Determination of Stress Intensity Factor on Circumferential Notched Round Bar

Chaitany Maccha[1], K.S.Mangrulkar[2]

[1].(ME. in Design Engineering Student of Mechanical Department, ,N.B.Navale Sinhgad College of Engineering, Solapur India.)

[2](Professor, Department of Mechanical Engineering, N. B. Navale Sinhgad College of Engineering, Solapur India.)

Email – macchachaitany@gmail.com

Abstract— Cylindrical components have many applications in aircraft design. These structural components are subjected to cyclic stresses, which can cause damage and premature failure by fatigue crack growth. As it is well known, the design of engineering components in the past was only based on the S-N curves and did not consider the crack initiation and crack growth phases to predict life. The stress intensity factors of surface notch on circular bar have been evaluated by singular element with detailed mesh on crack front and appropriating adjacent area. The attention is focused on a circular bar with notch surface crack under tension load. Stress intensity factors (SIF) are considered using the finite element method. For that purpose a straight round bar under tension is investigated. The stress intensity factors are calculated for various dimensions of surface cracks. Using the derived analytic formulae for the stress intensity factor based on the FEA, a crack growth analysis is carried out.

Keywords— Stress Intensity Factor(SIF), Circumferentially Crack Round Bar(CCRB), Crack Profile, Fracture toughness, Al7075-T6, Ultimate Tensile Strength, V notch, Semi Elliptical Crack

I. INTRODUCTION

The surface crack embedded with cylindrical component, such as shaft, bar, bolt, wire, is the most common crack model, and has received widespread attention in the past. Due to geometrical complexity, some simplification had been made for the crack profile, such as straight-edged, circular, notch and elliptical crack model, to analyse such crack problems.

Most of mechanical failures by fatigue process on rotor shafts have origin on surface cracks that grow with a notch shape. Surface cracks emanating from stress concentrating locations are the most common phenomena of fatigue failure. Bars with variable cross-sections are a category of cylindrical parts and components extensively used in engineering mechanisms. Surface fatigue cracks are frequently initiated in such components at the stress concentrating locations, then they propagate into the interior of the parts and can cause final fracture abruptly. In addition, smooth and notched round bars have been used as standard specimens to obtain the fatigue property of materials for safe design and assessment. The fatigue failure of round bars often develops from surface defects, and therefore several authors have done study on the stress-intensity factor by variation along the front of these flaws. The assumption that an actual part through crack can be replaced by an equivalent notch at surface edge flaw is experimentally supported, and therefore many analyses have been carried out related to this equivalent configuration. The three-dimensional notch has been used to model the crack front in cylindrical rods under axial loading. In the first section of the present work, the stress intensity factors along the crack front are computed using the FEM. The crack growth can be analysed subjected to Mode I loading.

The determination of fracture toughness is based on the stress intensity factor (KIC) at the crack tip.

The advantages of using circumferentially notched bars for fracture toughness testing can be summarized as follows:

1) The plane strain condition can be obtained because the circumferential crack has no end in the plane stress region compared with the standard specimen geometries.
2) Because of radial symmetry microstructure of the material along the circumferential area is completely uniform.
3) Preparation of CCRB specimen & Fracture toughness test is easy.

II. ANALYTICAL

a) According to Wang C.H

The determination of fracture toughness is based on the stress intensity factor (KIC) at the crack tip, where I- denotes that the fracture toughness test is performed in tensile mode and C- denotes that the value of k is critical.

International Journal of Engineering Research and General Science Volume 3, Issue 6, November-December, 2015
ISSN 2091-2730

$KIC = \frac{0.932 Pf \sqrt{D}}{d^2 \sqrt{\pi}}$……… (Eq1)

Where,
Pf= fracture load,
D= diameter of the specimen,
d= diameter of the notched section.

b) **According to Dieter** for round notched tensile specimen, fracture toughness KIC found using following Eq.

$KIC = \frac{Pf}{D^{3/2}[1.72(\frac{D}{d})-1.27]}$…...............(Eq 2)

Where,
Pf = fracture load,
D= diameter of the specimen,
D=diameter of the notched section

II. Geometrical Configuration OF SPECIMEN

Following Specimen shown in Fig:1 is taken for the experimental result
Crack is initiated from points of high stress concentration on the surface of the component such as sharp changes in cross-section, slag inclusions, tool marks etc then spreads or propagates under his influence of load cycles until it reaches critical size.

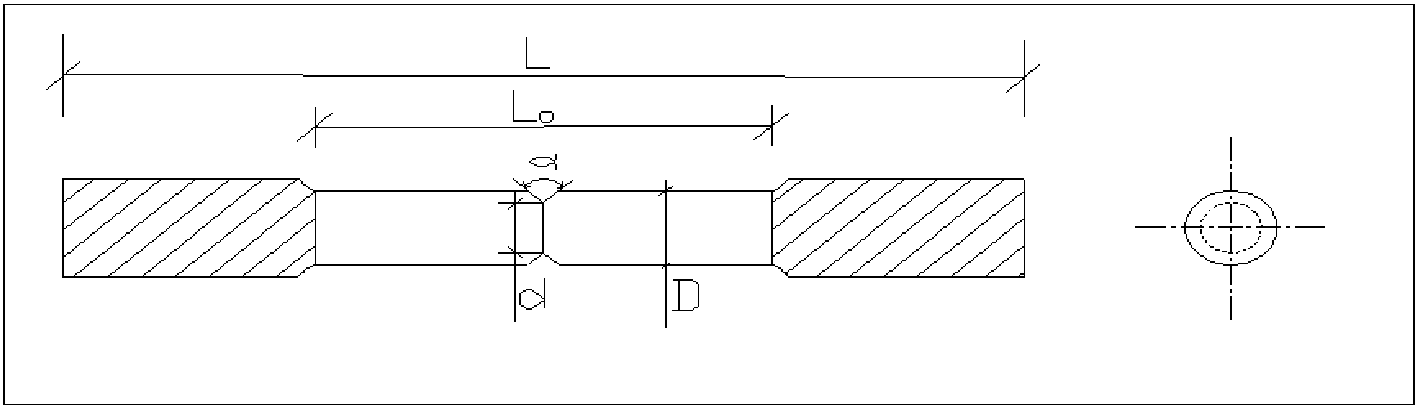


Fig-:1 Schematic representation of round notched tensile specimen

Where,
D= diameter of bar (mm),
d= diameter of notched surface (mm)
L= total length of bar (mm),
Lo= original length in consideration (mm).
α= notch angle (60º)

Assumptions

The SIF solution of a notch surface crack front on round bar under tension is investigated under the following assumptions:
1. The round bar is made of a homogenous, isotropic and linear elastic material.
2. The square-root stress singularity is filled with the vicinity of the crack front.
3. A notch surface crack is located at the half-length of the round bar.
4. Only the mode-I fracture is considered.

III. UTM TESTING

The tensile test of circumferentially cracked round bar (CCRB) specimen was performed on Universal testing machine at room temperature. After conducting the experimental work on universal testing machine the experimental values of ultimate stress and fracture load of each CCRB specimen is given in table.

The UTS is usually found by performing a tensile test and recording the engineering stress versus strain. The highest point of the stress–strain curve is the UTS. It is an intensive property; therefore its value does not depend on the size of the test specimen. However, it is dependent on other factors, such as the preparation of the specimen, the presence or otherwise of surface defects, and the temperature of the test environment and material.

UTM Testing Result Table

Table 3.1 Corresponding Ultimate Tensile strength and Facture load

Sr.No	Notch angle (α)	Specimen diameter (D)	Notch diameter (d)	Ultimate Tensile Strength(KN)	Fracture load (Pf) in KN
1	60º	16	13	41	37
2	0º	16	-	59	43

Table 3.2Corresponding Average Strain

	Average Strain
Crack Specimen	0.005228
Uncracked Specimen	0.001612

VI. FINITE ELEMENT MODELING

In this study, the finite element model is formed by a using the ANSYS Parametric Design Language (APDL). First a material is selected, Aluminium. Then, the line of the crack front for the initial step is defined. Next, two areas are created, one with the crack front and one that is the uncracked interior of the model. Each of these areas is extruded to form a volume. The lines surrounding the crack surface are duplicated and attached to the original crack front. These lines form another area. This new crack surface and the original uncracked area are extruded in the direction opposite to that of the previous extrusion. This new portion is given the material properties of the material. Finally, these four volumes are meshed. The model consists of four volumes and is composed of material. Since the model is parametric, new values for these parameters can easily be specified with each new execution of the algorithm. The values above length units of meters. The two beginning crack shapes that were studied, shown in top view, are a quarter-circular comer crack and what will be called a fillet-shaped comer crack. A side view showing the two materials and the level of refinement at the crack front and along the interface. All volumes are meshed using 20-noded brick elements. The fillet shapes have equal numbers of nodes and elements because the method which creates the finite element models divides the lines into equal numbers of sections each time it is executed. In ANSYS, the volumes are meshed using the VMESH command for the uncracked volumes; for volumes with crack faces, a sweep mesh is used (the VSWEEP command in ANSYS). After examining numerous cases, it was found, for both types of crack fronts, that the number of crack-front elements is critical to the accurate calculation of smooth strain energy release rate results. In order to obtain the greatest level of crack tip refinement and resolution, 40 elements were placed along the crack front. The integration order of the crack front enriched elements is critical in calculating accurate results, therefore high integration were used.

Boundary Conditions

One fourth model has been analysed. Boundary condition has been given on one fourth model. Fixed at the one end and tensile force at the other end.

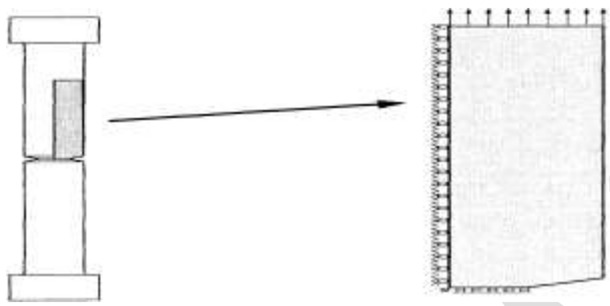
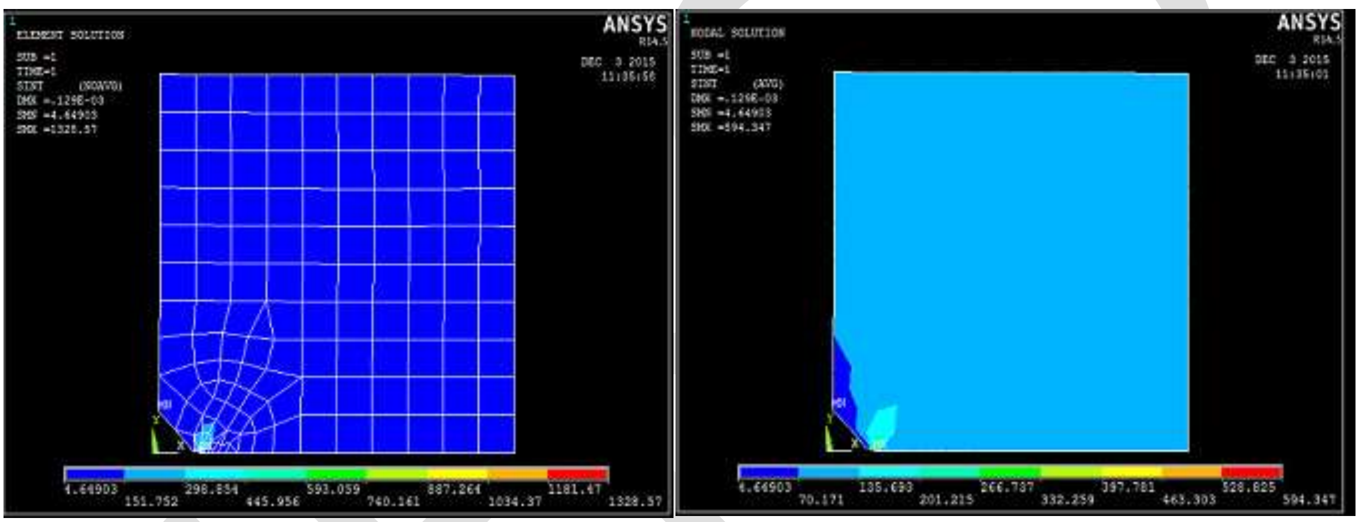


Fig 2 : Boundary Condition On Specimen



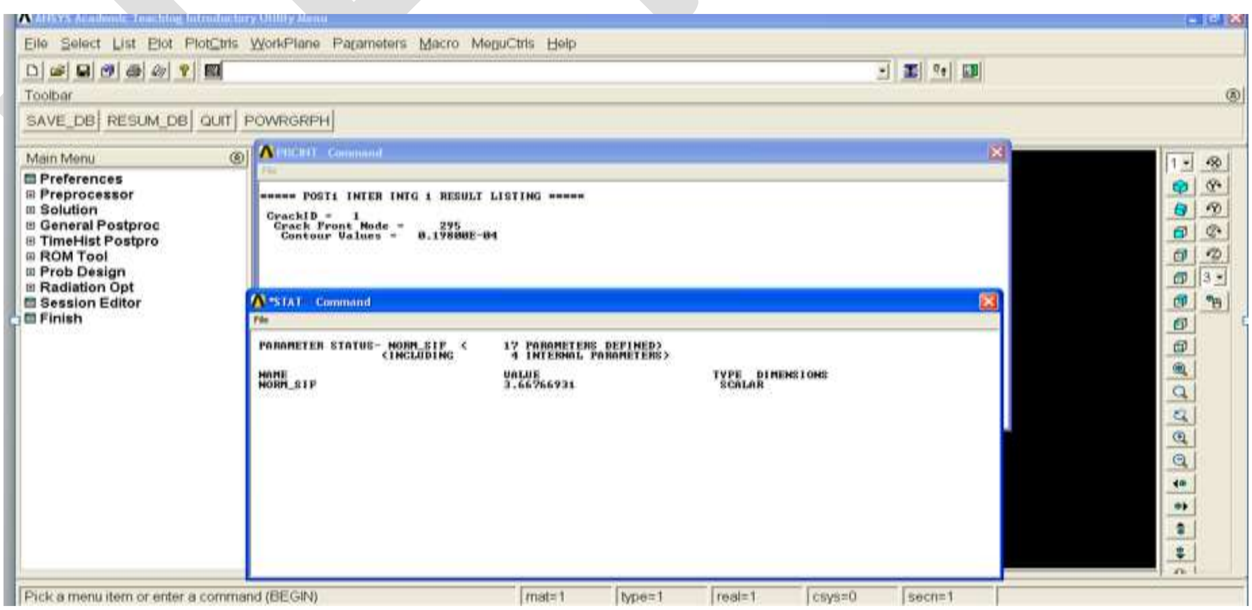


Fig-:3 Ansys Stress Intensity Factor Results

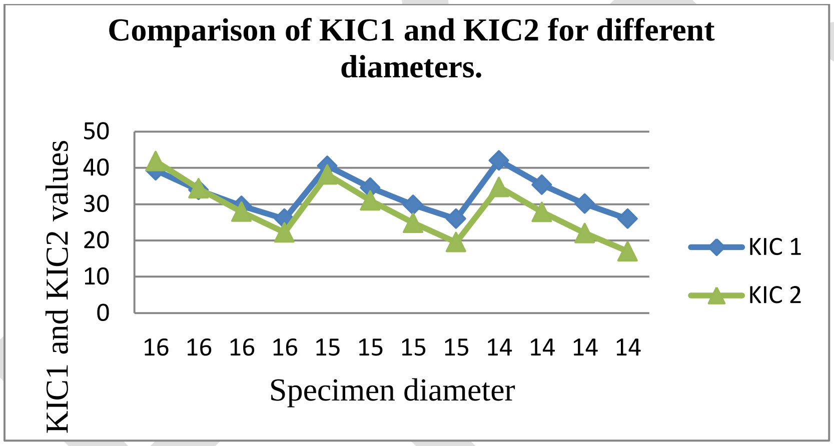
International Journal of Engineering Research and General Science Volume 3, Issue 6, November-December, 2015
ISSN 2091-2730

IV. RESULTS AND DISCUSSIONS

1) The specimen having different notch angles and different notch diameter as well as specimen diameter was considered and results are drawn. The measurement of fracture toughness is based on the critical stress intensity factor (KIC) of the test specimen under Mode-I loading condition.

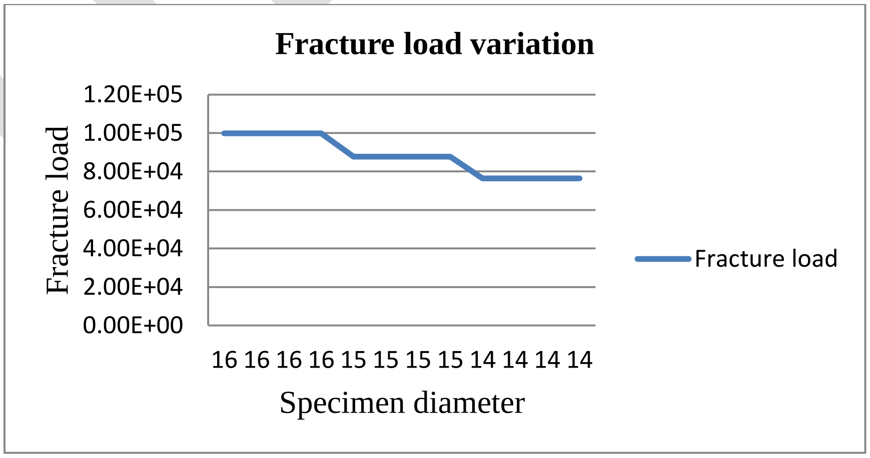
Approach	SIF	Error (%)
Theoretical	3.65	-
Ansys	3.66	0.27
Experimental	3.2431	12.54

2) Result Table show the experimental observations of maximum loads and ultimate stresses of each specimen. The plane-strain fracture toughness of Al 7075-T6 alloy tested using CCRB specimen geometry, it was found to be in a range of 25.9349 to 39.286 as per Eq. (1) and 22.2 to 41.81 as per Eq. (2). These two equations give KIC value in a valid range as available in the literature using standard CT (Compact Tension) specimens. The notch diameter 15mm gives fracture toughness lower value and notch diameter 13mm gives fracture toughness higher value. It is observed that as notch diameter increases KIC value decreases.

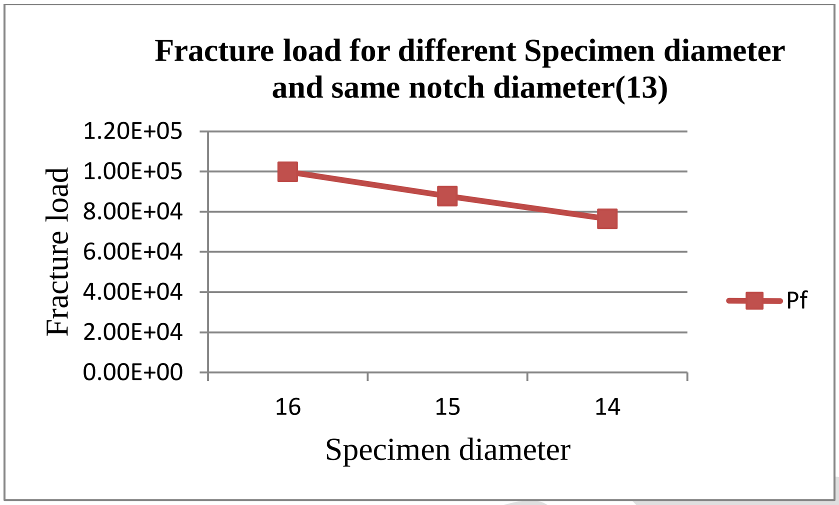


Comparison Of KIC1 and KIC2 Value

3) After introducing notch to the testing specimen the load require for fracture of material are changes and it is observed that as notch diameter and specimen diameter decreases the load require for specimen decreases.



Fracture load variation



Fracture load for different Specimen diameter and same notch diameter(13mm)

VI. CONCLUSION

- Fracture toughness (KIC) of metallic material can be successfully determined by using round bar tensile specimen and the obtained results are found to be in good agreement with simulation and experimentation results obtained from tensile test specimens.
- The plane-strain fracture toughness of Al 7075-T6 alloy tested using CCRB specimen geometry was found to be in a range 25.9349 to 39.286 as per Eq. (1) and 22.2 to 41.81 as per Eq.(2). which is valid range of KIC for Al7075-T6 as available in literature obtained by standard tests.
- Stress Intensity factor changes as notch diameter and specimen diameter varies.
- It is observed that as specimen diameter along with notch diameter decreases the fracture load for specimen also decreases.
- The presence of notch in tensile test specimen causes brittle failure although the material is ductile & also the % elongation of the material specimen.
- With the increase in notch angle the value of KIC decreases.

REFERENCES:

[1] Marija Blazic, mirko Maksimovic, Ivana Vasovic, Yasmina Assoul, "Stress Intensity Factors for Elliptical Surface Cracks in Round Bars and Residual Life estimation" , Scientific Technical Review, 2011, Vol.61, No.1

[2] Yan-Shin Shiha and Jien-Jong Chenb, "The stress intensity factor study of an elliptical cracked shaft" ,Nuclear Engineering and Design 214 (2002) 137-145.

[3] R. Brancoa, F.V. Antunes , "Finite element modeling and analysis of crack shape evolution in mode-I fatigue Middle Cracked Tension specimens", Science Direct, Engineering Fracture Mechanics 75 (2008) 3020-3037

[4] L. Rubio ,B.Munoz-Abella, G.Loaiza, "Static behavior of a shft with an elliptical crack", Science Direct, Mechanical Systems and Signal Processimg 25 (2011) 1674-1686

[5] Dr. S. Suresh Kumar, K.A.Dularish, G.S. Deepak Kumar, "Determination of Stress Intensity Factor and Interaction Behavior of Radial Cracks in an Un-notched Round Bar", Proceedings of the 1st International and 16th National Conference on Machines and Mechanisms (iNaCoMM2013), IIT Roorkee, India, Dec 18-20 2013.

[6] Trimbak K. Todkari, M. C. Swami, P. S. Patil, " Effect of Specimen Diameter and Notch Diameter On The Fraccture Toughness Of AL7075 T6 Alloy-An Experimental Approach", International Journal of Research in Engineering and Technology, Volume: 04, Issue:01, Jan-2015

[7] Andrea Carpinteri, Roberto Brighenti, Andrea Spagnoli and Sabrina Vantadori, "Fatigue Growth of Surface Cracks in Notched Round Bars", Department of Civil and Environmental Engineering & Architecture University of Parma – Parco Area delle Science 181/A-4300 Parma- Italy

[8] Trimbak K. Todkari, M. C. Swami, P. S. Patil, " Effect of Notch Angle on the Fracture Toughness of Al7075 T6 Alloy-An Experimental Approach", IOSR Journal of Mechanical and Civil Engineering, Volume 12, Issue 1Ver. III (Jan - Feb 2015), PP 01-05

[9] A E Ismail, A K Ariffin, S Abdullah & M J Ghazali, " Stress Intensity Factor under Combined Tension and Torsion Loading", Indian Journal Of Engineering & Materials Sciences, Vol.19, Feb 2012, pp. 5-16

[10] Upamanyu Banerjee, " Modeling Stress Intensity Factor of Rail Steel under Situation of Growing Fatigue Crack-A Noval Technique", Open Journal of Metal, 2012, 2, 74-78, Published September 2012

[11] M.Zappalorto, P. Lazzarin, F. Berto, " Elastic notch stress intensity factor for sharply V - Notched Rounded Bars Under Tension", Engineering Fracture Mechanics, 76 (2009) 439 – 453

[12] P. Lazzarin, S. Filippi, "A Generalized Stress Intensity Factor to be applied to rounded V- Shaped notches", International Journal of Solids Structures 43 (2006) 2461 - 2478