Viability of Using a Low Frequency FBG Sensor System for Dynamic Strain Measurement

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Abstract: In this paper a dynamic strain testing system based on FBG sensor system is set up to study the viability of using a low frequency FBG sensor system for dynamic strain measurement. By the statistical and comparative analysis, the result shows that the amplitude of the dynamic strain can be estimated by the peak of FBG measurements by this FBG sensor system for dynamic strain measurement. This FBG sensor system can also be applied to measure the dynamic strain of a bearing.

Keyword: *FBG, Sensor System, Dynamic Strain, Low Frequency, Contrast Test*

1. Introduction

Strain is one of the key parameters to mechanical equipment condition monitoring, which could tell us the reliability and security of the equipment through deformation and the actual stress distribution. Once the total or partial stress of the equipment is super heavy, light has impact on the performance of the equipment or cause casualties. Therefore, the study on the dynamic strain measurement of a mechanical structure is of great significance.

Traditional means, such as strain gauges, are used to obtain data [1]. The method of using strain gauges for strain measuring is mature and low cost, but it is susceptible to electromagnetic interference, zero drift, complex wiring, etc. [2]. Fiber Bragg grating is a new passive optical sensors with strong anti-interference, small size and easy to implement distributed measurement, etc. [3], so it is widely used in engineering testing [4,5].But subject to the rate of the fiber grating demodulator, it is still unable to meet the requirements of high-frequency vibration testing .

In this paper, we explore the feasibility of using a low-frequency FBG sensor system, in a comparative test way, for dynamic strain measurement and provide guidance for the application of FBG in high frequency dynamic strain measurement.

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2. Principle of FBG sensor

When the FBG is illuminated by a broadband light, only one particular wavelength will undergo constructive waveform condition. As a result, a narrowband spectrum is reflected. This condition is expressed as follows:

$$\lambda_B = 2n_{eff}\Lambda \quad (1)$$

Where λ_B is the Bragg wavelength, n_{eff} is the effective refractive index of the grating and Λ is physical period of the grating. The equation that governs the shift of the peak reflected wavelength under strain is given by

$$\Delta\lambda_B/\lambda_B = (1-p_e)\ \Delta\varepsilon_Z \quad (2)$$

Where p_e is the effective photo elastic constant of the fiber; $\Delta\varepsilon_Z$ is the strain increment on the fiber; $\Delta\lambda_B$ is the wavelength change. The theoretical value of p_e has been calculated to be 0.22 [6].

3. Experiment setup and scheme

The Dynamic strain experiment is carried out on the cantilever; the cantilever is a tapered beam with equal thickness and isosceles triangle surface. The test system mainly includes signal generator, power amplifier, shaker, signal acquisition unit, cantilever beam, sensors and computer, etc. the physical diagram of the test system is shown in figure 1.

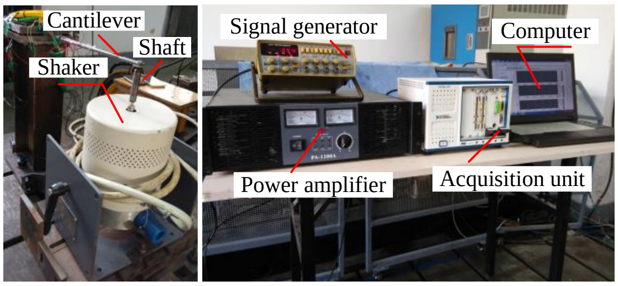

Figure 1　Physical diagram of the experiment setup

Two measurement points are arranged on the surface of the cantilever, Point 1 from the fixed end 45mm, Point 2 from the fixed end 120mm. At each point along the axis of the cantilever beam arranged a fiber grating and a strain gauge, as close to paste, physical layout is shown in Figure 2.

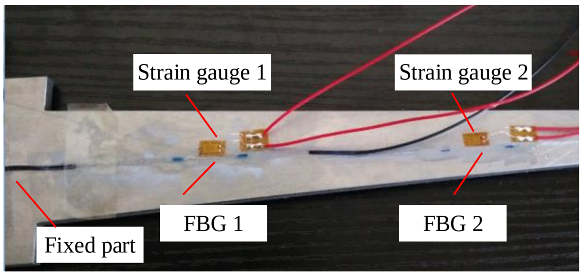

Figure 2　Physical layout of the sensors

Fix the front end of the cantilever on the shaker shaft by a screw, so that the front end of the cantilever moves with the shaft. The generator generates a sinusoidal signal, then the amplifier amplifies the signal and sends it to the shaker. We can set the frequency of the signal by adjusting the signal generator and set the amplitude of the signal by adjusting the shaker. Set FBG sampling rate f_s =10Hz, strain gauges sampling rate of 500Hz.

4. Results and discussion

One second experimental results under sinusoidal excitation form point 1 are shown in Figure 3.It can be seen: (1) When the sample rate meet the Nyquist theorem, the results from FBGs and strain gauges have very good consistency on the peak and the vibration frequency can be accurately obtained by Fourier fit. (2) When the FBG sample rate don't meet the Nyquist theorem, we cannot obtain the frequency correctly. But the experimental results also have very good consistency on the peak.

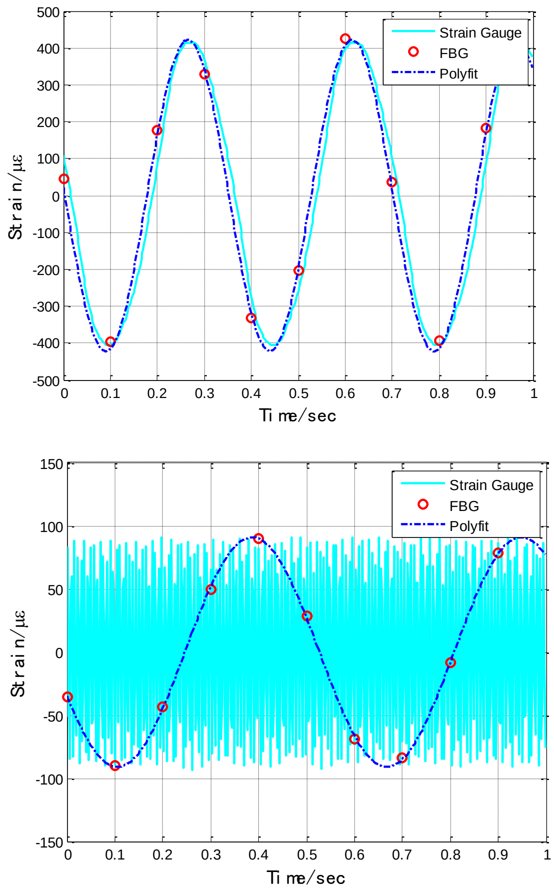

Figure 3　Experimental results (3Hz left,150Hz right)

Table 1 Statistic of the results and its errors

Frequency	Sensor	Name	1st	2nd	3rd
3Hz	FBG 1	P-P	824.2	809.2	811.3
	SG 1	P-P	836.4	817.6	825.0
	---	δ(%)	1.5	1.0	1.7
	FBG 2	P-P	723.6	701.1	711.4
	SG 2	P-P	695.0	681.6	689.0
	---	δ(%)	4.1	2.9	3.2
150Hz	FBG 1	P-P	181.9	181.8	177.4
	SG 1	P-P	187.8	187.9	185.7
	---	δ(%)	3.1	3.3	4.5
	FBG 2	P-P	100.1	102.8	96.2
	SG 2	P-P	102.3	100.3	96.4
	---	δ(%)	2.2	2.5	0.2

In order to obtain the consistency level of the peak, we collect the peaks and the errors of the results 5 times which are shown in Table 1.

It shows the error between FBG and strain gauge is small, the average relative error is just 2.5%.

5. Conclusion

In this paper, we study the dynamic strain measurement by using a low frequency FBG sensor system for FBG. The results show that: 1) for low frequency vibration, it can accurately estimate the amplitude of the dynamic strain by the FBG results and we can obtain the frequency of the signal by Fourier fit; 2) for high frequency vibration, though it cannot obtain the frequency by Fourier fit, the vibration amplitude still can be accurately estimated by the FBG results.

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