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Computer Aided Analysis, Design and Optimization of EOT Crane Hook

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Abstract— Electric overhead travelling crane is commonly known as EOT crane, which is commonly used in almost all industries. Main purpose of using this crane is to lift the load from one place to another which is beyond the lifting capacity of humans. Hook is the most stressed part as it is the component where load is attached with the help chain or rope. So the main aim of this paper is to design crane hook for 500 kN load lifting capacity for three different type of cross sections namely circular, rectangular and trapezoidal and to minimize its volume. The cross section which has least stress is considered for optimization. Pro-e 5.0 wildfire is used as a modeling software and ANSYS 11.0 is used for carrying out analysis.

Keywords- Crane, Crane hook, Pro-e, ANSYS, ANSYS Workbench, Shape optimization.

I. INTRODUCTION

Electric Overhead Travelling Crane is the most adaptable and the most widely used type of power driven crane for indoor services. It serves a larger area of floor space within its own travelling restriction than any other permanent type of hoisting arrangement. As the name implies, this type of crane is provided with the movement above the floor level and hence occupies no floor space and this can never interface with any movement of the work being carried out at the floor of the building. It is classified as a Single Girder or Double Girder. Hook is the most stressed part as it is the component where load is attached with the help of chain or rope. As of now very less literature is available related to this field.

II. DESIGN OF CRANE HOOK

EOT crane hook is designed for 500 kN load capacity. Material selected is 20C15. This material has modulus of elasticity (E) 200 GPa and Poisson's ratio (μ) 0.30.

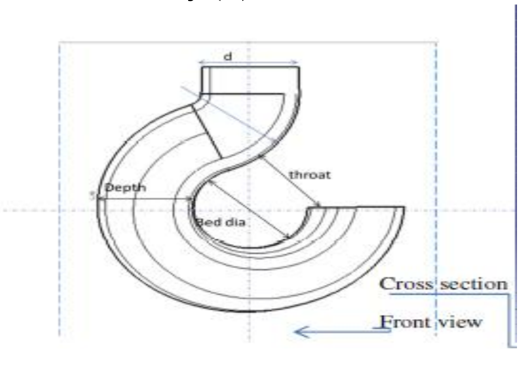

Figure 1. Basic dimensions of crane hook

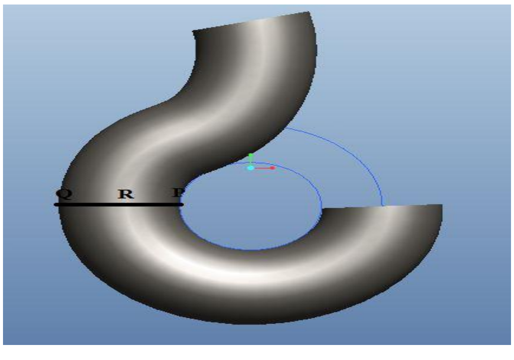

Figure 2. Stress at points to be known

Hook bed diameter (C) is given by the formula,

$$C = \mu(P)^{1/2} \text{ cm}$$

Where, P = working load,

C = bed diameter,

μ = material constant varying from 3.80 to 7.60

Now considering μ = 4.24 (for economy of material)

C = 30 cm = 300 mm

Throat of the hook (T) is taken as,

T = 0.75C = 225 mm (empirical relation)

Depth of hook (d) = $3.2\sqrt{P} + (C/10)$

Substituting the values, we get, d = 256.20 mm

Safe load (Proof load) = F = 1.7 x 500 = 850 kN = 85 Tons

III. THEORETICAL STRESS CALCULATIONS

For simplifying the analysis, a crane hook is assumed as a curved beam. In case of straight beams under bending, the neutral axis of cross-section coincides with its centroidal axis and bending stress distribution in the beam is linear. But in case of the curved beams, the neutral axis of cross-section is located between centroidal axis and centre of curvature and bending stress is non-linear in nature. Stress distribution in a curved beams is useful in the design of crane hooks, frames of punches, presses etc.

Bending stess in curved beam is calculated as,

$$\sigma_b = My/ Ae (R_n - y)$$

Direct stress is calculated as,

$$\sigma_r = \sigma_b + (F/A)$$

Refer Fig. 2 which shows the points where stresses are found out and values are tabulated as below

Table 1. Stress at different points of crane hook

Type of Hook Cross Section	Outer Face of Hook **Q**	Mid Point of Hook **R**	Inner Face of Hook **P**
Circular	120.35	32.98	236.47
Rectangular	96.87	32.98	173.02
Trapezoidal	108.60	48.52	147.17

After calculating the theoretical stresses at different points namely Q (outer face of hook), R (mid point of hook) and P (inner face of hook). It was found that trapezoidal cross section has minimum stress concentration compared to circular and rectangular cross section. Hence trapezoidal cross section was taken for optimization.

IV. ANSYS RESULTS

After theoretical calculations, crane hook was modeled using Pro-e wildfire 5.0 software for all three cross sections and then .prt file was converted to .igs file and then exported the geometry in ANSYS. Upper part of the hook was fixed and on curved surface load was applied.

Table 2. Stress and deflection in hook cross sections

Type of Hook Cross Section	Stress (N/mm^2)	Deflection (mm)
Circular	239.490	1.988
Rectangular	181.194	1.502
Trapezoidal	174.359	1.647

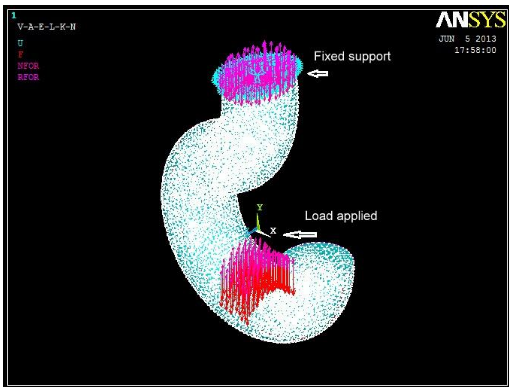

Figure 3. Boundary conditions for crane hook

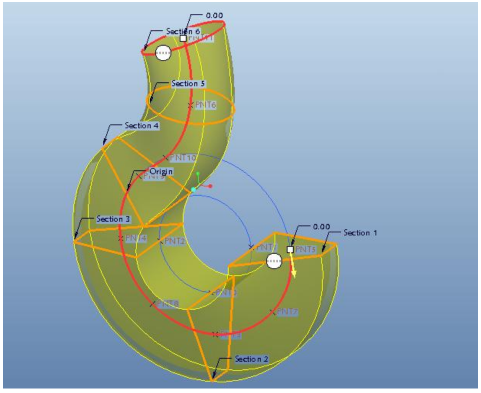

Figure 4. Trapezoidal section shows six different locations

From ansys results it is seen that trapezoidal shape has less stress concentrations as compared to other two cross sections. Hence trapezoidal cross section is selected for further optimization.

V. OPTIMIZATION

Trapezoidal cross section is selected for optimization as it has less stress concentration compared to circular and rectangular cross sections. As it is having less stress value compared to the other cross sections, hence it has much chances of modifying the geometry. Main objective of this study is to reduce volume of crane hook which is obtained by using shape optimization as a tool, which is carried in ANSYS Workbench 11.0. For carrying out this optimization six sections were created at six locations as shown in fig 4. and then, by modifying the geometric cross section at these six locations seven iterations were performed. Basic analysis of trapezoidal cross section obtained is used for comparing it with the iterations performed.

A. Iterations

For the Basic analysis, all dimensions of the previous cross section has been kept same, so that comparison can be carried out with reference to basic section.

Table 3. Change in cross sectional area for basic analysis

Section No.	Change in Cross Sectional Area at Section in %
Section 1	0
Section 2	0
Section 3	0
Section 4	0
Section 5	0
Section 6	0

Table 4. Result for basic case

Parameter and Unit	Values for Basic Cross Section
Volume (mm^3)	7.850 x 10^7
Surface area (mm^2)	1.440 x 10^6
Mass (ton)	0.616

Cross sectional area at six sections are varied in percent reduction or addition for finding the best optimum shape. And the result obtained is compared with results obtained for basic case. From shape optimization and ansys results, it was seen that stress is very less at the tip of the hook where as stress is maximum at section three. Hence material at the tip can be removed and material could be added at sections where stress is more. So by trial and error and shape optimization, optimum shape is obtained by performing six iterations. Result obtained after performing analysis is tabulated as below.

Table 5. Comparison between basic case and all iterations

Basic case and Iteration No.	Volume (x 10^7) (mm^3)	Stress (N/mm^2)	Deflection (mm)
Basic case	**7.850**	**147.37**	**1.6031**
1	7.660	164.64	1.5515
2	7.044	144.61	1.4211
3	6.517	161.56	1.3530
4	**6.400**	**111.18**	**1.0379**
5	5.800	191.58	1.2494
6	6.650	194.23	1.2644
7	6.810	162.28	1.4013

From the above table it is seen that, section derived in iteration no. 4 gives section, having less volume, less stress and less deflection as compared to basic cross-section. By comparing the results for basic cross-section and optimized cross-section, it is seen that, for optimized cross-section, volume is reduced by 22.65%, stress is reduced by 32.55% and deflection is reduced by 54.45%. Hence section derived in iteration no. 4 is the best possible optimized cross section of crane hook.

CONCLUSION

From the results obtained from ANSYS 11.0, hook with trapezoidal cross section has the less stress while hook with circular cross section has maximum stress. Hence, hook with trapezoidal cross section is selected further for optimization. While optimizing, number of iterations were conducted and it is seen that iteration no. 4 gives less values of stress, volume, deflection, mass and surface area. For iteration no.4, the reduction in cross sectional area at various sections and that of trapezoidal cross section are tabulated in table no.7 as shown below

Table 6. Changes in cross sectional area at six location for iteration No. 4

Section No.	Change in Cross Sectional Area at Section in %
Section 1	Decreased by 60%
Section 2	Decreased by 15%
Section 3	Increased by 15%
Section 4	Decreased by 0%
Section 5	Decreased by 15%
Section 6	Decreased by 15%

Table 7. Comparison of results between Basic case and Iteration No. 4

Parameter and Unit	Values for Basic Cross Section	Values for Optimized Cross Section	Change in Values
Volume (mm^3)	7.850 x 10^7	6.400 x 10^7	- 22.65 %
Surface area (mm^2)	1.440 x 10^6	1.220 x 10^6	- 18.03 %
Mass (Ton)	0.616	0.502	- 22.70 %

Table 8. Comparison of Results- Basic cross-section Vs. Optimized cross-section

Parameter and Unit	Values for Basic Cross Section	Values for Optimized Cross Section	Change in Values
Volume (mm^3)	7.850 x 10^7	6.400 x 10^7	- 22.65 %
Surface area (mm^2)	1.440 x 10^6	1.220 x 10^6	- 18.03 %
Mass (Tonne)	0.616	0.502	- 22.70 %
Stress (N/mm^2)	147.37	111.18	32.55
Deflection (mm)	1.6031	1.0379	54.45

A. Comparison of Shape

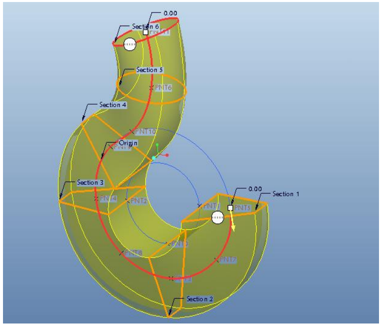

Figure 5. Basic trapezoidal cross sectional shape

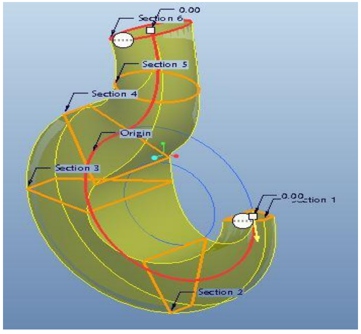

Figure 6. Optimum shape obtained in iteration no. 4

B. Comparison of Stress

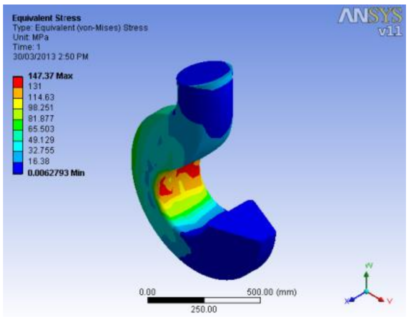

Figure 7. Stress pattern for Basic cross-section

Minimum value= 0.00 N/mm^2

Maximum Value= 147.37 N/mm^2

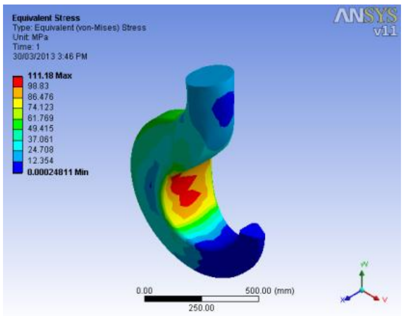

Figure 8. Stress pattern for Optimized cross-section

Minimum value= 0.00 N/mm^2

Maximum Value= 111.18 N/mm^2

C. Summary

Section derived in iteration no. 4 is the best possible optimized cross section of the hook. In optimized cross section, total volume is reduced by 22.65%, total surface area is reduced by 18.02%, total mass is reduced by 22.70%, stress is reduced by 32.55% and deflection is reduced by 54.45%.

FUTURE SCOPE OF STUDY

Literature available till date on this topic is very less and hence it has wide scope for carrying out analysis for hook with different cross sections. As it is mainly related to optimization hence the cross section which is to be optimized, should be so optimized that, the stability of structure and its function should not be affected.

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