FATIGUE CRACKS INITIATION IN A LOW ALLOY STEEL: IMPACT OF HYDROGEN ON PLASTICITY

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Hydrogen gas transportation has been facing several technological and ecological challenges for decades. In particular, hydrogen embrittlement of steels issues are still being addressed [1]–[3]. The objective of this work is to give some elements about the interaction between hydrogen and cyclic plasticity, and the link with fatigue cracks initiation on a C-Mn low alloy ferritic steel. The studied material, L485MB, is issued from the GRTgaz grid.

First, the macroscopic cyclic results are presented. L485MB smooth specimens were tested in fatigue with a stress-control and a load ratio of 0.1 under 85 bar of natural gas (NG), gas mixtures of NG and several quantities of hydrogen (NG/x%H_2) or pure hydrogen (H_2). Under these peculiar conditions, no impact of hydrogen on lifetime is evidenced. Whereas, for notched specimens, in the same conditions, hydrogen environment leads to a decrease of the cyclic lifetime. Compare to smooth specimens, a notch enables not only stress and strain concentrations on the notch tip but also a local negative load ratio.

Second, a microscopic approach is proposed to analyse the previous results. We focused on notched specimens and other smooth specimens tested in fatigue in air with a strain-control with a load ratio of -1. For these smooth specimens tested with a half plastic strain amplitude $\Delta\varepsilon_p/2$ of 0.2%, we observed, at 30% of lifetime, several crack initiations. They are localized inside a grain and seems to be issued from surface relief. No slip lines are observed on the surface. Then the small cracks propagate in a transgranular way until 20 µm. On SEM images of notched specimens tested until 50% of lifetime, small cracks of about 10 µm are observed in all NG, NG/25%H_2 and H_2 environments. They are localized inside ferrite grain, near grain boundaries.

Finally, at a lower scale, we sampled FIB lamellas on the strain-controlled smooth specimens in air and thanks to STEM analysis, we confirmed the presence of surface relief, such as intrusions and extrusions. They appear from emergence of bands of dislocation structures oriented in the same way at the surface. Then the very small cracks propagate along dislocations walls for approximately 0.5 µm. FIB lamellas are sampled on notch tip of specimens tested under NG, NG/H_2 mixture and H_2. Crack initiation sites will be presented.

References

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