Quantitative strain analysis of a creep damaged hydrogen reformer tube made out of high alloyed austenitic stainless steel using EBSD and quantitative NDE to enable remaining life prediction.

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Summary:
The purpose of this work was to quantify creep damage in high alloyed austenitic stainless steels using SEM-EBSD and non-linear ultrasonic parameters. The component studied is a hydrogen reformer tube, which during service operates at an average temperature of 1000ºC and an internal stress of 4.4MPa. Inside the tube, methane is cracked to produce hydrogen, used to reduce iron ore to iron. Creep damage is a common mode of failure in these components. The ultimate objective of this work is to develop a model that aids structural health monitoring of components using instiu measurements of damage. The changes in the microstructure of the sample manifest as strains that can be identified and quantified using EBSD. Further, NDE based on non-linear ultrasonics (NLU) is employed to characterize creep damage.

It is known from previous studies [1] that as creep damage progresses, the carbide/matrix interfaces turn magnetic. It is also established in literature that precipitate coarsening and secondary precipitation results in misfit strains with the matrix [2], and EBSD, is capable of quantifying these misfit strains. Researchers have used SEM-EBSD to study the change in misorientations as a result of creep damage and have established a correlation that worked extremely well for 316NG stainless steel [3, 4]. There exists a direct relationship between the interactions of the ultrasonic waves with the microstructural features in a material[5]–[7]. Non-linear ultrasonics based parameters have been successfully used to quantify different forms of damage in the material like fatigue, creep, precipitation of new phases, etc in steel, aluminum, titanium alloys, etc [8-10].

In this work, four samples containing different levels of creep damage were taken from the retired reformer tube. Optical microscopy confirmed the presence of different levels of creep damage existing in the same tube. EBSD was performed on the samples and the Grain Average Misorientations (GAM) and the Kernel Average Misorientations (KAM) were studied for all samples at two different magnifications (40X and 1000X), step sizes (20µm and 1 µm). Results of the KAM analysis at different magnifications are presented in figure 1. It was observed that the KAM and GAM increase to a certain point after which there is a decrease in the value. This behavior of the misorientations differs from the monotonous increase or decrease reported in literature. We account this behavior of the misorientation values to (i) increasing dislocation density with creep damage, following which there will be an annealing at higher temperatures, (ii) increasing incoherency of the precipitate matrix interface reaching a plateau when there is no more diffusion of alloying elements across the carbide matrix interface (iii) a possible dynamic recrystallization at higher temperatures during creep damage can also relieve the strains in the microstructure.

The ultrasonic tests were conducted using two piezo electric transducers (5 and 15 MHz) in a through transmission mode. The NLU parameters showed a steady decline in their value with creep damage in the sample, this can be associated with the decreasing dislocation density in the samples as a result of the increasing creep damage and the increased attenuation of the waves as a result of the coarsening precipitates. A model utilizing the dependency of the misorientations and NLU parameters on the dislocation density and precipitate sizes is being considered as a further direction of this research.

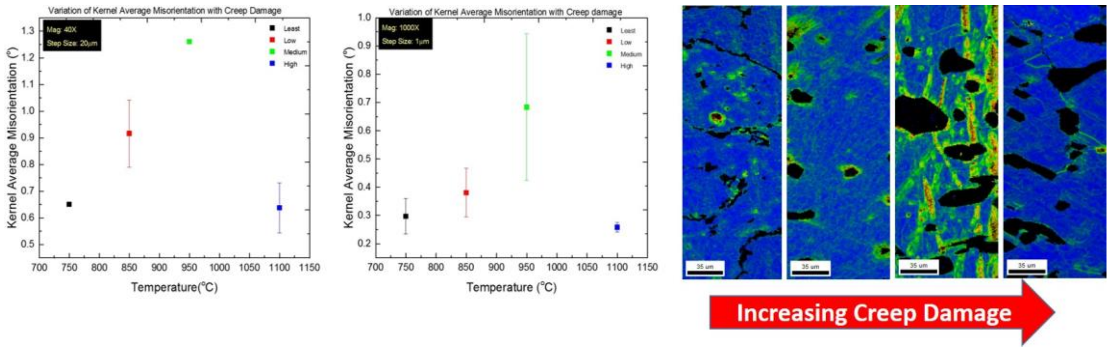

Figure 1. Variation in the KAM of the samples, as measured at different magnifications.

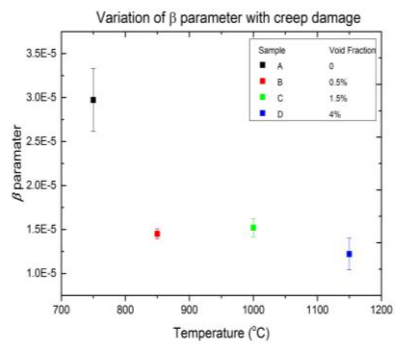

Figure 2. Variation in the β parameter of the samples as a result of creep damage.

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