Title: Strain development during thermal cycling of metal matrix composites

Experiment: HC 247

Beamline: ID/l 1 BL-2

Date of Expt: 18/9/95 - 21/9/95

Shifts: 6

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The two phases of a metal matrix composite (MMC) will typically have widely differing coefficients of thermal expansion. As a result, when an MMC undergoes a change in temperature, the different thermal expansions cause misfit strains and induce internal stresses. During continued thermal cycling under even small applied loads, large scale macroscopic deformations can occur. Long term diffraction based studies of thermal cycling in MMCs have already been carried out by the authors ‘ , and the aim of this experiment was to monitor transient internal strain development during the initial thermal cycling of a metal matrix composite under an applied load.

The composite was commercially pure aluminium reinforced with 10vol% silicon carbide whiskers (all in the cubic form), produced by a powder and extrusion route, then machined into specimens of 3mm gauge diameter and 15mm gauge length. The thermal cycle was imposed through the use of a portable infra-red furnace with cooling by directed jets of nitrogen gas. The temperature was monitored via a thermocouple placed in a hole drilled into the specimen shoulder 2. A 0.5 mm x 0.5 mm beam cross section was employed, entirely within the bulk of the specimen, at the 80keV (O. 155Å) setting. Measurements were made using the CCD camera, allowing the whole of both the Al (111) and SiC (111) diffraction cones to be monitored.

The high flux gave extremely short count times of between 0.05s and 1.4s, due to the advantageous texture produced by the extrusion processing route. This allowed the monitoring of strain development with high time resolution throughout the cycles. Typically measurements were taken at 15 second intervals. A range of cycles with various temperature excursions between 175°C and 400°C were employed. Ramp rates of 50 °C/minute, dwell times of O to 180 seconds and loads varying from 25MPa to 45MPa were used. Typical results are shown in Fig. 1 for the elastic strain of the Al matrix, with stress free thermal expansion effects $\alpha\Delta T$ removed, during a 175-325°C cycle under a 35MPa tensile load. The transients which occur over the first 3-4 cycles are clearly seen. The Eshelby based prediction shown is for an aspect ratio 5 ellipsoid reinforcement and represents the gradient of misfit strains generated in a completely elastic system.

These elastic misfit strains dominate the internal strain response. As the specimen heats up the matrix goes into compression due to the constraint imposed by the reinforcement's lower coefficient of thermal expansion, then the reverse occurs as the specimen cools. There are also inelastic processes occurring at the top of the heating ramp (creep and localised plasticity) and base of the cooling ramp (bulk plasticity) as evidenced by a departure from the elastic predicted gradient. These are especially pronounced at the top of the first heating ramp.

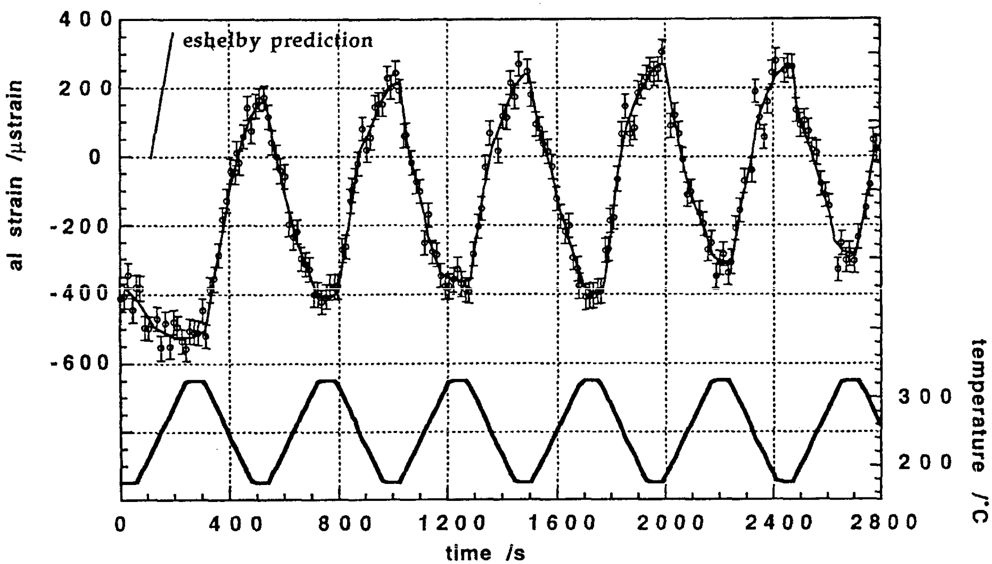

Fig. 1: Internal strain of Al during a 175-325°C cycle, with 35MPa tensile load. Stress free thermal expansion effects have been removed. A ramp rate of 50°C/min, and a 60 second dwell time was used.

In the past neutron diffraction studies have revealed time changes averaged over many cycles using a stroboscopic data collection method. This is the first time that measurements of this resolution have been possible, allowing the changes in individual cycles to be resolved, and has been achieved because of the very fast data accumulation rates at the ESRF.

1. M.R. Daymond and P.J. Withers. in *Int. Con. on Composite Materials IO. 1995.* Conference, 621-628, Location: Whistler, Canada, Woodhead.
2. M.R. Daymond and P.J. Withers, Scripts Met, 1996. *To be published.*
3. P.J. Withers, W.M. Stobbs and O.B. Pedersen, Acts metall. mater., 1989.37: p. 3061-3084.