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Prediction of Fatigue Cracking In Life Edge Has Achieved a Single Package Using the Exponential Model

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ABSTRACT: Metal beams are extensively used in structures, automobile sectors and machine components. Some of their applications include connecting rod of IC engine, shafts, axles, and gears, structures members of bridges and also components of machines. Most of them experience fluctuating or cyclic load condition in their service life's such loading conditions may initiate a crack and cause fatigue crack growth. The monitoring and modelling of fatigue crack growth are necessary for the stability and safety of machines and structures. In the present investigation an attempt has been made to develop a fatigue life prediction methodology by using an Exponential Model in single edge notched (SEN) cracked beams. The predicted results are compared with experimental crack growth data. It has been observed that the results obtained from the models are in good agreement with experimental data.

Keywords: -Beams, crack profile, fatigue crack propagation, constant amplitude loading, life prediction, exponential model.

INTRODUCTION

Failure due to repeated loading, that is fatigue, has accounts for at least half of this mechanical failure. No exact data is available, but many books and articles have suggested that between 50 to 90 per cent of all mechanical failures are due to fatigue, most of this is unexpected failures. In many situations a beam experiences fluctuating loading conditions. This may initiate and propagate a crack. The monitoring and modelling of fatigue crack growth is more significant for the stability and safety of machines components, bridges, aircraft and structures. In this project (EN8) medium carbon steel beam is used. In fatigue fracture the stress is generally below the yield stress. In general ductile material deforms before fracture and gives warning before failure of a component but in case of fatigue failure the ductile materials fails suddenly. This becomes more significant when failure is related to automobile sectors or machinery parts in which heavy loads or continuous work being done. In a dynamic world, however, failure occurs at stresses much below the materials ultimate strength or yield strength. This phenomenon, failing at relatively low stresses, came as quite a surprise to most engineers in the early years of metal component design and manufacturing. The other frustrating aspect is that the material exhibited no sign of its tiredness or fatigue and could fail without much warning. This could be more dangerous if proper selection of design criteria is not selected and validation of those criteria with experiment is not done. There are many areas where the fatigue criteria should be in mind before designing the component.

OBJECTIVES The objective of present work is: To develop compliance correlation of a-N data and estimation of fatigue crack propagation life by using exponential model.

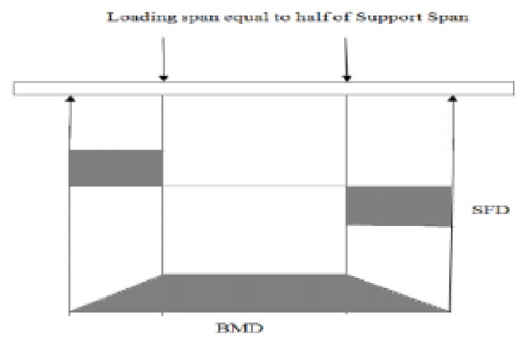
1. To conduct fatigue crack propagation test of supplied (EN8) medium carbon steel under constant amplitude loading condition with different stress ratios.

2. To propose an exponential model to predict fatigue crack propagation in single edge notched cracked beam.

The crack initiation starts in a point where the stress concentration is high. This stress concentration may be due to abrupt change in cross section or due to defect present within the system. The change of the cross section can do in such a way that the stress concentration will be lower. But the defect due to manufacturing process cannot be eliminated completely because of the complex nature of manufacturing and human interference.

EXPERIMENTAL INVESTIGATION

The fatigue crack propagation tests were conducted on (EN-8) medium carbon steel beams. All the tests were conducted in a servo-hydraulic dynamic testing machine (Instron-8800) using through crosssectional of cracked beam specimen under load control mode. A four point bend fixture was fabricated for conducting fatigue crack propagation tests. Before conducting the test, COD gauge was calibrated for single edge straight notched cracked beams specimens. All the tests were conducted in air and at room temperature. Four Points bend Method: Four point bending (FPB) is a cornerstone element of the beam flexure portion of a sophomore level mechanics of materials course. The FPB lecture has traditionally developed the theory from body diagram through beam deflection, with related homework problems providing analytical practice. In FPB method Beam flexure represents one of the three most common loading categories for mechanical systems. As such, it is on the syllabi of nearly all sophomore- level mechanics of materials courses, including the mechanical engineering technology course under consideration here. Within the lecture setting, FPB theory is developed from free-body diagram through beam deflection. This theory is reinforced by analytical practice solving related homework problems. By this FPB the result to experimentally and analytically verify and Validated beam flexure theory. According to the convention specified in ASTM D6272-00 transverse vertical loads are applied to horizontal beams such that a constant bending moment results between the two inner load locations. Figure below shows the corresponding loading diagrams, from free-body to bending moment. The major difference between the three point and four point flexural tests is the location of bending moment. The four point bending method allows for uniform distribution between the two loading noses, while the three point bending method, stress is located under the loading nose. But in four point bending test, no shear force acts in between two inner spans, while in case of three point bending test maximum shear force act a loading nose.



Four points bend method

LITERATURE REVIEW Several experiments and models have been proposed till date in order to predict fatigue crack propagation with load control method under constant amplitude loading conditions with different stress ratios with the help of INSTRON-8800. Generally crack length is measured by travelling microscope determined by mathematical modeling of standard specimens or by empirical relationship or by experimental investigation. We are here doing the experimental procedur e to find out the crack length for beams. Generally compliance crack length relationship and four point bend test are used for determination of crack growth. The objective of present work is to develop compliance correlation of a-N data and estimation of fatigue crack propagation life by using exponential model. Cyclic fatigue involves the microstructural damage and failure of materials under cyclically varying loads. Structural materials, however, are rarely designed with compositions and microstructures optimized for fatigue resistance. Metallic alloys are generally designed for strength, intermetallics for ductility, and ceramics for toughness; yet, if any of these materials see engineering service, their structural integrity is often limited by their mechanical performance under cyclic loads. In fact, it is generally considered that over 80 percent of all service failures can be traced to mechanical fatigue, whether in association with cyclic plasticity, sliding or physical contact (fretting and rolling contact fatigue), environmental damage (corrosion fatigue), or elevated temperatures (creep fatigue). Accordingly, a large volume of literature has been amassed particularly over the past twenty-five years, dealing with the mechanics and mechanisms of mechanical fatigue failure [1, 2]. Subcritical crack growth can occur at stress intensity K levels generally far less than the fracture toughness Kc in any metallic alloy when cyclic loading is applied (ΔKTH/Kc is nearly equal to 0.1 – 0.4). In simplified concept, it is the accumulation of damage from the cyclic plastic deformation in the plastic zone at the crack tip that accounts for the intrinsic mechanism of fatigue crack growth at K levels below Kc. The process of fatigue failure itself consists of several distinct processes involving initial cyclic damage (cyclic hardening or softening), formation of an initial „fatal" flaw (crack initiation), macroscopic propagation of this flaw (crack growth), and final catastrophic failure or instability. The physical phenomenon of fatigue was first seriously considered in the mid nineteenth century when widespread failures of railway axles in Europe prompted Wohler in Germany to conduct the first systematic investigations into material failure under cyclic stresses Wohler, 1860 [3]. However, the main impetus for research directed at the crack propagation stage of fatigue failure, as opposed to mere lifetime calculations, did not occur until the mid-1960s, when the concepts of linear elastic fracture mechanics and so-called „defecttolerant design" were first applied to the problem of subcritical flaw growth (Paris et al., 1961; Johnson and Paris, 1967). Such approaches recognize that all structures are flawed, and that cracks may initiate early in service life and propagate subcriticaly. This paper [4, 5] presents the fatigue crack growth analysis on the perforated wide flange I-beam which is subjected to constant amplitude bending loadings. I-beam of grade steel is widely used in building and other structural constructions. The detailed geometries according to the size and weight have been standardized such as ASTM, ISO etc. Since

I-beam has a significant contribution in building and other structural constructions, careful considerations has to be taken if defects or cracks are present in the beams. Many researchers have reported the behaviors of beam. Dunn et al.have introduced closed-form expressions for stress intensity factors for cracked square -beams subjected to a bending moment. GAO and Herman [6] have estimated the stress intensity factors for cracked beams. Most structural components are often subjected to cyclic loading, and fatigue fracture is the most common form of failure. In general, fatigue process consists of three stages: initiation and early Crack propagation, subsequent crack growth, and final fracture. The fatigue crack growth rate, da/dN, which determines the fatigue life of the cracked components, has extensively been investigated experimentally and theoretically. Stephens et al. [7] reported that fatigue crack growth curve for constant amplitude loading consisting of the crack growth rate (da/dN) versus the stress intensity factor range (ΔK) in the log–log scale typically includes three regions. Region-I is the near threshold region and indicate the threshold (ΔKth) value which there is no observable crack growth. Microstructure, mean stress, frequency, and environment mainly control Region I crack growth. Region II corresponds to stable macroscopic crack growth that is typically controlled by the environment. In Region III the fatigue crack growth rates are very high as they approach to instability. In Region III crack growth is often ignored in practice due to the insignificant fatigue life remaining upon entering the region. Structural engineers have been utilizing numerical tools/ software packages of Finite Element Method or Boundary Element Method to assess their designs for strength including crack problems. BEM has emerged as a powerful alternative to Finite Element Method (FEM) for cases where better accuracy is required due to situations such as stress concentration (as in the case of a crack), or an infinite domain problem. Since BEM only requires discretization of surfaces (in case of 3D problems) and discretization of lines (in case of 2D problems), it allows modeling of the problem becoming simpler. Aliabadi [8] reported various applications of BEM to solve solid mechanics problems. Boundary element formulations for modeling the nonlinear behavior of concrete were reported by Aliabadi and Saleh [9]. Fatigue crack growth is required for the assessment of residual fatigue life, or for a damage tolerance analysis to aid structural design. In this paper fatigue crack growth of corner crack in wide flange I-beam under constant amplitude bending loading are presented. A quarter-elliptical corner crack in a prismatic solid is analyzed as benchmarking model for the available analytical solution [10] prior to making further modeling of the cracks. This paper [11] examines the fatigue crack growth histories of a range of test specimens and service loaded components in Aircraft structures and Joint failures. The crack growth shows, as a first approximation a linear relationship between the log of the crack length or depth and number of cycles. These cracks have grown from; semi- and quarter elliptical surface cuts, holes, pits and inherent material discontinuities in test specimens, fuselage lap joints, welded butt joints, and complex tubular jointed specimens‟ .This application of exponential crack growth are discussed. The stress intensity factor range, ΔK has for many years been known to have a significant correlation with the crack growth rate, da/dN. The first paper making this correlation was published in 1961 by Paris, Gomez and Anderson [12], who adopted the K-value from the analysis of the stress field around the tip of a crack as proposed by Irwin in 1957 [13]. The results of the constant-amplitude crack growth tests by Paris were expressed in terms of da/dN (where N is the number of fatigue cycles) as a function of ΔK (which is Kmax - Kmin) on a double log scale. Plotting such data shows a region of growth where a linear relation between log (da/dN) and log (ΔK) appears to exist. This paper examines the Compliance crack length relations for the four-point bend specimen geometry in the laboratory. Crack lengths can be measured by direct and indirect means. While direct methods of crack length measurement, e.g. by travelling microscope, are tedious and prone to human error, the indirect methods are not only

CONCLUSIONS

1. The calibration curve of COD gauge is found to be straight line, which shows linear relationship between COD gauge and crack depth of straight notched beam.

2. The crack front profile is approximately thumbnail shape in nature as the crack depth increases.

3. Exponential model of the form has been used for other specimen geometries and can also be used to determine the fatigue life in beams without going through numerical integration.

4. Subsequently, to predict fatigue life, the exponent, mij (specific growth rate) has been judiciously correlated with crack driving parameters ΔK and Kmax and

material properties KC (for specific specimen geometry) E, Ϭys and R in the form of dimensionless quantities.

5. The proposed exponential model may be used to predict fatigue crack propagation under constant amplitude loading condition with different stress ratios.

FUTURE WORK

1. The proposed models may be tested for other specimen geometries.

2. The soft computing methods may be used to determine the specific growth rate.

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