UD hybrid composite overload sensors

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Composite materials are widely used in various structural applications due to their low density, high specific strength and stiffness, corrosion resistance, and good fatigue properties. However composites usually fail in a catastrophic manner and detecting damage, if there is any, prior to final failure has been a significant challenge. This puts limitations on structures comprising such materials as larger safety margins and conservative design envelopes need to be implemented. Sudden failure usually occurs without preceding damage or warning of any kind that is crucial in high volume applications such as in the automotive industry or civil engineering where a sudden collapse or failure could lead to the loss of human life and significant financial costs [1], [2]. It would be desirable if catastrophic failure could be prevented by detecting damage at earlier stages of loading/service. As a result, overload detected in time, can indicate the need for further investigation by more thorough non-destructive testing (NDT) methods and appropriate repair or maintenance can be carried out leading to no excessive/unexpected down-time and enhanced service lives.

A purpose-designed, thin interlayer glass/carbon hybrid composite overload sensor concept can be used for structural health monitoring (SHM) of composite structures, leading to a safer operation in service. The UD hybrid composite sensors indicate the overload of a certain structure by simply exhibiting a change in appearance when loaded over a predefined strain value. The originally intact carbon layers absorb the incident light through the translucent glass layer showing a dark appearance as seen in Figure 1 (a). After the strain exceeds the failure strain of the carbon layers, the incident light is reflected back from the damaged glass/carbon interface exhibiting light stripes around the cracks in the carbon layer as illustrated in Figure 1 (b). The visible interfacial damage is caused by the fragmentation of the carbon fibre reinforced sensing layer followed by stable, dispersed delamination as previously demonstrated by Czél et al. [1]. These robust and lightweight sensors are completely wireless, do not require any data acquisition or evaluation system so they offer low-cost and simple solutions for visual strain overload indication.

An analytical model developed here allows for the sensors to be tailored to suit different substrate materials and design strains. The sensors can be attached to a component either as a structural sensing layer or integrated locally to the structure as demonstrated in this study through application examples. Furthermore, various test methods have been used to investigate the accuracy, optimum geometry and sensing capability of these sensors including mechanical testing, digital image correlation and acoustic emission measurements. The thin-ply UD hybrid composite concept is a very promising technology not only for structural health monitoring purposes but at the same time for local strengthening of structures with pseudo-ductile materials. It can potentially be applied in advanced lightweight applications such as sporting goods, civil engineering structures (e.g. truss and bridge elements) as well as pressure vessels. These new type of sensors could potentially provide information about overloads in terms of the magnitude of strains. An array of sensors can be applied comprising various sensing materials indicating different strains showcasing the versatile nature of this concept.

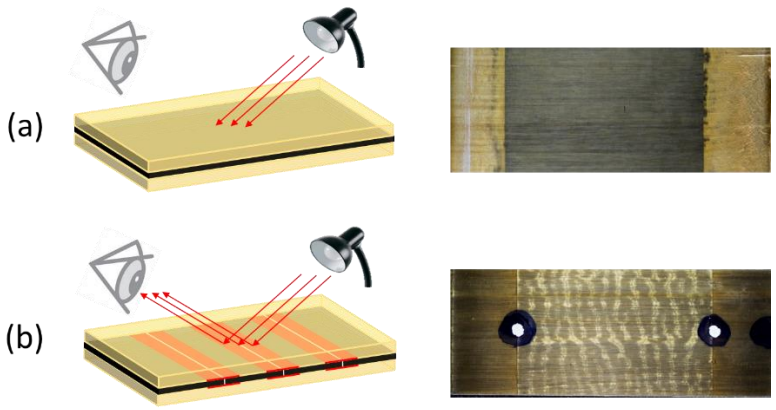

Figure 1. The sensing mechanism behind the UD hybrid composite strain overload sensors: (a) intact carbon layers absorbing light at glass/carbon interface (b) stripy pattern visible due to light being reflected back from locally damaged glass/carbon interface around the sensing layer cracks

[1] G. Czél, M. Jalalvand, and M. R. Wisnom, "Design and characterisation of advanced pseudo-ductile unidirectional thin-ply carbon/epoxy– glass/epoxy hybrid composites," *Compos. Struct.*, vol. 143, pp. 362–370, Feb. 2016.

[2] M. Jalalvand, G. Czél, and M. R. Wisnom, "Parametric study of failure mechanisms and optimal configurations of pseudo-ductile thin-ply UD hybrid composites," *Compos. Part A Appl. Sci. Manuf.*, vol. 74, pp. 123–131, Jul. 2015.