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Effect of Notch on Tensile Strength of EN 8

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ABSTRACT

EN 8 (Medium Carbon Steel) is used for large parts, forging and automotive components such as axle shafts, crankshafts and gearing plates. Notch is a small cut that is shaped like V or U and that is made on an edge or a surface. The notch effect increases stress in an area of a component near a crack, or a change in section, such as a sharp angle. It can be enough to cause failure of the component although the calculated average stress may be quite safe. Researchers demonstrated that the fatigue growth analyses of various cracks commonly occurring in bars can reliably be made by using the automated finite element technique proposed. In general, most of the previous analysis were primarily qualitative and based only on a single concept of basic material behavior, such as plasticity, damping capacity, cohesive strength, work-hardening capacity, elementary structural unit, or statistical theories of fatigue. Review revealed that several researches have been done on strength of materials but no work is done on effect of notch on tensile strength of EN 8 i.e. medium carbon steel. Author belief's that strength of notched structural components should be evaluated by taking into account the notch effect. Since the bar can be subjected to axial tensile loading, hence effect of notch for axial tensile loading can't be neglected. Literature also revealed that no work has been done on effect of notch on tensile strength of EN 8 material. In this work, six specimens of plain bar, notched bar with shape V & U have been analysed under tensile load on Universal Testing Machine. The results of Universal Testing Machine were compared with results determined from ANSYS software. It is concluded from the result that generation of notch increases the tensile strength of the material as compared to bar without notch. The deviation in ultimate tensile strength on comparing U Notch with V Notch is 9.7 N/mm^2 for 12mm diameter. The deviation in ultimate tensile strength on comparing U Notch with V Notch is 10.76 N/mm^2 for 9mm diameter. It can be concluded from the results that the sharper section offers less resistance as compared to smooth sections. It is also evident from the results, the effect of notch increases ultimate tensile strength of bar. On comparing both the graph it is concluded that on increasing depth of notch (width is kept constant), the results for both types of depth show that the sharper section (V Notch) offers less resistance than smooth section (U Notch). The tensile strength in the material increases on generation of notch as compared to Plain Bar. It can also be concluded, EN 8 on increasing the depth of cut reduces resistance offered by the material.

KEYWORDS

Notch, Ultimate Tensile Strength, Tensile Load, EN 8, SolidWorks, ANSYS

I. INTRODUCTION

EN 8 (Medium Carbon Steel) is used for large parts, forging and automotive components such as axle shafts, crankshafts and gearing plates. The chemical compositions of this material are 0.29%-0.54% Carbon and 0.60%-1.65% Manganese. It is ductile, strong and long-wearing properties. The density of EN 8 is approximately 7850 kg/m^3 and the Young's modulus is 210 GPa.

Figure 1.1: Crank Shaft (media.appliednanosurfaces.com)

Notch is a small cut that is shaped like V and U and that is made on an edge or a surface. The notch effect increases stress in an area of a component near a crack, or a change in section, such as a sharp angle. Notches are hardly avoidable in engineering practice; they may occur as a metallurgical notch, which is inherent in the material due to metallurgical processes as inclusions, blowholes, laminations, quenching cracks, etc. or a mechanical notch, of some geometrical type which usually results from a machining process. It has been observed that effect of Notch is affecting the strength.

II. LITERATURE REVIEW

2.1 Introduction

The aim of literature review is to find out the scope of research in the area of effect of notch on carbon and alloy steels. An extensive review of research work has been done on the effect of notch on strength of carbon and alloy steels.

The following literatures have been reviewed related with presented research work.

Wang et al., (2010) studied that on performing tensile tests at room temperature on 20 notched bars fabricated from constructional steel Q235 specified in Chinese National Standards. As the stresses at the notched section reach the limiting values determined from the elliptical fracture model, macroscopic fracture failure in the notched bar occurs.

Wang et al., (2010) analysed the uniaxial tension tests for 20 notched bars fabricated from high strength steel Q345 specified in Chinese National Standards. As the stresses at the notched section reach the limiting values determined from the elliptical fracture criterion, macroscopic fracture failure in the notched bar occurs.

Tanaka et al., (2010) studied the two specific subjects related to the fatigue strength and life of notched bars under combined torsional and axial loading. On the basis of the electrical potential monitoring of the initiation and propagation of small cracks at the notch root, the crack initiation life decreased with increasing stress concentration, while the crack propagation life increased.

Ohkawa et al., (2011) studied notch effect in austenitic stainless steel under cyclic torsion depending on the superposition of static tension. Because of a small amount of the crack face contact, the reduction of lifetime in notched specimen is revealed irrespective of superposition of static tension.

Gates et. al., (2015) evaluated the methodology for, and effectiveness of, common equivalent stress and strain based fatigue life analysis. The importance of considering stress gradient effects in notched specimen life prediction is also demonstrated.

Benedetti et. al., (2016) studied the residual stress (RS) field in the vicinity of a notch is of paramount importance to understand the fatigue resistance of shot peened components containing such stress raisers. The proposed approach can be very useful to estimate the notch fatigue resistance of shot peened components on the basis of local stress and fracture mechanics approaches.

Brighentiet. al., (2016)analysed about the defect tolerance which is usually understood as the ability of a material to withstand an external load in the presence of a geometrical flaw. It is shown as the safety against notch concentration effect (that can reduce up to about 40–70%) can be greater than in low deformable materials, and so notch blunting and plate's localized instability are beneficial contributions, leading to an increase of the element’s tensile strength.

Bourbitaet. al., (2016) studied the formation of short cracks at notched members of superalloy single crystals under high temperature low cycle fatigue was analysed. A good correlation between experimental results and model predictions is achieved for all test orientations and frequencies.

2.2 Objective of Research Work

The main objectives of this research are as follows:

- To identify the effect of notch on tensile strength of EN 8.
- To identify the effect of shape of Notch i.e. V and U on tensile strength of EN 8.

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- Comparison of tensile strength of Notch bar with plain bar.

III. EXPERIMENTAL WORK

3.1 Introduction

The most common testing machine used in tensile testing is the universal testing machine. This type of machine has two crossheads; one is adjusted for the length of the specimen and the other is driven to apply tension to the test specimen. The machine must have the proper capabilities for the test specimen being tested. There are four main parameters: force capacity, speed, precision and accuracy. Force capacity refers to the fact that the machine must be able to generate enough force to fracture the specimen. The machine must be able to apply the force quickly or slowly enough to properly mimic the actual application. The test process involves placing the test specimen in the testing machine and slowly extending it until it fractures. During this process, the elongation of the gauge section is recorded against the applied force.

3.2 Experimental Setup

The experimental setup is shown in figure 3.1. The specifications of setup are:

1. Make: Bharat Engineers
2. Model: AMT 20 UTM
3. Capacity: 20 Tonnes
4. Load Range: 0-20 kN
5. Least Count: 0.02 kN
6. Max. Dia.: 20mm
7. Min. Dia.: 6mm

Figure 3.1: Experimental Setup with Specimen

3.3 Specification of Specimen

The specifications of specimen are:

1. Material: EN 8
2. Notch: V & U

Figure 3.2: Specimens

Table 3.1 : Description of Specimen

S. No.	Material	Specimen					
	EN 8	V Notch		U Notch		Plain	
		1.5mm depth	3mm depth	1.5mm depth	3mm depth	9mm dia	12mm dia
1	√	√					
2	√		√				
3	√			√			
4	√				√		
5	√					√	
6	√						√

3.4 SolidWorks

SolidWorks is a solid modeller, and utilizes a parametric feature-based approach to create models and assemblies. Parameters refer to constraints whose values determine the shape or geometry of the model or assembly. Shape based features typically begin with a 2D or 3D sketch of shapes such as bosses, holes, slots, etc. Building a model in SolidWorks usually starts with a 2D sketch. The sketch consists of geometry such as points, lines, arcs, conics, and splines. Dimensions are added to the sketch to define the size and location of the geometry. The dimensions in the sketch can be controlled independently, or by relationships to other parameters inside or outside of the sketch.

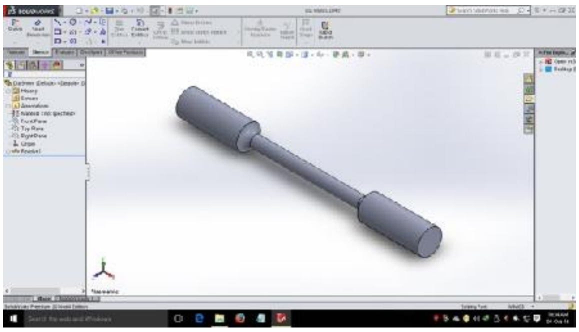

Figure 3.3: Plain Bar of 9mm Dia

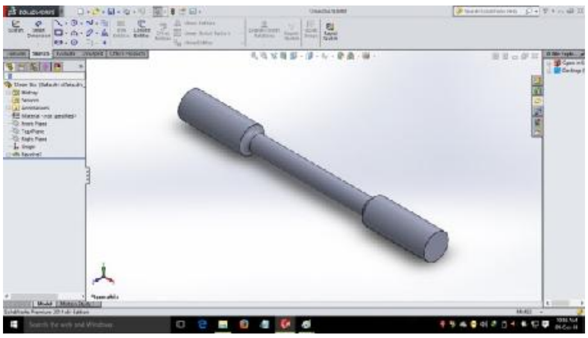

Figure 3.4 : Plain Bar of 12mm Dia

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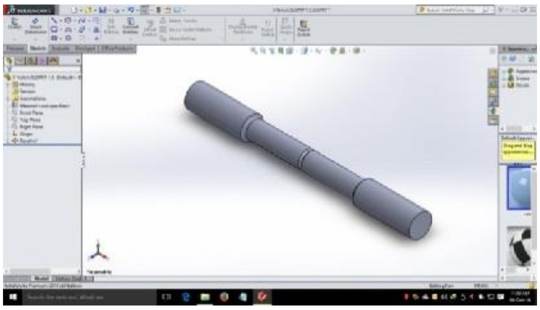

Figure 3.5: Bar with V Notch 1.5mm depth

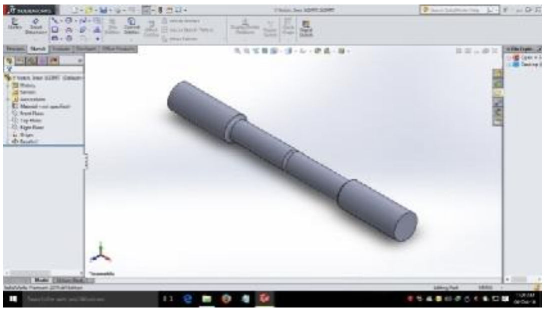

Figure 3.6: Bar with V Notch 3mm depth

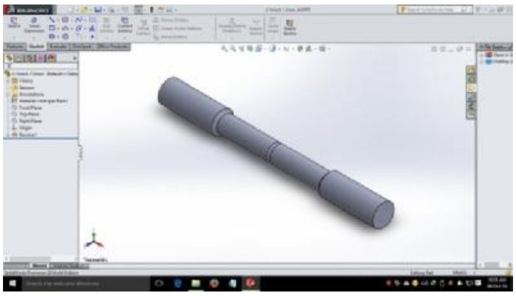

Figure 3.7: Bar with U Notch 1.5mm depth

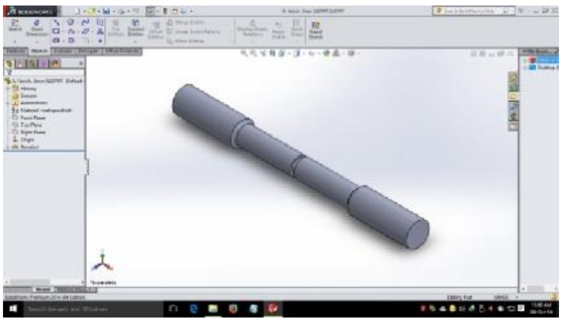

Figure 3.8: Bar with U Notch 3mm depth

3.5 ANSYS

ANSYS is a general purpose software, used to simulate interactions of all disciplines of physics, structural, vibration, fluid dynamics, heat transfer and electromagnetic for engineers.ANSYS can work integrated with

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other used engineering software on desktop by adding CAD and FEA connection modules. ANSYS can import CAD data and also enables to build geometry with its “pre-processing” abilities. Similarly in the same pre-processor, finite element model (i.e. mesh) which is required for computation is generated. After defining loadings and carrying out analyses, results can be viewed as numerical and graphical.

ANSYS can carry out advanced engineering analyses quickly, safely and practically by its variety of contact algorithms, time based loading features and nonlinear material models.

The mesh type is coarse and the element is teterahedral in shape for all 6 analysis in ANSYS

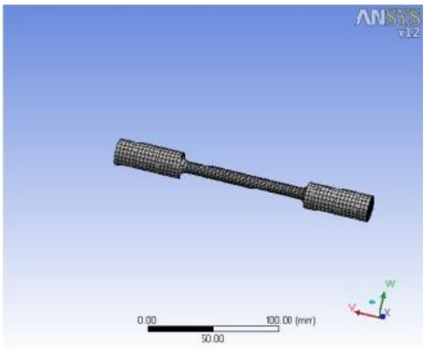

Figure 3.9: Mesh (Plain Bar of 9mm Dia)

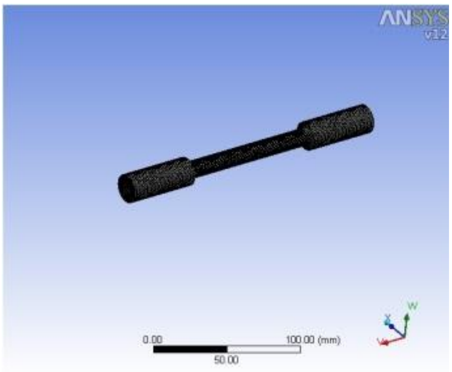

Figure 3.10: Mesh (Plain Bar of 12mm Dia)

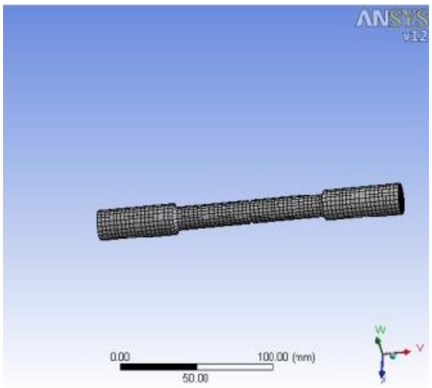

Figure 3.11: Mesh (Bar with V Notch 1.5mm depth)

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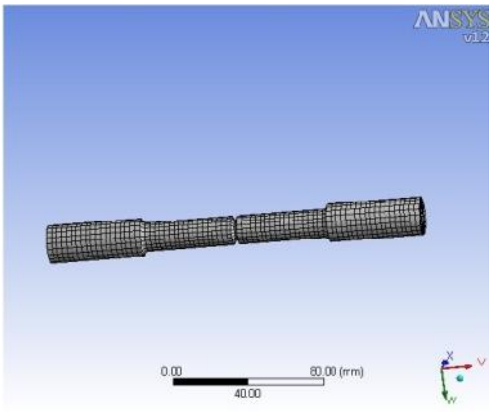

Figure 3.12: Mesh (Bar withV Notch 3mm depth)

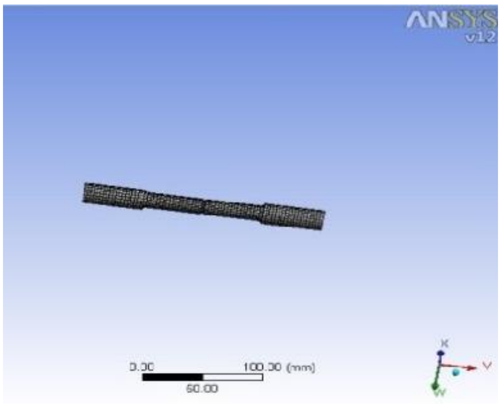

Figure 3.13: Mesh (Bar with U Notch 1.5mm depth)

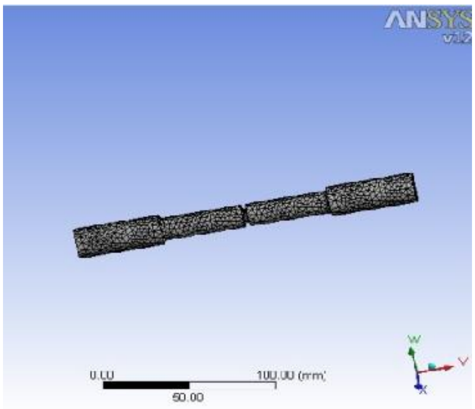

Figure 3.14: Mesh (Bar with U Notch 3mm depth)

IV RESULTS

The experimental results are evaluated on the tensile testing machine experimentally and on ANSYS software.

4.1 Analysis Results for 12mm diameter

Figure 4.1: Specimen after Tensile Testing on UTM (12mm)

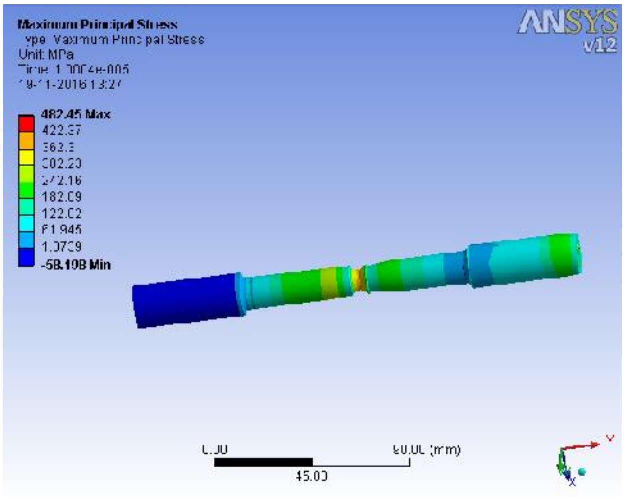

Figure 4.2: ANSYS Analysis of Bar with U Notch 1.5mm Depth

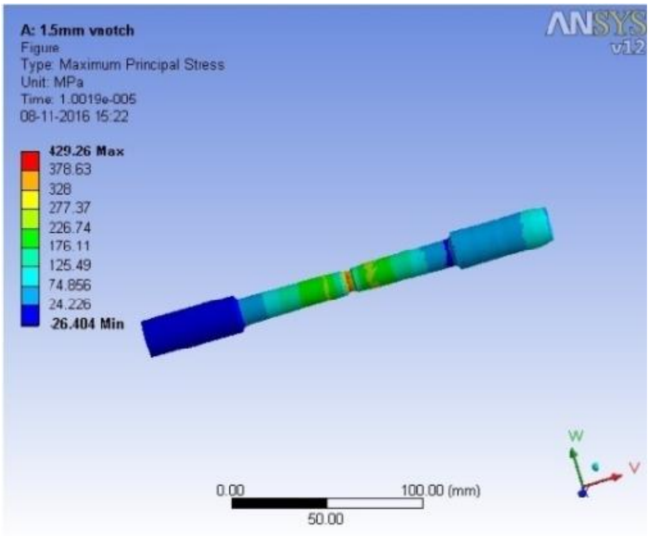

Figure 4.3: ANSYS Analysis of Bar with V Notch 1.5mm Depth

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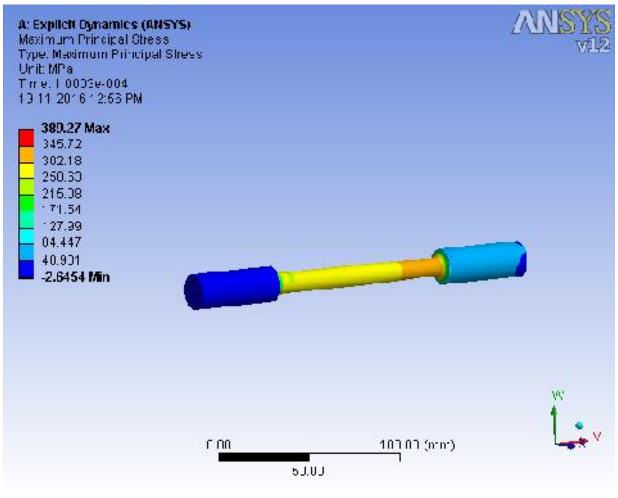

Figure 4.4: ANSYS Analysis Plain Bar (12mm Dia.)

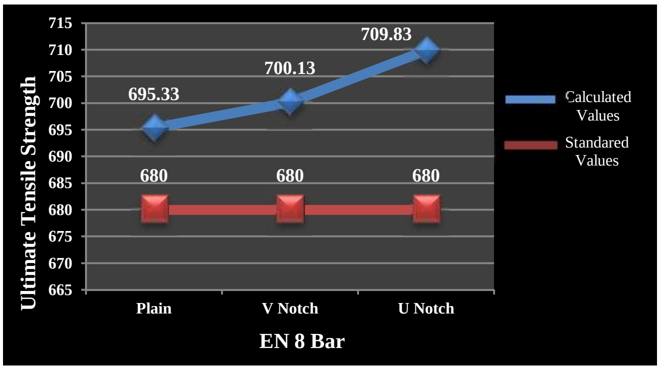

Figure 4.5: Notch Effect on Ultimate Tensile Strength of Bar (12mm Dia.)

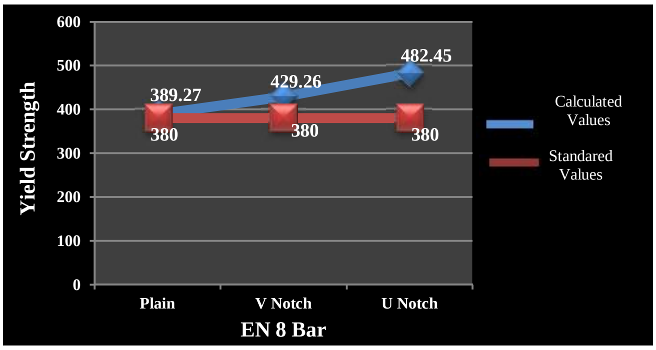

Figure 4.6: Notch Effect on Yield Strength of Bar (12mm Dia.)

The results are calculated for plain bar (12mm dia.) and bars with V and U Notch.

It have been observed from the graph plotted (Fig. 4.5 & 4.6) that Ultimate Tensile Strength are 695.33 N/mm^2 and 700.13 N/mm^2 for plain bar (dia. 12mm) and bar with V Notch (Notch dia. 12mm) respectively and Yield Strength are 389.27 N/mm^2 and 429.26 N/mm^2 for plain bar (dia. 12mm) and bar with V Notch (Notch dia. 12mm) respectively. It is also observed from the graph plotted (Fig. 4.5 & 4.6) that Ultimate Tensile Strength are 700.13 N/mm^2 and 709.83 N/mm^2 for bar with V Notch (Notch dia. 12mm) and bar with

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U Notch (Notch dia. 12mm) respectively and Yield Strength are 389.27 N/mm^2 and 429.26 N/mm^2 for bar with V Notch (Notch dia. 12mm) and bar with U Notch (Notch dia. 12mm) respectively. Hence, the load carrying capacity of the bar with U Notch is more than the bar with V Notch for notched diameter 12mm. It is also concluded that load carrying capacity of the bar with V Notch is more than the plain bar of notched diameter. It is evident from the results that the sharper section i.e. (V Notch) offers less resistance to tensile load as compared to smooth sections (U Notch).

The percentage increase in tensile strength on comparing bar with V Notch and Plain Bar is 0.68% and for bar with U Notch and Plain Bar is 2.04%. On comparing bar with U Notch and bar with V Notch the percentage increase on tensile strength is 1.36%. The percentage increase on yield strength on comparing bar with V Notch and Plain Bar is 9.31% and on comparing the bar with U Notch and Plain Bar the percentage increase in yield strength is 19.31%. On comparing bar with U Notch and bar with V Notch percentage increase in tensile strength is 11.02%.

4.2 Analysis Results for 9mm diameter

Figure 4.7: Specimen after Tensile Testing from UTM (9mm)

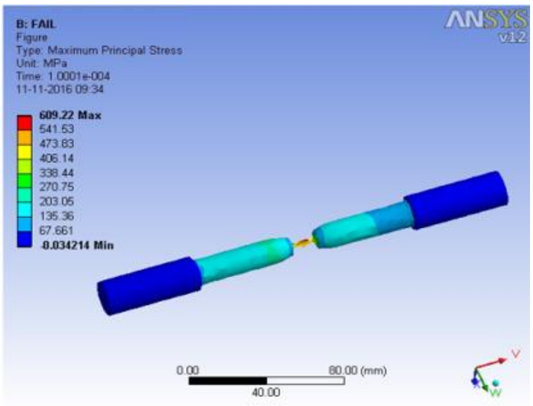

Figure 4.8: ANSYS Analysis of Bar with U Notch 3mm Depth

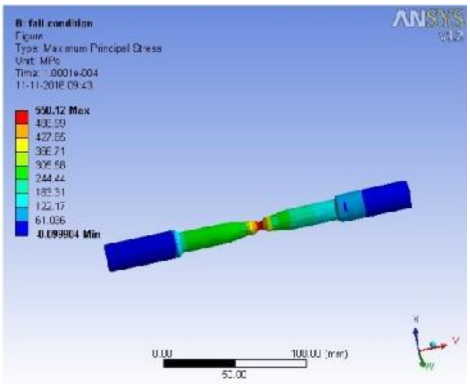

Figure 4.9: ANSYS Analysis of Bar with V Notch 3mm Depth

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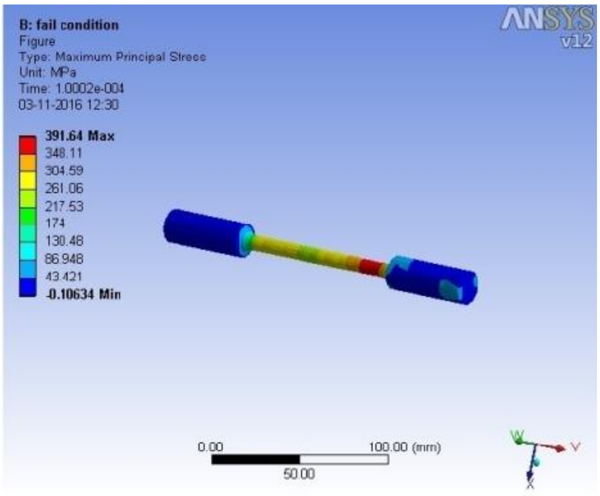

Figure 4.10: ANSYS Analysis Plain Bar (9mm Dia)

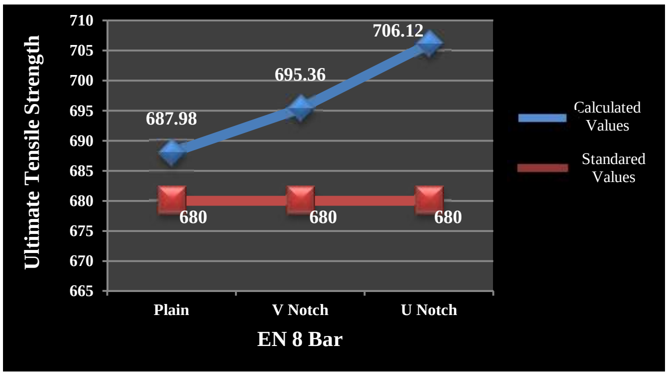

Figure 4.11: Notch effect on Tensile Strength of Bar (9mm dia)

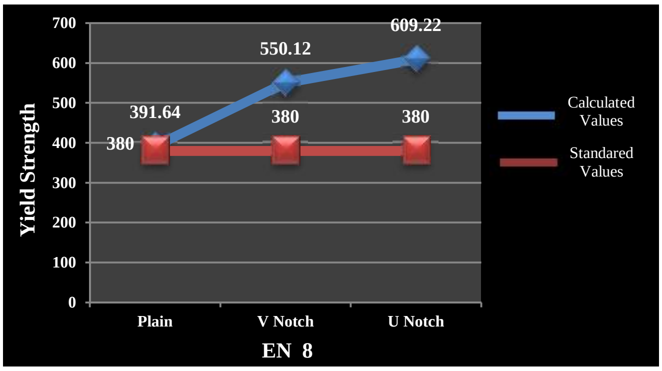

Figure 4.12: Notch effect on Yield Strength of Bar (9mm dia)

The results are calculated for plain bar (9mm dia.) and bars with V and U Notch.

It have been observed from the graph plotted (Fig. 4.11 & 4.12) that Ultimate Tensile Strength are 687.98 N/mm^2 and 695.36 N/mm^2 for plain bar (dia. 9mm) and bar with V Notch (Notch dia. 9mm) respectively and Yield Strength are 391.64 N/mm^2 and 550.12 N/mm^2 for plain bar (dia. 9mm) and bar with V Notch (Notch dia. 9mm) respectively. It is also observed from the graph plotted (Fig. 4.11 & 4.12) that Ultimate Tensile

Strength are 695.36 N/mm^2 and 706.12 N/mm^2 for bar with V Notch (Notch dia. 9mm) and bar with U Notch (Notch dia. 9mm) respectively and Yield Strength are 550.12 N/mm^2 and 609.22 N/mm^2 for bar with V Notch (Notch dia. 9mm) and bar with U Notch (Notch dia. 9mm) respectively. Hence, the load carrying capacity of the bar with U Notch is more than the bar with V Notch for notched diameter 9mm. It is also concluded that load carrying capacity of the bar with V Notch is more than the plain bar of notched diameter. It is evident from the results that the sharper section i.e. (V Notch) offers less resistance to tensile load as compared to smooth sections (U Notch).

The percentage increase in tensile strength on comparing bar with V Notch and Plain Bar is 1.06% and for bar with U Notch and Plain Bar is 2.56%. On comparing bar with U Notch and bar with V Notch the percentage increase on tensile strength is 1.52%. The percentage increase on yield strength on comparing bar with V Notch and Plain Bar is 28.8% and on comparing the bar with U Notch and Plain Bar the percentage increase in yield strength is 35.71%. On comparing bar with U Notch and bar with V Notch percentage increase in tensile strength is 9.7%.

On comparing both the graph it is concluded that on increasing depth of notch but if width is kept constant the results are same. Therefore, sharper section (V Notch) offers less resistance than smooth section (U Notch). So it can also be concluded for EN 8 on increasing the depth of cut resistance offered by the material reduces strength of material.

V CONCLUSION

5.1 Conclusion

It is concluded from the analysis on Universal Testing Machine and ANSYS that the tensile strength of notched bar is more as compared to plain bar of notched diameter of EN 8 material. The deviation on ultimate tensile strength on comparing U Notch with V Notch are 9.7 N/mm^2 and 10.76 N/mm^2 for 12mm notched diameter and 9mm diameter respectively of same material. It can also be concluded that the sharper section offers less resistance as compared to smooth section. It can also be concluded that on varying depth of notch (width is kept constant), the result is same i.e. sharper section (V Notch) offers less resistance than smooth section (U Notch).

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