The Influence of Adhesive on Fiber Bragg Grating Strain Sensor

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ABSTRACT

A fiber Bragg grating (FBG) sensor was fixed on the uniform strength beam with three adhesives, which were modified acrylate, glass glue and epoxy resin. The influence of adhesive on FBG strain sensor was investigated. The strain of FBG sensor was varied by loading weight to the uniform strength beam. The wavelength shift of the FBG sensor fixed by the three kinds of adhesive were measured with different weight at the temperatures 0℃, 10℃, 20℃, 30℃, 40℃. The linearity, sensitivity and their stability at different temperature of FBG sensor which fixed by every kind of adhesives were analyzed. The results show that, the FBG sensor fixed by the modified acrylate has a high linearity, and the linear correlation coefficient is 0.9996. It also has a high sensitivity which is 0.251nm/kg. The linearity and the sensitivity of the FBG sensor have a high stability at different temperatures. The FBG sensor fixed by the glass glue also has a high linearity, and the linear correlation coefficient is 0.9986, but it has a low sensitivity which is only 0.041nm/kg. The linearity and the sensitivity of the FBG sensor fixed by the glass glue have a high stability at different temperatures. When the FBG sensor is fixed by epoxy resin, the sensitivity and linearity is affected significantly by the temperature. When the temperature changes from 0℃ to 40℃, the sensitivity decreases from 0.302nm/kg to 0.058nm/kg, and the linear correlation coefficient decreases from 0.9999 to 0.9961.

Keywords: fiber Bragg grating; adhesive; uniform strength beam; strain

1. INTRODUCTION

With the development of society, safety and durability of civil engineering have attracted more and more attention. Being aware of the strain in the civil engineering timely and correctly, civil engineering structure can be realized on the health status of long-term real-time monitoring, and it provides the basis for assessment of the status of their injuries. Sensor technology is the foundation and pillars to monitor the safety of these projects. As the projects are becoming more and more complex, traditional sensor technology has been increasingly revealed its limitations, such as its low anti-jamming capability, which is important to realize large-capacity, long-range distributed and digital monitoring. Fiber Bragg grating (FBG) sensor is a new type of optic fiber sensor, whose sensing principle is based on the sensitive characteristic of its wavelength to the measurand such as temperature and strain. And FBG sensors are in high reliability with large anti-jamming capability. Therefore, FBG sensors have been gradually replacing the resistance strain chip sensors in recent years, and they are being widely used in large-scale civil engineering[1-4].

When civil engineering is monitored by FBG sensor, sensing characteristics of FBG sensor are affected by different fixing methods. Fixing method of FBG sensor is mainly divided into three kinds. The first method is to fix FBG sensor with screw. But there always exists a slight gap between the screw and the object to be monitored which will weaken the strain transfer. The second method is to fix FBG sensor with weld, which is the most important method of fixing FBG sensor. But it is not easy to be realized in fields and comparatively high cost. The third method is to fix FBG sensor with adhesives. Its advantage is easy to operation in fields and with a low cost. It has become a hot issue for people to research. In this paper, a FBG sensor was fixed on the uniform strength beam with three kinds of adhesives, which were modified acrylate, glass glue and epoxy resin. The influence of adhesive on FBG strain sensor was investigated. The

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wavelength shift of the FBG sensor was measured with different strain while the temperature was increased from 0℃ to 40℃ with an interval of 10℃. And their linearity, sensitivity and stability at different temperatures of the FBG sensor were analyzed. Therefore, it can provide reference for the application of FBG sensors.

2. PRINCIPLES

When the light generated from a broadband source interacts with the grating, a single wavelength, known as the Bragg wavelength, it will be reflected. The Bragg wavelength is related to the grating period, Λ, and the effective refractive index of the fiber by[5]

$$\lambda_B = 2n_{eff}\Lambda \tag{1}$$

Both the effective refractive index and the grating period vary with the changes of the strain and temperature in the fiber. The Bragg wavelength shift caused by variation of the strain is given by[6]

$$\frac{\Delta\lambda}{\lambda} = (1-P)\Delta\varepsilon \tag{2}$$

where P is the valid elastic-optic constant, Δε is the variation of the strain, which in the uniform strength beam is given by[7]

$$\varepsilon = \frac{hX}{l^2} \tag{3}$$

where h and l are the thickness and the length of the uniform strength beam, respectively. X is the deflection of the uniform strength beam. According to material mechanics, the deflection of the uniform strength beam changes linearly with the weight loaded at the end of beam[8]. Therefore, from the above equations, it is easy to find that the Bragg wavelength shift is also linear with the weight loaded.

3. EXPERIMENTS

3.1 Experimental setup

The experimental setup is shown in Fig. 1. The probing light is transmitted to the FBG sensor from the broadband source which is integrated in the demodulator (SM130, MOI Company). During the experiment, the weight at the end of the uniform strength beam was varied in order to change the strain in the FBG sensor, and then the reflected signal of the FBG sensor was transmitted back to the demodulator. Finally, the modulated signal information was displayed on the computer. The uniform strength beam is put in the thermostat during the whole experiment to make sure that every temperature is constant.

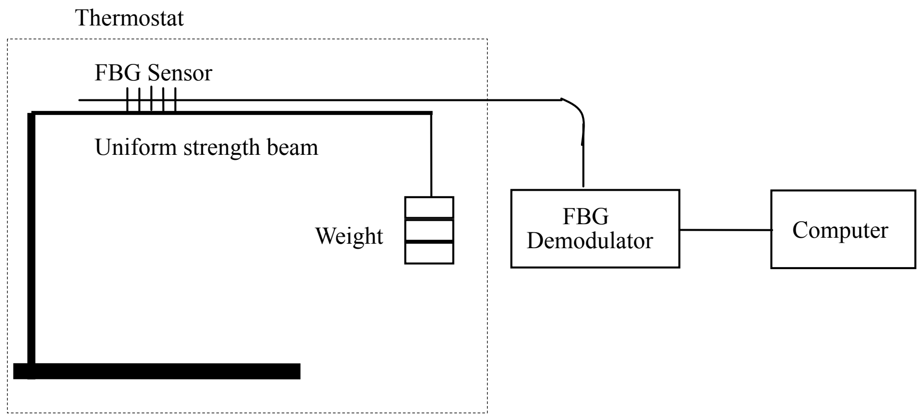
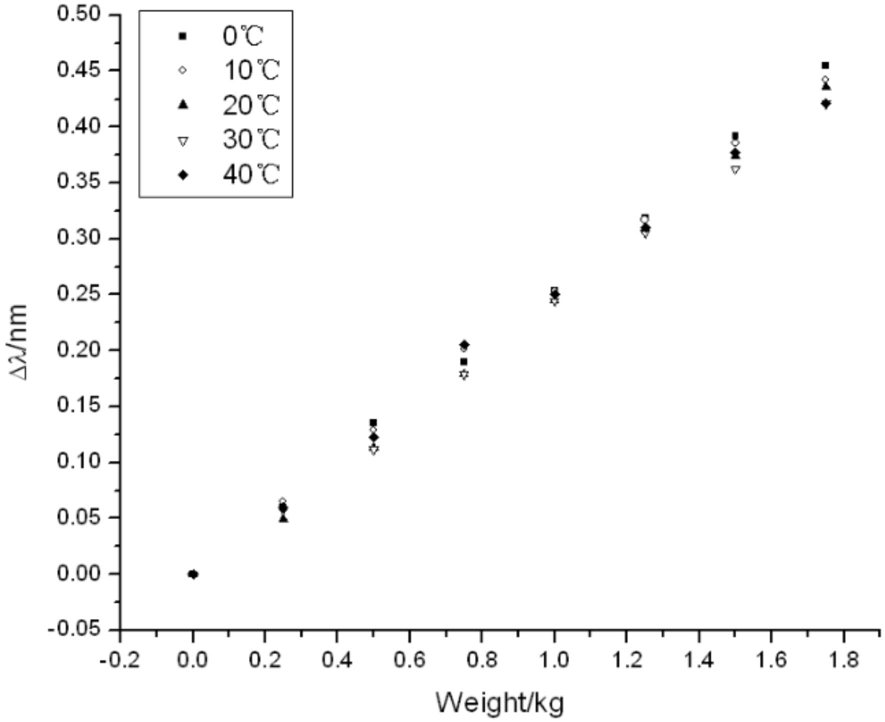


Fig. 1 Experimental setup

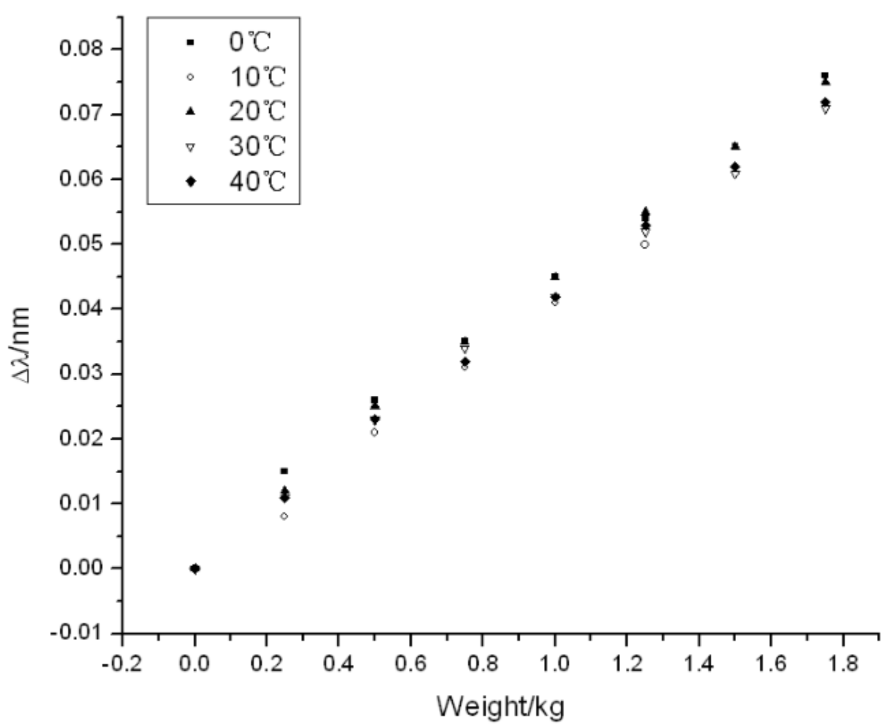
3.2 Results and analysis

The wavelength of FBG sensor fixed with modified acrylate, glass glue and epoxy resin were measured at the temperatures 0℃, 10℃, 20℃, 30℃, 40℃, respectively. Polyamide resins were used as curing agent of epoxy resin. The thickness and the length of the uniform strength beam is 4mm and 290mm, respectively. The varied loading weight is 250g every time, which lead to the uniform strength beam producing a 0.9mm deflection every time. The loading weight was changed from 0.25kg to 1.75kg. The results as shown in Fig.2(a) represent the relation of wavelength shift $\Delta\lambda$ and loading weight when the FBG sensor was fixed by the modified acrylate at the temperatures 0℃~40℃. Fig.2(a) shows the sensitivity of FBG sensor fixed by the modified acrylate is 0.251nm/kg, which almost is not varied with temperature, and it has a high stability and a high linearity, the linear correlation coefficient is 0.9996. Fig.2 (b) shows the relation of wavelength shift $\Delta\lambda$ and loading weight when the FBG sensor was fixed by the glass glue at the temperatures 0℃~40℃. Fig.2(b) shows the FBG sensor fixed by the glass glue also has a high linearity, and the linear correlation coefficient is 0.9986, but it has a low sensitivity which is only 0.041nm/kg. Fig.2(c) shows the relation of wavelength shift $\Delta\lambda$ and loading weight when the FBG sensor was fixed by the epoxy resin at the temperatures 0℃~40℃. Fig.2(c) shows the FBG sensor fixed by epoxy resin has a low stability, the sensitivity and linearity is affected significantly by the temperature. The sensitivity and the linearity decrease obviously at the temperatures 30℃ and 40℃. When the temperature changes from 0℃ to 40℃, the sensitivity decreases from 0.302nm/kg to 0.058nm/kg, and the linear correlation coefficient decreases from 0.9999 to 0.9961.

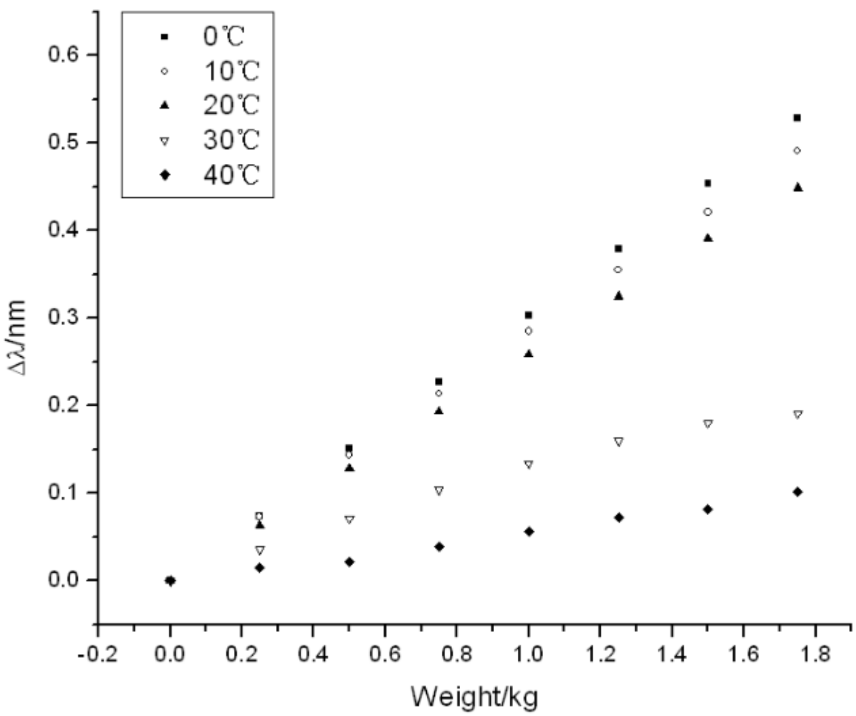
The relation of wavelength shift of the FBG sensor fixed by three kinds of adhesive and loading weight at the temperatures 0℃, 10℃, 20℃, 30℃, 40℃ as shown in Fig.3(a)-(e). Fig.3(a) shows the sensitivity of FBG sensor fixed by the modified acrylate and epoxy resin is larger than glass glue. Fig.3(e) shows the sensitivity of FBG sensor fixed by modified acrylate is much higher than the FBG sensor fixed by epoxy resin and glass glue at the temperature 40℃,and the sensitivity of FBG sensor fixed by epoxy resin decreases significantly, and it is low as the FBG sensor is fixed by glass glue.


0℃
10℃
20℃
30℃
40℃
Δλ/nm
Weight/kg
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
-0.05
-0.2
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8

(a)

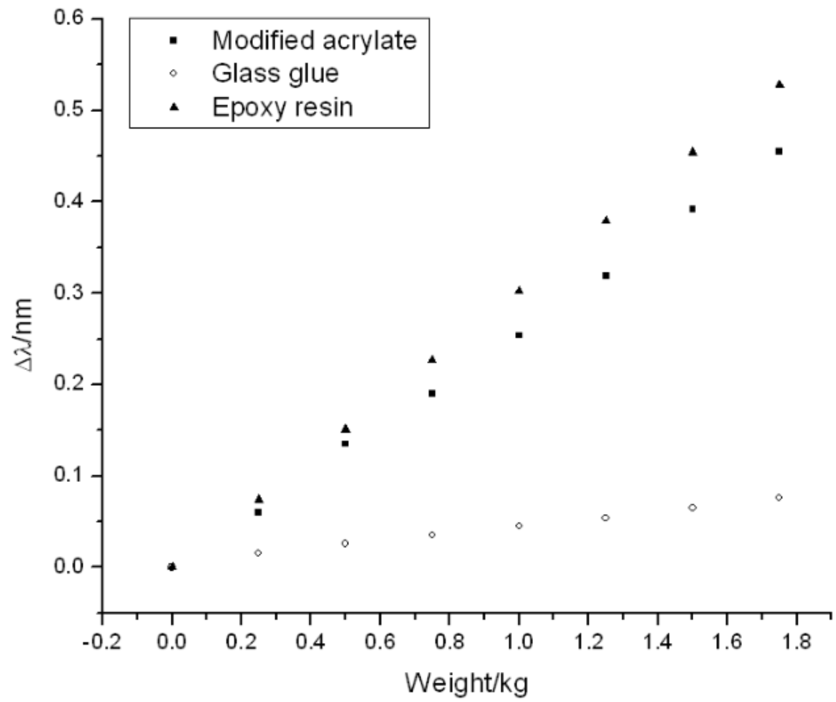

0℃
10℃
20℃
30℃
40℃
Δλ/nm
Weight/kg
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
-0.01
-0.2
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8

(b)

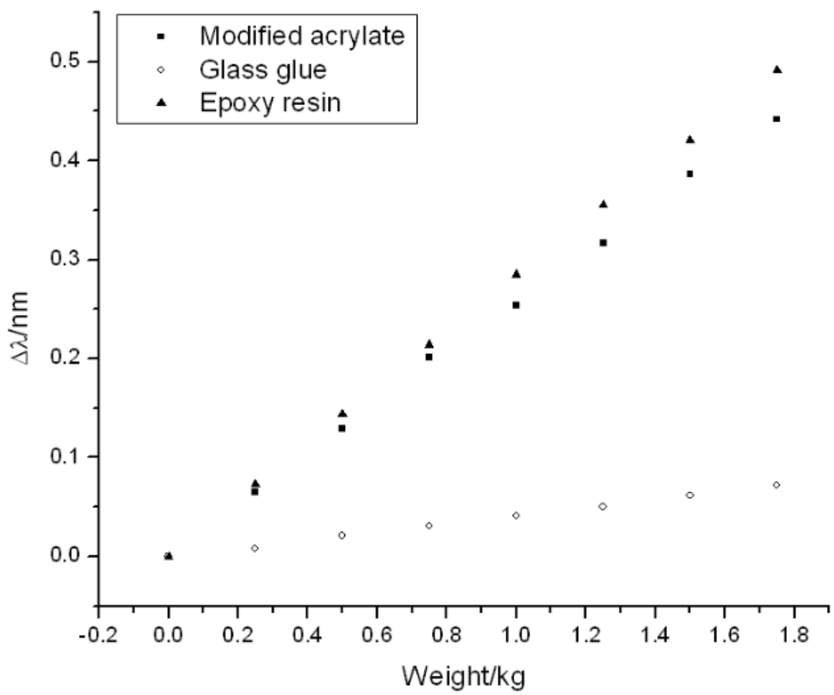


(c)

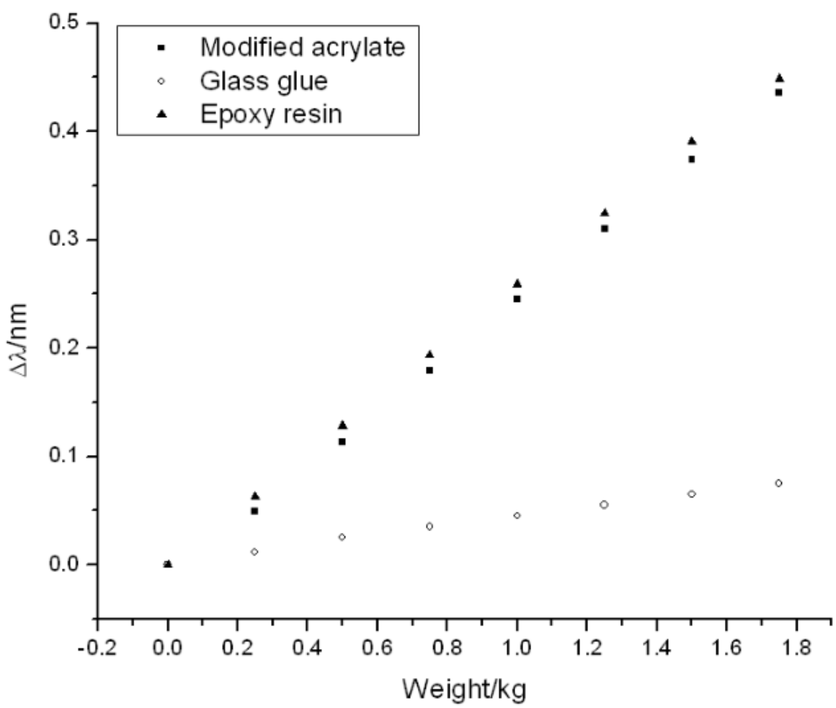
Fig.2 Strain characteristic of FBG sensor at different temperatures, (a) -(c) corresponding to modified acrylate, glass glue and epoxy resin respectively.



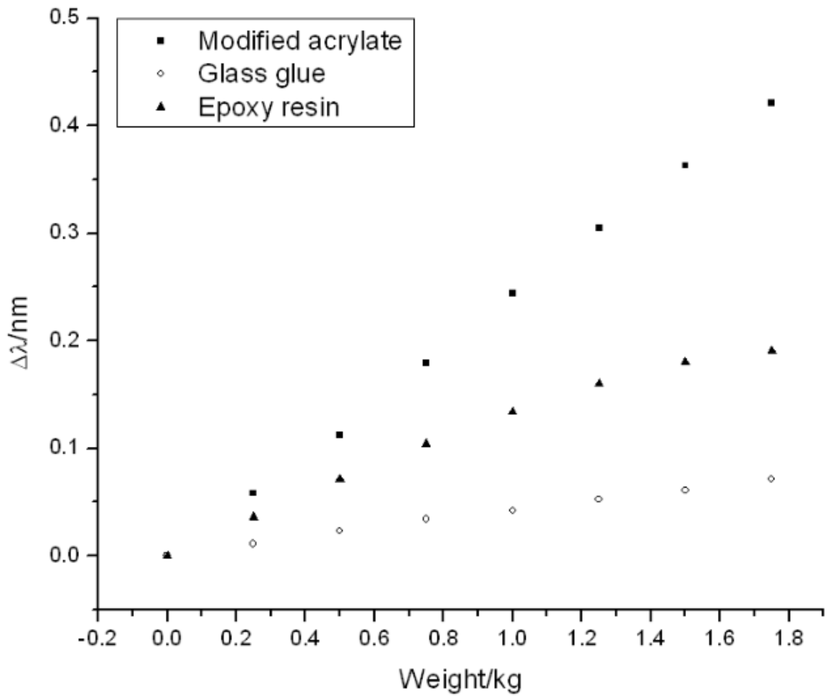
(a)


Modified acrylate
Glass glue
Epoxy resin
0.0
0.1
0.2
0.3
0.4
0.5
Δλ/nm
-0.2
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
Weight/kg

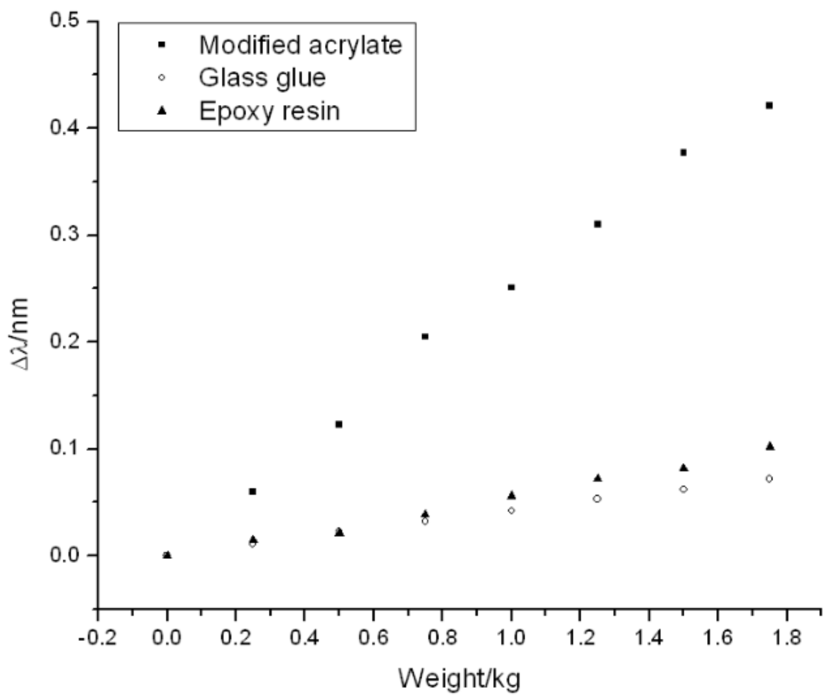
(b)


Modified acrylate
Glass glue
Epoxy resin
0.0
0.1
0.2
0.3
0.4
0.5
Δλ/nm
-0.2
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
Weight/kg

(c)



(d)



(e)

Fig.3 Strain characteristic of FBG sensor fixed with three kinds of adhesives at different temperatures, (a)-(e) corresponding to 0℃, 10℃, 20℃, 30℃, 40℃, respectively.

4. CONCLUSIONS

A FBG sensor was fixed on the uniform strength beam with three kinds of adhesives, which were modified acrylate, glass glue and epoxy resin. The influence of adhesive on FBG strain sensor was investigated. The strain of FBG sensor was varied by loading weight to the uniform strength beam, and the loading weight was changed from 0.25kg-1.75kg. The wavelength shift of the FBG sensor fixed by the three kind of adhesive was measured with different weight at the temperatures 0℃, 10℃, 20℃, 30℃, 40℃. The linearity, sensitivity and their stability at different temperature of FBG sensor which fixed by every kind of adhesive were analyzed. The results show that, the FBG sensor fixed by the modified acrylate has a high linearity, and the linear correlation coefficient is 0.9996. It also has a high sensitivity which is 0.251nm/kg. The linearity and the sensitivity of the FBG sensor have a high stability at different temperatures, which almost have no change in temperature range 0-40℃. So the modified acrylate is a good choice to fix the FBG sensor in field test.

ACKNOWLEDGMENT

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