ESRF	**Experiment title:** Internal stress development in high-strength metal matrix composites	**Experiment number**: ME531
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Report:

Metal Matrix Composites (MMCs) are of increasing engineering importance due to their enhanced physical properties and are of particular interest to the automotive and aerospace industries. In this experiment we conducted a series of experiments on load sharing in novel steel-based MMCs.

Steel-based metal matrix composites reinforced with TiB_2 offer a significant increase in modulus (for 25% volume fraction reinforcement E = 242 GPa compared to 190 GPa for an unreinforced steel; for a typical aluminium MMC with similar SiC volume fraction E = 125 GPa). Initial research has shown that this increase of modulus produces an improvement in fatigue resistance; additional improvements are also noted in wear resistance and hardness. The inclusion of a reinforcing particle also produces a reduction in density (up to 18% reduction).

The material used in this investigation was supplied by Aerospace Metal Composites, UK, and was produced by a mechanical alloying, powder metallurgy route. Three materials were tested: unreinforced 316L stainless steel, W14418 steel reinforced with 10% TiB_2 and 316L steel reinforced with 25 % TiB_2.

The composites were subjected to two further heat treatments;

- A- 3 hours @ 1040°C and water quench followed by a further 4 hours @ 550°C and air cooled.
- B- 3 hours @ 1040°C and water quench followed by a further 1 hour @ 480°C and air cooled.

The effects on load transfer between the matrix and the reinforcement of the different heat treatments for both metal matrix composites was investigated using the synchrotron source. A variety of different tensile and cyclic tests were conducted in strain control to investigate fully the load transfer between the matrix and the reinforcement. All the materials were first strained to failure at two different strain rates. Tension-tension cycling for 5 cycles with either 0.2% or 2% plasticity was also performed for the MMCs. Separate tests were performed for measuring both the axial and transverse strain components, so allowing for calculation of the full internal stress field.

The data obtained allows us, in general, to analyse two peaks from each phase of the composite. We therefore have the possibility of investigating the development of intergranular strain in the matrix as well as inter-phase stresses between the Fe and TiB_2.

The data analysis so far has concentrated on the monotonic strain-to-failure tests (see figures below). The results show that:

- There is effective load transfer between the matrix and reinforcement, almost exactly as predicted by an Eshelby model for this composite system in the elastic region.
- The evolution of strain during plasticity shows a redistribution of load from reinforcement to matrix (exhibited by the change in slope after ~500 MPa applied in figure 1), though the stress in the reinforcement increases sharply as shown in figure 2.
- Differences in the behaviour of different crystal planes in the Fe can be seen in figure 1: the (200) is softer than the (111), as is well-known for this system. Accounting for the different plane stiffnesses in calculation of the internal stresses gives comparable macrostresses as seen in figure 2.

Future work will concentrate on the evolution of the internal stresses during full tension-compression cycling of the materials, which is needed in order to shed light on data obtained from complementary evaluation of their fatigue properties.

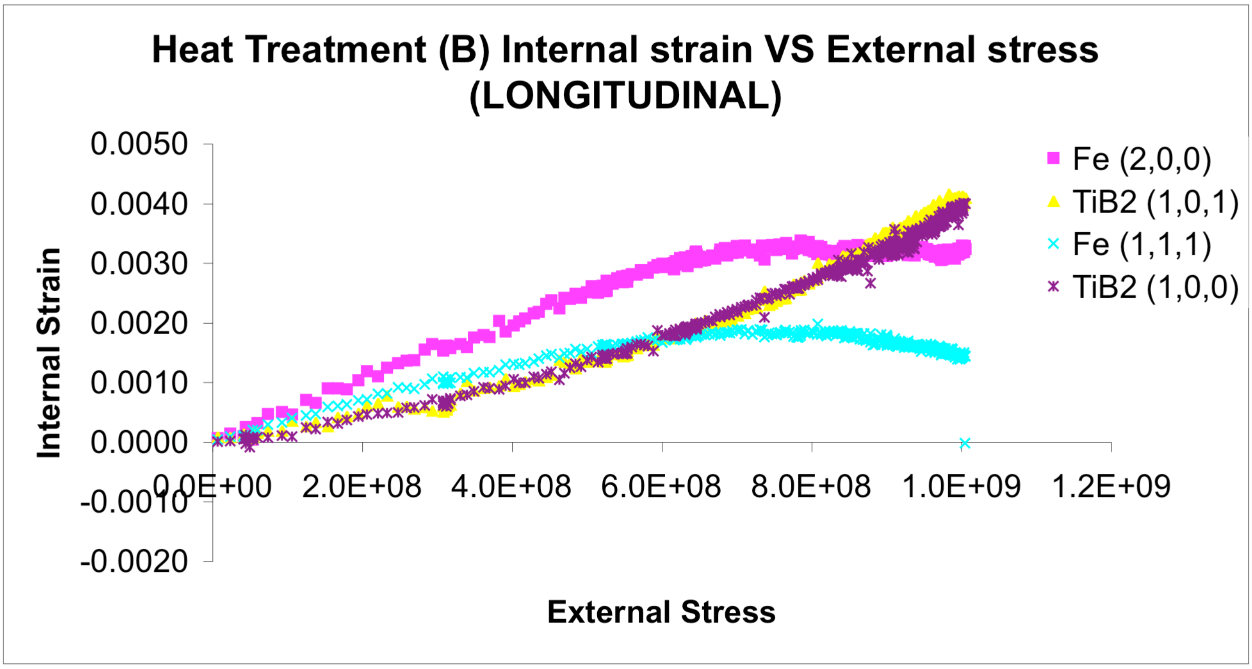

Figure 1- measured longitudinal internal strains in both phases of a 316L/25% TiB_2 metal-matrix composite (transverse strains were also measured but are not shown here)

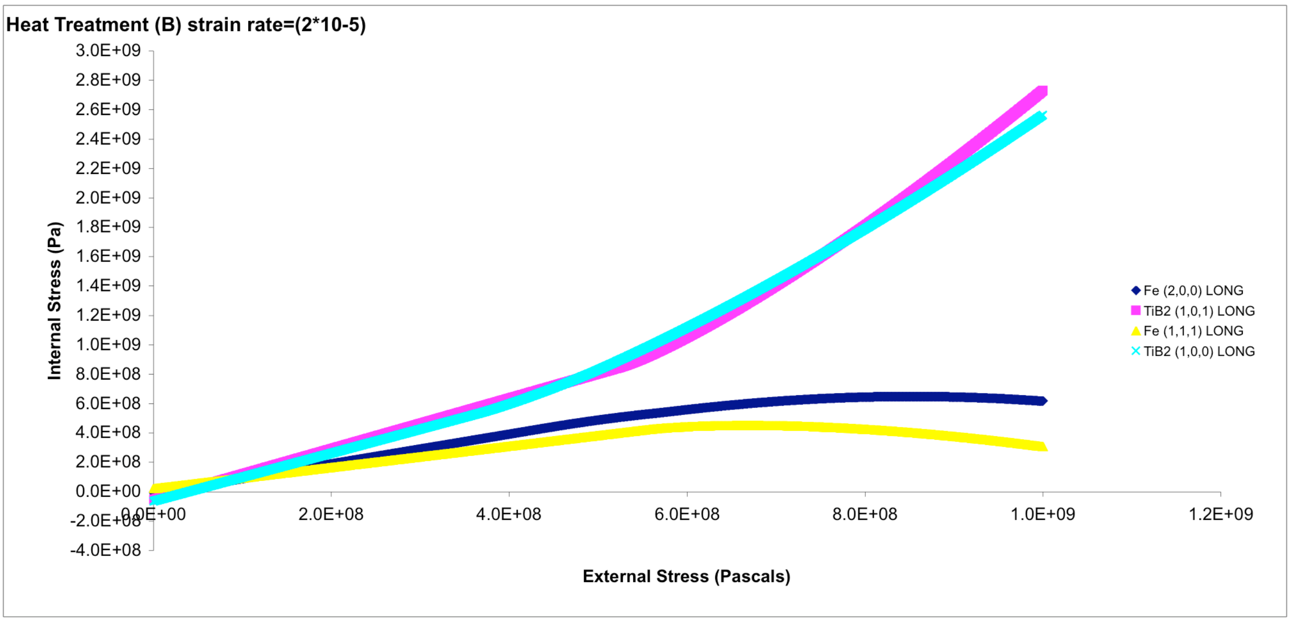

Figure 2: Calculated longitudinal internal stresses in both phases of the composite The stresses in the elastic region are as predicted from Eshelby modelling. The data is obtained by calculation on smooth fits to the measured strains