MINIATURIZED FRACTURE EXPERIMENTS ON PEARLITIC STEEL: CHALLENGES AND SOLUTIONS

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Pearlitic steels with their lamellar microstructure of thin Fe_3C lamellae embedded in the α-Fe matrix finds multiple applications from railway steels to thin wires. During service as railway steels or during wire drawing a refinement and modification of the microstructure occurs due to the exposure to severe plastic deformation. The Fe_3C lamellae are thinning and the α-Fe matrix becomes supersaturated with C turning it in body centered tetragonal structure which corresponds to martensite as we recently resolved by combining atom probe tomography and synchrotron experiments [1]. Severe wire drawing also reduces the wire diameter down to ca. 20 µm which prevents conventional mechanical fracture testing, thus requiring miniaturized fracture approaches. Similarly, at the surface of railway steels the lamellar microstructure decomposes and martensite formation together with Fe_3C dissolution is observed leading to a so called white etching layer.

In this talk we summarize our recent results on small scale fracture testing of white etching layers on pearlitic steels and pearlitic wires cold drawn upto 520%. The changes in fracture behavior upon annealing of a 420% deformed wire are monitored and brittle to ductile transitions linked to the microstructure evolution. The experiments also show the limits of linear elastic fracture mechanics to probe reliable and meaningful fracture toughness values. The elasto-plastic fracture toughness for the 320% drawing strain sample (see Fig. 1), was determined by the procedure as established by Wurster et al. [2]. Similarly, the white etching layer of a surface deformed pearlitic steel did not fulfill linear elastic fracture mechanics and the J-Integral approach was taken. The testing strategy and data analysis is discussed in the presentation.

1. Djaziri, S., et al., Deformation-Induced Martensite: A new Paradigm for Exceptional Steels. Advanced Materials 28/35, (2016), 7753-7757.
2. Wurster, S., et al., Characterization of Fracture Toughness of Micro-Sized Tungsten Single Crystal Notched Specimens. Phil. Mag. 92, (2012), 1803-25.

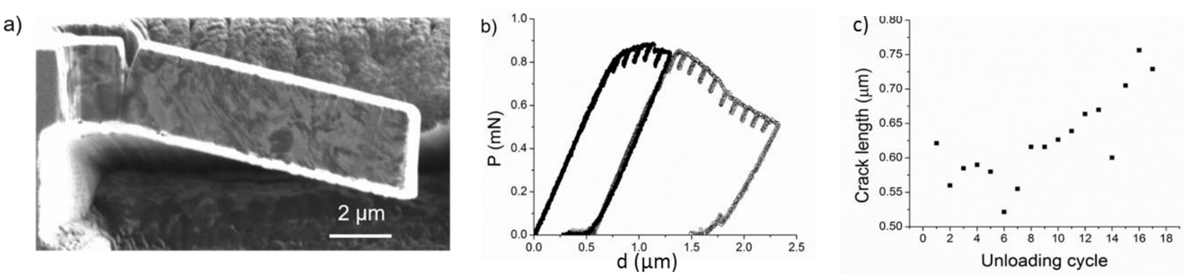

Fig. 1 (a) A 320% drawn pearlitic wire specimen with L=7.09 µm, W=2.2 µm, B=1.55 µm and notch depth of 0.62 µm, loaded cyclically to determine the elasto-plastic fracture toughness J_C. (b) Corresponding load-displacement response, and (c) incremental increase in crack growth as a function of unloading cycle, calculated using the measured stiffness change after every cycle. The final crack length measured from scanning electron microscopy images is 0.8 µm which comes close to the crack length of 0.75 µm calculated from compliance changes.