Reheat cracking in 316H stainless steel

Dr. Hedieh Jazaeri, Feb 2018 (web version)

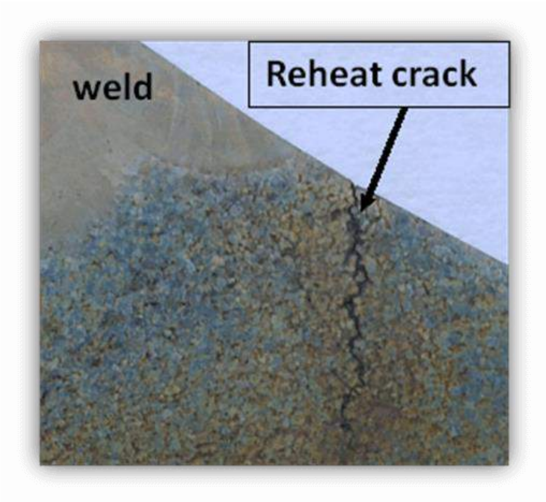

Figure 1: Reheat crack near a weld in 316H stainless steel.

Introduction

Creep cavitation is an important failure mechanism in components operating at high temperature. Reheat cracking is associated with creep cavitation in weldments, which occurs either during post-weld-heat-treatment or during high temperature service.

Challenges

StressMap has been working with EDF Energy UK to investigate plastic deformation and creep cavitation around reheat cracking in order to provide better understanding of reheat cracking and creep damage development mechanisms. This is required to improve models for predicting the life and integrity of susceptible welded structures operating at high temperatures.

Study of creep damage around reheat cracking in a 316H austenitic stainless steel weldment

This study carried out on a 316H austenitic stainless steel weldment, which has developed reheat cracking after prolonged service.

The electron backscatter diffraction (EBSD) technique has been emerged as a promising tool to quantify strain induced lattice misorientations due to development of geometrically necessary dislocations (GNDs) during deformation in polycrystalline materials. Kernel average misorientation (KAM) and low angle boundary fraction (LABF) maps were used to quantify inelastic strain around the reheat crack. The EBSD studies (Figures 3 and 4) revealed higher levels of lattice misorientation towards the weld region where the crack initiated with strain particularly concentrated at grain boundaries. The pattern of deformation shown by the EBSD measurements was confirmed by the hardness survey.

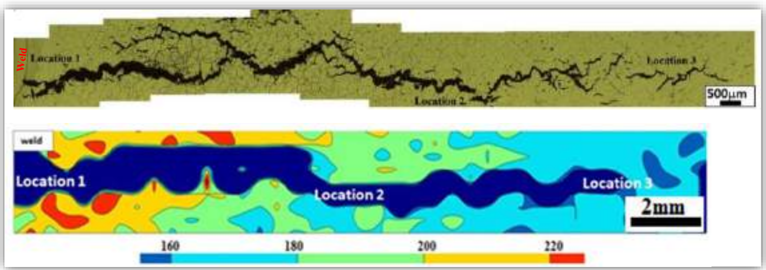

Figure 2 (a) Optical microstructure and (b) hardness map around the reheat crack.

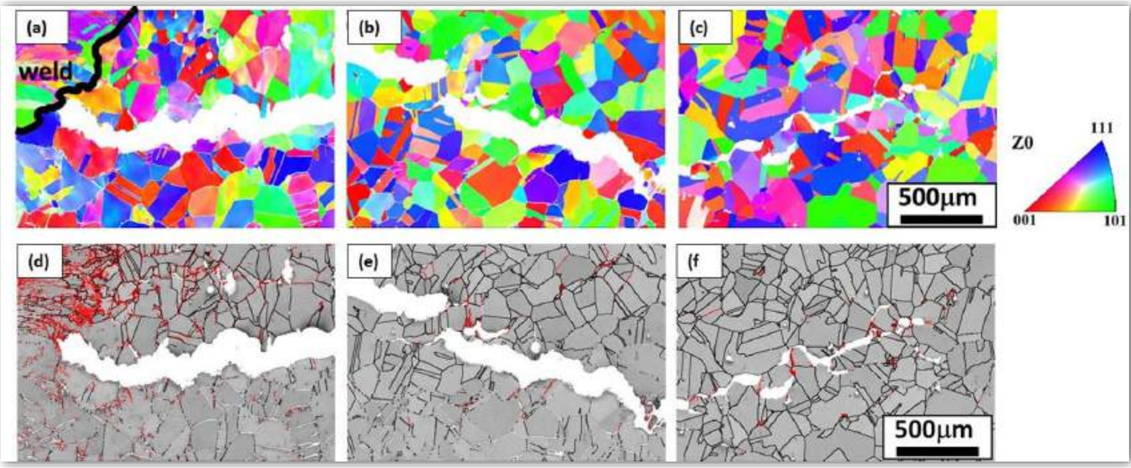

Figure 3 (a-c) Orientation maps and (d-f) grain boundary maps of reheat crack at location 1 (a, d), location 2 (b, e) and location 3 (c, f). Position of each location is marked in Figure 2(a).

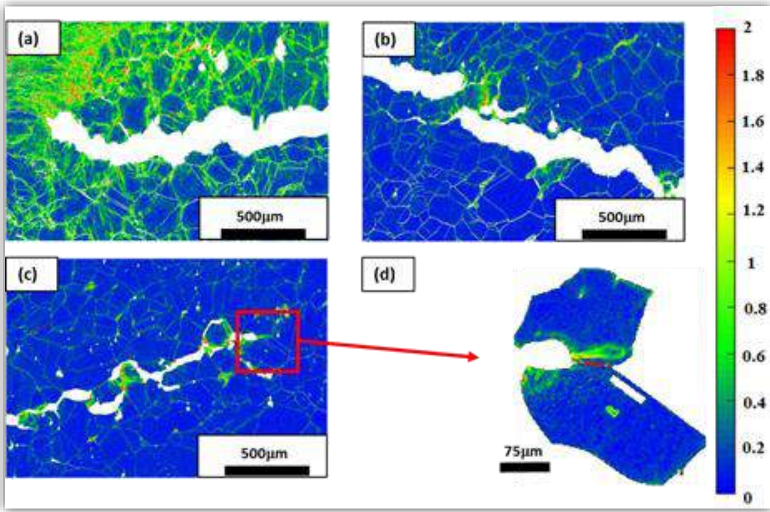

Figure 4 - Kernel average misorientation (KAM) maps of the reheat crack at (a) location 1, (b) location 2, (c) location 3 and (d) magnified map of grains at the crack tip.

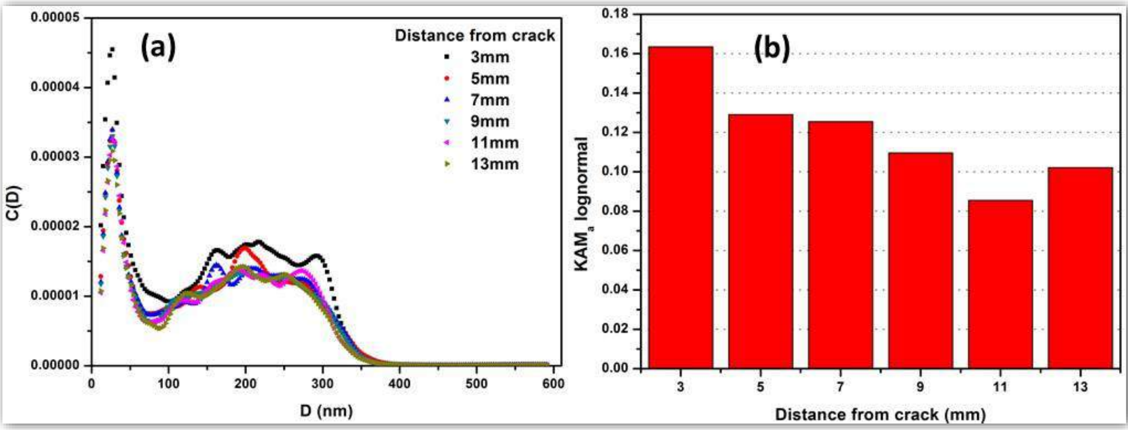

Figure 5(a) SANS data showing the increase in fractional size distribution of cavities and (b) EBSD data showing higher values of KAM$_a$ lognormal, as approaching the crack, along a line normal to the crack.

The SANS2D small-angle scattering instrument (SANS) at the ISIS Pulsed Neutron Source (STFC Rutherford Appleton Laboratory, Didcot, UK) was deployed in order to measure cavity distribution around the around reheat cracking, in particular along a line normal to the crack (Figure 5a). Comparing SANS cavitation measurements data with EBSD data, shows that the areas with higher cavity densities had higher local misorientations (Figure 5b).

Findings

- EBSD studies on reheat crack shows higher local misorientation in areas closer to crack.
- The KAM maps revealed higher levels of lattice misorientation towards the weld region, where the crack initiated, with strain particularly concentrated at grain boundaries.
- The pattern of deformation shown by the EBSD measurements was confirmed by the hardness survey.
- SANS technique was successfully used to give an absolute quantitative description of cavitation damage up to about 350 nm in size near the reheat cracking. Cavitation is found to increase significantly as the crack path is approached, near the crack mouth.
- KAM was higher at areas with high density of cavities as confirmed by SANS.

References

[1] R. Unnikrishnan, S. M. Northover, H. Jazaeri, and P. J. Bouchard, "Investigating plastic deformation around a reheat-crack in a 316H austenitic stainless steel weldment by misorientation mapping", *21st Eur. Conf. Fract.*, vol. 2, pp. 3501–3507, 2016.

[2] H. Jazaeri, P. J. Bouchard, M. T. Hutchings, A. A. Mamun, and R. K. Heenan, "Application of small angle neutron scattering to study creep cavitation in stainless steel weldments", *Mater. Sci. Technol.*, vol. 31, no. 5, pp. 535–539, 2015.