ANALYSIS OF FATIGUE CRACK INITIATION IN CYCLIC MICROPLASTICITY REGIME

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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 [1]. Due to imperfections (inclusions, cavities), grain boundaries, free boundary effects, dislocation microstructure, the local stress and strain concentrations develop (Fig. 1).

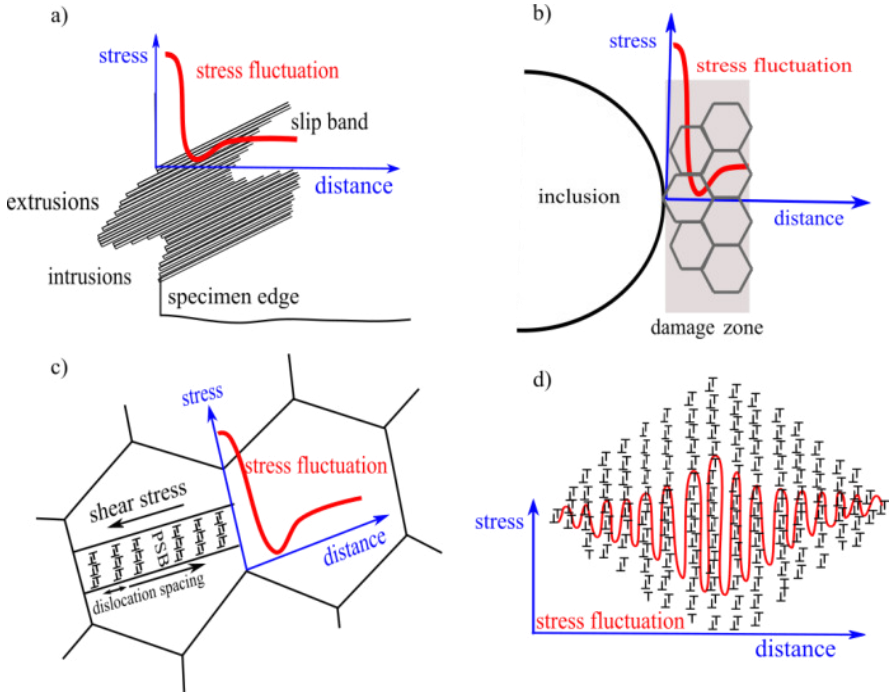

Fig. 1. Formation of stress and strain fluctuations a) boundary fluctuation, b) stress fluctuation at the inclusion, c) grain boundary fluctuation d) stress fluctuation due to dislocations microstructure

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 is 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 is also aimed at development of consistent description of the microplastic state of material [2]. The analysis of the stress and strain localization preceding crack initiation is performed by means of the optical method ESPI (Electronic Speckle Pattern Interferometry), apparatus using the coherent laser light. On the basis of strain fields specified at different load levels local hysteresis curves can be generated at selected points of specimen. The strain distribution maps, obtained for the first loading-unloading cycle, corresponding to the selected points of the curve are also presented in Fig. 2.

Additionally, the microindentation method has been applied to determine the damage variable from the data of the stiffness modulus.

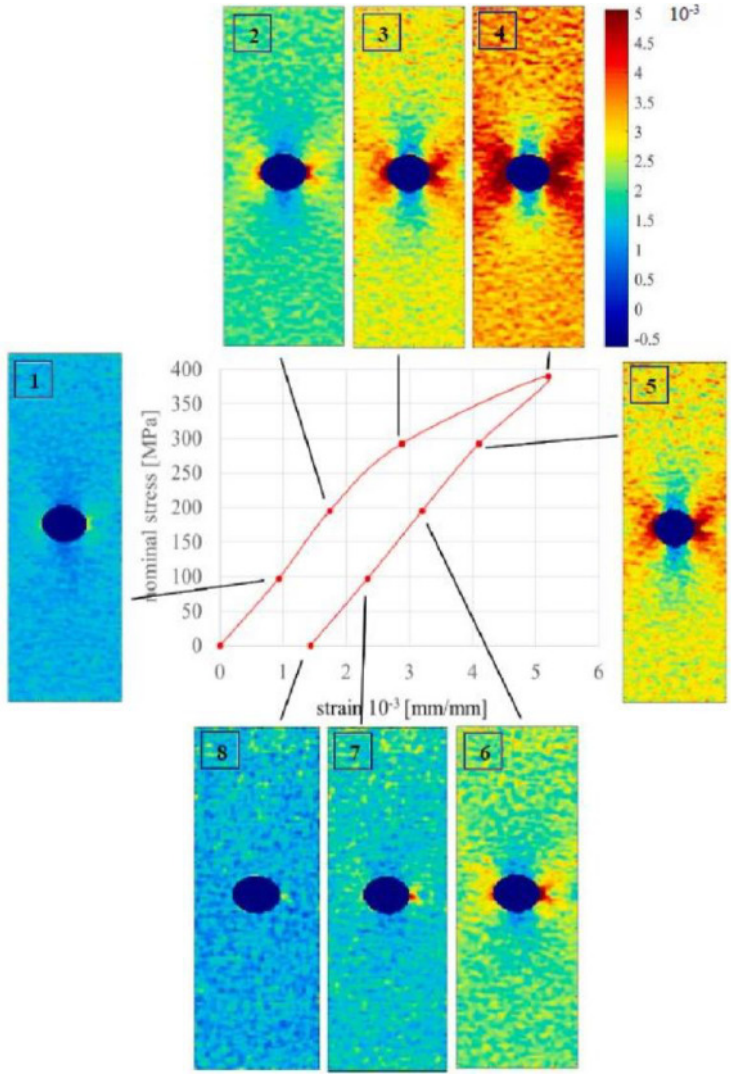

Fig. 2. Local hysteresis curve showing the first loading-unloading cycle paused at selected stress levels for the strain distribution maps capturing

In this work, the 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 [3]. 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.

References

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