Local deformation behaviour of pure magnesium under dynamic loading

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Abstract. The local deformation mechanism of pure magnesium was investigated using recently developed experimental method utilizing in-situ Digital Image Correlation (DIC) technique. This method was first developed to measure the local deformation mechanism in energetic material and now been extended to characterize the microstructural response of magnesium at in the vicinity of multiple grain boundaries and triple junctions. As expected, the local deformation was highly heterogeneous with the highest concentrations of the localized response was occurred primarily at the interfaces between the grains. Also, the contribution of deformation at the interface to the overall deformation of the interest area was substantial. The amount of in-grain deformation was affected by the grain size, the larger grains shown minimal deformation by comparison.

Introduction

Magnesium and its alloys have been widely used in many engineering applications mainly in aerospace and automotive industry [1]. Such material is subjected to high strain rate loading during application. Most engineering materials are sensitive to loading rate, and the strain rate sensitivity usually related to the grain size, orientation and overall coarseness of the grains [2]. In order to understand the mechanical response of such materials, measurements at the microstructure scale size is essential. Recently, the local deformation of heterogeneous materials at dynamic loading condition has have been effectively measured using in-situ DIC [3, 4]. In this paper, the method is extended to polycrystalline metal, and the local deformation behaviour of pure magnesium subjected to dynamic loading is investigated.

Experimental Method

Specimen Preparation

Nominally pure (99.9%) as-cast magnesium with grain size about ~500-1000 μm of was used in the present work. A cubic sample with dimension 12×12×12 mm3 was cut the as received material using a band saw and machined to its final dimensions using a milling instrument. In order the microstructure to be cleary visible, the surface of the sample was polished using sandpapers and alumina powders.

For DIC measurement, using a flat white paint and a black carbon powder with a nominal size of 10 μm the surface was speckled.

Experimental Setup

A Hopkinson bar made of a 25 mm diameter stainless steel, incident and transmitter bars was used. The length of the two bars was 1.82 m. A stainless steel striker bar was propelled towards the indent bar by the help of an inert helium gas gun. The deformation of the specimen, held in place between the incident and transmitted bars, was captured in-situ using an ultra-high-speed CCD camera (HPV-X2, Hadland Imaging) at 500,000 frames per second with an exposure time of 1700 ns, while illuminated by a Photogenic flash lamp. Strain gauges attached to the bars were used to measure the incident, reflected and transmitted wave signals.

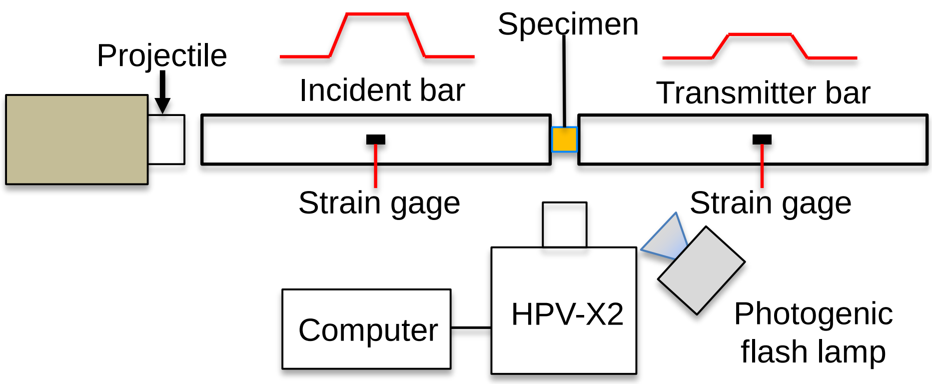

Fig . Experimental Setp up (Hopinson bar with high speed imaging)

Results and Discussions

Typical deformation profile of magnesium specimen subjected to dynamic loading is shown in fig2.

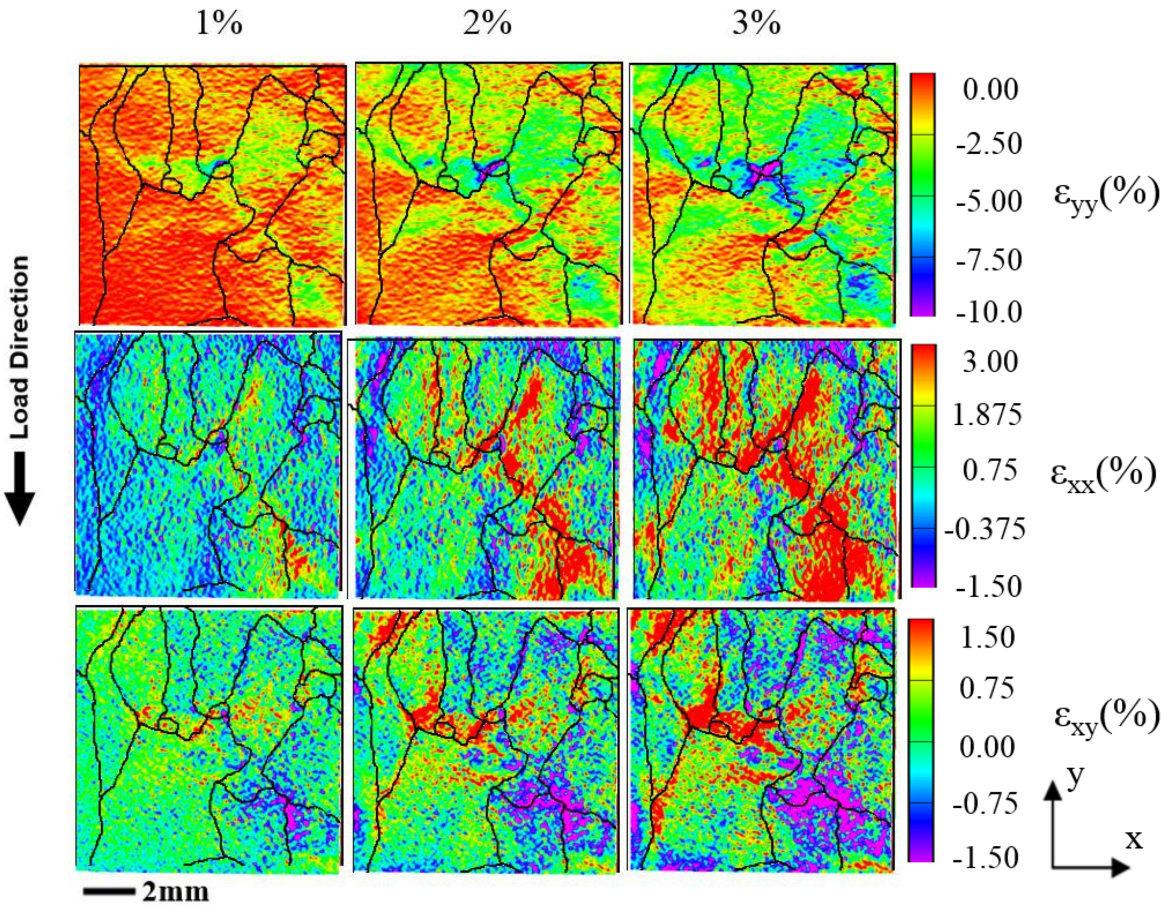

Fig.2. Typical local full field strain in pure magnesium

As shown in fig 2 the deformation is heterogeneous and localized in the grain boundary region mainly at triple junction points. It was also observed that the deformation inside big grains is relatively small, indicating the size of the grain has influence on the local deformation of magnesium.

Summary

DIC base experiment is developed and used to understand the deformation mechanism of pure magnesium subjected to high strain rate loading. It was proved that DIC-based method is an effective method to exclude local deformation at grain-scales under dynamic loading conditions. The observed phenomena can be summarized as;

- The deformation at dynamic condition shows high activity at triple junctions
- High strain localization is captured mainly at the boundaries
- Axial strain concentrations in large-grained do not appear until later stage of the loading
- Localization initiation appears sooner in multi-scale grain structure

References

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