Al/SiC$_p$ Functionally Graded Composites Microtomography: Holotomographic Mode vs. Phase-contrast Mode

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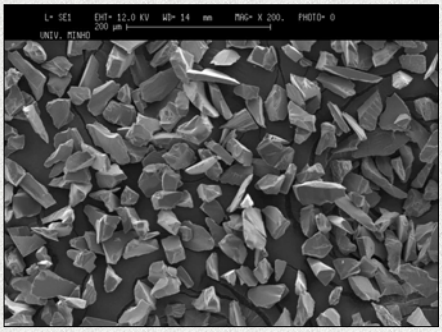
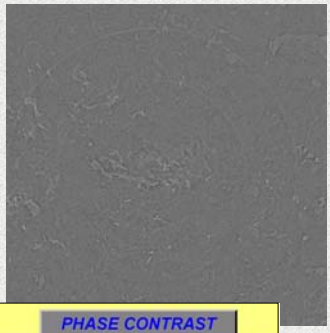
Abstract: For any Al/SiC$_p$ composite, the reinforcement distribution has a two-fold relevance. First, the presence of reinforcing particles is directly implied on the local mechanical properties, with reflection on the overall properties of the composite. On the other hand, the presence of reinforcement clusters will bring a higher probability of crack nucleation, i.e. fatigue failure. Furthermore, in the case of functionally graded composites (FGMMC's), which feature engineered gradual transitions in reinforcement volume fraction and/or size, the existence of both reinforcement-rich and reinforcement-poor regions is inherent to the very nature of the material; in such a case, a smooth transition between those regions must be assured, while at the same time avoiding particle clustering or total depletion. In order to assess the spatial distribution of the reinforcing particles in centrifugally cast Al/SiCp FGMMC's, two different microtomography experiments were performed at the ID19 beam line of the European Synchrotron Radiation Facility. In both cases, samples with a circular cross-section of ~1 mm diameter and 30 mm long were machined by EDM from the FGMMC's and analysed. The first microtomographic experiment resorted to the absorption contrast acquisition mode [1], and required the application of a specially developed segmentation procedure [2-4] before a 3-D reconstruction could be performed. A subsequent experiment, whose results are currently being exploited, was carried out with employment of the holotomography acquisition mode [1]. In the present work, the authors try to establish a preliminary comparison between the respective advantages and inconvenients of the two methods.

SiC particle morphology

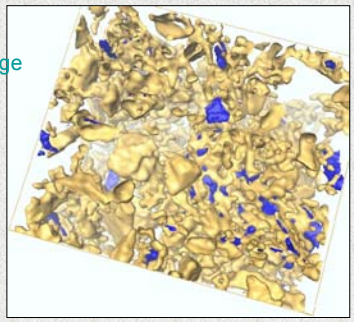


SEM image showing the true morphology of the reinforcing particles: sharp-edged particles, cuboid-like to platelet-like shaped.

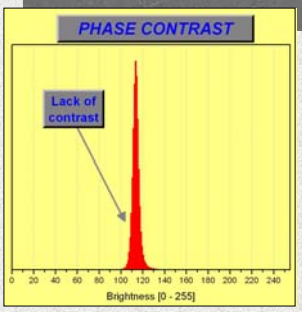
Absorption contrast tomography



Untreated slice image obtained from the absorption-contrast microtomographic experiment



3-D reconstruction of a 0.19^3 mm^3 volume, showing SiC particles (yellow) and some voids (blue) present in the material.

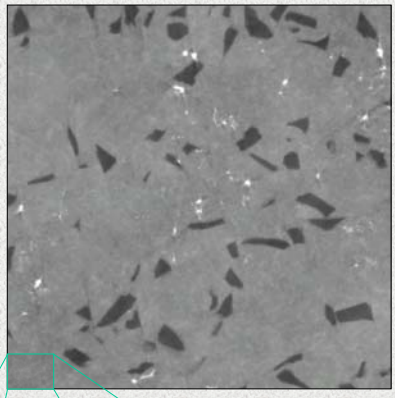


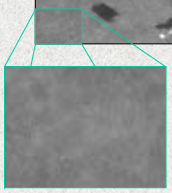
Brightness histogram from the phase-contrast slice image

Weak Al/SiC$_p$ contrast requires the use of a segmentation technique originally developed by Vignoles [2], exploiting the interference fringes occurring near the matrix/reinforcement interfaces. This treatment, however, tends to originate round-edged reconstructed reinforcing particles, as seen in the 3-D reconstruction above.

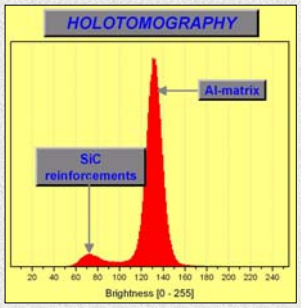
Holotomography

Untreated slice image obtained from the holotomographic experiment





Matrix microstructural details can be distinguished in the holotomographic slice image



Brightness histogram from the holotomographic slice image

Given the strong matrix/reinforcement contrast, no special segmentation procedure is expected to be needed. This circunstance, together with the already apparent sharpness of the reinforcing particle's contours, is expected to permit a more accurate morphology of the particle 3-D reconstruction. Furthermore, matrix microstructural details become distinguisheable, opening new prospects for the study of particle pushing/engulfment phenomena.

CONCLUSIONS

- In spite of the weak Al/SiC contrast, the segmentation applied to absorption contrast data allows the obtention of 3-D information about particle distribution in the FGMMC;
- The procedure introduces some morphological inaccuracy of the reconstructed particles;
- On the other hand, holotomograpic raw data exhibits much stronger Al/SiC contrast, and thus should permit a much more accurate 3-D reconstruction;
- Moreover, due to a reduced noise level, holotomography slices show matrix microstructural details;
- However, these advantages are countered by much increased acquisition time and data volume.

References

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