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DESIGN AND ANALYSIS OF CRANE HOOK WITH DIFFERENT CROSS SECTIONS AND MATERIALS

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Abstract: Now-a-days Crane Hook is mainly used for the lifting and moving of heavy objects or products. Crane hook mainly works on hydraulic systems to provide a much greater lifting capability. Whenever the lifting is taking place there is a chance of failure of the crane hook due to the stress or by the repetitive loads, so that it can cause huge loss in terms of assets and it can increase death rate. So the design of hook and the materials used for the preparation of the hook need to be good. Hook is highly liable component and are always subjected to failure due to the amount of stresses concentration which can eventually lead to its failure. In the present work a crane hook is designed using different materials with different cross sections and the von-Mises stress distribution and total deformation, are calculated for a 5 ton load applied at an ambient temperature of 25°C. Real time pattern of stress concentration in 3D model of crane hook are obtained. This work is considered mainly to gain an insight on deformation and stress distribution in hook. Different materials like Wrought Iron, Stainless Steel, Structural Steel and Forged steel are considered for the analysis. Four cross-sections like triangular, rectangular, circular and trapezoidal are used for lifting in practical scenarios (under normal working conditions).The modelling of crane hook is done in PTC CREO. The analysis of hook is carried out in ANSYS WORKBENCH. So by predicting the stress concentration area, the stress failure rates are estimated for different materials and cross-sections with the sole intention of enhancing crane hook life. It is to be found that Forged Steel with trapezoidal cross-section is best suited for the Crane Hook.

***Keywords- Crane hook, Stress concentration,* Von-Mises, PTC CREO, ANSYS WORKBENCH.**

I. INTRODUCTION

Cranes are modern machines that are primarily utilized for material developments in constructional locales, creation lobbies, sequential construction systems, stockpiling zones, control stations and comparative spots. Crane Hooks are the parts which are for the most part used to lift the overwhelming burden in businesses and constructional work. As of late, excavators having a crane-Hook are generally utilized in development works site. one reason is that such an excavator is helpful since they can play out the regular burrowing assignments and in addition the suspension works. Another reason is that there are work destinations where the crane trucks for suspension work are not accessible due to the limitation of the site. All in all an excavator has predominant mobility than a crane truck. not very many individuals have just dealt with the enhancement of crane Hook. by and large material compose and cross segment region and sweep are plan parameter that influences the heaviness of crane Hook. Cast iron, structural steel is for the most part utilized as assembling material for crane Hook. crane hook are various types for the present scenario hook with eye and shank will be used

figure 1.1 Crane Hook

Crane Hooks are exceedingly obligated segments and are constantly subjected to disappointment because of aggregation of vast measure of stresses which can in the long run prompt its failure. Crane Hooks are the segments which are by and large used to lift the substantial load in ventures and constructional destinations. A crane is a machine, furnished with a derrick, wire ropes or fastens and bundles used to lift and move substantial material. Cranes are for the most part utilized in transport, construction and assembling industry. Overhead crane, versatile crane, tower crane, adjustable crane, gantry crane, deck crane, jib crane, loader crane are a portion of the ordinarily utilized cranes. A crane Hook is a gadget utilized for snatching and lifting up the heaps by methods for a crane. It is fundamentally a raising apparatus intended to draw in a ring or connection of a lifting chain or the stick of a shackle or link attachment. Crane Hooks with trapezoidal, roundabout, rectangular and triangular cross area are regularly utilized. In this way, it must be outlined and fabricated to convey most extreme execution without disappointment. In this way the point of this examination is to contemplate pressure distribution design inside a crane Hook of different cross segments utilizing systematic, numerical and trial strategies[1]. To limit the disappointment of crane Hook, the pressure initiated in it must be examined. A crane is subjected to nonstop stacking and emptying. This may causes weakness disappointment of the crane Hook however the heap cycle recurrence is low. On the off chance that a break is produced in the crane Hook, predominantly at stretch focus zones, it can make crack of the Hook and lead genuine mischance's. In bendable break, the split proliferates persistently and is all the more effortlessly discernible and consequently favoured over weak crack. In weak break, there is sudden spread of the split and the Hook bombs all of a sudden. This sort of break is extremely perilous as it is hard to identify [2].

In this undertaking work Stress examinations of crane Hook with various cross areas and load conveying limit is 5 ton according to Seems to be: 3815-1969 have been conveyed out[3]. The crane Hook is fabricated by for the most parts with Wrought iron, Structural Steel, Stainless Steel , forged steel .The 3-D model of the Hook is designed utilizing PTC CREO. Furthermore, the static examination on the Hook is continued by FEM programming ANSYS. From the view purpose of well being, the Stress incited in crane Hook must be broke down with a specific end goal to diminish disappointment of Hook.

II. LITERATURE REVIEW

The relative examination by Mr. A Gopichand. Et al. [4] has demonstrated that taguchi strategy can be utilized for enhancement of crane Hook. In his work improvement of plan parameters is completed utilizing Taguchi technique. He considered aggregate three parameters and made blended levels a L16 symmetrical cluster. The ideal mix of info parameters for least Von-mises stresses Are resolved. From that cluster he discovered ideal mix of zone sweep for least Von-mises pressure.

Slam Krishna rathour. et al. [5] has taken a shot at a general approach for the various reactions. He started optimization with the relapse models to compute the connection between's reaction capacity and control work. A target work is created with the assistance of framework for gathering different reaction works together. By utilizing fake neural system (ANN) to discover the reaction work. He utilized different target hereditary calculations (MOGA) to improve shape capacity of the crane Hook for same limit by considering blend of target capacity to discover the streamline state of crane Hook. The outcome demonstrates that the decrease in mass and in addition wellbeing of factor isn't bothered. To discover the outcome by MOGA he utilized fake neural system for reaction capacity and gauge the connection with control capacity, and proselytes the target work into multi target calculation. For the mass advancement entire process is done in three stages. At a beginning it utilizes test outline with focal composite plan strategy. Also it use counterfeit neural system to ascertain the reaction of each parameter in type of connection with yield work. In the event of crane Hook shape reaction is ascertained for the advancement of mass and factor of security. The given strategy demonstrates the connection amongst results and reaction work.

Nishant soni et al. [6] has chipped away at the improvement of low carbon steel for its self-weight. The self-weight and segment stack going ahead the crane– Hook subsequently he worked with target of the streamlining of the mass for stick Hook under the impact of static load involving the pinnacle weight stack. He utilized limited component examination for the shape streamlining of crane Hook and also for approval of definite geometry. He likewise considered geometry and assembling oblige amid advancement process and results demonstrates that upgraded stick Hook is 14% lighter then unique crane Hook.

Chetan N. Benkar.et al. [7] took a shot at crane Hook for the streamlining. He evaluated the pressure example of crane Hook in its stacked condition by setting up a strong model with the assistance of ANSYS 14 workbench. By considering different cross sectional territory he acquired ongoing example of stress fixation with the assistance of 3-D model of crane Hook. His similar investigation demonstrates that the adjustments in result for various topology of cross segment for same cross segment zone. He computed pressure design for different cross segment topology, for example, rectangular, triangular, trapezoidal, and roundabout by keeping the territory consistent and found that rectangular cross sectional zone gives least pressure and twisting level.

Rashmi Uddanwadiker.et.al. [8] has ascertained the pressure design delivered because of the heap on Hook. He looked at the explanatory after effect of stress and the pressure assessed from the FEM examination and found that there was 8.26% percent mistake between them. He found that conceivable purpose behind the variety is because of the supposition that 1) stacking is considered as point stacking in systematic computation while it is gone up against a group of hubs in ANSYS.2) cross segment zone s thought to be trapezoidal and 3) plane segment stays plane after misshapening. His entire examination is an activity to build up a FEA method, by approving the outcomes with the assistance of photograph versatility. Photograph versatility test depends on the property of birefringence. From the investigation he found the territory at which high pressure focus happens. For the plan change if the inward side of Hook at the bit of most extreme pressure is broadened then the pressure will get diminished. He evaluated that the pressure is diminished up to 17% if the thickness of the internal ebb and flow is lessened by 3mm

C. Oktay Azeloglu.et al. [9] has contemplated the technique for the estimation of stress in view of the diverse presumption. First of these technique is estimated figuring strategy and in this technique ebb and flow of the Hook is dismissed and computations depend on a straight shaft. He embraced Timoshenko‟s bended hypothesis and Bach estimate on the basic Hooks computation. He utilized limited component technique to assess the pressure and contrasted it and distinctive strategy

III. DESIGN OF HOOK WITH DIFFERENT CROSS-SECTIONS

Crane hook dimensions are evaluated according to the "Indian standard specification" (IS 3815-1969)[10] for the 5 tons of load

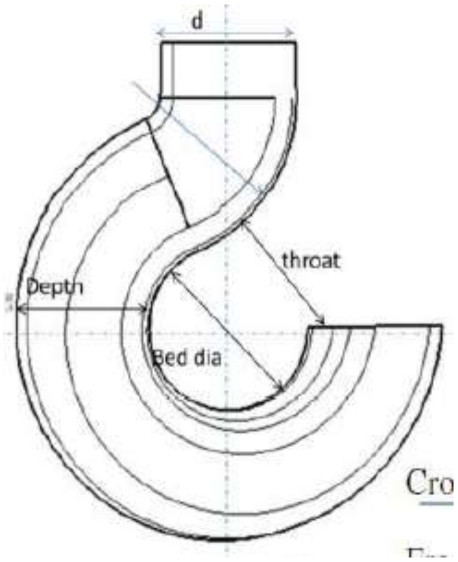


Figure 3.1:Crane hook with main dimensions

As shown in figure there are 3 important dimension in crane hook namely: Bed diameter, Throat, Depth .

3.1.Dimensions of the hook are taken as follows

1) Bed diameter (C):

$$C = x\sqrt{P}, mm$$

Where, P=load, KN x=constant ranging between 12 to 24. for econonmic design,x should be as minimum as possible

$$C = x\sqrt{P} = 12\sqrt{5 * 9.81} = 84\ mm$$

2) Throat of Hook (J):

$J = 0.75C = 0.75 * 84 = 63\ mm$

3) Depth of the Hook(h):

depth of the hook is calculated using empirical relation as,

$h = 0\ .82C = 0.82 * 84 = 69.30\ mm$

Here depth of the hook is equal to the radius of circular cross section by evaluating area of circular cross section and keeping the values of depth and area as constant dimensions for rectangle, triangular and trapezoidal cross-sections are obtained

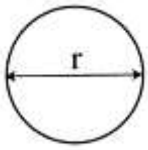
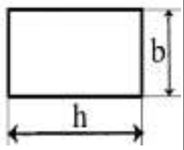
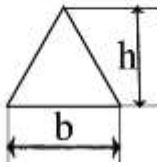
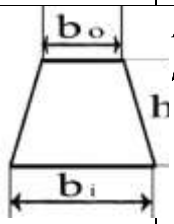
Cross-sections	Dimensions
	Depth of the hook is equal to the radius of the circle: $r = \text{h} = 69.30\ mm$ Area of circular cross-section: $A = \pi r^2 = \pi * 69.30^2$ $= 3771.86\ mm$
	To find b Area of rectangle=bh, so $b = \frac{A}{h} = \frac{3771.86}{69.30} = 54.42\ mm$
	Area of triangle= $\frac{1}{2}bh$ $b = \frac{2 * A}{h} = \frac{2 * 3771.86}{69.30}$ $= 108.85\ mm$
	Area of trapezoidal = $\frac{1}{2}(b_i + b_o)h$ $b_0 = 0.49C = 34.22\ mm$ $b_i = \frac{2 * A}{h} - b_0$ $= \frac{2 * 3771.86}{69.30} - 34.22$ $= 74.63\ mm$

Table 3.1 dimensions of different cross-sections

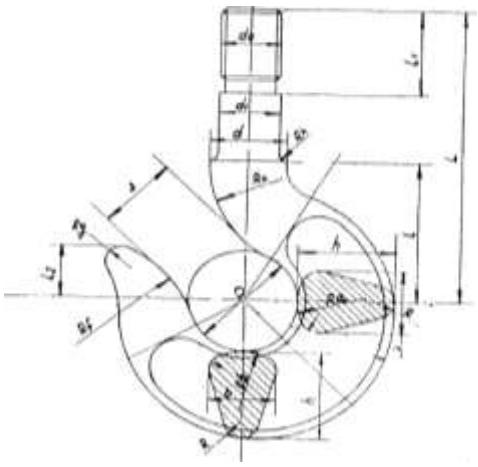


Figure 3.2:Crane hook with perimeters

Other perimeters for the Crane hook

$$l = 1.31C = 1.31 \times 84 = 110.04\ mm$$
$$l_1 = 0.83C = 0.83 \times 84 = 70\ mm$$
$$l_2 = 0.5C = 0.5 \times 84 = 42\ mm$$
$$R_f = 1C = 1 \times 84 = 84\ mm$$
$$R_e = 0.92C = 0.92 \times 84 = 77.2\ mm$$
$$d = 0.6C = 0.6 \times 84 = 56\ mm$$
$$d_1 = 0.59C = 0.59 \times 84 = 50\ mm$$
$$d_0 = 48\ mm$$

IV. THEORITICAL ANALYSIS OF CRANE HOOK

The crane hook is a curved beam [11], basic hypothesis of bending for shallow, straight bar does not yield precise outcomes. Stress dissemination over the depth of such bar, subjected to pure bending, is nonlinear (to be exact, hyperbolic) and the situation of the neutral surface is displayed from the centroidal surface towards the Centre of Curvature. If there should be an occurrence of hook as appeared in Figure , the individuals are not slim but instead have a sharp bend and their cross-sectional measurements are expansive contrasted with the span of curvature[12].

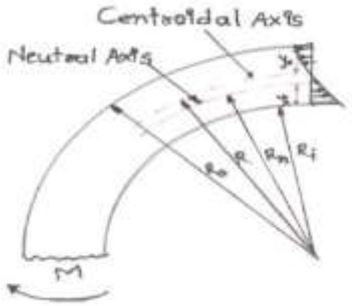


Figure 4.1 Stress distribution in curved beams

4.1Trapezoidal Cross section stress calculation

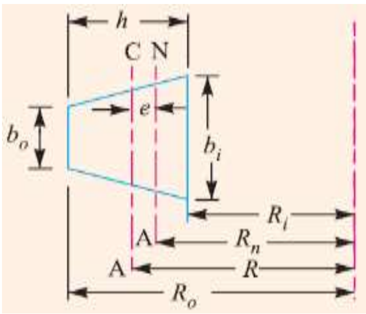


Figure 4.2 Trapezoidal stress perimeters

Load carrying capacity, $F = 5\ tonne = 49050\ N$

Bed diameter of hook, $C = 84$ mm

Depth of the triangular section, $h = 69.30$ mm

Breath of the triangular section,

$b_i = 74.63$ mm, $b_o = 34.22$ mm

Inner radius of curve beam, $R_i = \frac{C}{2} = 42.26\ mm$

Outer radius of curve beam,

$$R_o = R_i + h = 111.56\ mm$$

Radius of the neutral axis, $R_n = \frac{\left(\frac{b_i+b_0}{2}\right)h}{\left(\frac{b_i R_o - b_0 R_i}{h}\right)\log_e\left(\frac{R_o}{R_i}\right) - (b_i - b_0)} = 67.4\ mm$

Radius of centroidal axis from inner fiber,

$R = R_i + \frac{h(b_i+2b_0)}{3(b_i+b_0)} = 72.62\ mm$

Distance of neutral axis to centroidal axis,

$e = R - R_n = 5.22\ mm$

Distance of neutral axis to inner radius,

$C_i = R_n - R_i = 25.14\ mm$

Distance of neutral axis to outer radius ,

$C_0 = R_0 - R_n = 44.16\ mm$

Distance from centroidal axis to force,

$I = R = 72.62\ mm$

Area of the cross-section,

$A = \frac{1}{2}bh = 3771.86\ mm^2$

Bending moment about centroidal axis,

$M_b = F \times I = 3562109.1\ N.mm$

Direct stress, $\sigma_d = \frac{F}{A} = 13.5\ N/mm^2$

Bending stress at the inner fiber,

$$\sigma_{bi} = \frac{M_b C_i}{AeR_i} = 126.63\ N/mm^2$$

Bending stress at the outer fiber,

$$\sigma_{bo} = -\frac{M_b C_o}{AeR_O} = -81.61\ N/mm^2$$

Combined stress at inner fiber,
$\sigma_{ri} = \sigma_d + \sigma_{bi} = 139.63\ N/mm^2$(Tensile)
Combined stress at outer fiber,
$\sigma_{ro} = \sigma_d + \sigma_{bo} = 71.61\ N/mm^2$(Compressive)

same steps need to be followed to find other cross-sectional stresses by replacing their respective formulas of cross-sections

Cross-sections	Theoretical stress
Circular	177.43
Trapezoidal	139.63
Rectangle	153.46
Triangular	146.79

Table 4.1: Theoretical stress of different cross-section

V. MODELING OF CRANE HOOK IN PTC CREO

3D CAD Model of Crane hook with different cross-sections will be carried out in (PTC CREO) with the help of designed dimensions (3.1).By using simple tools, swept blend as options the 3D CAD model is drawn.

Figure 5.1: 3D Model of Rectangular and Circular Cross-sections Crane hook

Figure 5.2: 3D Models of Triangular and Trapezoidal Cross-section Crane hook

VI. FINITE ELEMENT ANALYSIS OF CRANE HOOK USING ANSYS

6.1 Ansys work setup

The created 3D models are imported in to the ANSYS WORKBENCH by means of .IGES (Initial Graphics Exchange Specification) format. This is a general format used for exchanging of CAD models data into another software's.

The work setup is placed under static analysis .In Engineering data book of ANSYS WORKBENCH 4 typess of material properties are added namely:1)Structural steel 2)forged steel 3)Wrought Iron 4)Stainless Steel

6.2 Meshing

Meshing plays an important role in evaluating of results. In this case tetrahedral method of meshing is carried for the imported CAD model and fine type of meshing with Advanced Curvature option is used for the meshing .

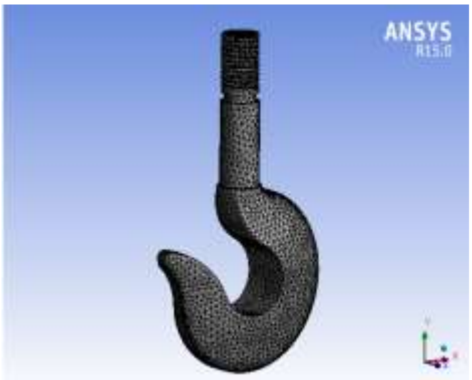


Figure 6.1: Meshed 3D Model

6.3 Boundary conditions and load placements

The one end of the hook is fixed with the help of fixed support option and at the other end load is applied on bunch of node at the lower centre of the hook of load(5 ton) in downward direction as shown in figure.

Figure 6.2: Boundary Conditions of hook

6.4 Solution work setup

In solution column 2 types of results will be needed to evaluate the project namely 1)Equivalent stress 2) Total Deformation. This two are added in solution column.

6.5 Solutions of crane hook with different material:
TREPEZOIDAL CROSS-SECTION:

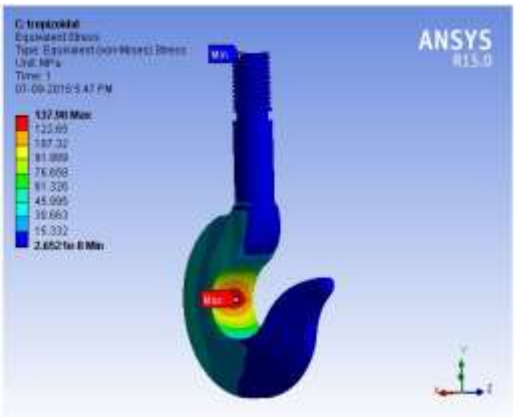


Figure 6.3: Equivalent (von-mises) stress for wrought iron material

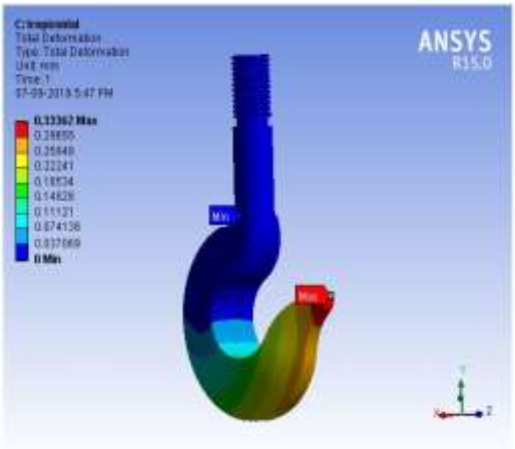


Figure 6.3: Total deformation for wrought iron material

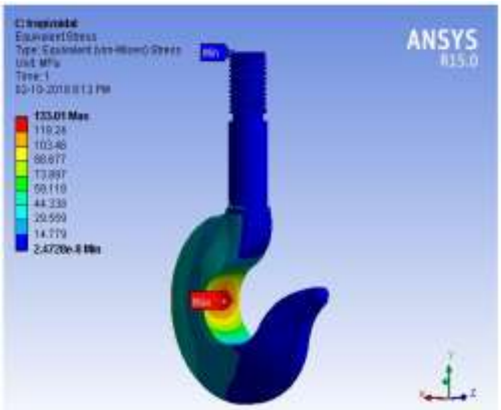


Figure 6.3: Equivalent (von-mises) stress for Stainless steel material

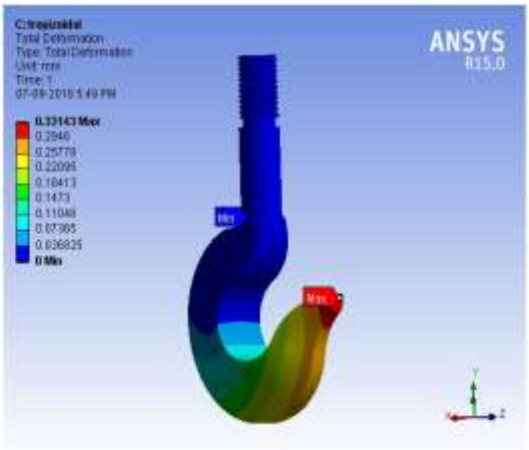


Figure 6.3: Total deformation for Stainless steel material

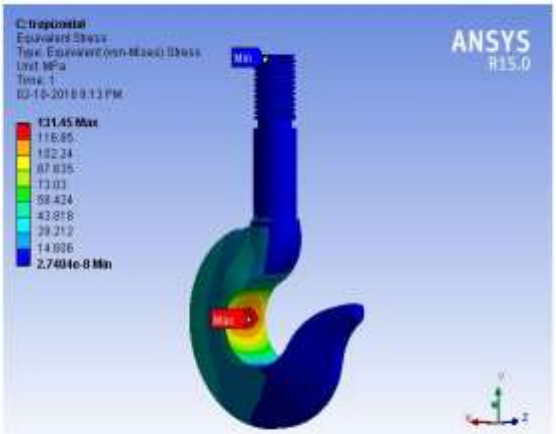


Figure 6.3: Equivalent (von-mises) stress for Structural steel material

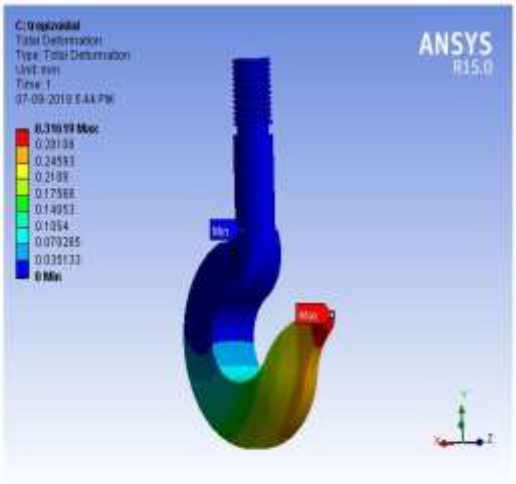


Figure 6.3: Total deformation for Structural steel material

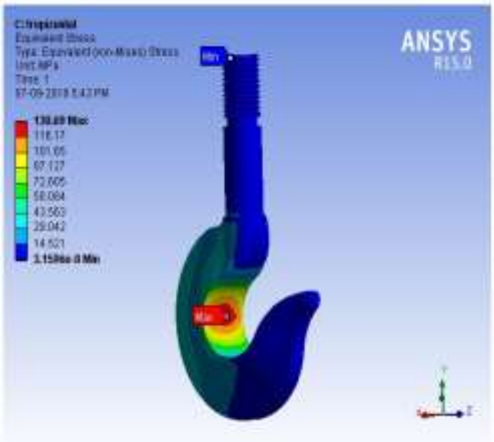


Figure 6.3: Equivalent (von-mises) stress for Forged steel material

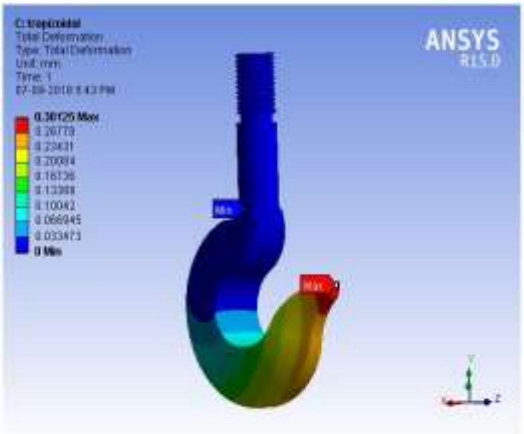


Figure 6.3: Total deformation for Forged steel material

The above steps(6.1,6.2,6.3,6.4,6.5) are carried out for the other cross-sections also.

VII. RESULTS AND DISCUSSION

The results of Equivalent(von-mises) stress analysis and total deformation are evolved from FEM(ANSYS WORKBENCH) software by importing the 3D CAD model from PTC CREO for various cross sections such as triangular, rectangular, circular and trapezoidal, to analyses models with different materials such as Stainless Steel, Wrought Iron, Structural Steel, Forged Steel. The structural and the theoretical analysis details are presented in following tables.

Theoretical Stress Results :

Crane Hook is a curved beam so the Theoretical Stress values are calculated by combining Direct stress and the bending stress. The outcome of the theoretical calculation are as shown in Table 7.1 .The circular cross-section gives maximum stress where as trapezoidal cross-section gives minimum stress.

Cross-sections	Theoretical stress
Circular	177.43
Trapezoidal	139.63
Rectangle	153.46
Triangular	146.79

Table 7.1: Theoretical stress of different cross-section

Von-Mises Stress Result

Table 7.2 gives us clear information about the von-mises stress of different materials and cross-sections it states that circular cross-section of Wrought Iron(171.58) gives maximum von-mises stress and Trapezoidal cross section of Forged steel (130.69) gives minimum von-mises stress

	Wrought Iron	Stainless Steel	Structural Steel	Forged Steel
Circular	171.58	165.58	163.59	162.65
Rectangle	149.64	144.10	142.46	141.62
Triangular	146.78	141.68	139.96	139.16
Trapezoidal	137.98	133.01	131.45	130.69

Table 7.2: Equivalent (von-mises) stresses(Mpa) for different materials and cross-sections

The below graphs gives us brief information about the cross-sections and their respective Von-Mises stress with different materials.

Graph 7.1: Von-mises stress VS Different Materials

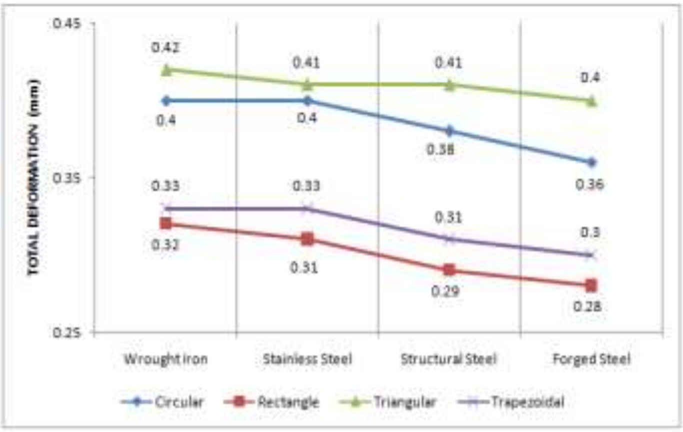
Total Deformation Result

Total deformation also plays a major role in this project from the above Figure 7.1 and the Table 7.3 gives clear information that rectangular cross-section curve gives minimum deformation which is followed by trapezoidal cross-section curve with a piece of distance and the maximum deformation occurs in the circular cross-section curve.

	Wrought Iron	Stainless Steel	Structural Steel	Forged Steel
Circular	0.40	0.40	0.38	0.36
Rectangle	0.32	0.31	0.29	0.28
Triangular	0.42	0.41	0.41	0.40
Trapezoidal	0.33	0.33	0.31	0.30

Table 7.3: Total Deformations for different materials and cross-sections

The below graphs gives us brief information about the cross-sections and their respective deformations with different materials.



Graph 7.2: Total Deformation VS Different Materials

Trapezoidal cross-section gives the least amount of stress compared to the other cross-sections. Even though it gives second least deformation value when compared with the rectangular cross-section the stress value is far better than rectangular cross-section and that to the difference between them is just 0.02mm, so on that criteria trapezoidal cross-section is selected and were as it comes to the selection of the materials forged steel gives the least amount of stress and total deformation. So, overall trapezoidal cross-section with forged steel gives the best output .

VIII. CONCLUSION

The main aim of the project is to increase the lifespan of crane hook by evaluating their structural analysis. A Crane Hook of different cross-section (Circular, Triangular, Rectangular, Trapezoidal) were designed according to the Indian Standards (IS 3815-1969) with a load of 5 ton and the Theoretical stress calculations are also performed on the basis of Curved beam. The designed Hooks are CAD modeled using PTC Creo software. The Structural analysis was carried out in ANSYS WORKBENCH for the evolution of Equivalent(Von-Mises) Stress and Total Deformation with Different materials such as Wrought Iron, Structural Steel, Stainless Steel, Forged Steel at a Room temperature of 25 c^{o} by adding the point load of 5 ton(49050N).

So by evaluating the Results of stress ,The theoretical calculations showed that the maximum stress induced in all the structures with all considered combinations are in permissible limits i.e. the simulated stress values are less than theoretical plateau stress values. Thus all the structures at all the loading conditions behave within elastic limit when subjected to load.

The energy absorption rate is directly proportional to the amount of matter present in the structure. Thus energy absorption rate is more in trapezoidal cross-section when compared to others. Thus as the stress are more therefore the deformation and strain is also more. From all the materials the energy absorption rate is more for Structural steel and forged steel materials.

When we consider the cost of the materials, the forged steel is little bit high compared to structural steel.

By taking all the above findings in to consideration, it is suggested that the crane hook with trapezoidal cross-section and Forged Steel as core material gives better performance among all of them at loading conditions.

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