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Research on displacement monitoring based on laser spot identification

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Abstract

It is difficult to monitor the displacement of large structures accurately in real time for the health monitoring of structures. We studied a laser displacement monitoring system. When the inclination of the structure is negligible, it can achieve real-time monitoring of the horizontal displacement of the structure precisely. The system is composed of a laser transmitter, a receiver board and a camera. The laser transmitter is fixed on the datum plane. Both the camera and the receiver board are fixed on the structure to be monitored. When the structure has horizontal displacement, that camera monitors the position variation of the laser spot on the receiver board. The actual displacement of the structure is obtained through the camera's built-in program. To evaluate the accuracy of the system, we performed two sets of model experiments and obtained the conclusion by comparing the experimental data, determining that our laser displacement monitoring system can monitor horizontal displacement with a high degree of accuracy.

Keywords: Health monitoring; Horizontal displacement monitoring; Laser displacement monitoring system

Introduction

Structure displacement monitoring is an important topic in the field of structural health monitoring. Traditional methods of displacement monitoring of large structures rely mainly on total station, displacement sensors, accelerometers or GPS. However, the total station is greatly restricted by surroundings and cannot monitor the displacement in real time. Displacement sensors should be installed near a fixed reference point, which is difficult in actual displacement monitoring of large structures.

Using the quadratic integral, accelerometers still cannot obtain complete information about the displacement of the structure, which leads to low accuracy. A laser transmitter, a receiver board and a camera constitute a whole system. As shown in Fig. 1, the laser transmitter is fixed on the datum level [2]. The camera and receiver board, which are encapsulated together, are fixed on a point of the structure that needs to be monitored [3]. When the structure undergoes horizontal displacement, the camera monitors the

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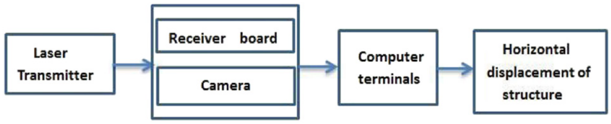

Fig. 1. The schematic diagram of the laser displacement monitoring system.

position variation of the laser spot on the receiver board [6]. The position data are transformed into the actual displacement of the structure by the camera's built-in program. This method to monitor structure displacement is highly specific and effective.

General information

The schematic diagram of the laser displacement monitoring system is shown in Fig. 1 [7]. The laser transmitter is fixed on the datum level; the receiver board is fixed on the structure; [1] the camera and the receiver board are relatively static. The camera is marked with accurate calibration grid paper, which can transform pixel coordinates into a functional relationship of the actual coordinates of the laser spot on the receiver board. The receiver device is fixed on the structure rigidly.

Because it is small compared to the whole structure, the receiver device can be treated as a point fixed on the structure, which is the target monitoring point of the structure.

When the target point of the structure moves from (X_0, Y_0) to (X_1, Y_1), it has a horizontal displacement ΔV. The projection of ΔV on the x and y axes is denoted by $\Delta X'$ and $\Delta Y'$, respectively. Fig. 2 shows that the actual spatial position of the laser spot does not change, whereas the relative position of the light spot on receiver board changes, which is what the camera is monitoring. Assuming the corresponding moving distances are ΔX and ΔY on the x and y axes, respectively, using the simple mathematical relationship, the following formulas can be obtained:

$$\Delta X = |\Delta X'| = X_1 - X_0 \quad (1)$$

$$\Delta Y = |\Delta Y'| = Y_1 - Y_0 \quad (2)$$

Consider the following plane conditions in Fig. 3, where the structure changes in a small dip angle (Fig. 4).

The displacement of the structure and the camera are $\Delta X = X1'\cos\alpha - X1$ and $\Delta X = X1' - X1$, respectively. The error is $\delta = X1' - X1'\cos\alpha$. Compared to the whole structure, the displacement can be considered to be small. Given the values of α of 0.5°, 1°,1.5°, 2°, 2.5°, the error, δ, can be obtained. The results are shown in Table 1.

Thus, when the angle variation is less than or equal to 2.5°, the horizontal displacement of the structure can be considered as $\Delta X = X1' - X1$, with absolute deviation of less than 0.05 mm. In this way, the monitoring accuracy reaches 0.1 mm

The displacement in space is similar to that on the plane. In the case of a small rotation, the monitoring system can also capture the horizontal displacement accurately.

Statics experiment

The experimental setup includes one laser transmitter, one spiral regulator, a piece of receiver board and one camera. The spiral regulator is used to precisely control the actual horizontal displacement of the laser. During the experiment, the camera collects the

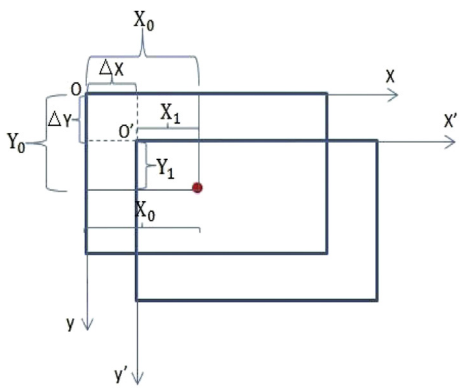

Fig. 2. Geometric relationship in plane motion.

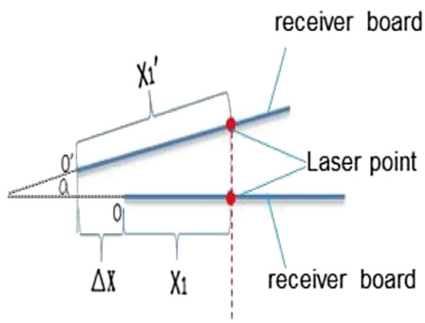

Fig. 3. Geometric relationship in a small dip.