Strain mapping during in-situ tensile loading using FIB-DIC

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When multi-phase alloys are exposed to mechanical loading, the strain distribution in the microstructure is rather inhomogeneous, due to different behavior of various phases. This affects the overall mechanical behavior of the material. Thus, in order to optimize material properties, it is crucial to have a detailed understanding of its behavior in microstructural level. Digital image correlation (DIC) has been used for measuring local strain distributions on the microstructure of various metallic alloys. In such a method, a speckle pattern is applied on the microstructure of the material before deformation. By mechanical loading, the pattern would follow the material deformation. Thus, by tracking the speckles in the pattern during deformation, it is possible to quantify the amount of mechanical strain. Nevertheless, in order to quantify strain in or around small microstructural features, it is important to use fine and randomly distributed speckles. Various techniques have been used to provide fine patterns such as fine painting on the microstructure or pit etching [1]. Despite their versatility, these methods have drawbacks, such as masking the microstructure beneath in painting or not being applicable for all materials in etching technique.

Focused Ion Beam (FIB) milling is a technique with sub-micron resolution that can provide homogeneous and controlled speckle patterns on any type of material, making it an attractive alternative for other speckle-pattern-making methods [2].

In this study, the FIB milling was used to generate micron size speckles with controlled geometry and dimensions on different types of metallic alloys. Scanning Electron Microscopy (SEM) was used for imaging, in order to provide suitable resolution. Match-ID software was used to quantify the strain on the material.

The effect of possible thermal drifting, due to SEM imaging, on the strain measurement was also investigated. An Al-Si alloy was investigated as a case study, since it has a multi-phase structure and is commonly used in many applications. After casting the alloy, the dog-bone-shape specimens were produced and finely polished. After applying the speckle pattern in a 300x300um area, the samples were loaded in the tension mode. The amount of local and overall strain was measured and compared. Local strain maps varied by changing the shape and morphology of secondary phases in the microstructure. It was shown that the softer phases in the microstructure take more of the strain during loading, while the more brittle phases do not participate much in overall plastic deformation.

It was shown that FIB-DIC method can provide proper speckle patterning for a high-resolution strain mapping during mechanical loadings, which is essential to investigate in order to optimize materials' microstructure and overall behavior.

References

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