DAMAGE ACCUMULATION AND TENSILE STRENGTH ASSESSMENT IN CARBON/EPOXY COMPOSITES USING HIGH RESOLUTION COMPUTED TOMOGRAPHY

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Keywords: x-ray tomography, in-situ, tensile testing, carbon fibre reinforced polymers

Summary: *In situ* tension tests have been carried out to capture and quantify fibre failure progression from low to high strains. Two modes of cluster formation were noted, where breaks were either closely co-planar with each other, or, alternatively, distributed over a short distance along the fibre length, but within the ineffective load transfer length that may be expected for such material (see [1]). These results are discussed in the light of previous materials tested, and established modelling methods, particularly in terms of the chronology of cluster formation.

1. INTRODUCTION

Carbon fibre reinforced polymers (CFRPs) are a critical structural material for aerospace engineering. Current conservative design approaches lead to manufacturing and testing methods that are unnecessarily inefficient and costly. The use of well-understood, physically accurate performance simulations will allow for more efficient use of material, reducing aircraft weight and improving fuel efficiency, without compromising safety.

Fibre failure is the key mechanism controlling final failure in CFRPs, particularly under tensile loading. High resolution *in situ* computed tomography enables identification and quantification of individual fibre break formation. This can be used to improve directly and validate predictive failure models, which as yet are still unable to account for factors controlling the onset of unstable failure [2,3].

2. EXPERIMENTAL METHOD

Damage accumulation has been assessed in two carbon fibre/epoxy materials, made of aerospace and industrial grade pre-preg, each with a stacking sequence of $[90/0]_s$. Double edge notched specimens tested, as in [4]. Preliminary *in situ* tests were carried out at the Swiss Light Source (preferable to laboratory μCT for its higher temporal resolution, i.e. reduction of motion artefacts caused by creep effect). A 2560x2560 pixel detector was used for a resolution of 0.32μm (sufficient to observe distinctly individual fibre breaks) with a field of view of ~0.7 mm. Based on previous studies [1,3], the sample-detector distance was set to provide phase edge enhancement, enabling differentiation between fibre and matrix and the region of interest for all the scans kept approximately the same (see Figure 1a). Using a compact loading device, specimens were loaded in five discrete steps until tensile failure.

3. RESULTS

Fibre breaks were individually and easily detected at the selected voxel size. The formation of single and multiple fibre breaks was assessed, in terms of both fibre neighbours, and individual fibres that were susceptible to multiple breaks. Contrary to conventional expectation and independently of the grade of CFRP material, as the tensile load was increased, neighbouring clusters were always seen to form instantaneously (i.e. at a specific load step), with no further growth of the cluster occurring with subsequent loading. Figure 1c conversely illustrates the build-up of breaks along *individual* fibres that was seen to occur as a function of load.

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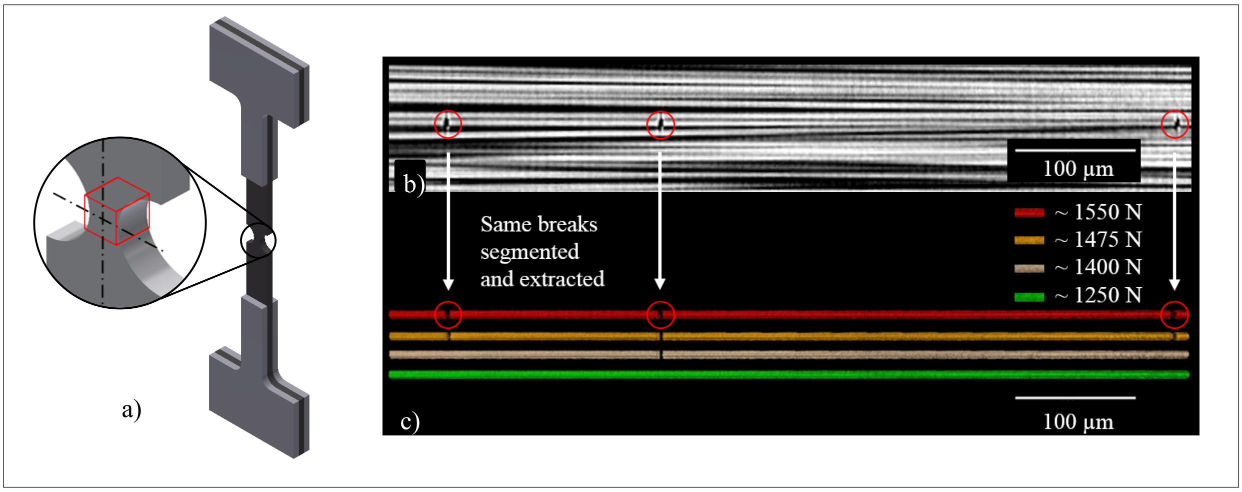

Figure 1: a) Sample geometry with approximate region of interest for all scans. b) Build-up of fibre breaks within an individual fibre as a function of increasing load. CT image at the highest load step (i.e. ~ 1550N) showing 3 breaks within the field of view along a fibre; c) the same fibre as identified in (b) segmented and extracted from each of the different load steps.