Scientific Journal Impact Factor (SJIF): 1.711
International Journal of Modern Trends in Engineering and Research
IJMTER
ISSN (ONLINE) : 2349 - 9745
ISSN (PRINT) : 2393 - 8161

Design, Analysis and Optimization of Electric Overhead Travelling Crane Hook

Jayesh Rajendra Chopda[1] , S. H. Mankar[2]

[1]*Department of Mechanical Engineering, Trinity College of Engineering and Research, Pune.*
[2]*Department of Mechanical Engineering, Trinity College of Engineering and Research, Pune.*

Abstract— Electric overhead travelling crane popularly known as EOT crane, which is widely used in the industries for lifting and moving the loads. EOT crane consists of hoist mechanism, electric motors, end carriage, upper and lower block, bearing, drum, wire rope, pulley, hook, girder etc. Hook is used for lifting the load and it is one of the most stressed component of EOT crane, so it has been selected as an area of interest. Design of hook depends upon load lifting capacity, as per requirement. In this work, 50 kN is the working load lifting capacity. Modeling, design, analysis and optimization of EOT crane hook is carried out. Pro-Engineer software has been used for modeling and ANSYS software has been used for obtaining analysis results. From the stress diagram, dimensions are optimized as per stress pattern and saving in the material has been carried out without disturbing the stability and safety, as per IS code and prevailing engineering practice.

Keywords- Analysis, ANSYS, Crane hook, Design, EOT, Modeling, Optimization, Pro-Engineer

I. INTRODUCTION

A crane is hoisting device used for lifting or lowering load by means of a drum or lift wheel around which rope or chain wraps. EOT crane is a mechanical lifting device used for lifting or lowering the material and also used for moving the loads horizontally or vertically. It is useful when lifting or moving the loads is beyond the capacity of human. Cranes are commonly employed in the transport industry for loading and unloading of freight, in construction industry for the movement of materials; and in the manufacturing industry for the assembling of heavy equipment [1,2,3].

Appropriate solution of shape and materials of hooks enables the increase of loading capacity of hoisting machines [4]. In order to optimize the weight of the crane hook, the stress induced in crane hook must be studied [2]. It is also mentioned that till date very few papers are published regarding the stress analysis of crane hook [6].

Here design, analysis and optimization of EOT crane hook is carried out for 5 ton (50 kN) working load lifting capacity. Pro-Engineer software is used for hook modeling and ANSYS software is used for analysis.

II. METHODOLOGY

In this work, design, modeling, analysis and optimization of EOT crane hook is carried out.
Basic cross sectional dimensions for crane hook are calculated like bed diameter, throat diameter, depth of crane hook. Three type of cross-section are considered namely circular, rectangular and trapezoidal. Area and depth are kept constant for all cross sections.

As per dimensions calculated, all three types of cross-sections are modeled in Pro-engineer software and file is saved in .igs format. Then this file is imported in ANSYS software. By applying load and proper boundary constraints, analysis is carried out. From analysis results we get stress and

@IJMTER-2015, All rights Reserved

deformation. These results are then compared with theoretical calculations and section having least stress concentration is taken for further optimization.

In optimization, shape optimization is used as a tool. Based on stress pattern, the cross-sectional dimensions i.e geometry is modified, so that material from the area which is not stressed is removed. For shape optimization, sections are taken at twelve locations. These locations are used for modifying cross sectional dimensions as per stress pattern. Various number of cases are performed. Then results of basic case and other cases are compared. The section which has less volume, stress and deformation are within permissible limits without disturbing the safety and stability is selected.

This optimized cross-section is then given for manufacturing and testing as per IS code 3815-1969. Type of test includes Physical test, Chemical test, Hardness test, Ultra sonic test and Load test.

III. DESIGN AND ANALYSIS CRANE HOOK

3.1 Design of Crane Hook

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

$C=\mu^{1}\sqrt{P}$ ------- Eq. (1) [14]

C = 85 mm

Where,

W = Safe working or service load = 5.00 ton = 50.00 kN

P = Proof Load = (2.00 x W) = 10.00 ton = 100.00 kN

W_L = Limit Load = (1.25 x W) = 6.25 ton = 62.50 kN

μ^1 = Factor (For economic design, value ranges between 12 to 36)

= 26.73 from IS code 3815-1969 (for economy of material)

Throat of the hook (T) is calculated using empirical relation as,

T = (0.75 C) ----- Eq. (2)

= 64 mm

Depth of hook (d) is calculated using empirical relation as,

d = (0.82 C) ----- Eq. (3)

= 70 mm

Radius of hook (r) is given by,

r = (0.50 d)

= 35 mm

Area (A) is given by,

A = 3848.45 mm^2

Now, keeping the values of area and depth as constant, dimensions for circular, rectangular and trapezoidal cross-sections are obtained.

3.2 Theoretical Stress Calculations

For simplifying the analysis, a crane hook is assumed to be a curved beam. In case of straight beams under bending the neutral axis of the 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 nonlinear in nature.

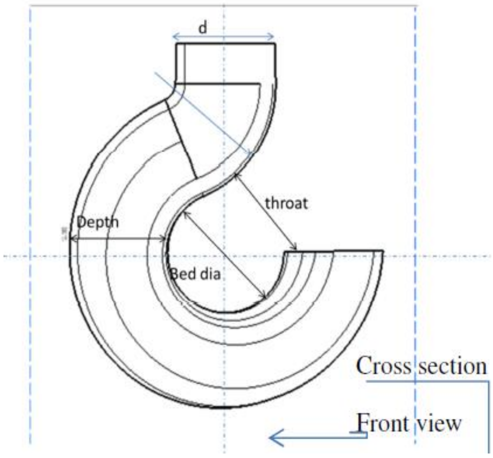

Figure 1. Crane hook notations

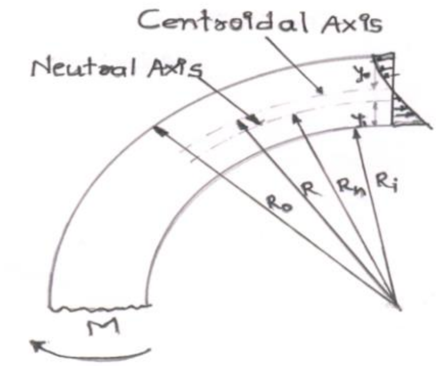

Figure 2. Hyperbolic stress distribution in curved beam

Figure 2 shows the hyperbolic stress distribution in curved beam. Stress distribution in a curved beam is useful in the design of crane hooks, frames of punches, presses etc.

Bending Stress Calculations

In a curved beam at any fibre at a distance y from the neutral axis,
Bending stress (σ_b) is given by,

$$\sigma_b = \frac{M \times y}{A \times e \times (Rn - y)} \quad \text{---------} \quad \text{Eq (4) [11]}$$

where,
M = Bending moment with respect to the centroidal axis
A = Area of cross-section
e = Eccentricity = distance between the centroidal axis to neutral axis
R_n = Radius of curvature of neutral axis to the fiber under consideration.

Resultant Stress Calculations

Resultant Stress (σ_r) = (direct Stress + bending Stress)

Resultant Stress (σ_r) is given by,

$$\sigma_r = \frac{W_L}{A} + \frac{M \times y}{A \times e \times (Rn - y)} \quad \text{---------} \quad \text{Eq (5) [11]}$$

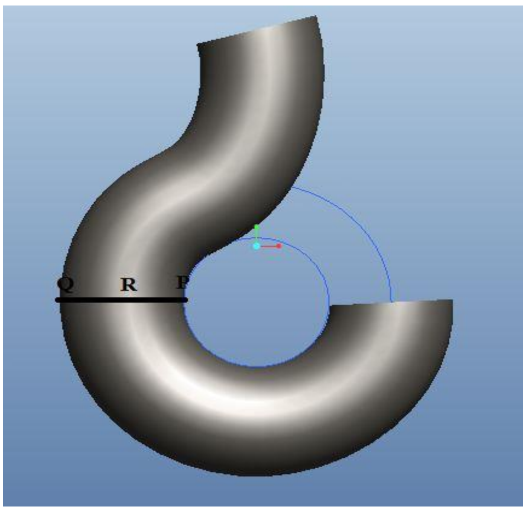

Figure 3. Sketch showing stress points P-Q-R

Stress at outer face of hook (Q), middle face of hook (R) and inner face of hook (P) are calculated theoretically. And results obtained for three cross-sections at three points are tabulated below.

Table 1. Theoretical Resultant Stress at Points P-Q-R

Type of Hook Cross-section	Outer Face of Hook Q (N/mm^2)	Mid Point of Hook R (N/mm^2)	Inner Face of Hook P (N/mm^2)
Circular	121.10	33.40	234.59
Rectangular	97.35	33.74	171.71
Trapezoidal	114.80	35.01	156.24

From the table it is seen that, on the outer face of hook (at point Q) stress is minimum in rectangular cross-section as compared to circular and trapezoidal cross-section, where as on the inner face of the hook (at point P) stress is minimum in trapezoidal cross-section as compared to rectangular and circular cross-section. As stress coming at inner face of hook (at point P) is of primary importance, hence trapezoidal section is selected.

3.3 Analysis of Crane Hook

Material selected for crane hook is Structural steel having following properties,
Modulus of elasticity (E) = 200000 N/mm^2 ,
Poisson's ratio (μ) = 0.30,
Density of steel = 7850 kg/m^3 = 78.50 kN/m^3,
Tensile strength = 460 N/mm^2

Modeling of EOT crane hook was done in Pro-E Wild Fire 5.0 with the obtained dimensions. Then its .igs file was created and imported in ANSYS Workbench 11.0. Element type chosen was SOLID92 which is 3D 10-Noded tetrahedral structural solid.

3.4 Input Data- Boundary Conditions

The upper surface is fixed (all degrees of freedom are zero) as shown by B and load is applied in negative Y- direction on selected surface as shown by A. Applied limit load is W_L = 62.50 kN. Similarly, the boundary conditions are same for rectangular and trapezoidal cross-section of hook. After applying boundary conditions for three types of cross-sections, output obtained is as shown below.

3.5 Output Results

3.5.1 Hook with Circular Cross-section

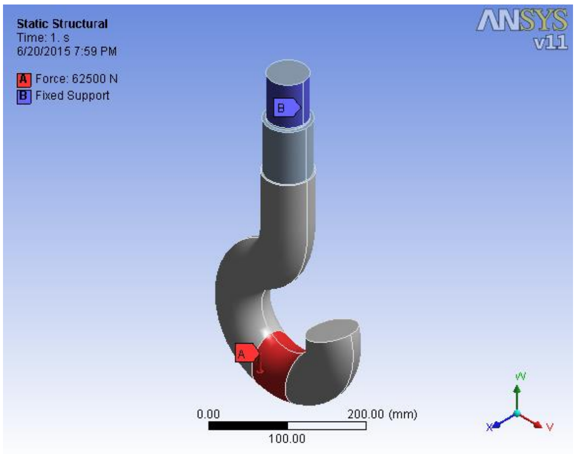

Figure 4. Boundary conditions for circular cross-section

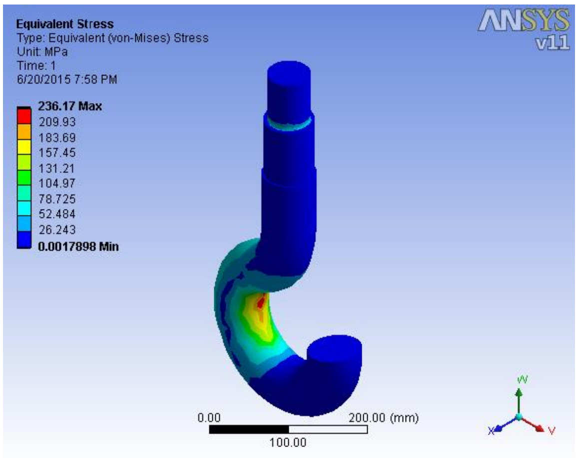

Figure 5. Stress pattern for circular cross-section
Maximum Value = 236.17 N/mm^2

3.5.2 Hook with Rectangular Cross-section

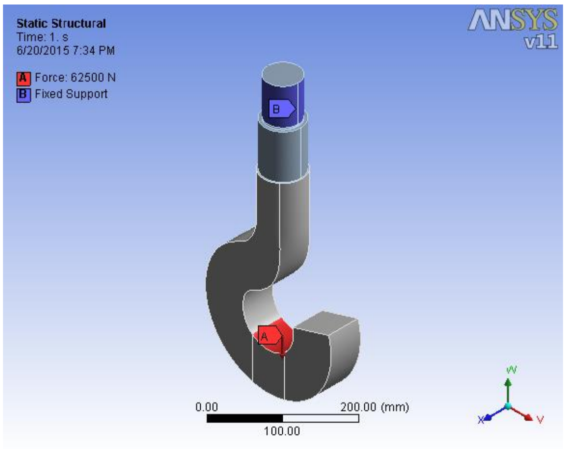

Figure 6. Boundary conditions for rectangular cross-section

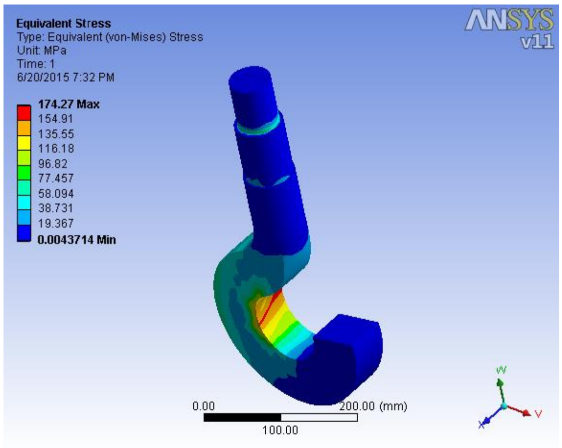

Figure 7. Stress pattern for rectangular cross-section
Maximum Value = 174.27 N/mm^2

3.5.3 Hook with Trapezoidal Cross-section

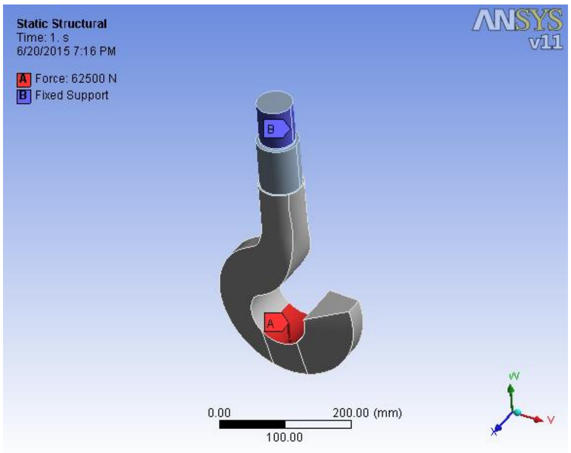

Figure 8. Boundary conditions for trapezoidal cross-section

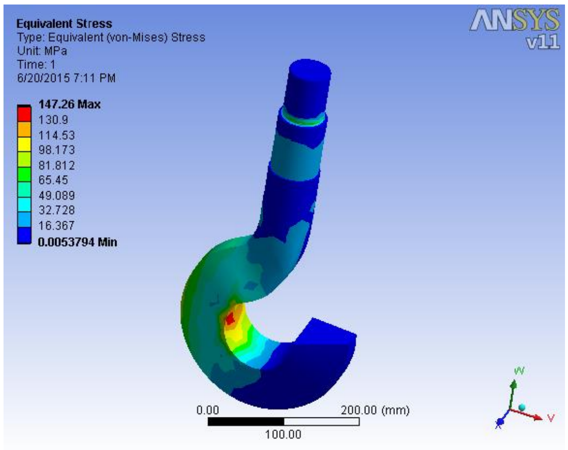

Figure 9. Stress pattern for trapezoidal cross-section
Maximum Value = 147.26 N/mm^2

Table 2. Results- Stress and total deformation

Type of Hook Cross-section	Theoretical Stress (N/mm^2)	Stress using ANSYS (N/mm^2)	Total Deformation (mm)
Circular	234.55	236.17	0.6702
Rectangular	171.71	174.27	0.5184
Trapezoidal	156.24	147.26	0.5245

From the above table it is seen that, trapezoidal cross-section has less stress as compared to circular and rectangular cross-section. Hence trapezoidal cross-section is selected for further optimization.

IV. OPTIMIZATION OF HOOK CROSS-SECTION

In optimization main aim is to minimize volume such that values of stress and total deformation remains within permissible limits without disturbing safety and stability. Shape optimization is the method used for optimizing hook and finding the best possible geometrical shape of hook with trapezoidal cross-section. ANSYS Workbench is used for carrying out analysis.

@IJMTER-2015, All rights Reserved

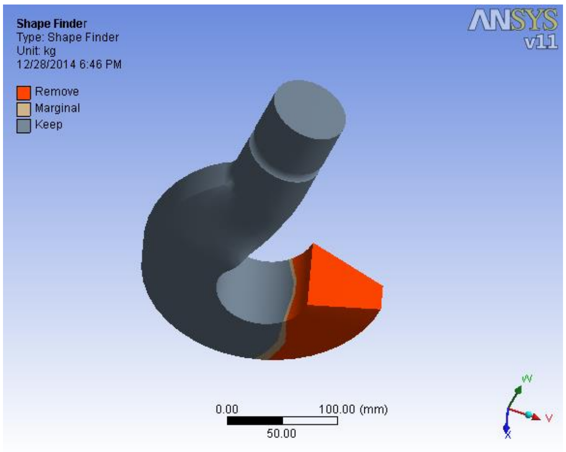

Figure 10. Hook portion for shape Optimization

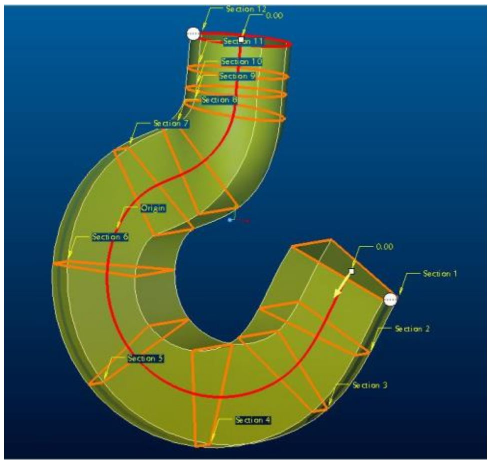

Figure 11. Sketch shows location for twelve cross-section

From this result we come to know that material at the tip of hook can be removed to reduce volume. So based on this result further optimization process is carried out.

Above figure shows hook having trapezoidal cross-section. Twelve locations have been selected on this cross-section to study the stress pattern. Dimensions between section 9-9 to section 12-12 kept same where as other dimensions modified. From the stress calculations, it is seen that stress at section 6-6 is more as compared to stresses at other sections, so the cross-sectional dimension needs modification. Now, we are taking the trapezoidal cross-section for further study of optimization. Hence, dimensions of the trapezoidal cross-section has been modified, such that sufficient cross-section is provided at section 6-6 to reduce the stress and extra sectional dimensions are reduced at other sections, where so much heavy cross-section is not required. After analysis in ANSYS, stress pattern has been studied and accordingly cross-sectional dimensions are so modified that the provided section is to be best utilized to its maximum permissible stress level. This way, optimization of hook cross-section can be achieved. Six cases are carried out and analysis results are compared with the basic case of trapezoidal cross-section.

4.1 Basic Case and Other Cases

Basic case means case of trapezoidal cross-section. Change in cross sectional dimension of other cases at section 1-1 to section 12-12 are compared with cross sectional dimensions of the basic case. Following table shows change in cross sectional dimensions of basic case and other cases.

Table 3. Change in cross-sectional dimensions

Section No.	Change in Cross-sectional Dimensions (%)						
	Basic Case	Case No. 1	Case No. 2	Case No. 3	Case No. 4	Case No. 5	Case No. 6
Section 1-1	0	67.5	20	32	62	67	72
Section 2-2	0	31	20	32	40	43	37
Section 3-3	0	19	15	32	37	36	37
Section 4-4	0	20	15	32	37	36	37
Section 5-5	0	20	15	32	37	36	37
Section 6-6	0	20	15	30	37	36	34
Section 7-7	0	20	15	30	37	36	34
Section 8-8	0	20	15	30	37	37	34
Section 9-9 to 12-12	0	18	20	22	24	26	27

@IJMTER-2015, All rights Reserved

As shown in table 3, there are 12 sections showing changes in cross-sectional dimensions at each section and after applying boundary conditions, results obtained are tabulated in table 4. Similarly six cases are carried out by changing cross-sectional dimensions at all 12 sections.

Basic Case (Trapezoidal cross section)

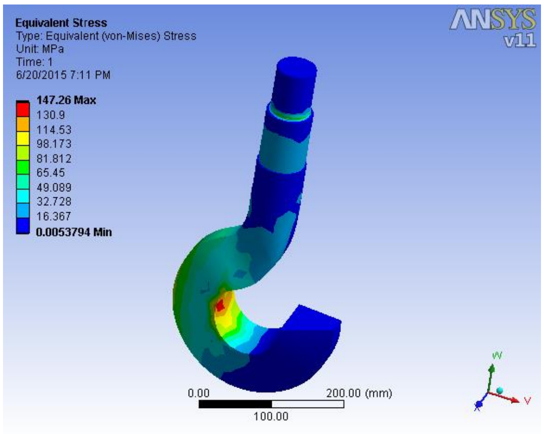

Figure 12. Stress pattern for basic case

Maximum Value= 147.26 N/mm^2

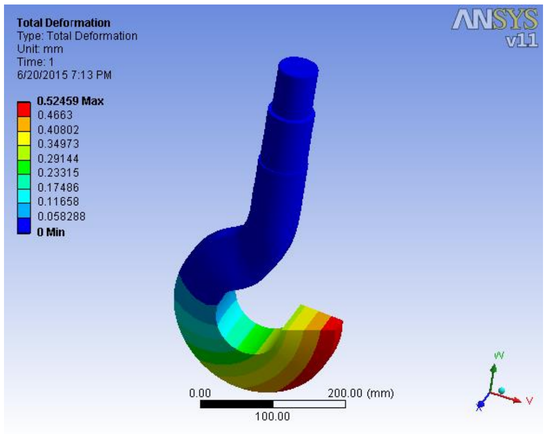

Figure 13. Total deformation pattern for basic case

Maximum Value= 0.5245 mm

Case No. 1

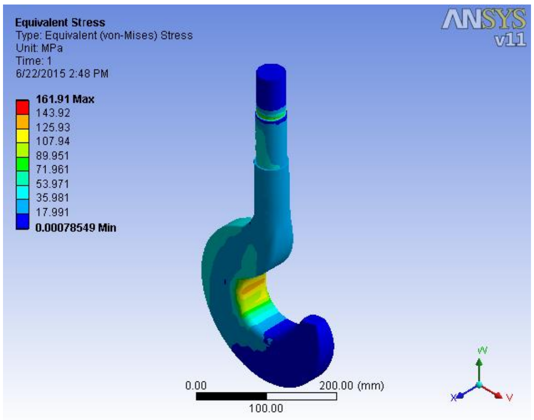

Figure 14. Stress pattern for case No. 1

Maximum Value= 161.91 N/mm^2

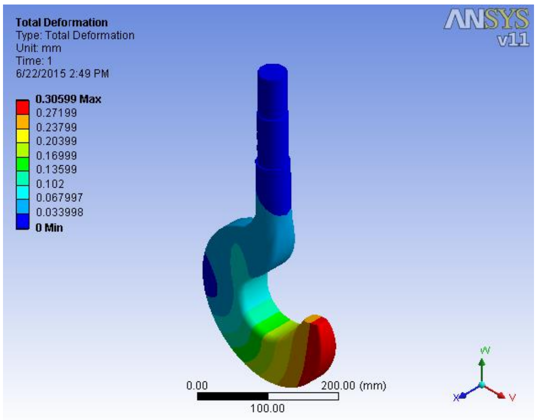

Figure 15. Total deformation pattern for case No. 1

Maximum Value= 0.3059 mm

Case No. 2

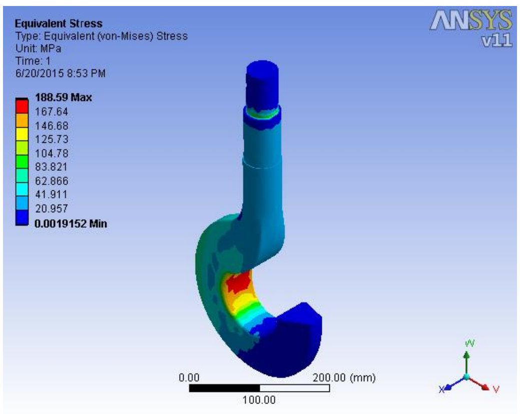

Figure 16. Stress pattern for case No. 2

Maximum Value= 188.59 N/mm^2

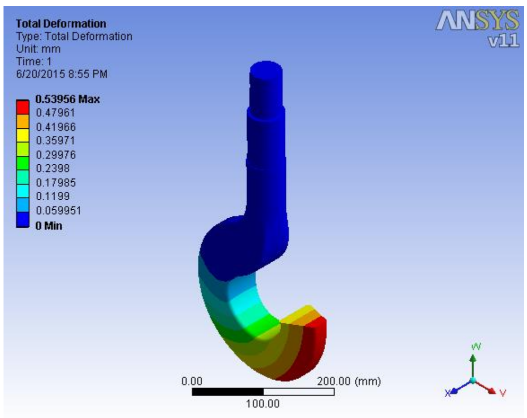

Figure 17. Total deformation pattern for case No. 2

Maximum Value= 0.5395 mm

@IJMTER-2015, All rights Reserved

Case No. 3

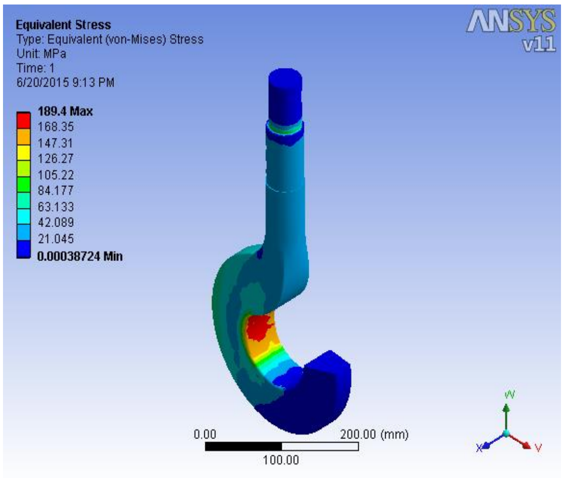

Figure 18. Stress pattern for case No. 3

Maximum Value= 189.40 N/mm^2

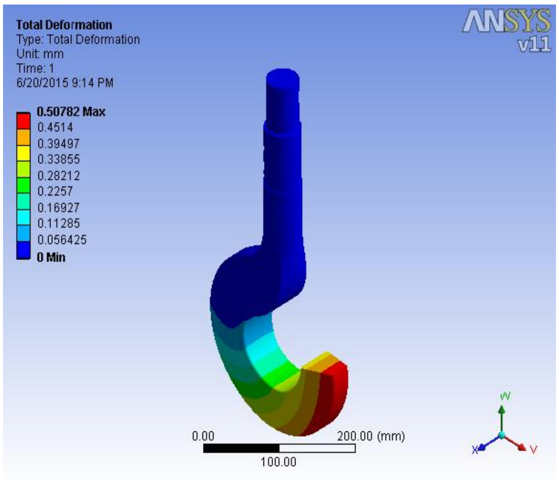

Figure 19. Total deformation pattern for case No. 3

Maximum Value= 0.5078 mm

Case No. 4

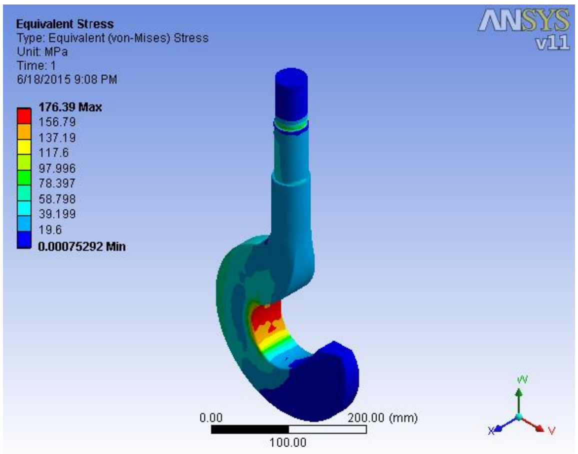

Figure 20. Stress pattern for case No. 4

Maximum Value= 176.39 N/mm^2

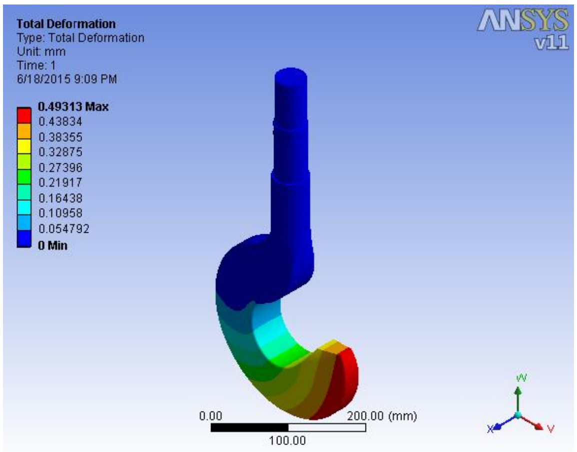

Figure 21. Total deformation pattern for case No. 4

Maximum Value= 0.4931 mm

Case No. 5

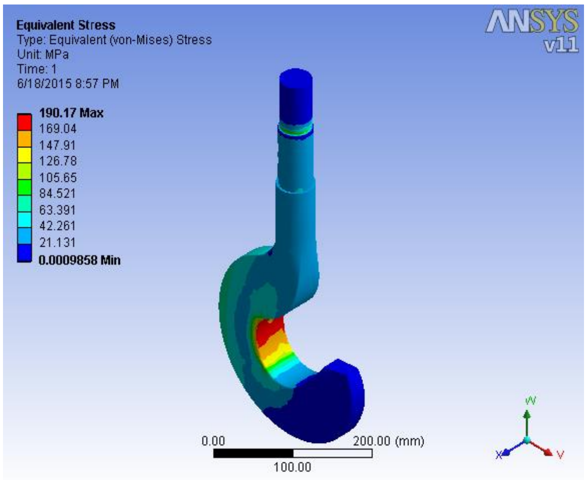

Figure 22. Stress pattern for case No. 5

Maximum Value= 190.17 N/mm^2

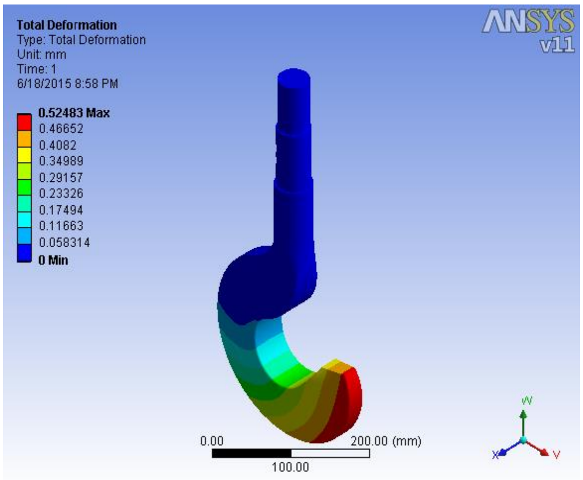

Figure 23. Total deformation pattern for case No. 5

Maximum Value= 0.5248 mm

Case No. 6 (Optimized case)

@IJMTER-2015, All rights Reserved

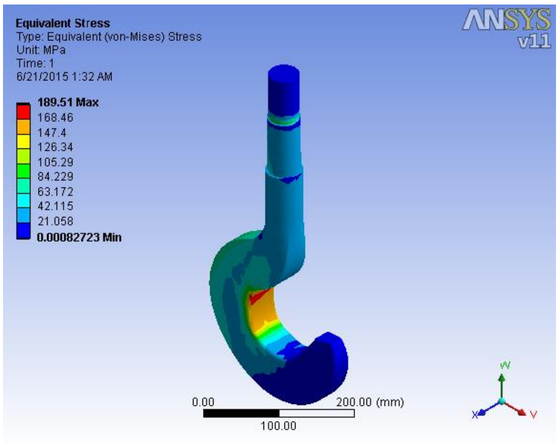

Figure 24. Stress pattern for optimized case
Maximum Value = 189.51 N/mm^2

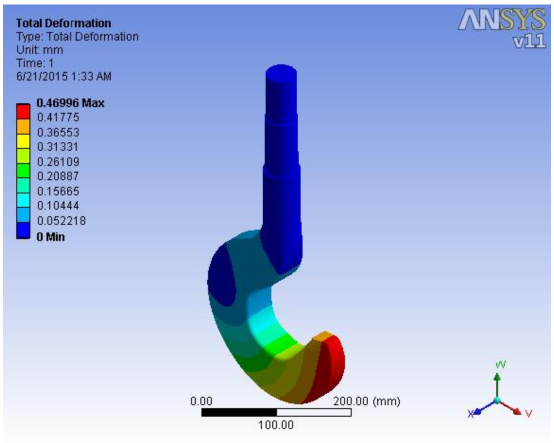

Figure 25. Total deformation pattern for optimized case
Maximum Value = 0.4699 mm

The result obtained are compared with the basic case and tabulated as below.

Table 4. Comparison of Results - Basic Case Vs All Other Cases

Basic Case and Case No.	Volume (x 10^6 mm^3)	Volume Change in %	Stress (N/mm^2)	Stress Change in %	Total Deformation (mm)	Total Deformation Change in %
Basic Case	**2.48**	**00.00**	**147.26**	**00.00**	**0.5245**	**0.00**
1	1.97	- 20.56	161.91	9.94	0.3059	- 41.67
2	1.87	- 24.60	188.59	28.00	0.5395	2.85
3	1.76	- 29.03	189.40	28.61	0.5078	- 3.18
4	1.73	- 30.24	176.39	19.78	0.4931	- 5.98
5	1.67	- 32.66	190.17	29.13	0.5248	0.01
Optimized Case	**1.62**	**- 34.67**	**189.51**	**28.69**	**0.4699**	**- 10.40**

From the above table, it is seen that, as compared to basic case, the section derived in case no. 6 gives optimized cross-section having less volume, less total deformation and stress is within permissible limit.

V. CONCLUSION

Results for basic cross-section and optimized cross-section are as below,

Table 5. Results for basic case and optimized case

Parameter and Unit	Basic Cross-section	Optimized Cross-section	Percentage Change
Volume (mm^3)	2.48 x 10^6	1.62 x 10^6	- 34.67
Stress (N/mm^2)	147.26	189.51	28.69
Total deformation (mm)	0.5245	0.4699	- 10.40

From the above table it is seen that, for the optimized cross-section volume is reduced by 34.67 %, total deformation is reduced by 10.40 %. Stress is within permissible limits and section is utilized properly without disturbing the safety and stability. Hence, optimized cross section gives reduction in volume, in turn gives saving in material, also saving in use of natural resources and ultimately saving in cost of the product.

@IJMTER-2015, All rights Reserved

REFERENCES

[1] Narvydas E. And Puodziuniene N, 2012, “Circumferential stress concentration factors at the asymmetric shallow notches of the lifting hooks of trapezoidal cross-section”, ISSN 1392-2007, MECHANIKA, 18 (2), pp. 152-157.
[2] Solanki Mahesh, Bhatt Antriksh, Rathour Anilkumar, 2014, “Design, Analysis and Weight Optimization of Crane Hook: A Review”, International Journal for Scientific Research & Development, 2 (09).
[3] Soni Nishant, 2013, “Crane-hook shape optimization and thermal analysis using finite element tool”, IJAIR, pp. 124-127.
[4] Ozer Derya, Erdil A. Burak, Gerdemeli Ismail, 2007, “Finite element approach to 3-D modelling and stress analysis for crane lifting hooks”, Eleventh International Research/Expert Conference, "Trends in the Development of Machinery and Associated Technology", Hammamet, Tunisia, pp. 1007-1010.
[5] Fetvaci M. Cuneyt, Gerdemeli Ismail, Erdil A. Burak, 2006, “Finite element modelling and static stress analysis of simple hooks”, Tenth International Research/Expert Conference “Trends in the Development of Machinery and Associated Technology”, Barcelona-Lloret de Mar, Spain, pp. 797-800.
[6] Tripathi Yogesh, Joshi U. K., 2013, “Investigation Stress of A Lifting Hook with Different Methods: A Review”, International Journal of Emerging Trends in Engineering and Development, 3 (1), pp. 195-200.
[7] Bhatia A., 2012, “Electric Overhead Travelling (EOT) Cranes and Hoists”, PDH Course M245
[8] Patel Apeksha K., Prof. Jani V. K., 2012-2013, “Design and dynamic analysis of 70 t double girder electrical overhead crane”, Journal of information, knowledge and research in mechanical engineering, ISSN 0975 - 668X, 02 (02), pp. 496-503.
[9] Suratkar Abhinay, Shukla Vishal, 2013, “3-D Modelling and finite element analysis of eot crane”, International journal of mechanical and production engineering, ISSN: 2320-2092, 1 (2), pp. 34-37.
[10] Nishimura Takuma, Muromaki Takao, Hanahara Kazuyuki, Tada Yukio, Kuroda Shigeyuki, and Fukui Tadahisa, 2010, “Damage Factor Estimation of Crane-Hook (A Database Approach with Image, Knowledge and Simulation)”, 4th International Workshop on Reliable Engineering Computing, pp. 623-636.
[11] Dr. Sharma P.C. and Dr. Agarwal D. K., 2012, “A Textbook of Machine design (SI units)”, 11th edition, S. K. Kataria and sons, New Delhi, pp.986.
[12] Parmanik Rajendra, “Design of hoisting arrangement of eot crane”, posted on July 26, 2008 http://rparmanik.wordpress.com/about-me-rajendra-parmanik/
[13] ISSP 1859-1969 (industry standard steel plant).
[14] IS 3815-1969 “Indian standard Specifications for point hooks with shank for general engineering purpose (reaffirmed 2000)”.