ESRF	**Experiment title:** Fatigue damage characterisation of particle reinforced metal-matrix composites by phase contrast microtomography	**Experiment number**: ME-288
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Report:

Advanced materials like particle reinforced metal–matrix composites (PMMC) have already many industrial applications, however the mechanisms governing their deformation and damage behaviour are not completely understood. Theoretical questions like the influence of the particle arrangement on the mechanical and damage behaviour of composites are still open due to the lack of adequately 3D microstructural data. The aim of the present work is to quantitatively determine the particle arrangement and damage in a fatigued commercial Al6061 aluminium alloy reinforced with 20vol% alumina particles. During this second round of measurements (19.-20.02.2002) the phase-contrast microtomography as well as holo-tomography was applied for the microstructural characterisation of the composite.

The separation of the particles from the matrix is very difficult working in phase-contrast microtomography. Particle edges can be however, obtained by applying 3D- edge detection filters and the method gives good results for single particles. When local grouping of particles takes place their detection becomes very difficult. An alternate possibility is to use measurements made at many defocusing distances in order to obtain the phase of the X-ray beam travelling the sample. Using only two defocusing distances we succeed to make this reconstruction, where the particle and matrix phases are well separated. Such a binarized volume of 256^3 μm^3 size is shown in Fig. 1. In the evaluation of the particle assemblage, the particle form was approximated by an ellipsoid the principal axis of which, were obtained by solving the eigenvalue problem associated to the scattering matrix of each particle. The axis ratios show that the particles are in fact platelets. One of the main parameters characterising particle clustering is the local volume fraction of particles (lf_V), which is defined as the ratio between the volume V_P of a given particle and the volume of the matrix V_M, which lies closest to it ($lf_V = V_P/(V_P+V_M)$). The knowledge of this local parameter is of crucial importance in modelling the mechanical behaviour of the composite. Its distribution is shown on Fig. 2 and the best fit to it is given by a Gaussian function cutted at lower values. The statistical evaluation of the two and three-point correlation functions, which determine the transport and effective elastic properties of the composite is under way.

Damage evolution during fatigue was evaluated from reconstructions obtained by the phase-contrast method. Figs. 3 and 4 show the evolution of the number and volume fraction of damaged volumes (voids) in a

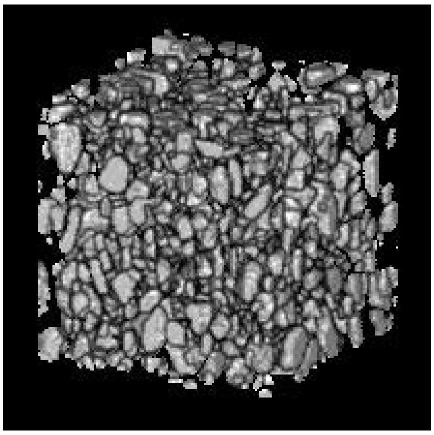

Fig.1. Binarized volume of 256^3 mm^3, obtained by holo-tomography

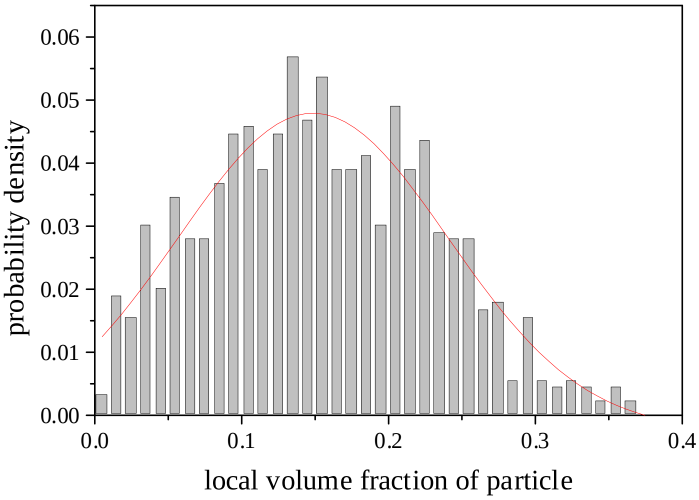

Fig. 2. Probability density of the local volume fraction of particles. The best fit is given by a Gaussian.

fatigued sample along its gauge length. The investigated cylindrical volume is of about 6.3 mm^3, with spatial resolution of 2^3 µm^3. Fig. 3 presents the distribution of the number of voids for the same sample (p07), fatigued until different cycle numbers N=11 and N=800 (results on other samples, free of large initial defects show similar characteristics). Only voids having a volume larger than 6 voxels (48 µm^3) were considered. The number of voids increases toward the middle part of the gauge length, where the cross section of the sample is smaller and a higher stress is acting during the deformation. Very interesting is however that larger peaks and valleys in this distribution remain at the same positions. A similar increase is obtained for the volume fraction of the voids. Fig. 4 shows both, the distribution of the volume fraction and number of holes for the sample deformed until N=800. The two distributions are very similar. The histogram of the voids' volume shows in addition that during the first 800 cycles a large quantity of new voids form, and void growth is restricted only to the smaller ones. These typical characteristics of the damage suggest that in this first part (approx. 2/3) of the fatigue life a stress dependent, spatially uniform damage exists in the composite, similar to the Gurson model for the monotonous deformation of ductile materials. Since the total volume fraction of voids is very small (of about 0.6% at N = 800) there is no interaction between them, which explains the dominant role of the stress in the damage. The results of the forthcoming sessions have however to elucidate how the final damage occurs and which are the conditions that lead to the formation of the macro – crack and final failure.

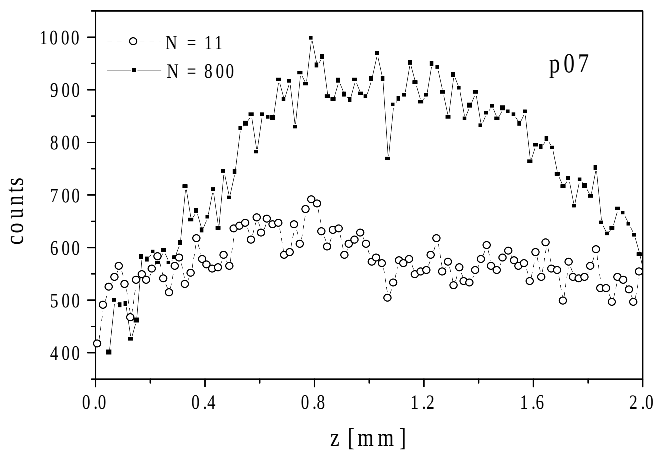

Fig. 3. Number of holes along the gauge length of the same sample fatigued until N=11 and N=800 cycles. $\Delta\varepsilon/2 = 0.004$. Bin size 0.02 mm

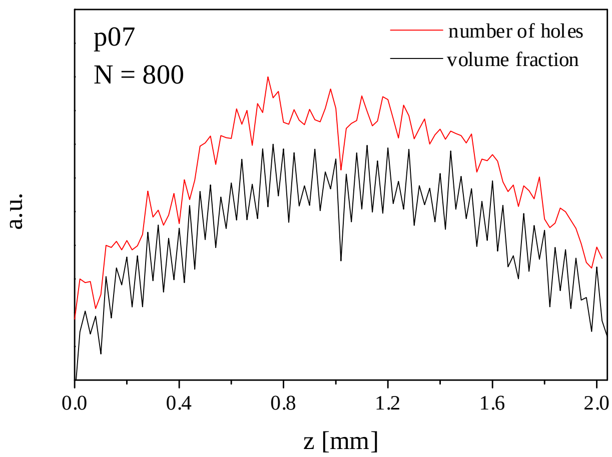

Fig. 4. Distribution of the number and volume fraction of holes along the gauge length. N=800. Bin size 0.02 mm.