# ICEM/082 **Characterization of Damage Evolution Supported by ESPI Analysis**

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## 1. Introduction

The present work is devoted to simulation of fatigue crack initiation for cyclic loading within the nominal elastic regime. It is assumed that damage growth occurs due to action of mean stress and its fluctuations induced by crystalline grain inhomogeneity and free boundary effect. The macrocrack initiation corresponds to a critical value of accumulated damage. The modelling of damage growth is supported by Electronic Speckle Pattern Interferometry (ESPI) apparatus using coherent laser light.

## 2. Applications of ESPI method

The present paper concerns the fatigue crack initiation and evolution for metals subjected to loading at stress level below the conventional yield strength. The process of fatigue damage development and structural degradation is of local nature. In FCC polycrystalline metals or alloys the interaction of persistent slip bands or twin boundaries with grain boundaries generates stress amplitude concentration leading to subsequent crack initiation. Using the potential offered by novel experimental techniques it is possible to identify physical phenomena and to study evolution of the fatigue induced degradation [2]. In the present work the analysis of strain localization preceding crack initiation was performed by means of the optical method ESPI, namely the Electronic Speckle Pattern Interferometry apparatus using the coherent laser light. During the process of pulsating cyclic loading the material deforms heterogeneously and numerous strain concentration spots are visible. The microstructure of the materials plays an important role in strain localization. It can be expected that cracks start to nucleate in the zones containing large strain accumulation during cyclic loading.

## 3. Mathematical modelling of fatigue damage evolution

The usual approach is based on averaged stress or strain amplitudes, with numerous fatigue conditions formulated for uniaxial or multiaxial stress states. The proposed mathematical description of fatigue damage growth and crack initiation is based on the concept of critical plane. The damage growth on the material plane is related to evolution of surface tractions. The process of fatigue damage growth is of local nature and the account for stress fluctuations should be included. The profile of normal strain $\varepsilon(x)$ and stress $\sigma(x)$ along the damage zone $\Omega$ is expressed as a sum of mean $(\bar{\varepsilon}, \bar{\sigma})$ and fluctuation $(\tilde{\varepsilon}(x), \tilde{\sigma}(x))$ components.

$$\varepsilon(x)=\bar{\varepsilon}+\tilde{\varepsilon}(x), \qquad \sigma(x)=\bar{\sigma}+\tilde{\sigma}(x) \tag{1}$$

It is assumed that, when the critical stress condition is attained on the material plane, a damage zone is generated.
The condition of damage accumulation is formulated after Mróz et al., [1].

$$dD=A\left(\frac{\sigma-\sigma_0^*}{\sigma_c-\sigma_0}\right)^n \frac{d\sigma}{\sigma_c^*-\sigma_0^*} \tag{2}$$

where $\sigma_0$ is the damage initiation threshold values, $\sigma_c$ denotes the failure stress in tension for the damaged material, $\sigma_0^*$ and $\sigma_c^*$ are the threshold values for the undamaged material. In the steady state the process of cyclic loading is described for the period of stress variation. It was noted that the influence of edge defects on the damage evolution and crack initiation is significant. In order to account for the edge effect, the edge stress fluctuation function is also introduced

$$\tilde{\sigma}_b(x)=\bar{\sigma}\, y_b(x)=\bar{\sigma}\left(B+Ce^{-\alpha x^2}\cos(\beta x)\right) \tag{3}$$

where $y_b(x)$ denotes the fluctuation function, $\alpha$, $\beta$ and $C$ are the material parameters. The proposed model was applied to study damage evolution under cyclic tension [2], with its parameters calibrated by the experimental data. The numerical prediction and the experimental results indicate a good correlation.

References
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