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Design and Stress Analysis of Single Girder Jib Crane

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***Abtract* - Present work has been undertaken in order to ensure the smooth functioning of the jib crane in various areas. In general the jib crane requires at least two times maintenance in a year. The present work has been taken to reduce the servicing required and to ensure smooth functioning without any breakdown through analyzing of various parameters on beam sections MB150, MB125, MB100 and 140*80 rectangular sections. Comparative analysis is carried out by using analytical and FEM approaches on the beam. It has been found that the I section beam MB150 is most suitable and safe in the working load range of 1000kg.This study aims at stress analysis of single girder wall mounted jib crane of following specification:**

i. load carrying capacity 1000 kg,
ii. span length 2.5 m
iii. swing range 180 degrees

Keywords - Jib crane, FEM (Ansys), Beam, Analytical.

I. INTRODUCTION

Jib crane system is used in various industries in the shop floor for material handling which needs interrupted, reliable and safe working to maintain continuous functioning. On an average a jib crane system needs repair and maintenance twice in a year. To avoid such frequent breakdown the various sections of beams have been considered for analysis. It is proposed to carry out analysis of critical component of jib crane using theoretical calculation and FEM Ansys (14.5), Catia (V5R21) on various beam sections MB150, MB125, MB100 and 140*80 rectangular sections are taken for the study.

While designing the class of operation and classification of the crane has to be known so that appropriate loads can be considered while designing the crane, along with that the standard practices of respective countries has to be followed and design shall conform to the standards given by the authority of countries. The following crane design has been considered according to Indian standards. The detail classification of the crane is specified. Wall mounted jib crane of 2.5m span and having load carrying capacity of 1000kg is selected for the analysis. Here the crane was identified to be from group M5 with class of utilization “B” i.e. regular use on intermittent duty with moderate state of loading/stress.

II. ANALYTICAL ANALYSIS

The analytical calculation is carried out for four different cross sections of cantilever beam for stress analysis and maximum deflection. The four different sections of beam examined which are:

MB100, MB125, MB150 } I section beams
140*80 } Rectangular section beams

Beam sections shall be designated by the respective abbreviated reference symbols followed by the depth of the section, for example: MB 150 — for a medium weight beam of depth 150 mm and for the rectangular section 140*80 designates depth*width of the section. The analytical calculation is carried out for MB150 cantilever beam for stress analysis and maximum deflection.

Following is Jib crane specification used for calculation:
Maximum load to lift: Q = 1000 [Kg]
Distance between raceways: S = 2.5 [m]
Translation speed of the whole crane: V_{trans} = 2.5 [m/s]
Acceleration time of the trolley: t_{accel} = 6.3 [sec]

i. *Cantilever I-Type beam, MB150, carrying load -1000Kg*

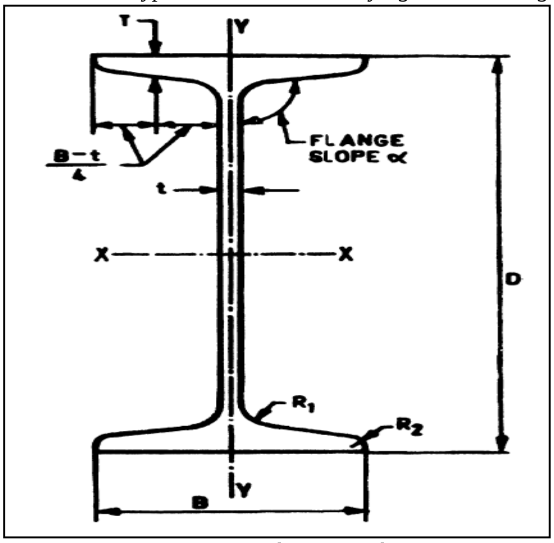


Figure no 1: Cantilever I-type beam.

Designation	Depth	Width	WT	RT	I_{XX}
MB150	150	75	5	8	7180000

Table no 1**:** Design details of I beam of size MB150

Sectional Modulus: $W_x = 95.7\ cm^3 = 95.7 * 10^{-6}\ m^3$, $W_y = 12.5\ cm^3 = 12.5 * 10^{-6}\ m^3$

Self Weight:

$q_g = \rho.S$

$= 147.08$ [N/m]

$= 147.08 * 2.5 = 367.7$ [N]

Service Load:

P = 10006.2 N

Horizontal load due to the own weight in the translation of the crane (S_H):

$$q_H = \frac{a}{g}\, q$$

$$q_H = \frac{V_{tras}}{t_{acc}} * \frac{qg}{g}$$

$q_H = 14.87$ [N/m]

The flexure moments created by the loads in most critical section (L/2) are:

$m_{max,I} = 1149$ [N/m]

$m_{max,II} = 25015.5$ [N/m]

$m_{max,III} = 46.46$ [N/m]

As the loads I and II are vertical and loads III and IV are horizontal, different section modulus (W) are used. Stresses created by the flexure moment are:

$$\sigma_I = \frac{m_I}{w_x} = \frac{1149}{95.7 * 10^{-6}} = 12 * 10^6\ [N/m^2]$$

$$\sigma_I = 12\ [MPa]$$

$$\sigma_{II} = \frac{m_{II}}{w_x} = \frac{25015.5}{95.7 * 10^{-6}}$$

$$\sigma_{II} = 261.3\ [MPa]$$

$$\sigma_{III} = \frac{m_{III}}{w_y} = \frac{46.46}{12.5 * 10^{-6}}$$

$$\sigma_{III} = 3.8\ [MPa]$$

Stress on the most critical section:

$\sigma = \sigma_I + \sigma_{II} + \sigma_{III}$

$\sigma = 12 + 261.3 + 3.8$

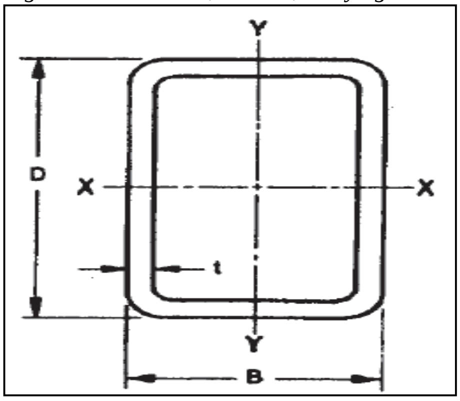
$\sigma = 277.1\ [MPa]$

Stress acting on beam is 277.1 [MPa]

$$y = \frac{PL^3}{3EI_{XX}} + \frac{WL^3}{8EI_{XX}}$$

Maximum deflection of the beam is 0.0345mm

ii. *Rectangular section beam, 140*80, carrying load - 1000Kg*



Designation	Depth	Width	WB	I_{XX}
140*80	140	80	5	429.60

Table no 2: Design details of rectangular section beam of size 140*80

Sectional area $S = 16.55 * 10^{-4}\ m^2$

Sectional Modulus: $W_x = 61.37 * 10^{-6}\ m^3$, $W_y = 45.10 * 10^{-6}\ m^3$

As it was seen in the theory it is necessary to calculate the own weight, the service load, the horizontal load due to the own weight as the result of the crane translation.

I. Self Weight (S_G):

$q_g = \rho.S$

$q_g = 318.02$ [N]

II. Service Load:

P = 10006.2 N

III. Horizontal load due to the own weight in the translation of the crane (S_H):

$$q_H = \frac{a}{g}\, q = \frac{V_{tras}}{t_{acc}} * \frac{qg}{g}$$

$q_H = 12.88$ [N/m]

The given loads (service loads), the own weight of the structure and the movements of the crane will create the following distributions: flexure moments and the stresses. The flexure moments created by the loads in the most are:

$$m_{max,I} = \frac{q_G\, L^2}{2} = 995.68\ [N/m]$$

$$m_{max,II} = PL = 25015.5\ [N/m]$$

$$m_{max,III} = \frac{q_H\, L^2}{2} = 40.25\ [N/m]$$

As the loads I and II are vertical and loads III and IV are horizontal, they will have different section modulus (W). The stresses created by the loads in the most critical section are:

$$\sigma_I = \frac{m_I}{w_x} = 16.2\ [MPa]$$

$$\sigma_{II} = \frac{m_{II}}{w_x} = 408\ [MPa]$$

$$\sigma_{III} = \frac{m_{III}}{w_y} = 9\ [MPa]$$

Stress on the most critical section:

$\sigma = \sigma_I + \sigma_{II} + \sigma_{III}$

$\sigma = 16.2 + 408 + 9$

$\sigma = 433.2\ [MPa]$.

Stress in Rectangular section beam 140*80 carrying load of 1000Kg is 433.2$[MPa]$.

Total deformation created due to the loads acting is:

$$y = \frac{PL^3}{3EI} + \frac{WL^3}{8EI}$$

y=35.03mm

Where, σ = Stress (N/m^2)

y= Deflection (mm)

W =Sectional modulus (m^3)

I_X= Moment of inertia about X-axis

Q= Load carrying capacity (Kg)

L= Span of the beam (m)

S = Sectional area (m^2)

q_g= Self weight of the beam (N)

q_h= Horizontal load acting on the load (N)

P= Density of the material (Kg/m^3)

P= Service load/hoisting load (N)

IV. ANALYSIS OF BEAM USING ANSYS FEM SOFTWARE:

The material considered is structural steel ASTM A36 steel in this work, stress analysis of a girder beam of jib crane is done using ANSYS. The model was prepared in CATIA software using all the geometric parameters given in the standard list, and then imported to ANSYS. The beam will be simulated, as in the theory of cranes calculation, beam is fixed at one end and free at another end.

- Own weight due to gravity
- Vertical service load
- Mesh

i. FEM Analysis for Cantilever I-Type Beam, MB150, carrying load -1000Kg

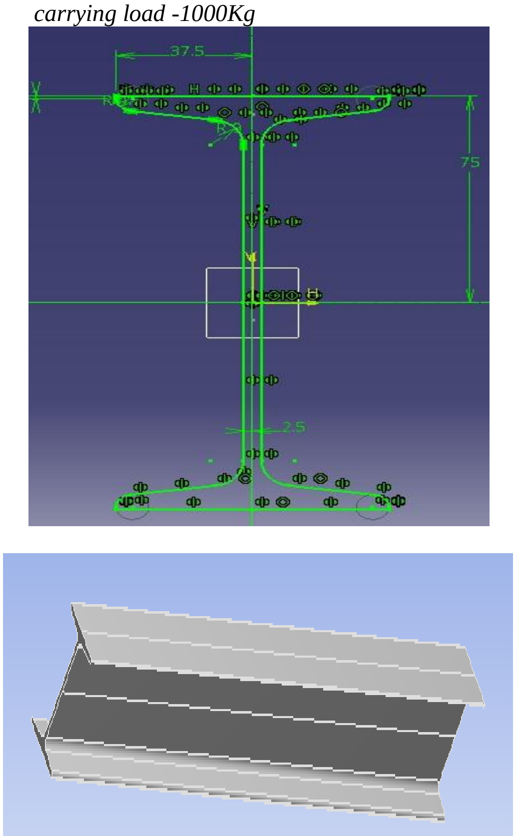


Figure no 4: Model of Cantilever I-Type beam MB150 in Catia (V5R21) and in Ansys (14.5)

The model was prepared using CATIA software, and imported to ANSYS. The beam will be simulated, as in the theory of cranes calculation, beam is fixed at one end and free at another end. Own weight due to gravity -9.81 [m/s^2] is applied in Z direction. Then the vertical service load is applied (load of the trolley (accessories) + load to lift). As we saw in the theory, we put this value in the end of the beam.

P = 1000*9.81 + 20*9.81 = 10006.2 N

Meshing is done using automatic meshing method.

Results: Von misses stress and Deformation of the beam:

After analyses of the beam section in Ansys, we get the following distribution shown in the figures below:

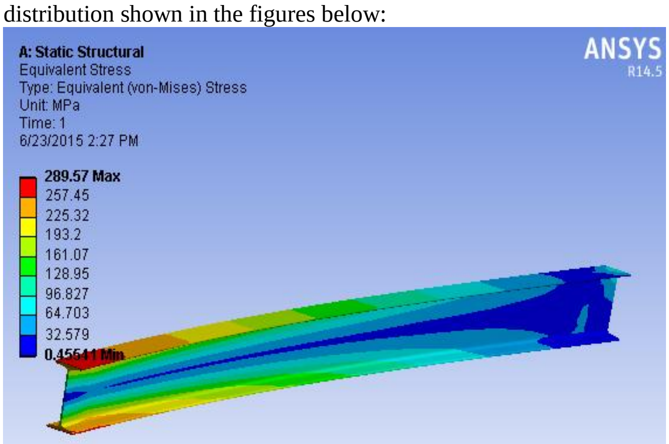


Figure no 5: Equivalent (von -misses) stress for MB150 Cantilever I shaped beam

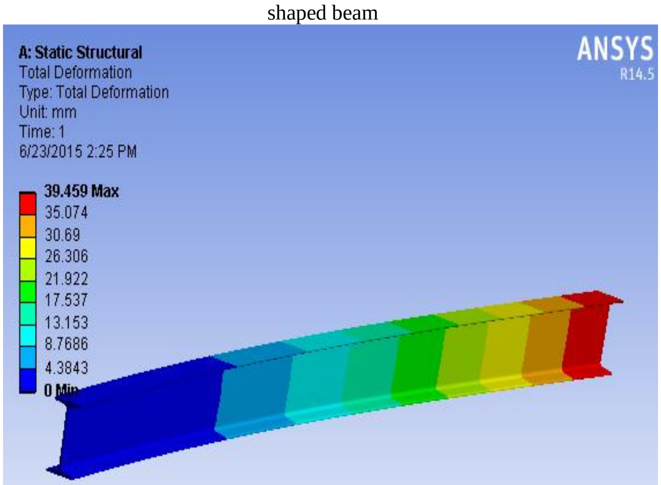


Figure n0 6:Total deformation for MB150 Cantilever I shaped beam *ii. FEM Analysis for Cantilever Rectangular Section Beam (140*80), carrying load -1000Kg*

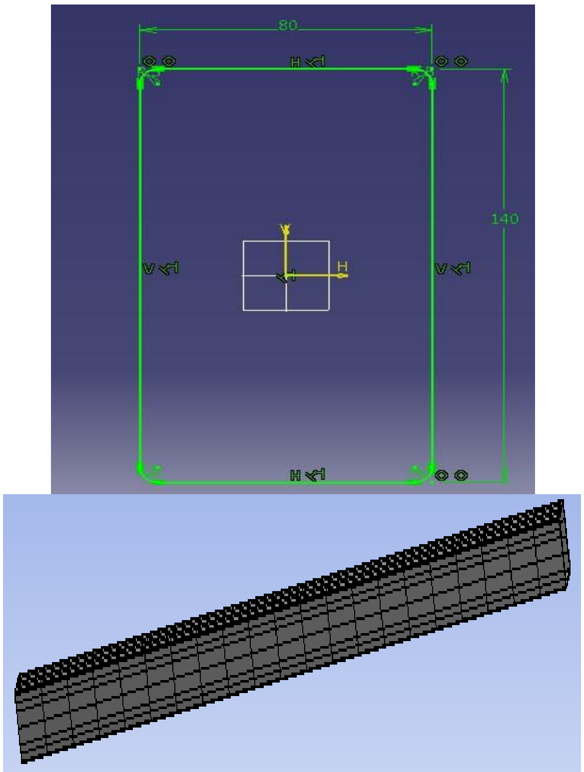


Figure no 7: Model of Rectangular section beam 140*80 in Catia (V5R21) and imported to Ansys (14.5)

Results: Von misses stress and Deformation of the beam:
After analyses of the beam section in Ansys, we get the following distribution shown in the figures below:

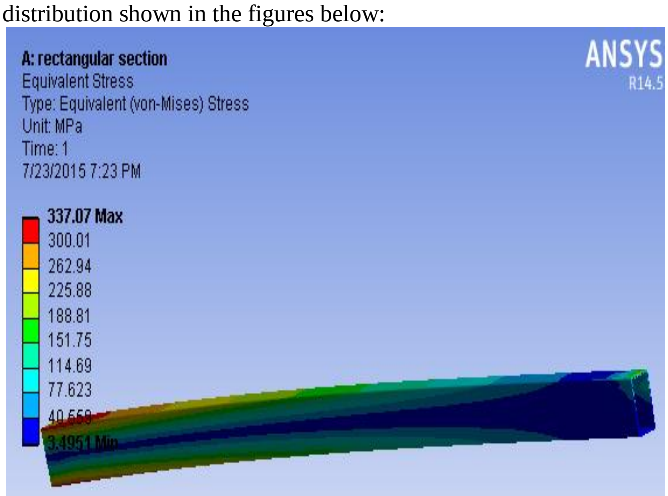


Figure no 8: Equivalent (von -misses) stress for rectangular section beam

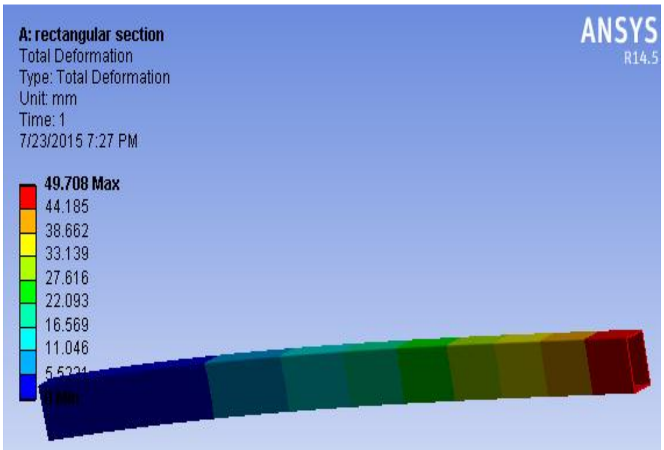


Figure no 9:Total deformation for Rectangular section beam.

V. RESULTS:

The analytical and FEM calculations for four different beam section were carried out and results are listed in the following table. For which it is clear that beam having I shape cross section (MB 150) has developed minimum value of stress and deflection. Hence it is recommended and suggested for the development of wall mounted jib crane of span 2.5m and having a load carrying capacity of 1000kg.The analytical and ANSYS results are compared and the findings shows that results are appropriate with the error of 0.8% (for MB100) to14.75 % (for MB150) in stress.

Cross section Types	Beam Types	Analytical analysis		FEM analysis	
		Stress [MPa]	Deflection [mm]	Stress [MPa]	Deflection [mm]
I shapes	MB150	277.1	35.03	289.57	39.45
	MB125	369.4	56.03	377.14	62.752
	MB100	707.6	136.71	726.59	152.14
Rectangular	140*80	433.2	58.49	337.04	49.07

Table 3: Comparison of analytical and software analyzed values (stress and deflection)

VI. CONCLUSION:

The analytical and FEM (ANSYS 14.5) results obtained are very close. From the static and analytical analysis it is clear that the I sectioned jib crane has got lesser deformation and stress developed which makes it more suited in situations where there is harsh climate. Further the operating life of the jib is also improved. Beam having I shape cross section MB 150 is recommended for the development of wall mounted jib crane of span 2.5m and having a load carrying capacity of 1000kg.As the computed stress values in the jib are smaller than the allowable stress of Material (Structural Steel) of the components, thus the jib crane is safe according to I.S norms IS 807:2006 Design, Erection And Testing, Structural Portion of Cranes and Hoists and IS 15419:2004 Jib Cranes- Code Of Practice. The results obtained from FEM analysis show that the boundary conditions have been chosen correctly. Use of FEM method for structural analysis of girder beam of Jib crane is validated which will save considerable computing time.

ACKNOWLEDGMENT

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