EXPERIMENTAL ANALYSIS AND MODELLING OF FATIGUE CRACK INITIATION MECHANISMS

Mini-Symposium MS-11

Z.L. Kowalewski[a], M. Kopec[a], A. Brodecki[a]

[a]Institute of Fundamental Technological Research, Pawinskiego 5B, Warsaw, Poland
Corresponding email: zkowalew@ippt.pan.pl

ABSTRACT: The present work provides description of fatigue crack initiation in metals subjected to cyclic loading within the nominal elastic or initial elastic-plastic regimes. When a polycrystalline metal or alloy element is subjected to mechanical loading inducing uniform mean stress and strain states, the fluctuation fields develop due to material inhomogeneity related to grain anisotropy and inhomogeneity. Due to imperfections (inclusions, cavities), grain boundaries, free boundary effects, dislocation microstructure, the local stress and strain concentrations develop. These stress fluctuations, developing at a fraction of the macroscopic elastic limit, are the source of initial structural defects and microscopic plastic mechanisms controlling the evolution of defect ensemble toward the state of advanced yielding.
The purpose of this work was to provide experimental and analytical description of stress and strain fluctuations and incorporate them into the fatigue criteria based on the local stress values. The analysis was also aimed at development of consistent description of the microplastic state of material. Using the potential offered by the novel experimental techniques, it was possible to identify physical phenomena and to describe the mechanisms of degradation and fatigue damage development in modern structural materials. The analysis of the stress and strain localization preceding crack initiation was performed by means of the optical method ESPI (Electronic Speckle Pattern Interferometry), and DIC (Digital Image Correlation). The nano-indentation method is used to estimate local mechanical properties.
In this work, a new concept of constitutive modelling of fatigue crack initiation mechanisms is proposed. The new model is based on the continuum approach with account for local stress fluctuations, usually neglected in formulation of the damage models. Depending on the accuracy of description of stress and strain fluctuations, such type of modelling may become close to microstructural models, usually requiring numerous material parameters.

Key words: fatigue crack initiation, micro-plasticity, damage evolution, optical ESPI method, micro indentation

Acknowledgement
This research has been partially supported by the Polish National Science Centre (Grant No. 2019/35/B/ST8/03151).