Weight Optimization in Crane Hook

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Abstract: Crane hook are highly liable component and are always subjected to failure due to accumulation of large amount of stress which can eventually lead to its failure .In this present work, to study the different design parameter & stress pattern of crane hook in its loaded condition for different cross section, the design and drafting of crane hook will be prepared using software. By finite element analysis, the stress which is to be formed in various cross section are compared with design calculation .The stress concentration factors are used in strength and durability evaluation of structure and machine element. So, here changing the cross sectional area, and removing material from low stress concentration area in lifting hook and then comparing design stress, the hook is to be optimized.

Key words: Crane Hooks, Various cross Sections, FEA analysis, Weight Optimization.

Nomenclature

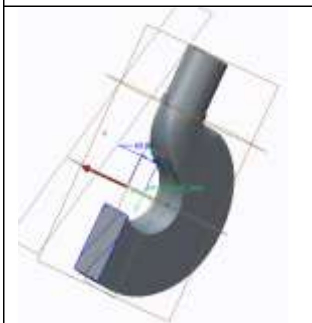
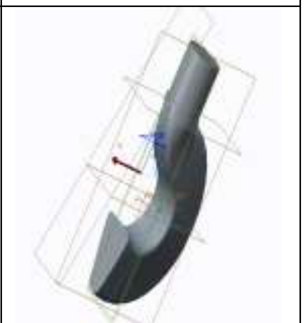
C= Bed diameter
P = Load (KN)
X = Constant ranging between 12 to 24.for economic design should be as minimum as possible
J = Throat of hook
b_i = Width of cross section
σ_t = Direct stress
σ_b = Bending stress
M = Bending moment about neutral axis (N-mm)
A = Cross section area
R_g = Radius of centroidal axis (mm)
R_n = Radius of neutral axis
R_i = Radius of inner surface of crane hook (mm)
R_o = Radius of outer surface of crane hook (mm)
e= Distance between centroidal axis and neutral axis (mm) = R_g-R_n
h_i = Distance of inner most surface from neutral axis (mm)
h_o= Distance of outer most surface from neutral axis (mm)

1. INTRODUCTION

Crane hooks are the components which are generally used to lift the heavy load in industries and constructional work. Recently, generally crane hook are used in constructional work such a machine is useful since they can

Do 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 manoeuvrability than a crane truck. Hooks are also available in following different cross section area.

Table 1:- Different cross section area of crane hook

Circular	Triangular
	
Rectangular	**Trepezoidal**
	

Very few people have already worked on the optimization of crane hook. Generally material type and cross section area and radius are design parameter that affects the weight of crane hook. Cast iron, structural steel is generally used as manufacturing material for crane hook.

2. LITERATURE SURVEY

Patel A Ket.et.al. [1] Has worked on reduction of weight of girder which has reduced the cost of girder and also life of girder is increased. They made a mathematical design for crane component by using ANSYS workbench V12.They also optimized hook by using Trapezoidal cross sectional area.

Maharana P. [2] has estimated hook dimensions for various cross section topologies by keeping the depth and cross section area. He concludes from his work that the trapezoidal section was lest stressed.

Narvydas E.et.al. [3] Calculated the stress concentration with shallow notches of the lifting hook. For the durability evaluation and machine element the stress concentration factor is very important. Result is obtained and used with selected generic equation. This gives the formula for the stress concentration factor without the usage of FEM. The design rule of the lifting hooks requires ductile material to avoid brittle failure.

G U Rajkumar.et.al [4] has worked on investigation of stresses in crane Hook by finite element method. By considering a crane hook as a curved beam and using flexure formula to find out analytical stress. He also prepared a CAD model of crane hook and analysed the stress produced in crane hook by ANSYS. For the validation purpose he performed a photo elasticity test and compares the result with analytical as well as FEM result and found that the result obtained from the ANSYS is within permissible Error.

Bergaley Ajit et al. [5] tested crane hook in UTM machine in tension to locate the area having maximum stress and to locate the yield point. He made a model of crane hook in CEA software and compare result with theoretical analysis.

Tripathi Yogesh et al [6] has conducted FEM analysis to study the stress pattern of crane hook in its loaded condition , for that a solid model is made with help of CATIA .For the correctness of result the stress in hook compared with the winker- Bach theory.

2.1 Conclusion Derived From Literature Review

Crane hook is generally available in four cross sectional area that is rectangle, trapezoidal, triangular and circular cross section area.The crane hook is mainly made of cast iron, mild still and high tensile steel and designed with factor of safety between 2 and 6.For the evaluation of strength and durability of machine element concentration factor are generally used. In order to optimization the weight of the crane hook, the stress induced in crane hook must be studied .the review of previous research permits to conclude that curved beam such as crane hook need more broad investigation since very few articles in this field have been published yet. The study of the earlier publication enables us to conclude that it is possible to remove unwanted material where stress concentration is low and for that finite element method is one of the most effective and powerful for the stress analysis of the crane hook.

3. ANALYTICAL METHOD FOR STRESS CALCULATION

The curved beam flexure formula is used when the curvature of the member is pronounced as in case of hook for different cross section mathematical analysis of stress.

3.1 Dimensions Of Crane Hook (20 Ton)

Bed diameter (C)

$C = x\sqrt{P}$

P = load, KN

X= constant ranging from 12 to 24. For economic design, x should be minimum as possible.

$C = 12\sqrt{20\times 9.81}$	$C = 169$ mm
$H = (10\sqrt{P} + \frac{C}{10})$	$H = 10\sqrt{20\times 9.81} + \frac{169}{10}$
$H = 157$ mm	
$B = 1.31C$	$B = 221$ mm
$P = 0.50C$	$P = 84$ mm
$N = 1.20C$	$N = 203$ mm
$A = 2.75C$	$A = 465$ mm
$K = 0.92C$	$K = 155$ mm
$F = 1.00C$	$F = 169$ mm

3.2 Stress In Crane Hook:

The crane hook is a curved bar subjected to:

a) Direct stress(σ_t)

b) Bending stress(σ_b)

In curved beam the bending stress distribution is non-linear. In curved beam, the neutral axis does not coincide with the centroidal or geometrical axis but is shifted towards the centre of curvature by distance ‘e’. This is due to non-linear distribution of bending stress.

Resultant stress at inner surface of crane hook (σ_i):

$$\sigma_i = \sigma_t + \sigma_{bi}$$

$$\sigma_i = \frac{P}{A} + \frac{Mh_i}{AeR_i}$$

Resultant stress at outer surface of crane hook (σ_o):

$$\sigma_o = \sigma_t + \sigma_{bo}$$

$$\sigma_o = \frac{P}{A} - \frac{Mh_i}{AeR_i}$$

The resultant stress at inner surface is additional of tension stress due to direct load and tensile stress due to bending moment. Thus, net stress is additional of two stresses. The resultant stress at outer surface is tensile stress due to direct load and compressive stress due to bending moment. Thus, net stress is different of two stresses.

Table 2: - Total stress in various cross section of hook (20 Ton)

CROSS SECTIONAL AREA	BENDING STRESS N/MM^2	DIRECT STRESS N/MM^2	TOTAL STRESS N/MM^2
CIRCULAR	127.61	10.14	137.75
TRIANGULAR	151.83	24.50	176.33
RECTANGULAR	101.51	12.25	113.76
TRAPEZOIDAL	109.94	16.33	126.27

4. FEA ANALYSIS FOR CRANE HOOK WITH DIFFERENT CROSS SECTION AREA

Finite element analysis consists of a computer model of a material or design that is stressed and analyzed for specific results. It is used in new product design and existing product refinement. For the FEA analysis cad model of crane hook is prepared in Creo 2.0.Anysis workbench 14.5 is used for static structural analysis for crane Hook.

4.1 Mechanical Properties

Table 3:-Mechanical properties of SAE 1040 [4]

Quantity	Value	unit
Young's Modulus	210000	Mpa
Tensile Strength	550-630	Mpa
Elongation	8-25	%
Density	7800	Kg/m^3
Yield Strength	320-530	Mpa

Quantity	Value	unit
Young's Modulus	210000	Mpa

4.2 Setup

In the setup window the different boundary conditions given to the crane hook is applied which is shown in below figure the fix support is given on the top shank of the hook.

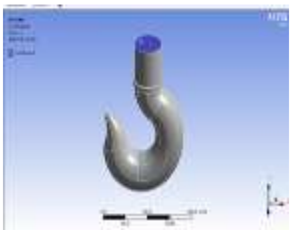


Fig 5:- Fixed support

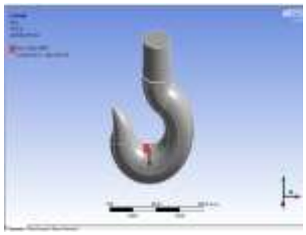


Fig 6:- Fixed load

Fixed support is applied on the top shank of the crane hook and 20 Ton load is applied on crane hook with cross sectional area and stress produced on crane hook is calculated and optimum cross sectional area is selected.

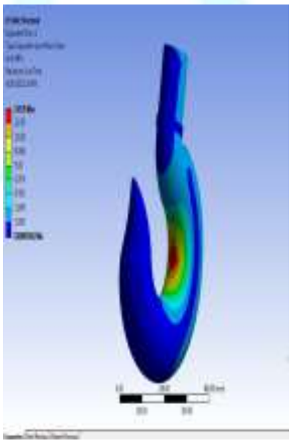


Fig 1:-Stress in Circular Hook

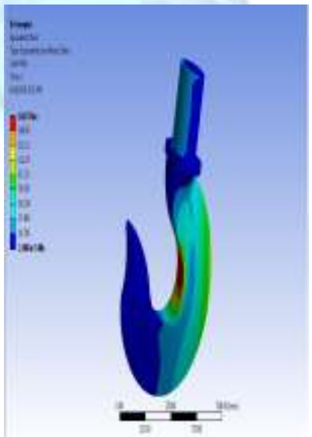


Fig 2:-Stress in triangular Hook

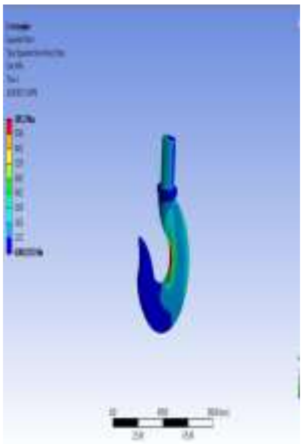


Fig 3:-Stress in Rectangular Hook

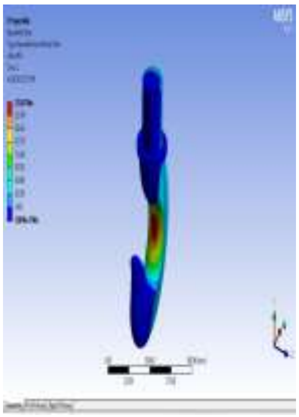


Fig 4:-Stress in Trapezoidal Hook

From the previous figures describe the stress and deformation produced in crane hook when hook is loaded. The results are displayed below in form of table for different cross sectional area and different load condition.

Table 5: - Comparison between analytical stress and von misses stress (20 Ton)

Sr No	Cross section	Analytical stress	Von misses stress	% Error	Deformation (mm)
1	Circular	137	143.95	4.3	0.5381
2	Triangular	176	168.7	4.54	0.9807
3	Rectangular	113	109.17	3.38	0.5517
4	Trapezoidal	126	131.67	3.96	0.5823

The results of the ANSYS are within the range of error. So this can be used in optimum model selection.

Table 6:- Comparison between Weight & Stress in Hook

Sr No	Cross section	Weight (kg)	Von misses stress (N/mm^2)
1	Circular	134.28	143.95
2	Triangular	66.75	168.7
3	Rectangular	116.16	109.17
4	Trapezoidal	87.018	131.67

So from the above table we can see that the Hook with Trapezoidal cross sectional area has minimum weight and stress compared to the other cross sections of crane Hook.

4.3 Optimization in crane Hook

After performing the static structural analysis in various section of crane hook we can see the stress produced in crane hook as shown in below figure. We can see that the stress produced in the nose portion of hook is minimum so by removing the material in such way that there is no effect of material removal in stress pattern produced in crane hook.

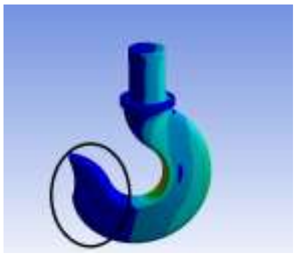


Fig 7:-Stress pattern in crane hook

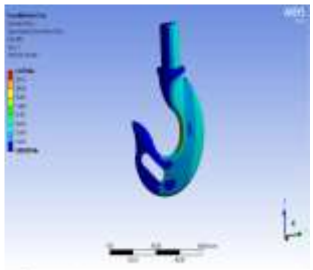


Fig 8:-Stress produced in modified crane hook

Table 7:-Comparison of results between old model and modified model

	Crane Hook (20 Ton)	
	Before	After Modification
FEA stress (N/mm^2)	131.67	134
Deformation (mm)	0.582	0.582
Weight (kg)	87.18	81

4.4 Safe working condition for crane Hook

$$\text{Design stress} < \frac{\textit{yeild point stress}}{\textit{factor of saftey}}$$

$$131 < \frac{320}{2}$$

$$131 < 160$$

The above result shows that the modified design for crane hook is safe.

5. CONCLUSION

For the evaluation of strength and durability of machine element stress concentration factor are generally used. In order to optimize the weight of the crane hook, the stress pattern produced in crane hook is used. Material is removed from nose portion is a feasible way of weight optimization of crane hook. Finally the optimized Crane Hook is 7.08% lighter than the original model of crane Hook. For the further optimization crane Hook is modeled with I section and should be analyzed for better results.

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