Effect of Band-Overload on Fatigue Crack Growth Rate of HSLA Steel: A Perspective Review

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Abstract- Fatigue crack growth behavior is important parameter of structural materials. This parameters can be used to predict their life, service reliability and operational safety in different conditions. The material used in this investigation is an HSLA steel. In this investigation effect of single overload and band-overload on fatigue crack growth of same steel are studied using compact tension (CT) specimens under mode-I condition and R=0.3. It is observed that overload and band-overload applications resulted retardation on the fatigue crack growth rate in most of the cases. It is also noticed that maximum retardation took place on application of seven successive overload cycles. The JQ fracture toughness values of 1-CT specimens with reduced thickness prepared from the as received steel fulfills the validity criteria according to ASTM E-1820-13 standard. This JQ value can be used as fracture toughness value of this steel. The experimental results of fracture toughness test show that the elastic plastic fracture toughness parameters JIc and δIc decrease with increasing displacement rate. The application of overload and band Overload reduces the crack growth rate.

Keyword: EDS, EPFT, LEFM, EPFM, HSLA

I. INTRODUCTION

Fatigue and fracture are common cause of service failure of engineering components and structures. to study about fatigue and fracture related problem is very important of any kind of machine parts, components and engineering structure that is related to various type of loading condition during their operation, so realistic fatigue crack growth and fatigue life prediction is one of the most importance part in terms of economic and safety point of view.

Fracture mechanics is based on the inherent assumption that there already exists a crack in a work-component or engineering structure. The crack may be man-made as a key- hole, a grooves, a notch, a re-entrant corner, or a slot, etc. The crack may exist within a component due to manufacturing defects like slag or impurities inclusion, cracks in a weld-ment or heat affected zones due to irregular cooling and existence of foreign particles. A serious crack may be nucleated and start growth during their service of the machine elements or structure (fatigue caused cracks, nucleation of cracks in notches due to environmental dissolution).Fracture mechanics is also applied to crack growth under fatigue loading condition. Initially, the fluctuating load nucleates a crack, which then propagates slowly and finally the crack growth rate per cycle accelerated and followed the fast fracture. Subsequently comes to the stage when the crack-length is long enough to be considered critical for a catastrophic fracture failure.

II. PREVIOUS WORK

J.R. Rice et al [2020] In case of EPFM generally use the J- Integral (JIc) or CTOD (δ). Crack tip opening displacement (CTOD) suggested by Wells, popular in Europe, and the J- Integral widely used in the United States However, most of investigator found that a distinctive correlation between J and CTOD exists for a material. Thus, these two parameters are valid in describing crack tip toughness for nonlinear and elastic plastic materials.

Griffith A. A et al [2019] The experimental measurement and mathematical based conceptual analysis of fracture toughness playing a very important role in application of fracture mechanics methods to structural integrity valuation, damage tolerance design, fitness-for-service evaluation, and residual strength analysis for different structures and engineering components as automotive, ship, pressure vessels, and aircraft structures.

J. Rice et al [2018] describe the intensity of elastic plastic crack-tip fields, and represents the EPFM.

The CTOD concept to assist as an engineering fracture parameter, and can be equivalently used as K or J in practical applications. By most of research and experimental results shows that the crack depth, specimen physical parameters, crack configuration and geometry, loading condition all are have a mostly effect on the fracture toughness analysis and investigation *(K, G, J* and CTOD). These effects are mentioned as constraint effect on fracture toughness.

Brog TK, Jones JW [2017] This work investigates overload-induced retardation effects for semi-elliptically cracked steel round bars. The specimen geometry equals the shaft area of a 1:3 down-scaled railway axle and the material is extracted from railway axle blanks made of EA4T steel. Rotating bending tests under constant amplitude loading as well as overload tests considering overload ratios of ROL = 2.0 and ROL = 2.5 are conducted. The experimental results are compared to a crack growth assessment based on a modified NASGRO equation as well as the retardation model by Willenborg, Gallagher, and Hughes. The evaluated delay cycle number due to the overload by the experiments and the model shows a sound agreement validating the applicability of the presented approach.

Anderson T L [2016] more sophisticated models for material behavior are being incorporated into fracture mechanics analyses. While plasticity was the important concern in 1960, more recent work has gone a step further, incorporating time-dependent nonlinear material behavior such as viscoelasticity and viscoelasticity. The former is motivated by the need for tough, creep-resistant high temperature materials, while the latter reflects the increasing proportion of plastics in structural applications.

Mohanty JR, Verma BB et al.[2015] Almost all load bearing components usually experience variable amplitude loading (VAL) rather than constant amplitude loading (CAL) during their service lives. A single overload cycle introduced in a con-stint amplitude fatigue loading retards fatigue crack growth and increases residual fatigue life. Although many models have been proposed on this subject, but life prediction under these complex situations is still under constant improvement.

The present study aims at evaluating retardation in fatigue life due to application of a single tensile overload spike by adopting an exponential model. The proposed model calculates not only parameters related with overload induced retardation in fatigue crack growth, but also residual life in case of 7020-T7 and 2024- T3 aluminum alloys with reasonable accuracy without integration of rate equation. The model also covers stage- II and stage-III of post-overload period.

III. METHODOLOGY

The Elastic plastic fracture toughness test (JIc and CTOD) at different displacement rate, and fatigue crack growth rate tests under different loading conditions on an HSLA steel. All tests were done using a 100kN, servo-hydraulic universal testing machine. Tests were on compact tension (CT) specimens under displacement control for elastic plastic fracture toughness test. The fatigue crack growth tests were done on CT-specimens under load control condition and also followed overload and different successive number of overloads (band overload) cycles on the specimens during test Tensile tests are performed on round bar specimens of diameter 6 mm and gauge length 30 mm out of the as received material. The tests were conducted following the ASTM standard E8-M. The nominal dimensions of the tensile specimens.

All tests were carried out with the help of a 100kN servo- hydraulic Universal Testing Machine connected with computer that is running Windows based monotonic application software supplied by BiSS. The software has facility for controlling the test control parameters, like strain rate, cross head speed and data acquisition system on load, displacement and extensometer in the channels.

During test using a 25 mm gauge length extensometer at room temperature, carried out at a displacement rate 1 mm/min. The true strain was measured through 25mm gauge length extensometer, mounted to the mid-section of the specimen length.

The tensile test generated data after test were investigated to estimate the various mechanical properties of the material.

The fracture toughness tests in this investigation were done on 1-CT (compact tension) with reduced thickness specimens. JIc test had been done in two processing test steps as first on is fatigue pre crack up to a/W is 0.45 to 0.70 by ASTM- E1820-13 [14]. And second one is JIc test of pre cracked specimen, by machine each specimen were pre cracked by fatigue, to produce a very sharp initial crack. Only three typical crack length to width ratios (a/W) (0.45, 0.58 and 0.542) are selected and analyzed in this investigation. All the pre-cracking experiments were done by computer controlled 100 kN load capacity BiSS servo-hydraulic universal testing machine using application software VAFCP (variable amplitude crack propagation) fatigue software. The software permitted on-line monitoring of the crack length (a), compliance, ΔK, load range and da/dN etc.

IV. RESULTS AND ANALYSIS

Approximately 12 mm long parts of samples were cut from the fractured surface of tested specimen for factor graphic examinations. The specimen parts were selected as the parts having contained as fatigue pre-cracked and the fractured surface.

The fractured surfaces were well cleaned by ethanol and were examined with the help of a field emission scanning electron microscopy (*FESEM*). The various images taken by *FESEM* at different magnitude and resolution for proper understanding the fracture behavior of the material.

V. CONCLUSIONS

In the present work, the elastic plastic fracture toughness test and fatigue crack growth study was conducted on 1- CT specimen with reduced thickness of an HSLA steel. The *JIc* tests were performed under three different displacement rates and finally the effect of displacement rate on fracture toughness are studied. In fatigue crack growth study three different loading conditions were applied: constant amplitude loading with fixed stress ratios, constant loading interspersed with single spike overload, and constant amplitude loading interspersed with multiple (band) spike overload. Effect of overload and band overload on fatigue growth life is determined.

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