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Effect of Length of Boom Support Leg on Free Standing Jib Crane

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Abstract: ***Free standing jib cranes are one of the materials handling equipment used intensively. Various design standards are available for design of jib crane, which helps designer to choose appropriate design parameters. Numbers of analysis techniques are available for design and validation of jib crane elements. In this paper an attempt has been made to optimize the length of boom support leg of free standing jib crane having capacity of 1Ton. With the help of FEM software i.e. ANSYS 15, by using trial and error method, it is found that, stresses developed in crane were minimum when length of leg boom support equals to near about 1/3rd of column height.***

Keywords: Jib crane, Boom support leg, ANSYS, Indian Standards, Analysis

1. Introduction

Jib cranes are very useful for lifting and transferring heavy loads in circular work volume. Jib crane provides easy, safe and faster transfer of load from one place to another. Standard jib cranes can lift much heavier loads than other similar material handling equipment; with a standard capacity of 5 tons and span up to 20-feet.Jib crane provides flexibility in design; therefore jib cranes are available with many designs as per requirement. There are various parts of jib crane like its column or mast which supports whole crane, cantilever beam, boom support leg nd hoist which moves on the boom of crane.

Classification of crane has importance in design. For example, Sandip Shinde has suggested that, on the basis of classification of crane, designer has to choose number of design parameters [4]. Therefore designer must be aware of classification of crane, design standards and failure causes of cranes.

Since many elements of jib crane are designed on the basis of trial and error method. Therefore there is always requirement of optimized design. Krunal Gandhare and Prof. Vinay Thute suggested a method for optimization of boom i.e. evolutionary algorithm [8]. Evolutionary algorithm can solve the problems only when problem satisfies all the required criteria of algorithm.

According to respective standards of crane, it was found that there are numbers of constraints or limit state conditions for design which has suggested the limits of design parameters like total deflection of crane, stresses, section ratio, slenderness ratio, etc. These parameters should not go beyond the limit stated.

Indian standards used in this work for design of crane are: IS 15419:2004 (Jib cranes - code of practice), material for Jib crane was chosen from IS 2062:2011 (Hot rolled medium and high tensile structural steel – specification). IS 800:2007 (General Construction in Steel) is used for construction of crane, IS 3177:1999 for EOT overhead crane design and IS 807:2006 (Design, Erection and Testing, Structural Portion of Cranes and Hoists).

2. Problem Statement

In this present work jib crane having capacity of 1 ton is analyzed to find optimum length of boom support leg.

In jib crane, load is transferred to column by means of boom support leg. Loading conditions of crane are analyzed and found that the most affected area by load is contact point of boom support leg and collar of column. At this point stresses will be more. And as per Indian Standards the value of stresses should not go beyond the allowable stress. Therefore care is taken to propose a length of boom support leg by keeping all the stresses within limit.

In present work jib crane is analyzed by numerical method with the help of ANSYS 15 to get optimum length of boom support leg. Figure 1 shows line diagram of jib crane.

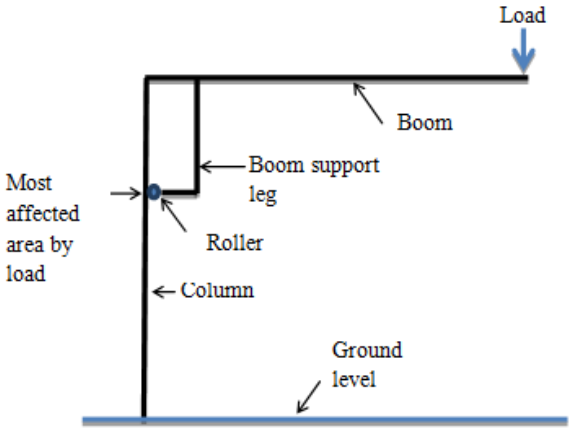

Figure 1: Line diagram of Jib crane

3. Design of Jib Crane

In this work boom support leg used was rectangular in shape; dimensions used for analysis are shown in figure 2.

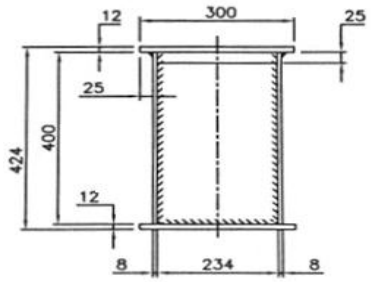

Figure 2: Cross sectional dimensions of boom support leg

Image Courtesy: Shree Abhay Cranes, Shegaon (India)

In Figure 3 various elements of jib crane are shown.

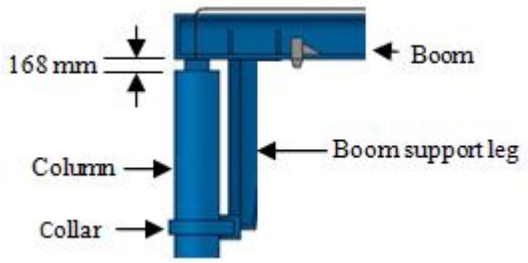

Figure 3: Dimensions between Boom and Column

In this section boom support leg length and weight calculations are discussed.

Total length of BSL is calculated as,

$$= \begin{pmatrix}\text{Distance between column}\\ \text{end plate and boom}\end{pmatrix} + \begin{pmatrix}\text{Length of collar}\\ \text{from top of column}\end{pmatrix}$$

And distance between column end and boom for the crane chosen is taken as 168mm

Roller of boom support leg moves on collar which is mounted on column. Hence, position of collar varies with changing length of boom support leg.

Weight of boom support leg influence the stresses generated in crane. With increase in weight of boom support leg stresses also increases, therefore weight of boom support leg should be minimum as possible. Total weight of boom support leg is calculated as follows:

From equation of mass,

$$\text{Mass} = \text{Density} \times \text{Volume} \quad (1)$$

$$\text{Volume} = \text{Area} \times \text{Length} \quad (2)$$

$$A_{BSL} = 2(b_{af} \times t_f + h_w \times t_w) \quad (3)$$

where,

A_{BSL} = Cross sectional area of the boom support leg

b_{af}, t_f = Breadth and thickness of top and bottom cover plate respectively

h_w, t_w = Depth and thickness of web respectively

Calculated cross sectional area of boom support leg is,
$A_{BSL} = 13600\ mm^2$

Crane under consideration has capacity of1 ton, whose dimensions are shown in Table 1.The material for used for crane is structural steel whose properties are shown in Table 2.

Table 1: Dimensions of Jib crane

Sr. No.	Elements/ parts	Dimensions
1.	Mast height	4072 mm
2.	Outer diameter of Mast	425 mm
3.	Inner diameter of Mast	405mm
4.	Thickness of Mast	10 mm
5.	Boom length	4800 mm

Table 2: Material properties of Jib crane

Sr. No.	Particulars	Value
1.	Density	7850 kg/m^3
2.	Young's modulus	200 GPa
3.	Yield Strength	250 MPa
4.	Max. Tensile Strength	410 MPa
5.	Poissonratio	0.3

4. Indian Standards design constraints and calculation formulae for crane

Indian Standards are the guidelines need to follow while designing a structural member. Indian Standards has stated the design constraints for jib crane. Therefore at the time of designing, these constraints should be taken into account. In present work these constraints are considered while analysis. In this section design parameters of crane and their limits are discussed.

4.1 Total Deflection of Crane

According to IS 15419: 2004, design of column and boom should be such that, total deflection of crane (δ_{max}) should not exceed equation (4)

$$\delta_{max} = \frac{\text{Boom Length} + \text{Height of Column}}{300} \quad (4)$$

For given dimensions of crane, total deflection should be,

$$\delta_{max} < \frac{4800 + 4072}{300}$$

$$\delta_{max} < 29.57\text{mm}$$

4.2 Limiting Stresses

Stresses occurred in the crane should not exceed following limit (As per Clause 9.2[2])

a) Tensile stress $<\sigma_a$
b) Compression stress $<\sigma_a/1.5$
c) Shear $<\sigma_a/\sqrt{3}$

where,
σ_a = Fundamental allowable stress

It is calculated as given in equation (5) or (6)

$$\sigma_a = \frac{\text{Yield Stress}}{\gamma} \quad (5)$$

Or

$$\sigma_a = \frac{\text{Tensile Stength}}{\gamma} \quad (6)$$

γis factor of safety whose value depends upon loading conditions and combination of loads acting on crane. Value of γ is chosen as 1.5 from Clause 9 [2].

4.3 Total Design Load

Design load is always greater than applied load because of safety factor. An assumption is made that crane under consideration is working without wind effect, therefore total weight applied is calculated by equation (7)(As per IS 807:2006)

$$W = S_L + W_L \times \psi \quad (7)$$

where,
W = Total design load
S_L = Static load due to dead weight of boom
W_L = Working Load
ψ = Dynamic Coefficient or Impact Factor

The dynamic coefficient depends upon the classification of the crane. Here the crane identified is from group M_6 with class of utilization "C" i.e. regular use on intensive duty with moderate state of loading/stress [2].The Dynamic coefficient or Impact factor is selected as 1.4.

Here design load taken as 22339.21 N

5. Optimization of boom support leg Length

Optimization is the method of selecting best feasible solution from available. In other word optimization means maximization or minimization of one or more functions with given constraints. Three techniques are available for optimization of jib crane elements: classical approach, automated computing technique and trial and error method. In this work, trial and error method is used to get optimum length of boom support leg, so that evaluated length of boom support leg gives optimum lesser value of stresses.

The procedure followed for trial and error method is discussed below:

In this method, first a CAD model of complete jib crane is built-in ANSYS 15, as per given dimensions of crane. Then boundary conditions are applied. Mesh is generated for whole crane which is shown in Figure 6, the numbers of nodes generated for the crane which has 1518mm boom support leg length were 24586 and numbers of elements generated were 10812. Then results obtained from ANSYS 15 for deflection and various stresses are analyzed.

Same procedure is followed for numbers of trials of boom support leg length. Two trial samples are shown in Figure 4 and Figure 5.

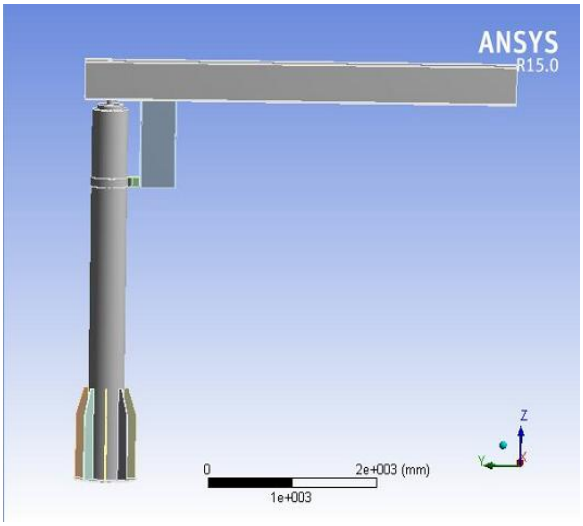

Figure 4: Boom support leg having 800 mm length

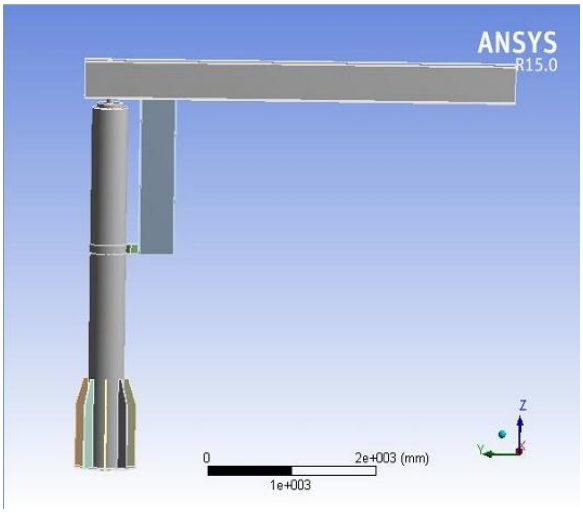

Figure 5: Boom support leg having 1650 mm length

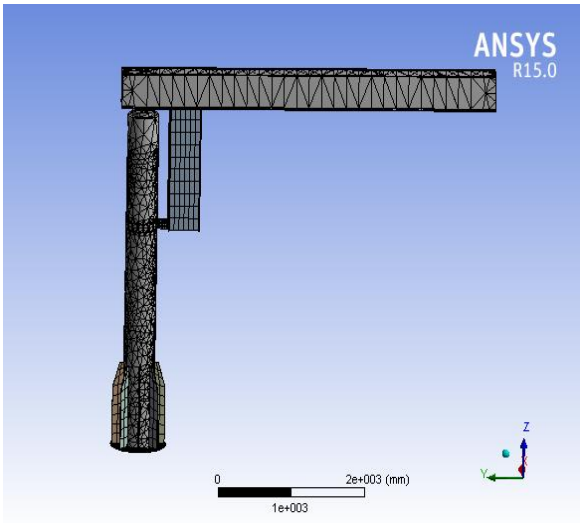

Figure 6: Meshing of crane having boom support leg length of 1518 mm

6. Results and Discussion

The results obtained from trial and error method are compared and results are plotted. By using trial and error method with the help of ANSYS 15, it is found that 1518 mm length of boom support leg is optimum length. At this

length value of maximum principal stress is optimum. Figure 7 and Figure 8 shows values of maximum principal stress and deflection obtained at 1518 mm of boom support leg length respectively.

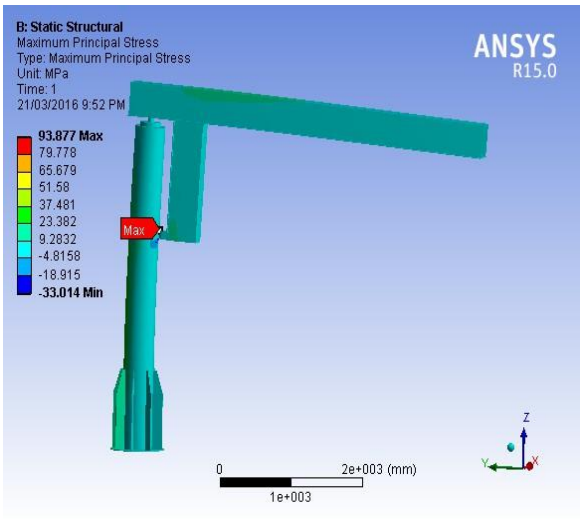

Figure 7: Max. Principal Stress inJib crane

Figure 9 shows that as the length of boom support leg increases the values of total crane deflection decreases. As the length of boom support leg increases, its weight also increases.

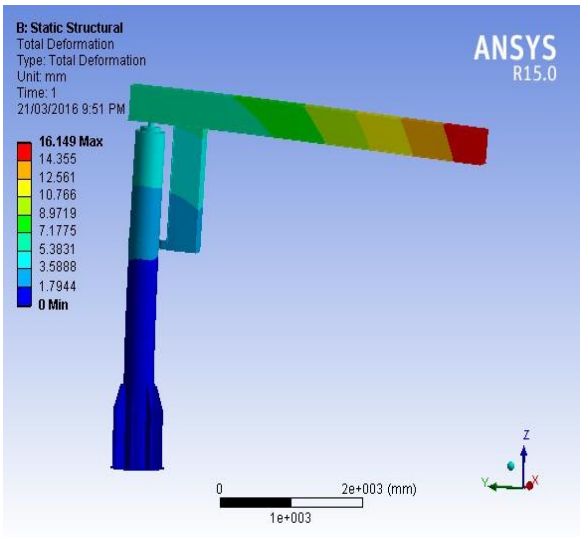

Figure 8: Deflection of Jib crane

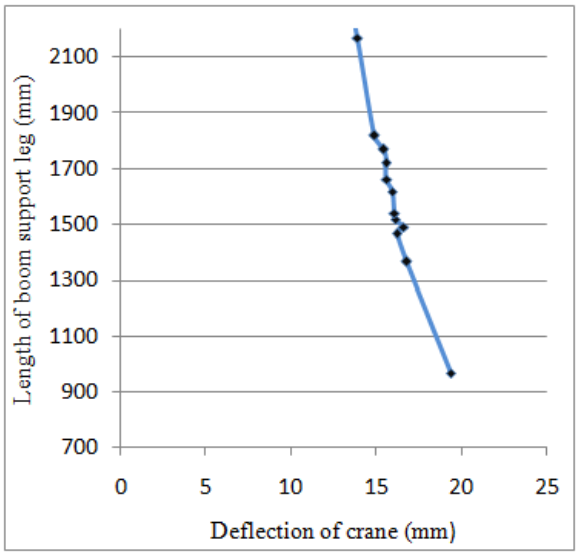

Figure 9: Effect of boom support leg length on deflection

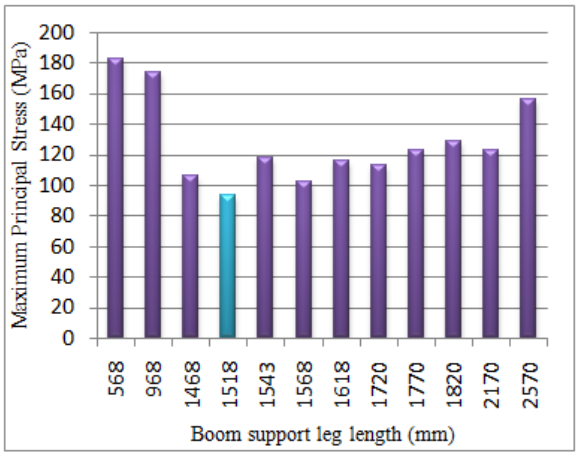

Figure 10: Effect of boom support leg length on max. principal stress

The effect of length of leg boom support leg on developed principal stress in crane is shown in Figure 10.

At1518mm length of boom support leg, value of max.principal stress is minimum which is 93.877 MPa and deflection of crane obtained is16.149mm. These values are under limitsspecified by Indian Standards.

From column height and boom support leg length following relation is generated

$$\frac{\text{Height of column}}{\text{Length of BLS}} = \frac{4072}{1518} \approx 2.7$$

The value 1518 mm is near about 1/3rd of column height. Hence, it can be concluded that the length of boom support leg from top of columnshould be 1/3rdof column height for given dimension ofjib crane.

7. Conclusion

In this work an attempt is made to get optimum length of boom support leg with the help of trial and error method by usig ANSYS 15. And found that 1518mm is the optimum lengthof boom support leg.Though trial and error method is time consuming, ithas given satisfactory and reliable results.

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