, and the main implementation steps are as follows:

(1) Check the vacuum pump, three-phase voltage regulator and vacuum pump power control box. In the process of checking the vacuum pump, it was found that the vacuum pump lubricating oil was already turbid, and then it was replaced, and the time control of the vacuum pump was set in Xiacheng (vacuum pumping started at 23 o'clock every day), and the air pressure value of the vacuum pump was controlled in Lianlv (400-900 Pa, median value of 600 Pa), and the vacuum pump was activated to the upper limit of 900 Pa in normal measurements, and the vacuum pump was started automatically when it was larger than 900 Pa, and was stopped automatically when it was smaller than 400 Pa. Stop the pump, measurement system detection if greater than 600 Pa, will automatically start the pump, after checking the vacuum pump, vacuum pump control device, three-phase voltage regulator have been working normally.

(2) Laser transmitter and receiver maintenance. First of all, the light treatment, at the launching end, receiving end and vacuum tube connection with rubber sheet for light treatment, and clean up the launching end as well as the receiving end of the optical components, mainly using alcohol and cotton gauze will be on top of the paint stains, dust clean up. Secondly, the size of the emitting hole at the emitting end was adjusted by using a screwdriver to further improve the collimation of the light and eliminate the influence of the laser beam dispersion on the measurement of the system.

(3) Completion of the first maintenance of the vacuum pipeline and the measuring point device. First of all, the vacuum pipe will be practiced pressure relief: open the top cover screws of the measuring point device, use a screwdriver to pry open a small gap in the top cover for pressure relief, until there is no sound of air flow, the end of pressure relief. During the removal process, it was found that the top cover was not sealed tightly with the vacuum pipe, which was an important factor affecting the accuracy of the measurement value. After removing all the screws in the top cover, use a gray knife to carefully remove the sealant around the top cover, but not to destroy the sealing rubber ring. After removing the top cover, the band plate and the optics are cleaned to remove dust and iron filings from the inside. In order to completely remove the fine iron filings inside, a magnet is used to adsorb them and clean them thoroughly. At the same time on the wave belt plate lifting spindle gear lubrication processing, in the spindle gear lubrication processing, due to the work of the motor spindle gear gap and the work space is small, with the conventional injection of lubricating oil way of working difficulty, and lubrication effect is not good. Through the medical syringe injection of lubricant, the rotor gear and other parts of the comprehensive and detailed lubrication treatment, after the completion of the above work, to re-seal the top cover of the wave plate, the main work includes re-playing the sealant, replacing the connecting screws and so on. After the sealant air-drying, vacuum experiment and debugging were carried out, during the experiment, the vacuum value can be pumped to the set value,

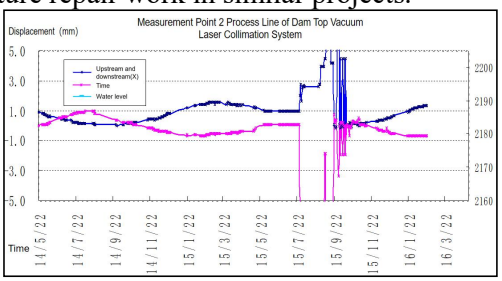
the leakage rate is lower than the specification limit of 120Pa/h, and the wave belt plate runs flexibly. Proved that the maintenance of the vacuum tube sealing effect, mechanical transmission flexibility and optical components cleanliness compared to the previous has been greatly improved, can meet the corresponding needs of the measurement system operation.

(4) Through the operating characteristics of the system, the software parameters are modified, and the automatic measurement time is set in the early morning, avoiding the possibility of the influence of the strong light environment during the day.

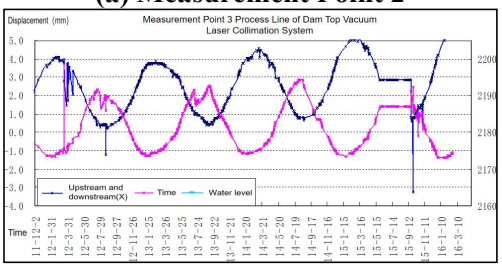
4 Stability Analysis of Vacuum Laser Collimation Systems

Based on the rich experience of vacuum laser maintenance at the top of Lianlu Dam, we successfully applied the new dam vacuum laser collimation system maintenance method and process to carry out a comprehensive maintenance of two sets of vacuum laser measurement systems at the Lianlu corridor and the dam face of Xiacheng. After the repair work was completed, the systems were verified after four months of stable operation. The anomalies and disturbances in the measurement values of the measurement points, which occurred frequently from May to September, have been effectively controlled, and the data of each measurement point have been gradually stabilized. Especially in the key measurement points at the top of Lianlu Dam, such as measurement point 2, measurement point 3 and measurement point 4, the measurement value abnormality and turbulence have been significantly improved.

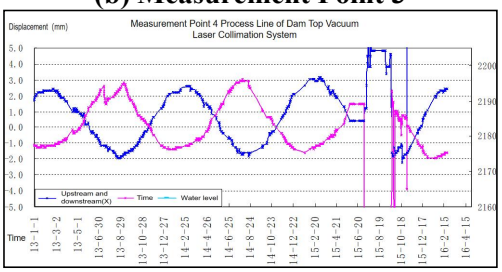
As shown in Figure 1, by comparing the process line diagrams of Lianlu Dam before and after the repair, the fluctuation of the measured values of measurement points 2, 3 and 4 during the period from May to September can be clearly seen. After the repair work was completed in September, the measured values of these points began to stabilize gradually and returned to the normal level. This change not only proved the effectiveness of the repair work, but also further verified the reliability of the methods and processes used. The successful implementation of this repair work not only improves the overall performance of the vacuum laser measurement system, but also provides valuable experience and reference for future repair work in similar projects.



(a) Measurement Point 2



(b) Measurement Point 3



(c) Measurement Point 4

Figure 1. Analysis Results of the Stability of the Empty Laser Collimation System after Maintenance

After a comprehensive and detailed inspection, it was found that the automated measurement system had resumed normal operation, and the number of regular measurements had remained stable at over 99%. Compared with before, the vacuum degree of each system has also been significantly improved, which meets the actual demand of engineering measurement. In addition, the hardware facilities of each vacuum measurement system also showed good operating conditions. The failure rate of the lubrication and cooling system of the vacuum pump has been significantly reduced, and the take-off and landing process of the wave plate has been smoother.

For the optical components in the system, monthly cleaning is recommended to remove accumulated dust and impurities and maintain their good light transmission performance. After cleaning, strict light avoidance measures are taken to prevent external light from damaging the optical components.

5. Conclusions

With the background of the maintenance methods and processes of the vacuum laser collimation systems of Lianlu and Xiacheng, a new set of maintenance methods and processes for the vacuum laser collimation systems of dams is proposed. Through comparative analysis, the following main conclusions are drawn:

(1) The vacuum value for vacuum pipe operation is between 400 Pa and 900 Pa. The median value is 600 Pa, which avoids the damage to the equipment caused by the frequent starting and stopping of the vacuum pump.

(2) Lubricating the rotating shaft of the wave band plate and removing debris by means of oiling with a medical syringe as well as magnetite adsorption can eliminate the factors hindering the lifting of the wave band plate.

(3) Adopting rubber plates to shield the transmission end and the receiving end from the vacuum pipeline, which can avoid the influence of external light on the vacuum laser.

Acknowledgments

The authors gratefully acknowledge supports from Geotechnical Engineering Research Institute, Xi'an University of technology and the funding by Gansu Provincial Higher Schools Innovation Fund Project: Research on Seismic Performance of Existing Reinforced Concrete Frame Structures with Additional Floors Retrofitted in High Intensity Zones, (Project number:2024B-233).

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