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Stress Analysis of Crane Hook with Different Cross Section Using Finite Element Method

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Abstract: ***Crane hook is a mechanical component used for material handing or transfer, observes stresses, induced when different kinds of load applied. From the safety point of view the crane hook damaged must be prevented due to crack fracture developed caused mainly at stress concentration areas. Stress on crane hook depends upon various geometric variables as well as material properties. In this analysis the material properties of hook kept constant throughout the analysis and stress is to be reduced by varying different geometric parameters. After optimizing the cross section of crane hook the approach turned towards the material saving during manufacturing of crane hook. For material saving the maximum stress region is to be identified by using FEM analysis and then material is removed by considering the maximum bending stress at failure point.***

Keywords: Crane Hook, ANSYS, Curved Beam, Stress, Winkler-Bach Theory

1. Introduction

Crane hooks are the components which are used to lift the heavy load in constructional sites and industries. In this paper the crane hook model is prepared in CREO 2.0 with specified material properties. The model is imported in ANSYS 15.0 and the fixed load is applied on crane hook model. Results are analyzed and the optimum geometric shape is adopted for minimum stress induced in failure region. . The complete study is an initiative to establish an ANSYS based Finite Element procedure, by validating the results, for the measurement of stress with Winkler-Bach theory for curved beams. [6]

2. Theoretical Analysis

Winkler batch theory is used to calculate the theoretical stress. For the straight beams, the neutral axis of the cross section coincides with its censorial axis and the stress distribution in the beam is liner. But in case of curved beams, the neutral axis of the cross-section is shifted towards the centre of curvature of the beam causing a non-linear distribution of stress. The application of curved beam principle is used in crane hooks. This article uses Winkler-Bach theory to determine stresses in a curved beam. [5]

$$\sigma = \frac{M}{AR}\left[1 + \frac{R^2}{H^2} \times \left(\frac{Y}{R+Y}\right)\right] \text{..(Tensile)}$$

$$\sigma = \frac{M}{AR}\left[1 - \frac{R^2}{H^2} \times \left(\frac{Y}{R-Y}\right)\right] \text{..(Compressive)}$$

Where,
d = Depth of the section
B = Width of the section on lower portion
b = Width of the section on upper side
d1 = Distance of center of gravity from the bottom side.

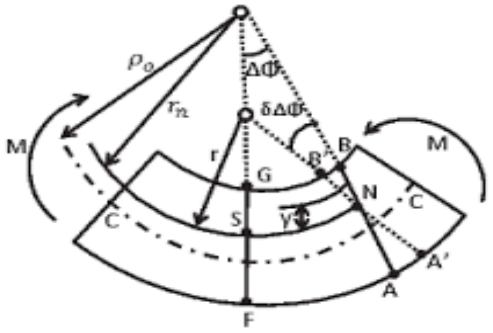

Figure 1: Curved Beam Nomenclature

d2 = Distance of center of gravity from the upper side.
R = Radius of curvature

3. Dimensions, Designation and Material of Hook

Drop forged un machined part with nose for single hook has been considered for modeling in CREO software. Dimensions chosen for hook are tabulated below

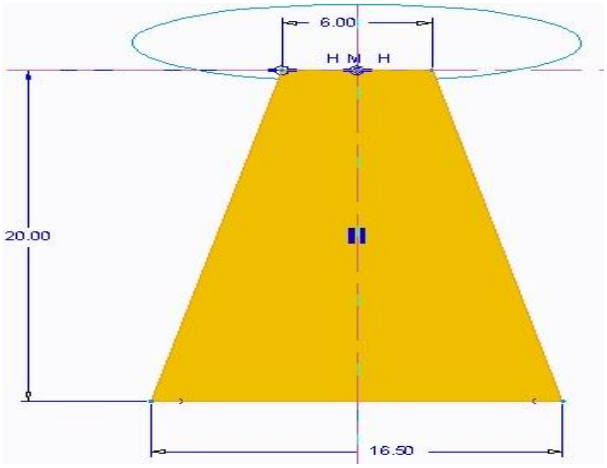

Figure 2: Trapezoidal Cross Section

Table 1: Dimensions Reference

Hook Cross Section	Dimension
circular	d=18
rectangular	b=15,h=18
trapezoidal	b=6,B=16.5,d=20

Table 2: Material Properties Reference

Density	7.85e-009 tone mm^{-3}
Coefficient of Thermal Expansion	$1.2e^{-005}$
Compressive Yield Strength MPa	250
Tensile Yield Strength MPa	250
Reference Temperature C	22

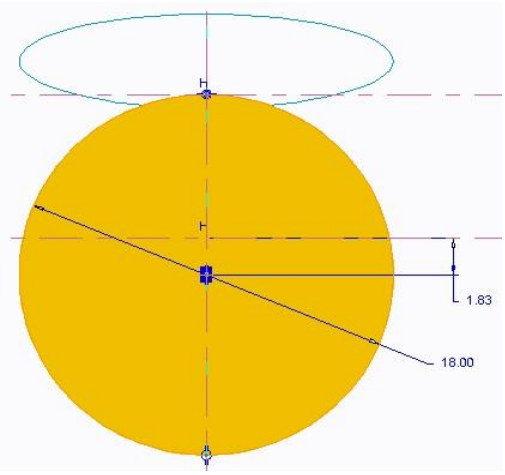

Figure 3: Circular Cross Section

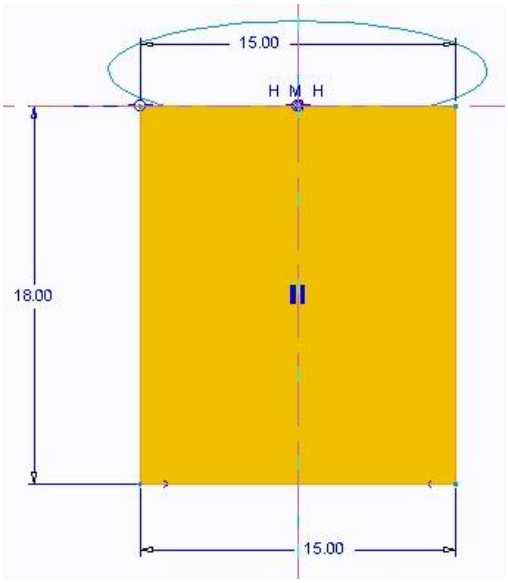

Figure 4

Figure 4: Rectangular Cross Section

4. Procedure for Finite Element Method

ANALYSIS Model
Geometry – Imported from CREO in "prt" format.
Solid - generated ANSYS geometry.
Mesh-uniform structured element selection.

Table 3: Number of Nodes and Elements

Geometry	*Nodes*	*Elements*
circular	19561	4095
rectangular	25527	14371
trapezoidal	10055	5457

5. Static Structural Analysis

Analysis has been done for static structural, single step loading loads of 5000 N is applied at principal cross-section of the hook. Eye section at top of the shank, kept fixed.

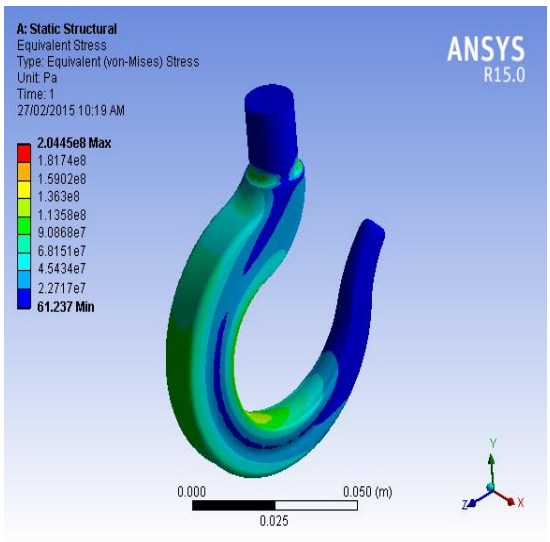

Figure 5: Rectangular Hook Analyses

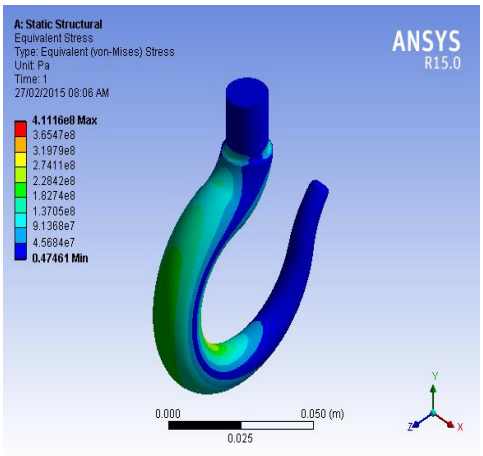

Figure 6: Circular Hook Analyses

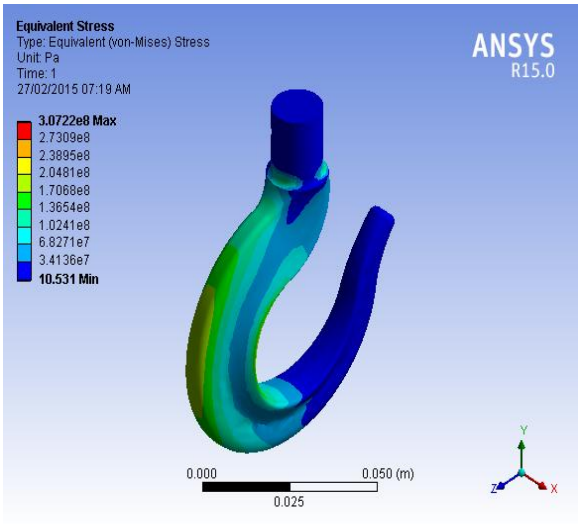

Figure 7: Trapezoidal Hook Analysis

6. Comparison of Stresses

Table 4: Stresses for the Hook by ANSYS, and Winkler Bach Theory

Geometry	Stress(Von-Mises Stress)MPa		Variation
	ANSYS	WANKLER THEORY	
Circular	411.6	378.28	8%
Rectangle	204.45	258.51	26%
Trapezoidal	307.22	272.21	11%

7. Results

The induced stresses as obtained from Winkler-Bach theory for curved beams, explained in the previous section are compared with results obtained by ANSYS software. The results are in close accord with a small percentage error of 11%. Probable reasons for variation might be due to following assumptions, loading is considered as point loading in case of Winkler-Bach Formula calculation while it is taken on a bunch of nodes in ANSYS . Principal cross section is assumed to be perfect trapezoidal. Assuming sections that are initially plane remain plane after bending. The complete study is an initiative to establish an ANSYS based Finite Element procedure, by validating the results, for the measurement of stress with Winkler-Bach theory for curved beams. This model has an important meaning to design larger tonnage lifting hook correctly.

Table 5: Compression between old and new cross section of hook

S.No.	**WEIGHT**	**STRESS (**Mpa)
OLD TRAPAZODAL	2.123 N.	307.22
NEW TRAPAZODAL	2.142 N.	287.11

Increase in mass = $\frac{2.142-2.123}{2.123} \times 100$ =0.89%

Decrease in Stress= $\frac{307.22-287.11}{307.22} \times 100$ = 6.54%

8. Future Scope

Further it is advisable to conduct photo elasticity test for the crane hook under investigation in order to get better insight for stress concentration. Material saving approach by optimization of cross section area with consideration of stress concentration can be also done to put away manufacturing cost.

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