Stress Concentration analysis and optimization of rectangular beam subjected to maximum load

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Abstract: A simple cantilever beam has multiple uses whether it be vehicle’s foot rest or as big as modern day bridges. Cantilever beam; beam supported at one end and carrying a load at the other end or distributed along the unsupported portion. Stresses are an integral part of any mechanical structure and its optimization is one of the main aspects for any engineer. This paper will try to optimize the configuration of a rectangular cantilever beam so as to distribute the stress concentration and to apply to the same loading conditions. Analysis of the beam is done with the help of software application “Dassault’s Solid works” and the results are compared with the use of same software.

Keywords: about four key words separated by commas.

1. Introduction

Cantilever beam; beam supported at one end and carrying a load at the other end or distributed along the unsupported portion. The upper half of the thickness of such a beam is subjected to tensile stress, tending to elongate the fibers, the lower half to compressive stress, tending to crush them. Cantilevers are employed extensively in building construction and in machines. In building, any beam built into a wall and with the free end projecting forms a cantilever. Longer cantilevers are incorporated in a building when clear space is required below, with the cantilevers carrying a gallery, roof, canopy, runway for an overhead travelling crane, or part of a building above.

One of the biggest problems with cantilever beam is that most of the stresses are concentrated to the fixed end. These stresses should be needed to distribute. For this we need to do an analysis of stress concentration on beam and through removal of material either by through hole or by notches should be distributed throughout the beam. here.

1. Theory:
1.1 Stress Concentration

In design of any mechanical element the following three fundamental formulas are applied:

\[ \sigma_t = \frac{P}{A} \]

\[ \sigma_b = \frac{M_b y}{I} \]

\[ \tau = \frac{M_r}{J} \]

Figure 2: Elementary equations applied to cantilever

The main assumption we consider while applying these equations is that the cross section is same throughout the area. But in real life problems the cross section always changes. According to Design of Machine elements by V.B.Bhandari, stress concentration is defined as localization of stress due to irregularities present in the component and abrupt changes in cross section.

Geometric discontinuities cause an object to experience a local increase in the intensity of a stress field. Examples of shapes that cause these concentrations are cracks, sharp corners, holes, and changes in the cross-sectional area of the object. High local stresses can cause objects to fail more quickly, so engineers must design the geometry to minimize stress concentrations.

Figure 3: Stress Concentration about hole.

1.2 Cantilever Beam

A cantilever is a beam anchored at only one end. The beam...
carries the load to the support where it is forced against by a moment and shear stress. Cantilever construction allows for overhanging structures without external bracing. Cantilevers can also be constructed with trusses or slabs.

Main advantages are:-
Building out from each end enables construction to be done with little disruption to navigation below
The span can be greater than that of a simple beam, because a beam can be added to the cantilever arms
Because the beam is resting simply on the arms, thermal expansion and ground movement are fairly simple to sustain  
Cantilever arms are very rigid, because of their depth
Main disadvantages are:-
Like beams, they maintain their shape by the opposition of large tensile and compressive forces, as well as shear, and are therefore relatively massive
Truss construction is used in the larger examples to reduce the weight

2. Problem Statement:
Suppose we have to design a cantilever beam with cross section 10in x 0.5in x 0.38in. The beam is required to support a load of 50lbs. We need to check if the beam with given cross section is suitable for carrying this much load. If not then what are the stress generating in the beam and what ways does we evolve to reduce these stresses.

3. Methodology
1. We design the prototype of the beam using solidworks and using the material as plain carbon steel.

Fig 4: Software application in analysis

2. Now we are using finite element analysis module of solidworks. Initially we are applying a load of 50lbs

3.1 Model Information

<table>
<thead>
<tr>
<th>Model</th>
<th>Treated As</th>
<th>Volumetric Properties</th>
</tr>
</thead>
</table>
| Boss-Extrude2 | Solid Body | Mass:0.292739 kg  
Volume:3.8018e-005 m³  
Density:7700 kg/m³  
Weight:2.86884 N |

Table 1: Showing material properties

<table>
<thead>
<tr>
<th>Model Reference</th>
<th>Properties</th>
<th>Components</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name: Alloy Steel</td>
<td>Model type: Linear Elastic</td>
<td>SolidBody 1(Boss-Extrude2)(Part2)</td>
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<tr>
<td>Default failure criterion:</td>
<td></td>
<td>Max von Mises Stress</td>
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<tr>
<td>Yield strength:</td>
<td>6.20422e+008 N/m²</td>
<td></td>
</tr>
</tbody>
</table>

3.2 Material Properties

<table>
<thead>
<tr>
<th>Name</th>
<th>Type</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tensile strength</td>
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<td></td>
</tr>
<tr>
<td>Elastic modulus</td>
<td>2.1e+011 N/m²²</td>
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<td></td>
</tr>
<tr>
<td>Poisson's ratio:</td>
<td>0.28</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mass density:</td>
<td>7700 kg/m³</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shear modulus:</td>
<td>7.9e+010 N/m²²</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thermal expansion coefficient:</td>
<td>1.3e-005 /Kelvin</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
of purpose, according to results we get from static analysis of given cross section it is clear that circular cross section is most suitable among designs. This not only helps in distributing the stress concentrations but on the same end, it also minimizes the overall weight of the configuration thus optimize its structural dimensions.

References


