TUDY OF FATIGUE CRACK CLOSURE AND RACK PROPAGATION FOR OPENING AND HE MIXED MODE IN ALUMINIUM ALLOYS

by

A. M. ABDEL-MAGEED

Department of Applied Mechanics

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CERTIFICATE

This is to certify that the Thesis entitled,"**STUDY OF FATIGUE CRACK CLOSURE AND CRACK PROPAGATION FOR OPENING AND THE MIXED MODE IN ALUMINIUM ALLOYS**" being submitted by **A.M. ABDEL-MAGEED** to the Indian Institute of Technology, Delhi, India, for the award of the degree of '**Doctor of Philosophy**' in Applied Mechanics Department is a record of bonafide research work carried out by him under my supervision and guidance. The thesis work, in my opinion, has reached the standard fulfilling the requirements for the 'Doctor of Philosophy Degree'. The research report and results presented in this thesis have not been submitted in part or in full to any other University or Institute for the award of any degree or diploma.

(DR. R.K. PANDEY)

Professor

Centre for Materials Science & Technology,
Indian Institute of Technology
New Delhi-110 016, **INDIA**

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ABSTRACT

In the present work, two aluminiumn alloys (2024-T3 and 7075-T6) have been employed to investigate the crack closure behaviour at different stress ratios. The study has been conducted over a wide range of maximum stress intensity factor, K_{max} by using two measurement teschniques (Compliance Gauge and Eddy Current). The study has also been carried out for the effect of clip gauge location behind the crack tip on opening stress intensity factor, K_{op} and normalized K_{op} (K_{op}/K_{max}). Also the crack growth rate, with and without closure, has been studied in both the alloys.

The static and cyclic mixed mode loading behaviour (crack initiation angle, θ_o and crack path) for 2024-T3 alloy has been investigated using inclined centre cracked specimens and the cyclic mixed mode crack closure has been measured for different angles of crack inclination. The experimental static and cyclic crack path have been compared with some of the available mixed mode cracking criteria, i.e. Maximum Tensile Stress (MTS), Strain Energy Density (SED) criteria etc. Based on this comparison, it is suggested that in presence of large plastic zone size at the crack tip, the static mixed mode crack will propagate in a direction perpendicular to the loading axis (i.e., $\beta + \theta_o = 90^o$). Also, the MTS criterion has been modified by incorporating the effective stress intensity range, ΔK_{eff} for better prediction of cyclic crack path. The mixed mode cyclic crack growth rate and fatigue life have been predicted using SED criterion (following two different approaches) and the MTS criterion using equivalent stress intensity range, ΔK^{eq}. Based on crack closure studies in the opening mode and mixed mode, equations have been proposed to predict mixed mode closure behaviour from the opening mode data

and the loading parameters. The thesis is divided in 8 chapters as follows:

Chapter-I provides an introduction to the thesis highlighting the application of fracture mechanics to fatigue problem. The significance of crack closure and its influence on crack propagation life has been indicated. The importance of mixed mode crack growth studies has been described and finally the broad objectives of the present investigation are spelled out.

Chapter-II presents a review of literature on types of crack closure and the measurement techniques for closure. The parameters affecting the crack closure behaviour and different closure models are also reviewed. Literature on different mixed mode crack growth criteria are reported along with their salient features. The effect of mixed mode loading on cyclic crack growth rate by various investigators has also been included. The aim and scope of the present investigation has been highlighted at the end.

Chapter-III deals with the details of materials, specimens and the experimental techniques used for the measurement of crack closure and crack propagation in the opening mode and the mixed mode.

Chapter-IV reports the tensile properties, fatigue crack propagation and crack closure results for the opening mode loading. Also, the results on the effect of measurement location on opening stress intensity factor, K_{op} have been reported.

In Chapter-V, a comparison between the 'compliance gauge' and the 'eddy current technique' for crack closure measurement has been made. Dependence of crack closure behaviour on differ-

ent loading parameters (i.e. ΔK_{max}, R, σ_y etc.) has been discussed. The crack closure results are compared with some empirical and numerical models. The effect of gauge location on K_{op} and K_{op}/K_{max} ratio for different crack lengths (i.e. K_{max}) has been presented. To ascertain the nature of dependence of K_{op} on R and measurement location, the results of some other investigators from literature are replotted and analysed. Crack growth rate as a function of ΔK and ΔK_{eff} are also reported and discussed in this chapter.

The initial results on cyclic mixed mode crack propagation and crack closure are presented in Chapter-VI. The characterization of mixed mode crack growth under static loading is presented based on J integral approach. The evaluation of crack initiation angle and crack path using different mixed mode criteria are also reported in this chapter.

A comparison of static and cyclic crack path against the predicted crack path using different mixed mode criteria has been taken up in Chapter-VII. An interrelation between the mode I and mode II fracture toughness has been developed and the results are compared with the reported findings. The static and cyclic crack growth mechanisms have been investigated based on the macroscopic and the microscopic examination. The crack closure results for the mixed mode loading have been discussed and compared with mode I closure behaviour. The mixed mode cyclic crack growth rate and fatigue life have been obtained and discussed in the light of the predictions based on the SED and MTS criteria.

Main conclusions based on the present investigation are reported in Chapter-VIII.

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