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Analysis Of Stress Concentration Of Notched Bar

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Abstract- Mechanical shafts, bars and many mechanical components contain geometrical discontinuities, such as circumferential notches. These circumferential notches are of prime importance in the life assessment of circular bars or shafts, since they act as local stress and strain raisers. When a notched component is loaded, local stress and strain concentrations are generated in the notch area. The stresses often exceed the yield limit of the material in the small region around the notch root, even at relatively low nominal elastic stresses. The knowledge of stress distributions on the net section is valuable for practical design and application of various engineering elements. In addition to the concentrations introduced by the notch, there is also a change in the stress state even if the stress state is uni axial throughout the remainder of the gage length. That is, the stress state becomes tri axial stress state in the immediate vicinity of the notch root.

These circumferential notches may be single or many. Few attempts are been made towards evaluation of interference effect in case of double symmetrical notches. This study aims that finite element analysis of double circular U notch and its analytical validation to enhance the knowledge of stress pattern, stress concentration along the length of circular bar under static tension.

Keywords- Stress concentration, FEA, Stress interference

I. INTRODUCTION

Stress and strain concentrations in any type of loading arise when uniformity of geometry is disrupted. Particularly, geometrical irregularities such as notches, grooves, holes, or defects are acting as local stress and strain raisers. They alter the lines of the principal stress; and bring about the stress and strain concentrations at the notch tip. Moreover, biaxial or triaxial stress state is produced at the net section even if the single loading, like axial tension, is applied to the notched bars. This single loading generates the uniaxial stress state in the un-notched part with the gross section. It should be noted that the net section is subjected simultaneously to the stress and strain concentrations and the multiaxial stress state. Many numerical analyses and theoretical studies have been conducted to obtain the elastic stress-concentration factor (SSCF); the results have been published and used for engineering design. [4-7]

II. PROBLEM DEFINITION

The problem under consideration for this phase is to investigate the interference effect of stress concentration of circumferential double notch shaft tensile loading conditions and effect of following notch parameters such as 1) notch depth 2) notch width, 3) notch centre distance and 4) notch inclination of circumferential double notch shaft, on elastic stress concentration for tensile loading conditions.

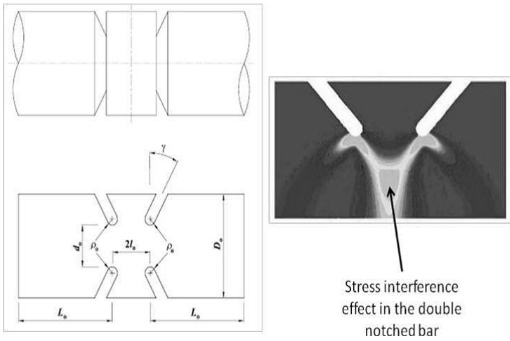

Fig. 1 - Stress Concentration & interference effect in double circumferential inclined notch

III. ANALYTICAL INVESTIGATION

For U-shaped circumferential groove in circular shaft having circumferential notch at notch inclination angle 0^0, diameter of un-notched portion of shaft is indicated by D, and notched diameter is denoted by the d, also r is the root radius and h is depth of the notch. Notation are used as, Kt = Stress Concentration Factor in Elastic Range, σ = Applied stress in N/mm^2, P = Applied axial force in N, σ_{nom} = Nominal normal stress in N/mm2, σ_{max} = Maximum normal stress at stress raiser in N/mm^2. For tensile loading, the stress concentration factor is given by,

$$K_t = C_1 + C_2\left(\frac{2h}{D}\right)^1 + C_3\left(\frac{2h}{D}\right)^2 + C_4\left(\frac{2h}{D}\right)^3$$ ----------------------------------- Equation (1)

Where, for 2.0 ≤ h/r ≤ 50.0

$$C_1 = 1.037 + 1.967\sqrt{(h/r)} + 0.002(h/r)$$
$$C_2 = -2.697 - 2.980\sqrt{(h/r)} - 0.053(h/r)$$
$$C_3 = 3.090 + 2.124\sqrt{(h/r)} + 0.165(h/r)$$
$$C_4 = -0.424 - 1.153\sqrt{(h/r)} - 0.106(h/r)$$

Maximum stress is calculated by, $\sigma_{max} = K_t \times \sigma_{nom}$ where $\sigma_{nom} = (4 \times P)/(d^2 \times \pi)$

IV. FEA INVESTIGATION

A typical ANSYS analysis has three distinct steps: 1. Build the model, 2. Apply loads and obtain the solution, 3. Review the results. These 3 steps are performed using pre-processing, solution and post-processing processors of the ANSYS program. Actually, the first step in an analysis is to determine which outputs are required as the result of the analysis, since the number of the necessary inputs, analysis type and result viewing methods vary according to the required outputs. After determining the objectives of the analysis, the model is created in pre-processor. The next step, which is to apply loads, can be both performed in pre-processor or the solution processor. However, if multiple loading conditions are necessary for the required outputs and if it is also necessary to review the results of these different loading conditions together, solution processor must be selected for applying loads. The last step is to review the results of the analysis using post-processor, with numerical queries, graphs or contour plots according to the required outputs.[1-3]

A. Specimen Geometries:

The employed cylindrical bar with double circumferential U-notches is shown in Fig. 2. The gross diameter Do of 50mm. The specimen length is expressed as (2Lo+2lo), where 2Lo is the un-notched length from the notch center to the loaded end, and 2lo is the notch pitch or the distance between the centers of the two notches. γ is notch inclination angle. If γ is zero means notch is perpendicular to axis of bar as shown in Fig. 2.

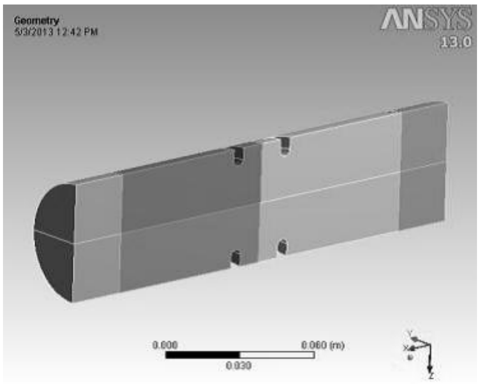

Fig. 2 – Half Specimen Geometry

B. FE modeling:

In order to take the advantage of geometrical symmetry, modeling the only half geometry is used for analysis. The material of the specimen is considered as Structural Steel (selected from Fatigue Data at zero mean stress comes from 1998 ASME BPV Code, Section 8, Div 2, Table 5-110.1.) With Yield tensile strength and Yield compression strength are Syt=Syc=2.5E+08Pa, Ultimate tensile strength is, Sut =4.6 E+08Pa, Density of Structural Steel =7850kg/m^3.

C. Results:-

After post processing, results obtain as follows

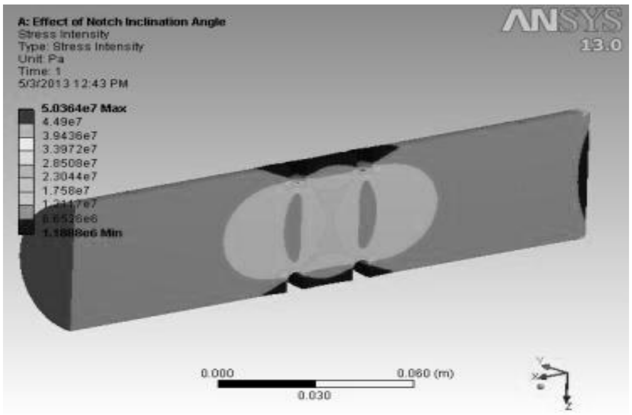

Fig. 3 – Stress intensity

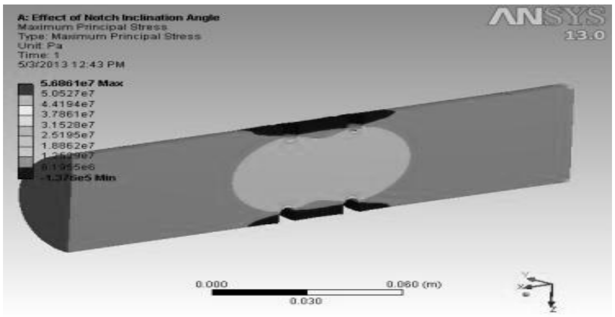

Fig. 4 – Maximum Principal Stress

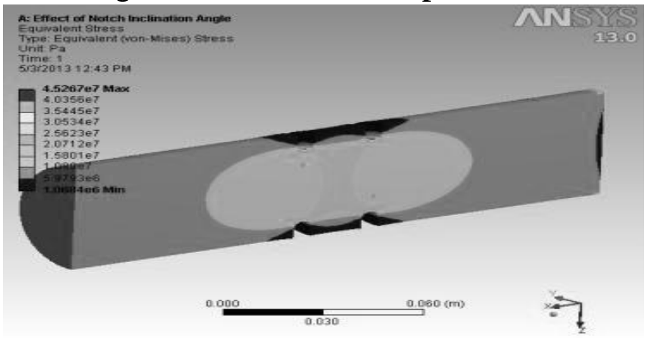

Fig. 5 –Equivalent stress

V. ANALYTICAL VALIDATION

As analytical investigation is given in section III, for considered specimen, $\left(\frac{h}{r}\right) = 4$, for the same calculated coefficient values are as C1=4.974, C2= -10.71, C3=8.808, C4= -3.154, by using this calculated values stress concentration factor is calculated as $K_t = 2.8697$,

$$\sigma_{nom} = 17.634 \times 10^6$$

$$\sigma_{max} = K_t \times \sigma_{nom} = 2.8697 \times 17.634 \times 10^6 = 5.060 \times 10^7 Pa$$

As (σmax)analytical and (σmax)FEA are approximately same for concentrated stress intensity, concentrated maximum principal stress and concentrated equivalent stress with deviation 0.09%, 0.11% and 0.12% respectively. Hence we can say that FEA output for stress concentration is validated by analytical method.

VI. EXPERIMENTAL VALIDATION

To validate the above result experimentally, specimen with significant parameters are manufactured. Specimens are tested by Universal Testing machine at SNJB's Polytechnic, Chandwad. The results of testing are plotted in following graphs in fig. 6 to fig. 9.

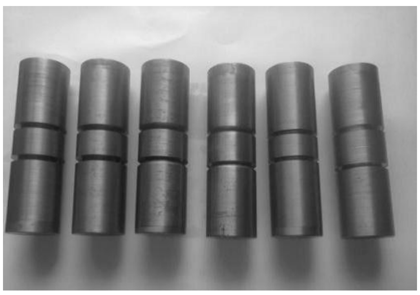

Fig. -6 Specimens with significant parameters

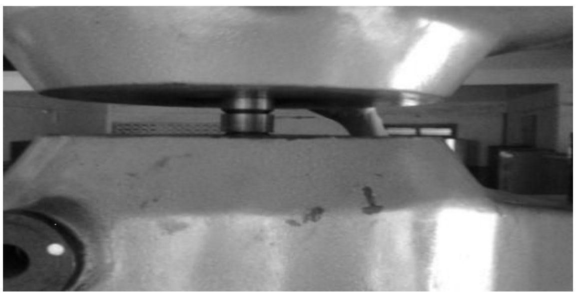

Fig. 7 Specimen location in UTM

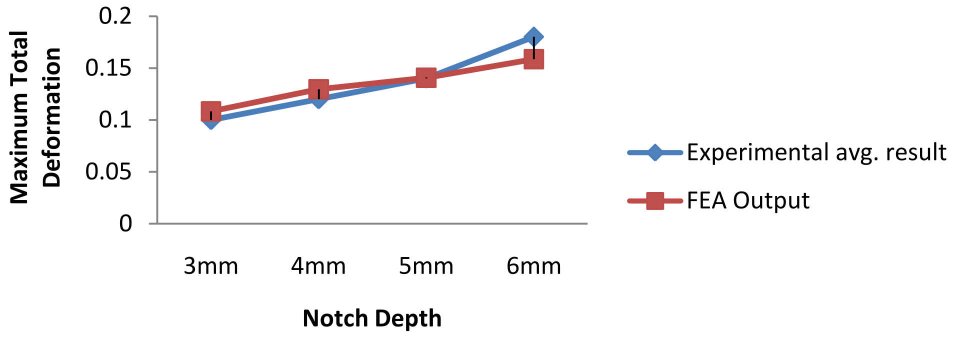

Fig. 8 Max. Total deformation vs U Notch Depth

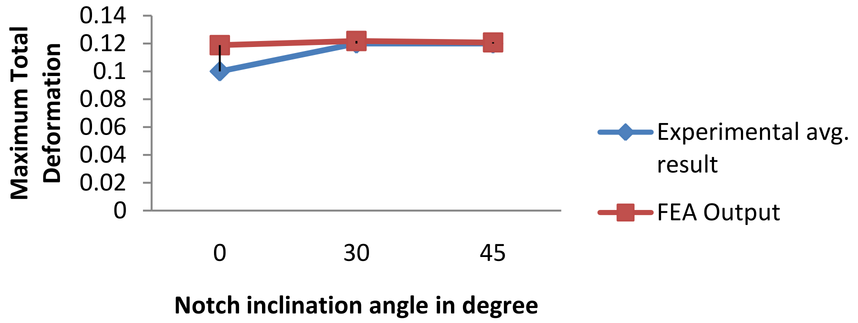

Fig. 9 Max. Total deformation vs U Notch Inclination angle

The above graph in fig. 8 to fig. 9 signifies that Experimental Average results maximum deformations are approximately same as FEA results which mean that FEA results are validated by experimental testing.

CONCLUSION

In axial loading of double circumferential notched bar stress and strain interference effect is occurred at notch length and stress concentration at notch root. FEA results are validated by standard analytical analysis by using equivalency concept, analytical analysis results of maximum stress concentrated are approximately same. Also experimental results predict the approximately same result for maximum total displacement. Hence FEA results are validated by analytically and experimentally.

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