FINITE ELEMENT STRESS ANALYSIS OF CRANE HOOK WITH DIFFERENT CROSS SECTIONS

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Abstract : ***Crane hooks are highly liable components and are always subjected to failure due to accumulation of large amount of stresses which can eventually lead to its failure. To study the stress pattern of crane hook in its loaded condition, a solid model of crane hook is prepared with the help of ANSYS 14 workbench. Real time pattern of stress concentration in 3D model of crane hook is obtained. Finite Element Analyses have been performed on various models of crane hook having triangular, rectangular, circular and trapezoidal cross sections.***
Keywords: Crane hook, Equivalent Stress, FEA, Shear Stress, Total Deformation.

I. INTRODUCTION

Crane hooks are the components which are generally used to elevate the heavy load in industries and constructional sites. Recently, excavators having a crane-hook are widely used in construction work sites. One reason is that such an excavator is convenient since they can perform the conventional digging tasks as well as the suspension works. Another reason is that there are work sites where the crane trucks for suspension work are not available because of the narrowness of the site. In general an excavator has superior maneuverability than a crane truck. However, there are cases that the crane-hooks are damaged during some kind of suspension works. From the view point of safety, such damage must be prevented. Identification of the reason of the damage is one of the key points toward the safety improvement. If a crack is developed in the crane hook, mainly at stress concentration areas, it can cause fracture of the hook and lead to serious accidents. In ductile fracture, the crack propagates continuously and is more easily detectable and hence preferred over brittle fracture. In brittle fracture, there is sudden propagation of the crack and the hook fails suddenly. This type of fracture is very dangerous as it is difficult to detect [1-5].

II. FAILURE OF CRANE HOOKS

Strain aging embrittlement [6] due to continuous loading and unloading changes the microstructure. Bending stresses combined with tensile stresses, weakening of hook due to wear, plastic deformation due to overloading, and excessive thermal stresses are some of the other reasons for failure. Hence continuous use of crane hooks may increase the magnitude of these stresses and eventually result in failure of the hook. All the above mentioned failures may be prevented if the stress concentration areas are well predicted and some design modification to reduce the stresses in these areas.

III. THEORETICAL ANALYSIS

Machine members and structures subjected to bending are not always straight as in the case of crane hooks, chain links etc., before a bending moment is applied to them. For initially straight beams the simple bending formula is applicable and the neutral axis coincides with the centroidal axis. A simple flexural formula may be used for curved beams for which the radius of curvature is more than five times the beam depth. For deeply curved beams, the neutral and centroidal axes are no longer coinciding and the simple bending formula is not applicable.

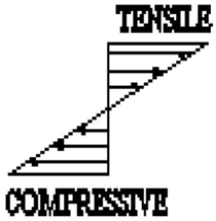
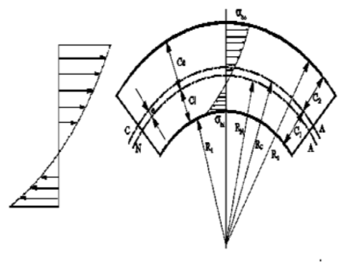
A. Curved Beam

A beam in which the neutral axis in the unloaded condition is curved instead of straight or if the beam is originally curved before applying the bending moment, are termed as "Curved Beams Curved beams find applications in many machine members such as c–clampers, crane hooks, frames of presses, chains, links, and rings.

B. Straight Beam

A beam is a straight structural member subjected to a system of external forces acting at right angles to its axis

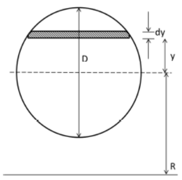
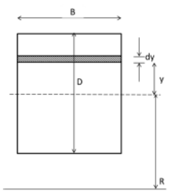
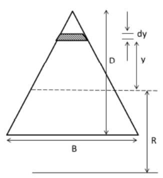
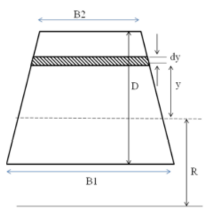
Table1. Differences between Straight Beam & Curved Beam

Fixed Beam	Curved Beam
Neutral axis of the cross-section passes through the centroid of the section.	Neutral axis does not coincide with the cross-section, but is shifted towards the centre of curvature of the beam.
The variation of bending stress is linear, magnitude being proportional to the distance of a fiber from the neutral axis. 	The distribution of the stress in the case of curved beam is non-linear (Hyper- bolic) because of the neutral axis is initially curved. 
No stress concentration	Stress concentration is higher at the inner Fibers

Neutral axis remains undisturbed along the CG.	Neutral axis always shifts towards the center of curvature.
We use Euler equation to calculate bending stress M/I = F/Y=E/R $\sigma = \frac{M}{\frac{I}{C}} = \frac{M}{Z}$	We use $\sigma_i = \frac{Mc_i}{A_e R_o}$ or $\sigma_o = \frac{Mc_o}{A_e R_o}$ to calculate inner and outer fiber stress

Stress calculations are to be done in following way for different cross section crane hook.

Table2. Stress Calculations

Circular Cross Section 	$D = d = 256.2$ $A = \frac{\pi d^2}{4} = 51526.1\ mm^2$ $R = c + \frac{d}{2} = 428 \qquad h^2 = 4280.89$ $\sigma = \frac{W}{A} + \frac{M}{AR}\left[1 - \frac{R^2 y}{h^2(R-y)}\right]$ Considering $M \approx W \times R$ we can have $\sigma = \frac{W}{A}\left[2 - \frac{R^2 y}{h^2(R-y)}\right]$ $\sigma = -368.7 \quad for\ y = \frac{d}{2}\ \&\ for\ y = -\frac{d}{2}$
Rectangular Section 	$D = 256.2\ mm$ $A = 51562.1\ mm^2$ $B = 120.4\ mm$ $h^2 = 2.3\frac{R^3}{D}\log\left(\frac{2R+D}{2R-D}\right) - R^2$ $h^2 = 5626$ $\sigma = 12.50\ for\ y = \frac{d}{2}$
Triangular Cross Section 	$D = 256.2\ mm$ $A = 51552\ mm^2$ $B = 402.5\ mm$ $h^2 = \frac{R^3}{D} \times \frac{B}{D}\left[2.3R_2 \log\left(\frac{R_2}{R_1}\right) - D\right] - R^2$ Considering $M \approx W \times R$ we can have $\sigma = 17.97$
Trapezoidal cross section 	$B_1 = 300\ mm$ $B_2 = 102.4\ mm$ $h^2 = \frac{R^3}{A}\left[2.3\left(B_2 \frac{(B_1 - B_2)R_2}{D}\right)\log\left(\frac{R_2}{R_1}\right) - (B_1 - B_2)\right] - R^2$ Considering $M \approx W \times R$ we can have $\sigma = 16.35$

IV. MODELING

For generation of CAD model of crane hook various geometrical features and dimensions are selected from IS: 3815-1969 [7]. ANSYS 14 software is used for creating solid model of crane hook. Swept Bend advance feature in ANSYS 14 is used.3-D model is prepared which is shown in figure1and similarly for all required cross sections such as circular, triangular and trapezoidal model is prepared.

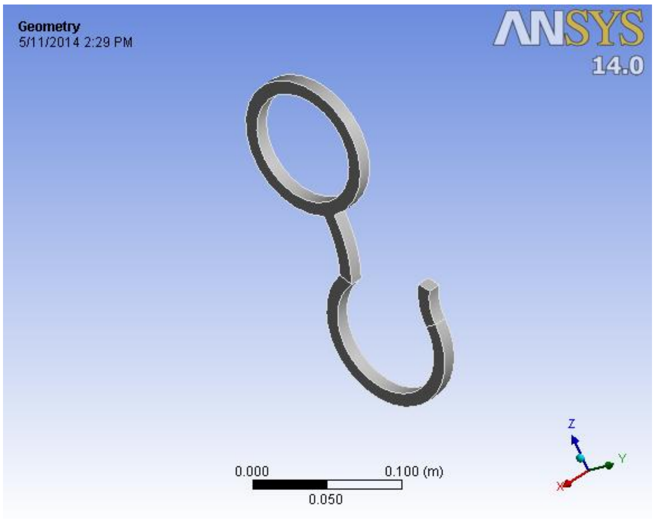


Fig. 1: Solid model of crane hook.

V. MESHING

A model prepared in workbench is used for static analysis. A structural 10 node Tetrahedral Solid 187 element is selected for creating FE model of the crane hook and a fine meshing is carried out. The meshed model created is shown in figure2.

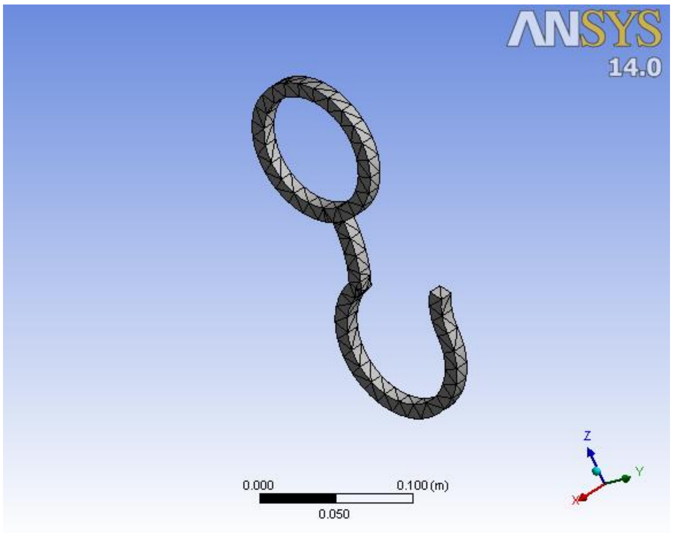


Fig.2: Meshed model of crane hook.

VI. BOUNDARY CONDITIONS AND MATERIAL PROPERTIES

A shank end of crane hook is fixed and a various loads are applied on bunch of nodes at lower centre of hook in downward direction. The nodes and elements created by meshing are given below:

Nodes	1085
Elements	424

Material selected for crane hook is stainless steel and the properties of material are given below:

Structural Steel > Constants

Density	7850 kg m^-3
Coefficient of Thermal Expansion	1.2e-005 C^-1
Specific Heat	434 J kg^-1 C^-1
Thermal Conductivity	60.5 W m^-1 C^-1
Resistivity	1.7e-007 ohm m

Structural Steel > Compressive Yield Strength

Compressive Yield Strength Pa
2.5e+008

Structural Steel > Tensile Yield Strength

Tensile Yield Strength Pa
2.5e+008

Structural Steel > Tensile Ultimate Strength

Tensile Ultimate Strength Pa
4.6e+008

Structural Steel > Isotropic Secant Coefficient of Thermal Expansion

Reference Temperature C
22

VII. FEA SIMULATION OF CRANE HOOKS WITH DIFFERENT CROSS SECTIONS

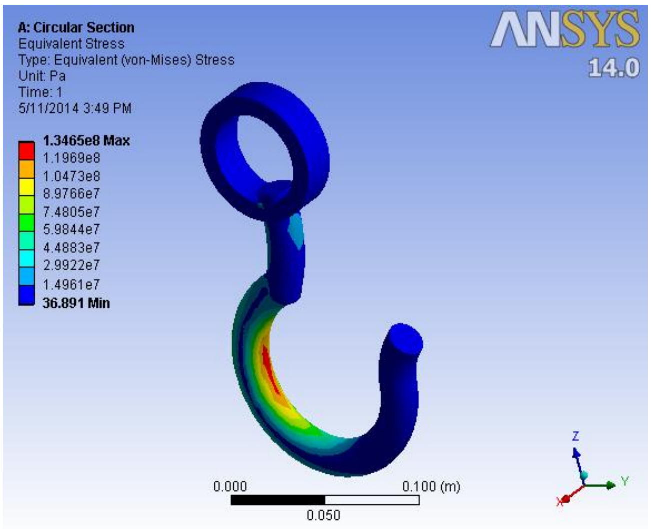


Fig. 3: Equivalent stress in circular crane hook

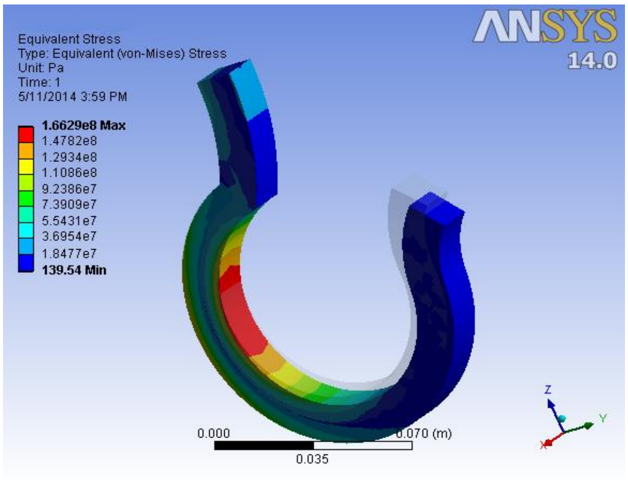


Fig. 4: Equivalent stress in Rectangular crane hook

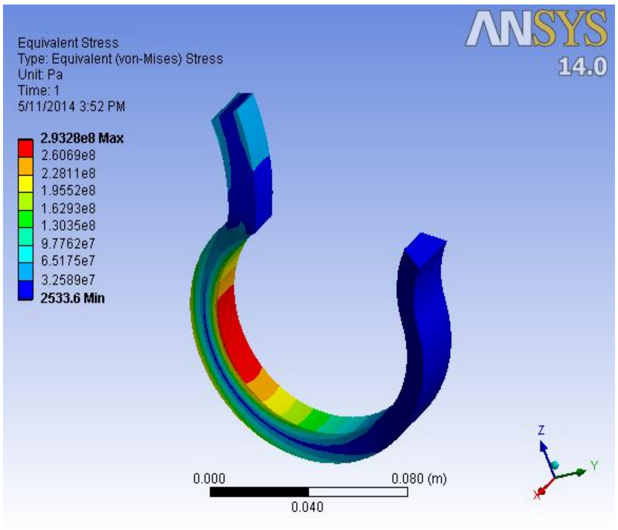


Fig. 5: Equivalent stress in trapezoidal crane hook

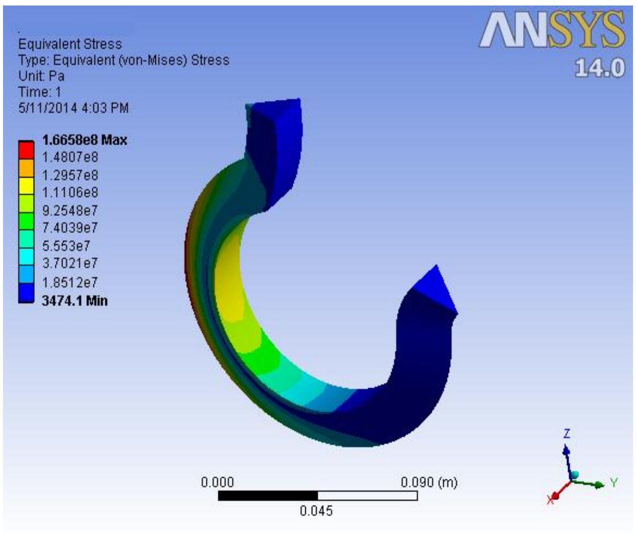


Fig. 6: Equivalent stress in triangular crane hook

VIII. RESULT, DISCUSSION AND CONCLUSIONS

The results of stress analysis calculated from FEM for various cross sections such as triangular, rectangular, circular and trapezoidal are presented in table3.

Table3. Comparison between FEA results for different cross sections.

Section	Sectional Properties	Area of Cross Section (mm²)	Max. Equivalent Stress (N/mm²)	Max. Shear Stress (N/mm²)	Max. Deformation (mm)
Triangular	W = 20	200	238.31	119.46	1.4402
Rectangular	A=14.15 B=14.15	200.22	196.9	98.628	1.1579
Circular	D=16	200.96	245.19	123.86	1.2407
Trapezoidal	A=20 B=20 H=10	200	272.88	137.17	2.3098
	A=10 B=30 H=10	200	292.13	149.35	2.6107
	A=10 B=30 H=10	200	333.57	173.33	2.4826

During entire analysis for different cross sections it is observed that keeping area cross section same with different cross section topology we will get different results, but from the above table it is found that the rectangular cross section gives minimum stress and deformation levels. Further it is necessary to study variation of stresses and deformation with variation of parameters. So, the graph is plotted between Equivalent stress Vs Load for the rectangular cross section which is shown in figure7.

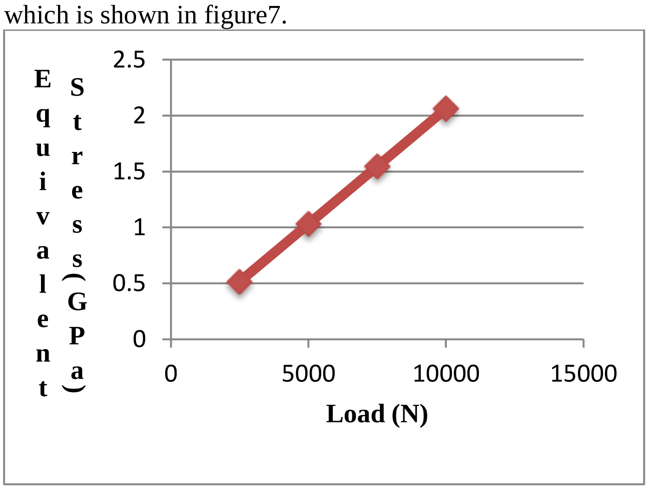


Fig. 7: Variation of equivalent stress for rectangular cross section hook.

It is observed that for a rectangular cross section crane hook, when we gradually increase the load (2500 N to 10000 N), the equivalent stress also goes on increasing and the behavior is linear.

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