Data Article

Data on measurement of the strain partitioning in a multiphase Zn-Al eutectic alloy

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**Abstract**

This paper presents original data related to the research article “Local mechanical properties and plasticity mechanisms in a Zn-Al eutectic alloy” (Wu et al., 2018). The raw data provided here was used for in-situ digital image correlation on the microstructural level using a new method described in the related study. The data includes sample preparation details, image acquisition and data processing. The described approach provides an approach to quantify the local strain distribution and strain partitioning in multiphase microstructures.

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**Specifications table**

| Subject area       | Physics          |
|--------------------|------------------|
| More specific subject area | Materials science |
| Type of data       | Micrographs and tables |
| How data was acquired | *FEI Helios Nanolab 600i scanning electron microscope at an acceleration voltage of 3 kV with an in-lens secondary electron (SE) detector* |

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Data format | Raw data
---|---
Experimental factors | A monolayer of SiO$_2$ particles with average particle size of 40 nm was dispersed on the specimen surface.
Experimental features | Quasi in-situ tensile tests were performed at 85 °C at a constant strain rate of 5 × 10$^{-4}$ s$^{-1}$. The tests were interrupted at 2% and 5% global engineering strain.
Data source location | Institute of Physical Metallurgy and Metal Physics, RWTH Aachen University, D-52056 Aachen, Germany
Data accessibility | With this article and on Mendeley: http://dx.doi.org/10.17632/y269sfgw6m.1
Related research article | [1] Z. Wu, S. Sandlöbes, R. Jing, J.S.K.L. Gibson, B. Berkels, S. Korte-Kerzel, Local mechanical properties and plasticity mechanisms in a Zn-Al eutectic alloy, Materials and Design, 157 (2018) 337–350.

Value of the data

- The data shows quantitative and qualitative descriptions of the local strain partitioning in a multiphase Zn-Al eutectic alloy, which may give indications for the strain partitioning in other multicomponent materials.
- Combination of DIC and SEM enables the measurement of strain partitioning at a very high resolution.
- The data provides a water-free method of how to deposit SiO$_2$ particles suitable for DIC measurements on a specimen surface.
- The particle disposition method may be expanded to other materials that are reactive with water.

1. Data

This data set contains 189 high-resolution in-lens SE micrographs of a ZnAl$_4$Cu$_1$Mg$_{0.31}$ (wt%) specimen showing the microstructural evolution during tensile deformation. At each deformation step, the same region of interest (ROI) was observed using SEM. Fig. 1a shows a backscattered electron (BSE) overview micrograph of the region of interest (ROI) prior to deformation. To ensure sufficiently high resolution of the micrographs, the ROI was divided into subsets of 7 × 9 micrographs, as described in Table 1. Fig. 1b shows the spatial distribution of these individual micrographs. Fig. 2 presents individual SE micrographs in the region of interest.

2. Experimental design, materials, and methods

2.1. SiO$_2$ particles speckle deposition

μ-DIC measurements were performed using dog-bone shaped specimens with a gauge length of 3.56 mm and a centre cross-section of 1 × 1.5 mm$^2$. A monolayer of SiO$_2$ particles with an average particle size of 40 nm was dispersed on the specimen surface, Fig. 3. Table 2 gives the detailed procedure of pattern deposition, all steps were performed water-free.

2.2. Image acquisition

A universal electromechanical testing machine (DZM) was used to deform a sample with deposited SiO$_2$ particles at 85 °C and a constant strain rate of 5 × 10$^{-4}$ s$^{-1}$ to 2% and 5% global engineering strain. SE micrographs of the samples were obtained prior to deformation and after 2% and 5% global
strain, respectively, at an FEI Helios Nanolab 600i scanning electron microscope. To achieve micro-
graphs suitable for \( \mu \)-DIC processing, the images were achieved with an in-lens SE detector, a low
beam voltage of 3 kV and a small working distance of 3 mm \([2,3]\). A region of interest with an
area of 300 \( \times \) 255 \( \mu \)m\(^2\) was identified prior to deformation and divided into 7 \( \times \) 9 subsets each
having a resolution of 1536 \( \times \) 1024 pixels (51.8 \( \times \) 34.5 \( \mu \)m) with 20% overlapping between two
adjacent images in both horizontal and vertical directions, Fig. 1.

2.3. \( \mu \)-DIC processing

We applied two different approaches of calculating the local strain distribution and strain partition-
ing from the deformation microstructures based on (i) the commercial software GOM Correlate,
and (ii) non-rigid image registration.
The images were analysed using the software GOM Correlate (V8.1, GOM mbH) with a facet size of 17 x 17 pixels and a point distance of 10 pixels, which corresponds to a facet size of around 0.5 x 0.5 \( \mu \text{m}^2 \), and an overlap of 40% between the facets.

Non-rigid image registration was applied as an alternative approach to estimate the local deformation. To register a deformed image to the original undeformed image, we used the multi-level non-rigid registration approach as described in [4]. Instead of the Dirichlet energy used in [4], we used a hyperelastic regulariser [5] to account for the highly non-linear structure of the local material deformation. This also required the replacement of the Gauss quadrature by a Simpsons quadrature to ensure that the energy stays finite when the estimated solution is prolonged from one level to the next, finer level. In addition, the approach described in [4] was generalised to non-dyadic grids.

Fig. 2. High magnification in-lens SE images in the region of interest (ROI) in alloy ZnAl4Cu1Mg0.31 after 2% global strain at positions (a–c) 17–19; (d–f) 26–24; (g–i) 31–33 and (j–l) 40–38. The locations are illustrated in Fig. 1. The scale bar of all images is given below (l).
A dyadic grid is a quadratic grid with 2^k nodes in each coordinate direction) following [6], i.e. the full resolution data were downsampled to the largest dyadic grid that is smaller than the full data grid. Then, the registration algorithm for the dyadic case was applied. Its result was resampled to the full data grid and used there as the initial value. Finally, on the full resolution grid, the minimisation was done using the Quasi Newton BFGS algorithm instead of a regularized gradient descent.

The 2-D equivalent von Mises strain was calculated using Eq. (1) [7]:

\[ \varepsilon_{eq} = \sqrt{\varepsilon_{xx}^2 + 2\varepsilon_{xy}^2 + \varepsilon_{yy}^2} \]  

Assuming (u, v) are the components of displacement of an arbitrary point in x- and y-directions, the strains \( \varepsilon_{xx} \), \( \varepsilon_{yy} \) and \( \varepsilon_{xy} \) were obtained through Eqs. (2)–(4) [8]:

\[ \varepsilon_{xx} = \frac{\partial u}{\partial x} + \frac{1}{2} \left[ \left( \frac{\partial u}{\partial x} \right)^2 + \left( \frac{\partial v}{\partial x} \right)^2 \right] \]  

\[ \varepsilon_{yy} = \frac{\partial v}{\partial y} + \frac{1}{2} \left[ \left( \frac{\partial u}{\partial y} \right)^2 + \left( \frac{\partial v}{\partial y} \right)^2 \right] \]  

\[ \varepsilon_{xy} = \frac{1}{2} \left( \frac{\partial u}{\partial y} + \frac{\partial v}{\partial x} \right) + \frac{1}{2} \left( \frac{\partial u}{\partial x} \frac{\partial v}{\partial y} + \frac{\partial u}{\partial y} \frac{\partial v}{\partial x} \right) \]
Acknowledgments

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Transparency document. Supporting information

Transparency data associated with this article can be found in the online version at http://dx.doi.org/10.1016/j.dib.2018.09.010.

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