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Finite Element Analysis of Cantilever Beam with Circular Hole of Different Materials

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Abstract- This study investigates the deflection in a cantilever beam of uniform rectangular cross section made of linear elastic material that is homogeneous and isotropic. In this study, the effects of circular hole location on the homogenous cantilever beams with three different material have been investigated.Design affects the maximum stress and maximum deflection of structure. Maximum stress is stress after which structure is fracture, at that time deflection is called maximum deflection. In this paper we are working for analysis of deflection due to circular hole. The structure is beam or rod with rectangular cross section. We are performing this experiment with three different materialwhich are steel, aluminium and titanium. Circular hole are at three different locations 15, 30 and 45mm. This experiment is performed by finite element analysis software here we are using Lisa Fea software for analysis.
Keywords- cantilever beam, material, maximum deflection, circular hole, finite element analysis.

I.INTRODUCTION

It is required that any structure must work properly during its service life time. However, due to the internal damage of structures, there may be a chance of breakdown. Detection of damage in early stages reduces chances of sudden failure of that structure which is important from safety and economic point of view.

Defects can be micro and macro level, micro level defects can’t see by naked eye here we are performing experiment in macro level. Failure of structure is caused by either natural defects or defects due to design of structure. Design of structure may be type of material used in structure, dimension used for beam column and frame of other type etc, type of notches or hole also provided in structural for some reason.

II. LITERATURE REVIEW

Many numerical and experimental studies have been done on effect of notches on beam. [1] Samalet. al. studied the deflection and stress distribution in a long, slender cantilever beam of uniform rectangular cross section made of linear elastic material properties that are homogeneous and isotropic.[2] Pasinliet. al. was investigated the effects of hole dimension, shape and position, and beam thickness on the lateral buckling behaviour of woven fabric laminated composite cantilever beams, having two square or two circular holes,. Firstly, the theoretical, experimental and numerical critical buckling loads of the beams without holes were found and compared with each other.[3] Erklig et.al. studied the effects of different cutouts on the lateral buckling behaviour of composite beams made of polymer matrix composites. Cut-outs like circular, rectangular, square, elliptical and triangular are generally used in composites. This paper includes two parts; first part is an experimental part and second is a numerical part. In the experimental part, samples with square, circular and without cutouts are used and critical

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lateral buckling loads are determined experimentally. In the second part, finite element analysis is performed to predict the effects of different cutouts, location and size of cutouts on the lateral buckling behaviour of the beam.

III. METHODOLOGY

In this chapter we will discuss about how to perform analytical work. It included how to make an object from node, creation of nodes, creation of element, meshing, apply load and constraint etc. In this project we use isotropic metallic material for rectangular cross-section beam. Here notch used is of two type circular hole and V notch. Homogeneous material is used in this project. Software used for this analytical experiment is LISA FEA.
Dimension of beam - $60\times 12\times 10$ mm^3

Step.1 Selection Of Material- We select three material steel, titanium and aluminium and its property are given below.

Table 1- Property of material

Material	Young's modulus (E) N/mm^2	Poisson's ratio (μ)	Density(ρ) Kg/mm^3
Steel	206×10^3	0.30	7.84×10^{-6}
Aluminium	67×10^3	0.34	2.7×10^{-6}
Titanium	105×10^3	0.34	4.548×10^{-6}

Step.2 Create A Node - Create a node by specifying its X, Y & Z co-ordinate

Fig 1- Creation of nodes by coordinate point

Step.3 Create An Element - Create an element either by selecting the nodes using the mouse or entering a list of node numbers. Follow the number sequence to form element.

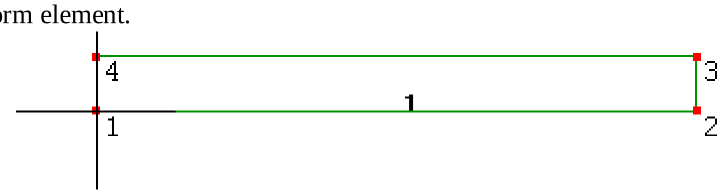

Fig 2- Creation of element by nodes

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Step.4 Meshing- Meshing is done either by a combination of nodes and elements or by using ready-made template patterns. It is of two types that is 2D and 3D mesh.

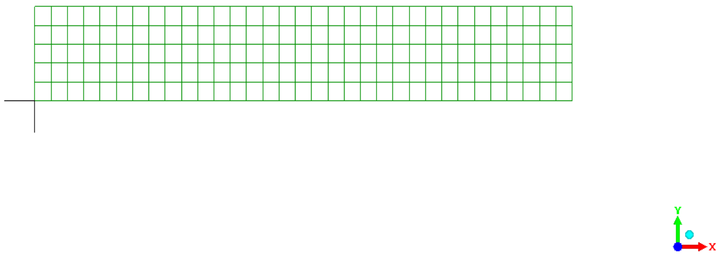

Fig 3 – Meshing of element

Step.5 Extrude **-** In this process any surface is given its width. Once a 2D plane mesh has been created it can be extruded, revolved or lofted to create a 3D model.

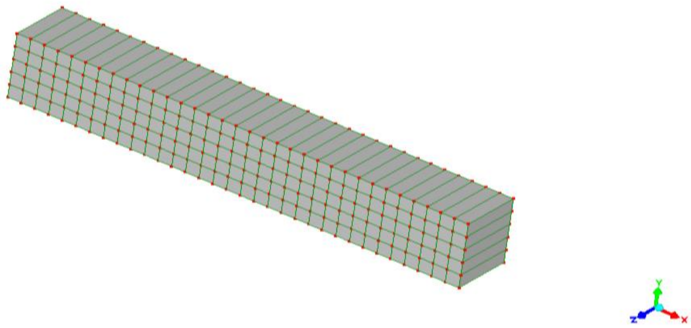

Fig 4- Extrusion of element

Step.6 Create A Hole **-** Hole is created using tool given in software and in this tool side of square and radius of circle need to be given.

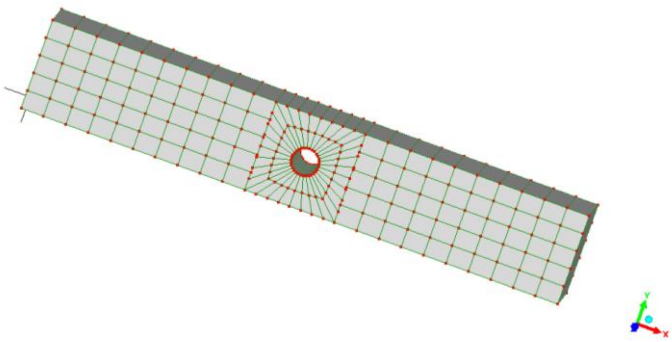

Fig 5 – Circular Hole In Beam

Step.7 Apply Load And Constraint- A fixed support constrains all the face's nodes against displacement in any direction.A force applied to nodes is divided equally between the nodes. A force can be applied to a named selection containing nodes or faces. Let us force is applied to right side of the beam.

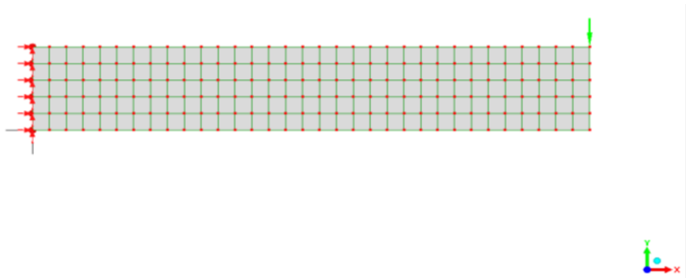

Fig 6- Constraint and load is applied on beam

Step.8 Solve - After applied force and constraint Click "=" to solve the model.
Select any item below Solution to display a field value as a colour coded contour plot.
The results are listed in the outline tree below Solution

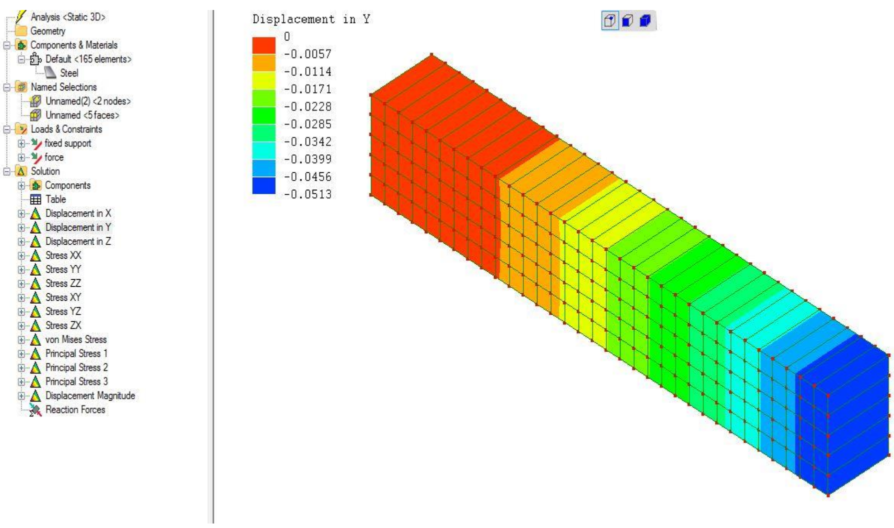

Fig 7- Results are listed below solution

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IV.RESULTS AND DISCUSSION

In this section, Maximum stress and displacement for different material in the elastic beam are determined with the help of LISA Fea software. The results are displayed with the help of figures, Tables and Bar graphs. The effects of load with and without hole in beam are analysed. Thus a number of experiments performed by three materials with different hole position it is also compare by beam with no notch.

Consider beam without hole made up of steel, the dimension of beam is 60×10×8 mm^3

Here we are considering the displacement in Y direction of upper right corner node for analysis.

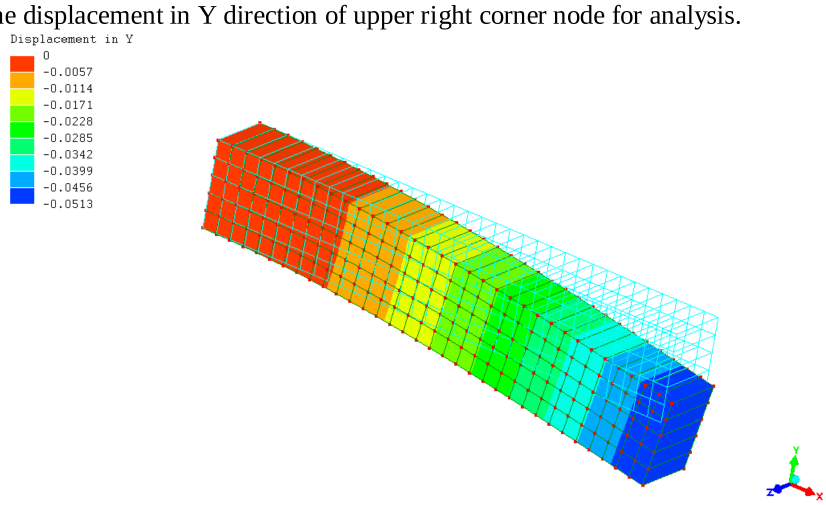


Fig 8 - Displacement of beam without hole

Circular holes are located at three different places which are given below-

Location No.	Location of hole
1.	hole at 15mm from fixed end
2.	hole at 30 mm from fixed end
3.	hole at 45 mm from fixed end

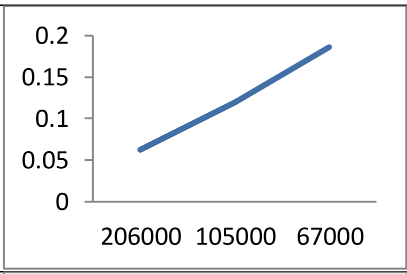
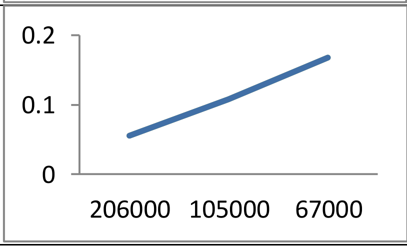
Table.2 - Deflection (in mm) of node at corner (60,10,8) due to presence of circular hole

Mate rial	1st location	2nd location	3rd location	Without circular hole	Combination of three location

Steel	0.0621	0.05579	0.05215	0.05129	0.061785
Aluminium	0.1862	0.1679	0.1573	0.15607	0.188558
Titanium	0.1197	0.1079	0.1011	0.09958	0.119002

From table we can say as the modulus of elasticity increases the displacement will decreases. As the distance between hole and fixed end increase the displacement will reduces and minimum in case of no hole.

Table.3 - Graph and equation of displacement with respect to hole position

<table>
<tr><th>S.No.</th><th>Table</th><th>Graph</th><th>Equation</th></tr>
<tr><td>1</td><td><table><tr><td>Steel</td><td>Titanium</td><td>Aluminium</td></tr><tr><td>0.0621</td><td>0.1197</td><td>0.1862</td></tr></table></td><td>
</td><td>y = 0.062x - 0.001</td></tr>
<tr><td>2</td><td><table><tr><td>Steel</td><td>Titanium</td><td>Aluminium</td></tr><tr><td>0.05579</td><td>0.1079</td><td>0.1679</td></tr></table></td><td>
</td><td>y = 0.056x - 0.001</td></tr>
</table>

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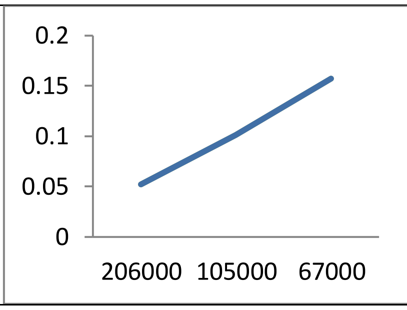
<table>
<tr><td>3</td><td><table><tr><td>Steel</td><td>Titanium</td><td>Aluminium</td></tr><tr><td>0.05215</td><td>0.1011</td><td>0.1573</td></tr></table></td><td>
</td><td>y = 0.052x - 0.001</td></tr>
<tr><td colspan="2">Generalised equation -</td><td colspan="2">y = 0.057x - 0.001</td></tr>
</table>

Here we can replace all equation of circular Hole by generalised equation of circular hole
Generalised equation of circular hole

$$y = 0.057x - 0.001 \quad (1)$$

From equation 1 it is clear that equation is linear that means it follow straight line there are two parameter displacement and modulus of elasticity, if one parameter is known then another can be evaluate. It helps us to find the displacement of any particular material.

V.CONCLUSION

In this experiment, by putting circular hole at fixed distance from fixed end when load is applied on three different material the displacement of upper right node is obtained.By plotting graph between displacement and modulus of elasticity a straight line is obtained. Thus three straight lines is obtains from three different circular hole locations. By this equation if one parameter is known then another can be evaluate. It helps us to find the displacement of any particular material.

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