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SELF-HEALING COMPOSITES FOR USE IN SPACE

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ABSTRACT

One of the most hazardous problems for a vehicle operating in Low Earth Orbit is meteoroid and orbital debris impact. The extent of man-made orbital debris now outnumbers meteoroids by more than ten to one. Debris is a problem that will continue to get worse over this century as the particle population increases due to collisions between objects already in orbit [1].

Fibre reinforced plastic (FRP) composite materials are being selected for use in a growing number of aerospace applications. This trend is particularly prominent in space as their high specific mechanical properties and thermal expansion customisation offer weight and dimensional stability benefits. However, these laminate materials can suffer extensive damage when impacted by debris travelling at hypervelocity which results in damage areas hundreds of times greater than the particle cross-section, see Fig 1.

Self-healing composites offer an opportunity to make FRPs more durable which extends the lifetime and reduces the need for maintenance, both highly desirable characteristics when operating in space. This work focuses on three key obstacles for developing self-healing technology for use in space. First, to obtain a greater understanding of desirable characteristics for a self-healing resin which will allow for improved custom resins to be formulated. Second, to develop a better understanding of damage interaction with hollow glass fibres embedded within FRP. Finally, to conduct impact testing at hypervelocity to assess the benefit of a self-healing system on residual mechanical properties.

This work uses hollow glass fibres embedded within carbon fibre/epoxy (CFRP) laminates to deliver a liquid epoxy resin to delaminations and microcracks which result from impact damage [2]. Three promising commercially available epoxy resin systems, with different attributes, were selected for investigation as healing agents. They were tested in their unmodified form to assess a range of mechanical and physical properties. Their properties were then compared with the performance of the post-impact recovery of mechanical properties within FRP laminates. This study has also sought to develop a greater understanding of how the hollow glass fibres carrying the healing agent interact with the impact damage by examining different impact boundary conditions.

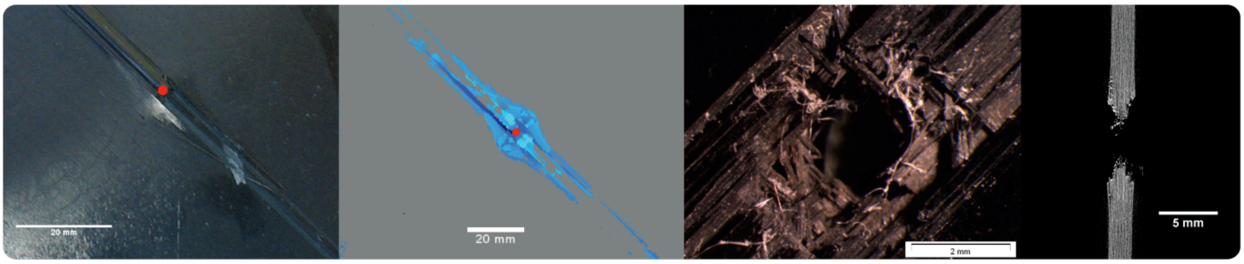

Figure 1: 3786m/s impact of a 1.5mm diameter steel sphere on a carbon fibre/epoxy laminate. L-R: Visual, Ultrasonic C-Scan, Optical Microscopy & microCT scan. Red dot shows approx. size of the crater.

Prior to undertaking full hypervelocity (>3 km s^{-1}) self-healing trials, a series of preliminary 'shots' were performed on plain CFRP panels and those containing hollow glass fibres. Images from one test are shown in Figure 1. Hypervelocity impacts on CFRP laminates have different damage characteristics compared to those at low velocity due to the inelastic nature of the event. The impact establishes shock waves in the material that travel quicker than the speed of sound which means energy must be dissipated by surface creation, either within the intact laminate or by ejecting material from a crater as the material cannot elastically deform [3, 4]. Although not able to heal the central crater the aim of this work is to heal some of the surrounding internal delamination and microcracking to help stabilise the structure and partially restore the loss in mechanical properties [5].

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