RESEARCH ARTICLE OPEN ACCESS

Crack Propogation Analysis Of Single Edge Notch Beam

Mr. Shashikant Ashok Sandhan, Prof. V. L. Kadlag
ME Mechanical, Mechanical Engineering Department
SVIT, Chincholi, Sinner, Nashik
Maharastra - India

ABSTRACT

Metal beams are extensively used in 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 various load condition in their service life's such loading conditions may initiate a crack and cause crack growth. These forces may be tension, compression, internal pressure, bending or any combination of all. The monitoring and modeling of crack growth are necessary for the stability and safety of machines and structures. A finite element based two dimensional crack propagation simulator software Ansys14.0 used propagation in two dimensional beam. Four point bending test experiment is carried out on aluminium beam and crack growth behaviour is observed. These two observations i.e. from Ansys and experiment are compared. In the present work an attempt has been made to develop a failure 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:- SEN

I.INTRODUCTION

Beams are used in factories and industries for support and to give strength to various elements. It is important to predict crack growth to obtain flaw acceptance criteria for an existing initial planar notch. Many experiments are performed to study the crack growth behaviour of beams containing initial surface notch under different loading condition [1,2]. Practical methods are not often used to study crack growth as these require a lot of time and money and are destructive in nature. So analytical methods are used to solve this problem based on finite element method and fracture mechanics. Analyses of three dimensional partial circumferential cracks need complex computational work to keep pace with the mesh pattern and large computer storage memory. Hence it is essential to have two dimensional analysis of the beam for ease of study. Thus a three dimensional beam is converted to a two dimensional beam having same thickness. For conversion a method has been proposed based on equating deflection of both the pipe specimen and the beam. Four point bending test experiment is performed by taking a bar made of EN8 material having a initial crack at one edge. A mesh generation program software CASCA is used and then for crack propagation simulation , a finite element based program FRANC2D software is used. Values of C and m (constants of Paris model) obtained from both the process are compared.

Progress has been made in the development of bending theory for cracked thin plates since the first work (Williams, 1961). His equations for the elastic stresses local to the crack tip contained two unspecified constants, which were defined by Sih, Paris and Erdogan (1962). Additionally, other theories have also described the local stress near the tips of through cracks in plates, the surfaces of the crack were taken to be stress free in either the Kirchhoff or the Reissner sense, and the crack tip was taken to be straight through the thickness of the plate (Williams, 1961; Knowles and Wang, 1960; Hartranft and Sih, 1968). However, there is ample experimental evidence that the restrictions of the mathematical model are violated in reality (Erdogan, Tuncel and Paris, 1962). Out-of-plane bending will produce tension on one surface of the plate and compress on on the other. This compression induces contact of the crack faces. In this circumstance, the behavior of the front crack during growth is not so simple. To the knowledge of the authors, there are few studies that address the numerical simulation of crack propagation in plates under cyclic bending, other than that by Roy et al. (2005). However, Roy et al. combined out-of plane bending with a tension load. Further more, there are no experimental studies of crack propagation under cyclic bending loads. For example, Erdogan et al. (1962) and Yan et al. (2010) did experiments using out-ofplane bending, but in these works the loading is applied statically. Potyondy considered cyclic loading in fracturing analysis of shells, but the crack face contact was not taken into account because a membrane loading and a bulge-out effect were considered. (Potyondy, Wawrzynek and Ingraffea, 1995).

The behavior of pre-catastrophic crack extension in a plate in combined extension and approximately cylindrical bending was studied by Wynn and Smith (1969). They compared the experimental stress with Sih-Hartranft bending theory. The results are similar to experiment results in regions where the crack remained open at fracture, but appeared to provide a lower bound in the region where crack closure occurred. Smith and Smith (1970) first studied this problem experimentally using frozen stress photoelasticity and the data were also compared with Hartranft-Sih theory. They concluded that crack face contact during bending increased the crack tip stress over the no contact case. More frozen stress photoelasticity experiments were presented in Mullinix and Smith (1974), but an extension load was applied simultaneously with the bending load to ensure that the crack did not close. Those experimental results agree with the Sih theory only for thin to moderately thick cracked plate geometries (/ 2 1 t a <). In 1992, a theoretical work was performed using a line contact analysis for Kirchhoff theory (Young and Sun, 1992). This study considered closure at the compressive edges for an infinite plate containing a center crack under bending. It was found that the closure at the compressive edge tends to reduce the crack opening displacement at the tension side and as a result, reduce the stress intensity factors. In addition, Heming (1980) used finites elements with Reissner theory kinematics, and also assuming a line contact during bending. He also found that the opening displacements on the crack are reduced. Alwar and Ramachandran (1983) considered a three dimensional finite element analysis for this problem. By iteration they were able to accurately determine the actual area of contact. As Young and Heming, they concluded that closure reduces the crack tip stress intensity. Later, analytical works were developed for an infinite plate that solves the area contact using Reissner theory (Slepyan, Dempsey and Shekhtman, 1995; Dempsey, Shekhtman and Slepyan, 1998). They determined the shape of the closure region and its dependence on the remote loading, as well as length to plate thickness ratio for a pre-existing through crack. Zehnder and Viz (2005) provide some reviews on this subject.

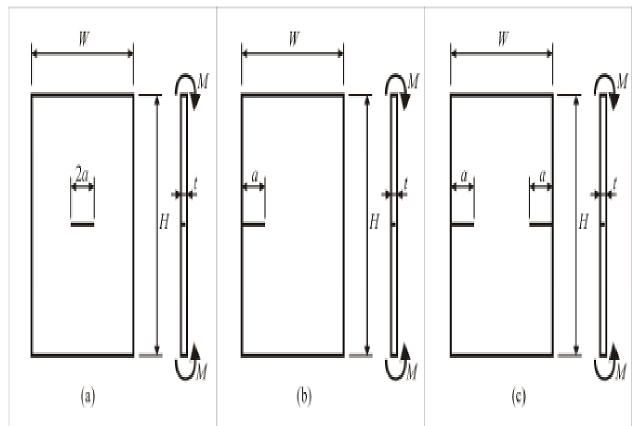

Figure 1: Geometry (a) Central cracked plate. (b) A single edge-cracked plate. (c) Double edge cracked plate.

This work presents an initial investigation of the stress intensity factor under out-of-plane bending using three geometries of a pre-existing through cracked plate. Additionally, the crack opening in three different thicknesses was studied. Three dimensional finite element analyses (FEA) were conducted, simulating the partial crack-face contact for elastic-linear material using FRANC3D and ABAQUS. The FEA and experimental results are compared for a single edge-cracked plate. The preliminary findings here should help to further work on this subject.

II. LITERATURE REVIEW

When a metal is subjected to a repetitive or cyclic stress it fails at a stress much lower than that required to cause fracture or failure on a single application of load. These failures which occur under closures of dynamic loading are known as failures.

Failures occur when a metal is subjected to a repetitive, cyclic or fluctuating stress (load) and will fail at a stress much lower than its tensile strength. This kind of failure occurs without any plastic deformation. The appearance of the fracture surface, which shows a smooth region, due to the rubbing action of a crack propagated through a rough section, where the member has failed in a ductile manner at a point when the cross section was no longer able to carry the load. Three basic factors are necessary to cause failures.

These are:

1. A high value Maximum tensile stress,
2. A large variation in fluctuation on the applied stress, and
3. A sufficiently large number of cycles of the applied stress.

Coming to the processes involved in the process:

1. *Crack initiation* – damage is developed and that can be removed by thermal annealing.
2. *Slip band crack growth* – involves the deepening of the initial crack on high shear stress planes. This frequently is called stage I crack growth.
3. *Crack growth on planes of high tensile stress* –this involves growth of well-defined crack in a direction perpendicular to maximum tensile stress. Usually called stage II crack growth.
4. *Ultimate ductile failure* – this occurs when crack reaches sufficient length so that the remaining cross section cannot support the load.

The relative proportions of the total failure that are involved with each stage depend on the test conditions and the material. However, it is well established that a crack can be formed before 10 percent of the total life of the specimen has elapsed. In general, larger proportions of the total cycles to failure involves the propagation of the stage II cracks in low-cycle than in long-life, while stage I crack growth comprises the largest segment for low-stress, high-cycle. If the tensile stress is high, as in the sharply notched specimens, stage I crack growth may not be observed at all. Several experiments and models have been proposed till date in order to predict 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 procedure 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, intermetallic 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 ($\Delta KTH/Kc$ 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 „defect-tolerant 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 subcritical.

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 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 superior in these respects but are also amenable to automation and therefore useful for computer-controlled fatigue testing. The simulation and analysis process is done at various locations in four point bend test. A beachmarked fatigue fracture is produced under 4PB loading. The crack length at each beachmark obtained by optical measurements and compared with that obtained by the crack mouth CCL relation developed [14]. This paper examines the life prediction methodology by adopting an „Exponential Model‟ that can be used without integration of fatigue crack growth rate curve. The predicted results are compared with experimental crack growth data obtained for 7020-T7 and 2024-T3 aluminum alloy specimens under constant amplitude loading. It is observed that the results obtained from this model are in good agreement with experimental data and cover both stage-II and stage-III of fatigue crack growth curve [15]. The aim of developing a fatigue crack growth model is to predict a safe operating life while designing a structure/component subjected to cyclic loading. The service life of a structure/machine component under cyclic loading can be estimated by integrating the rate equation of the Paris type. However, direct integration becomes robust and complicated as the geometrical factor „f (g)‟ in the expression of ΔK varies with crack length. Therefore, fatigue life may be estimated by numerical integration using different values of „f (g)‟ held constant over a small crack length increment [16]. To overcome this difficulty, the authors have attempted to introduce a life prediction procedure by adopting an „Exponential Model‟. The model can predict the fundamental a– N curve to calculate life without integration of FCGR curve. It is worth mentioning that an exponential model is often used for calculation of growth of population/bacteria, etc. In this paper, the fatigue cracks propagate in longitudinally reinforced concrete beams without stirrups. The experimental program has been designed to investigate the influence of the shear span-to-depth ratio on diagonal crack propagation and load carrying capacity of tested beams under four point bend test. The obtained test results were compared with numerical results made on the basis of Finite Element Method .In this paper, Fatigue crack growth tests were conducted on double cantilever beam bonded specimens with the aim to characterize an adhesive for structural applications. The tests were conducted in lab air at two different load ratios, and at two different loading frequencies, Crack propagation was monitored using the compliance method by three point bend test and FE model was used also.

III. CRACK PROPAGATION

3.1 CRACK PROPAGATION

A component containing a crack, when loaded statically, no crack growth is seen as long as the crack length or the loading remains below a critical value. If the loading is oscillating crack growth in small steps can be observed for loading amplitudes far below the critical static load. This type of crack growth is called crack growth. Usually crack growth is specified by the crack growth rate (da/dN), where N is the number of load cycles.

Crack propagation behaviour for metals can be divided into three regions. The behaviour in Region I exhibit a -threshold cyclic stress intensity factor range, ΔKth below which cracks do not propagate under cyclic stress fluctuations. Region II represents the crack propagation behaviour above ΔKth which can be represented by [5],

Where, a = crack length; N = no. of cycles; ΔK = stress intensity factor range,

'c' and 'm' are material constants.

The crack growth per cycle in region III is higher than that for region II.

Region wise following characteristics are shown by the metal.

Region I: The stage I propagate initially along the persistent slip bands. This stage is a non-propagating stage or very slow propagating stage with around 1 nm per cycle. The crack growth here is largely influenced by mean stress, microstructure and environmental factors.

Region II: This is widely studied stage among all the stages of crack propagation. This is also stable stage crack propagation process. Continuous behaviour, striations or transition from non-continuous behaviour with,

(a) Large influence of certain combinations of environment, mean stress and frequency,

(b) Small to large influences of microstructures, depending on material.

Region III: In this stage unstable crack growth occurs which followed by failure. Static mode of behaviour is shown by the object. In this stage there is a large influence of microstructure, mean stress and thickness but a little influence of environmental changes, inter-granular and dimples affects this stage of crack growth.

3.2 Stress analysis for members with cracks-fracture mechanics approach.

For analyzing fracture and behaviour of sharply notched structural members (cracked or flawed) fracture mechanics is the recommended engineering method to be used in terms of stress and crack length. So as to analyze stress in vicinity of a well-defined crack or a sharp crack, stress concentration factor and stress intensity factor are the main factors to be observed at these points respectively.

Stress concentration Factor is used for analyzing stress at a point in vicinity of any well-defined notches. The discontinuities in structural components like holes, notches, fillets etc. when have a well-defined geometry, the value of stress intensity factor, Kt can be determined [7]. This Stress Concentration factor gives an important relationship between applied nominal stress and local maximum stress. However when the stress concentration goes severe, like while approaching a sharp where the radius of the crack tip is nearly zero, an analytical method which is different from the stress concentration is needed to analyse the behaviour of that structural component containing imperfections.

The parameter Stress Intensity Factor (K) which is related to both nominal stress level in the member and length of crack (a) and it has a unit of ksi√ (MPa√). To establish methods of stress analysis for cracks in elastic solids, it is surely defined in three types of relative movements of adjacent crack surfaces. The displacement modes (fig 2) represents the local deformation ahead of a crack. The opening mode I is characterized with local displacements which are symmetric with respect to x-y and x-z planes. The two fractured surfaces displace perpendicularly to each other in opposite directions. Mode II, is skew-symmetric with respect to the with respect to x-z plane and is symmetric with respect to x-y plane. The sliding surfaces slide over each other in the direction which is perpendicular to the line of crack tip. Mode III, the tearing mode is associated with the local displacement which are skew symmetric with both x-y and x-z planes. Here the two fracture surfaces slide over each other in the direction parallel to the crack front line. Each of these modes of deformation corresponds to a basic type of stress field which is in the vicinity of the crack tips.

IV. METHODOLOGY

Objectives

The objective of present work is:

1. The basic aim of present work is to develop a crack propagation model for SEN beam without going through numerical integration process. The specific growth rate (m) is an important parameter of our model. The value of m is correlated with two crack driving forces (ΔK and Kmax), and with material parameters fracture toughness (KC), yield strength (σYS), stress ratio(R), and Young‟s modulus (E) by curve fitting.
2. Plates with a pre-existing through-the-thickness crack were studied under the action of a remote bending moment.
3. The dependence of the contact region in the crack tip was investigated, as well as the bending effect on the stress intensity factor.
4. Two sets of numerical analyses were performed. One set uses different crack geometries for a constant plate thickness, and the second set uses a single crack geometry for three different plate thicknesses.
5. The experimental a-N data of four specimens were used for formulation of model, and its validation has been checked for 5th and 6th specimens.
6. The predicted result by using exponential model has been compared with the experimental results.

Methodology:

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.

Detection and measurement of cracks and damage can, in general terms, be classified into the following two groups according to their areas of application: laboratory methods and field service assessment methods. Numerous approaches and techniques are available to specify crack initiation and measure crack size for laboratory and field applications are summaries. This damage can be measured as the progressive development of a crack from the sub-microscopic phases of cyclic slip and crack initiation, followed by the macroscopic crack propagation stage, to the final distinct fracture. These three stages are important in defining the life of specimen and structural components. In many situations, crack initiation can, however, be the primary event for life estimation and design analysis. Crack initiation is the originator of failure. If the early stage of crack initiation can be identified, the mechanisms of crack initiation can be better understood and failure may be banned. When selecting a method or technique for crack detection or monitoring and measurement, sensitivity or crack size resolution plays an important role. The selection of crack measurement technique depends on loading type, specimen type, material, environment, crack initiation site, crack detection method, and sensitivity. For example, loading condition could be bending, axial, reverse bending, tension, and mode II loadings. Specimen types could be plate, bar, welded plate, cylindrical bar, compact-type (CT) specimen, blunt-notched specimen, and three-point bend bar, four points bend specimen etc. The environmental condition could be air, hydrogen water, vacuum, helium, and oxygen.

V. FINITE ELEMENT ANALYSIS

5.1 First Createing Model on ansys.

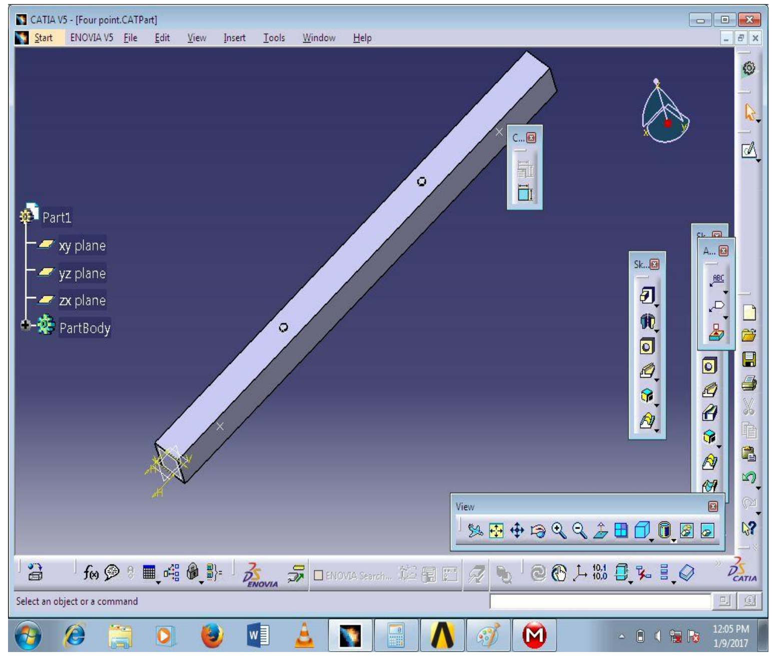

Figure 5.1 four Point.

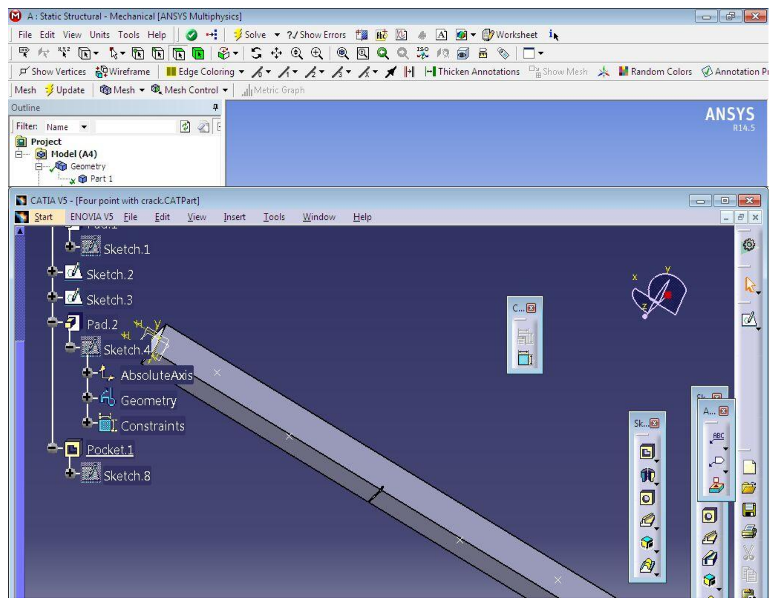

Figure 5.2 four Point with crack.

5.2 Ansys Modeling- After Creating Model in Catia which is import in ansys. For further analysis.

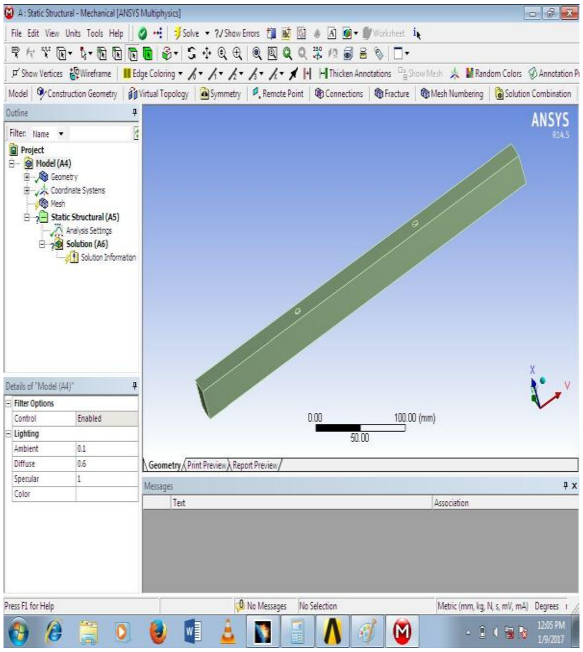

Figure 5.3 Static Structure.

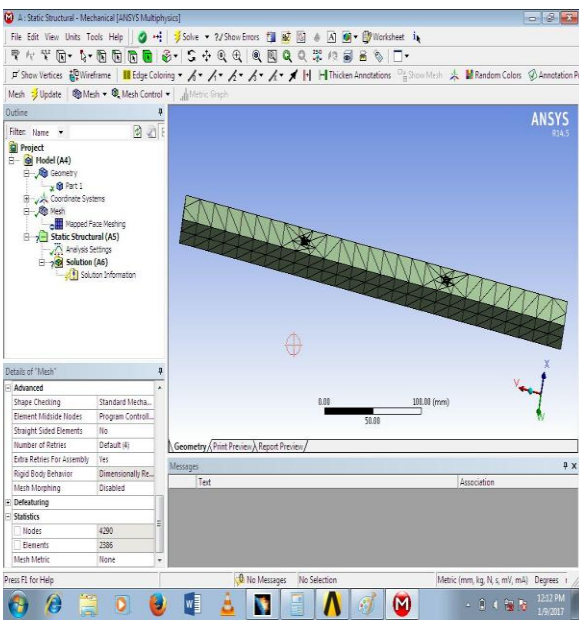

Figure 5.4 Static Structure Mesh(a).

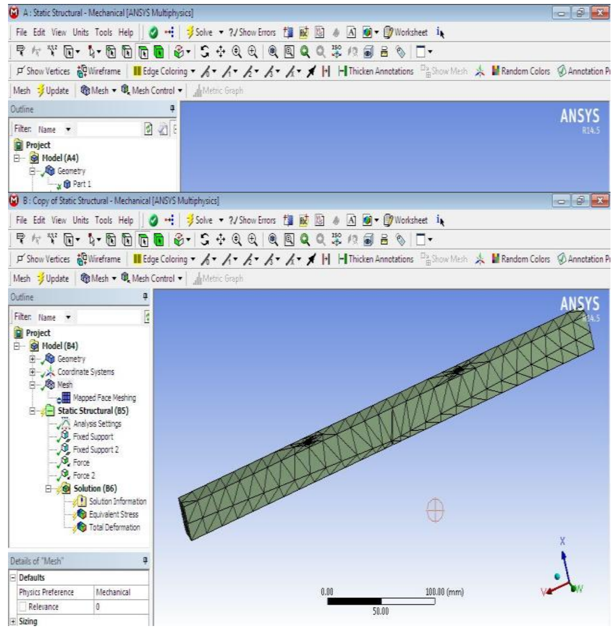

Figure 5.5 Static Structure Mesh(b).

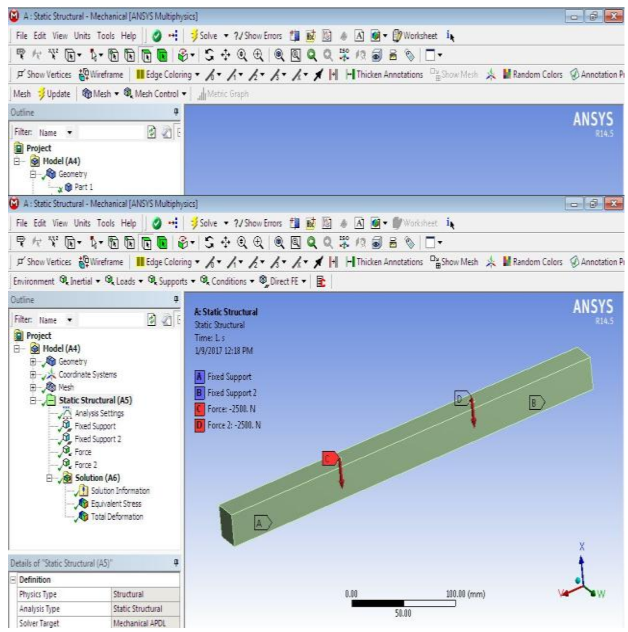

Figure 5.6 Support systems(a)

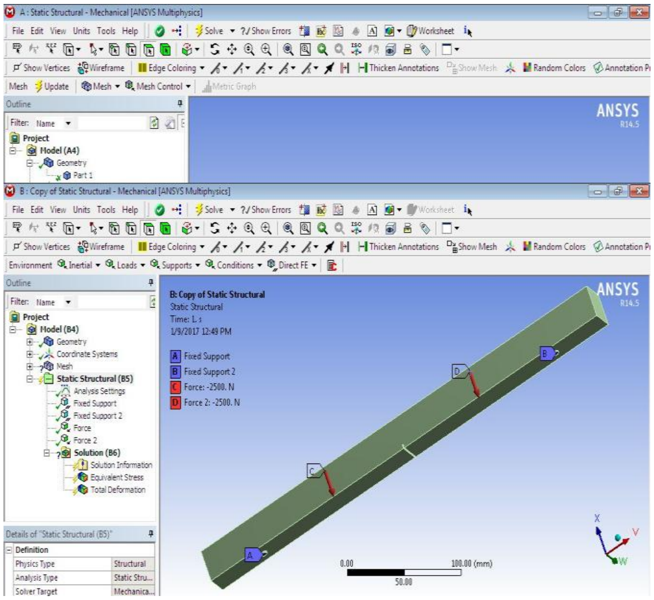

Figure 5.7 Support systems(b)

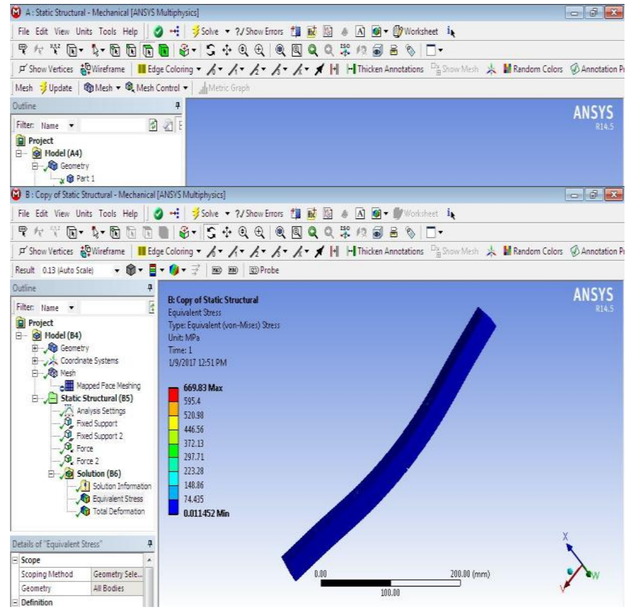

Figure 5.9 Equivalent Stress(b)

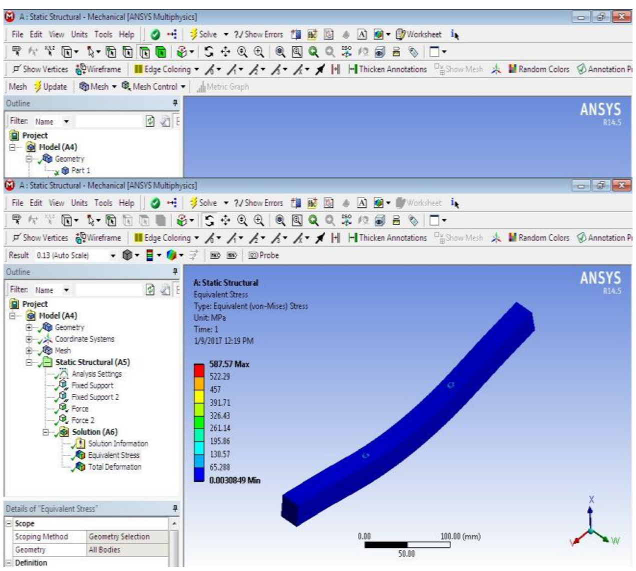

Figure 5.8 Equivalent Stress(a)

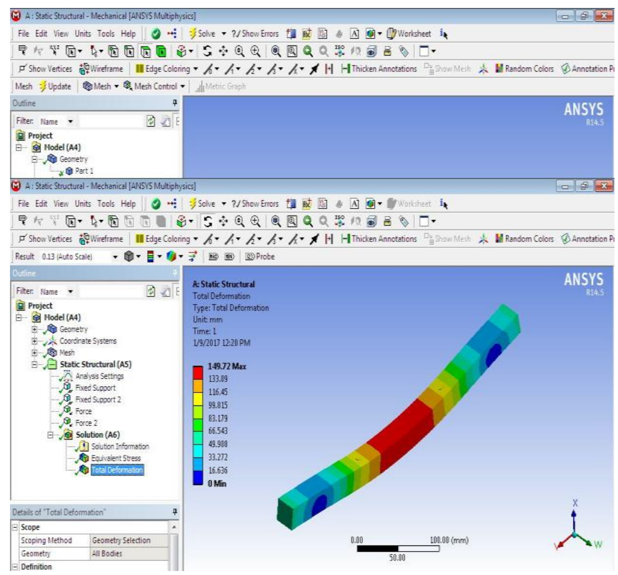

Figure 5.10 Total Deformation(a)

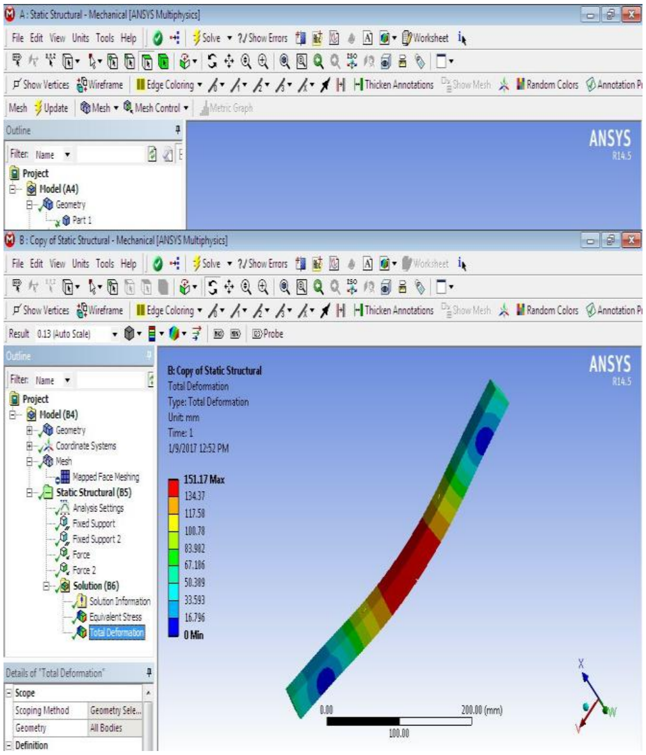

Figure 5.11 Total Deformation(b)

VI. SPECIMEN DETAILS

6.1 Specimen Details

Chemical and mechanical properties are of the alloy are given in the following table.

6.1.1 Chemical Properties

Chemical Element	% Present
Manganese (Mn)	0.50 max
Iron (Fe)	0.40 max
Magnesium (Mg)	2.60 – 3.20
Silicon (Si)	0.40 max
Aluminium (Al)	Balance

Table: 5.1 Chemical Properties of Aluminium 5754

6.1.2 Mechanical Property

Mechanical Property	Value
Yield Strength	276 MPa
Shear Strength	160 MPa
Ultimate Strength	580 Mpa
Poison's ratio	0.34

Proof stress	185-245 MPa
R(σmin/ σmax)	0.3

Table: Mechanical Properties of Aluminium 5754

EXPERIMENAL DETAILS

Beam materials

1. EN8 is an unalloyed medium carbon steel with good tensile strength, which is readily machinable in any condition.
2. Tensile properties can vary but are usually" between "500 to 800 N/mm2.
3. It is available from stock in bar, square, flat plate, and hexagon, etc.
4. It is used for shafts, stressed pins, studs, keys, nuts, bolts, axles, and gears etc.
5. Crack growth behavior depends on the stress state at the notch tip, the geometry of the component, the shape and size of the notch and loading conditions.
6. The medium carbon steel beams used in automobiles, machine shop etc.

Dimension of Tensile Test Specimen

Sr. NO.	Mean Dia. In mm	Length In mm
1	*6.84*	*25*
2	*6.66*	*25*

Table 3.2; Mechanical Properties of EN8

Young"s modulus	205 MPa
Poission"s ratio	0.3
Yield stress	530MPa
UTS	660MPa

Table 3.3; Chemical composition of EN8

Elements	Alloy(% by weight)
Carbon	0.40
Silicon	0.25
Manganese	0.80
Sulphur	0.05
Phosphorus	0.05
Iron	Bal.

Dimension of Test Specimen

Four Point Bend Test

An experiment was designed to simulate pure bending of a plate. To that end, a steel plate with thickness of 5 mm was tested. A servo-hydraulic machine was used to do this experiment. The load applied is cyclic and sinusoidal with constant amplitude. In this experiment, a frequency of 5 Hz was used initially, which was then increased to 10 Hz. The rollers have lengths near the width of plate. The detailed sketch is illustrated in Figure As found in the numerical simulations, the highest stress intensity factor K is at the tension surface. Consequently, the crack grows faster in the region with highest K , as shown in Figure 9. The through-the-thickness crack has become a two-dimensional crack. In crack initiation, the crack opening is 70% of the thickness. Thus, the error between numerical and experimental result is 18%.

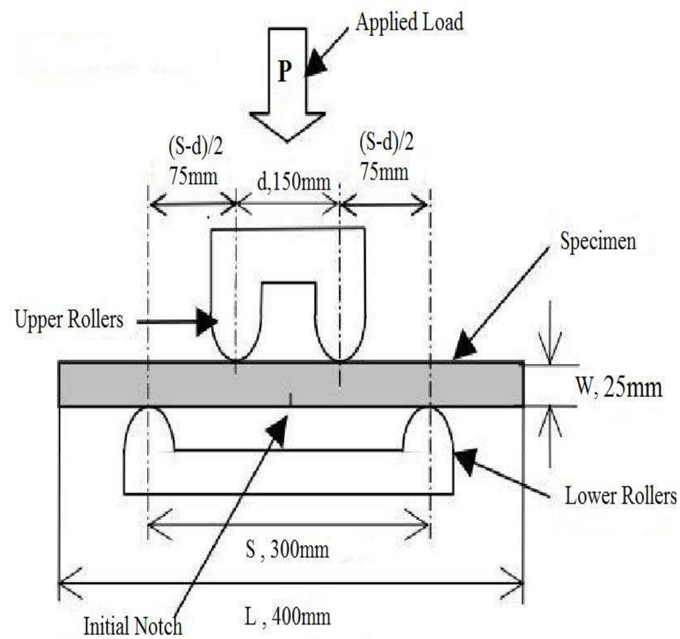

Figure 9: Experimental setup.

Specimen and notch dimension of beam

Specimen	**Dimension (mm)**
Length of beam(L)	400
With of beam(B)	25
Thickness of beam (*t*)	25
Notch length of beam(l)	3
Upper span length(S/2)	225
Lower span length(S)	350

Figure 10: Specimen and notch dimension of beam

Test setup and procedure

1. The test has been done on Universal Testing Machine. It consists of a servo hydraulic loading system, support for the specimen and various instruments for measurement of data.
2. A servo hydraulic controlled actuator of ±250 KN capacity and ±50 mm displacement has been used for loading.
3. The support system consists of two pedestals with two rollers, at a span of 450 mm and a pair of inner loading rollers with a span of 225 mm, which provides four-point bending.

4. The test specimen was gripped between rollers.
5. The fig. shows the four point bend arrangement for beam.
6. This type of loading ensures that the mid-section of the specimen, where the notch is located is subjected to pure bending.
7. The monitoring of crack was done using a COD gauge with data acquisition system, the data storage system is integrated with machine which stores data at every point of testing.
8. After the test, fractured surface is extracted by Power saw and it was cut in such a way that the crack surface is not damaged.
9. Then the extracted crack length will be examined in scanning electron microscope (SEM) at various loading stages.
10. The crack surface is again examined in travelling microscope. The loading is given in the form of sinusoidal wave.

VII. CONCLUSION

The basic aim of present work is to develop a fatigue crack propagation model for SEN beam without going through numerical integration process. Plates with a pre-existing through-the-thickness crack were studied under the action of a remote bending moment. The dependence of the contact region in the crack tip was investigated, as well as the bending effect on the stress intensity factor. Two sets of numerical analyses were performed. One set uses different crack geometries for a constant plate thickness, and the second set uses a single crack geometry for three different plate thicknesses.

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.

REFERENCES

[1] Anthony Andrews and Peter Folger. Nuclear Power Plant Design and Seismic Safety Considerations, Congressional Research Service, 2012

[2] Sharif Rahman: "Probabilistic elastic-plastic fracture analysis of circumferentially cracked pipes with finite-length surface flaws" Nuclear Engineering and Design, 195 (2000) 239-260.

[3] George E Dieter. Mechanical Metallurgical. 1988

[4] Dietmar Gross and Thomas Seelig. Fracture Mechanics with an Introduction to Micromechanics, Springer Verlag Publication. 2006.

[5] P. C. Paris and F. Erdogan, "A Critical Analysis of Crack Propagation Laws," J. Basic. Engineering. Trans. ASME, Vol. 85, pp. 528-534, 1963.

[6] [6]http://www.apesir.com/mechanical-engineering/ -crack-growth-rate-properties.

[7] [7]W. D. Pilkey, Peterson's Stress Concentration Factors, 2nd Edition, John Wiley & Sons, 1997.

[8] [8]John Barsom and Stanley Rolfe, Fracture and Control in Structures: application of fracture mechanics, 3rd Edition, ASTM, 1999.

[9] [9http://www.afgrow.net/applications/DTD Handbook/sections/page2_2_0.aspx

[10] [http://www.aalco.co.uk/datasheets/Aluminium-Alloy-5754-H22-Sheet-and

[11] http://www.azom.com/article.aspx?ArticleID=2806

[12] Tom Atul Dung Dung, and Ashutosh Sharan, Prediction of Crack Propagation in Circumferentially cracked pipe using CASCA and FRANC2D. NIT Rourkela, B Tech thesis, ID Code-3629, 2012.

[13] http://www.cfg.cornell.edu/software/franc2d_casca.htm

[14] http://www.asetsdefense.org/documents/Workshops/SURF-FIN-TempeAZ-02

[15] 08/Briefings/Brown-Cd_alts_&_non-Cr_primer.pdf S Tarafder, M Tarafder, V Ranganath, "Compliance Crack Length Relation For The Four Point Bend Specimen",Engineering Fracture Mechanics , Vol.47, No. 6 1994.