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Fatigue Analysis of Medium Carbon Steel Plate with Different Locations of the Circular Hole.

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ABSTRACT:

The fatigue analysis of the Medium carbon steel plate with different hole locations was carried out using the ANSYS. The life, damage, and safety factor of the design was studied with various loading condition for the two cases. Case 1 with a central hole and case 2 is three holes at equidistance in the plate. The geometry of the plate, meshing, and analysis was carried out with ANSYS software. Boundary conditions and suitable material properties are mentioned to determine the suitable load under which the design is sustainable for long life.

Keywords: Fatigue Analysis, ANSYS, Medium Carbon steel, safety factor.

INTRODUCTION:

Fatigue means weakness in the metals due to repeated variation of stresses. The stress concentration in the plate with a hole at the center is also depending upon the materials. The main advantages of composite materials are high strength, stiffness, and low density.

The main objectives are to estimate of fatigue life of the structural components on the plate with the hole.

Many of the researchers study and investigated the stress analysis of plates with different cutouts in them for better safety purposes in automotive and aerospace. The structural members are usually subjected to in-plane tensile loading. The literature review shows many investigations of stress concentration factor (SCF), aspect ratio, and how hole diameter influences the stress distributions.

Boundary conditions in the finite element method are very crucial. Because entire results depend on the type of boundary conditions applied to the geometry for analysis.

Boundary conditions used for the structural and solid mechanics are **Dirichlet boundary conditions.**

Material selection is an essential part of research or product design and development. Material selection should meet the basic criteria they are efficient manufacturability, performance, reliability non-degradability, and recyclability. Steel is the most preferable material for the automobile due to its properties. Steel is enhanced safety, good recyclability, and high-strength steel gives better fuel efficiency.

The finite element method is a popular method used to solve the differential equation of the engineering problems, such as structural problems, heat transfer problems, fluid flow, mass transport, and electromagnetic potential. FEM is a general numerical method used for solving partial differential equations of 2D or 3D problems.

Weakness in the structural part of the component due to bending stress, repeatedly stress is called fatigue. Weakened conditions may be induced in any of the metals, which are in the machines, vehicles, or structures due to repeated loading. Fatigue in the material is also due to the thermal stresses, which are common in automotive parts. Automotive parts like crankshafts, connecting rods, and many plates with holes or brackets.

The majority of engineering failures are caused by fatigue. Fatigue failure is defined as the tendency of a material to fracture by means of progressive brittle cracking under repeated alternating or cyclic stresses of an intensity considerably below the normal strength.

Fig 1. Fatigue zone and failure of the stainless steel material.

Estimating the Fatigue Life

This is the second phase in the fatigue analysis. Strain based approach has been used for fatigue life estimation. Morrow's criterion, which deals with the mean stress effect, has been applied for accurate fatigue life estimation. Strain range results obtained from the first phase using the Romberg-Osgood equation have been used to estimate cycles to crack initiation.

METHODOLOGY:

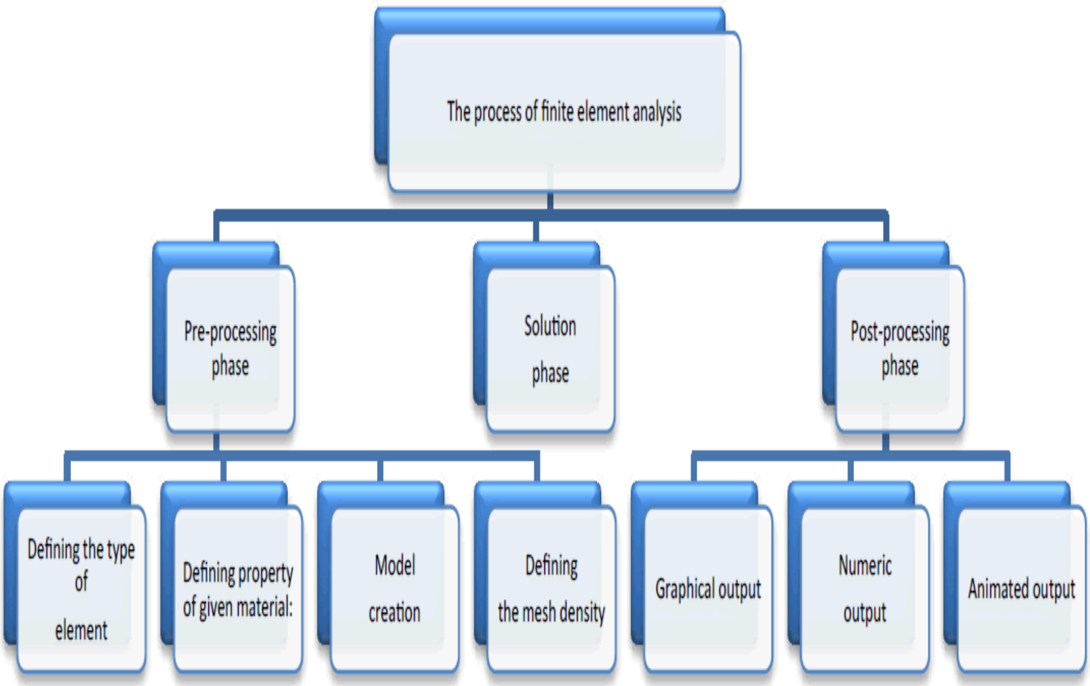


Fig 2. The flow chart of ANSYS Methodology.

The methodology to follow to determine the fatigue life of the component and stress analysis of the component for both cases as shown in the above chart, i.e fig 2. Literature survey, problem identification from the literature survey, material selection, geometry modeling and meshing with suitable software, applying the suitable boundary conditions, solving the analysis using ANSYS workbench and APDL 2022, and plotting the results and discussion about the results.

The material selected for the stress and fatigue analysis the both components is medium carbon steel. The percentage of the carbon in it is 0.3% to 0.6% and manganese from 0.6% to 1.66%.

Properties of the Medium Carbon Steel.

Table 1. Material properties of medium carbon steel

Property	**Value**	**Units**
Elastic Modulus	210000	N/mm^2
Poisson's Ratio	0.28	N/A
Shear Modulus	790000	N/mm^2
Mass Density	7700	kg/m^3
Tensile Strength	723.8256	N/mm^2

Modeling and Meshing of the Geometry

The geometry of the component is done using the ANSYS workbench itself. The references for the dimensions of the geometry are taken from the research publications. The dimensions of both components are as follows.

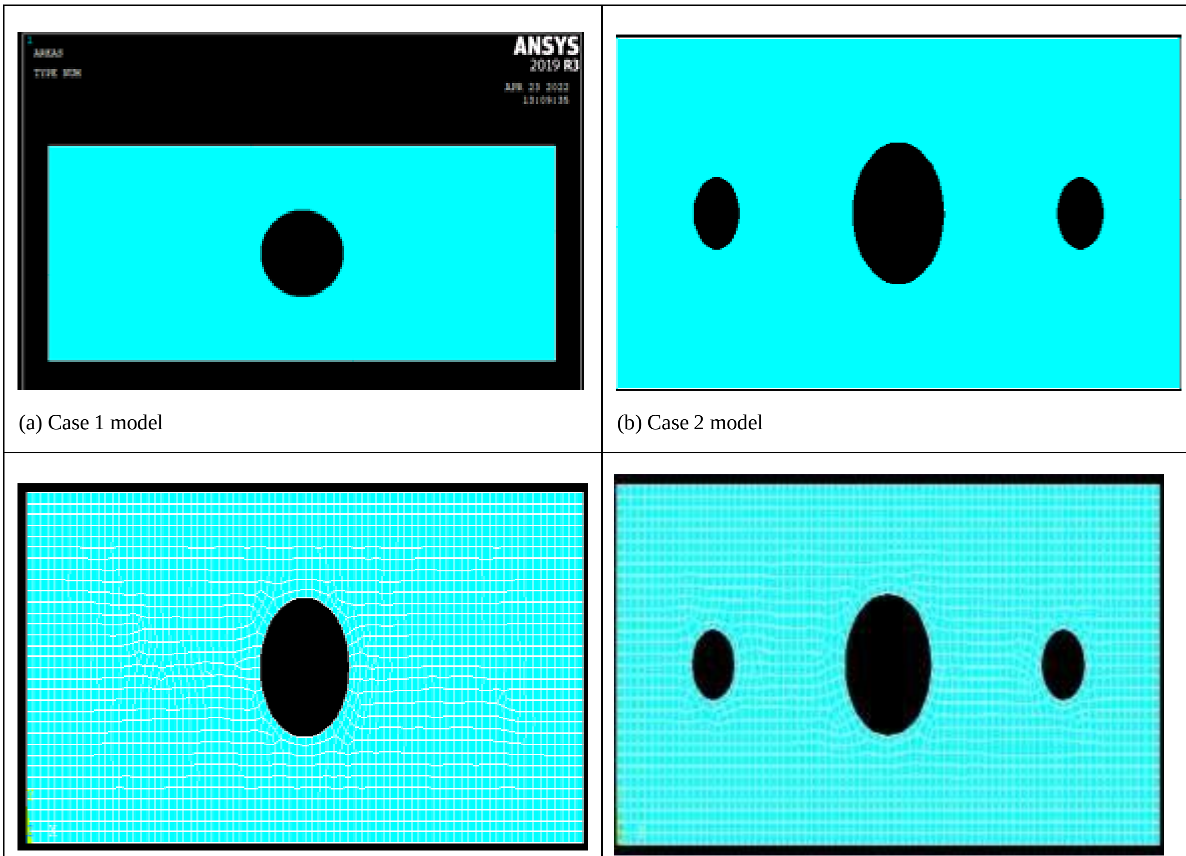
Case 1: 310 mm x 125 mm x 5 mm (thick) with hole at center of diameter d = 50 mm

Case 2:310 mm x 125 mm x 5 mm (thick) with one hole at center of diameter d_1 = 50 mm and two holes on either sides with diameter d_2 = 25 mm.

The meshing of both components cas1 and case 2 is done in the ANSYS workbench only. Quadrilateral elements are used for meshing with an element size of 4 mm. the quality of the mesh is within the limit.

RESULTS AND DISCUSSIONS:

Fig 3. The geometry and meshed model of case 1 and case 2 components.



(a) Case 1 model

(b) Case 2 model

(c) Meshing of the case 1

(d) Meshing of the case 2

The meshing of both components did in the ANSYS workbench with quadrilateral mesh. The element size of the meshing is 4 mm and the measured quality of the mesh. The geometry and meshed part are shown in fig 3.

The number of elements and nodes for case 1 are 4706 and 26907 respectively and for case 2 are 4606 and 26499 respectively.

Fatigue Life Analysis for Case 1:

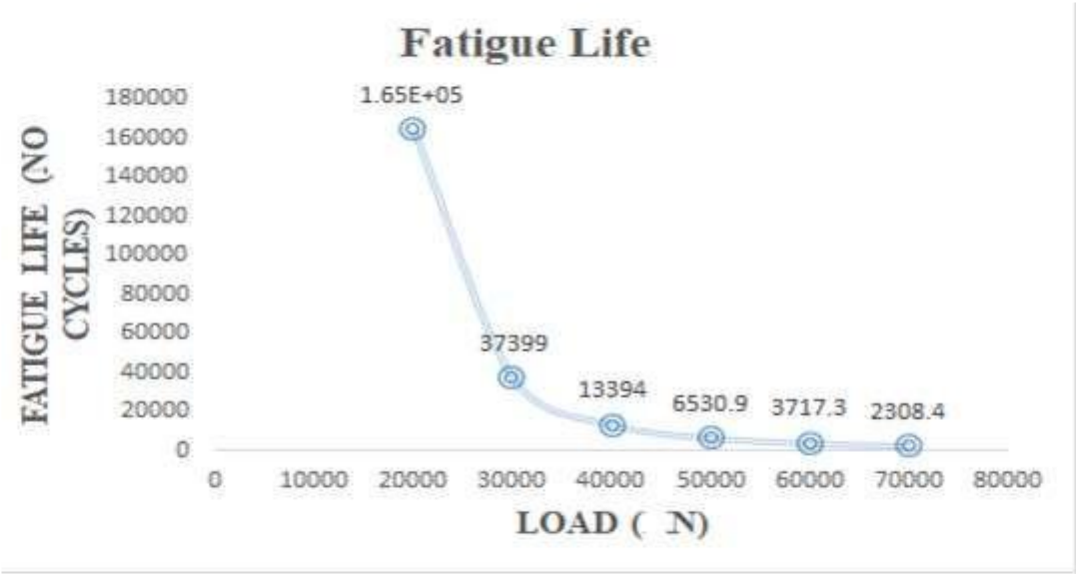


Fig 4. Fatigue life analysis of case 1.

The graphical representation of these things explains in the fig 4. The number of cycles to failure of the component is more at 20 kN and very less at 70 kN. Hence, the design is safer at the load of 20 kN and 30 kN. Design is not safer other than these loads.

Fatigue Damage analysis of the case 1.

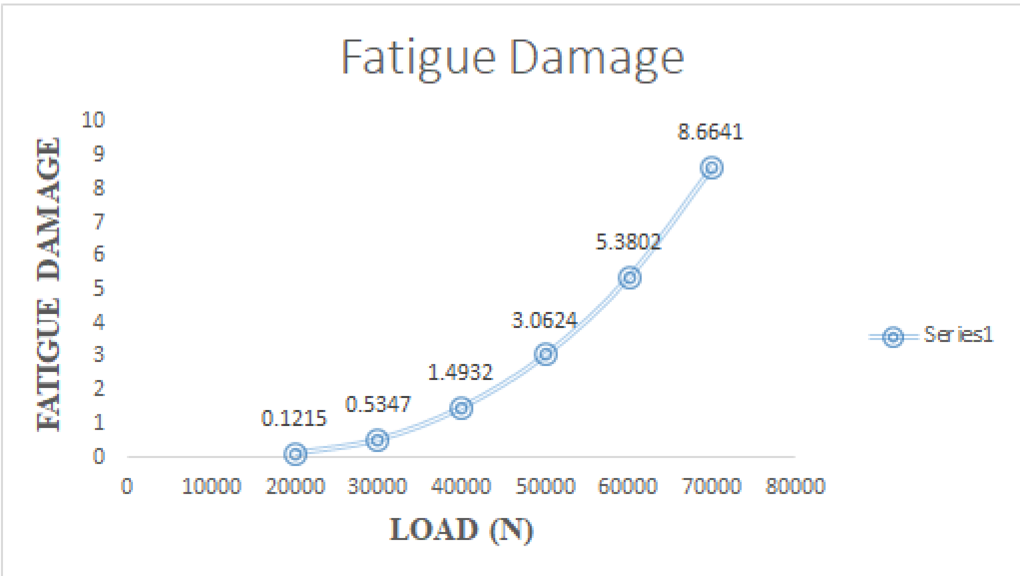


Fig 5. Fatigue damage analysis with varying load for case 1.

Fatigue damage values of component 1 at the load 20 kN and 30 kN are 0.1215 and 0.5347. Hence, the design is safer under these loading conditions. The damage values are increases with an increase in the load on the components.Damage values are more at the location of the hole where the deformation and stress are maximum. The damage values are minimum at the location other than the hole.

Fatigue Safety Factor of Case 1.

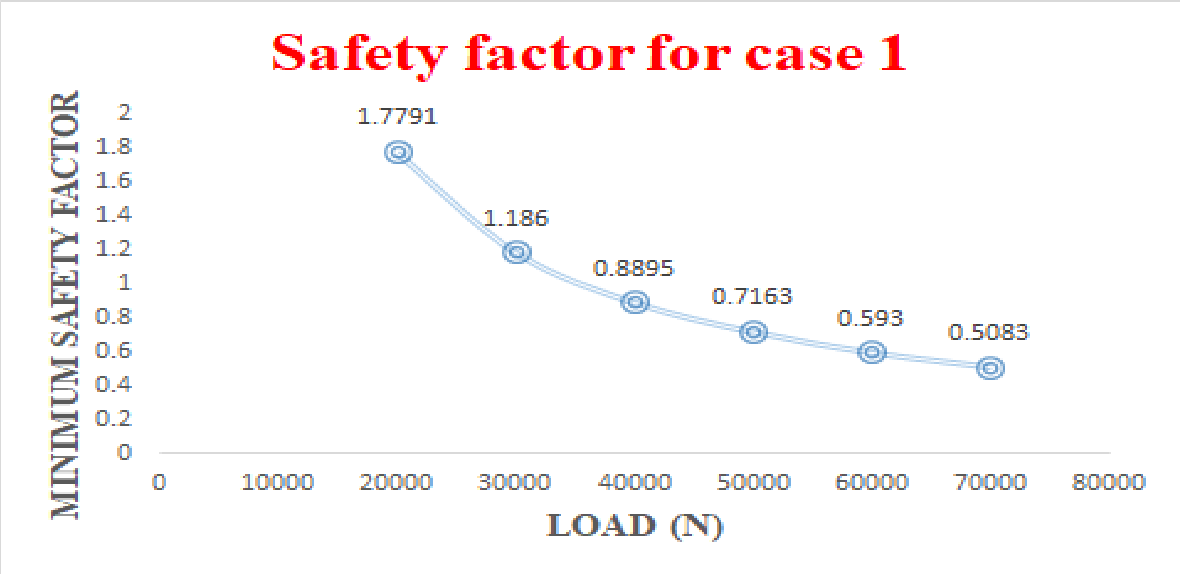


Fig 6. Safety factors with different loading conditions for case 1.

Safety factor is more at the load 20 kN and 30 kN (greater than one). The design of the component of case one is safer at the loading conditions 20 kN and 30 kN. With the increases in the loading the safety factor are decreases, hence, the safer load for the case 1 is 20kN, the maximum safety factor available is 15. The safety factor is very less at the location of the hole.

Life of the Component for Case 2

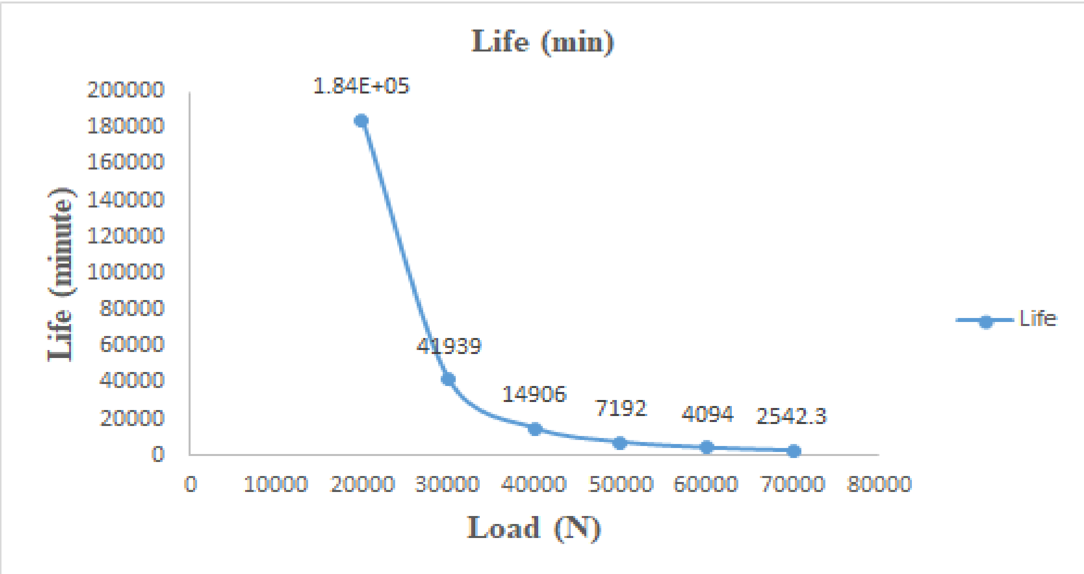


Fig 7. Life of the component of case 2 with various load.

The fig 7Explain the life behavior of the component 2 under the various load

The life of component 1 decreases with an increase in the load from 20 kN to 70 kN. The maximum life for the component occurred at 20 kN, which is the value of 1.843e5 minute and the minimum life occurred at the 70 kN shown in fig 25. Hence, as per the fatigue analysis life of the component for the case is maximum at 20 kN.

Fatigue Damage Analysis of the Component for Case 2.

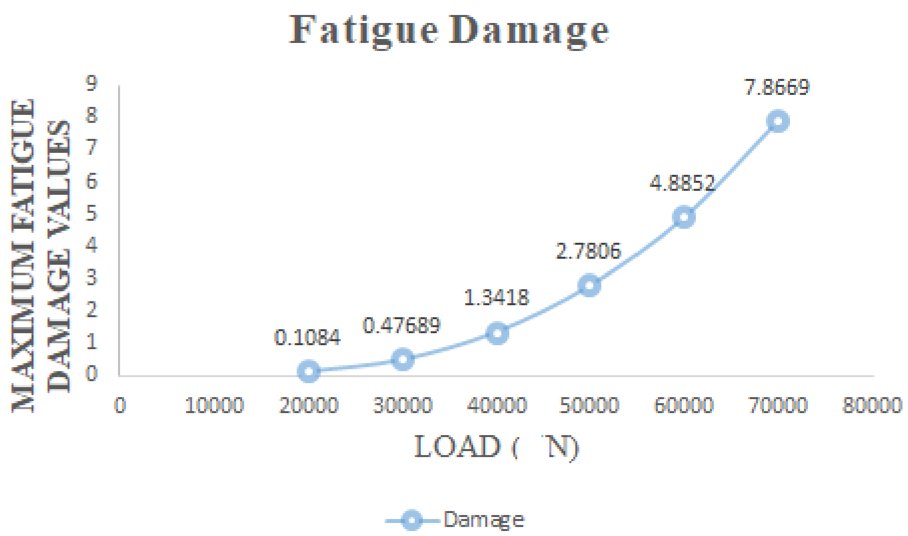


Fig 8. The fatigue damage values of case 2.

Fatigue damage is defined as the design life divided by the available life. This result may be scoped. For Fatigue Damage, values greater than 1 indicate failure before the design life is reached. The lesser values of the damage at the load condition of the 20 kN and 30 kN are 0.1084 and 0.47689 respectively. Hence, at 20 kN and 30 kN design is safe and if the load increases damage values also increase and the design is not safe at higher load conditions. The maximum damage valuethat occurred at the 70 kN load is 7.86. the failure of the component is more with fewer cycles.

Fatigue Safety Factor of Case 2.

The maximum Factor of Safety displayed is 15. Like damage and life, this result may be scoped. For Fatigue Safety Factor, values less than one indicate failure before the design life is reached. The values of the safety factor are more than 1 in the case of 20 kN load and 30 kN load. Hence, the design is safer at 20 kN and 30 kN.

CONCLUSION:

The FEA analysis was conducted on a medium-strength steel plate with varying load conditions for case 1 and case 2 to determine the fatigue life, fatigue damage, and safety factor using the ANSYS workbench 2022.

1. The value of fatigue life of both case 1 and case 2 more at the 20 kN applied load and less at 70 kN applied load. Hence, design is safe at 20 kN.
2. Fatigue damage value is below one (1) for the 20 kN applied load, which determines the design is safe until 20 kN and if damage value above one (1) indicates failure of the component for the particular load.
3. The safety factor values for both case 1 and case 2 is above 1 at the applied load of 20 kN.
4. Considered all the parameters discussed above. The design is safe at the 20 kN for both cases 1 and 2.

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