MEAN-WINDOW METHOD FOR THE EVALUATION OF EFFECTIVE PROPERTIES OF PARTICLE REINFORCED METAL-MATRIX COMPOSITES

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The microtomographic method developed during the last decade at synchrotron sources provides an excellent experimental tool for the investigation of the microstructure of heterogeneous materials. This is true in particular for materials science ever since the resolution of the method reached the micrometer and submicrometer range, so that the important three-dimensional (3D) mesostructure of engineering materials can be now obtained (Fig.1). Based on a thorough statistical evaluation of the 3D microstructure of a real particle-reinforced metal-matrix composite (Al6061-20vol.% Al2O3) obtained by holotomography, a new numerical approach for the estimation of effective properties is presented. The method uses finite element calculations performed on small mesoscopic windows and the ergodic principle for the estimation of the overall properties. Averaging over the microstructure variability at the mesoscopic level, which is characterized by fluctuations in particle local volume fraction and local arrangement, is performed in two steps. It is shown first that if the size of the simulation cell is large enough (larger than the two-point correlation length) then the physical properties of such mesoscopic windows are linear functions of the local volume fraction for the relevant interval. Next considering the symmetrical Gaussian type probability density distribution of the local volume fraction we arrive at the remarkable conclusion that the effective properties can be obtained from windows having local volume fractions equal to the mean volume fraction of the composite. This finding enables a simple estimation of the contribution of particle arrangement by considering only windows that have mean local volume fractions. Results for the elastic and plastic properties obtained by this method are compared with experimental data as well as with two and three-point bounds for the elastic constants [1].

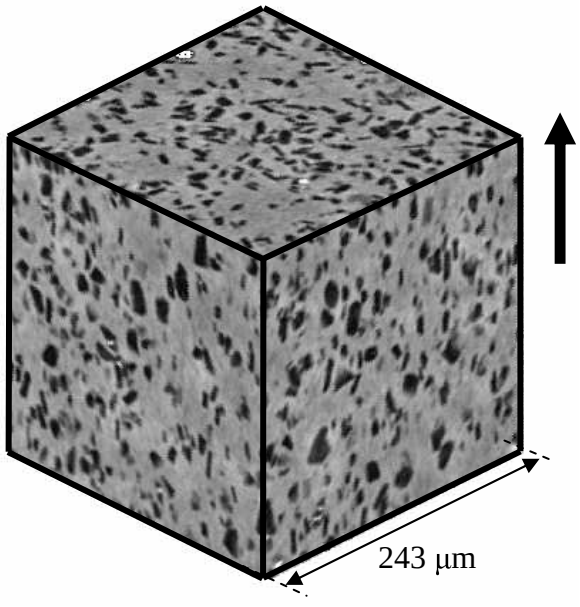

Fig. 1. Holotomographic reconstruction of the 3D structure of an Al6061-20vol.% Al_2O_3 MMC. The arrow indicates the extrusion direction.

References

[1] Borbély A., Kenesei P. and Biermann H. “Estimation of the effective properties of particle-reinforced metal–matrix composites from microtomographic reconstructions”. *Acta Materialia* 54 Vol. 54, pp 2735-2744, 2006.