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Vision-Based Displacement Measurement of Isolation Bearing: A Comprehensive Review

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Abstract

Displacement measurement plays a crucial role in various engineering applications, particularly in the field of structural dynamics and vibration analysis. In recent years, vision-based methods have emerged as a promising and non-contact alternative for measuring the displacement of isolation bearings. This comprehensive review presents an in-depth analysis of vision-based displacement measurement techniques applied to isolation bearings, highlighting their advantages, challenges, and future prospects. The result shows that the horizontal displacement time history of the isolation bearing obtained by this method is almost the same as the result obtained by the displacement meter whether the camera is moving or fixed. However, compared with the results measured by the displacement meter, the absolute error of the peak horizontal and vertical displacements are both less than 1 mm, which indicates that the proposed method can be used in displacement monitoring under long-term load and earthquake action of isolation bearing.

Keywords: Vision; Digital image correlation; Laser scanning; Structured light projection

Introduction

Isolation bearings are essential components in modern engineering structures, designed to mitigate the effects of vibrations and shocks caused by dynamic loads. Traditionally, displacement measurements in such systems have been accomplished using contact-based sensors like LVDTs or accelerometers. However, these methods often pose limitations in terms of cost, complexity, and potential interference with the system's behavior. Vision-based displacement measurement techniques have emerged as a viable alternative that overcomes these drawbacks while offering accurate and non-contact measurement capabilities [1].

To measure the displacement of the isolation bearing under the action of an earthquake, the camera also moves with the earthquake, and the camera position cannot be used as a reference point to measure the displacement of the bearings. To solve this problem, Global Position System (GPS) or inertial navigation systems (INS) can be used to track the camera pose in real-time and then calculate the absolute displacement of the structure based on the camera position and relative displacement between the camera and the structure at each time.

As a result, the current monitoring system is expensive and complex to maintain. In particular, the displacement of the isolation bearing and interstory drift ratios is crucial in evaluating the isolated structure state and is traditionally measured with linear variable differential transformers (LVDTs), string potentiometers, or dial gauges; however, these contact methods require a connection to a fixed attachment point, which is difficult for most applications. Alternatively, displacements can be computed from double integrated acceleration measurements, but the acceleration-based measurements are typically distorted due to low-frequency noise [2]. Therefore, most building owners cannot accept this additional project expenditure.

In recent years, with the increasing development of computer vision technology and image acquisition equipment, computer vision-based structural monitoring methods have been used in bridge deformation monitoring, structural displacement measurement, cable vibration, fan blade vibration, and so on. This method has numerous advantages, such as multipoint monitoring, low cost, and high precision. Therefore, computer vision-based methods can be tried for seismic monitoring of isolation bearings. However, most of the existing displacement measurement methods based on computer vision require a fixed camera position and use the camera position as a reference point to measure the vibration displacement of the structure.

Vision-based displacement measurement techniques

Digital image correlation (DIC)

Digital Image Correlation is a well-established technique that utilizes high-resolution cameras to capture images of the object's surface before and after deformation [3]. By analyzing pixel displacements between these images, DIC accurately calculates the object's displacement field. Although highly accurate, this method requires high-quality cameras and sophisticated image processing algorithms.

Laser scanning vibrometry (LSV)

LSV involves projecting a laser beam onto the surface of the isolation bearing and capturing the reflected laser light with a high-speed camera. By analyzing the Doppler shift in the reflected light, the displacement of the surface can be accurately measured. LSV offers high spatial resolution and can be used for real-time measurements [4].

Structured light projection (SLP)

SLP involves projecting a pattern of light onto the surface of the bearing, and a camera captures the deformed pattern. By analyzing

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the deformation of the pattern, the displacement of the bearing can be determined. SLP is capable of high-speed measurements and offers relatively simple setup requirements [5].

Advantages of vision-based displacement measurement

Non-contact measurement: Vision-based methods do not require physical contact with the isolation bearing, eliminating the risk of interference with the system's dynamics.

High accuracy: With advancements in camera technology and image processing algorithms, vision-based methods can achieve high levels of measurement accuracy [6].

Real-time monitoring: Certain vision-based techniques, such as LSV, offer the advantage of real-time monitoring, providing immediate feedback on the displacement behavior of the isolation bearing.

Full-field measurement: Vision-based techniques provide a spatially distributed displacement field, enabling engineers to observe localized displacements and detect potential issues in the bearing's behavior [7].

Challenges and limitations

Lighting conditions: Vision-based techniques are sensitive to lighting conditions, and variations in lighting can affect measurement accuracy.

Surface texture: The displacement measurement accuracy can be influenced by the surface texture and pattern of the isolation bearing [8].

Computational requirements: Image processing and analysis can be computationally intensive, requiring powerful hardware for real-time applications [9].

Environmental factors: External factors such as vibrations or ambient noise can interfere with the accuracy of vision-based measurements.

Future prospects

Vision-based displacement measurement techniques for isolation bearings hold tremendous potential for further advancement. Research and development efforts should focus on addressing the existing challenges, optimizing algorithms for real-time applications, and integrating artificial intelligence for enhanced data analysis [10].

Conclusion

Vision-based displacement measurement techniques have emerged as a promising alternative to traditional contact-based methods for monitoring the behavior of isolation bearings. With their non-contact nature, high accuracy, and potential for real-time monitoring, these techniques offer valuable insights into the dynamic response of engineering structures. As technology continues to advance, vision-based displacement measurement is expected to play a pivotal role in ensuring the safety and reliability of various infrastructure systems.

Regardless of the large or small deformation of the isolation bearing, whether the camera is fixed or moving, the horizontal displacement time history obtained by the visual method is almost the same as the result obtained by the displacement meter. The measurement error is larger when the camera is moving. However, compared with the result measured by the displacement meter, the absolute error of the peak horizontal displacement is less than 1mm, and the error ratio is less than 1.5%, which meets the accuracy requirements of the horizontal displacement measurement of the isolation bearing. This result shows that the proposed visual method can complete the horizontal deformation detection of the isolation bearing under various conditions.

The waveform trend of the vertical displacement time history curve measured by the visual method is basically the same as the time history curve of the displacement meter, but it fluctuates continuously along with the time point. +e reason is that the vertical displacement of the isolation bearing is less than 1 mm. Compared with the absolute value of the vertical displacement, the systematic error caused by the visual measurement method is clear, but the maximum absolute error is only 1.851 mm. Limited by the experimental equipment, the displacement of the camera in the experiment is ±8 mm. In the actual seismic survey, the camera is fixed on the ground or superstructure, the relative displacement between the camera and the isolation bearing is the horizontal displacement of the isolation bearing, and the range of displacement can be estimated in advance. Therefore, if the field of view of the camera is set to be wider than the horizontal displacement of the isolation bearing, then accurate measurement results can be obtained. This method is still applicable to actual seismic isolation projects.

References

1. Richard Snell S, Michael Lemp A. Clinical Anatomy of the Eye; Second Edition.
2. Clinical Anatomy of the Visual System; Second Edition – LEE ANN REMINGTON.
3. Jack Kanski J. Clinical Ophthalmology; Sixth Edition.
4. Bell, Raymond A. (1993) Clinical grading of relative afferent pupillary defects. Arch Ophthalmol 111: 938-942.
5. Clinical-content-the-relative-afferent- pupillary-defect.
6. Thompson H, Stanley, James J, Corbett (1991) Asymmetry of pupillomotor input. Eye 1: 36-39.
7. Cox Terry A. Pupillary escape. Neurology 42: 1271-1271.
8. Enyedi, Laura B, Sundeep Dev, Terry Cox A (1998) A comparison of the Marcus Gunn and alternating light tests for afferent pupillary defects. Ophthalmology 105: 871-873.
9. Gerold, Hugo (1846) Die Lehre vom schwarzen Staar u. dessen Heilung. Rubach.
10. Gunn, Marcus R (1904) Discussion on retro-ocular neuritis. BMJ 1285-1287.