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THE APPLYING RESEARCH ON VIBRATION AND ACCELERATION TEST USING FIBER OPTIC SENSORS DISPLACEMENT MEASUREMENT TECHNIQUE

Zhang Yi*[1], Wen Yong[1], Hong Jianzhong[1] , He Rongjian[1] , Zhu Changchun[1]

[1]Institute of Structural Mechanics. CAEP.P.O.Box919-402 ,
Mianyang, Sichuan, 621900,China
hjianhua@mail.china.com (e-mail address of lead author)

Abstract

Displacement measurement is very important in the industrial manufacture and environmental test. For example, when a specimen is accelerated, the distortion will often be measured to evaluate the resistance to pressure. Therefore, displacement measurement may reflect the performances of the structure of the specimen, providing scientific basis for designer. In order to measure displacement more precisely and satisfy the test conditions more perfectly, a new mask intensity modulation type of displacement measuring system using fiber optic sensor is designed, avoiding using expensive optical system and reducing the complexity in debugging, as well as linearity being good and anti-electromagnetic interference capability being strong. It is composed of three parts, the fiber optic sensor whose structure is compact and reliable, the displacement measuring circuit and the computer. By the appropriative software, it can measure and display the displacement in real time. This paper briefly introduces its operating principles and circuit design, meanwhile it can be applied in the linear acceleration test.

INTRODUCTION

Compared with traditional sensors, the fiber-optic sensors have many advantages, such as anti-electromagnetism interference, bearing erosion, adapting to dangerous environment, as well as data easy to be handled by computer. Because of all above reasons, the mask type of intensity modulation fiber optic sensors have been chosen, whose structure is simple and reliable .The whole system is much feasible to practical engineering application.

THE OPERATING PRINCIPLE OF MASK SENSORS

Common modulation equipment and coordinate system are shown in Fig.1. Light source and mask, the optic fibers to send and receive light, are primary components.

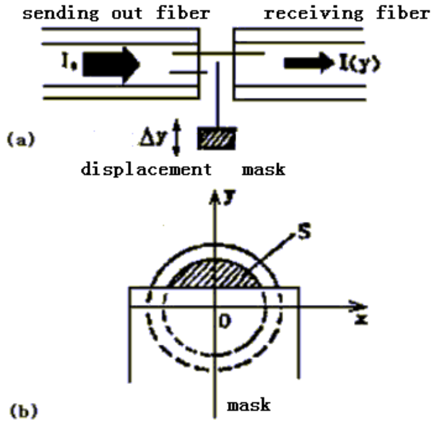

Figure 1 – Analysis diagram of the mask type system

Operating principle of the system is: a symmetrical circular light spot sent out from the optical fiber is shaded by the mask,moving Δy along fiber core direction.The luminous flux into the detector changes, so the electric current is altered.

The distribution of light field on multimode quartz fiber end is given by the following equation.

$$\phi(x,y,z)=\frac{I_0}{\pi\sigma^2 a_0{}^2\left[1+\zeta\left(z/a_0\right)^{3/2} tg\theta_0\right]^2}\times\exp\left[-\frac{x^2+y^2}{\sigma^2 a_0^2\left[1+\zeta\left(z/a_0\right)^{3/2} tg\theta_0\right]^2}\right] \qquad (1)$$

Where, ϕ (x, y, z) is luminous flux density on the position(x, y, z), I0 is the light intensity of fiber coupled with light source,σ is correlation coefficient to represent refraction index profile of fiber, a0 is fiber-optic core radius, ζ is coupling modulation parameter ,θ0 is fiber optic maximal emergence angle.

The light intensity received by optic fiber corresponds to shadows in fiber-optic core, namely for the Fig.1(b). Hence there exists:

$$I(y)=\frac{I_0}{2}\left[1-\frac{2}{\sqrt{\pi}}\int_0^y \exp(-m^2)dm\right] \qquad (2)$$

This multi-integral calculus function can be drawn by MATLAB software. The modulation curve is gained and shown in Fig.2 .The linearity is measured about 20%, so this type of sensors cannot be applied in the actual engineering .

Some measures have been taken to improve its performances, as follows：

a) The multimode quartz fiber is changed into fiber optic bundle, which is composed of many thin fiber glass filaments. Compared with the former, the transverse section of single fiber glass filament is too small. Much light field of fiber filaments is piled up, so the Gauss effect of fiber optic is reduced. Its core radius can be made very big, light intensity transmitted is strong, and output of signal is stable.

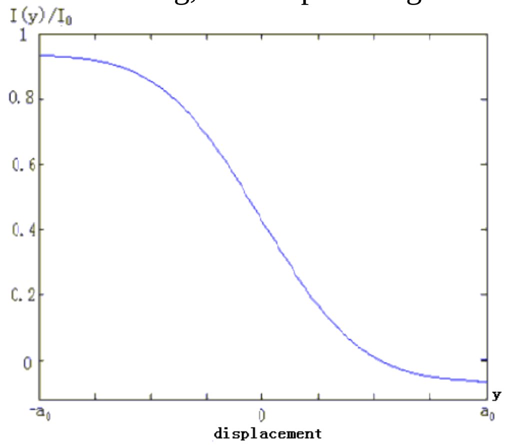

Figure 2– Modulation curve

b) The circular pore is changed into rectangular one, whose width is W and the length is H. If I_1 is total light intensity inside fiber coupled with light source, when the mask moves y , The equation of received light intensity is:

$$I(y) = \frac{I_1}{H} \cdot y \tag{3}$$

So the linearity of sensors greatly increases.

c) This type of sensors is very sensitive to variety of light source and characteristic of optic fiber, therefore compensation measure must be taken.

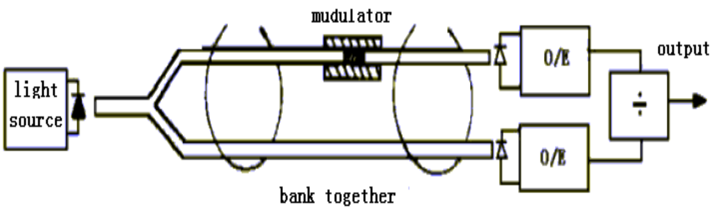

Figure 3– Compensation measure

As shown in Fig.3.The light signals that come from the same light source pass the Y type of coupler, transmitted along two light roads，then the light signal received respectively by two detectors with identical sensitivity, finally make two output signals divided. This two optic fiber arms are banked together . Besides a modulator is added in measuring arm, the condition and environmental temperature are similar. Therefore, the intrinsic loss and bending loss of the optic fiber are equal, so this kind of method can diminish the interferences from fluctuation of light source and the variety of light intensity in the arms.

DISPLACEMENT MEASURING SYSTEM

Displacement measuring system composes the fiber optic sensor, the circuit of displacement measurement and the computer.

With above compensation method, the measuring circuit mainly consists of photoelectric converter, amplifier, band-pass filter, true RMS-to-DC converter, the division integrated circuit. Adopting pulse frequency modulation circuit to drive LED light source availably rejects the interference from quiescent current of detector, zero drift of amplifier, which cause direct current and random error. The computer adopts interpolation method to get the displacement by comparing the measured electric voltage with calibrated value, and then the curve of displacement can be drawn out and the value can be shown in real time.

EXPERIMENTAL RESULT AND ANALYSIS

Contract experiment using two type of sensors on centrifuge which is important to verify the fiber optic displacement system can be used in the linear acceleration test, such as the sensor is working normally when undergoing centrifugal force. A mass block is fixed on the cross beam installed on the top of centrifuge making the beam with mass block move horizontally when being accelerated, meanwhile causing the beam without mass block to move vertically. Two type of displacement sensors have been used. One is LVDT, the other is mask type sensor, respectively installed as shown in the Fig.4.The output of two type sensors changing with linear acceleration is drawn in Fig.5.

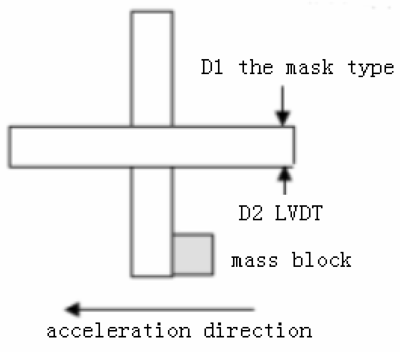

Figure 4 – Installation diagram

From the experiment data, the linearity of the improved mask type sensor is 1.4 ％ which is better than common type sensor compared with Fig.2. The mask sensor is operated normally in the actual engineering application, because the operation curves of the two sensors are similar whose difference is quite little.

A high accurate calibration device controls the mask moving along the radial direction of optic fiber, from the calibration experiment data, the performances of sensor are calibrated：revolution is 0.5μm, dynamic range is 2mm, repeatability is 0.

2%, hysteresis is better than 0.15%.

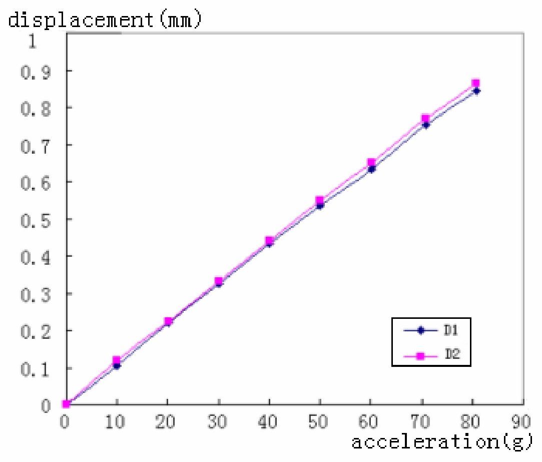

Figure 5 – Operation curve

CONCLUSIONS

To avoid using the expensive optical system and reduce complexity of debugging, displacement measurement system using the mask sensors has been studied. The particular design of structure and circuits not only decreases the interference, but also improves the linearity without reducing measuring range.

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