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INVESTIGATION ON MODE I FRACTURE TOUGHNESS OF CARBON EPOXY COMPOSITES ASSISTED BY DIGITAL IMAGE CORRELATION

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Abstract: The interlaminar fracture toughness of a carbon-epoxy composite system is investigated for both static and fatigue Mode I loading with double cantilever beam specimens (DCB). The Digital Image correlation (DIC) technique is utilised for determination of the delamination length. An average initial fracture toughness is measured together with an increasing crack resistance curve (R-curve). During static Mode I loading a strong influence of fibre bridging on the fracture toughness is observed.

1. Introduction

One of the major concerns today is that composite materials are very sensitive to delamination damage which may initiate for example from manufacturing defects or may be induced by a low velocity impact. The presence and growth of delaminations causes a reduction in stiffness, strength and fatigue life [1]. In order to be capable to simulate the delamination behaviour of fibre reinforced polymer composites in automotive and aeronautic applications, the delamination damage tolerance under static and fatigue loading must be thoroughly understood [2].

In a first step, the behaviour of a carbon-epoxy composite system under static Mode I delamination is investigated. The critical delamination resistance $G_{lc}$ is determined using DCB specimens (Figure 1) which consists of a unidirectional 0° lay-up with a Teflon insert of 13μm thickness as a precrack in the midplane. From larger plates, specimens are cut with a diamond saw with final dimensions of 155mm length, 25mm width and a thickness of 4,15mm. Load blocks were glued to the specimens for load introduction. The length of the precrack is approximately 55mm and is measured from the load introduction line to the insert tip.

The specimens are tested at room temperature on a Bose Electroforce system with a load cell of 7 kN at a cross head displacement of 6mm/min. The load-displacement curve is obtained during static testing and a 3D-DIC system is used for determination of the crack length during

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loading (Figure 2). In the full paper, the fatigue delamination behaviour, i.e. crack initiation and crack growth of the composite material system under Mode I loading will be reported.

2. Results
Post processing of the DIC data makes it possible to automate determination of the crack length during static loading (Figure 3), increase the test speed (6mm/min instead of the often used 1mm/min) and the results are less operator dependent. Results obtained with DIC are compared to microscopic images of the crack to check the validity of the results. Data reduction is done using the Modified Beam Theory (MBT) according to the ASTM D 5528 test standard [3] for determination of the Mode I interlaminar fracture toughness. An average value of $G_{lc} = 0.11N/mm$ is obtained with a standard deviation of 0.0056 and a coefficient of variation of 4.92%. During testing, an extensive amount of fibre bridging is observed, an artefact of DCB specimens with a unidirectional lay-up [4]. This is reflected in the increasing R-curves where no plateau value is reached for the fracture toughness $G_{lc}$ (Figure 4). After a crack growth of 55mm, the fracture toughness has almost doubled compared to the initial value.

![Figure 3: Evolution of crack length during Mode I opening for specimen 2.](image)

![Figure 4: R-curve for static mode I opening of specimens 1-3.](image)

3. Conclusions
By using microscopic images of the crack front, it is proven that the evolution of the crack length during loading can be monitored with the aid of Digital Image Correlation. Increasing R-curves are obtained as a consequence of the observed fibre bridging during static loading. A strong increase of the fracture toughness during loading is observed.

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