AMBIENT FRACTURE BEHAVIOUR AND ENVIRONMENTAL CRACK GROWTH KINETICS IN A LOW ALLOY AND A MICROALLOYED STEEL

THESIS
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requirements for the degree of
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by

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CERTIFICATE

This is to certify that the thesis entitled "Ambient fracture behaviour and environmental crack growth kinetics in a low alloy and a microalloyed steel" being submitted by A.N.Kumar 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 our supervision and guidance. The thesis work, in our 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.

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ABSTRACT

The present investigation is concerned with the studies on mechanics of ambient fracture and the kinetics and mechanisms of environment induced cracking at room temperature in two typical structural steels - a low-alloy steel (Ni-Cr-Mo type) and a microalloyed steel. The Ni-Cr-Mo steel has been studied in the quenched and tempered condition while the microalloyed steel has been investigated in the as-rolled (normalised) condition. The tempering (between 200-600°C) in Ni-Cr-Mo steel results in substantial change in microstructure and tensile properties, crack tip stress and strain distribution are influenced significantly and a transition in the mode of fracture, i.e. from cleavage and intergranular to micro-void coalescence is obtained.

The tensile and fracture toughness test results have been combined with the findings from microstructural and microfractographic investigation to present a cohesive and integrated picture of the mechanics of fracture in these steels. The morphology and distribution of inclusions (their size, shape and volume fraction) have been determined and used to get an insight of the micromechanics of crack initiation and growth. The crack tip fracture strains have been computed by using a void coalescence model as well as COD data. The fracture strains are found to be reduced by nearly an order of magnitude in FT specimen.

In the region of maximum triaxiality in FT specimens, the fracture strain is further reduced by almost the same factor. The process zone size has been determined and related to the characteristic microstructural features. It is believed that for the quasi-cleavage and intergranular fracture, the process zone is given by the prior austenite grain size. On the other hand, for a ductile mechanism of crack it is given by a number of effective dimples (around 10 to 15) present over the process zone.

An attempt has been made in this investigation to propose a criterion for cleavage and strain induced fracture on the basis of stress and strain distribution at the crack tip. The effective inclusions for initiating voids in tensile as well as FT specimens have been identified. The quantitative analysis of the microfractographic features has been used to relate with the toughness levels in the steels investigated.

The kinetics and mechanisms of subcritical crack growth in the Ni-Cr-Mo and microalloyed steel have been studied with the help of an elaborate set up, designed and constructed for the purpose. Two typical environments used are 3.5 % NaCl solution and H_2S impregnated 0.5 % acetic acid solution. SEN specimens were subjected to sustained cantilever loading under the environment. The threshold parameters K_{ISCC}/J_{ISCC} have been determined and the crack growth kinetics studied using K and J approaches as found appropriate.

The threshold K_{ISCC} (J_{ISCC}) values are found to be lowered and the crack growth rate significantly higher under the H_2S environment as compared to that under NaCl environment. Various stages are observed during the subcritical crack growth in Ni-Cr-Mo steel under NaCl environment. While the stage I and III are characterized by the increased crack growth rate with K, stage II exhibits a plateau region (K-independent). The stages are found to be virtually absent for H_2S environment. The terminal K/J values for unstable fracture are significantly influenced by the environment and their implications have been discussed.

The crack growth studies using COD/J approaches reveal that the crack opening angle, and the tearing modulus ecrease with the cr ck extension fr r AQ, 200°C and 400°C tempering conditions. The macro crack branching is found to be associated with the K-independent region of crack growth and a limiting K value (K_{IB}). The in-situ cracking study using miniature specimens has also been carried out to reveal the cracking process in relation to the microstructure. The susceptibility to subcritical crack growth under H_2S environment is believed to be mainly due to hydrogen embrittlement for microalloyed and Ni-Cr-Mo steel. The fracture micromechanism under the ambient condition has been compared with the one under the environmental condition and the results have been discussed. The important conditions of the present investigation have been reported.

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