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Research Article **Engineering**

ANALYSIS OF EFFECT OF SHAPE AND DEPTH OF NOTCH ON TWISTING STRENGTH OF MEDIUM CARBON STEEL 40C8 BAR

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Abstract: This work presents the comparison of twisting strength of plain bar of 40C8 material with notched bar of same diameter with U/V/Square notch. It has been found from the results that the twisting strength of notched bar is more than the plain bar of 40C8 material. The results indicate that the notch geometry plays an important role in the twisting strength of the bar. The twisting strength of U shaped bar is greater than the twisting strength of notched bar (V-Shape) is greater than the twisting strength of notched bar (Square Shape). It has also been found that on increasing depth of notch but if width is kept constant the results are same. Results of Torsion Testing Machine have been compared with results from ANSYS software. It is concluded from the analysis that the Twisting Strength of the notched bar is more as compared to plain bar of 40C8 material. The deviations in twisting strengths on comparing bar with V Notch and Square Notch are 17.43 % & 25.80% and on comparing bar with Square Notch and U Notch is 25.93% & 27.69% for 9mm and 12mm notched diameter respectively of same material. This behavior of the material is due to presence of the notch, triaxial stress state generated due to this general yield stress of a notched specimen is more than the uniaxial yield stress because it is more complex to spread the yield region in the presence of triaxial stresses.

Keywords: Twisting Moment; Notch Shapes; Twisting Strength; EN 8; Torsion; Triaxial Stress; uniaxial Stress; 40C8.

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INTRODUCTION

Automobiles need a very broad variety of raw materials for their production. Now a day's automobile industry is leading in manufacturing because of new technologies. Different types of materials are used in automobile but 40C8 i.e. medium carbon steel is mostly used in automobile parts likes shaft, stressed pin, studs, keys, crankshafts, automobile axle beams etc. It is in general used for rather stressed parts of Motor vehicle, common engineering works etc. The chemical compositions of this material are Carbon 0.40-0.45 %, Silicon 0.05-0.35%, Manganese 0.60-1% and Chromium 0.06%. These allow objects made of alloy steel to return to their original form in spite of important deflection or twisting. It is the mostly used form of steel because its price is moderately small while it provides materials properties are appropriate for lots of applications. It has low twisting strength, but it is economical and easy to manufacture, surface hardness of EN 8 can be improved through carburizing. The density of 40C8 is approximately 7850 kg/m^3 and Young's modulus is 210 GPa [1]. Notch is a little cut that is shaped like V, U and Square that is finished on an edge or a surface. The notch effect increases stress in an area of a component near a crack, depression, etc. or a modifying in section, such as a sharp angle. It can be adequate to cause failure of the component although the calculated average stress may be quite safe. The term "notch" in a wide sense is used to pass on to several discontinuities in shape or non-uniformity in material. The fatigue "notch-sensitivity," or susceptibility of a member to succumb to the destructive effects of stress-raising notches (this susceptibility varies with different materials) is therefore an important consideration in approximately each branch of machine design involving the proportioning of members for service under repeated stress. The pronounced reduction of fatigue strength due to a sudden change in cross-section of a load-carrying element has been noted in many experimental investigations. It has been observed that effect of Notch is affecting the strength of automobile components. In general, most of these earlier analyses were mostly 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. Numerous works have been done on various alloys. In this analysis the torsion testing is mainly focused. It has been observed that the analysis on the 40C8 notched bar has not been performed when material is subjected to torsion loading. That's why the analysis is needed to be done in this area. Author beliefs that the work on 40C8 i.e. medium carbon steel is needed to be done for analyze the effect of shape and depth of notch on strength of vehicle components.

II Literature review

The aim of literature review is to find out the shape of research in the area of effect of shape and depth 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 literature has been reviewed related with presented research work.

Zhang et al in (1992) [2] concluded for the spherical section assumption, which is an effective method for determining the local stress and limit load of a thick-walled tube with an external hoop direction U-shaped notch under tension, and discusses the relationships of the stress concentration factor with notch depth t, radius ϱ of the notch root and the internal radius of the tube. Expressions for the elastoplastic local stress and limit load, which have not been considered by previous workers, are proposed. Comparison of the results of this paper with those of previous work for the case where shows that the method of this paper is simple and effective in engineering.

Lin et al., (1998) [3] studied fatigue crack growth for various cracks in both unnotched and notched round bars by using an automated numerical technique, which calculates the stress intensity factors at a set of points on the crack front through the three dimensional finite element method and then applies an appropriate fatigue crack growth law to this set of points to obtain a new crack front. This technique also has the capability of automatic remising so that the crack propagation can conveniently be followed. A surface crack in different semi circularly notched bars under both tension and bending, a surface crack initiated from the root of a V notched bar and an initially twin crack configuration within a smooth tension bar. Some fatigue growth characteristics relevant to each type of cracks are also revealed. It is 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.

Gomez et al., (2000) [4] evaluated the mechanical response (i.e. peak loads and load–displacement) of a notched component. A cracking criterion is given, applicable to quasi-brittle materials under monotonic loading. This procedure is based on a cohesive zone-crack model. Numerical predictions are in good agreement with a large experimental program in which PMMA specimens of different shapes and sizes including U-notch radius and U-notch depth were tested. All experimental results are reported. The paper closes with a discussion of the proposed cracking criteria and some proposals for future work.

Seweryn et al., (2002) [5] analyzed of crack initiation in plane elements with V-shaped notches under biaxial loading (mode I and II) was presented.

The following fracture criteria were used to evaluate the critical loads and directions of crack initiation: strain energy release rate criterion; strain energy density criterion; modified McClintock's stress criterion; non-local stress criterion. Results of numerical analysis obtained using the boundary element method and path independent *H* and *J* integrals were compared with experimental data.

Nowell et al., (2003) [6] evaluated for gas turbine engines can be subject to ingestion of small hard particles, leading to foreign object damage. This can take the form of sharp V-notches in the leading edge of blades and there is a need to predict the initiation and propagation behavior of fatigue cracks growing from the base of the notch. The notch geometry is quite extreme and is not normally covered in standard references for notch stress concentration factors. Similarly, stress intensity factor solutions for this geometry are not widely available. This paper uses the dislocation density approach to solve the two-dimensional elastic problem of a V-notch with a radius root. Stress concentration factors are found for the notch itself, and stress intensity factors are determined for cracks growing away from the notch for cases of applied and residual stress distributions. Comparisons are made with existing notch solutions from the literature.

Fonte et al in (2006) [7] Suggested that Most of catastrophic mechanical failures in power rotor shafts occur under cyclic bending combined with steady torsion: Mode I (ΔK_I) combined with Mode III (K_{III}). An analysis of the influence of steady torsion loading on fatigue crack growth rates in shafts is presented for short as well as long cracks. Long cracks growth tests have been carried out on cylindrical specimens in DIN Ck45k steel for two types of testing: rotary or alternating bending combined with steady torsion in order to simulate real conditions on power rotor shafts. The growth and shape evolution of semi-elliptical surface cracks, starting from the cylindrical specimen surface, has been measured for several loading conditions and both testing types. Short crack growth tests have been carried out on specimens of the same material DIN Ck45k, under alternating bending combined with steady torsion. The short crack growth rates obtained are compared with long crack growth rates. Results have shown a significant reduction of the crack growth rates when a steady torsion Mode III is superimposed to cyclic Mode I. A 3D Finite Element analysis has also shown that Stress Intensity Factor values at the corner crack surface depend on the steady torsion value and the direction of the applied torque.

Lazzarin et al in (2006) [8] concluded that in the presence of sharp (zero radiuses) V-shaped notches the notch stress intensity factors (N-SIFs) quantify the intensities of the asymptotic linear elastic stress distributions. They are proportional to the limit of the mode I or II stress components multiplied by the distance powered $1 - \lambda i$ from the notch tip, λi being Williams' eigen values. When the notch tip radius is different from zero, the definition is no longer valid from a theoretical point of view and the characteristic, singular, sharp-notch field diverges from the rounded-notch solution very next to the notch. Nevertheless, N-SIFs continue to be use as parameters governing fracture if the notch root radius is sufficiently small with respect to the notch depth.

AkiNoda et al in (2006) [9] Analyzed that the stress concentration factors (SCFs, K_t) of a round bar with a circular-arc or V-shaped notch are considered under torsion, tension and bending. First, for the limiting cases of deep and shallow notches, the body force method is used to calculate the SCFs; then, the formulas are obtained as K_{td} and K_{ts}. On the one hand, upon comparison between K_t and K_{td}, it is found that K_t is nearly equal to K_{td} if the notch is deep or blunt. On the other hand, if the notch is sharp or shallow, K_t is mainly controlled by K_{ts} and the notch depth. The notch shape is classified into several groups according to the notch radius and notch depth; then, the least squares method is applied for calculation of K_t/K_{td} and K_t/K_{ts}. Finally, a set of convenient formulas useful for any shape of notch in a round test specimen is proposed. The formulas yield SCFs with less than 1% error for any shape of notch. The effect of notch opening angle on the SCF is also considered for the limiting cases of deep and shallow notches.

Livieri et al in (2008) [10] concluded the physical meaning of J_V (namely, the classic *J*-integral applied to either sharp V-notch) is discussed. Consider a Cartesian reference frame having the *x*-axis parallel to the notch bisector, each mode of J_V, for a given circular path, is proportional to the correspondent mode of the classic *J*-integral of a virtual crack having length equal to the path radius and emanating from the tip of the V-notch. Analytical and numerical results have been performed for linear elastic materials. Additionally, in order to verify the formulations of J_V, experimental result of embedded cracks of sharp V-notch was considered.

Wang et al., (2010) [11] summaries the uniaxial tension tests for 20 notched bars fabricated from high strength steel Q345 specified in Chinese National Standards. The effects of the notch radius, *r*, and that of the notch depth ratio, d/D , on the ductility and fracture resistance of this high strength steel are examined. The experimental data are further analyzed using a generalized yield model together with an elliptical fracture stress envelope originally proposed by the first author. The experimental results demonstrate that cracks initiate at the notched section, with the fracture surface filled with many dimples and shearing marks. Specimens with a sharper notch radius (a smaller *r*) and a larger notch depth (a smaller *d*/*D* ratio) show poor ductility, but high fracture strength. The stress field computed from the numerical procedure including the generalized yield model indicates that the crack initiation occurs at the centre of the notched section which experiences the highest stress triaxiality ratio ($\sigma m/\sigma seq$). 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.

Majzoobi et al., (2010) [12] studied the notch sensitivity of a material is a measure of how sensitive a material is to notches or geometric discontinuities. Notch sensitivity is influenced by many parameters such as notch geometry. Three types of notch geometries, V-shape, U-shape and -shape notches of various sizes are considered in this investigation. Two steel alloys of high and low strength (designated by HS-steel and LS-steel) are used in this work. Stress concentration is obtained by numerical simulation and the literature and fatigue reduction factor is determined by experiment using rotating bending fatigue device, Moore. The results show that the notch geometry has profound effect on fatigue life of materials. For HS-steel this reduction is roughly about 50%. For LS-steel alloy, however, the reduction depends on fatigue life and varies from 20% for low cycle fatigue tests up to 75% for high cycles fatigue tests. The maximum and minimum fatigue life reduction occurs for the V-shape and U-shape notches, respectively. The Equations proposed by Hardrath and Peterson underestimate the fatigue reduction parameters, *q* and Kf and it seems that they are not adequate for prediction of notch sensitivity and they must be used with care.

Anaka et al., (2010) [13] studied the two specific subjects related to the fatigue strength and life of notched bars under combined torsion 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.

Citarella et al in 2010 [14] Worked on Comparison of DBEM and FEM crack path predictions in a notched shaft under torsion, they analyzed that the rather complex 3D fatigue crack growth behavior of two anti-symmetric “bird wing” cracks, initiated from the two crack front corner points of a notched shaft undergoing torsion, is investigated by the Dual Boundary Element Method(DBEM) and by the Finite Element Method (FEM). Different criteria for the crack path assessment (Minimum Strain Energy Density, Maximum Principal Stress and Approximate Energy Release Rate) and for the Stress Intensity Factor (SIF) evaluation (COD and *J*-integral) are adopted. The SIF’s and the crack path, calculated by such different approaches, turn out to be well consistent with each other. Moreover the simulated crack path qualitatively agrees with experimental findings available from literature.

Ohkawa et al., (2011) [15] 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.

De-Souza et al in (2012) [16] analysed the influence of test method factors (notch shape, square or angular, and pre-cracking method, by tapping onto or pressing a razor blade) on the results obtained in plane strain fracture toughness test according to standard ASTM D5045 using SENB specimens made of a commercial PMMA resin were investigated. Results were analyzed quantitatively by comparing the obtained KIc values and qualitatively by observing their effect on the Moiré fringes observed using photoelasticity, showing that, at 95% significance level, the KIc values are affected by the pre-cracking method, with the most conservative value being obtained when natural pre-cracks were introduced by tapping onto a razor blade (KIc = 1.15 ± 0.11 MPa·m0.5). This correlates with a perturbation in the stress field close to the pre-crack tip observed in the photo elasticity test sample when it was introduced by pressing the razor blade. Surprisingly, notch geometry only slightly affects the results.

Torabi et al in (2013) [17] analysed U-notched Brazilian disc specimens made of a type of commercial graphite were used to measure experimentally the mode I notch fracture toughness of material. The experimental results were estimated by means of the mean stress and the point stress fracture criteria. An excellent agreement was found to exist between the results of the mean stress criterion and the experimental results for different notch tip radii. Also, found in this research was that the point stress criterion provides weaker estimates compared to the mean stress model except when one deals with larger values of the notch tip radius.

Bader et al., (2014) [18] studied the effect of notches with various notch geometries and dimensions on fatigue life in steel beam made of Mild Steel AISI 1020 which has a wide application in industry. Fatigue life of notched specimens is calculated using the fatigue life obtained from the experiments for smooth specimens and by use Numerical method (FEA).The fatigue experiments were carried out at room temperature, applying a fully reversed cyclic load with the frequency of 50Hz and mean stress equal to zero (R= -1), on a cantilever rotating-bending fatigue testing machine. The stress ratio was kept constant throughout the experiment. Different instruments have been used in this investigation like Chemical composition analyzer type (Spectromax), Tensile universal testing Machine type (WDW- 100E), Hardness Tester type (HSV- 1000), Fatigue testing machine model Gunt WP 140, Optical Light Microscope (OLM) and Scanning Electron Microscope (SEM) were employed to examine the fracture features. The results show that there is acceptable error between experimental and numerical works.

Barsoum et al in (2014) [19] presents a finite element modelling framework to determine the torsion strength of hardened splined shafts by taking into account the detailed geometry of the involutes spline and the material gradation due to the hardness profile. The aim is to select a spline geometry and hardness depth that optimizes the static torsion strength. Six different spline geometries and seven different hardness profiles including non- hardened and through-hardened shafts have been considered. The results reveal that the torque causing yielding of induction hardened splined shafts is strongly dependent on the hardness depth and the geometry of the spline teeth. The results from the model agree well with experimental results found in the literature and reveal that an optimum hardness depth maximizing the tensional strength can be achieved if shafts are hardened to half their radius.

Gupta et al in (2017) [20] concluded that 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. They considered U and V shaped notched bar for analysis.

Outcome of Literature Review:

The several works has been done on austenitic stainless steel, SUS 316L, carbon steel, SGV410, and AZ-6A-T5 magnesium alloy & EN8 Material. The researchers mainly focused on FEM, FDM, ANSYS and SOLID WORKS analysis. In the analysis the tensile testing is mainly focused.

- Researchers analysed the stress intensity factor along the crack front to calculate a finite element analysis by employing isoperimetric solid elements.
- Researchers analysed the tensile strength of EN 8 material.
- Researchers compared tensile strength of plain bar with bar of various shape of notch like, Square, V and U.
- Researchers also compared the tensile strength of plain bar with the bar of various shapes of notch like, Square, V and U on ANSYS software.
- Author found that comparative study on twisting strength of different notches i.e. square, V and U shapes have not been done yet.

Objectives of Research Work:

The main objectives of this research are as follows:

- To identify the effect of shape of notch shape i.e. U, V & Square on twisting strength of40C8 bar.
- To identify the effect of depth of notch on twisting strength of 40C8 bar.
- To compare the effect of various shape of notch on twisting strength of 40C8 bar.
- To compare twisting strength of notched bar with plain bar.

Problem Formulation:

Since researchers marked that notch affects the twisting strength of bar, hence work can be done to compare the effect of various shapes of notch on twisting strengths. The work can also be done to check the effect of depth of notch also.

The work can be summarized as:

1. Drafting of plain bar and notched bar specimens on Solid Works.
2. Manufacturing of bar as per dimensions.
3. Experimental study on Torsion Testing Machine i.e. calculation of twisting strength.
4. Comparison of twisting strength of plain bar with Square, V and U shaped notched bar.
5. Validation of result on ANSYS.

I. Research Work

A. Experimental Setup

The most general torsion testing machine used in torsion testing is the torsion testing machine. This type of machine has two crossheads; one is accustomed for the length of the specimen and the other is driven to affect tension to the test specimen. The machine must have the suitable capabilities for the test specimen being tested. The specimen is positioned in the machine between the grips and an extensometer if essential can automatically record the adjust gauge length during the test. If an extensometer is not fixed, the machines itself can authorization the displacement among the cross head on which the specimen is held.

There are four most important parameters: force capacity, speed, precision and accuracy. Force capability refers to the reality that the machine must be competent to produce sufficient force to crack the specimen. The machine must be able to apply the force speedily or gradually adequate to correctly mimic the real application. The test process involves placing the test specimen in the testing machine and gradually extending it until it fractures. During this method, the elongation of the estimate section is recorded against the applied force.

Machine Specifications are as follows:
Model: AMT-3
Capacity: 100 KGM
Max. Dia.: 20mm
Min. Dia.: 6mm

Table.1

Specification	Unit	DT-6
Max. Torque Cap.	Kg-m	6
Torque Range	Kg-m	6.3
No. Of division on dial Torsion Speed	RPM	600 0.5
Clearance Between Grips.	mm	0-420
Grips for Round Bars.	mm	4-8
		8-12
Grips for Flat Bars.	mm	1-5
Width	mm	1-5
Motor 3 Ph.	mm	0.33

Figure 1: Experimental setup of Torsion Testing Machine

Specification of specimen

For performing the experimental work the specimen mentioned in Fig 2, 3, 4, 5, 6, 7 , 8 & 9 , is manufactured of different notch as mentioned in Table 1

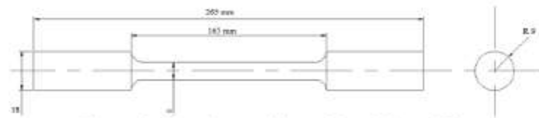

Figure 2: Specimen without Notch 9mm Dia.

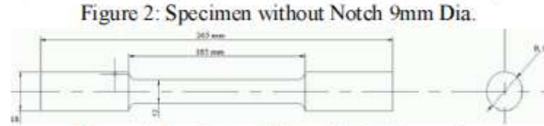

Figure 3: Specimen without Notch 12mm dia.

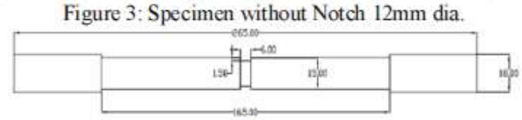

Figure 4: Specimen with Square Notch 1.5mm depth

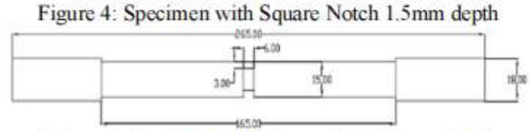

Figure 5: Specimen with Square Notch 3mm depth

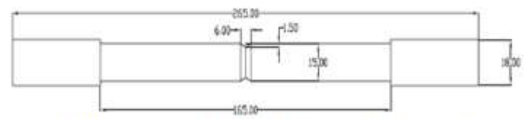

Figure 6: Specimen with V Notch 1.5mm depth

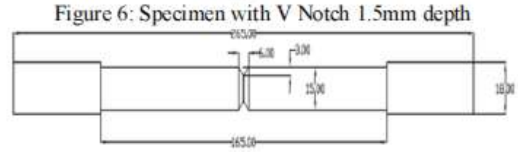

Figure 7: Specimen with V Notch 3mm depth

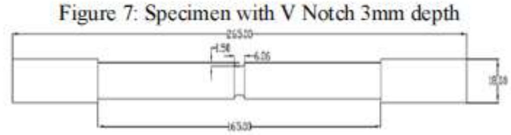

Figure 8: Specimen with U Notch 1.5mm depth

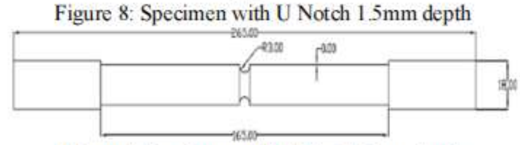

Figure 9: Specimen with U Notch 3mm depth

S. No.	Material	Specim n							
		Square Notch		U - Notch		V - Notch		Plain	
	EN 8	9 mm Depth	12 mm Depth	9mm Depth	12mm Depth	9mm Depth	12 mm Depth	9mm Dia.	12mm Dia.
1	√	√							
2	√		√						
3	√			√					
4	√				√				
5	√					√			
6	√						√		
7	√							√	
8	√								√

Figure 10: Specimens

Solid Works

It Works is a solid modeler and utilizes a parametric feature-based come within reach of to build models and assemblies. Standard values submit to constraints whose principles find out the form or geometry of the mock-up or assemblage. Parameters are able to what's more numeric parameter, such as procession lengths or circle diameters, or geometric parameters, such at the identical moment in time as digression, parallel, concentric, horizontal or vertical, etc. Numeric parameters can be connected with every one additional from beginning to end the use of associations, which consent to them to imprison design intention.

Form based facial appearance characteristically commence with a 2D or 3D rough draft of shapes such as bosses, holes, slots, etc. This profile is at that moment extruded or incises to put in or remove material from the part.

This feature are not sketch-based, and take account of facial appearance such as fillets, chamfers, shells, apply draft to the faces of a part, etc. construction a model in firm Works more often than not starts in the company of a 2D first attempt. The rough draft consists of geometry such as points, lines, arcs, conics, and splines. Proportions are supplementary to the rough draft to describe the magnitude and position of the geometry.

Relatives are used to describe attributes such as tangency, parallelism, perpendicularity, and concentricity. The parametric temperament of Solid mechanism means that the dimensions and kindred constrain the geometry, not the additional line of attack in the region of. The magnitude in the sketch can be forbidden in competition, or by relations to additional parameters contained by or outer surface of the rough draft. In an assembly, the correspondence to sketch associations is mates. a moment ago as first attempt family members characterize state of affairs such as tangency, parallelism, and concentricity in the midst of high opinion to sketch geometry, assembly mates characterize the same relations with respect to the individual parts or components, allowing the easy construction of assemblies.

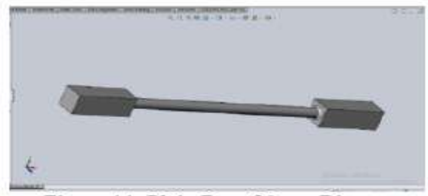

Figure 11: Plain Bar of 9mm Dia.

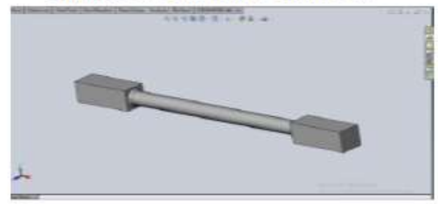

Figure 12: Plain Bar of 12mm Dia.

Figure 13: Bar with Square Notch 1.5mm depth

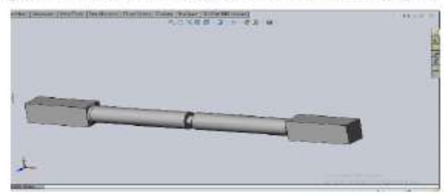

Figure 14: Bar with Square Notch 3mm depth

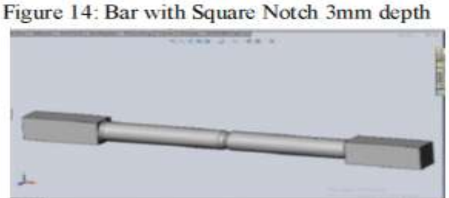

Figure 15: Bar with V Notch 1.5mm depth

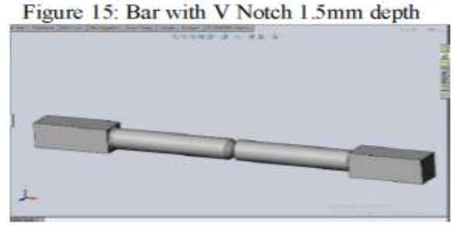

Figure 16: Bar with V Notch 3mm depth

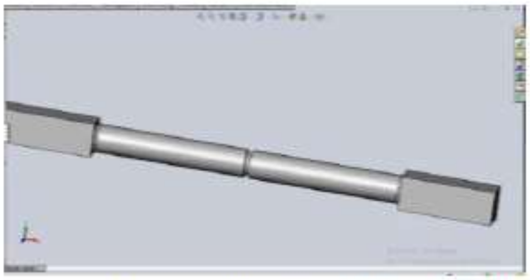

Figure 17: Bar with U Notch 1.5mm depth

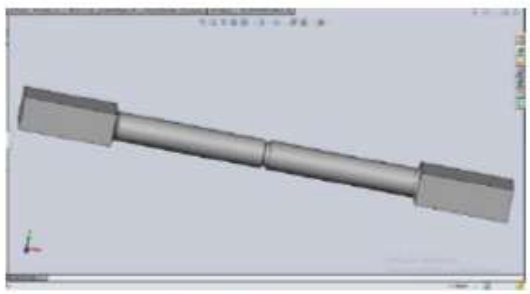

Figure 18: Bar with U Notch 3mm depth

ANSYS

ANSYS is a frequent occupation software, it is worn to put it to somebody the contacts of every discipline of physics, structural, vibration, fluid dynamics, heat transfer and electromagnetic for all. So this software, which enables to replicate tests or functioning circumstances of all atmospheres, enables to test in essential situation before mechanized prototypes of crop.

Additionally, influential and humanizing weak points, computing life and foresee feasible problems are probable by 3D simulations in essential surroundings. ANSYS software by means of its modular configuration as seen in the bench underneath gives an opening for pleasing only desirable features.

ANSYS can effort integrated with further used engineering software on desktop by adding up Computer aided design and finite element Analysis association modules.

ANSYS can bring in CAD data and also enables to put together geometry with its “pre-processing” abilities. Correspondingly in the similar pre-processor, finite element model (i.e. mesh) which is necessary for working out is generated. After important loadings and carrying out analyses, results can be viewed as numerical and graphical. It can transmit out advanced engineering analysis quickly, securely and virtually by its multiplicity of contact algorithms, time based loading features and nonlinear material models.

ANSYS Workbench is a stage which integrates simulation technologies and parametric Computer Aided Design systems with only one of its kind computerization and presentation. The command of ANSYS Workbench comes starting ANSYS solver algorithms with years of knowledge. Furthermore, the object of ANSYS Workbench is confirmation and civilizing of the creation in virtual atmosphere. ANSYS Workbench, which is on paper for high stage compatibility with specially PC, is more than an crossing point and everybody who has an ANSYS certify can work with ANSYS Workbench.

Structural Analysis

a. ANSYS Autodyn

ANSYS Autodyn is computer simulation tool for simulating the response of materials to short duration severe loadings from impact, high pressure or explosions.

b. ANSYS Mechanical

ANSYS perfunctory is a limited constituent analysis contrivance for structural analysis, together with linear, nonlinear and dynamic studies. This computer simulation product provides finite elements to model behavior, and supports material models and equation solvers for a wide range of mechanical design problems. It is involuntary in adding together includes thermal research and coupled-physics capabilities with submission to acoustics, piezoelectric, thermal–structural and thermo-electric analysis. The mesh type is coarse and the element is tetrahedral in shape for all 6 analyses in ANSYS

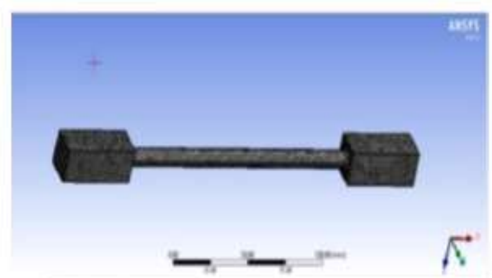

Figure 19: Mesh (Plain Bar of 9mm Dia.)

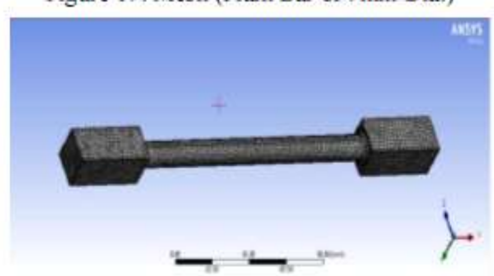

Figure 20: Mesh (Plain Bar of 12mm Dia.)

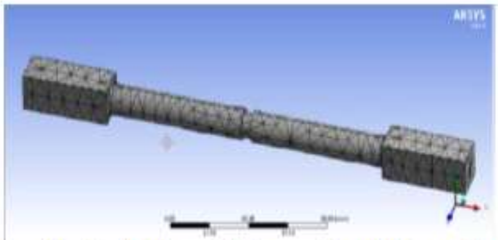

Figure 21: Mesh (Bar with Square Notch 1.5mm depth)

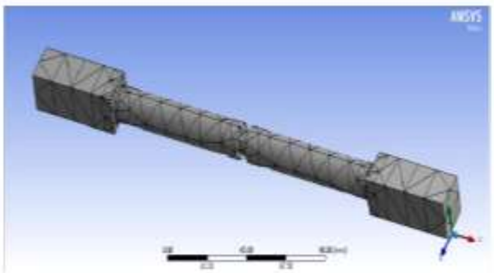

Figure 22: Mesh (Bar with Square Notch 3mm depth

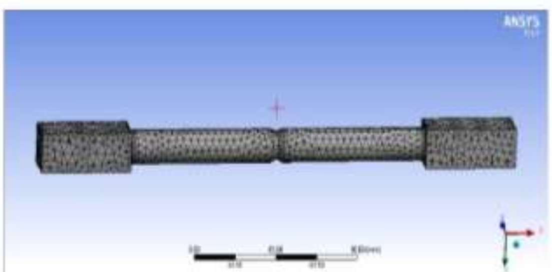

Figure 23: Mesh (Bar with V Notch 1.5mm depth)

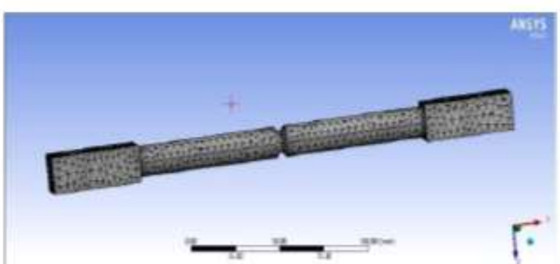

Figure 24: Mesh (Bar with V Notch 3mm depth)

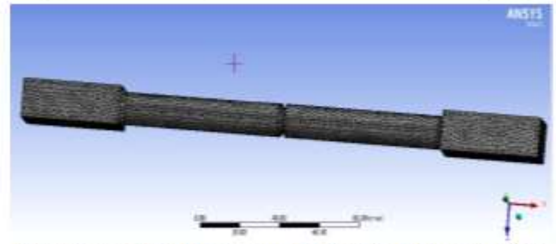

Figure 25: Mesh (Bar with U Notch 1.5mm depth)

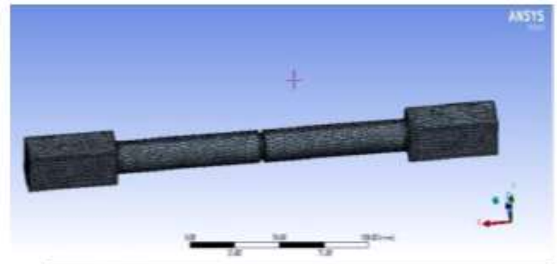

Figure 26: Mesh (Bar with U Notch 3mm depth)

V. Results & Discussion

Results

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

Results (9mm diameter bar)

The following Results (Twisting Strength) have been taken from Torsion Testing Machine-

a. Plain bar (9 mm diameter)- 524.29 N/mm²
b. Bar with Square Notch- 596.25 N/mm²
c. Bar with V-Notch- 623.66 N/mm²
d. Bar with U-Notch- 661.36 N/mm²

Figure 27: Specimens after Twisting Testing from Torsion Testing Machine

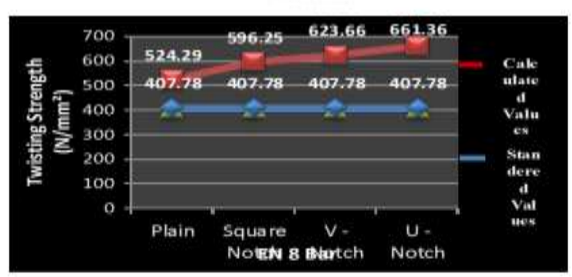

Figure 28: Notch Effect on Twisting Strength (9mm Dia.) (Determined by Torsion Testing Machine)

The results are finding from Torsion Testing Machine for plain bar (dia. 9mm), same bars with Square notch, V-Notch and U- Notch, it has been observed from (fig. 28) that the Twisting Strength are 524.29 N/mm², 596.25 N/mm², 623.66 N/mm² and 661.36 N/mm² respectively. The load carrying capacity of the bar with U Notch is more than the bar with V Notch and Square-notch for bar diameter of 9mm. It is evident from the results that the sharper section i.e. (Square Notch & V Notch) offers less resistance to torsion load as compared to smooth sections (U Notch). This type of unusual behavior of material is due to presence of the notch, because as a result of the triaxial stress state produced by the notch the general yield stress of a notched specimen is greater than the uniaxial yield stress because it is more difficult to spread the yield zone in the presence of triaxial stresses.

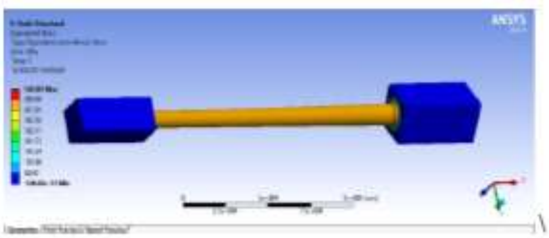

Figure 29: ANSYS Analysis Plain Bar (9mm Dia.)

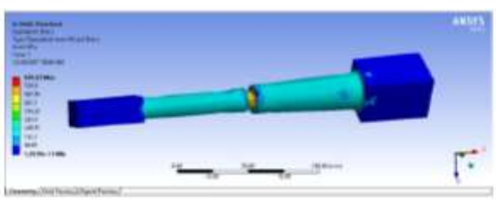

Figure 30: ANSYS Analysis of Bar with Square Notch 3mm Depth

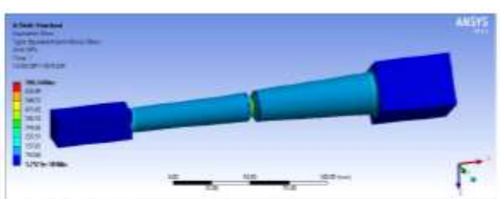

Figure 31: ANSYS Analysis of Bar with V Notch 3mm Depth

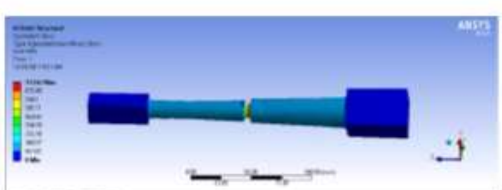

Figure 32: ANSYS Analysis of Bar with U Notch 3mm Depth

The following Results (Twisting Strength) have been taken from ANSYS Software-

a. Plain bar (9 mm diameter)- 543.87 N/mm²
b. Bar with Square Notch- 601.65 N/mm²
c. Bar with V-Notch- 706.54 N/mm²
d. Bar with U-Notch- 757.67 N/mm²

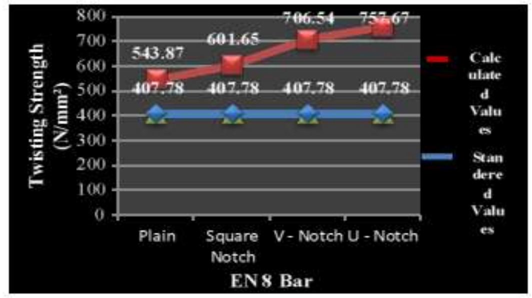

Figure 33: Notch Effect on Twisting Strength (9mm Dia.) {Determined by ANSYS Software}

These values are evaluated on ANSYS and we finds values of Twisting Strengths for Plain bar, Square Notch, V-Notch and U- Notch (dia. 9mm) , it has been observed from (fig. 33) that the twisting strength are 543.87 N/mm² , 601.65 N/mm², 706.54 N/mm² and 757.67 N/mm² respectively. Hence, the twisting strength of the bar with U Notch is more than the bar with V Notch and Square notch for notched diameter 9mm. It is also concluded that twisting strength of the bar with V Notch is more than the Square Notch of notched diameter and the twisting strength of the bar with Square notch is more than the plain bar of notched diameter. It is evident from the results that the sharper section i.e. (V Notch & Square Notch) offers less resistance to twisting load as compared to smooth sections (U Notch).

The percentage increase in Twisting strength on comparing bar with Square Notch and Plain Bar is 10.62% and for bar with V Notch and plain bar is 29.90% and for bar U Notch and Plain Bar is 39.31%. On comparing bar with V Notch and Square Notch the percentage increase on twisting strength is 17.43%. On comparing bar with V Notch and U Notch the percentage increase on twisting strength is 7.23%. 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 smoothe 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.

Results (12 mm diameter bar)

The following Results (Twisting Strength) have been taken from Torsion Testing Machine-

a. Plain bar (12 mm diameter)- 504.53 N/mm²
b. Bar with Square Notch- 537.78 N/mm²
c. Bar with V-Notch- 621.63 N/mm²

d. Bar with U-Notch- 630.31 N/mm²

Figure 34: Specimens after Torsion Testing Machine

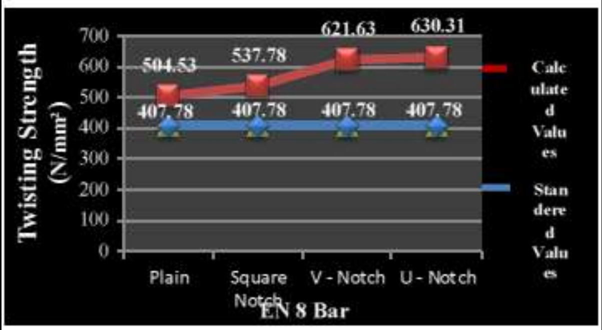

Figure35: Notch Effect on Twisting Strength of Bar (12mm Dia.) {Determined by Torsion Testing Machine}

The results are finding from Torsion Testing Machine for plain bar (dia. 12mm), same bars with Square notch, V-Notch and U- Notch, it has been observed from (fig. 35) that the torque are 504.53 N/mm², 537.78 N/mm², 621.63 N/mm² and 630.30 N/mm² respectively. The load carrying capacity of the bar with U Notch is more than the bar with V Notch and Square- notch for bar diameter of 12mm. It is evident from the results that the sharper section i.e. (Square Notch & V Notch) offers less resistance to torsion load as compared to smooth sections (U Notch). This type of unusual behaviour of material is due to presence of the notch, because as a result of the triaxial stress state produced by the notch the general yield stress of a notched specimen is greater than the uniaxial yield stress because it is more difficult to spread the yield zone in the presence of triaxial stresses.

The percentage increase of torque on comparing bar with Square Notch and Plain Bar is 6.59% and on comparing the bar with V Notch and Plain Bar the percentage increase is 23.21% and on comparing the bar with U Notch and plain bar the percentage increase is 24.93%.On comparing bar with Square Notch and bar with V Notch percentage increase is 15.59%. On comparing bar with V Notch bar with U Notch percentage increase in torque is 1.39%.

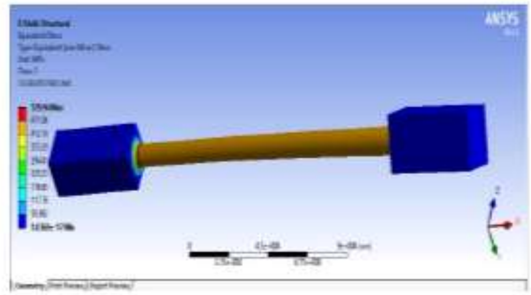

Figure 36: ANSYS Analysis Plain Bar (12mm Dia.)

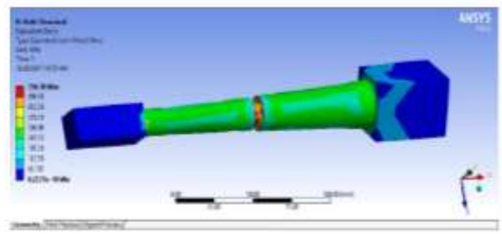

Figure 37: ANSYS Analysis of Bar with Square Notch 1.5mm Depth

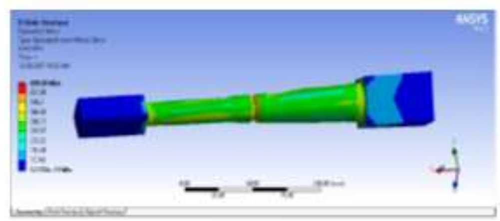

Figure 38: ANSYS Analysis of Bar with V Notch 1.5mm Depth

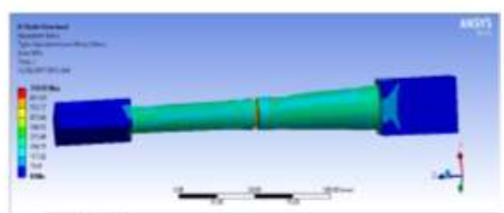

Figure 39: ANSYS Analysis of Bar with U Notch 1.5mm Depth

The following Results (Twisting Strength) have been taken from ANSYS Software-

a. Plain bar (12 mm diameter)- 543.94 N/mm²

b. Bar with Square Notch- 556.18 N/mm²

c. Bar with V-Notch- 699.69 N/mm²

d. Bar with U-Notch- 710.19 N/mm²

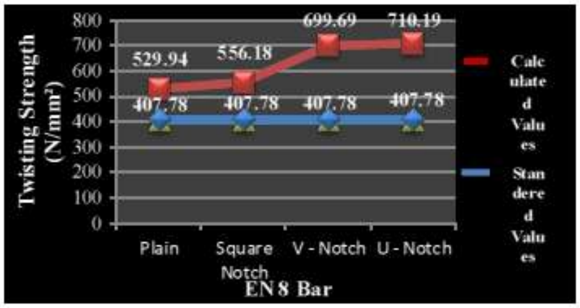

Figure 40: Notch Effect on Twisting Strength of Bar (12mm Dia.) (Determined by ANSYS Software)

These values are evaluated on ANSYS and we finds values of Twisting Strengths for Plain bar, Square Notch, V-Notch and U- Notch (dia. 9mm) , it has been observed from (fig. 40) that the twisting strength are 529.94 N/mm² , 556.18 N/mm², 699.69 N/mm² and 710.19 N/mm² respectively. Hence, the twisting strength of the bar with U Notch is more than the bar with V Notch and Square notch for notched diameter 12mm. It is also. concluded that twisting strength of the bar with V Notch is more than the Square Notch of notched diameter and the twisting strength of the bar with Square notch is more than the plain bar of notched diameter. It is evident from the results that the sharper section i.e. (V Notch & Square Notch) offers less resistance to twisting load as compared to smooth sections (U Notch).

The percentage increase in Twisting strength on comparing bar with Square Notch and Plain Bar is 4.95% and for bar with V Notch and plain bar is 32.03% and for bar U Notch and Plain Bar is 34.01%. On comparing bar with V Notch and Square Notch the percentage increase on twisting strength is 25.80%. On comparing bar with V Notch and U Notch the percentage increase on twisting strength is 1.50%.

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 (Square & 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

It is concluded from the analysis on Torsion Testing Machine and ANSYS that the twisting strength of notched bar (i.e. Square, V and U) is more as compared to plain bar of notched diameter of 40C8 material. The deviation in twisting strength on comparing bar with V Notch and bar with Square Notch is 17.43 % and on comparing bar with Square Notch and bar with U Notch is 25.93% for 9mm notched diameter respectively of same material. The deviation in twisting strength on comparing bar with V Notch and bar with Square Notch is 25.80% and on comparing bar with Square Notch and bar with U Notch is 27.69% for 12mm notched 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, Square Notch) offers less resistance than smooth section (U Notch). This analysis work may be beneficial for the research and development departments of Automobile industry. The shape of thread is generally V, U and Square, which are generally used in industries and these different notch shapes affect the stress carrying capacity of the thread portion. Hence the analysis proved the best thread shape which will ultimately improve its life.

Scope for Future Work

The further work can be done on

- Effect of materials- Different material can also be used.
- Material with heat treatment can also be considered for analyzing.

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