Experimental estimation of the heat energy dissipated in a volume surrounding the tip of a fatigue crack

Fatigue crack initiation and propagation involve plastic strains that require some work, W, to be done on the material. Most of this irreversible energy is dissipated as heat, Q, and consequently the material temperature increases during fatigue loading processes. On the basis of a theoretical model proposed by Meneghetti (2007), the heat energy dissipated in a unit volume of material per cycle has been averaged in a volume V surrounding the tip of a propagating crack. Such energy per cycle parameter, Q*, is estimated experimentally on the basis of the radial temperature profiles measured from the crack tip outward by means of an infrared camera, according to Eq.1 (see Fig. 1). Scd, Scv and Sir are parts of the control volume surface, through which Q is transferred to the surroundings by conduction, convection and radiation, respectively. Since the thermal power extracted from V by conduction is far greater than that dissipated by convection and radiation, it can be calculated from the thermal flux, h, through its boundary:

$$\int_V H \cdot dV \cong \int_{S_{cd}} -\lambda \cdot \mathrm{grad}\vec{T}_m \cdot \vec{n} \cdot dS_{cd} \rightarrow = -\lambda \cdot z \cdot R \cdot \int_{-\pi}^{+\pi} \left.\frac{\partial T_m(r,\theta)}{\partial r}\right|_{r=R} \cdot d\theta \qquad (1)$$

So far the averaged heat loss Q* has been estimated on cracked AISI 304L stainless steel specimens subjected to push-pull fatigue loads. The experimental temperatures close to the crack tip have also been compared successfully with an analytical solution available in the literature. It is anticipated that Q* is a promising parameter to evaluate experimentally the crack propagation rate, i.e. the residual service life of components and structures subjected to fatigue loadings.

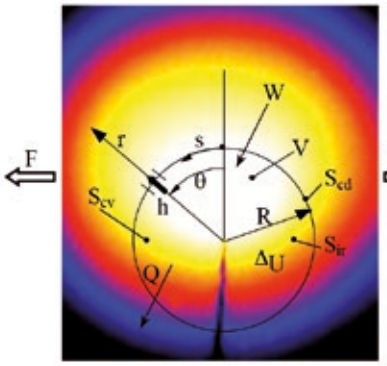

Fig.1. Energy balance for a volume of material V surrounding a crack tip subject to Mode I fatigue loadings.

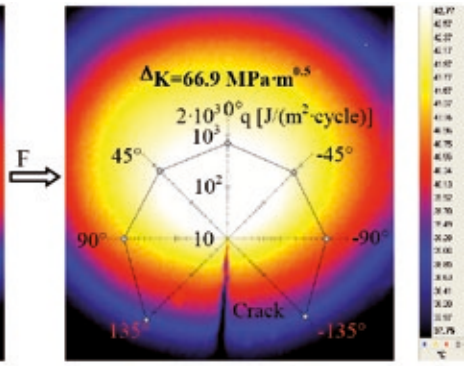

Fig. 2. Experimental distribution of the energy flux per cycle *q* along the boundary of the control volume V at different angles θ.

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Main research topics:

- Structural Integrity
- Fatigue behaviour of Metallic Materials and Structures
- Fracture Mechanics of Metallic Materials
- Fatigue and Fracture design methods of Metallic and Polymer materials