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Analysis of Fatigue Crack Propagation Life in a Single Edged Notched Beam Using FEA

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Abstract:
In present fast pace product development scenario, validated FEA simulations are considered to be one of the reliable source of preliminary fatigue life estimation. FEA simulations may not prove to be a complete replacement to the fatigue testing but they can provide a detailed insight into the fatigue damage phenomenon. Present study demonstrates the finite element methodology adopted for accurate prediction of fatigue life of a mild steel plate with notch at the centre. In the present investigation an attempt has been made to develop a fatigue life prediction methodology by using an FEA in single edge notched (SEN) beams. Also the relationship between load and fatigue life, and stress ratio to fatigue life was determined for actual behaviour of SEN beams under cyclic loading.

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I. INTRODUCTION

Fatigue in metals can be defined as failure of a member due to the application of cyclic or fluctuating loads which are far less than that of static ultimate strength of the member.Such failure under fatigue loading can be classified into five steps based on crack propagation as mentioned below.

- Crack nucleation formed by sub structural and micro structural changes.
- The formation of microscopic cracks
- Creation of dominant crack from the movement of dislocations and slip bands which causes catastrophic failure.
- Stable propagation of dominant crack so produced.
- Structural instability and complete failure of member.

According to Bauschinger's effect if a material is subjected to plastic deformation in tension or compression and afterwards if the direction of load is changed then the material will yield at lower loads than the load required for forward plastic deformation. So during the application of cyclic loading the load requirement will gradually decreases and may reach even less than that of operating cyclic loading because of which the material will fail. Many aluminium alloys containing non-sharable strengthening properties arestretched prior to temper treatments to relieve thermal residual stresses. Since many of these materials exhibits Bauschinger effects they will exhibit low flow stresses if stretching direction is reversed.

II. LITERATURE SURVEY

Vipin Wagare et al. demonstrates the FEM to be used for carrying out fatigue analysis. Fatigue analysis has been carried out for a standard specimen of a medium strength steel plate with hole at the centre subjected to cyclic loading. Cyclic stress strain behavior, surface roughness and mean stress effects have been accounted in the while estimating the fatigue life and predicting the fatigue damage. For realistic representation of variable amplitude loading; loads have been represented using tabulated cyclic load input. Predictions obtained from the fatigue analysis carried out using FEM for constant amplitude and variable amplitude loading show close agreement with the experimental results. Difference observed from experimental results is within 3%. Thus the methodology has been verified. Damage contours obtained give information regarding the crack initiation location and its orientation which can be further used for carrying out crack growth analysis or progressive damage and failure prediction. Methodology is generic in nature and can be extended to fatigue life estimations of structural elements with complex geometry multi axial loading.

III. METHODOLOGY

Methodology consist of finite element simulation of SEN beam. First of all material was selected for specimen which is mild steel in Ansys 15 Workbench. In next step model of specimen was created. After creating model meshing is done. Then boundary conditions specified in which one end is fixed and on other end tensile load is acting. After doing all above steps model tested foe fatigue analysis. Fatigue analysis of SEN beams were carried out using ANSYS workbench. The results were interpreted in terms of life cycles. The SEN beams made up of MS are tested for different loads i.e. 18.5KN,18.8KN,19.1KN,19.4KN and each load tested for different stress ratio i.e. 0,0.3,0.6.Results are obtained and collected for comparative study. All the Finite Element procedure is done on the ANSYS 15.0 Software.

Table I

Material Properties

MATERIAL	MILD STEEL
Poisson's Ratio	0.3
Young's modulus (N/mm^2)	2×10^{11}
Density (kg/mm^3)	7850

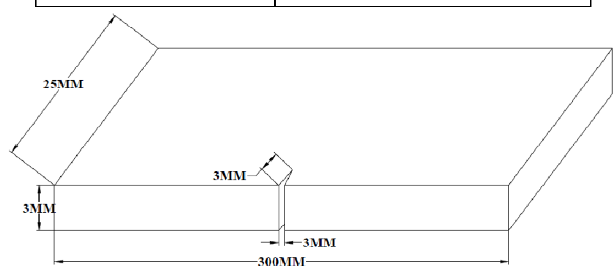

Fig. 1 SEN Beam Dimensions

IV. STEPS FOR FEA ANALYSIS OF SEN BEAM

A. Material Selection

Mild steel is selected for SEN beam.

B. Model Creation

As per geometry of specimen model is constructed in ANSYS Workbench.

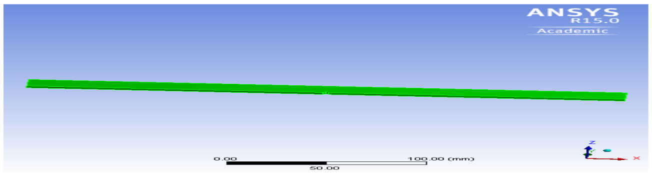

Fig. 2 SEN Beam Model

C. *Meshing*

In finite element analysis the basic concept is to analyse structure, which is an assemblage of discrete pieces called elements that is connected together at a finite number of points called nodes. Loading boundary conditions are then applied to these element and nodes. The network of elements is called mesh.

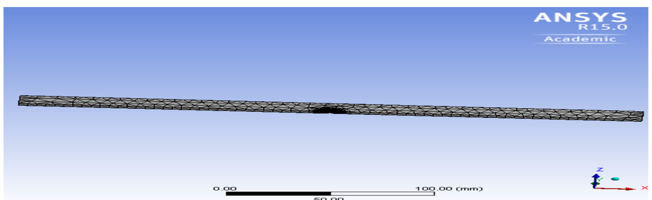

Fig. 3 Meshing of SEN beam

D. *Boundary Conditions and Loading*

After completion of finite elements model it has to constrain and load has to apply to the model.

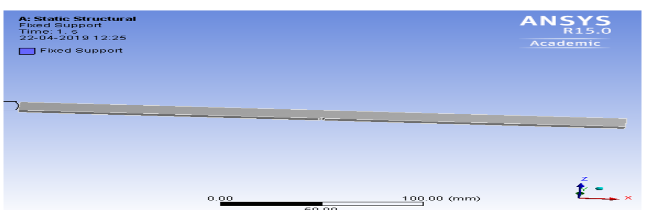

Fig. 4 SEN Beam Fixed at one end

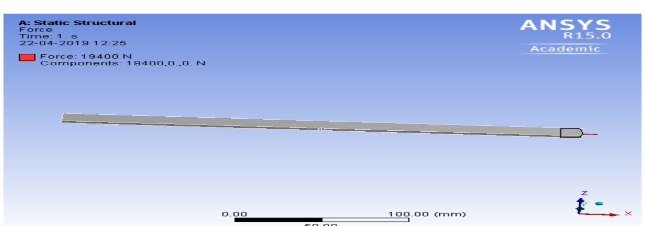

Fig. 5 Applying Load at one end

E. *Solution*

The solution phase deals with the solution of the problem according to the problem definitions. Strain Life theories are selected for solution. Morrow's theory is selected for solution.

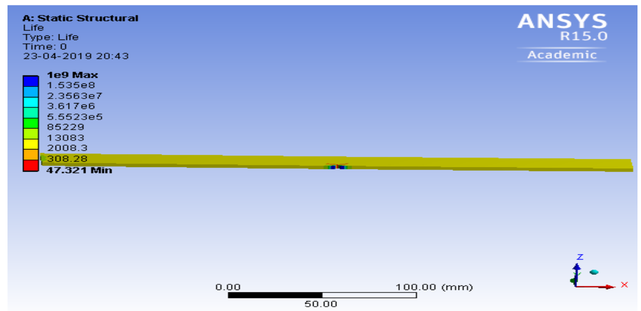

Fig. 6 MS SEN BEAM under the tensile load of 75 KN for stress ratio 0.1

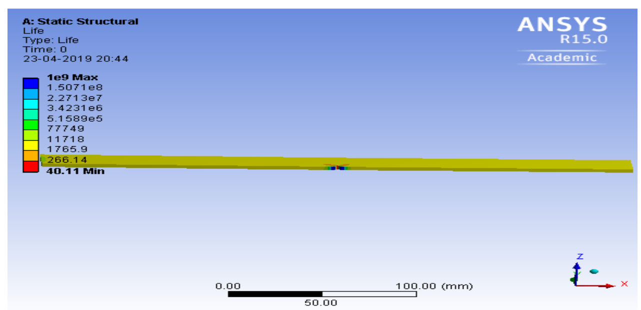

Fig. 7 MS SEN BEAM under the tensile load of 75 KN for stress ratio 0.15

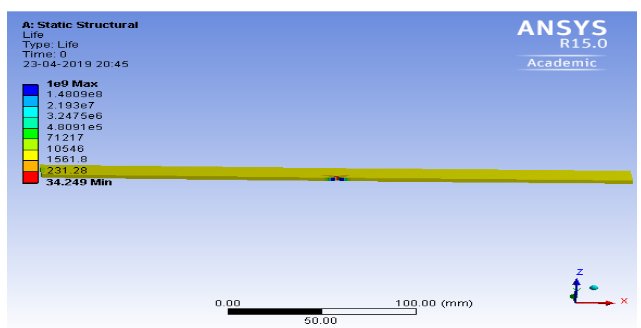

Fig. 8 MS SEN BEAM under the tensile load of 75 KN for stress ratio 0.2

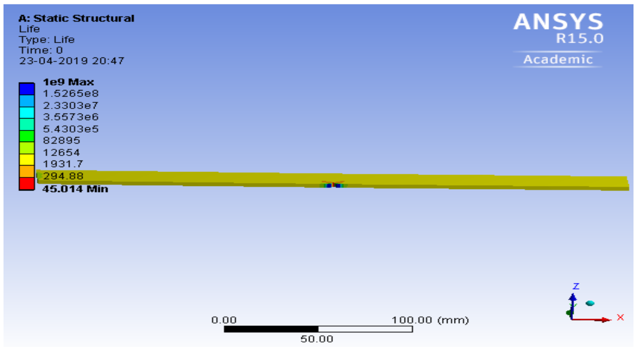

Fig. 9 MS SEN BEAM under the tensile load of 76 KN for stress ratio 0.1

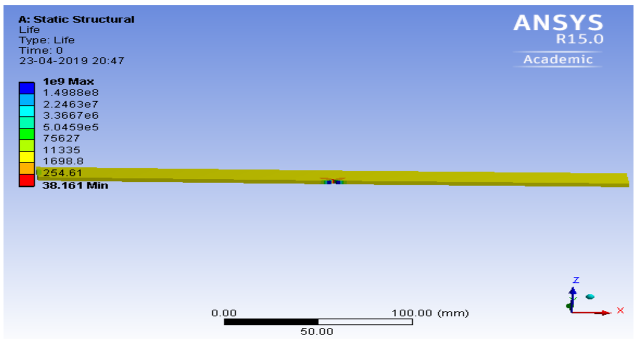

Fig. 10 MS SEN BEAM under the tensile load of 76 KN for stress ratio 0.15

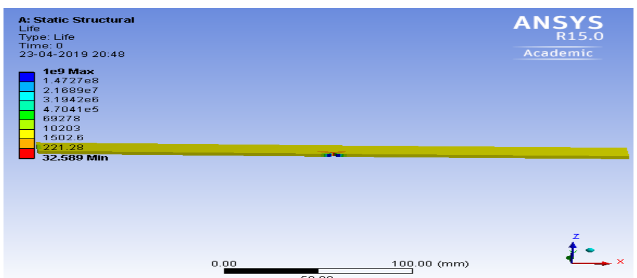

Fig. 11 MS SEN BEAM under the tensile load of 76 KN for stress ratio 0.2

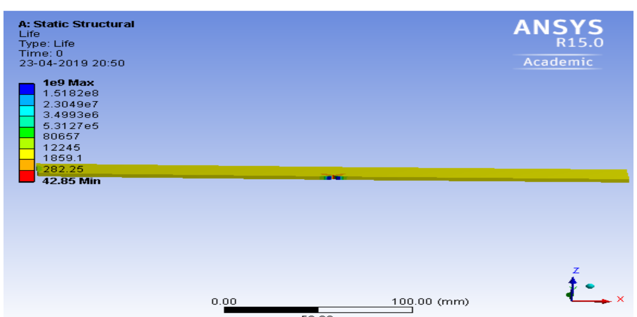

Fig. 12 MS SEN BEAM under the tensile load of 77 KN for stress ratio 0.1

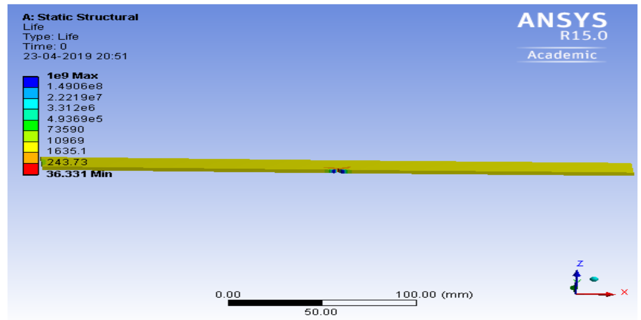

Fig. 13 MS SEN BEAM under the tensile load of 77 KN for stress ratio 0.15

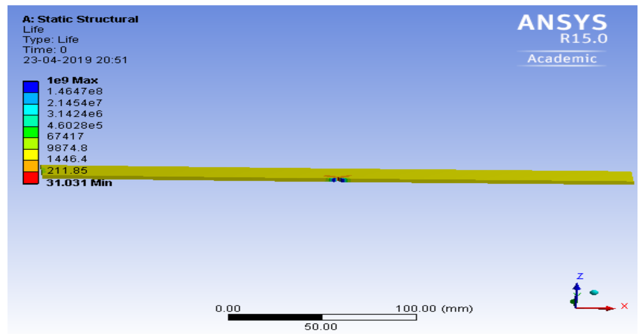

Fig. 14 MS SEN BEAM under the tensile load of 77 KN for stress ratio 0.2

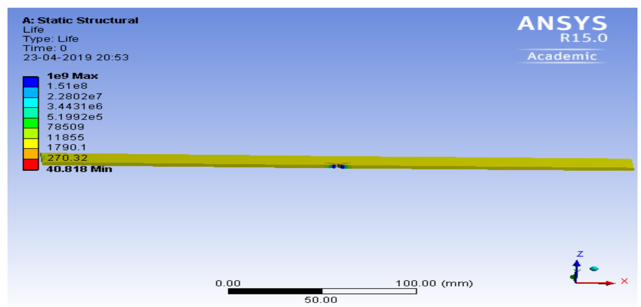

Fig. 15 MS SEN BEAM under the tensile load of 78 KN for stress ratio 0.1

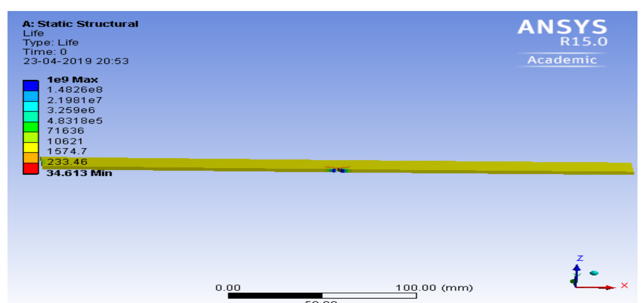

Fig. 16 MS SEN BEAM under the tensile load of 78 KN for stress ratio 0.15

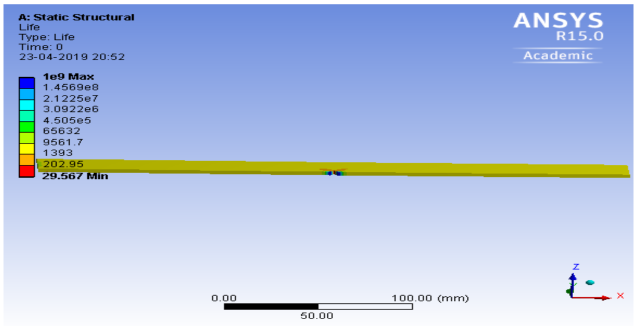

Fig. 17 MS SEN BEAM under the tensile load of 78 KN for stress ratio 0.2

V. RESULTS

Table. II
Analytical Solution

Sr.	P_{max} (N)	P_{min} (N)	R	N Cycles
1	75000	-7500	0.1	47
2	75000	-11250	0.15	40
3	75000	-15000	0.2	34
4	76000	-7600	0.1	45
5	76000	-11400	0.15	38
6	76000	-15200	0.2	32
7	77000	-7700	0.1	43
8	77000	-11550	0.15	36
9	77000	-15400	0.2	31
10	78000	-7800	0.1	41
11	78000	-11700	0.15	35
12	78000	-15600	0.2	30

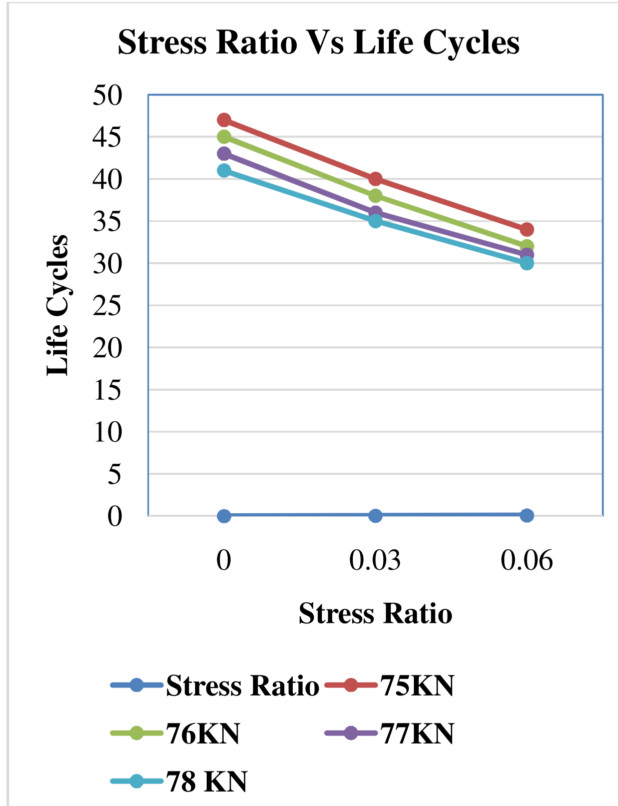

Fig. 18 Comparison of different loads for its different stress ratios and life

From the above study I conclude that fatigue life cycle of SEN beam form linear relationship with cyclic stress and stress ratios.

VI. CONCLUSIONS

Stress ratio vs. Life cycles graph is found to be straight line, which shows linear relationship between fatigue life and stress ratio of SEN beam. FEA has been used over experimental analysis for other specimen with different loads and stress ratios to determine the fatigue life in SEN beams.

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