From short to long crack in thermo-mechanical fatigue, a focus on crack closure

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Abstract

The role of crack closure has been established as a key factor in the long crack regime since the early work of Elber. Based on both advanced experimental characterization techniques and 3D finite element analysis (FEA), this topic can now be extended to the analysis of both short and long crack regimes. This paper focuses on the role of crack closure considering anisothermal fatigue loading, the so-called thermo-mechanical fatigue (TMF), focusing on the low cycle fatigue (LCF) regime inducing large scale yielding condition.
First, using machine learning techniques combined with in situ surface imaging, it has been shown that for out-of-phase TMF loading (OP-TMF) in the short crack regime, crack closure is partial along the cycle. This promotes high temperature damage where the crack experiences compression. Eventually, in this context, the fatigue crack growth rate (FCGR) reaches the FCGR for isothermal condition made at the maximum temperature of the cycle (1-2).

Second, for long crack analysis, it has been shown that damage mechanisms in OP-TMF and isothermal condition at the maximum temperature of the cycle could be very different (3): isothermal loading associated with large scale yielding induces creep damage (intergranular cracking) and a dense network of microcracks, whereas TMF promotes a single crack. Again, crack closure is a key factor in the subsequent FCGR, which is intermediate between the maximum and minimum temperature of the considered thermal cycle.

FEA has been systematically applied for both cases, based on conformal remeshing techniques, to highlight the driving forces controlling FCGR in the context of general scale yielding (4-5). Finally, the fatigue life assessment is discussed based on the combination of in situ measurements and such FEA method.

KEYWORDS:

TMF, micro-crack, machine learning, conformal remeshing, large scale yielding

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