POSSIBLE SOLUTIONS FOR DAMAGE EVALUATION
BY MICRO-CT IN SFRP

Francesca Cosmi 1), Salvatore Scozzese 1), Andrea Bernasconi 2)

1) Università degli Studi di Trieste, Dipartimento di Ingegneria Meccanica e Navale, Via Valerio 10, 34100 Trieste, Italy
2) Politecnico di Milano, Dipartimento di Meccanica, Via La Masa 1, I-20156 Milano, Italy
Corresponding author: cosmi@units.it

1. Introduction

Given the strong interest of transportation industry in applying Short Fibre Reinforced Polymers (SFRP), due to their competitive strength/weight ratio, assessment and possibly prediction of the multiaxial fatigue behaviour in relation to the fibre structure is of great significance [1]. The study of diffused fatigue damage development in injection moulded parts, made of SFRP, requires a careful observation of their evolutionary process and of the 3D damage geometry [2]. The methods normally used for this purpose are destructive or do not exhibit a sufficient spatial resolution. On the contrary, the imaging techniques based on X-ray micro-CT combine the advantage of a non-destructive method with high resolutions, but their application is limited by the propensity of the micro voids and cracks to reclose upon removal of the load that had caused the damage. This problem can be solved by using a test rig capable of exerting a tensile load during data acquisition, so that the defect could be kept open for the entire micro-CT duration. In this work, the issues and some preliminary results obtained with two different applicative solutions are discussed.

2. Experimental methods and results.

2.1 Commercial single-column tensile machine

With reference to the experimental set-up of the SYRMEP beamline at Elettra, the synchrotron facility in Trieste, the insertion of a commercial single-column machine for tensile testing between the ionization chamber and the new high resolution CCD camera represents a possible, simple, solution. However, the presence of the column represents a drawback, because it does not allow to capture the images over the usual 180°, but creates a cone of shadow on the sample. The impact of this downside on the final quality of the reconstructions was therefore evaluated. Using the data from a previous tomographic acquisition (9 microns resolution) of a PA6.6GF35 sample, it was possible to simulate the presence of the column and the consequent visual field reduction by neglecting an adequate number of projections in the reconstruction. Acquisition conditions corresponding to angles smaller than 180° could thus be reproduced artificially [3]. The parameters chosen for a quantitative evaluation of the quality of the reconstructions were those describing the fibre microstructure morphology within the polymeric matrix, previously introduced by some of the authors and based on the Mean Intercept Length (MIL) concept [4]. In particular, the values of the Index of Anisotropy (IA) and the first MIL eigenvalue (H1) were used as quantitative parameters. The results, presented in Figg. 1 and 2, show that a cone of shadow of about 30° is consistent with the preservation of the main morphological characteristics (error <10%).

Fig. 1 Index of Anisotropy as a function of the angle available for the reconstruction

Fig. 2 First MIL eigenvalue (H1) as a function of the angle available for the reconstruction.
However, even the use of a small commercial tensile testing machine requires appropriate modifications of the beamline set-up to accommodate for its size and weight, so that the economic advantage of using a commercial component is lost and designing a special purpose device becomes an interesting alternative.

2.1 Specially designed test rig

Taking into account the constraints in terms of space and weight that must be satisfied, a device was specifically designed and successively modified in order to apply the necessary load during the acquisitions [5, 6]. The framework of the small tensile equipment is made of PMMA and is thus transparent to X-rays (Fig. 3). Moreover, a newly acquired CCD camera could achieve a 2 microns spatial resolution.

One PA6.6GF35 specimen was subjected to interrupted uniaxial fatigue tests (R=0.1) at 75% of nominal life and its micro-CT was compared with that of a similar pristine sample, (0% of nominal life) obtained in the same conditions. In this way, it is possible to quantify the presence of micro-voids within the samples, and compare the changes in the structure due to the fatigue conditions applied [7]. The results show an increase in micro-voids of about 18% between the samples, which can also be observed visually (Fig. 4), indicative of a possible change in the internal structure.

The results obtained so far suggest that the developed test rig can represent an applicable solution for the visualization of damage evolution by micro-CT in SFRP materials.

Figure 3: 3D reconstructions of the structure of fibre (white) and micro-voids (red) in the samples at 0% (a) and 75% (b) of their nominal life.

3. Acknowledgements

The authors wish to thank the staff of the SYRMEP beamline for their support during beamtime at Elettra. The samples were provided by Radici Plastics, Italy.

4. References