Crack growth under multiaxial fatigue loading leading to large scale yielding

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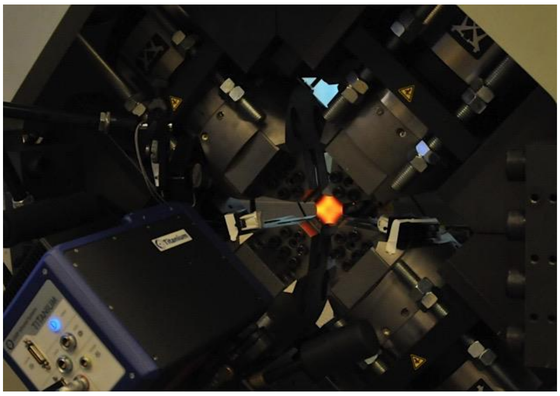

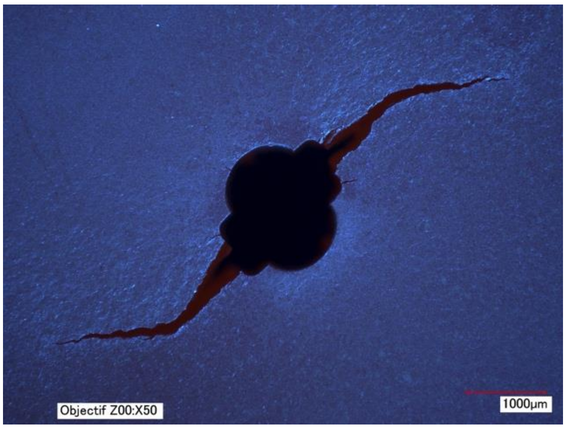

- Development of an experimental methodology in order to characterize fatigue crack growth under biaxial fatigue loading at high temperature and for large scale yielding
- Optimization of the thermal gradient with the design of a new inductor
- Experimental analysis of the fatigue crack path
- Numerical analysis of fatigue crack growth rate (FCGR)
- Validation of a FCGR model, identified on 1D, with biaxial loading under low cycle fatigue condition at high temperature

Abstract:

For very high temperature conditions and high mechanical loading, as found for instance for combustion chambers in engine aircraft, cracks could initiate and propagate near perforated zones. In particular, we are interested in the evaluation of the superalloy HAYNES® 188 and its degradation by fatigue crack growth. For such component and material, damage is the result of a complex set of phenomena: multiaxial fatigue loading, thermal gradients and large scale yielding under oxidizing environment. Fatigue crack growth has been experimentally analyzed and modeled for high temperature and large scale yielding for this kind of material but rather limited to uniaxial macroscopic loading. This study consists in experimentally characterizing and modeling crack propagation under 2D in plane macroscopic loading representative of in-service loading conditions, including high temperature and large scale yielding. The design of such an experiment is a challenging issue to control both thermal loading and strain/stress within the gage length. We first focused on the design of such an experiment using cruciform notched specimen heated by a new induction coil processed by laser beam melting. Additive manufacturing has allowed optimizing the geometry of the coil enabling the control of thermal field in both homogeneity and control of positioning (centering and parallelism to the gage length). Specific LVDT has been used to control cyclic displacement applied to the gauge length. Subsequent thermal and displacement fields have been measured using respectively Infrared thermography and digital image correlation. These fields are needed to prescribe relevant thermal and displacement boundary condition for a 3D FEA. Optical microscopy was also used to measure in situ the crack tip location. Typical loading was achieved by testing fatigue crack growth successively under equibiaxial and macroscopic shear loading for either force or displacement control. The obtained fatigue crack growth database tests the influence of large scale yielding under biaxial loading on fatigue crack growth mechanisms, fatigue crack growth rate as well as the mechanical condition of crack bifurcation. As a first attempt, previous model identified on uniaxial loading is tested with neither modification of the model nor modification of its constitutive parameters. This validation was successfully performed by post-processing of elastic and plastic energy obtained by 3D FEA in the vicinity of the notch loading by non-local approach. This post-processor does not take into account explicit meshing of the crack growth. A second attempt is proposed, using conform remeshing and a new version of the FCGR model, also based on the plastic and elastic strain energy partitioning, and again using a non-local approach for a 2D analysis. Experimental results and assessment of FCGR will be finally discussed so as to determine driving parameters for fatigue crack growth under large scale yielding condition for biaxial fatigue loading. The limitation of the proposed models will be also discussed.