Summary

Approximately half of this volume has been devoted to the general subject of fatigue crack growth, including effects of combined stress, nonperiodic load spectra, temperature, crack closure and residual stress, notches and material discontinuities. Other topics treated include the analytical and experimental analysis of surface flaws, K_{Ic}-J_{Ic} determination, elasto-plastic analysis, specimen geometry effects, experimental techniques for measuring fracture toughness and crack growth parameters, crack initiation, and a group of papers describing the application of fracture mechanics to engineering problems of current technological importance involving cracked bodies of complex geometry.

The influence of combined fields in fatigue crack growth studies was investigated. From experiments on aluminum alloys, Liu, Allison, Dittmer, and Yamane concluded that the transverse stress exerted no influence upon crack growth when constant stress ratios were applied cyclicly. In another study, Pook and Greenan found that the fatigue crack growth threshold depended upon the ΔK_I of the branch crack in some cases and upon the ΔK_I of the original crack in others where Mode II loads were combined with Mode I loads on the original crack.

Several papers focused on load spectrum effects. Based upon a comparison of experimental results with a continuum model, Nowack, Trautmann, Schulte, and Lütjering found that mechanical processes exert a strong influence upon load sequence effects on the fatigue crack growth in aluminum alloys, but that microstructural changes could produce significant deviations from the continuum mechanical analysis. In another study, Artley, Gallagher, and Stalnaker concluded, from an analysis of experimental data on aluminum alloy, that both overload magnitude and frequency exert significant effects upon crack growth rate. Gemma and Snow developed a mechanical model which used constant amplitude fatigue crack growth data at various stress ratios to predict reduced crack growth rates caused by high-low load sequences and showed that correct trends were predicted when compared with test results on several alloys.

The influence of temperature on fatigue crack growth was investigated. Douglas and Plumtree utilized a unified life prediction theory based upon damage accumulation in order to predict crack growth rates at elevated temperature. Tobler, Mikesell, and Reed recorded variations in K_{Ic} with temperature over a wide range of temperatures including the transitional range for low-carbon steels. On the basis of experiments on aluminum alloys at low temperatures, Pettit and VanOrden concluded that service temperature R-curves should be used in ranking materials for use in the cryogenic temperature region. Shih and Clark found that the influence of temperature on fatigue crack growth rates in rotor steel was frequency dependent, primarily at low frequencies. However, at all frequencies studied, the fatigue crack growth rate decreased initially with increasing temperature and then increased with continued temperature increase.

Several investigations were conducted which focused upon the influence of crack tip plasticity upon fatigue crack growth. Führing and Seeger developed a continuum mathematical model for describing load history induced residual stress effects upon crack-tip plasticity and fatigue crack growth. In another analytical study, Marci quantified the concentration of crack closure effects near specimen surfaces. Vazquez, Morrone, and Gasco conducted an experimental study of fatigue crack closure in steel from which they identified K_{max} as the most suitable parameter for correlating fatigue crack closure behavior. Glinka showed how the influence of residual stresses in cracked steel weldments on fatigue crack growth could be predicted qualitatively from existing models. On the basis of observations of experiments on aluminum alloys and steel, Saxena and Hudak explained the dependence of load ratio effects on crack growth rates through mean stress relaxation. Based upon experimental observations, Shaw and LeMay concluded that crack growth curves could be predicted accurately provided the proper crack closure load was used.

Several studies were reported upon which dealt with the initiation and growth of fatigue cracks from notches, where the use of Linear Elastic-Fracture Mechanics may be questionable. Dowling described a general approach to notch size effects based upon the growth of small cracks. El Haddad, Smith, and Topper presented an approach to the short fatigue crack emanating from a notch based upon a strain intensity factor. Braglia, Hertzberg, and Roberts identified the micromechanisms responsible for crack initiation in notched high-strength low-alloy steel.

Finally, an investigation by Clark is included which studies the influence of macroscopic spherical discontinuities upon the fatigue crack growth rate in powder metal steel specimens.

Several papers, both analytical and experimental, addressed three dimensional cracked body problems involving surface flaws. Using a boundary integral-influence function approach, Heliot, Labbens, and Pellissier-Tanon computed stress intensities for semi-elliptic cracks in meridional planes of thin-walled cylinders under internal pressure. McGowan and Raymund addressed the same problem utilizing a finite-element approach and their results correlated well with those of the previously mentioned study. Yagawa, Ichimiya, and Ando used the finite element method to compute the time dependent thermal stresses induced by the sudden cooling of a thick plate containing a surface crack. The results predicted by the model were compared with test results on plexiglas plates and estimated times to fracture agreed fairly well. Hodulak, Kordisch, Kunzelmann, and Sommer, in an experimental study of the fatigue crack growth of surface flaws in plates found evidence of nonuniform material behavior along the flaw border which they suggest may be due to a stress state dependent mechanical response. Raju and Newman, using a finite element model, computed stress intensities for the technologically important problem of a crack emanating from the intersection edge of a hole with a plate. In a frozen stress photoelastic study of the same problem, Smith, Peters, and Gou found that nonself-similar flaw growth appeared to produce changes in the stress intensity distribution during flaw growth and suggested that the cause may be due to an effect such as suggested by Hodulak et al.

Several papers were devoted to K_{Ic}-J_{Ic} evaluations for different materials, some of which included tear modulus measurements. Penelon, Bassim, and Dorlot, in evaluating J-integrals for material in the heat affected zone of steel alloys, observed a strong dependence of J_{Ic} upon geometry. Underwood measured J_{Ic} in steel using a bend test and presented a correction procedure for computing J_{Ic} values from C-shaped specimens.

Several papers presented studies which were directed towards the analysis and measurement of specimen geometry effects upon test results. Gudas, Joyce, and Davis studied such an influence upon the J_{Ir} curve Tear Modulus in HY130 steel and found that face-grooving effects were significant. deCastro, Spurrier, and Hancock quantified the influence of the crack length to specimen width ratio upon the crack opening displacement for structural steels in the cryogenic to room-temperature region. Mall, Kobayashi and Urabe conducted dynamic photoelastic studies on dynamic tear test specimens in order to measure the variation of the dynamic stress intensity factor with time. A finite element model was constructed which correlated with the experimental results. Garwood showed that the values of J and the crack opening displacements were essentially the same for both three-point bend and center-cracked tension specimens of pipeline steel. The corresponding resistance curves, however, were different, and analytical explanations were offered.

Several papers utilized particular experimental techniques for obtaining information on fracture parameters. Ori and Grandt evaluated the use of cracked coupons bonded to structures with expected preexistent cracks so that the coupons experienced load histories similar to the structure for predicting crack growth. Allison used X-ray stress analysis to measure both residual and applied stresses near a crack tip. Results confirmed the presence of crack closure type stress fields. Vary described a mechanical model which is based upon the assumption that microcracking is promoted by elastic wave interactions, and relations between ultrasonic and fracture parameters were obtained.

Reflecting the continued effort to adapt fracture concepts to plastic cracking, several papers focused upon the analysis of such cases. Ernst, Paris, Rossow, and Hutchinson developed analytical methods for computing J from load displacement test records which take into account the influence of the extension of the crack. Karabin and Swedlow, in a finite element analysis, found a path dependence in J when the plastic zone size is not small. They suggest that this effect is related to a resharpening of the crack flank near the tip in center-cracked specimens. Turner provided a description of stable and unstable crack growth for elastic-plastic behavior in terms of J_r resistance curves.

Three papers addressed the general topic of composite fracture. Williams and Reifsnider presented a strain energy release based finite element model for predicting failure modes in composite laminates which was correlated with experimental observations. Wang described a hybrid stress finite element analysis of the tapered double cantilever beam fracture toughness specimen which revealed a number of important features. Ramkumar, Kulkarni, Pipes, and Chatterjee presented an analysis of delaminations in a laminated cantilever beam of various locations in the beam. The model suggests mechanisms for progressive cracking in laminates.

A number of interesting papers were contributed which addressed special topics in fracture mechanics. Kong and Paris used a model of ductile fracture in tensile bars to suggest that tearing instability theory might apply to some cases of fracture in the presence of extensive plastic deformation. Pu and Hussain estimated stress intensity factors for a uniform array of radial cracks around a circular ring using a finite element approach. Smoley studied crack surface topologies in poly(vinyl chloride) for nucleation, subcritical and critical flaw growth for both plasticized and unplasticized material. Both craze and crack growth regimes were observed.

The preceding contributions to the developmental aspects of fracture mechanics were augmented by several papers which focused upon the utilization of fracture mechanics in specific engineering applications. McDermott and Stephens conducted tests on hollow rectangular tubes containing corner cracks and described a procedure for predicting K_I values and crack growth based upon existing solutions. Christ, Smith, and Hicho described the post failure analysis of a pneumatically burst seamless steel compressed gas cylinder which led to recommendations for minimizing the occurrence of such failures. Kapp and Eisenstadt described a procedure for modeling flaw growth in autofrettaged cylinders for use in design. Finally, Galliart described a design technique which utilized test data from a field test of a prototype as input data to a computerized program for designing against failure from fatigue crack growth in the ground vehicle industry.

The papers included in this volume show that fatigue crack growth continues to occupy an important position in fracture mechanics. Moreover, while crack initiation appears to be controlled mechanically, crack growth is shown to be sensitive to many other side effects as well, a number of which are quantified herein.

Another area of substantial activity involves the extension of the basic concepts of fracture mechanics to the prediction of fracture in the presence of substantial amounts of plasticity.

New results, both analytical and experimental, suggest that more complex models will be necessary in order to provide an acceptably accurate description of crack growth and fracture in problems involving complex three-dimensional geometries. It is encouraging to note that, as the problems under study become more complex, new analyses and experimental techniques are being developed for use in dealing with such problems.

Taken collectively, this volume records advances in the development and application of fracture mechanics along a broad front. It would seem to portend a trend which will extend the use of fracture mechanics to a wider range of environments and to more complex problems in the future.

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