Investigation of Stress Corrosion Cracking in CMSX-4 Turbine Blade Alloys Using Deep Learning Assisted X-ray Microscopy

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Single crystal Ni based superalloys are typically used in power generation and aviation applications due to their exceptional thermal and mechanical properties, specifically their ability to withstand high temperature and extreme environment. Recently, incidents of failure due increased temperature around root blade regions has caused Type II hot corrosion leading to cracking in blade roots resulting in catastrophic failure [1]. Understanding the failure mechanism and crack characterisation is vital in solving this issue and increasing service lifetime of structural components.

Here we demonstrate a unique workflow of hot corrosion related damage characterization using high resolution X-ray microscopy aided with deep-learning based algorithms for data reconstruction and segmentation (Figs. 1 & 2 respectively), combined with FIB-SEM and electron microscopy in order to characterize cracks and crack tips developed during stress corrosion cracking.

By extracting the fracture tip, both crystal plasticity and crystal deformity can be studied in detail resulting in orientation tomography of the corroded region of stress. Combining this correlative workflow we are able to demonstrate a unique technique in C-ring analysis and identifying structural defects not visible using typical microscopy techniques. A comprehensive three dimensional quantitative analysis of the data will be presented wherein we carefully investigate microstructural aspects of the nickel superalloy sample such as porosity, morphological characterization of surface cracks, the dendritic orientation and its influence on damage propagation. Such detailed analysis have never before been carried out and we demonstrate how recent developments in deep-learning based image reconstruction and segmentation methods are making it possible.
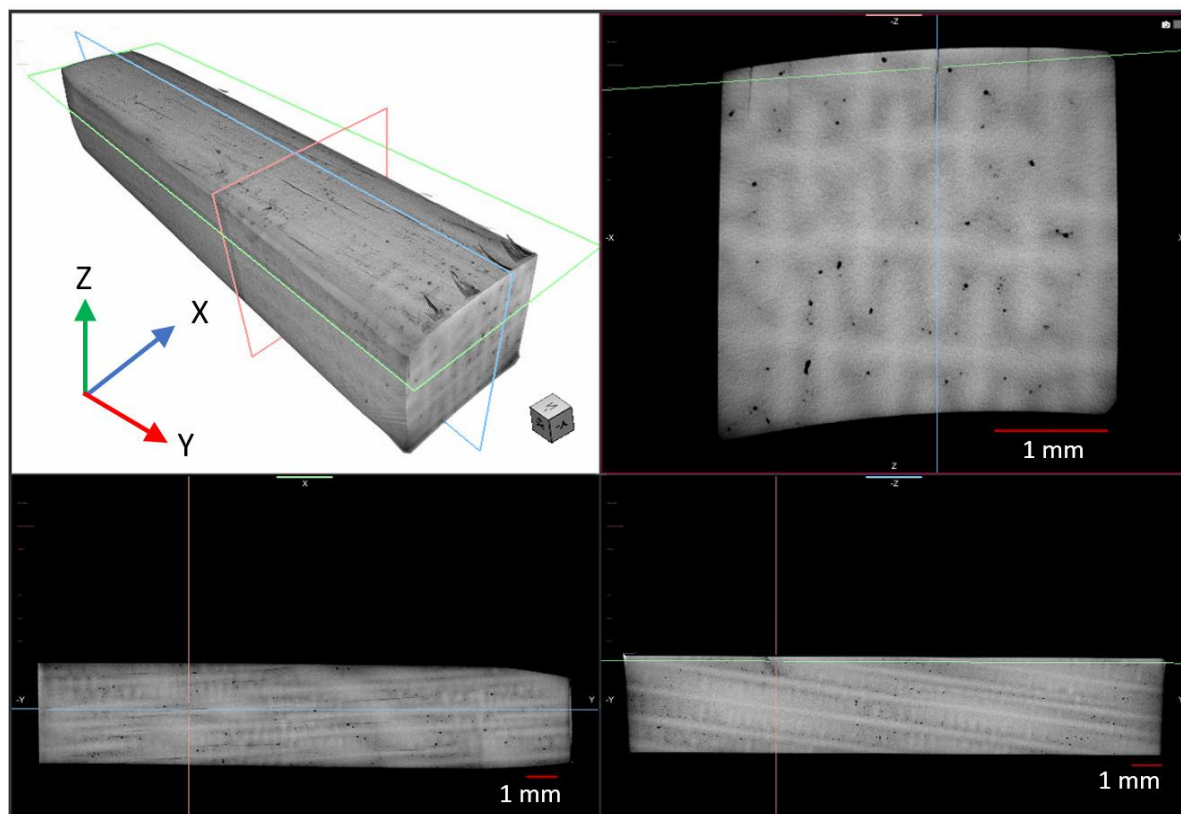
Figure 1. X-ray microscopy of a section of C-ring sample tested for hot corrosion. The reconstructed slices and 3D rendering shows the dendritic microstructure, the local porosity and occurrence of stress corrosion cracks at the exposed surface.
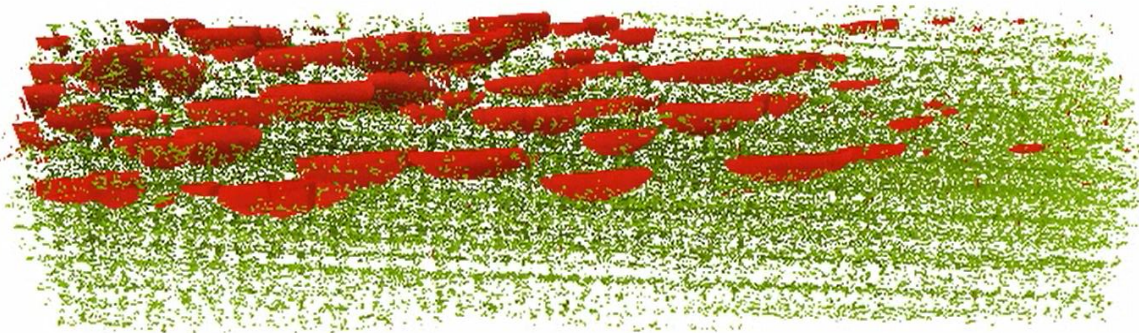

Figure 2. Deep learning based image segmentation provides detailed information on the semi-circular surface cracks appearing due to hot corrosion (shown in red) as well as the overall porosity (shown in green). The nickel matrix is rendered transparent for sake of clarity.

References

[1] L Brooking et al., Materials at High Temperatures, **35** (2018), p. 120-129. DOI: 10.1080/09603409.2017.1392414