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Structural Analysis of Crane Hook Using Finite Element Method

Ajeet Bergaley, Anshuman Purohit

Abstract**—*Crane hook are highly significant component used for lifting the load with the help of chain or links. In the present paper a crane hook is purchased from the local market for Finite element analysis. The hook was tested on the UTM machine in tension to locate the area having maximum stress and to locate the yield point. The model of hook is prepared in CAE software having dimension and material similar to the crane hook which was purchased from the market. The results obtained were compared with theoretical analysis. Then cross section in which minimum stress induced for given load was modified through FEM.***

KEYWORDS: Finite Element Method (FEM), Crane Hook, Curved Beam, Universal Testing Machine (UTM)

I. INTRODUCTION

Crane hooks are the components which are used to lift the heavy load in constructional sites and industries. In this paper, a crane hook was purchased from the local market. Then this hook is tested on the UTM for tensile testing to locate the area in which maximum stress induced and to know the magnitude of the yield point. The hook was tested in the laboratory to know the concentration of various elements present in the material of the crane hook [Chouksi Laboratories, Indore]. The model of crane hook prepared in the CAE software (solid works 2012 64 bit) having similar dimension and material to the hook which was purchased from the local market. The results obtained were compared with the theoretical analysis by Wrankler Bach equation. [11]

II. DIMENSION OF THE CRANE HOOK

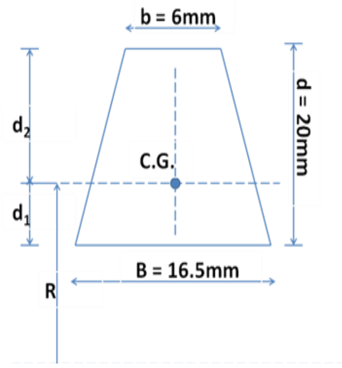
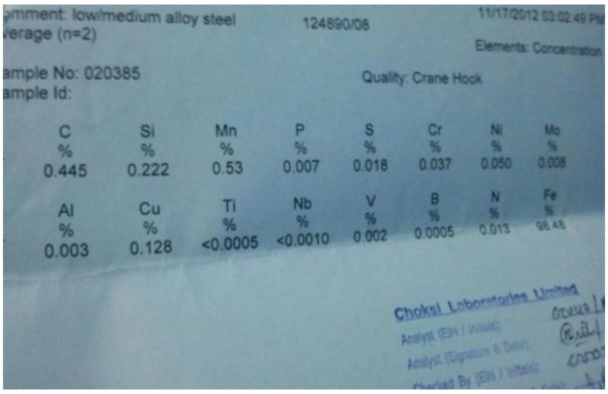


Figure. 1

II. MATERIAL OF THE CRANE HOOK

Figure 2 shows the element concentration of the crane hook: (Chouksi Laboratories, Indore)


omment: low/medium alloy steel 124890/08 11/17/2012 03:02:49 PM
verage (n=2)
Elements: Concentration
ample No: 020385 Quality: Crane Hook
ample Id:

C %	Si %	Mn %	P %	S %	Cr %	Ni %	Mo %
0.445	0.222	0.53	0.007	0.018	0.037	0.050	0.008

Al %	Cu %	Ti %	Nb %	V %	B %	N %	Fe %
0.003	0.128	<0.0005	<0.0010	0.002	0.0005	0.013	98.48

Choksi Laboratories Limited

Figure: 2 (Chouksi Laboratories, Indore)

III. MECHANICAL PROPERTIES OF THE MATERIAL

Table 1 shows the properties of the material assigned to the crane hook:

Table 1

S. No.	Properties	Value
1	Melting Point	1416^0 C
2	Tensile Strength	655 MPa
3	Yield Strength	415 MPa
4	Modulus of Elasticity	190-210 GPa
5	Modulus of Rigidity	140 GPa
6	Poisson Ratio	0.27 - 0.30

IV. WRANKLER BACH EQUATION [11]

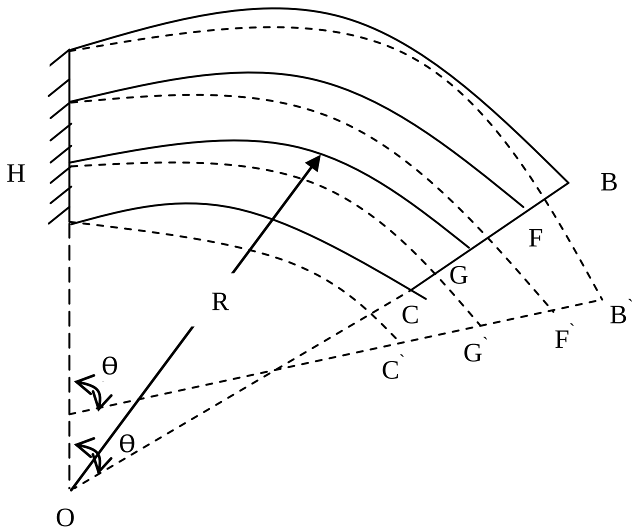


Figure 3 shows Bending of beam with larger initial curvature

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Where, d = Depth of the section
B = Width of the section on lower portion
b = Width of the section on upper side
d_1 = Distance of center of gravity from the bottom side.
d_2 = Distance of center of gravity from the upper side.
R = Radius of curvature.

Bending stress on the upper side of the layer HG, are given by

$$\sigma = \frac{M}{AR}\left[1 + \frac{R^2}{h^2} \times \left(\frac{y}{R+y}\right)\right] \quad \text{..(tensile)}$$

On the other side of HG, y will be negative, and stress will be compressive

$$\sigma = \frac{M}{AR}\left[1 - \frac{R^2}{h^2} \times \left(\frac{y}{R-y}\right)\right] \quad \text{..(Compressive)}$$

IV. TEST ON UNIVERSAL TESTING MACHINE

The following figure shows the area in which failure occurs and figure shows the load vs linear deformation graph**:**

Figure 4

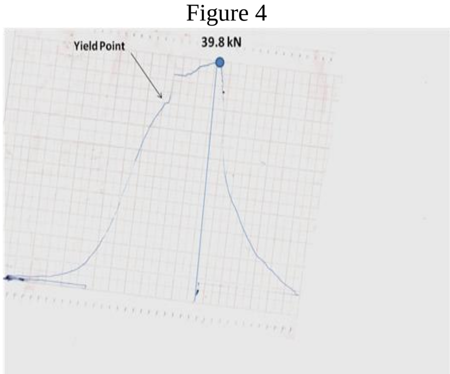
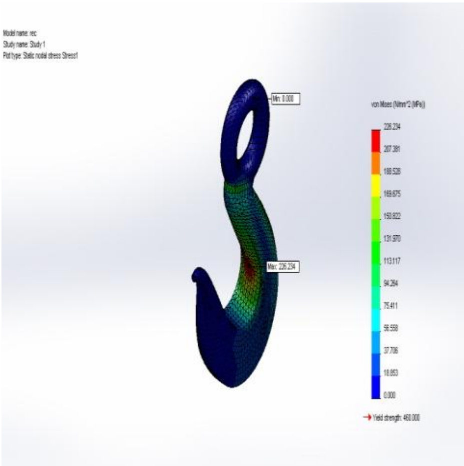
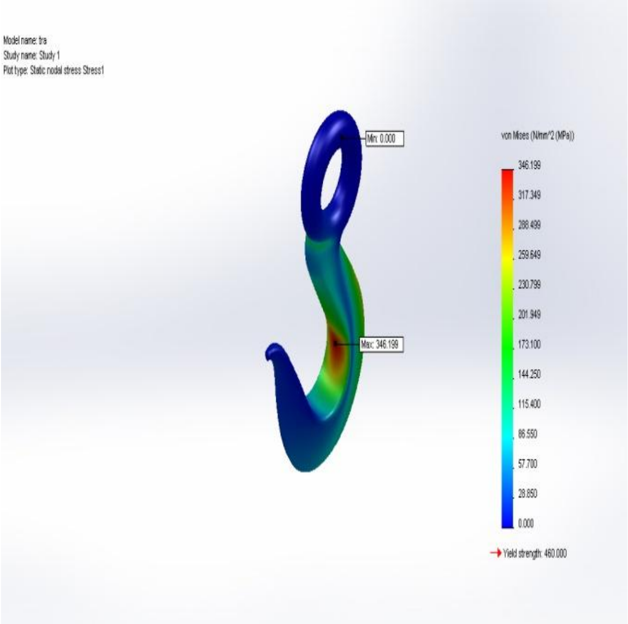


Figure 5

V. RESULTS FROM FEM ANALYSIS



(a)



(b)

Figure6 (a) Shows hook having rectangular cross section and 6(b) shows the hook having triangular cross section

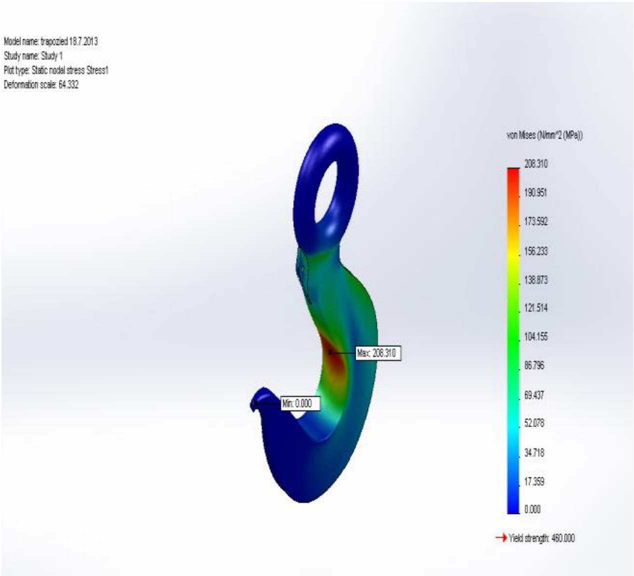


Figure7: Shows the FEM analysis of the hook purchased from the market

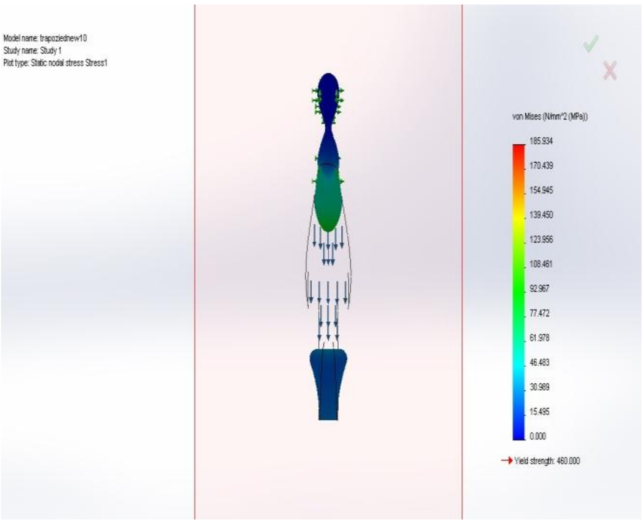


Figure8: Shows the cross section of the hook purchased from the market.

VI. EFFECTS ON CRANE HOOK BY CHANGING ONE PARAMETER VARYING WHILE OTHER REMAINS SAME

For optimization of crane hook, the effect of few geometrical parameters is studied by changing these parameters, like inner and outer width of the crane hook cross section. Table 2 shows the effect on mass, displacement and stress on crane hook by varying the inner width (b) of the hook cross section. The graph is plotted (shown in figure 7.1 and 7.2) between the set (including mass, stress, displacement, strain) and stress, strain for varying b. The other dimension during this analysis remains unchanged.

Table 2

S.NO	Parameter	Scenario 1 mm/mm^2	Scenario2 mm/mm^2	Scenario 3 mm/mm^2	Scenario 4 mm/mm^2	Scenario5 mm/mm^2
		5.5	5.8	6.1	6.4	6.7
1	Stress	214.61	209.92	209.29	208.4	205.22
2	Displacement	0.00361	0.00258	0.00223	0.00181	0.00145
3	Strain	0.000799	0.000803	0.000792	0.000776	0.000765
4	Mass	33.8101	33.8101	34.5465	34.9115	35.2777

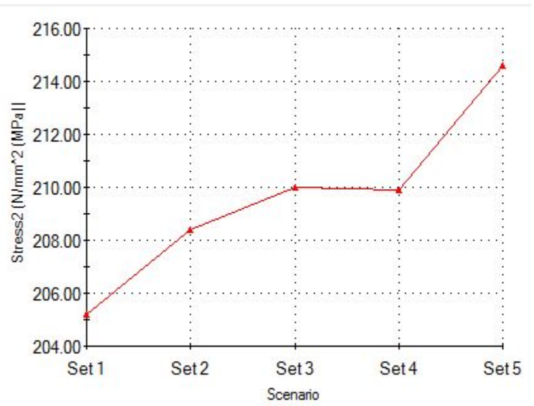


Figure 9

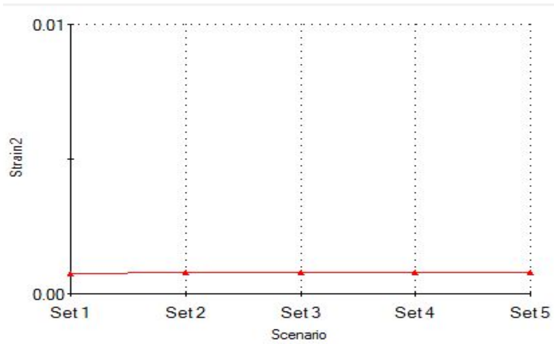


Figure 10

IX. EFFECTS ON CRANE HOOK BY CHANGING ONE PARAMETERS (OUTER WIDTH)

Now by changing outer width of the cross section of crane hook. The effects were observed in terms of mass, stress, strain and displacement. The graph is plotted (shown in figure 11 and 12) between the set (including mass, stress, displacement, strain) and stress, strain for varying B. The other dimension during this analysis remains unchanged.

Table 3

S.NO	Parameter	Scenario 1 mm/mm^2	Scenario2 mm/mm^2	Scenario 3 mm/mm^2	Scenario4 mm/mm^2	Scenario5 mm/mm^2
		14	15	16	17	18
1	Stress	251.53	225.52	209.81	204.19	201.21
2	Displacement	0.000988	0.000862	0.000779	0.000772	0.000780
3	Strain	0.05992	0.02683	0.00222	0.00506	0.0085
4	Mass	32.3409	33.4141	34.4878	35.5604	36.6363

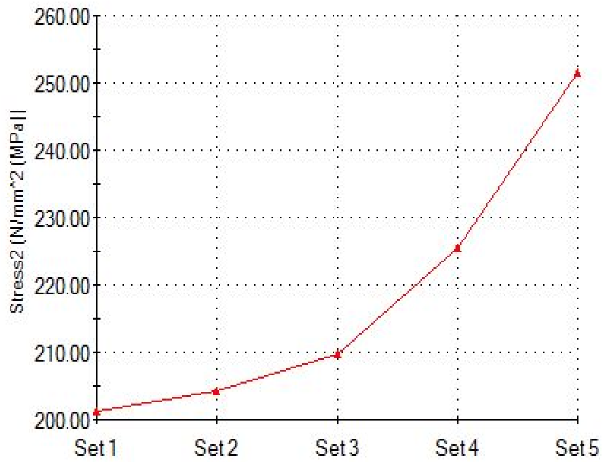


Figure 11

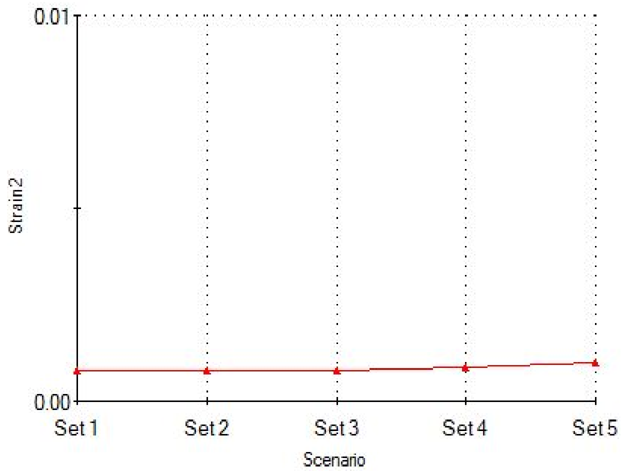


Figure 12

X. EFFECTS BY CHANGING BOTH PARAMETERS VARYING OF THE CRANE HOOK

Now by changing both inner and outer width simultaneously of the cross section of crane hook. The effects were observed in terms of mass, stress, strain and displacement. Table 4 shows the scenario when both outer and inner width are changed. The graph between set and various parameters like area (Fig. 13), mass (Fig. 14), strain (Fig. 15), displacement (Fig. 16), stress (Fig. 17) are shown in figures.

Table 4

S. NO	Parameter	Scenario1 mm/mm^2	Scenario2 mm/mm^2	Scenario3 mm/mm^2	Scenario4 mm/mm^2	Scenario5 mm/mm^2
		5.5	5.8	6.1	6.4	6.7
		14	15	16	17	18
1	Stress	256.15	226.66	210.82	200.83	197.62
2	Displacement	0.06348	0.02792	0.0022	0.00339	0.00543
3	Strain	0.001023	0.000872	0.000791	0.000767	0.000744
4	Mass	31.6215	33.0733	34.5206	35.9561	37.3931

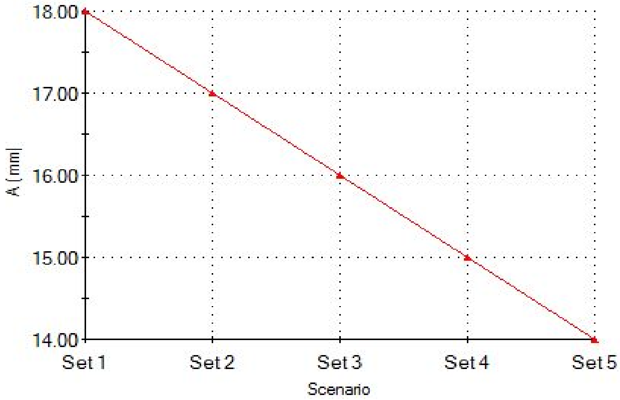


Figure 13

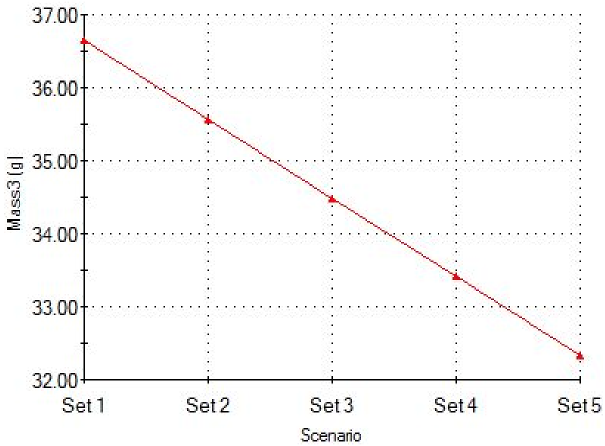


Figure 14

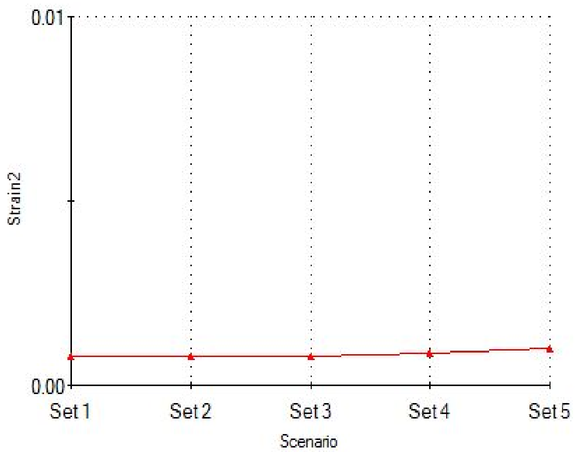


Figure 14

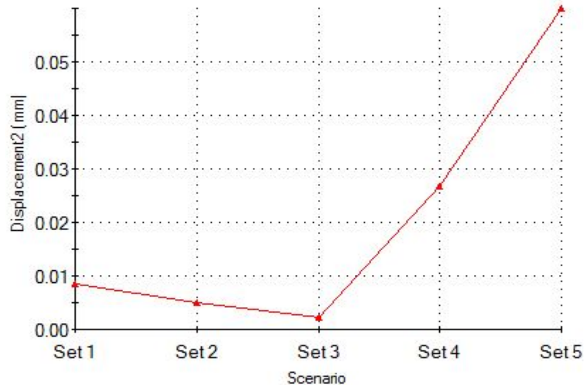


Figure 15

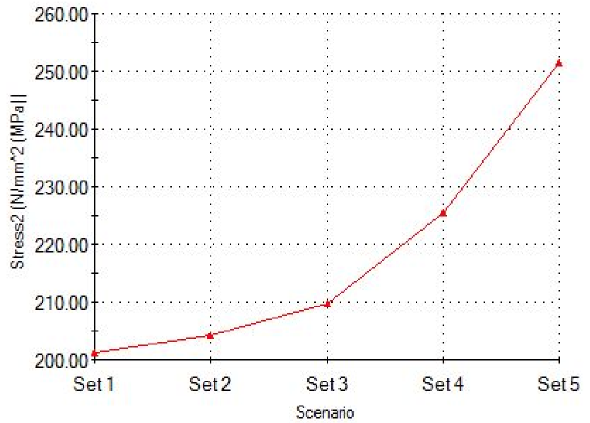


Figure 16

XI. OPTIMIZATION THROUGH FEM OF THE CRANE HOOK CROSS SECTION

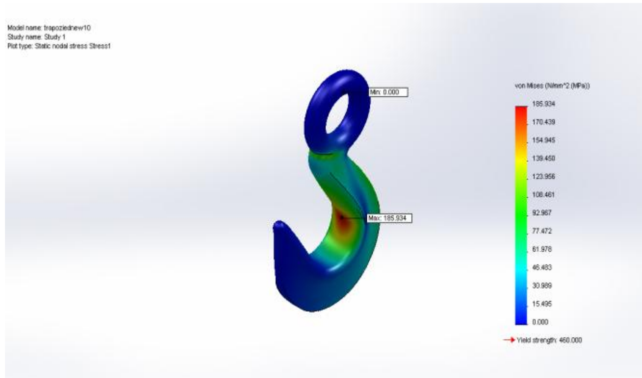


Figure17: Shows the FEM analysis of the hook after optimization of the cross section.

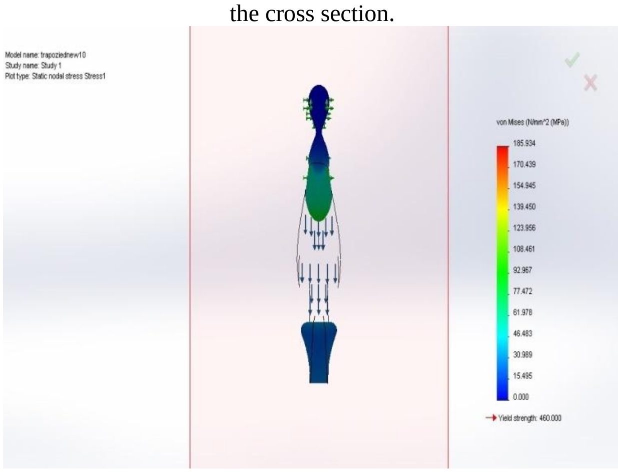


Figure18: Shows the cross section of the optimize hook.

A. THEORETICAL CALCULATION

The Table 6 shows the Values of h2, area and Table 5 shows bending stress.

Table 5

S. No.	SHAPE	Bending Stress σ_{bi}, N/mm^2
1	CIRCULAR	497.2
2	RECTANGULAR	166.7
3	TRIANGULAR	296.19
4	TRAPEZOIDAL	220.78

Table 6

S. No	SHAPE	VALUE h^2	CROSS-SECTIONAL AREA	VALUE A mm^2
1	CIRCULAR	61.76	$(\pi/4)*d^2$	380.13
2	RECTANGULAR	50.53	B*d	352
3	TRIANGULAR	26.38	½ * B * d	176
4	TRAPEZOIDAL	39.55	[(B+b)/2]*d	242

Table 7

S. No	Component	Theoretical Stress	FEM Stress	% Change in Stress
1	Trapezoidal	220	208	5.45
2	Triangular	346	297	15
All Stresses are in N/mm^2				

XII CONCLUSION

- Maximum Stress is generated at the point on the hook where the distance between CG of the Cross-section & line of action of acting load is maximum. The failure Occur at that cross section only.
- Depth at that where stress induced maximum cross-section should be more to decrease the failure during loading.
- Only Trapezoidal cross-section is suitable out of all. Triangular cross-section is also suitable but stress induced during loading is high as compare to Trapezoidal.
- The Cross-Section of Hook should not be designed perfectly Trapezoidal. Curvature should be provided at the corners to reduce the stress concentration.
- Table 2 shows all parameter are constant, only inner width of the crane hook section is increasing beyond 6.1mm, then mass increases but stress and displacement decreases by smaller amount. On the other side, when inner width of the carne hook cross section decreases, then mass decreases but stress, and displacement increases with large amount. When width of the inner side of crane hook is increased from 5.8mm to 6.1 mm, and then mass increased by 2% but stress decreased by only 3% and displacement decreased by 1.36%. When width is increased by 5.8 mm to 6.4 mm, and then mass increased by 3.25% but stress decreased by 0.72% and displacement decreased by 29.84 %. Hence out of all five scenarios, scenario three is most suitable.
- Table 3 shows all parameter are constant, again when outer width of the crane hook cross section increased beyond 14mm, then mass increased successively by 1% and stress decreased between 5-10% and mass decreased between 1-2%. But displacement is not increasing in such way. It increases gradually after Scenario 3. Again out of all five scenarios, scenario three is most suitable.
- Table 4 shows all parameter are constant, only both inner and outer width are changed. Again out of all five scenarios, scenario three is most suitable.

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