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

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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 is a failure of a member due to the repeated loadings or fluctuating loadings which are far less than that of static strength of the member. Failure of member under fatigue loading take place in five steps 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

J.B.Esnaulta, V.Doquet.a, P.Massin (2013)had studied the fatigue crack paths of thin metallic sheets usingthe three dimensional analysis, they reported that Tests for similar mechanical conditionsin air or in salt water produced different crack paths, shear lips being reduced due to the corrosive environment, in the aluminum alloy as well as in the steel.

## III. METHODOLOGY

Methodology divided into two parts

- Finite Element Analysis
- Experimental Testing

The first part of the Methodology is 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 load of 19KN, 19.5KN and each load tested for different stress ratio i.e. 0, 0.3, 0.6.Results are obtained and collected for comparative study.

Experimental testing is done on the dynamic testing machine. Specimen is tested for simple tensile test with repeated loading of different loads and its different stress ratio. The specimen's one side is fixed and tensile load is applied on other end. All the tests were conducted at room temperature. The SEN beams made up of MS are tested for different loads and different stress ratio against fatigue failure.The results are obtained. Finally the experimental and analytical results are compared.

Table I

Material Properties

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

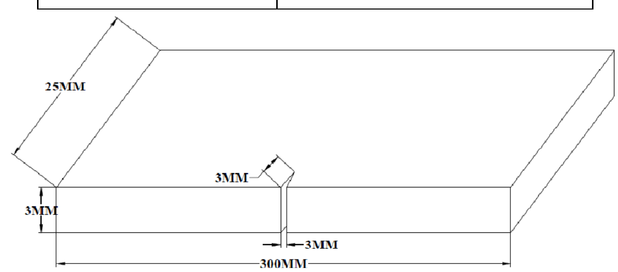


Fig. 1 SEN Beam Dimensions

## IV. STEPS FOR FEA AND EXPERIMENTAL ANALYSIS OF SEN BEAM

- **FEA STEPS**

### *A. Material Selection*

Mild steel is selected for SEN beam.

### *B. Model Creation*

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

  

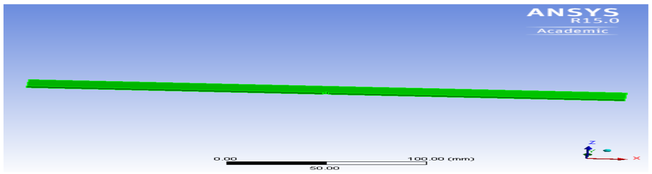


Fig. 2 SEN Beam Model

*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.

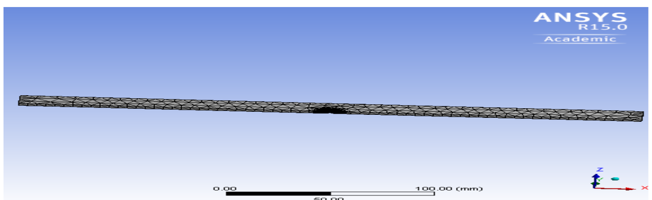


Fig. 3 Meshing of SEN beam

*D. Boundary Conditions and Loading*

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

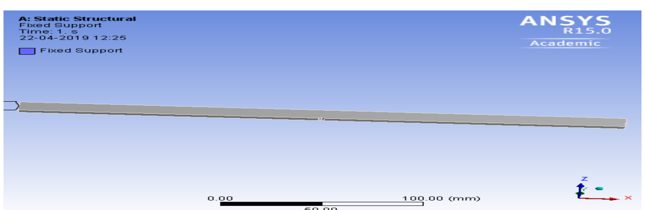


Fig. 4 SEN Beam Fixed at one end

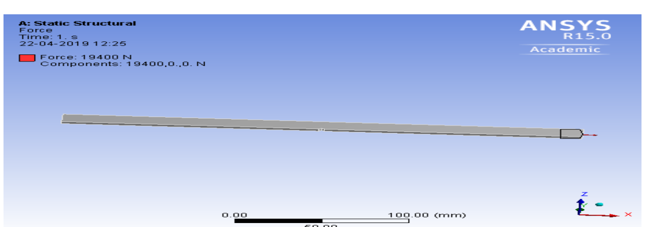


Fig. 5 Applying Load at one end

*E. Solution*

The solution phase deals with the solution of the problem according to the problem definitions. Stress Life theories are selected for solution. Gerber theory is selected for solution.

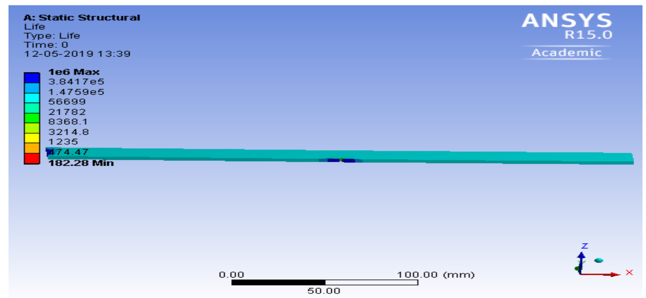


Fig. 6 MS SEN BEAM under the tensile load of 19 KN for stress ratio 0.0

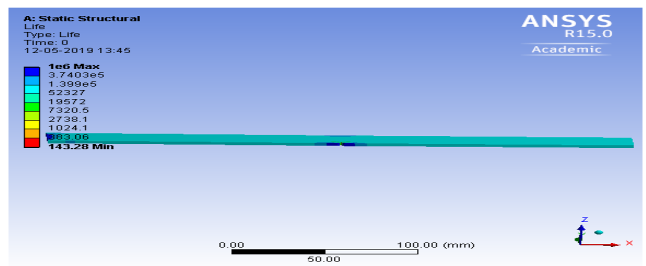


Fig. 7 MS SEN BEAM under the tensile load of 19 KN for stress ratio 0.03

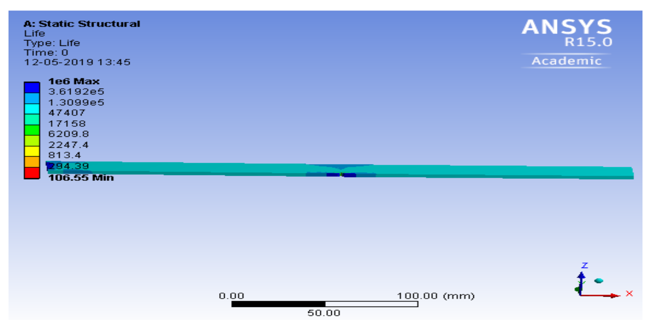


Fig. 8 MS SEN BEAM under the tensile load of 19 KN for stress ratio 0.06

  

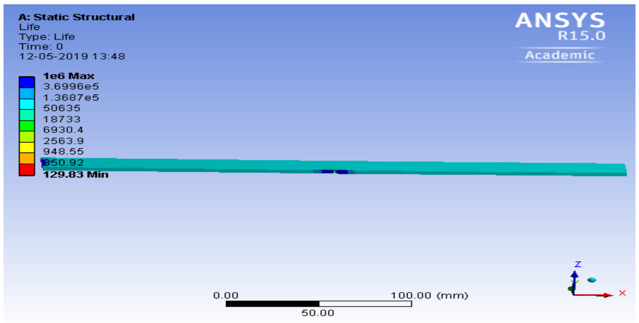


Fig. 9 MS SEN BEAM under the tensile load of 19.5 KN for stress ratio 0.0

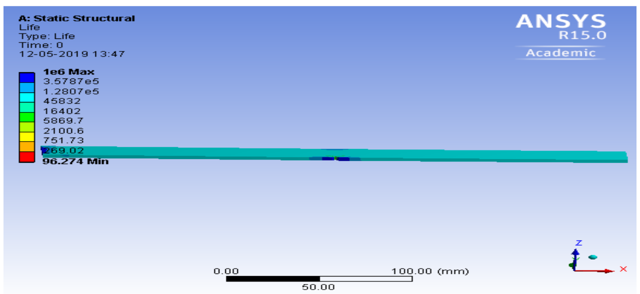


Fig. 10 MS SEN BEAM under the tensile load of 19.5 KN for stress ratio 0.03

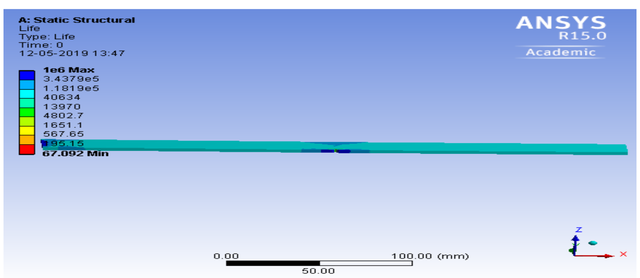


Fig. 11 MS SEN BEAM under the tensile load of 19.5 KN for stress ratio 0.06

- **Experimental Test**

Test consists of a servo hydraulic dynamic loading system, support for the specimen and various instruments for measurement of data. A servo hydraulic controlled actuator of ±100 KN capacity and ±20 mm displacement has been used for loading. The support system consists of two jaws which gripped specimen at both ends, which provides tensile fatigue. The test specimen was gripped between flat jaws. This type of loading ensures that the mid-section of the specimen, where the notch is located is subjected to pure tensile.

## V. RESULTS

Table. II
Analytical Solution

| **Sr.** | **$P_{max}$** (N) | **$P_{min}$** (N) | **R** | **$N_A$** Cycles | **$N_E$** Cycles |
|---|---|---|---|---|---|
| 1 | 19000 | 0 | 0 | 182 | 177 |
| 2 | 19000 | 570 | 0.03 | 143 | 145 |
| 3 | 19000 | 1140 | 0.06 | 107 | 104 |
| 4 | 19500 | 0 | 0. | 130 | 125 |
| 5 | 19500 | 585 | 0.03 | 90 | 87 |
| 6 | 19500 | 1170 | 0.06 | 67 | 68 |

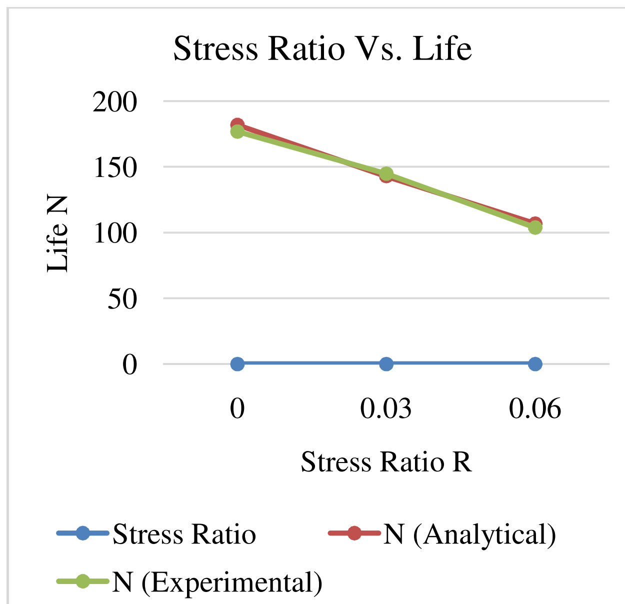


Fig. 18: Comparison of graph of ANSYS and experimental result for fatigue life for 19KN

  

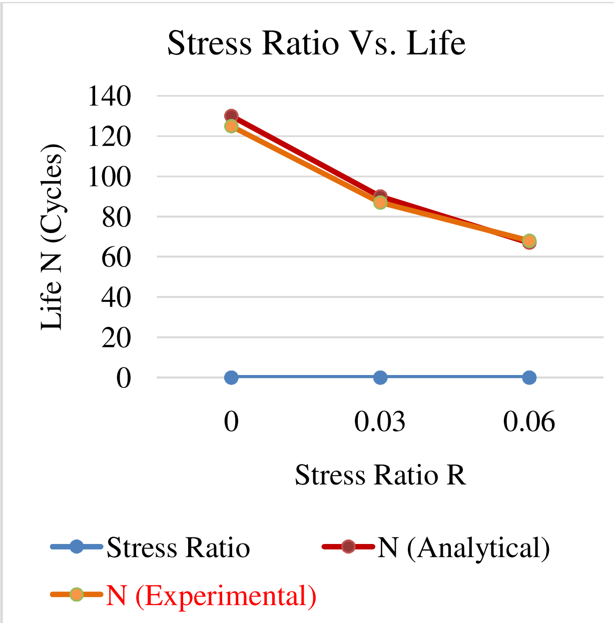


Fig. 19: Comparison of graph of ANSYS and experimental result for fatigue life for 19.5KN

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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