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

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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. Hooks are employed in heavy industries to carry tonnes of loads safely. These hooks have a big role to play as far as the safety of the crane loaded is concerned. With more and more industrialization the rate at which these hooks are forged are increasing. This work has been carried out on one of the major crane hook carrying a load. The cad model of the crane hook is initially prepared with the help of existing drawings. It is then followed by implementation of modified cross section of hook in the static structural analysis workbench 14.5. These results lead us to the determination of stress and deflections in the existing model. To study the stress pattern of crane hook in its loaded condition, a solid model of crane hook is prepared with the help of CATIA V5 R21. In order to reach the most optimum dimensions several models in the form of different dimensions of hook were tested and the most optimum dimension was selected. The selection was based on the satisfaction of several factors in the form of load carrying capacity, stress induced and deflection.

Keywords: Crane Hook, Stress, ANSYS, Total Deformation, FEA

1. 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. 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.

Fig.1 Image of Crane Hook

2. Problem Statement

There are different reasons of the failure of crane hook are as follows:
1. It occurs due to continuous loading and unloading changes the microstructure.
2. Bending stresses combined with tensile stresses,
3. Weakening of hook due to wear,
4. Plastic deformation due to overloading,
5. 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.

3. 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 center 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.

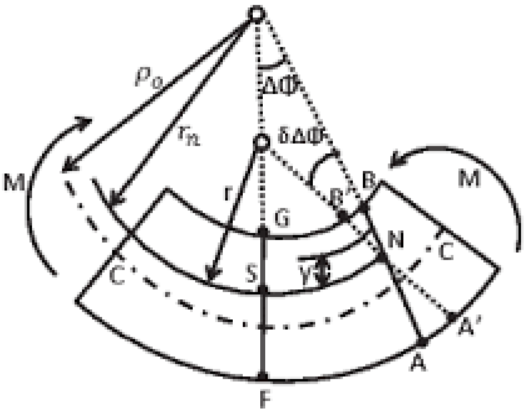

Fig.2 Curved Beam Nomenclature

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

σ = M/ AR [1 + R2/ H2 × Y /R+Y] ----------(Tensile)

σ = M/ AR [1 - R2/ H2 × Y /R-Y]---------- (Compression)

Table 1: Dimensions for Reference

Hook Cross Section	Dimension
Rectangular	B=51, H=75
Trapezoidal	B=51, b= 26 , D=75

3.1 Rectangular Section:

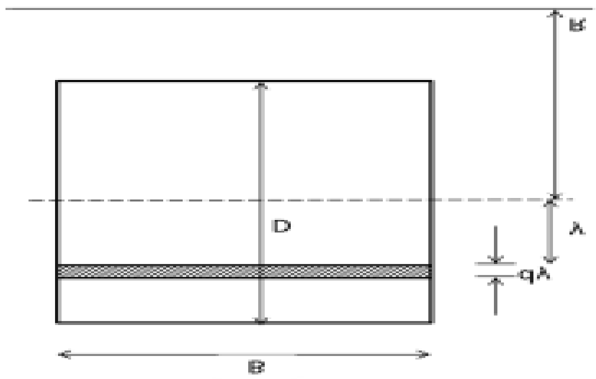

Fig.3 Rectangular Section

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.

σ = M/ AR [1 + R2/ H2 × Y /R+Y] (Tensile)

P=1 Ton =9806 N

H= 0.93 × C =0.93×51 = 47.43 mm

M= W× R= 9806×51=500106Nmm

R= C+ D/2= 51

A=3825mm^2

(6_t) total= 244 N/mm^2 $\leq$ 250 N/mm^2

3.2 Trapezoidal Section:

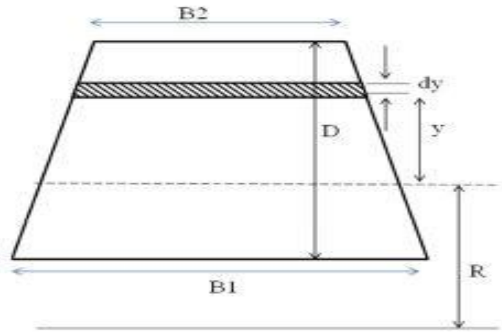

Fig. 4 Trapezoidal Section

Where, $\sigma = M/\ AR\ [1 + R2/\ H2 \times Y\ /R+Y]$.(Tensile)

$H= 0.93 \times C = 0.93\times25 = 23.25$ mm

$M= W\times R= 9806\times888629=372628$ Nmm

$R= C+ D/2= 38$

$A=5700/2= 2850mm^2$

(6_t) total= 194 $N/mm^2 \leq$ 250 N/mm^2

4. CAD Model

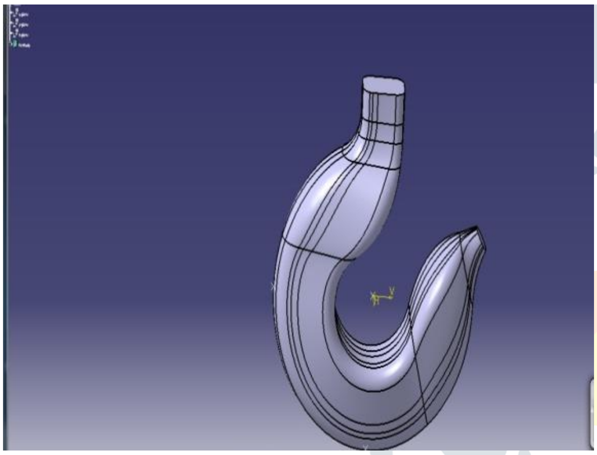

Fig 5: 3D Model of Trapezoidal Section

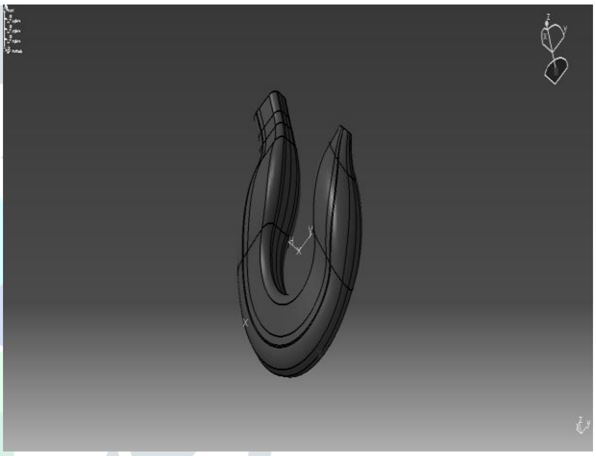

Fig 6: 3D Model of Rectangular Section

5. Mesh Generation

5.1 Meshing

A model prepared in CATIA is used for static analysis. Hook 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 following figure.

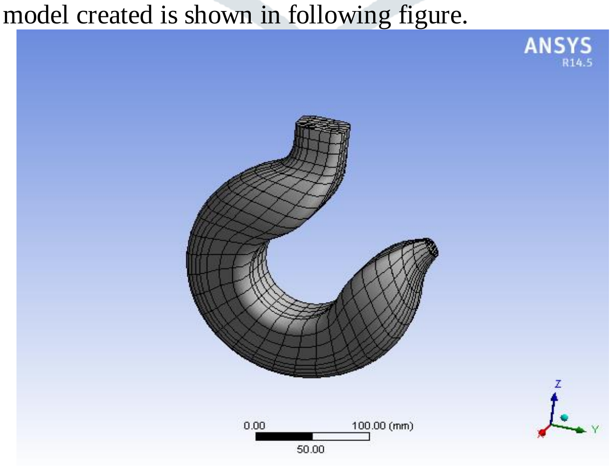

Fig.7. Meshing of Trapezoidal section

5.2 Material properties:

The values of young's modulus, poisons ratio, density, and yield strength for Crain Hook are taken from material library of the FEA PACKAGE.
Structural Steel > Constants

Table 2: Dimensions for Reference

Density	7850kgm^-3
Coefficient of Thermal Expansion	1.2e-005C^-1
Specific Heat	434Jkg^-1C^-1
Thermal Conductivity	60.5Wm^-1C^-1
Resistivity	1.7e-007ohmm

Table 3: Dimensions for Reference

Compressive yield Strength	2.5e+008Pa
Tensile Yield Strength Pa	2.5e+008
Tensile Ultimate Strength	4.6e+008
Reference Temperature C	22

6. FEA Simulation of Crane Hooks with Different Cross Sections

6.1 Boundary Conditions

Analysis has been done for static structural, single step loading loads of 9806 N (1 Tonn) is applied at principal cross-section of the hook. Eye section at top of the shank, kept fixed.

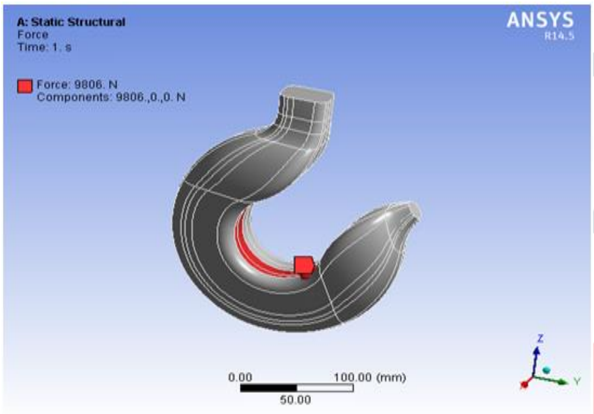

Fig.8.Boundary Conditions Applied On Trapezoidal Hook

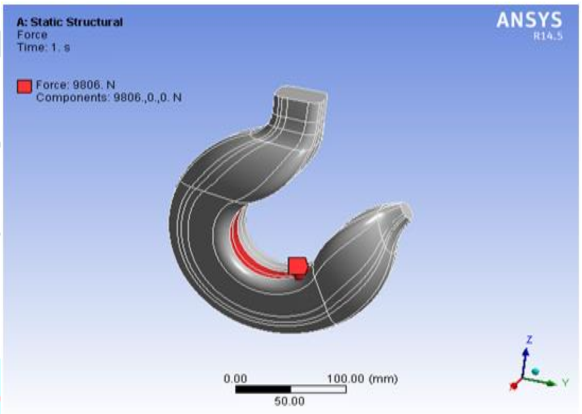

Fig.9 Boundary Conditions Applied On Rectangular Hook

6.2 Stress Plotting On Different Cross Section

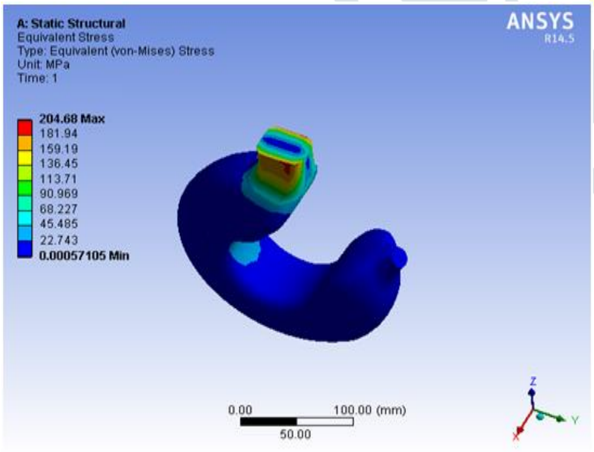

Fig. 10 Max. Equivalent (Von -Mises) Stress for Trapezoidal Hook

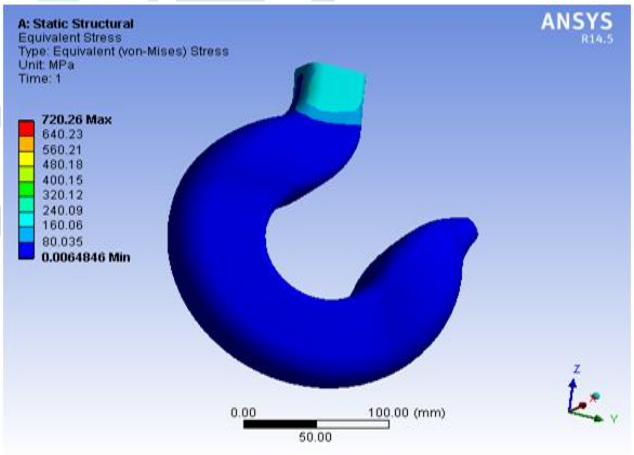

Fig. 11 Max. Equivalent (Von -Mises) Stress for Rectangular Hook

6.3 Deformation Plot on Different Cross Section

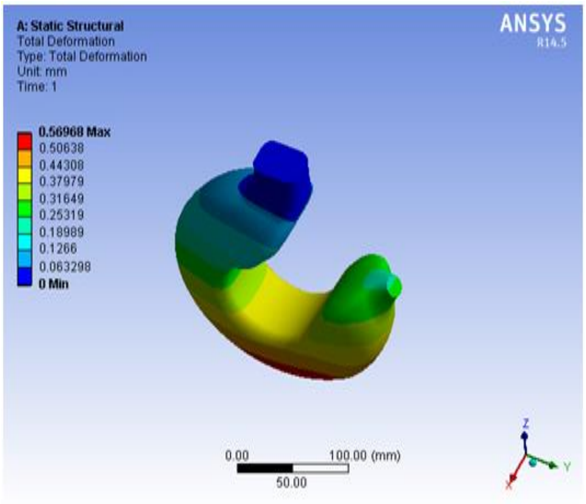

Fig.12. Deformation Plot for Trapezoidal CSA Of hook

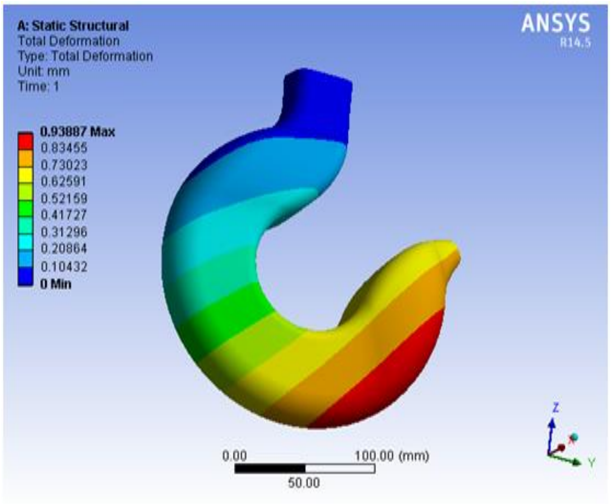

Fig.13. Deformation Plot for Rectangular CSA Of hook

7. COMPARISON OF STRESSES

Stress induced and displacement in trapezoidal is least because of its shape and fillet edges as well as stress concentration are distributed uniformly. It have less mass due to this we are able to save the material and balance economy.

Table 4**:** Stresses for the Hook by ANSYS and theoretical

Cross section	Theoretical Stress (MPa)	V.M.S. (MPa)	Load (N)	Displacement (mm)
Rectangular	224	720	9806	0.94
Trapezoidal	194	204	9806	0.57

The stresses obtained in theoretical and analytical method are good in agreement for the trapezoidal area .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 10%. Stress induced and displacement in trapezoidal is least because of its shape and fillet edges as well as stress concentration are distributed uniformly. It have less mass due to this we are able to save the material and balance economy.

8. CONCLUSION

Probable reasons for variation might be due to following assumptions,

1. Loading is considered as point loading in case of Winkler-Bach Formula calculation while it is taken on a bunch of nodes in ANSYS.
2. Principal cross section is assumed to be perfect trapezoidal. Assuming sections that are initially plane remain plane after bending. Trapezoidal area is selected for further static structural analysis with different materials. Because it gives better results in comparison with other one as because stresses induced is less in trapezoidal cross section. The model prepared is used for further work with different materials.

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