ON THE SIGNIFICANCE OF LOAD BIAXIALITY TO THE FRACTURE PROBLEM

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SUMMARY

The question of what, if any, may be the possible effects of biaxial load application on fracture has not as yet been properly clarified. On the analytical side, analysis of the biaxially loaded plane center-cracked sheet with a flat crack using conventional 'singular solution' formulae for the elastic crack-tip stress and displacements, reveals no effects whatsoever of the load applied parallel to the plane of the crack. On the other hand, the little experimental information that has been obtained that appears to show otherwise, that is, that does indicate biaxial load effects on fracture toughness, fatigue-crack growth rates, crack-tip shear isochromatics and angle of initial crack extension, cannot at this time be considered to be conclusive. The high costs and the technical difficulties associated with assembly and operation of biaxial load test apparatus is largely responsible for the current paucity of experimental data of this type. We have therefore a situation in which there is inconclusive experimental information that, furthermore, appears to be contradicted by the results of conventional analysis.

It is more or less accepted in fracture mechanics that the elastic stress and displacements close to the tip of a plane line crack can be approximated with sufficient accuracy for all geometries and outer boundary loading conditions by a one-parameter representation, i.e., entirely in terms of the stress intensity factors K_{I} and/or K_{II}. In recent work we have shown that this presumption, which appears to be reasonable on face value quantitatively speaking, is nevertheless unacceptable as a general proposition. The reason lies with the quite arbitrary practice of omitting the second term of the series representation for the stress, a contribution which is independent of distance from the crack tip. Such omission can lead to errors of serious qualitative as well as quantitative nature in the prediction of stress and displacement related quantities of interest to the fracture problem.

This is nowhere more clearly demonstrated than for the case of the infinite sheet with a flat central crack biaxially loaded along its outer boundaries. For this particular problem the entire effect of the load applied parallel to the plane of the crack shows up in the usually discarded second non-singular terms of the series representations for stress and displacement. Omission of these contributions is, in effect, equivalent to denying the presence of the boundary load applied parallel to the crack and, consequently, leads to prediction of results at variance with the limited experimental data available. Our analysis, which includes the second terms of the series representations for local elastic stress and displacement, shows highly significant biaxial load effects on crack edge displacement, maximum shear, angle of initial crack extension, and on local strain energy density and strain energy rate. The sheet problem with an inclined crack has also been examined in a similar manner. The combined effect of load biaxiality and crack orientation on K_{I} and K_{II}, on maximum shear, on angle of initial crack extension, as well as on local strain energy density and strain energy rate is made explicit. Once again it is shown that use of the 'singular solution' for representation of the local crack-tip elastic stress and displacements is not sufficient to give adequate account of biaxial load effects.