Report on “Residual stresses in Mg- and Al-matrix reinforced by continuous C-fibres” (MA57)

The thermal cycling behaviour of continuously and discontinuously reinforced Mg- and Al-based metal matrix composites (MMCs) has been thoroughly studied using dilatometry techniques [1-2]. The thermal mismatch due to the different coefficients of thermal expansion (CTE) of the constituents of the MMCs will generate internal stresses during heating and cooling of the composites that may eventually lead to the plastification of the matrix and shape change and/or damage of the composites [3]. Abnormalities in the CTE behaviour [1] as well as difference in the theoretical and measured volumetric thermal expansion have suggested to be originated by reversible opening and closure of micro-voids.

Our measurements at ID15a (MA57) aimed for the determination of the evolution of internal stresses as well as the measurement of the mentioned opening and closure of microvoids by means of diffractometry and tomography, respectively.

Following MMCs were investigated applying the indicated thermal cycles (the indicated temperatures correspond to a measurement step):

- **Al/C/65f:** 2 cycles RT → 60°C → 120°C → 60°C → RT + 2 cycles RT → 120°C → 160°C → 200°C → 160°C → 120 °C.
- **MgAl6/C/65f:** RT°C → 60°C → 120°C → 60°C → RT → 120°C → 160°C → 200°C → 160°C → 120°C → RT + 2 cycles RT → 120°C → 200°C → 240°C → 270°C → 300°C → 270°C → 240°C → 200°C → 120°C → RT.
- **AlSi12CuMgNi/Al_2O_3/15s:** RT → 120°C → 200°C → 240°C → 300°C → 240°C → 200°C → 120°C → RT.
- **AlSi7Mg/SiC/70p:** 2 cycles RT → 200°C → 300°C → 400°C → 300°C → 200°C → RT + 5 cycles ex situ between –100 and 400°C + RT → 200°C → 300°C → 400°C → 300°C → 200°C → RT + 25 ex situ cycles between –100 and 400°C + RT tomography

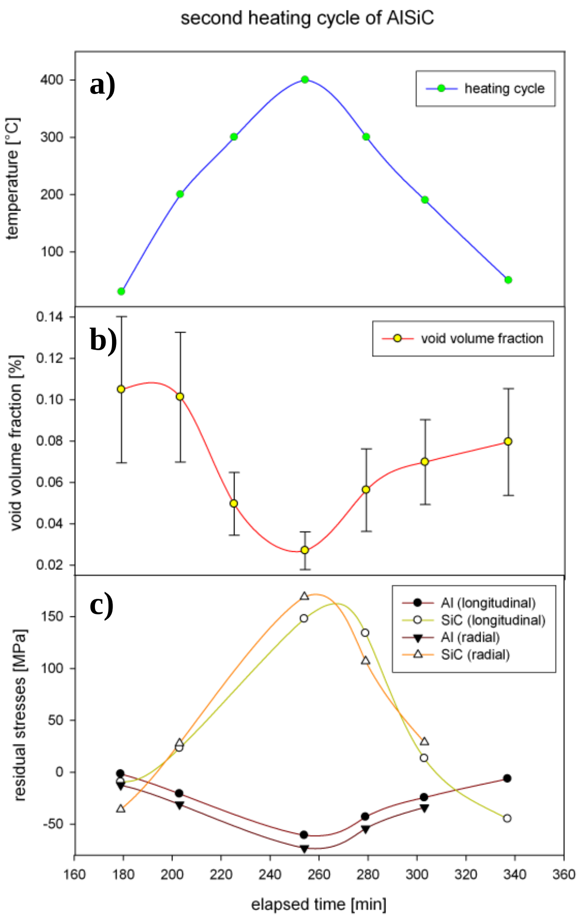

Figure 1. a) Temperature cycle applied during the second thermal cycle for AlSi7Mg/SiC/70p. b) Evolution of the pore volume fraction. c) Evolution of the internal stresses in Al and SiC both in radial and longitudinal direction

The corresponding unreinforced matrices were also measured by diffractometry at all investigated temperatures (without applying cycles) measured in order to be used as reference for the determination of the internal stresses. The results obtained for Al/C/65f, MgAl6/C/65f and AlSi12CuMgNi/Al_2O_3/15s are still in process of evaluation. The first results obtained for the AlSi7Mg/SiC/70p composite are shown in Figures 1 and 2. Figure 1 a) shows the temperature profile applied during the second thermal cycle. Figure 1 b) shows the evolution of the voids volume fraction as a function of temperature as obtained from the analysis of the tomograms. This is a remarkable result that confirms our hypothesis of viscoplastic opening and closure of pores during heating and cooling of MMCs and explains the already mentioned

anomalies observed during dilatometry [1-3]. The voids volume fraction is constant during heating up to a temperature of 200°C and then decreases reaching a minimum at the maximum temperature (400°C). During the cooling phase, the voids volume fraction increases again reaching a constant value at 200°C. Figure 1 c) shows the evolution of the internal stresses during the same temperature cycle measured both in radial and longitudinal direction. At the beginning of the cycle (RT), the residual stresses on the Al and SiC are negligible, while during the heating phase, tensile residual stresses are developed in the SiC phase that reach at 400°C. The Al matrix shows the development of compressive stresses in this part of this cycle with a maximum at 400°C, which originates partly from hydrostatic conditions in between the percolating SiC architecture [1].
Results of the tomography measurements are shown in Figure 2 for regions of 0.06 mm³. Figure 2 a) shows the pores of a sample at the beginning of the second thermal cycle and presents a pore volume fraction of 0.14 % (see Figure 1 a), while Figure 2 b) shows the results for the same sample after 25 thermal cycles between –100 and 400°C where the pore volume fraction has increased ten times to 1.4%. This is due to void formation by damage of the matrix and by decohesion of the interface between Al and SiC particles [4-5]. The results for the continuously reinforced materials will be the subject of [6].

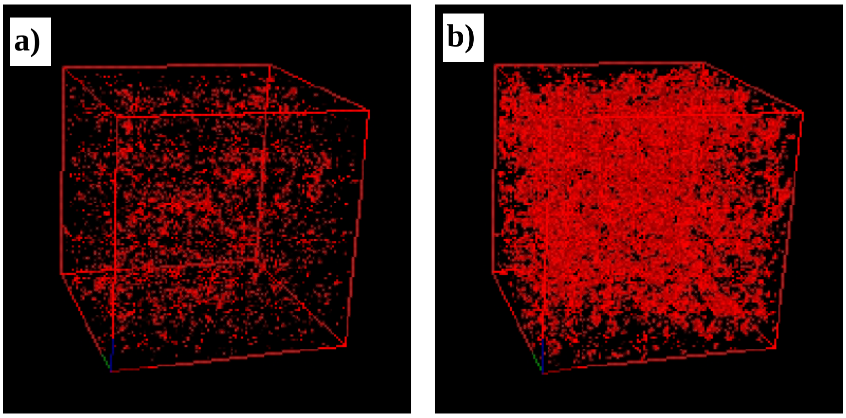

Figure 2. Comparison of the pore volume fraction for an AlSi7Mg/SiC/70p sample (a)at the beginning of the second thermal cycle (0.14 vol%) and (b) after 25 thermal cycles between –100 and 400°C reaching 1.4 vol%.

References

[1] T. Huber, H. P. Degischer, G. Lefranc, T. Schmitt, *Thermal expansion studies on aluminium-matrix composites with different reinforcement architecture of SiC particles*, Composites Science and Technology, 66, 2006, 2206-2217.

[2] A. Mohammed, H.P. Degischer, *Thermal expansion behaviour of long fibre reinforced Al- and Mg-based metal matrix composites*, Composites Science and Technology, submitted.

[3] U.Göbel, A.R.Pyzalla, G.Lefranc, H. P.Degischer, *Internal stress and porosity distribution in AlSiC heat sink materials*, Composites Science and Technology, in preparation.

[4] G. Requena, M. Schöbel, H. P. Degischer, *Thermal expansion behaviour of a SiCp reinforced Al alloy using synchrotron radiation*, Composites Science and Technology, in preparation.

[5] M. Schöbel, G. Requena, H. P. Degischer, *Voids in MMCs and their effects on thermal expansion*, Progress Report Extremat, TU-Vienna, 2006.

[6] G. Requena, H. P. Degischer, M. Schöbel, T. Buslaps, M. Di Michiel, *Study of internal stresses evolution and damage in Al and Mg based continuously reinforced MMCs during thermal cycling using synchrotron radiation*, Composites Science and Technology, in preparation.