Effect of Notch Diameter on the Fracture Toughness of Al7075 T6 Alloy- An Experimental Approach

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Abstract : In this paper fracture toughness (K_{IC}) of Al7075 T6 alloy has been determined by using circumferentially cracked round bar (CCRB) specimen having different notch diameters (d) with constant specimen diameter(D) and notch angle(α). The purpose of the study was to determine the effect of notch diameter on the fracture toughness of the Al7075 T6 alloy. The obtained fracture toughness results for different notch are compared with ASTM standards. The result shows that the notch diameter has significant effect on the value of fracture toughness (K_{IC}).

Key words: Al7075 T6 alloy, CCRB specimen, Fracture toughness, notched specimen.

I.INTRODUCTION

The need of high strength, low weight, and more corrosion resistant material is of current interest in the area of aerospace, marine etc. The Al 7075 T6 alloy material find wide applications in the different areas because of its excellent metallurgical properties. The Al 7075 T6 alloy is made more useful material with the characterization of material for fracture toughness. The determination of fracture toughness is based on the stress intensity factor (K_{IC}) at the crack tip with subscript I denotes the fracture toughness test is performed in tensile mode and C denotes the critical value of stress intensity factor. When K attains critical value then crack propagation becomes unstable and result in fracture of components [1].

Normally K_{IC} is determined by using compact-tension (CT) specimen or single edge notch bend (SENB) specimen or three point loaded bend specimens which are standardized by ASTM [14]. Also the standard test method for fracture toughness (K_{IC}) of metallic material is given by the American Society for Testing and Material (ASTM) (designation E99) [2]. The ASTM E99 standard test method is to be one of the most accurate ways of measuring K_{IC} of low ductility high strength alloys [3].These methods are difficult and also the preparation of specimen. Notched round bar specimens have widely used for finding mechanical properties of materials [4-5]. The advantages of using circumferentially notched bars for fracture toughness testing can be summarized as follows:

- 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 [6].
- Because of radial symmetry microstructure of the material along the circumferential area is completely uniform [7].
- Preparation of CCRB specimen is easy.
- Fracture toughness test is easy to perform.

In the previous studies, Bayram et al. [8] measured fracture toughness K_{IC} of various steels and aluminum alloys with CCRB specimens and summarized that the experimentally measured fracture toughness values using CCRB specimens are accurate and reliable considering some correction factors.

Christopher D. Wilson and John D. Landes [9] used circumferentially notched round bars with finite notch root radii. They observed that the circumferential crack propagates radially inwards in tensile loading unlike unique crack propagation towards one direction in case of CT or SENB specimens.

Wang Chang [10] determined the plane strain fracture toughness (K_{IC}) by single cylindrical tensile small scale specimen with ring-shaped crack.
NeelakanthaV Londe [11] determined the fracture toughness of metallic material by using CCRB specimen having notch angle (45^0) and unchanged outer diameter (D) with different notch diameter (d) of Al6082-T6 alloy. They have found the value of K_{IC} closer to standard tests.
Ali Bayram [8] determine the fracture toughness of metallic material using CCRB specimen having notch angle (60^0) andunchanged outer diameter (D) with different notch diameter (d) tested for different metallic materials also find the fracture toughness by adding the correction factor. They have concluded that fracture toughness measurement of metallic material using CCRB specimen is to be an accurate and reliable procedure.
S K Nath [1] determine the fracture toughness of medium carbon steel using CCRB specimen having different notch angles i.e. 45^0,60^0,75^0 and unchanged specimen diameter(D) with different notch diameter(d). They have tested the material before heat treatment and after heat treatment and concluded that samples with lower notch diameter shows higher K_{IC} for same notch angle as compared to higher notch diameter.

The objective of the present work is to determine the effect of notch diameter (d) on fracture toughness and to validate the results with the standards.

II.THEORETICAL BACKGROUND

The determination of fracture toughness is based on the stress intensity factor (K_{IC}) 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. Unstable crack propagation occurs when K attains a critical value and the component fails. In Linear Elastic Fracture Mechanics (LEFM) the critical Stress Intensity Factor (SIF) characterizes the fracture toughness [12].
According to Dieter [13] for round notched tensile specimen, fracture toughness K_{IC} found using following equation.

$$K_{IC}=P_f/ (D)^{3/2}[1.72(D/d)-1.27] \quad \ldots\ldots (1)$$

Where, P_f is the fracture load,
D is the diameter of the specimen, and d is the diameter of the notched section Figure 1.
The assumption made while formulating above expression is that the specimen retains its elastic behavior until fracture occurs. This relation is valid for the D/d ratio between 1.00 and 1.25.

III.MATERIAL SELECTION

The material used for present work is Al7075 T-6 alloy whose chemical composition is given in Table-: 1 and initially diameter of rod is 16mm.

Table- 1 Chemical composition of Al7075 T-6 alloy used, in wt%.

Al	Cr	Cu	Fe	Mg	Mn	Si	Ti	Zn
87.1-91.4	0.18-.28	1.2-2	Max 0.5	2.1-2.9	Max 0.3	Max 0.4	Max 0.2	5.1-6.1

Table- 2 Mechanical properties of Al7075 T-6 alloy

Property	**Value**
Ultimate Tensile Strength	572 MPa
Fracture Toughness (K_{IC} in L-T direction)	29 MPa-m½
Fracture Toughness (K_{IC} in T-L direction)	25 MPa-m½

IV. SPECIMEN PREPARETION AND EXPERIMENTATION

A. Specimen Preparations

The test specimen geometry is as shown in Fig-:1. Nine UTM testing specimens have been prepared as per standard specifications by using conventional lathe machine with following dimensions.

Specimen diameter (D): 10mm.
Gauge length (L_o): 5D.
Specimen length (L): 30D.
Notch diameters(d): 8.0,8.2,8.4,8.6,8.8,9.0,9.2,9.4,9.6mm(consider nine notch diameter).
Notch angle (α): 60^0.

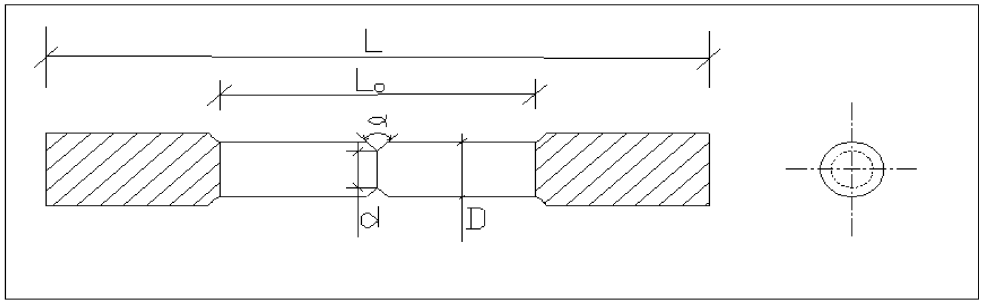

Figure 1. Schematic representation of round notched tensile specimen

Figure 2. Circumferentially crack round bar testing specimens

B. Experimentation

The tensile test of each CCRB specimen was performed on 400KN Universal testing machine at room temperature. After conducting the experimental work on universal testing machine the Table 3 shows that the experimental values of ultimate stress and fracture load of each CCRB specimen.

Table: 3 Details of Ultimate Stress, Fracture load values of various Notch diameters.

Trial No.	Notch angle(α)	Specimen diameter(D)	Notch diameter(d)	Ultimate Stress (MPa)	Fracture load (P_F) in KN
1	60^0	10	8.0	425	33.40
2	60^0	10	8.2	429	33.73
3	60^0	10	8.4	433	33.97
4	60^0	10	8.6	435	34.19
5	60^0	10	8.8	438	34.37
6	60^0	10	9.0	441	34.63
7	60^0	10	9.2	444	34.89
8	60^0	10	9.4	447	35.07
9	60^0	10	9.6	449	35.24

V.RESULT AND DISCUSSIONS

The specimen having different notch diameter loaded on UTM machine and results are recorded. Table -4 shows the experimental observations of maximum load and ultimate stress fracture toughness of each specimen. The plane-strain fracture toughness of Al 7075-T6 alloy tested using CCRB specimen geometry was found to be in a range of 27.64 to 29.16 as per equation (1) which is valid range of K_{IC} for Al7075-T6 alloy as available in literature obtained by standard tests. The measurement of fracture toughness is based on the critical stress intensity factor (K_{IC}) of the test specimen under Mode-I loading condition. The Dieter equations give K_{IC} value in a valid range as available in the literature using standard CT (Compact Tension) specimens. The variation of Fracture toughness versus notch diameter was drawn for all the values of K_{IC} determined using equation (1) as shown in Figure (3) and it is observed that as notch diameter increases the value of fracture toughness get increases. The tables- 5 shows that the comparison between the ultimate tensile strength of unnotched specimen with the notched specimen and it is observed that if notch diameter increases the value of tensile strength of material also increases.

Table- 4 Details of Ultimate Stress, Fracture load, Fracture Toughness (K_{IC}) values of Notch angle with different notch diameters.

Trial No.	Notch angle(α)	Specimen diameter(D)	Notch diameter(d)	Ultimate Stress (MPa)	Fracture load (P_F) in KN	Fracture Toughness K_{IC}(MPa$\sqrt{m}$)
						Eq 1
1	60^0	10	8.0	425	33.40	27.64
2	60^0	10	8.2	429	33.73	27.91
3	60^0	10	8.4	433	33.97	28.11
4	60^0	10	8.6	435	34.19	28.29
5	60^0	10	8.8	438	34.37	28.44
6	60^0	10	9.0	441	34.63	28.65
7	60^0	10	9.2	444	34.89	28.87
8	60^0	10	9.4	447	35.07	29.02
9	60^0	10	9.6	449	35.24	29.16

Table -5 Details of Ultimate stress of unnotched specimen and Notched specimen

Trial No.	Notch angle(α)	Specimen diameter(D)	Notch diameter(d)	Ultimate Stress (MPa)
1	0^0	10	-	**530**
1	60^0	10	8.0	425
2	60^0	10	8.2	429
3	60^0	10	8.4	433
4	60^0	10	8.6	435
5	60^0	10	8.8	438
6	60^0	10	9.0	441
7	60^0	10	9.2	444
8	60^0	10	9.4	447
9	60^0	10	9.6	449

C. Graphical representation of K_{IC} values as per Diater equation

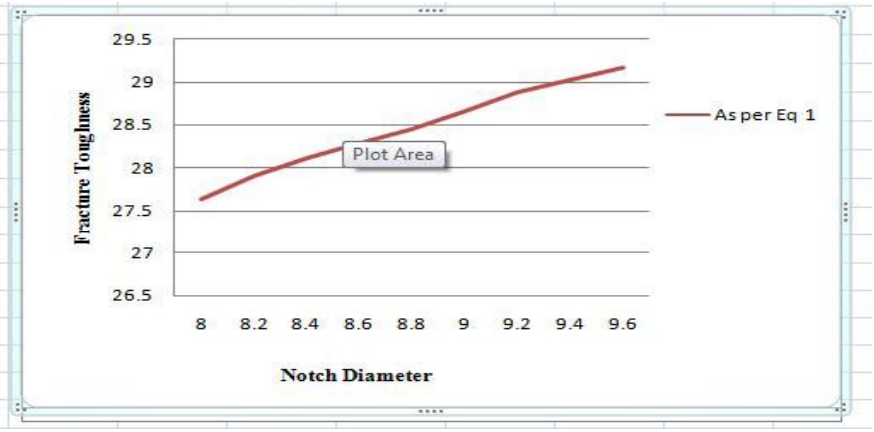

Figure 3. Variation in Fracture Toughness with Notch angle

VI.CONCLUSIONS

- Fracture toughness (K_{IC}) 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 other results obtained from compression tension (CT) specimens.

- The plane-strain fracture toughness of Al 7075-T6 alloy tested using CCRB specimen geometry was found to be in a range of 27.64 to 29.16 as per Eq. (1) which is valid range of K_{IC} for Al7075-T6 as available in literature obtained by standard tests.
- It was observed that the value of notch diameter changes the values of K_{IC}.
- The value of fracture toughness is lower for 8mm notch diameter and is higher for 9.6mm notch diameter.
- The result shows that as increasing notch diameter the values of fracture toughness get increases.
- It is observed that as notch diameter increases the ultimate tensile strength of material get decreases.
- It has been observed that the presence of notch decreases the % elongation of the material specimen.
- The presence of notch in tensile test specimen causes brittle failure although the material is ductile.

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