Mesomechanics of fatigue crack propagation as a non-linear wave process

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In cyclically deformed solid a fatigue crack nucleates and propagates at first stage within surface layer. This surface layer experiences to plastic deformation under elastic loading of substrate. Mesomechanics of this multiscale process is investigated experimentally and theoretically in this work. It is shown that fatigue crack propagates as zigzag non-linear wave of shears and rotations (Fig. 1,a) in surface layer. Non-local hidden variables managing this wave process are associated with mechanical field of "chessboard-like" distribution of compressive and tensile normal stresses at the interface "plastically deformed surface layer – elastically loaded substrate" [1], (Fig. 1,b).

a b

Figure 1. The optical image of the fatigue crack in aluminium foil, glued to titanium flat specimen, cyclic bending (a) and the scheme of fatigue crack propagation in the field of "chessboard-like" distribution of normal stresses at the "surface layer – substrate" interface with account of couple forces (b).

Light cells of "chessboard-like" interface are loaded by tensile normal stresses. Plastic shears develop along conjugate directions τ_{max} and crack propagates (as damping factor of non-linear wave process) in these cells only. Dark cells of the interface are loaded by compressive normal stresses. In these cells rotation couple forces are developed (as autocatalytic factor) under propagating of cracks. These rotation couple forces change direction of crack from τ_{max} to conjugate one at every zigzag. Description of this effect can be performed in the framework of multiscale approach of physical mesomechanics only. Couple forces in cells of compressive normal stresses are calculated with the help of the method of excitable cellular automata. The experimental data are in good agreement with the developed concept.

References

[1] Panin V.E., Panin A.V. and Moiseenko D.D. Physical mesomechanics of a deformed solid as a multilevel system. II. Chessboard-like mesoeffect of the interface in heterogeneous media in external fields. Phys. Mesomech., 10, N 1-2 (2007), p. 5.