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EXPERIMENTAL OBSERVATION OF LAMINATE STRUCTURE BY MICROSCOPICAL METHODS

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ABSTRACT
This paper collects some possibilities of investigation of microstructure characterization of laminate composite material by scanning electron microscopy (SEM) and optical microscope. The attention is aim to matrix cracking, cohesion between matrix and fibre, delamination, etc. Matrix cracking has been recognized as a major factor causing stiffness decrease of polymer laminates during fatigue life. The crack saturation also leads to a secondary stage fatigue development, such as delamination or longitudinal cracking in the critical layers. Crack saturation represents an important damage stage, i.e. a local failure of laminates. Consequently, the prediction of crack saturation in fibre reinforced composite structures represents an important task for the design of fibre reinforced structures.
Keywords: fractography, microstructures, continuous fibre composites

1. INTRODUCTION
In recent decades, composite materials have found increasing use in structural applications because of their high specific tensile and compressive strength, and good fatigue and corrosion resistance properties. [1, 2] However, the response of composite structures can be greatly affected by the presence of failure modes such a delaminations, matrix cracks, and fibre fractures, which are typical of laminated composite materials. In particular, due to the inherent weakness in the thickness direction of this class of materials, delaminations may develop as a consequence of low-velocity impacts, which inevitably occur during manufacturing, service or maintenance. The ensuing growth of delaminations under the action of external loads may degrade the mechanical properties of the structure up to a point, where replacement or repair may be necessary to preserve its structural integrity. Efficient damage evaluation techniques are therefore needed for inspection of components in composite materials in order to ensure a reliable service life, especially in safety-critical structures. [3, 4] Fractography is the detailed, microscopic analysis of the surface of a fracture to determine its cause and relationship between the fracture mode and the microstructure of the material. It is used to identify the origin of the crack and the crack propagation direction. It can also be used to determine the type of loading that caused the crack to initiate and propagate. The fractography of composite materials is complicated by the fact that these materials exhibit failure modes that are not normally encountered in metallic materials. The failure types and modes that can develop depend on the direction of applied load and on the orientation of the fibres.

2. MICROSTRUCTURES OF CONTINUOUS FIBER COMPOSITES
The object of this study is to investigate the fracture mechanism of Kevlar/fibre reinforced vinylester resin composite, Kevlar/fibre reinforced epoxy resin composite and glass/fibre reinforced epoxy resin composite. Continuous fibre reinforced composites are seeing significantly expanded levels of use in

hardware where reduced weight is critical. This paper will review the basic methods required to carry put a rudimentary analysis into the cause of failure for continuous fibre reinforced materials. Because these materials are significantly different from their metal counterparts, this paper will deal with several considerations unique to composite materials. Continuous fibre composites are typically made up of 3 – to 30-μm diam fibres that are oriented and surrounded in a supportive matrix material. Generally, the fibres used in these material systems are several orders of magnitude stiffer and stronger than the surrounding matrix. Fibre typically used for such applications include graphite, Kevlar, aramid, and fibreglass (Figure 1). Because of their continuity and oriented structure, fibre-reinforced composites have highly anisotropic properties. For example, unidirectional tapes commonly exhibit module in the fibre direction 20 times greater than that of the transverse direction. In most designs, this anisotropy is tailored by arranging plies of material (their tape or fabric) at a variety angles. This structuring produces a stacked, laminated construction (Figure 2).

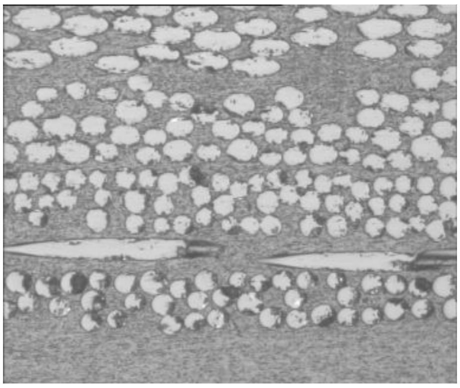

Figure 1. Microstructure of Kevlar - vinylester fabric. 200x

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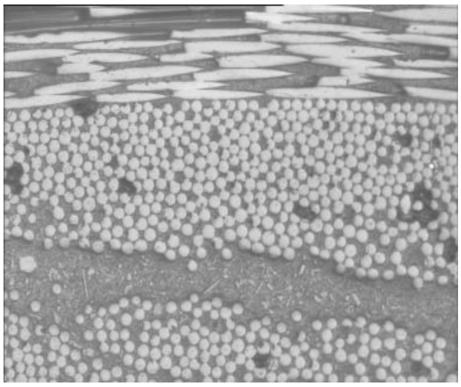

Figure 2. Cross-sectional optical micrograph illustrating laminated construction typical of continuous fibre composite materials (glass-fibre epoxy fabric). 100x

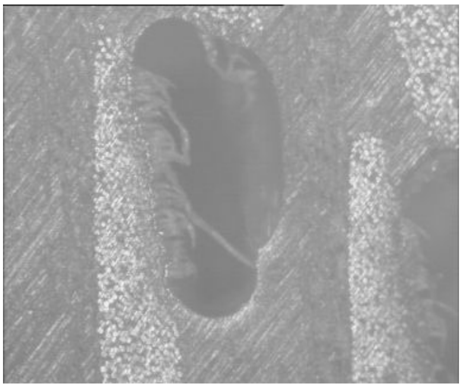

Figure 3. Microstructure of Kevlar - epoxy fabric with debond. 50x

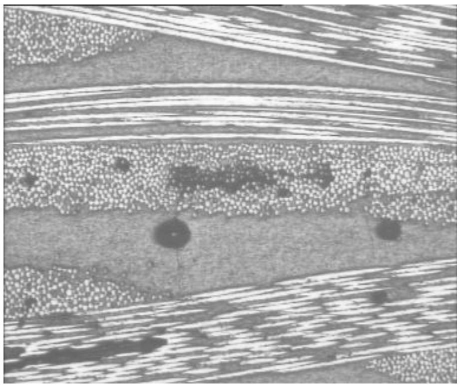

Figure 4. Microstructure of Kevlar - vinylester fabric with debonds. 50x

3. FRACTOGRAPHY FOR CONTINUOUS FIBER COMPOSITES

Fracture in composites can occur in a number of complex ways because of their laminated anisotropic construction. Fracture in continuous fibre reinforced composites can be divided into three basic fracture types: interlaminar, intralaminar, and translaminar. Translaminar fractures are those oriented transverse to the laminated plane in which conditions of fibre fracture are generated. Interlaminar fracture describes failures oriented between plies, whereas intralaminar fractures are those located internally within a ply. Translaminar fracture involve significant fibre fracture, while interlaminar or intralaminar fractures occur in the laminate plane and therefore break few if any fibres. Figures 5, 6, 7, 8 describe some SEM micrographs of laminate composite materials after tensile test.

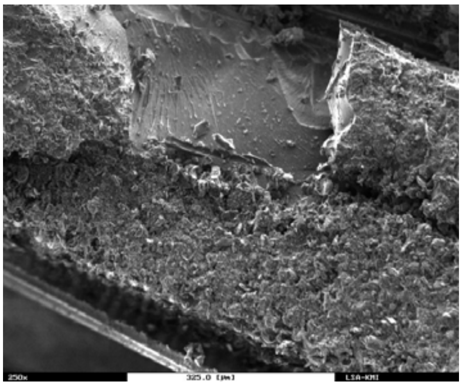

Figure 5. SEM micrograph of broken epoxy resin. 250x

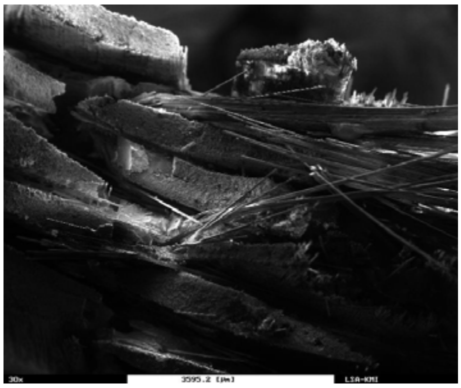

Figure 6. Typical fracture pattern of fatigue of laminates. 32x

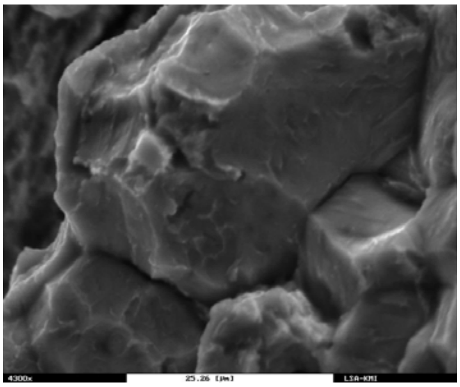

Figure 7. SEM micrograph of resin.30x

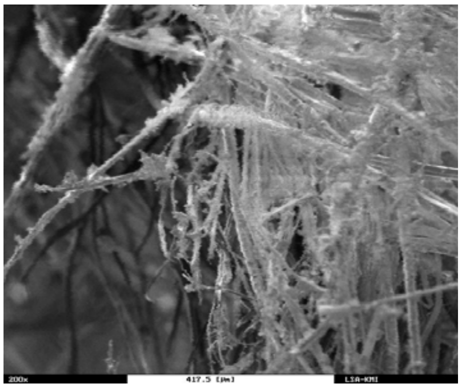

Figure 8. SEM micrograph of fibres. 200x

4. RESULTS AND DISCUSSION

This paper collects some possibilities of applications of scanning electron microscope (SEM) to make of fractographs of fracture surfaces of laminate composite materials and possibilities of optical microscope to take a micrograph, too. SEM micrographs show the complicated structures of the damage zone near the crack tip (broken and delamination fibres, fibre pull-out, broken epoxy resin).The very fast developments of technology of composite materials have led to newer and wider applications of such promising materials. Composite materials offer a number of potential advantages in the aerospace field, particularly in safety-critical structures such as primary and secondary aircraft components. [5, 6] The presence of several types of defects such as voids, inclusions, debonds, improper cure and delamination are almost common during the manufacture and use of composite materials. SEM and optical microscope can be very useful tool to investigate defects in those materials and zone of fracture. The failure analysis of composite materials is an area of active research that is only now beginning to be fully defined. The information presented in this study will aid investigators initiating failure analyses of laminate composite materials.

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