ICSMA19 Metz, France, June 26 - July 1, 2022
International Conference on Strength of Materials

Strain localisation in engineering alloys – quantifying discrete shear to improve understanding of strain hardening and crack initiation

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For many technologies, the degradation of materials presents significant and ongoing challenges, limiting the performance, operational life, and sustainability of assets. Materials often fail mechanically and our understanding and capabilities to predict such failures are still very limited. Plastic deformation in alloys is typically highly localised creating stress concentrations at the microstructural scale that can lead to premature failure particularly during cyclic loading. The discrete shear develops into heterogeneous strain patterns, which might depend on microstructural parameters, and which will affect strain hardening and crack initiation. Part of the challenge here is the wide range of length scale we need to consider while also quantifying very discrete shear.

Recent advancements in imaging nano-patterned mechanical test samples in a SEM for high resolution digital image correlation (HRDIC) and combining such data with grain orientation information from EBSD has opened new possibilities of understanding the impact of alloy chemistry and microstructures on the degree of strain localisation that develops during monotonic or cyclic loading. During my talk I will first present some examples of utilising HRDIC to quantify the effect of alloy chemistry and microstructures on the degree of strain localisation that raises interesting questions related to solid solution strengthening and other aspects. I will also discuss the potential of using HRDIC to determine shear directions within slip trace, which will be crucial in understanding strain pattern development, and slip trace evolution leading to crack initiation.

Finally, I will provide an outlook of the direction of travel with the development of fully integrated in-situ SEM systems enabling the automation of the complex imaging/loading procedures. This approach now allows us to capture strain pattern development from the earliest stage of plasticity, which will be used to understand strain hardening in relation to strain pattern development.

Keywords: discrete shear, in-situ analysis, strain patterns, digital image correlation