PROCEEDINGS PAPER

Microstructure Characterization of EU INCEFA-SCALE 316L Stainless Steel Fatigue Specimens - Mechanistic Understanding

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Proceedings of the ASME 2023 Pressure Vessels & Piping Conference (PVP2023)
July 16-21, 2023, Atlanta, Georgia, USA

Paper No.: **PVP2023-105888**; 8 pages
DOI: 10.1115/PVP2023-105888
Published Online: October, 2023 (*expected*)
URL: https://asmedigitalcollection.asme.org/

Abstract:

A pressurized water reactor (PWR) primary environment can have a deleterious effect on the fatigue lifetime of austenitic stainless steels. One of the main goals of a five-year INCEFA-SCALE (INcreasing safety in NPPs by Covering gaps in Environmental Fatigue Assessment - focusing on gaps between laboratory data and component SCALE) project, kicked off in October 2020 and supported by the European Commission HORIZON2020 programme, is to develop an improved mechanistic understanding behind the effect of a PWR primary environment on the fatigue behavior of austenitic stainless steels through coordinated extensive characterization of as-machined and tested specimens at partner organizations.

This work focuses on the microstructure characterization of as-received austenitic stainless steel 316L plate material and as-machined fatigue specimens, as well as the preparation of guidelines on post-mortem characterization for the consortium. The presented microstructure characterization is carried out using light optical microscopy (LOM), scanning electron microscopy (SEM), and analytical electron microscopy (AEM) (including electron backscatter diffraction (EBSD), scanning/transmission electron microscopy (STEM/TEM), X-ray energy dispersive spectroscopy (EDS) and electron diffraction). The hardness, grain structure, inclusions, and delta-ferrite of the as-received 316L material were investigated. The surface roughness, machining-induced deformation layers, and ultra-fine-grained structure of as-machined ground and polished specimens were studied.

A ground surface finish leads to significantly higher machining-induced deformation, and surface roughness, with plenty of machining-induced cracks and defects extending a few microns into the bulk material, compared to a polished finish. The guidelines on the post-mortem characterization for the whole consortium can guide partner organizations in their post-test analysis for a direct comparison of the characterization data, which facilitates the mechanism interpretation.

Keywords: environmentally assisted fatigue, pressurized water reactor, stainless steel, surface finish, electron microscopy

This project has received funding from the Euratom Research & Training programme 2019-2020 under grant agreement N^{o} 945300