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Low Velocity Impact Detection and Damage Assessment in Composite Materials using Fibre Bragg Grating Sensors

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Low velocity impact (LVI) is considered potentially dangerous for a composite structure mainly because the damage, in the form of delaminations and matrix cracking, is being created near the back face or within the laminate and might be left undetected. Most of the conventional damage assessment techniques require the composite structure or component to be taken out of service. The development of an in-situ damage monitoring system using embedded fibre optic sensors offers significant benefits. However, few of the efforts to develop an optical fibre sensor system for impact applications can be considered successful [1] due to the significant technical challenges facing the use of fibre optic sensors.

This paper presents a study carried out in the University of Southampton into the detection and assessment of LVI on carbon fibre reinforced plastics (CFRP) using in-fibre Bragg grating sensors and a novel interrogation system developed at the Optoelectronics Research Centre and the Department of Engineering Materials. Preliminary experimental results from impact tests in composites validated and confirmed the high sensitivity and accuracy of the developed system. Furthermore, the relationship between sensor readings and actual impact damage is presented.

Twenty panels were manufactured using identical lay-ups and resins. Ten of them incorporated the FBGS. All panels were non-destructively tested and then were subjected to successive LVI. The results obtained from the FBGS were compared with the ones obtained by conventional strain measuring techniques. Using the developed interrogation system the composite samples were tested over a period of 30 seconds. The obtained data are in the form of radio frequency (RF) as a function of time. Figure 1 shows the static and dynamic data measured in real time by the FBGS for a 2.2 J impact.

Since RF data are inversely proportional to direct strain, the following empirical equation (Eq. 1) is used to convert them to micro strain:

$$Strain(\mu\varepsilon) = 1.23 \times \left(\frac{RF - RF_0}{RF_0} \right) \tag{1}$$

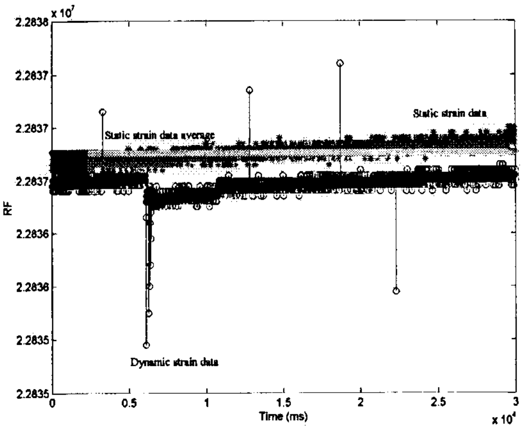

Fig. 1 FBGS response for a 2.2 J impact

The obtained dynamic data from all the impacts are then correlated with the detected delamination areas from image analysis presenting a quantitative relationship between them. Also from the conducted LVI experiments the maximum detected residual compressive strain is related to the existence of a threshold value, above which no further damage occurs in the composite laminate (fig 2). At this threshold level, the strain experienced by the FBGS becomes roughly stable.

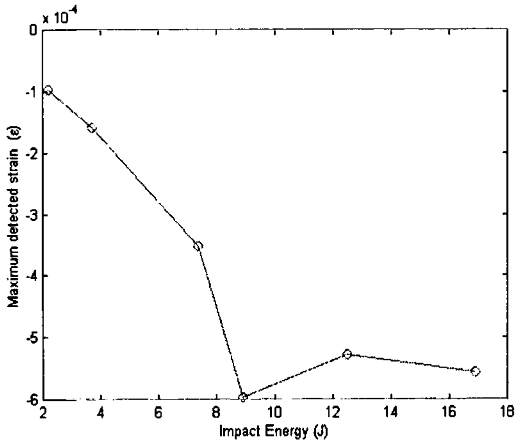

Fig. 2 Maximum detected microstrain

The validity of the obtained FBGS measurements is confirmed by using conventional non-destructive evaluation techniques. C-scans showed that we have damage initiation with the form of delaminations from the impact of 2.2J. This impact induces a temporary strain of -97 με on sensor. The delamination area is growing with the successive impacts of increasing energy until a certain point is reached. After this impact energy level the delaminated area remains roughly the same, confirming that no further damage occurs internally in the composite panel.

Reference

1. C.C. Chang and J.S. Sirkis, Design of fiber optic sensor systems for low velocity impact detection, Smart Materials & Structures, 7(1998), pp.166-177.