Tomography Based Approach for Finite Element Modelling of Particle Reinforced Metal-Matrix Composites

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Introduction

Three dimensional (3D) holotomographic scans were performed at the European Synchrotron Radiation Facility in Grenoble in order to characterize the microstructure of a Particle reinforced Metal-Matrix Composite (PMMC) consisting of an AA6061-T6 aluminium alloy as matrix, and 20 vol.% of Al_2O_3 particles as reinforcements. The structure of the composite was reconstructed with a resolution of 2 µm, an average particle of equivalent diameter of 12 µm being given by about 120 voxels.

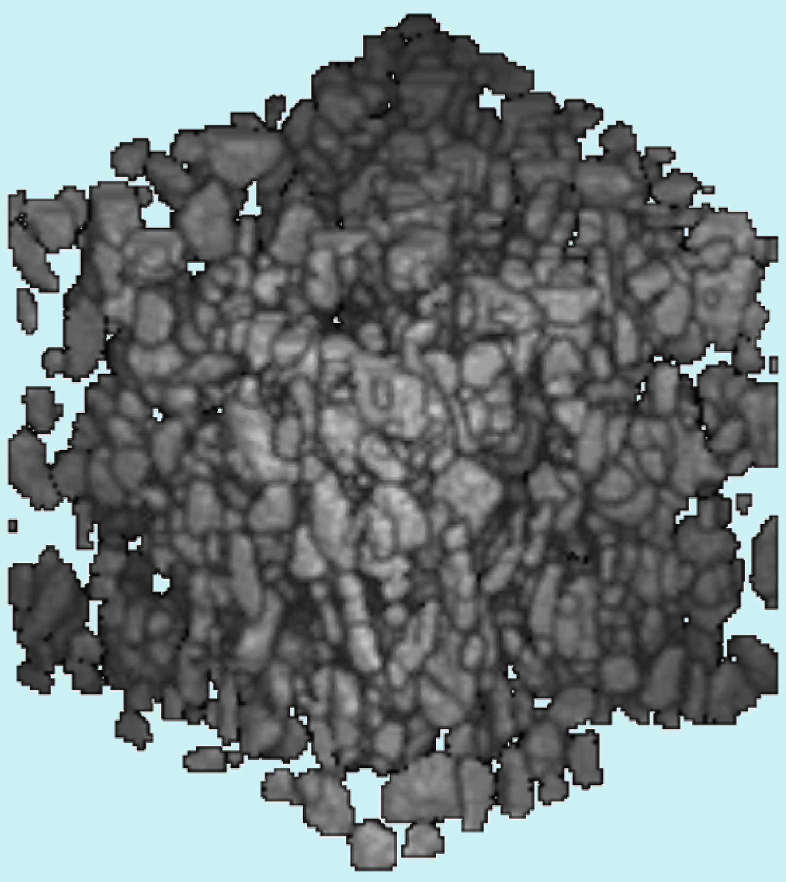

Fig. 1 Composite structure after tomographic reconstruction and binarization. Particles look like small platelets aligned vertically along the extrusion axis [1]. f_V = 20%

Aim

Our aim was to investigate the validity of the one-particle mechanical unit-cell models that consider the three dimensional microstructural properties of the real composites (Fig. 1).

We constructed one-particle unit-cell finite element models based on the local matrix volumes around particles (Fig. 2). The volume fraction (f_V) of these local volumes follows Gaussian distribution function (Fig. 3).

We investigated the resulting compressive stress-strain curves (Fig. 4) to compare the different approximations (Fig. 5-8).

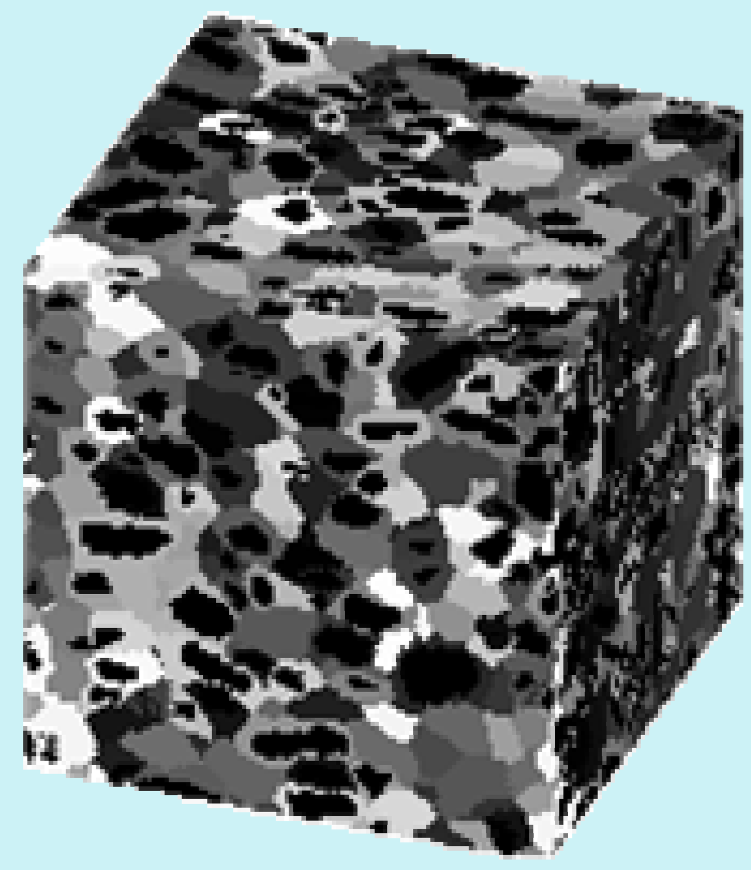

Fig. 2 Local matrix volumes belonging to particles distinguished by different grey levels. The local volumes are the bases of the one-particle unit-cell models.

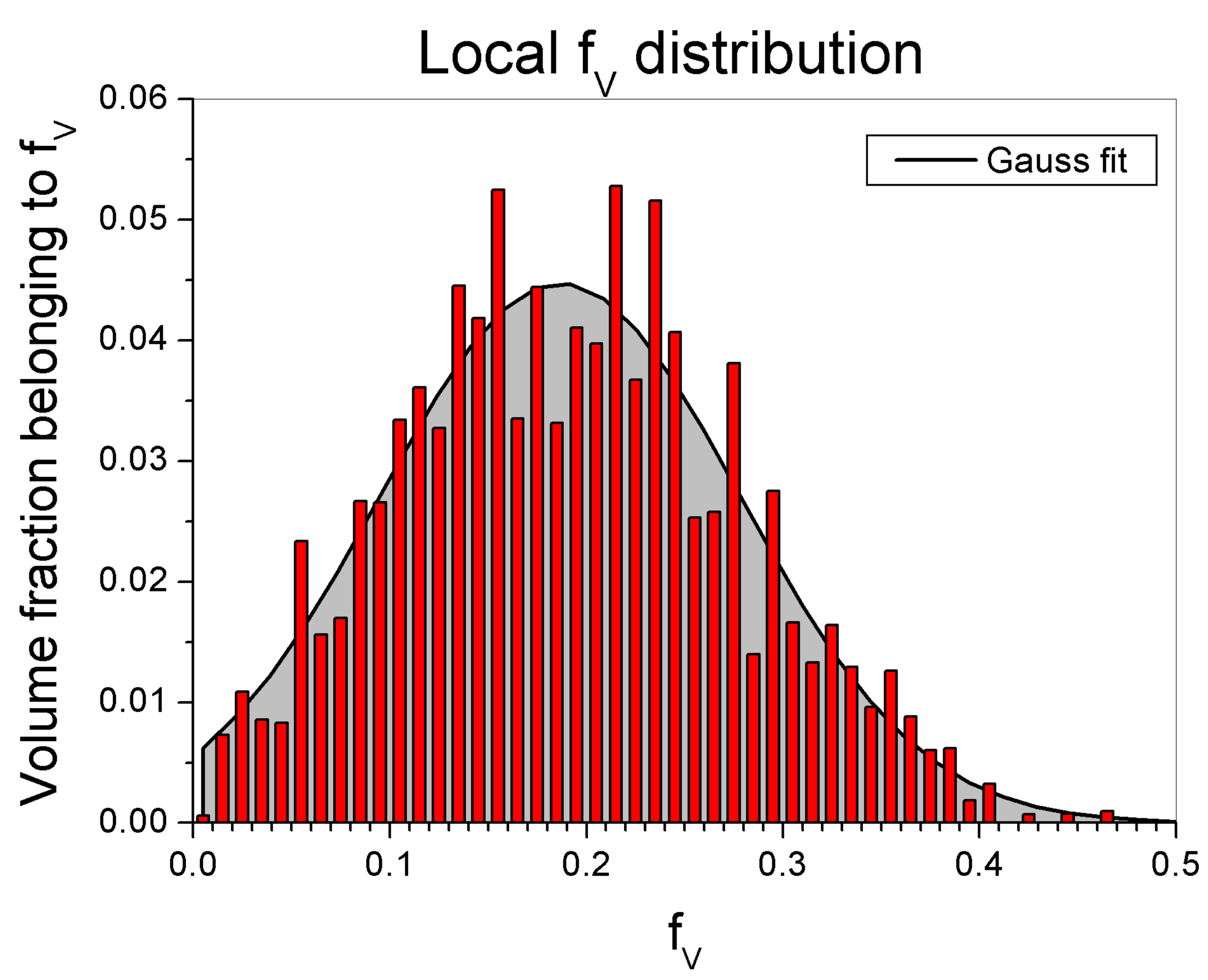

Fig. 3 Distribution of the local volume fraction

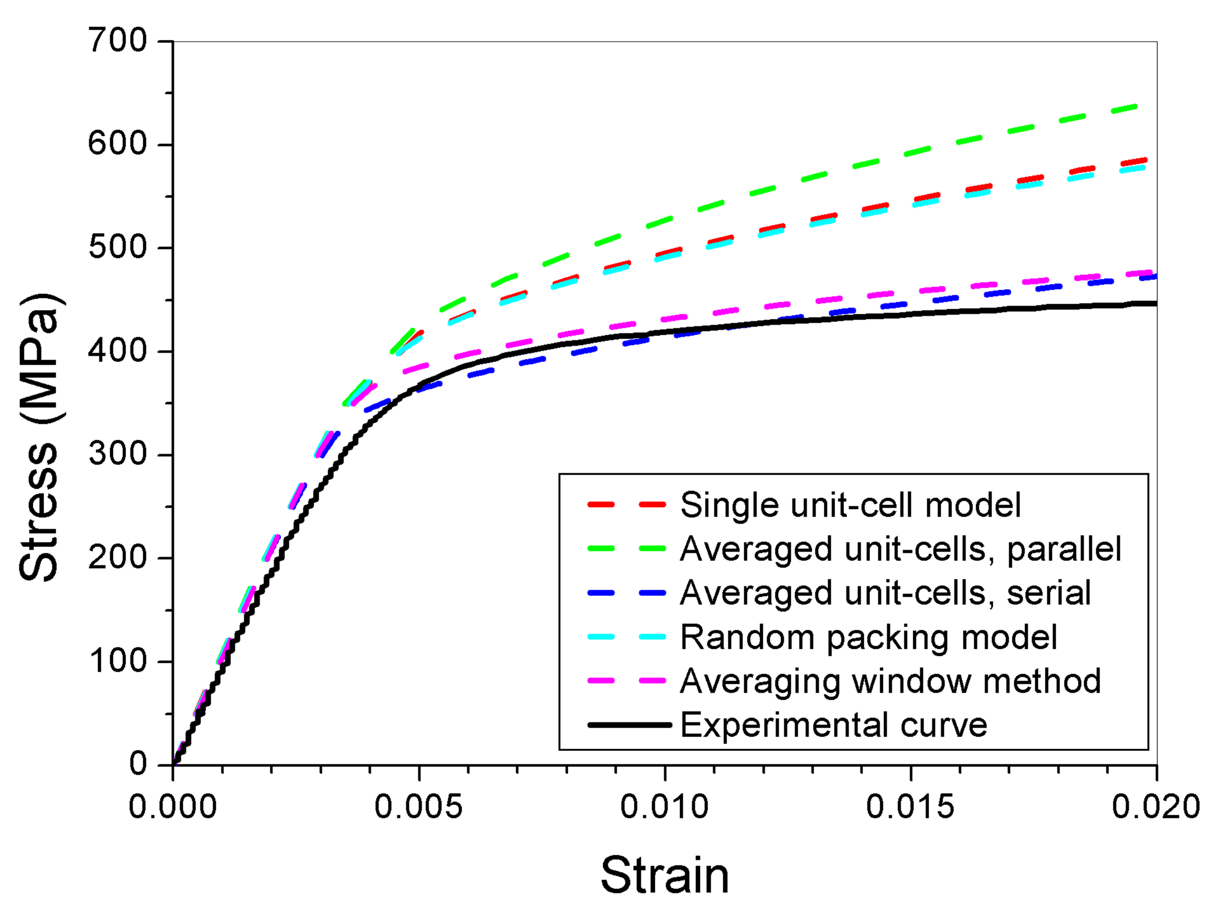

Fig. 4 Comparison of the calculated and measured stress-strain curves. The averaging window method is described in [2].

The models

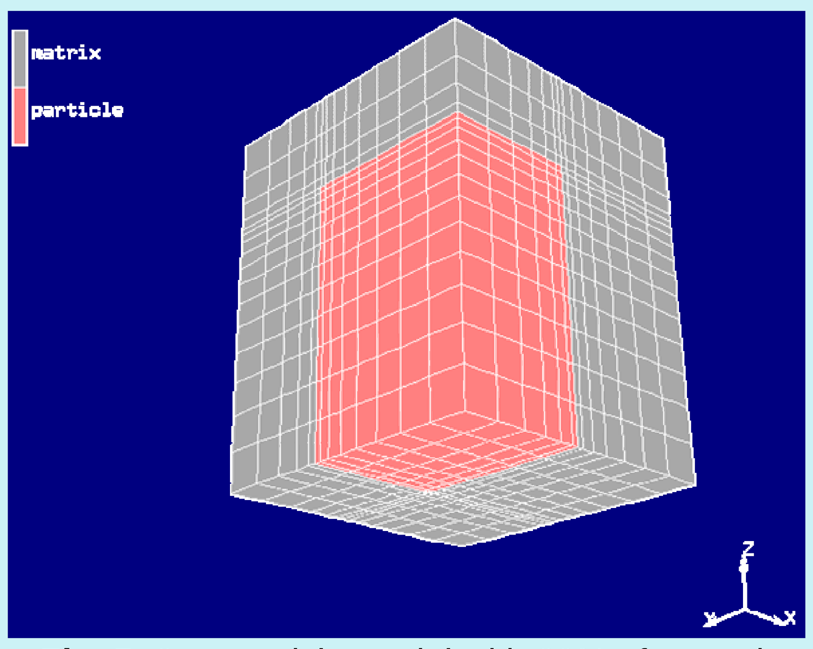

Fig. 5 One-particle model with 20% of ceramics (red) and 80% aluminium (grey)

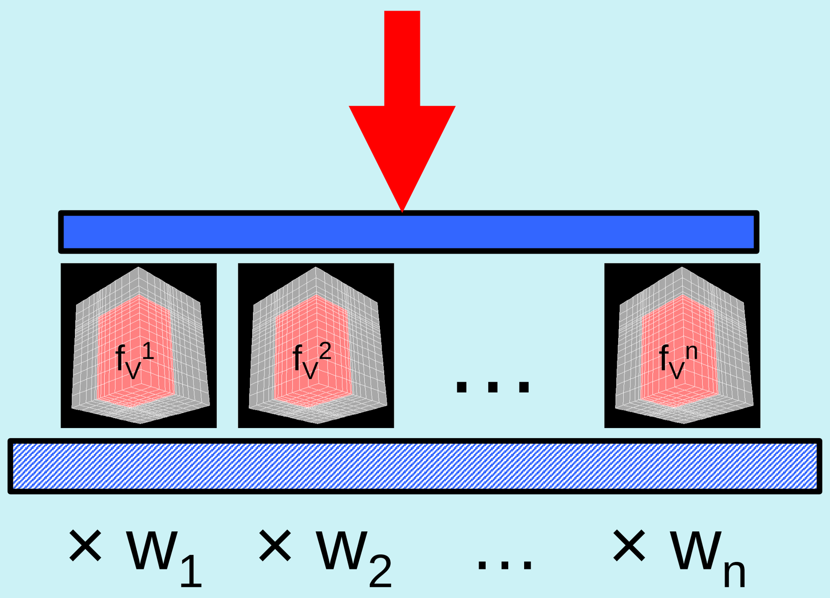

Fig. 6 Parallel averaging of one-particle unit-cell models using their volumetric distribution function as weights (w_1, w_2, ... w_n).

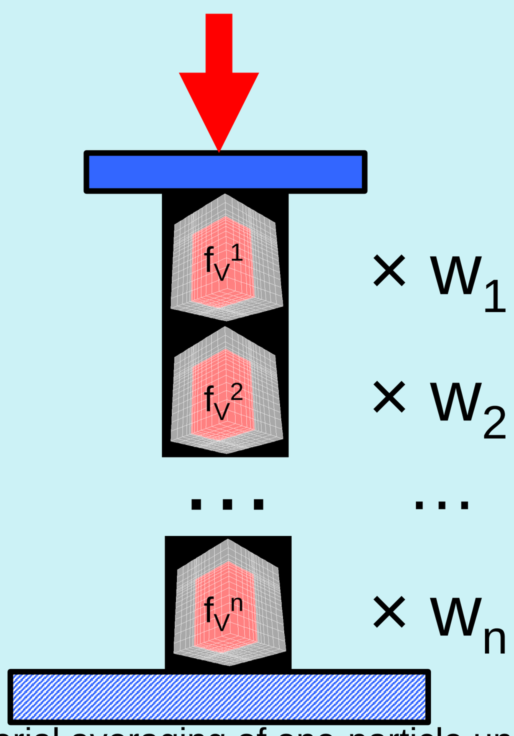

Fig. 7 Serial averaging of one-particle unit-cell models using their volumetric distribution function as weights (w_1, w_2, ... w_n).

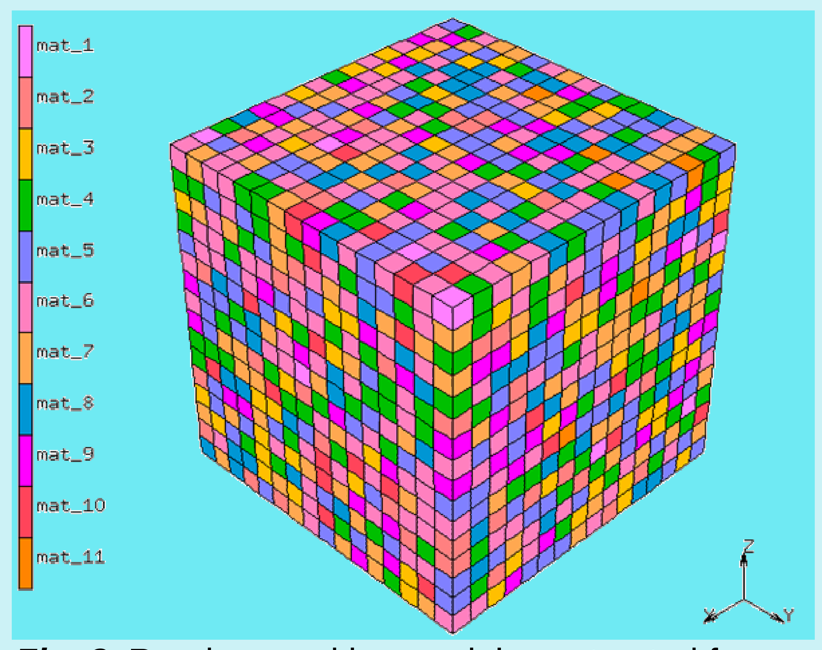

Fig. 8 Random packing model constructed from 11 different unit-cells (f_V = 1% … 40%) corresponding to the disribution of local volume fractions.

Conclusions

1. The one-particle unit-cell models give generally higher flow stress than the experimentally observed.
2. The serial (Reuss) averaging approaches better the experimental curve than the parallel (Voigt) one.
3. The random packing model gives nearly the same result as the one-particle model with the average volume fraction.
4. The averaging window method gives the most reliable results.

References

[1] A. Borbély, F.F. Csikor, S. Zabler, P. Cloetens, H. Biermann: Three-dimensional characterization of the microstructure of a metal–matrix composite by holotomography, *Mat. Sci. Eng. A* 367 (2004) 40–50

[2] P. Kenesei, A. Borbély, H. Biermann: Microstructure based three-dimensional finite element modeling of particulate reinforced metal–matrix composites, *Mat. Sci. Eng. A (2004), in press*

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