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Jib Crane Analysis Using FEM

#1S. S. Kiranalli,#2N.U. Patil

#1Department of Mechanical Engineering, Trinity Polytechnic, Pune

ABSTRACT

In this paper the analysis of Free Standing Jib Crane using Finite Element Method is Applied (ANSYS Software). Initially two-dimensional analysis of simple beam, simple column etc. is done to check the suitability and type of element. It also ensures that mesh density used for the analysis gives correct results when compared with results of analytical solutions.

For loading, various design factors were to be considered. The trolley weight is equal to 15% of the rated capacity of the crane. For impact loading, dynamic factor is taken into account. The value of dynamic factor is equal to 25% of the rated capacity of crane. Thus crane is analyzed at a total factor of 1.4 of the capacity of the crane.

Keywords— Jib crane, 2D Analysis, Deflection, FEM, ANSYS

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I. INTRODUCTION

Jib crane, a type of crane where a horizontal member (jib or boom) is supporting and moveable hoist, a key element of hoisting mechanism as an integral part of the machine. A typical jib crane consists of a top beam which is rotating around a fixed column. This configuration may be referred to as an L-shaped structure. The top beam is attached to the column at two points, directly on top and with down support. The trolley, with the hoist and payload, is moving along the top beam.

It is helpful for providing a heavy lifting facility covering virtually the whole area of the industry such as shipyards, factories, nuclear installations and high-building constructions. Cranes, whether fixed or mobile are driven manually or by power. Also, their design features vary widely according to their major operational specifications such as type of motion of the crane structure, weight, type of the load, location of the crane, geometric features, operating regimes and environmental conditions. Since the crane design procedures are highly standardized with these components, most effort and time are spent on interpreting and implementing the available design standards [1, 2]. Various international or national standards and rules e.g. BS 357, AISE Standard No.6, CMAA No.70, JIS B8801, DIN-Taschenbuch 44, FEM Rules are available to guide the crane designers which offer design methods and empirical approaches and formulae that are based on previous design experiences and widely accepted design procedures [3-7]. Many reports are available on the structural and component stresses, safety under static loading and dynamic behaviour of cranes [8-15]. It is believed from the study of literature that, computer automated access to above standards with pre-loaded interpretation and guidance rules increase speed and reliability of the design procedures and increase efficiency of the crane designers. In view of above, in the present work we have tried to demonstrate to modify the dimension of web thickness and web height to decrease the deformation and stress induced in the boom, for same capacity of loading.

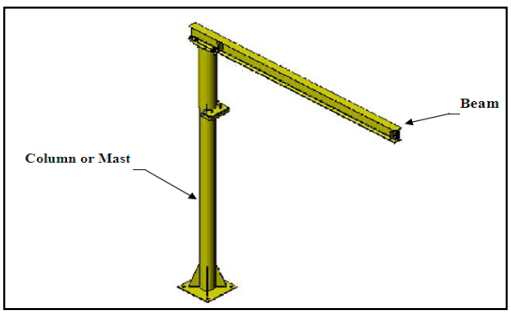

Fig.1. Main parts of Free Standing Jib Crane

II. DESIGN CONSIDERATIONS OF JIB CRANES

As discussed earlier design features of cranes vary widely according to their major operational specifications. The design factor for the stresses in the crane is based on the capacity plus 25% of the rated load for impact and 15% of the rated load for the weight of the hoist and trolley. Generally, this is used all along with the average yield stress of the material to find out the type of the design. This design provides a margin to allow for variations in material properties, operating conditions, and design assumptions. No crane should be supposed to ever, in any circumstance, be weighted beyond its rated capability.

III. ANALYTICAL SOLUTION

An existing jib crane from Industries is taken for the analysis. The details of the same are as below in Table No. I and Table No II.

The analysis will be done for static condition. For the sake of convenience load is applied at the end of the beam. Effect of various parameters, like web thickness, web height, and load will be studied during the analysis. Also tie rod will be used for the further part of analysis & effect of cross sectional area of tie rod will be seen. Deflection & Von Mises stresses will be observed throughout the analysis.

TABLE I

SPECIFICATIONS OF JIB CRANE CONSIDERED IN PRESENT WORK

Sr. No.	Parameter	*Value*
1	Capacity of Jib Crane	*1112.454 N*
2	Height of Column (Mast)	*3 m*
3	Beam length (Total)	*2.65 m*
4	Distance of Center of Column (Mast) to end of Beam	*2.44 m*
5	Web thickness	*5.8 mm*
6	Flange thickness	*9 mm*
7	Total height of I beam	*175 mm*
8	Width of flange	*85 mm*
9	Inner diameter of column (Mast)	*128.58 mm*
10	Outer diameter of Column (Mast)	*141.28 mm*

TABLE II

PROPERTIES OF STRUCUTRED STEEL

Sr. No.	Property	*Values*
1	Young's Modulus	*2.1 x 105 N/mm^2*
2	Poisson's Ratio	*0.3*
3	Density	*7840 kg/m^3*

A) ANALYSIS OF ONLY CANTILEVER BEAM CONSIDERING LOAD AT FREE END

Analytically the deflection at the end of the cantilever beam is calculated as below.

$$\delta = \frac{wxl^3}{3ExI}$$

Where,

δ = deflection at the free end of beam

w= Load applied = Rated capacity x Design Factor

= 1112.454 x 1.4 = 1557.43 N

L = Length of beam

E = Young's modulus of the material of the beam

I = Area moment of Inertia of beam about an axis passing through its center of gravity

$$\delta = \frac{1557.43x2440^3}{3x2.1x10^5 x1242.09x10^4}$$

$$\delta = 2.8912 \text{ mm} \quad (1.1)$$

Deflection due to load at the end = 2.8912mm

B) ANALYSIS OF CANTILEVER BEAM CONSIDERING ONLY SELF-WEIGHT

Analytically the deflection at the end of the beam is calculated as below.

Deflection due to self-weight is calculated by following formula.

$$\delta = \frac{wxl^4}{8xExI}$$

In the above formula, w is weight per unit of beam. Considering the density of material, its value is (19.13 x 9.81) N/m

$$\delta = \frac{19.13x9.81x2.44^4}{8x2.1x10^5 x10^6 x1242.09x10^{-8}}$$

$$\delta = 0.00031877 \text{ m} = 0.31877 \text{ mm} \quad (1.2)$$

Deflection due to self-weight only = 0.31877 mm

C) ANALYSIS OF CANTILEVER BEAM WITH SELF-WEIGHT & LOAD AT THE END

Total deflection at free end } (Deflection due to load only) + (Deflection due to self-weight only)

Hence,

Total deflection = 2.8912 + 0.31877 = 3.20977 mm (1.4)

D) ANALYSIS OF COLUMN (MAST) ONLY

Mast is also analyzed for some arbitrary value of load. This arbitrary value is 1000 N.

$$\delta = \frac{PxL}{AxE}$$

Here δ is deflection of column.

P = applied force.

L = length of the column or mast.

A = cross sectional area of column

E = Young's modulus of the material of column

$$\delta = \frac{1000x3000}{2691.73x2.1x10^5}$$

I. δ = 0.0053 MM

IV. FINITE ELEMENT ANALYSIS APPLIED TO JIB CRANE

Deflection Of Beam (Boom) Considering Its Weight & Load of 1557.43N

Load Condition & Boundary Condition are used as in Table No. III

Boundary Condition: The beam is constrained at left end for all degrees of freedom. i.e. rotary & linear are constrained.

Load Condition: Load is applied at the right end.

TABLE III
INPUT PARAMETERS TO ANALYZE THE BEAM

Sr No	Nature of Parameters	Parameters	*Values*
1	Geometric Parameters	Length of Beam	*2440 mm*
		Area of Cross section of Beam	*2440.6 mm^2*
		Area Moment of Inertia of Beam	*1242.09x10^{4}mm^4*
		Height of Beam	*175 mm*
2	Loading Parameters	Force	*1557.43 N*
3	Material Properties	Young's Modulus	*2.1x 105 N/mm^2*
		Poisson's Ratio	*0.3*

The length of element is taken as 100 mm. Figure No 2. Shows the discretized model.

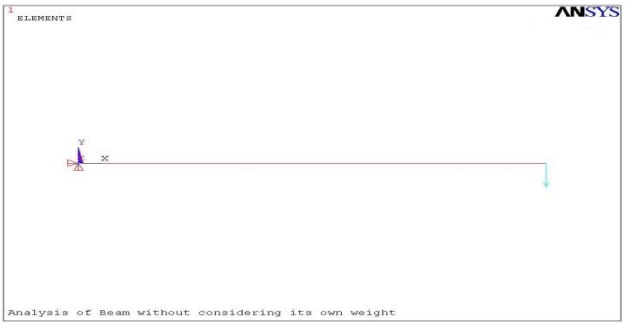

Fig.2. Model with load condition & boundary condition

A) DEFLECTION AT FREE END

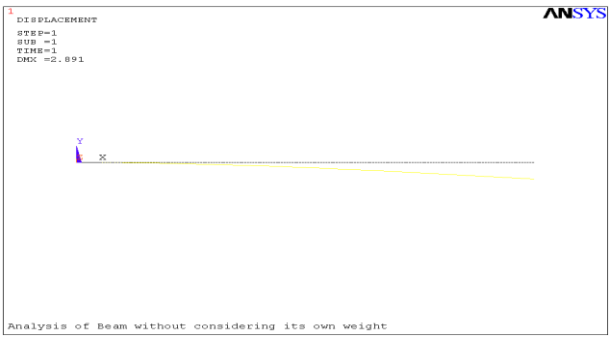

Fig.3. Deflection at Free End

The deflection at the free end obtained by Finite Element based software ANSYS is 2.891 mm. The same is seen in the figure No 3.

δAnsys= 2.891 mm

Observing the analytical & Finite Element analysis values it can be said that the type of element & mesh density used for above analysis is correct. The maximum stress for the above case is also observed in the post processing.

B) Maximum stress is also observed in the post processing. The same is shown Figure No 4.

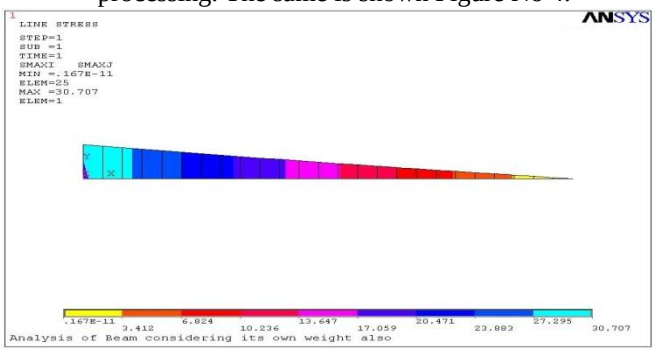

Fig.4. Maximum stress is observed in the post processing is shown.

Maximum Stress (Direct + Bending) = 30.707MPa (1.5)

C) FINITE ELEMENT ANALYSIS OF COLUMN ONLY

Deflection of Column (Mast) considering its weight & load of 1000N

TABLE IV

INPUT PARAMETERS FOR ANALYSIS OF COLUMN (MAST)

Sr No	Nature of Parameters	Parameters	*Values*
1	Geometric Parameters	Height of Column	*3000 mm*
		Area of Cross section of Column	*2691.73 mm^2*
		Area Moment of Inertia of Column	*613.93 x 10^4 mm^4*
2	Loading Parameters	Force	*1557.43 N*
3	Material Properties	Young's Modulus	*2.1x 105 N/mm^2*
		Poisson's Ratio	*0.3*

D) Load condition & Boundary condition are used as in Table No. 4.

Load condition: Load applied is a tensile force of 1000 N.
Boundary condition: All motions of the bottom end are constrained

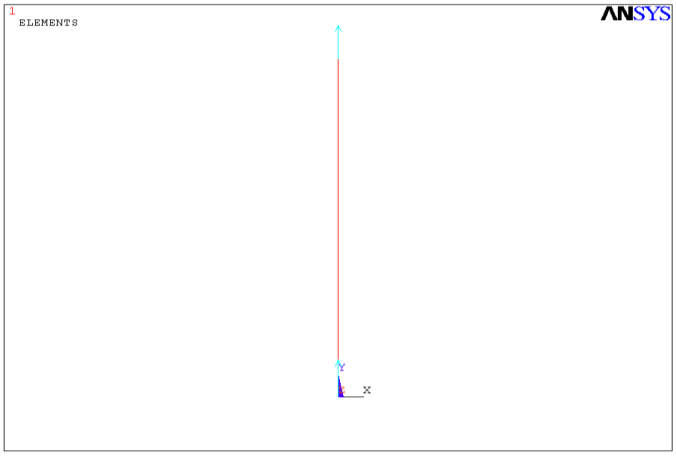

Fig.5. Model with load condition & boundary condition

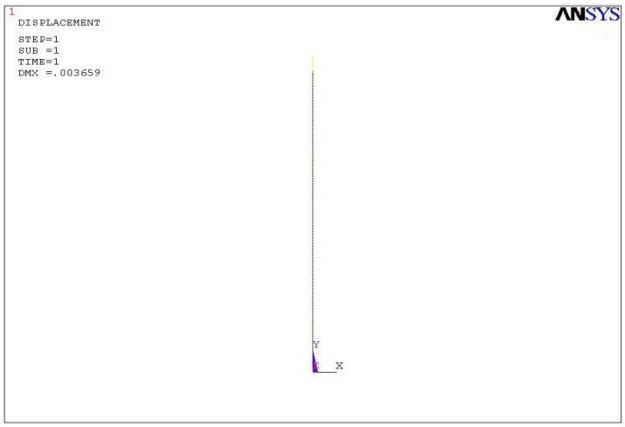

Fig.6. Deformation of Column (Mast)

Maximum Deformation: **Deformation is 0.005307 mm**

E) FINITE ELEMENT ANALYSIS OF JIB CRANE (Two Dimensional)

For the analysis of Jib Crane, simplified model is prepared using column (mast) & beam.(boom) Figure.7. shows simplified model (2D) of jib crane.

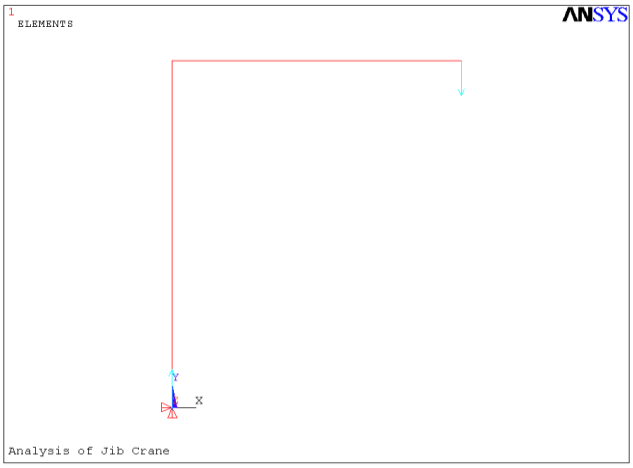

Fig.7. Simplified Model (2D) of Jib Crane

Meshed Model with load condition & boundary condition is shown in Figure.8. The load is applied at the end of the beam & base of the mast or column is constrained as in the earlier case.

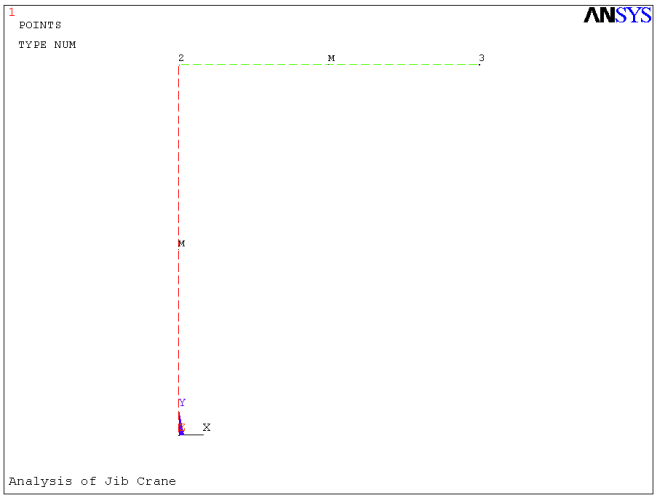

Fig.8.Discretization of the model of jib crane

Fig.9. Deformed shape (along with un-deformed shape) of jib crane

Figure.9. shows Deformed shape (along with un-deformed) shape of jib crane. The deformation obtained at the end of the beam is maximum & its value **δAnsys=31.841 mm**

V. RESULTS DEFLECTION OF BOOM

1. Deflection due to load at the end = 2.8912mm (Analytically)
2. Deflection due to self-weight only = 0.31877 mm (Analytically)
3. Deflection due to load at the end = 2.891mm (ANSYS)
4. Maximum Stress (Direct + Bending) = 30.707MPa (ANSYS)

DEFLECTION OF MAST

5. Analysis of Column (Mast) Only = 0.0053 mm (Analytically)
6. Maximum Deformation: Deformation is 0.005307 mm (ANSYS)

DEFLECTION OF 2D MODEL

7. The deformation obtained 2D model when Load is applied at the end of the beam is maximum & its value δ =31.841 mm (ANSYS)

VI. CONCLUSION

1. In present work, analytical results and results obtained via finite element method are compared to analyze the crane structure stress, forces, and accelerations. It has been observed that, there is no variation in results obtained from former and later. Thus, this provides us an alternate option for an experimental test which is required for the analysis of cranes.
2. The deformation obtained in 2D model when Load is applied at the end of the beam is maximum & its value δ =31.841 mm (ANSYS). This 2D analysis is valid for 3D Analysis.

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