MECHANICS AND SYNERGETICS OF SCATTERED DAMAGE AND FATIGUE FRACTURE

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Mechanical and synergetics methods are used to describe the processes of scattered damage, growth of fatigue cracks and fatigue fracture. Under the action of active static or cyclic stresses in ductile (metals, polymers) and brittle (rocks) materials self-organizing structures capable to dissipate mechanical energy are generated. As an example the dislocation structures are appeared in metals, crazes in polymers and micro cracks in rock materials. For metals the development of dissipative structures are well described by the logistical curve, which follows as a solution of the well known kinetic equation widely used in synergetics. To investigate the behavior of micro cracks compression loading experiments were carried out on the specimens made of marble and granite. During experiments the variation of damage parameter as a relation of current value of micro cracks to those at the moment of fracture was measured by acoustic emission techniques. It is shown that the experimental relation for the damage parameter is well described by the logistical curve. The dissipative structures generated at a small region of a crack tip in metals and polymers are also studied.

Evolution of damage state at a crack tip zone and the stepwise crack propagation of a fatigue crack were studied in many experiments on metals and polymers. These experiments show that at a small region of a crack tip different self organizing structures capable to dissipate the mechanical energy are generated. In metals the development of dislocation structures results to formation of micro cracks and pores. In polymers the main damage mechanism is associated with the crazing process. The damage structures in metals and polymers are formed first within the small crack tip region. At a thin section of the crack tip where the elastic stresses are the highest the material remained intact. The rupture started first somewhere inside of the tip region. The fracture of the thin section at the crack tip zone follows after the failure covers the whole tip region. During this period the crack remains in the arrest position then at some particular cycle it jumps. Completion of the crack jump resulted in incremental crack growth and the beginning of the nest arrest period. Cyclic repetition of the process leads to the stepwise propagation of the crack. This paradoxical experimental effect is not treated sufficiently in scientific literature. The mechanical approach considered in this presentation makes it possible to explain the effect mentioned above.

To describe these results the energy approach is applied. Assuming the existence of critical energy for the unit length of a crack the kinetic equation for a crack growth based on the Griffith's fracture theory is presented. For an example, this equation is applied to describe the stepwise crack propagation in polymer materials. It is shown that the theoretical stepwise crack growth curves are in good agreement with those received in experiments. Probabilistic fatigue fracture criterion based on the weakest link model and stepwise crack propagation equation is formulated. The rupture curve according to the present theory is constructed. It is shown that the number of cycles to fracture is widely decreased when the damage condition of the specimen is increased.