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Design and Analysis of Column Mounted JIB Crane

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Abstract

In this work, a static, modal and harmonic analysis of a column mounted jib crane using ANASYS software is presented. A column mounted jib crane of 1.5 Ton capacity is modelled using CATIA which is imported into ANASYS where calculations are performed. The detailed drawing of various parts of the crane is obtained from TATA Advanced systems Ltd (TASL) Adibhatta village, Hyderabad. The deflection values, Von Misses stress etc are obtained using the static analysis. The hand calculations of the column mounted jib crane have been done using simple strength of material expressions. The deflection is obtained as 3.709mm, when the load applied is 1.5 tons. The maximum stress obtained is 147.8Mpa which is less than the allowable stress. The static stress was found to be within the limits of safety. The model analysis shows the natural frequencies of the crane to be in the lower range 0-10Hz. The fundamental frequency is found out to be 0.323589 Hz. All the other higher frequencies are also found to be very low making the jib crane less stiff and highly stable for any transient loading. The harmonic analysis is performed with a view to predict the performance of the crane if a cycle time dependent load is allowed to act at the trolley. For this hypothetical situation, the von-mises stress and displacement along the z-directions were obtained using ANSYS. The maximum von-Mises stress of 60Mpa occurs at fundamental frequency of 1 Hz. The maximum z-direction displacement of 5mm was observed. These values indicate that the column mounted jib crane is safe to operate under the load of 1.5 Tons under static and cyclic time dependent loads also

***Keywords**:* JIB CRANE, ANSYS, CATIA.

1. Introduction

A jib crane is in effect a monorail that is cantilevered from its supporting members and pivoted at one end. The horizontal beam provides the track for the hoist trolley. Jib crane have three degrees of freedom. They are vertical, radial, and rotary. However they cannot reach into corners. They are usually used where activity is localized. Lifting capacity of such cranes may vary from 0.5 ton to 200 ton and outreach from a few meters to 50 meters. Such cranes find various applications in port area, construction site and other outdoor works. For handling general cargo, lifting capacities usually 1.5 ton to 5 ton with maximum out reach of 30 meter. Jib crane provided with grabbing facilities have usually a capacity ranging from 3 ton operating 50 to 100 cycles per hour. Lifting heights may be 30 meter or more. Jib cranes used in ship yards for lifting heavy machinery equipment, weighing 100 to 300 tons, are usually mounted on pontoons [1]. Frequently, these cranes are provided with two main hoisting winches which can be employed singly or together to lift a load. For handling light loads may hand auxiliary arrangement localized, such as in machine shops. Column mounted jib cranes are commonly used in packaging industry. The size of the crane can be visualized from the height of the operator. These cranes are used for hoisting up to 1 ton loads.

2. Material type

The material is considered is structural steel ASTM A36 steel [2] in this work, static, model, and harmonic analysis of an EOT using ANSYS has been performed. The model was prepared using CATIA software, and imported to ANSYS. The model is then meshed using 3-D solid elements (Solid45).

3. Manual Design of the parts of a JIB Crane

A column mounted jib crane consists of following distinct part, viz., (i) jib (ii) Post (iii) Base plate (iv)Tie rod. Figure (1) shows the various parts of the jib crane .the jib crane consists of a base which is fixed to the ground at the bottom. The bottom side of post is connected to the ground with the help of a fixed support. The motion of the trolley is derived from an electric motor mounted in the trolley itself. The wheels run on the flanges of the 'I' sectioned jib along the length of the jib.

The trolley consists of hoisting machinery which raises or lowers the load by connecting it with a hook. The load hook has three separate motions, these beings the hoisting, longitudinal traverse of the trolley, and swiveling of the crane through 180 degrees. Each motion is controlled independently of the other motions by separate controllers situated in a control cage or in a suitable position for controlling from the floor by pendant chains.

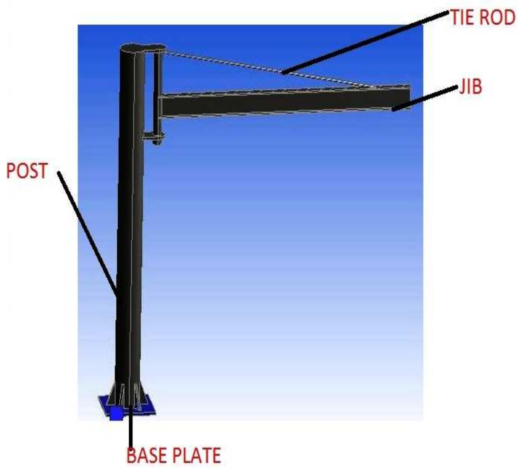

Figure 1: Various parts of a Column Mounted JIB Crane

3.1 Design of Tie rod:

The tie is inclined at an angle of 30^0 to the jib and is attached at a point 2.5 meters from the center line of the crane post, thus allowing a clear radius of 2.5 meters from the buckle, for facility in erection as well as to take up any adjustments due to faulty workmanship. Also it is assumed that no fixing moment is exerted on the jib by the crane post-in any case such moment would be extremely small in this design. The maximum load in the tie will occur when the hook block is at the extreme of our position i.e At 2.5 meters radios. Drawing the triangle of forces we get tension in the tie as=30,000 N. and compression in the jib=25980 N approx

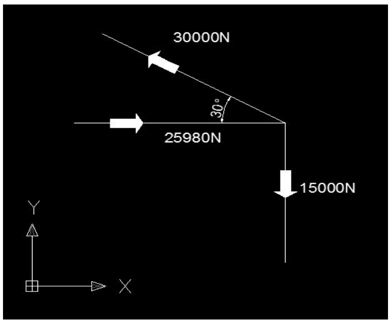

Figure 2: Resolution of Forces on the Tie-Rod (using AUTOCAD)

The weights of jib, tie rod and the trolley have been neglected for the time being actual loads will be checked later on when on some dimensions have been assigned to these parts. A round tie bar of M.S having the upper end forged into the shape of an eye for pin joint is proposed for attachment to crane post. A maximum permissible tensile stress of about 60 N/mm^2 would be allowed in all structural members. In slow motion hand cranes an important allowance of 15 to 20% must be allowed

In other words, all the actual working loads and stresses in various members of the structure should be increased by 30 to 40% to get their equivalent static values. A factor of safety of 4 should be allowed then on these static values on basic of ultimate stress to get the maximum permissible working stress. Suppose, actual working load in certain members is 1000 N. Then its static value after allowing 40% impact factor would be 1200 N. Tenacity of M.S=350 N/mm^2 .approx(static), or 350/(4*1.4)=62.5 N/mm^2 (dynamic), if the calculations are not complicated due to the introduction of the "impact factor"

Cross sectional area of the bar required=30000/62.5

A=480 mm^2 approx.

A=480 mm^2

$(\Pi/4)*D^2 = 480\ mm^2$ (1)

Therefore D=24.72 mm, D=25 mm,

This diameter is at the bottom of the thread.

Core diameter =25 mm,

Full diameter =25/0.85 mm, say 29.41mm,

Therefore the diameter of the tie rod required =30 mm.

3.2 Design of JIB

The maximum bending moment on the jib occurs when the load is at the free end of the jib which is 2.5 m from the fixed end. The shearing force will be 10000N only and may not be taken in to consideration.

Max Bending Moment

= WL = 150000×2500 = 375, 00,000N-mm (2)

Allowing a maximum permissible bending stress of 250N/mm^2.

Section modules of jib required $= \frac{37500000}{165}$ (3)

=227272.72mm^3

A rolled steel joist will be most suitable for this design. The load trolley will run on the inner tapered surface of the lower flange.

In the design of electric and hand operated cranes and crane gantries and runways etc. it is most important to check the deflection of the beam and girders so that they do not exceed certain prescribed limit. If the deflection of a girder (on which the trolley runs) is more than prescribed limit the trolley will be obstructed in their passage or probably inclination of the track to the horizontal will be increased, there by more power(or force) will be required to drag the load trolley along the girder length. This will also create a unpleasant jerky or surging B.S.466, clause 18, restricts the deflection of a crane girder at the point of its Max. B.M. to the following limits.

For bending stress intensity of 124N/mm^2.

The ratio of span/girder depth i.e, $\frac{L}{d}$ (4)

Should be 7.67 mm to get a maximum deflection of $\frac{SPAN}{325}$. [3] (5)

A reference to ISI hand book for structural engineers; "structural steel section " shown that depth of nearest std. R.S beam is either 300mm or 400mm. either a 300mm × 165mm section or 400mm×165mm. section, the moment of inertia I_{XX} being 8603.6cm^4 and 13630.3cm^4 respectively. The section modulus Z_{xx} in each case will be 8603.6/17.5 and 13630.3/20 i.e. 752 and 965 respectively. But we do not require a section modulus of more than 17.5 cm^4 if such bulky sizes of 400×165mm; or 350×165 mm, girders are used, They will not only be wasteful of material but will also increases the manufacturing costs unnecessarily and use less weight to the component of the crane. Try a 225mm×100mm. R.S. Beam and limit the compressive bending stress intensity to 63N/mm^2 approx. so that the ratio of girder length/width of compressive flange should not exceed 45:1 in the present case the ratio will be 250/10 =25:1 which is O.K.

And, maximum permissible compressive stress

$F_c = F_t$ [1-0.1× (I/b)] (6)

=165[1-(0.1×0.25)]

=124 N/mm^2.

The section modulus required at 124N/mm^2

stress = 375, 00,000/124

=302419.35mm^3 approx

The actual section modulus Z of a 225mm×100mm R.S girder having a weight of 23.5kgf/meter length 2502/10=250000 approx checking the deflection, it will be observed that the ratio of I/d, for a stress intensity of 124N/mm^2 should be 13.0 to given a deflection of span/1500, actual ratio of I/d, if a 350mm×100mm R.S beam is used, is 300/22.5=14.7. This ratio will serve our purpose; therefore adopt 350mm. 100mm, 23.5kg/meter length ISMB 350 R.S beam for the jib .when the trolley is at the outer end of the jib, the jib will be in the compression under a stress of 25980N, and under a shearing force of 15000N. The cross sectional area of the beam being 6671 mm^2 (large enough). The compressive or shear strength or principle stress need not be investigated.

The deflection of the jib a free end is given as $\Delta = \frac{WL^3}{3EI}$ [3] (7)

Where W=load acting on the jib =15000N

L=length of the jib =2500 mm.
E=young's modulus of jib material $=2\times10^{5}$ N/mm^{2}.
I=moment of inertia of jib section =1363030000 mm^{4}.
Know substitute this in the formula
Then Δ =2.86 (Apporx).

3.3 Design of the post:

The length of the crane post between the upper brackets and fixed support act as a beam, and the tension acts as an inclined concentrated load. The beam is subjected to the loading as shown in fig.3.3.1 taking moments about bearing bracket A,

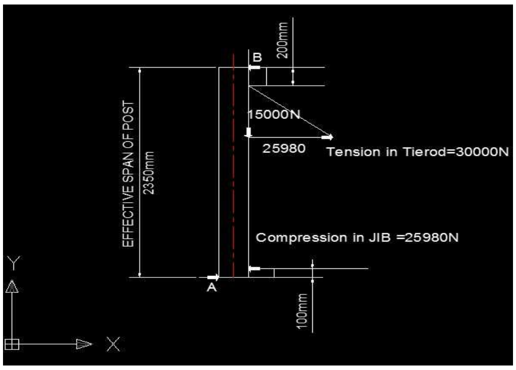

Figure 3: various forces acting on the post (using AUTO CAD)

$(25980\times10)+(B\times235)=25980\times215.0$ (8)
B=236583.82N approx
Similarly taking moments about bearing bracket B,
$(25980\times20)+(A\times235)=25980\times225$ or
$A=(25980\times225)-(25980\times20)/235$
Reaction force at A=22663.40 N approx.
Max B.M negative at L.H side
$=23658\times10=23658$N-cm.
Max B.M positive at R.H side
$=22663\times20=45326$N-cm.
=532600N-mm.
Allowing a max permissible stress of 94N/sq-mm,
Section modulus Z of crane post required =45326/940
$=48.22cm^{3}$ approx
$=48220\ mm^{3}$
For a CIRCULAR cross section

$$Z=\frac{\pi}{32}*60^{3} = 21205.75mm^{3}$$

Moment of inertia of post$=\frac{\pi}{64}*60^{4}=636172.51mm^{4}$

Designing of the post for deflection

Max deflection= $\frac{2\sqrt{2}\ PL3}{27^2 \times \sqrt{3} \times EI}$ = 4.56MM (9)

The nearest standard size of circular cross section of diameter 60 mm is used. In addition to the bending stress, a direct compressive stress or thrust is induced in the crane post whose value is 1.5tons (1500 kg).
Cross sectional area of 60 mm, circular rod=2827.4 mm^2

Actual stress intensity due to direct thrust=15000/2827.4 (10)
=5.3051N/mm^2 (approx)

Actual bending stress intensity =4532680/21205.75 (11)

=213.74/mm^2 (approx)

Total stress in the crane post
=213.74+5.305=219.05 /mm^2 (approx) will do.

The diameter of the crane post within the bearing may be reduced to 65 mm. The maximum load on each bearing is 236583N approx. allowing a bearing length of 1 $\frac{1}{2}$ times the journal diameters, the length of each bearing adopted 65×1.5=98, say to 100mm.

Bearing pressure= $\frac{23658}{65 \times 100}$ =3.6396N/mm^2 of projected area. (12)

Though the barring pressure appears to be high, yet the motion of slewing will be slow and very intermittent, and for this reason it may be allowed provided suitable oil holes or grease cup or nipples are allowed for in the bearing brackets..

3.4 Design of upper bearing bracket:

The reaction of the bearing 23658N will acts as shown in opposite. This force produces a direct horizontal tensile stress of 23658/4=5914.59N. Approx per bolt using an 18mm diameter bolt, the maximum tensile stress intensity = $\frac{5914}{(18)^2 \times 0.7854}$ =23.24N/mm^2 approx (O.K) (13)

The rest of dimensions of C.I bearing brackets as show opposite can be developed the drawing sheet.

3.5 Design of lower bearing bracket

The horizontal reaction in this case acts in the opposite direction: i.e towards the wall column there is therefore, the tensile stress induced in the bolts due to the vertical thrust of 20000 on the bracket each will be under a direct shear of 20000/4=5000N.

Shear stress intensity = $\frac{3750}{0.7854 \times 18^2}$ (14)

=14.73N/mm^2. Approx (O.K)

As the size of G.M bearing bush is exactly the same as that top for the top bearing bracket the same casting can be used for the lower bracket.

4 CATIA Model of JIB Crane

Column Mounted JIB Crane model produced using CATIA V5 R17 [4]

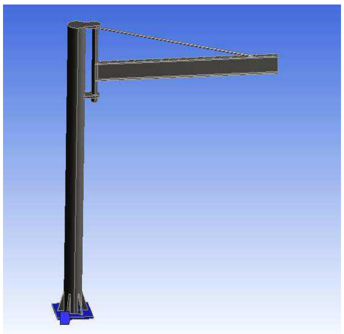

Figure 4: Final assembly of column mounted jib crane

5 Results and Discussion

5.1 Static Analysis

Importing of CATIA V5R17 file into ANSYS workbench R14.5 [5]

Model (A4)

Geometry:

Table 1: Model (A4) > Geometry

`	*Geometry*
State	Fully Defined
Definition	
Source	C:\Users\ome\Desktop\part123.igs
Type	Iges
Length Unit	Meters
Element Control	Program Controlled
Display Style	Body Color
Bounding Box	
Length X	0.6 m
Length Y	3.6663 m
Length Z	3.705 m
Properties	
Volume	0.29885 m³
Mass	2331.1 kg
Scale Factor Value	1.
Statistics	
Bodies	1

Active Bodies	1
Nodes	64968
Elements	35325
Mesh Metric	None
Basic Geometry Options	
Solid Bodies	Yes
Surface Bodies	Yes
Line Bodies	No
Parameters	Yes
Parameter Key	DS
Attributes	No
Named Selections	No
Material Properties	No
Advanced Geometry Options	
Use Associativity	Yes
Coordinate Systems	No
Reader Mode Saves Updated File	No
Use Instances	Yes
Smart CAD Update	No
Attach File Via Temp File	Yes
Temporary Directory	C:\Users\ome\AppData\Local\Temp
Analysis Type	3-D
Mixed Import Resolution	None
Decompose Disjoint Geometry	Yes
Enclosure and Symmetry Processing	Yes

Mesh:

Table 2: Model (A4) > Mesh

Object Name	*Mesh*
State	Solved
Defaults	
Physics Preference	Mechanical
Relevance	0
Sizing	
Use Advanced Size Function	Off
Relevance Center	Medium
Element Size	2.e-002 m
Initial Size Seed	Active Assembly
Smoothing	Medium

Transition	Fast
Span Angle Center	Coarse
Minimum Edge Length	1.4013e-003 m
Inflation	
Use Automatic Inflation	None
Inflation Option	Smooth Transition
Transition Ratio	0.272
Maximum Layers	5
Growth Rate	1.2
Inflation Algorithm	Pre
View Advanced Options	No
Patch Conforming Options	
Triangle Surface Mesher	Program Controlled
Advanced	
Shape Checking	Standard Mechanical
Element Midside Nodes	Program Controlled
Straight Sided Elements	No
Number of Retries	Default (4)
Extra Retries For Assembly	Yes
Rigid Body Behavior	Dimensionally Reduced
Mesh Morphing	Disabled
Defeaturing	
Pinch Tolerance	Please Define
Generate Pinch on Refresh	No
Automatic Mesh Based Defeaturing	On
Defeaturing Tolerance	Default
Statistics	
Nodes	64968
Elements	35325
Mesh Metric	None

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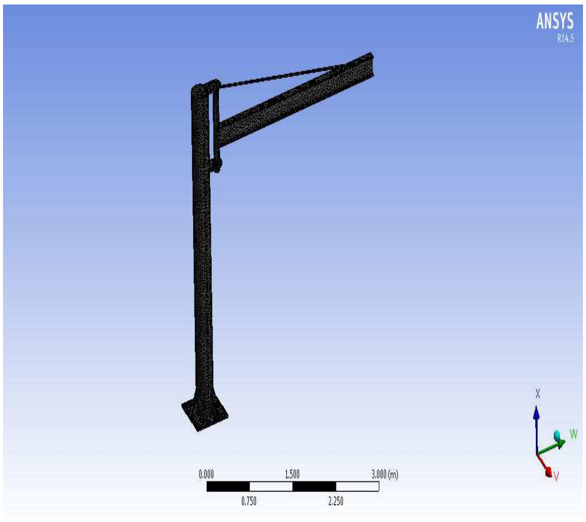

Figure 5 Meshed part of a column mounted jib crane

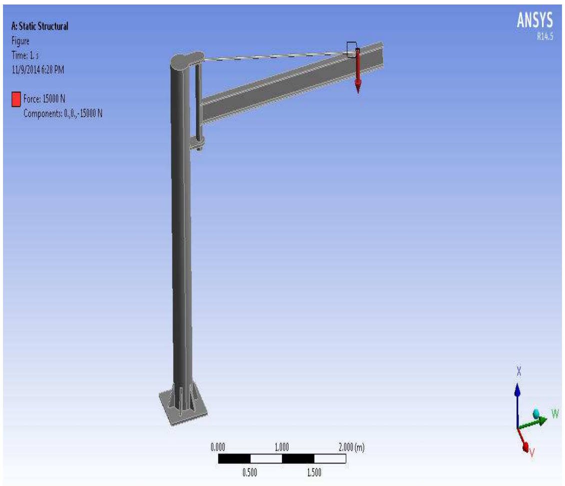

Figure 6: Load applied on column mounted jib crane

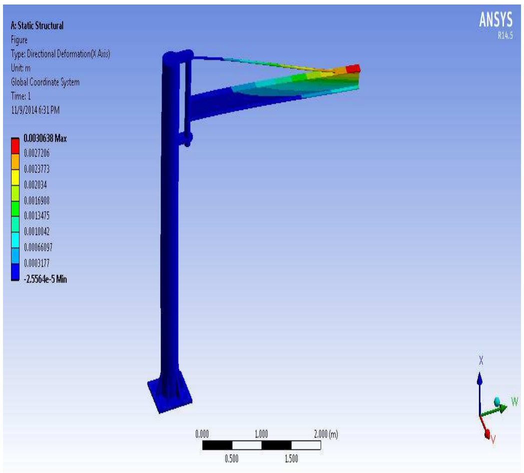

Figure 7: Displacement along the x-direction

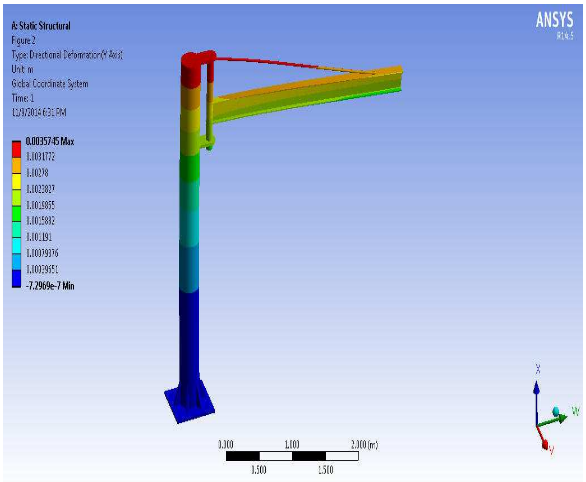

Figure 8: Displacement along the y-direction

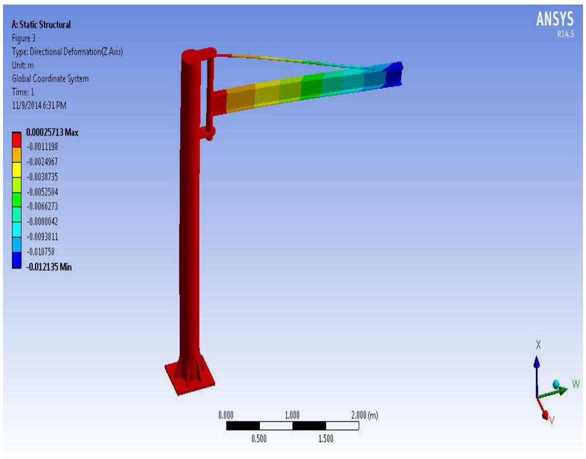

Figure 9: Displacement along the z-direction

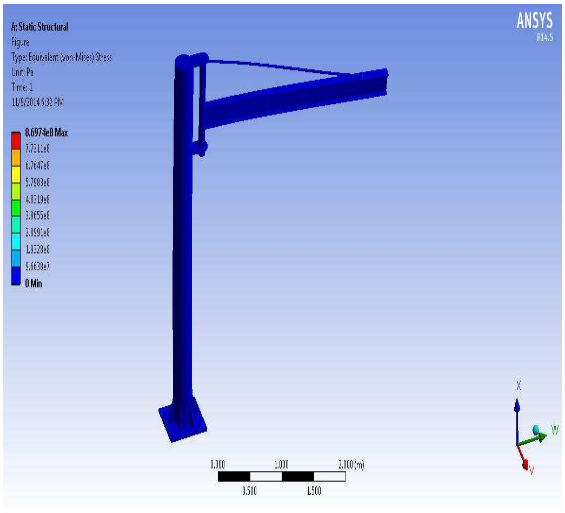

Figure 10: Von mises stress

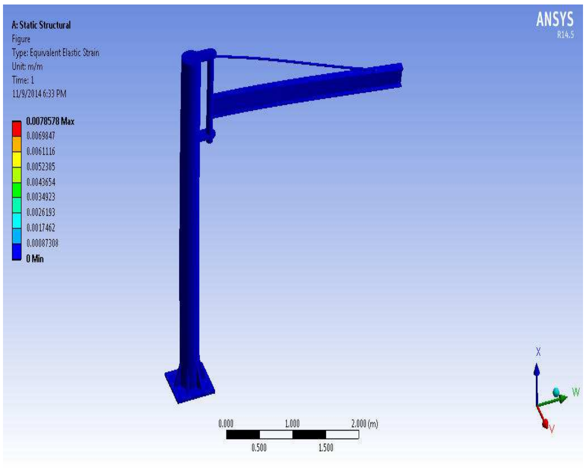

Figure 11: Von mises strain

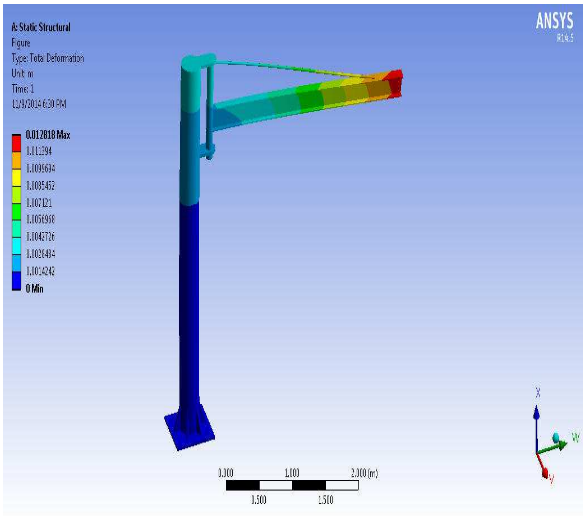

Figure 12: Total Deformation

5.1.1 Material Data

ASME A 36 Steel [2]

Table 3: ASME A 36 Steel > Constants

Density	7800 kg m^-3

Table 4: ASME A 36 Steel > Isotropic Elasticity

Temperature C	Young's Modulus Pa	Poisson's Ratio	Bulk Modulus Pa	Shear Modulus Pa
	2.e+011	0.32	1.8519e+011	7.5758e+010

5.1.2 Results:

Figure 5 to 12 shows the displacement along the x, y, and z-directions, von mises stresses and von mises strains when the load of 1.5 tons is applied at the free end of the jib. The maximum deflection can be seen to be 3.507 mm over a span of 2.5m. The displacement in the x direction is 2.72 mm, and the displacement in the y direction is 3.57mm and the displacement in the z direction is 0.25mm. The maximum von mises stress is 156.8N/mm^2 and the von mises strain is 0.00785. This is found to be acceptable for the operation of the jib crane**.**

5.2 Model Analysis

Importing of CATIA file in to ANSYS Workbench

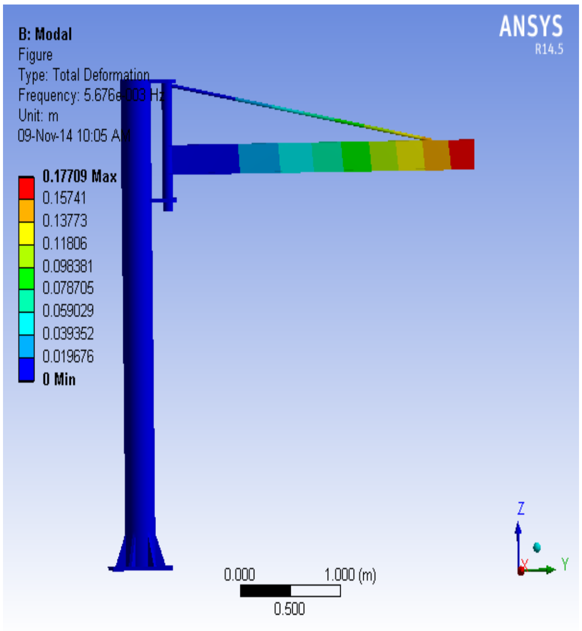

Figure 13: Model 1

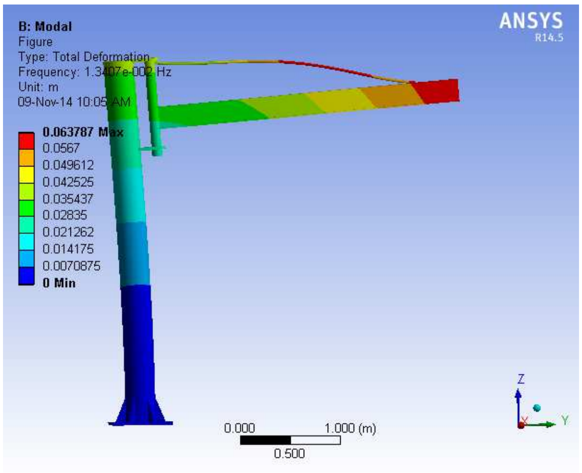

Figure 14: Model 2

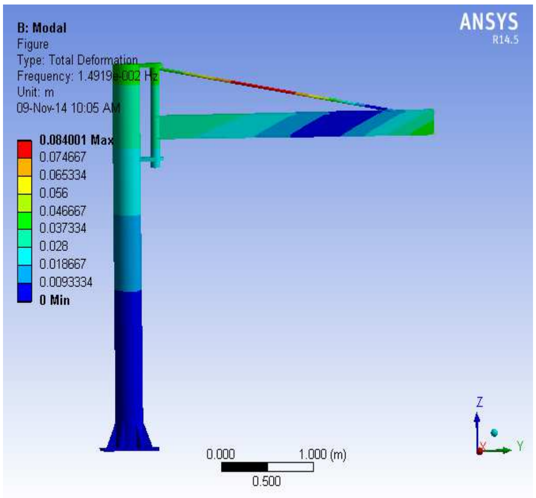

Figure 15: Model 3

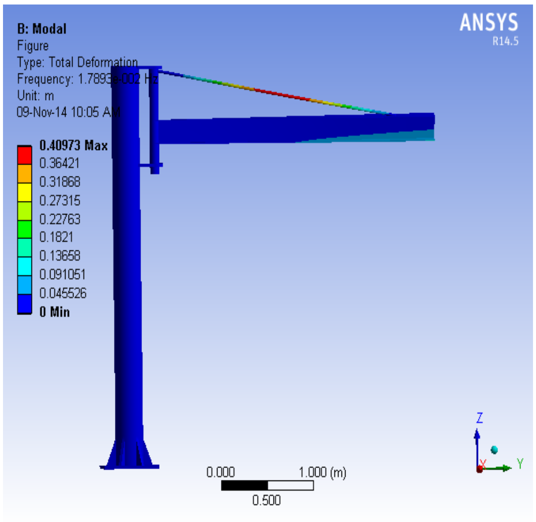

Figure 16: Model 4

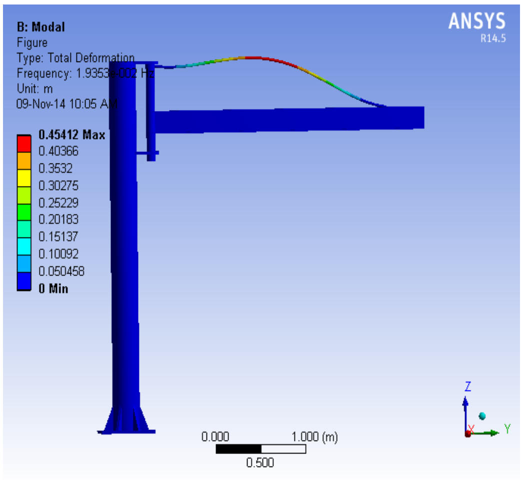

Figure 17: Model 5

5.2.1 Results:

Figure 13 to 17 shows the first five model shapes of the jib crane. For model 1the frequency is 0.2825 Hz and displacement is 0.177mm. For model 2 the frequency is 0.18Hz and the displacement is 0.63 mm. For model 3 the frequency is 0.20 Hz and displacement is 0.84 mm. For model 4 the frequency is 0.24Hz and the displacement 0.41 mm. For model 5 the frequency is 0.26Hz and the displacement is 0.41mm.These low frequencies indicate that the crane is not very stiff and hence it is stable in operation.

5.3 Harmonic Analysis

Model (C4) > Harmonic Response (C5) > Analysis Settings

Object Name	*Analysis Settings*
State	Fully Defined
Options	
Range Minimum	0. Hz
Range Maximum	10. Hz
Solution Intervals	5
Solution Method	Mode Superposition
Cluster Results	No
Modal Frequency Range	Program Controlled
Store Results At All Frequencies	Yes
Output Controls	
Stress	Yes
Strain	Yes
Nodal Forces	No
Calculate Reactions	Yes
General Miscellaneous	No
Damping Controls	
Constant Damping Ratio	0.
Stiffness Coefficient Define By	Direct Input
Stiffness Coefficient	0.
Mass Coefficient	0.
Analysis Data Management	
Solver Files Directory	C:\Users\Owner\AppData\Local\Temp\WB_OWNER-PC_3272_2\unsaved_project_files\dp0\SYS-2\MECH\
Future Analysis	None

6. Solution:

Type	Total Deformation	Directional Deformation			Equivalent Elastic Strain
Orientation		X Axis	Y Axis	Z Axis	
Coordinate System		Global Coordinate System			
Results					
Minimum	0. m	-2.6286e-003 m	-8.4173e-003 m	-4.7465e-002 m	0. m/m
Maximum	4.7628e-002 m	2.2296e-003 m	8.4786e-003 m	6.6611e-003 m	0.12174 m/m
Information					
Reported Frequency	10. Hz				

Above process is applied for the various frequencies for examples 1Hz, 2Hz, 3Hz, up to 10Hz .we got the values for various x-directional displacement, y-directional displacement, z-directional displacement, von-mises stress and von-mises strain. These values are plotted in graph.

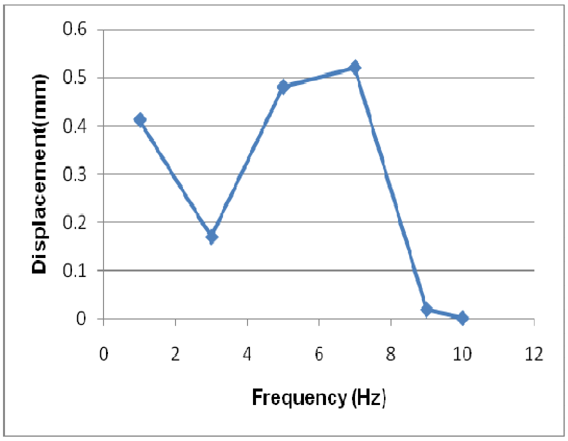

Figure 18: Displacement along the X-direction

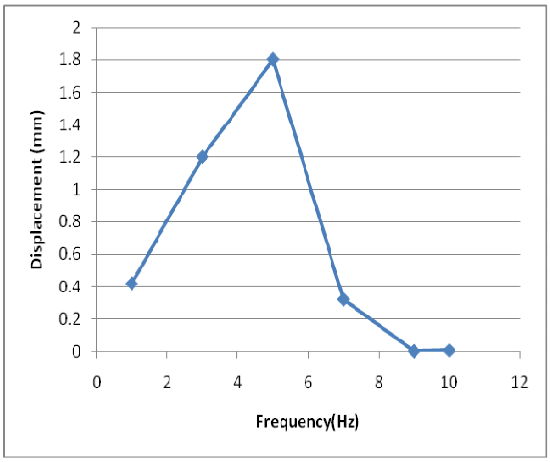

Figure 19: Displacement along the Y-direction

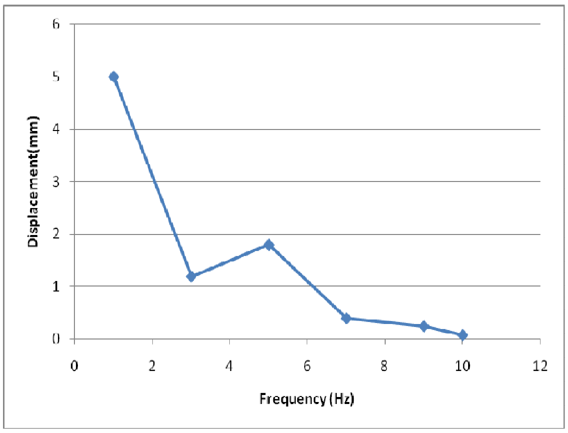

Figure 20: Displacement along Z-direction

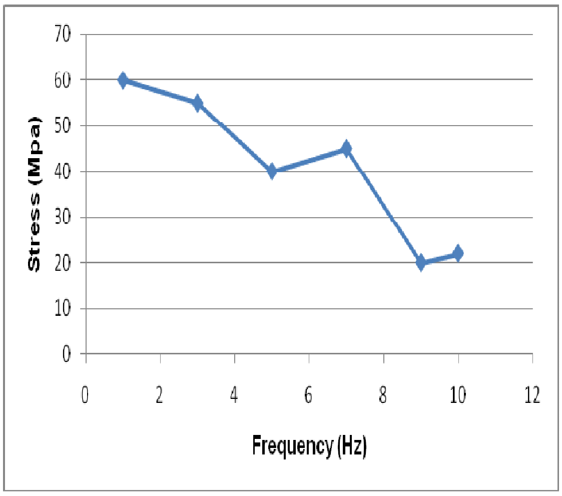

Figure 21: Von Mises stress

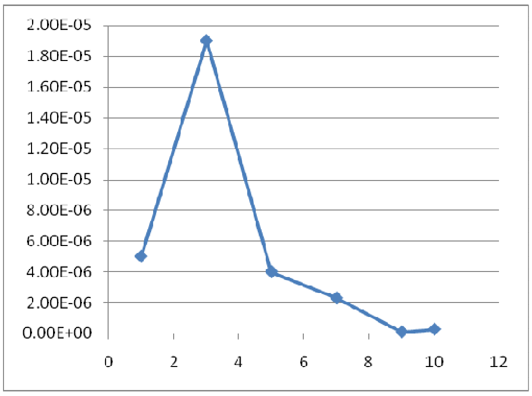

Figure 22: Von Mises strain

7. Result:

Figures 6.1 to 6.5 shows the graphs between X displacement Vs frequency, Y displacement Vs frequency, Z displacement Vs frequency, Von Mises stress Vs frequency, and Von Mises strain Vs frequency. The harmonic analysis is performed with a view to performance of the crane if a cycle time dependent load is allowed to act at the trolley. For this hypothetical situation, the Von-Mises stress and displacement along the z-directions were obtained using Ansys. The maximum Von Mises stress of 60Mpa occurs at fundamental frequency of 1 Hz. The maximum X-direction displacement of 0.52 at 7Hz and the maximum Y-directional displacement of 1.8mm were observed at a frequency of 5Hz and the maximum Z-directional displacement of 5mm was observed at a frequency of 1Hz and the maximum strain is found to be 1.9e-5 at a frequency of 3Hz. These values indicate that the column mounted jib crane is safe to operate under the load of 1.5 Tons under static and cyclic time dependent loads also.

8. Conclusion

The static, model and harmonic Analyses of a Column mounted jib crane have been performed as per the required load conditions. The model is obtained from TATA Advanced systems Ltd (TASL), Adibhatta village, Hyderabad.

The static analysis performed on jib crane yielded a maximum von-Mises stress of 156.8N/mm^2 which is the Yield stress limit of the material chosen (250 MPa). The results agreed very closely with hand calculations performed by assuming a simplified model.

The model analysis is provided information regarding the natural frequencies of the jib crane. The fundamental frequency is found out to be 0.2825 Hz and the 5th mode has a frequency of 0.26Hz. These low frequencies indicate that the crane is not very stiff and hence it is stable in operation.

The harmonic analysis is performed with a view to predict the performance of the crane if a cyclic time dependent load is allowed to act at the trolley. For this hypothetical situation, the Von-Misses stresses and displacement along the z-directions were obtained using Ansys. The maximum Von-Misses stress of 60 MPa occurs at fundamental frequency of 1Hz. The maximum displacement in the direction of the application of load is 5mm. These values indicate that the column mounted jib crane is safe to operate under the load of 1.5 Tons under static and cyclic time dependent loads also. It may be concluded that the column mounted jib crane is safe for operation up to 1.5 tons.

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A Brief Author Biography

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