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DAMAGE DEVELOPMENT AHEAD OF ARRESTED CRACKS IN A STRAIN GRADIENT IN UNIDIRECTIONAL FIBRE REINFORCED PLASTIC COMPOSITES

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Summary. *A set of experiments is being designed to validate the physical basis of the Onset Theory for failure of composite materials. The first step has been to design a specimen in which a crack can be arrested in a unidirectional laminate so that mechanism extending the crack growth can be investigated. This paper reports the design of the specimen and initial results.*

1 INTRODUCTION

The Onset Theory [1] for glassy polymers identifies two sources of irreversible behaviour. The first is a dilatational failure corresponding to breakdown of the intermolecular bonds and the formation of microcracks. The second involves irreversible damage due to distortion that is believed to relate to torsional unravelling of molecular structures and plastic-like flow between subregions bounded by weak crosslinking due to variations in the curing process. A research program is being undertaken to identify the correct physical basis for the irreversible processes. While microcracking can be investigated by microscopic inspection, the distortional damage is more difficult to investigate. Techniques used will include vibrational spectroscopy and solid state NMR aimed at identifying conformational changes.

Essential to the theory for fiber reinforced composites is that the resin is in a constrained environment dominated by the stiff fibers. Therefore, while insight is gained from investigation of neat resin, the investigation must include resin and fiber in cured specimens that have been taken to the point of failure. A first step in the investigation has been to develop a test specimen that can arrest a crack in a unidirectional specimen so that the region adjacent to the crack and ahead of the crack tip can be studied.

2 METHODS

The specimen was designed to grow a crack under a moving strain gradient but to allow the crack to be arrested before catastrophic failure of the specimen occurs. The configuration is identified in Fig.1. The edge of the unidirectional laminate is machined to create a thinned section. Fiberglass shoulders have then been bonded to the specimen to provide an alternate load path and the specimen is tested in three point bending placing the machined edge in tension. A crack initiates on the thin edge and propagates until the load transfers to the shoulder tabs and the crack then arrests. Specimens can be manufactured so that the crack grows normal or parallel to the fiber axis. Off axis specimens will extend the investigation to distortion critical behavior.

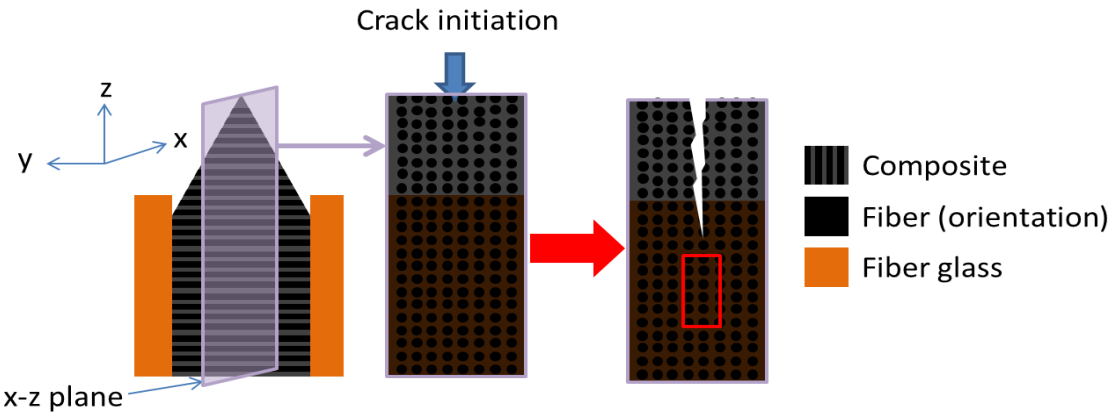

Fig. 1 Specimen configuration for crack arrest.

3 RESULTS AND DISCUSSION

Initial testing has focussed on dilatational behaviour. The growth of the crack has been found to occur through development of discrete localised micro regions of damage which eventually coalesce to produce catastrophic failure. After testing, three distinct zones are observed. The first is the undamaged zone. This is the region where the material has been strained less than the critical amount required to cause microcracking. Accordingly, visible damage is not observed. In the second region, referred to as the damage zone, the strain has been sufficient to cause microcracking (which increases progressively up the strain gradient) but without coalescence into continuous cracks. In the third zone, referred to as the coalescence zone, the strain has been sufficient to cause the microcracks developed earlier in the loading history to coalesce to form continuous macroscopic cracks.

The damage zone is of particular interest since the processes occurring here are those that precede catastrophic failure. This study examines the damage zone in unidirectional composites loaded at varying angles to the fibres. In some cases resin is infused into the crack while under load to keep the crack surfaces apart. Electron microscope images indicate the zones defined above. Preliminary results from the vibrational spectroscopy and NMR studies will also be reported.

ACKNOWLEDGEMENTS

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