

Interdependencies Between Mechanical Properties and Microstructural Development During One-Dimensional Shock Loading

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The mechanical response of materials under shock loading conditions is governed, as indeed it is at lower strain-rates by events occurring at the microstructural level. However, since shock loading experiments occur under conditions of one-dimensional strain (rather than the more familiar onedimensional stress of quasi-static loading conditions), the generation of useful, quantitative microstructural information is a non-trivial exercise. In a simple plate impact experiment, releases from the edge of the target assembly travel into the centre, taking the target into a complex three-dimensional strain-state, rendering meaningful microstrutural analysis difficult or even impossible. As a consequence, the target assembly must contain a series of momentum trapping rings around the region of interest, the interfaces of which will open up during the passage of release waves, which prevents their subsequent transmission. A typical recovery target assembly is shown in figure 1, based upon the work of Gray and his colleagues [1-2].

A further complication occurs due to the fact that plate impact experiments are generally performed using either propellant or gas driven gun systems. A natural consequence is that a great deal of forward momentum is imparted, both to the target assembly, and from the flyer plate and the polymer sabot it is attached to. To prevent these parts damaging the sample, they must be prevented from following the same path, and this is generally achieved by allowing the sample to progress down a narrow channel in a series of heavy steel plates. All other experimental components, including the flyer plate, sabot and momentum trapping rings are caught by these plates, thus preventing further impact damage. Finally, the sample will have been adiabatically heated during shock loading, although the subsequent release will cool the sample somewhat. However, there will be a degree of residual heat, which can potentially alter the resultant microstructure. Therefore, the sample needs to be quenched, using either a series of water soaked rags, or a mixture of hydrated sodium polyvinylacetate and wood pulp.

In the case examined here, the initial microstructural state of the aluminium alloy 6061 is used as an example [3]. Two sets of experiments were performed; one measured the shock induced shear strength, whilst the other was used to observe the shock induced microstructure. It can be seen from figure 2 that the structure of the lateral stress gauge traces is different between the two microstructural states. The solution treated state shows a faster rise time, with a more pronounced drop in lateral stress behind the shock front, showing that shear strength increases [4] more with time in the solution treated state than in the aged. However, determination of the shear strengths indicates that the shear strengths of both states are similar.

However, microstructural examination reveals significantly different behaviours (figure 3). In the case of the solution treated state, the shocked microstructure (in this case to a shock pressure of 3 GPa) is shown to consist of a series of dislocation cells, typical of a face centred cubic metal with a high stacking fault energy. In contrast, the aged material, when shocked to a similar pressure, shows a more randomised dislocation structure, along with some planar features as well. It has been suggested that the

