Proceedings of the 7th International Conference on Mechanics and Materials in Design,
Albufeira/Portugal 11-15 June 2017. Editors J.F. Silva Gomes and S.A. Meguid.
Publ. INEGI/FEUP (2017)

PAPER REF: 6816

ADHESIVE JOINTS INTEGRITY MONITORING USING FIBER OPTICS SENSORS

Chow-Shing Shin[1(*)], Yi-Jui Yang[1] and Shien-Kuei Liaw[2]

[1]Dep. Mechanical Engineering, National Taiwan University, Taipei, 10617, Taiwan, (R.O.C.)
[2]Dep. Elelctronic and Computer Engineering, National Taiwan University, Taipei, 10617, Taiwan, (R.O.C.)
[(*)]*Email:* csshin@ntu.edu.tw

ABSTRACT

Adhesive joining do not need the stress concentrating holes of mechanical fastener joints nor the material properties degrading intense heat input of welding. The availability of adhesive joints allows light alloys and fiber reinforced composites structures to overcome the problems of weak out-of-plane bending strength/stiffness, low joint toughness while improving their crash-worthiness associated with traditional joining. Occasional overloading and fluctuating service loading may cause degradation of these joints. If such degradation went undetected, serious structural failures and catastrophic outcome might follow. It is difficult and economically unviable to carry out regular monitoring for the joint integrity using traditional non-destructive examination techniques, especially in the case of practical structures with large scale adhesive joining. The feasibility of using FBG sensors for monitoring has been investigated in this work. FBG works by reflecting specific wavelengths from a broad spectrum incident light. The reflected wavelengths depend on the strain the FBG suffers. Internal damages will perturb the residual strain field in the joint and thus change the shape of the reflected FBG spectrum.

Keywords: adhesive joint, internal damage fatigue degradation, structural health monitoring, fiber Bragg grating sensor.

EXPERIMENTAL METHOD

Optical fibers with FBG are embedded at either 0^o, or 45^o or 90^o in the lap joint as schematically shown in Fig.1. The specimens were subjected to tensile or cyclic loading. Periodically, the specimens were unloaded to 400 N and 0 N to allow the reflected light spectra from the FBGs to be recorded using an optical spectrum analyzer. These spectra were compared with the original spectra at the respective loading before testing. A parameter to quantify the shape change of the FBG spectrum is proposed as an indicator of damage occurrence.

RESULTS AND DISCUSSION

Typical FBG spectra at different loadings are shown in Figs.2a and b. The shift in wavelength is caused by a general increase in strain on loading up. The widening and splitting are caused by the appearance/aggravation of non-uniform strain distribution. The latter may be the result of strain concentration near the edge of the joint. It can also be caused by internal damages. Strain concentration effect may be eliminated by unloading to zero load. If the widening and splitting of the spectra still persists (Figs.2c and d), then it should be brought about by internal damages.

The difference between the unloaded spectrum and the original pretested spectrum may be quantify by a V value, which is calculated by summing the difference in light intensity under the same wavelength between the two spectra. Based on a large number of carefully designed tests, a V value of 10 was chosen to differentiate a damaged joint with an intact one. Table 1 compares the loading (in terms of % failure load) which the V value first indicated damage occurrence. It can be seen that the 0^o fiber sensors are more sensitive than the 45^o ones. The 90^o sensors are the least sensitive. This observation was further confirmed by the V values very close to specimen failure (> 97% failure load).

The same measuring technique applied to cyclic loading was also shown to be successfully detected the occurrence of damage. Specimens were monotonically loaded to under or beyond the point of damage indication. Follow up cyclic loading showed the former gave a fatigue life close to virgin specimens while the latter exhibits greatly shortened life.

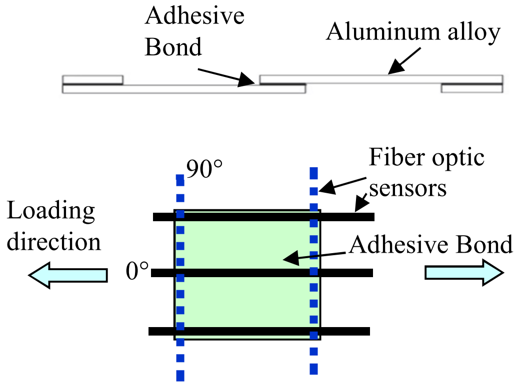

Fig. 1 - Schematic diagram showing how the fiber optics sensors are embedded in the adhesive joint.

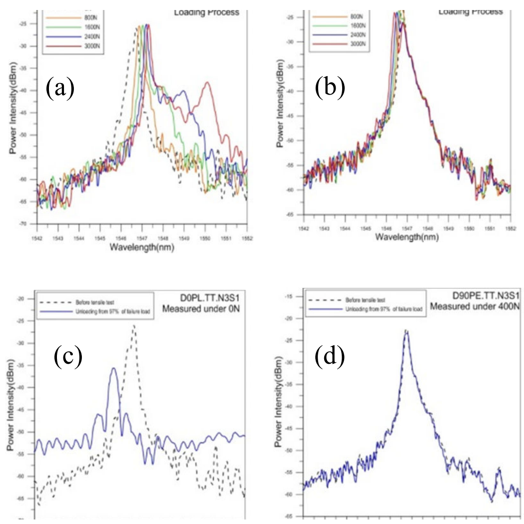

Fig. 2 - (a) 0^o; (b) 90^o FBG spectra at progressively increasing load; (c)0 N spectrum of 0^o FBG spectrum; (d) 400N spectrum of 90^o FBG after unloading from 97% of failure load.

CONCLUSION

Embedded FBG sensors have been demonstrated to be able to indicate in a quantitative manner internal damage in single lap joints caused by monotonic or cyclic loading. With this technique, it is possible to achieve on-line monitoring of the joint integrity in an economical way.

Table 1 - Comparison of the sensitivities of different fiber sensor orientation

First indication of damage by V value (%Failure load / V value)				
Fiber orientation	45^o	0^o Left	0^o Middle	90^o
Specimen 1	90% / 13.12	97% / 60.37	94% /12.72	(Fiber broken)
Specimen 2	98% / 29.62	77% / 14.88	77% / 20.41	82% / 11.63
Specimen 3	95% / 13.18	86% / 10.22	86% / 17.04	97% / 13.19
	V value for the last unloading (from over 97% of failure load)			
	D45	D0PL	D0PM	D90PE
Specimen 1	55.8	60.4	49.8	(Fiber broken)
Specimen 2	29.6	66.9	44.6	18.2
Specimen 3	20.7	23.2	56.9	13.2