Methods of Reducing Stress Concentration using Finite Element Technique

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***Abstract* : Metal failure can occur due to various reasons like fracture, fatigue and creep. Among these, fracture and fatigue play a vital role in the design of mechanical components. There are various factors affecting fatigue like stress concentration, Environmental conditions, Surface conditions and Residual Stresses. The clear concept of stress concentration helps the designers to identify the stress raisers and thereby taking the necessary steps to avoid fatigue in metal components. This presents the possible ways of reducing stress concentration in standard geometries using Finite Element Technique.**

Keywords : Fatigue, Finite Element Technique, Residual Stress

I. INTRODUCTION

The three important modes of failure are Fracture, Fatigue and Creep. The stages of fatigue failure are:

(1) Crack Initiation
(2) Crack growth
(3) Fracture (Failure)

Fracture and fatigue are essentially the two sides of the same coin. Since the fatigue failures invariably originate at the stress raisers the matter of minimizing the stress concentration is utmost importance. Hence the clear concept of stress concentration helps the designers to identify the stress raisers and thereby taking the necessary steps to minimize the stress concentration [1].

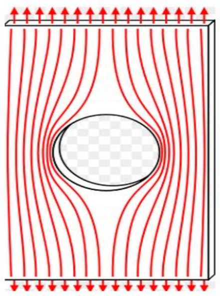
Stress concentration is a matter which should not be overlooked by designers. The high stress concentration found at the edge of a hole is of great practical importance. When the hull of a ship is bent tension or compression is produced at the decks and there is a high stress concentration at the holes. Under the cycles of stress produced by waves fatigue of the metal at the overstressed portion may finally result in fatigue cracks leading to fracture.

The Stress concentration is very important in plate with a hole, Bracket, Grooves andNotches [2]. Bracket which is critical component induces high cycle fatigue and shortens bracket life.

Stress concentration is measured by a factor called stress concentration factor. Stress concentration factor is defined as the ratio of maximum stress to the nominal stress.

Whenever a machine component changes the shape of its cross-section the simple stress distribution no longer holds good and the stress in the neighbourhood of the discontinuity is different. This irregularity in the stress distribution caused by abrupt changes of its form is called stress concentration. It occurs for all kinds of stresses in the presence of fillets, notches, surface roughness, keyways, holes etc [3].

Figure I. Stress concentration due to holes



From Figure.1, The stress at the point away from the hole is practically uniform and the maximum stress will be induced at the edge of the hole.

The presence of stress concentration cannot be totally eliminated but it may be reduced to some extent. In order to improve the situation fillets may be provided. The ways of reducing stress concentration in shafts and other cylindrical members are shoulders, holes and threads respectively [4].

Stress concentration is very serious in brittle materials since there is no yielding i.e. plastic deformation or negligible yielding where as it is not so serious in ductile materials because yielding will relieve the stress concentration.

In Fatigue loading, the load is repeated cyclically. Fatigue failure begins with a small crack. The cracks are more likely to develop in the region of holes, scratches, grooves etc.[5].

II. MEASUREMENT OF STRESS

(1) Photoelasticity: A plane polarized light is passed through a photoelastic material resulting in a colourful fringe pattern indicating the intensity of the stress. There are two types of polariscope (1) Plane Polariscope (2) Circular Polariscope

(2) Brittle Coating:Specially prepared lacquers are usually applied by spraying on the actual part. After air drying, the part is subjected to stress. A pattern of small cracks appears on the surface. Data could be used to locate strain gauges for precise measurement of the stress. The method is very sensitive to temperature and humidity.

(3) Electrical strain gauges: The method is most popular and widely accepted for strain measurements and stress analysis. The strain gauge consists of a grid of strain sensitive metal foil bonded to a plastic backing material. When the gauge is subjected to a mechanical deformation, its electrical resistance changes proportionally. The change in voltage is used to determine the strain and the stress is calculated from the strain.

(4) Finite Element Method:It is one of the various numerical discretization techniques and perhaps the most popular technique for solving complex problems in engineering. The method originated in aerospace industries as a tool to study stresses in complex airframe structures. Non-linear problems and complex problems like analysis of stresses in a tyre can be solved very easily with accurate results.

The material selected for the work isMild steel and the details of material properties is tabulated in TableI.

Table I. Material Properties of Mild Steel

SL.No	Material properties	Mild Steel
1	Young's Modulus	210 Gpa
2	Poisson's ratio	0.3
3	Density	7850 Kg/m^3
4	Yield stress	250 Mpa

III METHODS OF REDUCING STRESS CONCENTRATION AND VALIDATION USING SIMULATIONS

(1) Bracket

- Bracket without fillet

Figure II. Bracket without fillet dimension

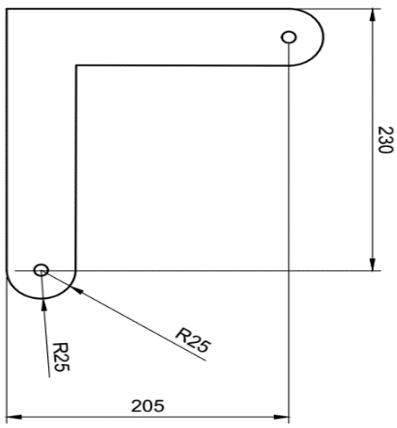


Figure III. Stress contour for bracket without fillet

Figure IV. Stress contour for bracket without fillet

From Figure. IV, the maximum stress is found to be 233080 N/m^2without considering the fillet.

- Bracket with fillet

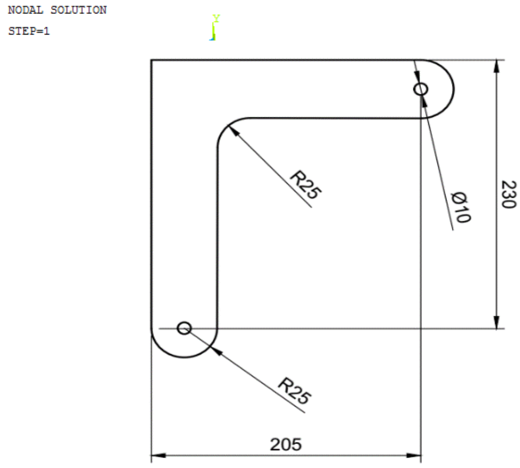
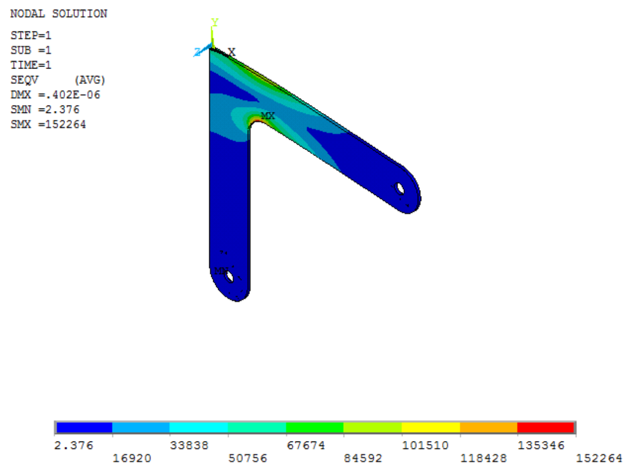


Figure IV. Bracket with fillet dimensions

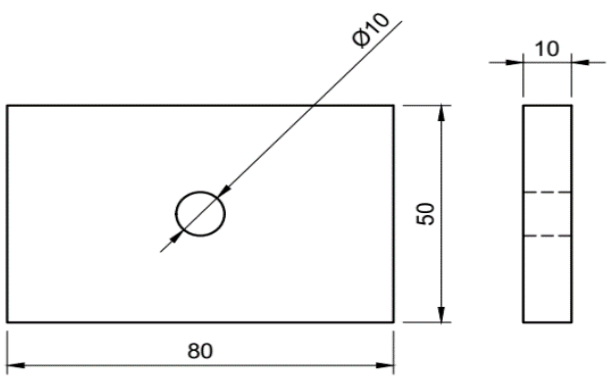
Figure V. Stress contour for bracket without fillet



From Figure V, the maximum stress is found to be152264 N/m^{2}after the addition of the fillet.

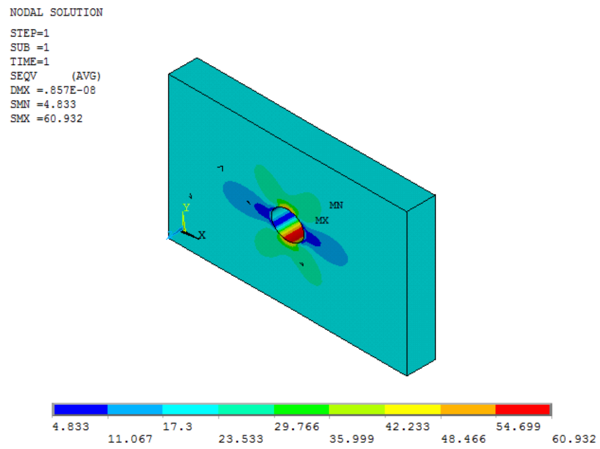
(2) Plate with hole

- Plate without additional holes



- Figure VI. Plate without additional holes dimension

Figure VII. Stress contour for Plate with single hole



From Figure VII, the maximum stress is found to be 60.922 N/mm^{2}with single hole

- Plate with additional holes

Figure VIII. Plate with additional holes dimension

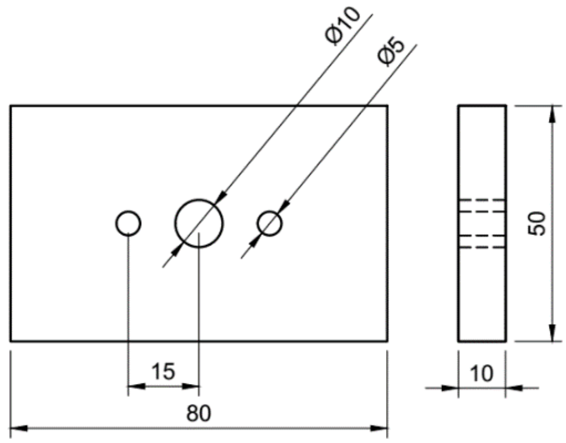
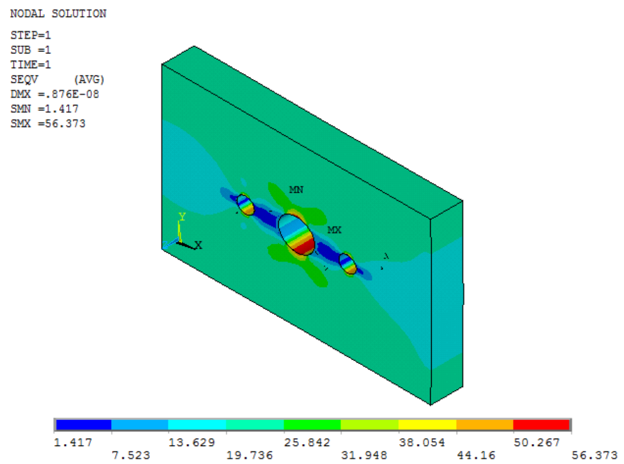


Figure IX. Stress contour for Plate with additional holes



From Figure IX, the maximum stress is found to be 55.733 N/mm^{2}with drilling of additional holes

(3) Plate with notch

- Plate with single notch

Figure X. Plate with single notch dimension

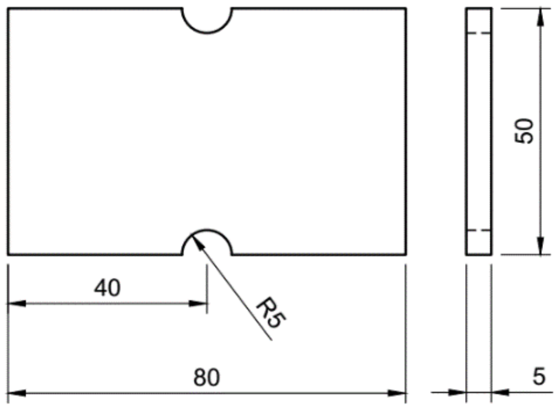
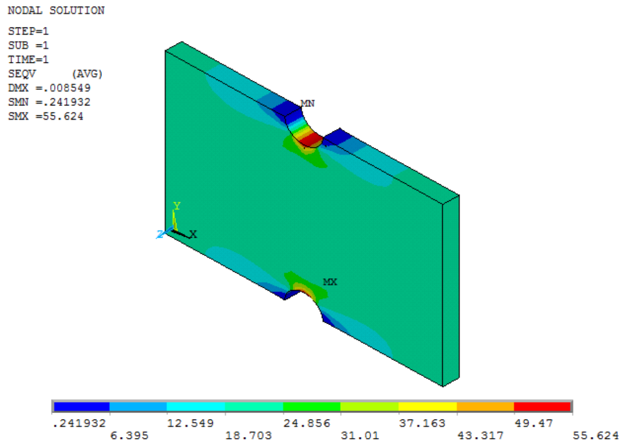


Figure XI. Stress contour for Plate with single notch



From Figure XI, the maximum stress is found to be 55.624 N/mm^2

- Plate with additional notches

Figure XII. Plate with additional notches dimension

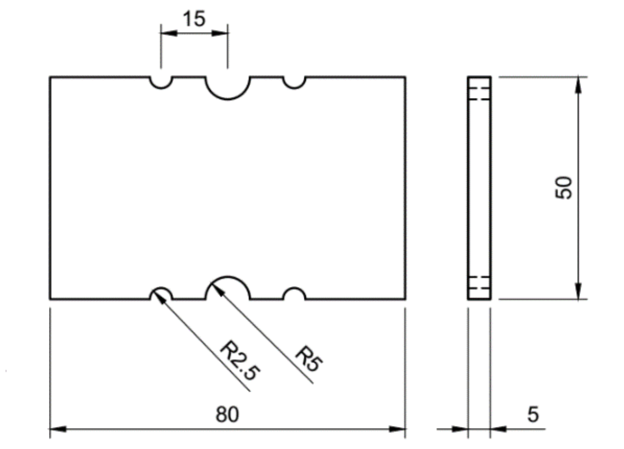
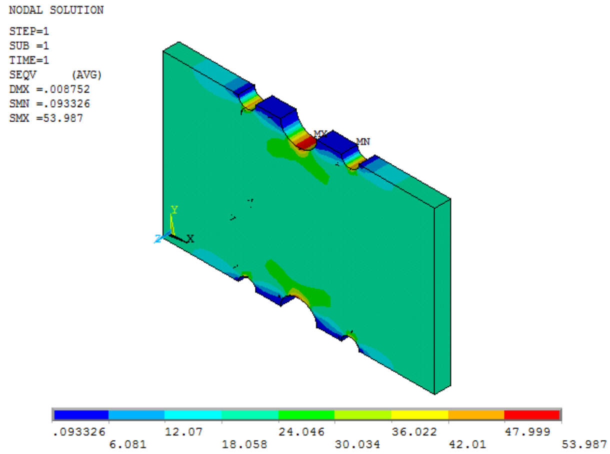


Figure XIII. Stress contour for Plate with additional notches



From Figure XIII, the maximum stress is found to be 53.987 N/mm^{2}after the machining additional notches

(4) Plate with groove

- Plate with single groove

Figure XIV. Plate with single groove dimension

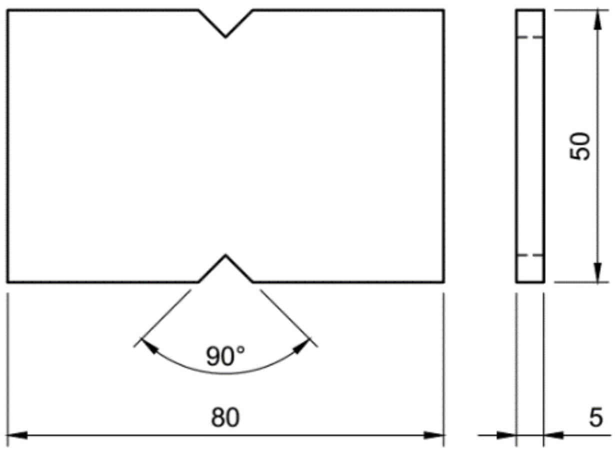
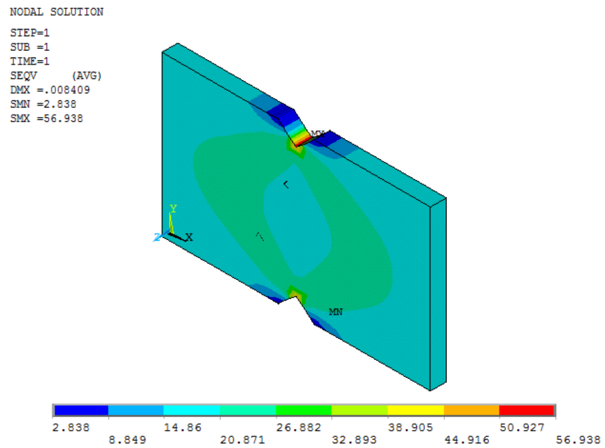


Figure XV. Stress contour for Plate with single groove



From Figure XV, the maximum stress = 56.938 N/mm^2

- Plate with additional grooves

Figure XVI. Plate with additional grooves dimensions

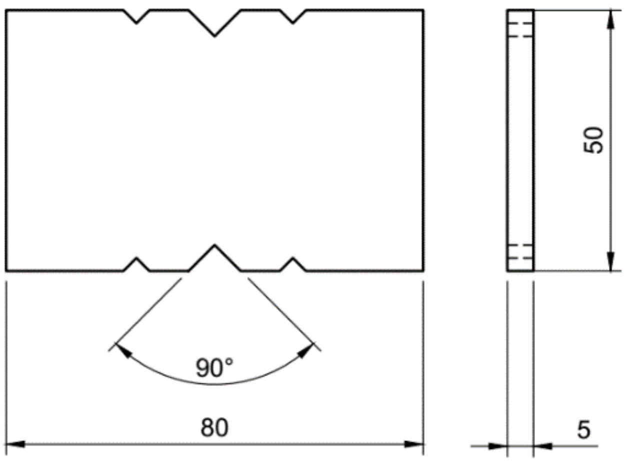
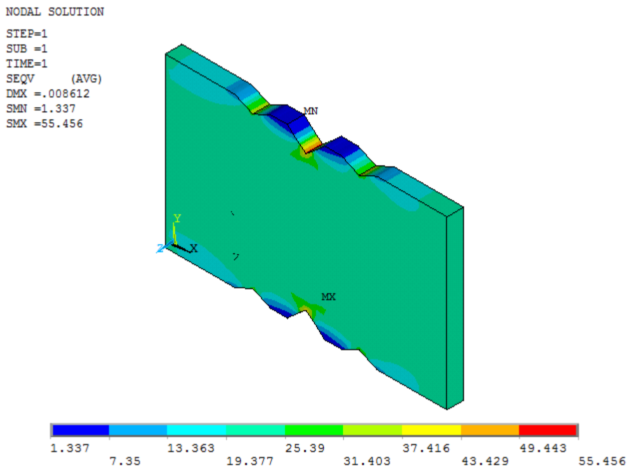


Figure XVII. Stress contour for Plate with additional grooves



From Figure XVII, the maximum stress is found to be 55.456 N/mm^{2}with the addition of multiple grooves.

IV IMPORTANCE OF STRESS CONCENTRATION

The importance of stress concentration is studied by taking simple example. Maximum stress is calculated using Ansys. Introduction of Stiffeners reduces the stress as well as displacements significantly.

V CONCLUSIONS

- For Bracket, Introduction of fillet results in reduction of maximum stress by 35%.
- For Plate with a hole, drilling additional holes results in reduction of maximum stress by 9%.
- For Plate with a notch, use of multiple notches results in reduction of maximum stress by 3%.
- For Plate with a groove, multiple grooves result in reduction of maximum stress by 2.6%.
- From the above results, it is clear that the presence of stress concentration cannot be totally eliminated but it may be reduced to certain extent by introducing fillets, drilling additional holes, use of multiple notches and grooves.

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