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Design and Force Analysis of Camera Jib Crane

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***Abstract*— Camera jib cranes are widely used in film shooting and capturing party functions by holding a camera on it. Therefore, a jib crane designer should seek a satisfactory design to withstand the developing loads and suppress the vibrations during shooting. Several factors have to be taken into consideration when a jib crane is being designed. Most important factors are; self-weight of the crane, weight of the camera and Lazy Suzan, counter weight added. Moreover, for the cranes which operate in open air, the external load caused by atmospheric conditions are also to be considered. In order to avoid losses after manufacturing, all these factors have to be taken into consideration during the design process. The aim of this work is to compare existing design of the jib with a new design and to study the stress developed due to random vibration in both cases. The modelling is done using CATIA software and the computational analysis is done using ANSYS 14.0 software.**

Keywords*— Jib crane, bending, deflection, natural frequency.

I. INTRODUCTION

A jib is a device with a camera on one end, and a counterweight and camera controls on the other. It operates like a see-saw, but with the balance point located close to the counterweight, so that the camera end of the arm can move through an extended arc. A jib permits the camera to be moved vertically, horizontally, or a combination of the two. A jib is often mounted on a tripod or similar support. A jib is useful for getting high shots, or shots which need to move a great distance horizontally or vertically, without the expense and safety issues of putting a camera operator on a crane for a crane shot or laying track for a camera dolly. A device known as a hot head or remote head is attached to the camera end of larger jibs. It supports the camera and enables remote pan/tilt functions with focus/zoom control. This setup can be operated by one person, or the circumstance may require two operators. In a two-operator situation, one person operates the jib arm/boom while another operates the pan/tilt/zoom functions of the remote head.

The cross section that is commonly used in the making of jib crane is triangular tube cross section. Circular and square tube cross sections are also rarely used for short cranes. Sometimes double bar designs are also used. Among the materials used in the manufacturing of jib cranes, structural steel and aluminium are most prominent. Since stiffness is the main criterion for minimizing the deflection, studies are conducted on the properties of these materials. It is found that the value of young's modulus, which is a measure of stiffness, for structural steel is three times as that of aluminium. Also the load bearing capacity of structural steel is much higher than that of aluminium. Hence structural steel is selected as the material for the analysis.

In recent years, with the development of technology, the demand for optimum or minimum-weight, high load bearing and vibration resistant structural components has been greatly increased. Hence there arises a need to replace the triangular sections with a new section to reduce the deflection and stresses developed and to withstand vibrations. This leads to develop the jib crane with an I section. The modelling of both I section and triangular tube section is done using CATIA and the analysis is done using ANSYS 14.0 software. This paper deals with the design, force and vibration analysis of camera jib cranes with triangular tube cross section and comparing the results with that of an I section.

II. DEIGN AND ANALYSIS

A. *Design Parameters*

For finding out the design parameters of the newly developed section, the dimensions of the existing jib crane is taken as reference. The existing jib crane is having a total length of 10m and a triangular tube cross section of each side 0.1m and thickness 0.013m. The dimensions of the I section is found out by considering same volume for both the cranes. Since the length is taken as the same value, the problem was reduced to the consideration of same area. Thereby the relation between the length of web and flange was obtained. Arbitrary values are substituted in this relation to obtain the same area as that of triangular tube section. Then the section modulus of both sections are calculated based on area. The results shows that the section modulus of an I section is very high than triangular tube section when same area is considered. Hence I section is selected as the substitute for triangular tube section. Then a number of iterations were performed by reducing the dimensions of the I section till the value of section modulus becomes slightly greater than triangular tube section. Thus an I section with optimum dimensions is found out. This helps in reducing the volume of material used in making the jib and also the effective weight of the jib.

B. *Modelling using CATIA*

The dimensions of the triangular section and the values of I section found out by iterations are used to model the jib cranes. Holes are provided in the model to reduce the amount of material used in making of jib. This makes the jib more economical and reduce the weight of the jib so that the transportation of jib from one location to another becomes easier.

TABLE I. DESIGN PARAMETERS OF I SECTION

PARAMETERS	DIMENSIONS (m)
Total length	10
Length of flange	0.06
Length of web	0.06
Thickness of flange & web	0.01
Hole diameter	0.05
Radius of fillet	0.015

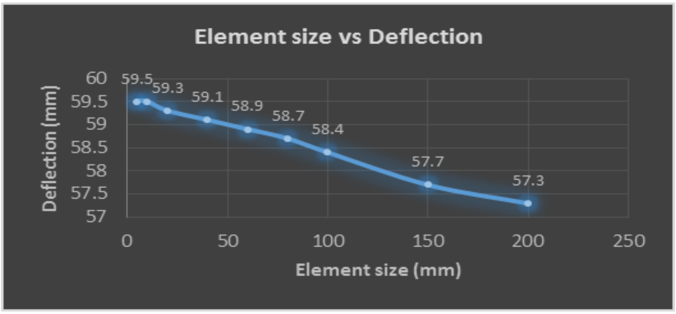
TABLE II. DESIGN PARAMETERS OF TRIANGULAR TUBE SECTION

PARAMETERS	DIMENSIONS (m)
Total length	10
Side	0.01
Thickness	0.013
Hole diameter	0.05
Radius of fillet	0.015

C. *Analysis using ANSYS 14.0*

The analysis of the modelled structure is carried out by using ANSYS 14.0 software. Before going into the analysis the ideal mesh size that will provide the correct result is found out by the method of mesh convergence. For doing mesh convergence, the crane with I section is considered and the size of the element is varied from coarse to fine and the deflections produced are observed. It is found that optimum result is obtained when the element size is 5mm.

GRAPH I. MESH CONVERGENCE DIAGRAM



The meshing adopted for analysis is triangular meshing and element selected is SOLID72 element which has got six degrees of freedom. The analysis is carried out by giving the self weight of the structure as UDL, weight of camera and counter weight added are given as point loads at the two ends of the jib. In vibration analysis, modal analysis is conduted to find out the mode frequencies. Also random vibration analysis is conduted in which power spectrum density displacement data is given as input. This is done to find out the stress developed and deflection that occurs in a jib.

III. RESULTS AND INFERENCE

From the analysis it is clear that for the same loading condition, crane with I section has got lesser deflection than that with triangular tube section. The stress developed is also lesser for I section.

A. *Static Analysis Results*

Fig 1. *Equivalent stress developed for triangular tube section*

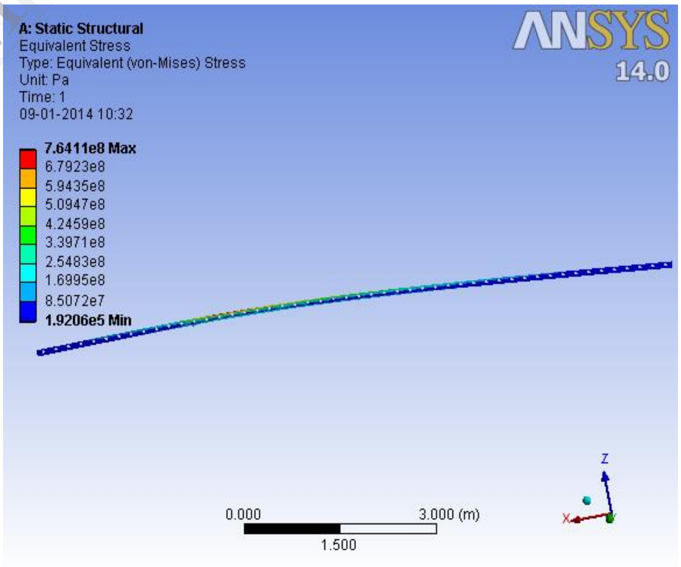
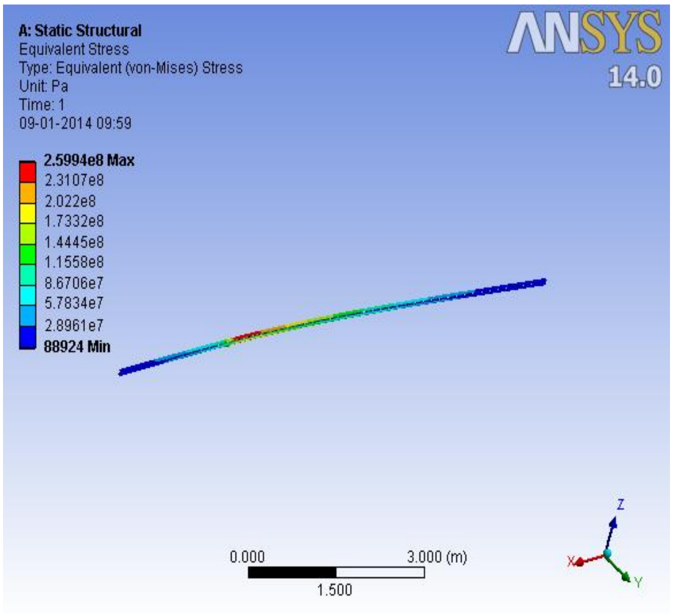


Fig 2. *Equivalent stress developed for i section*



From the above figures it is clear that in both the cases maximum stress is developed at the hinged point. But the stress developed in triangular section is almost three times as that of I section. The least stress is developed at the end points of jib.

In case of deformation, deformation along the vertical axis only is considered. This is because of the reason that all the loads that are acting on the jib are in downward direction and hence the maximum deformation will takes place along this direction. The value of deformation obtained for I section is __ and that for triangular tube section is____. This shows that the I section is more effective than triangular tube section.

Fig 3. *Directional deformation in triangular tube section*

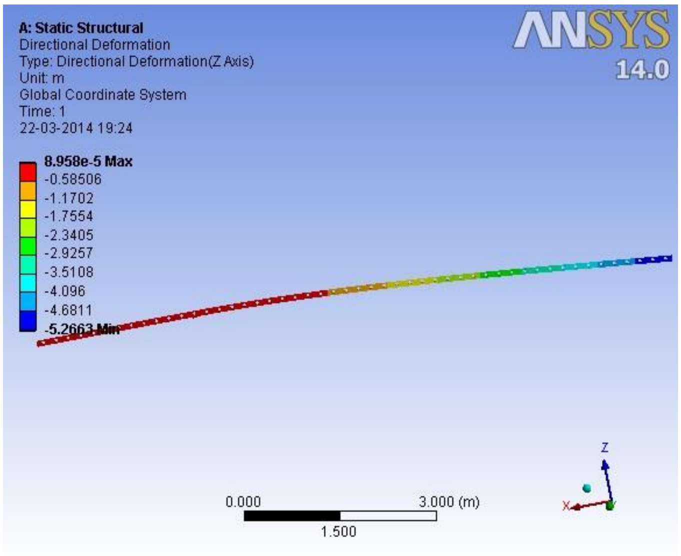
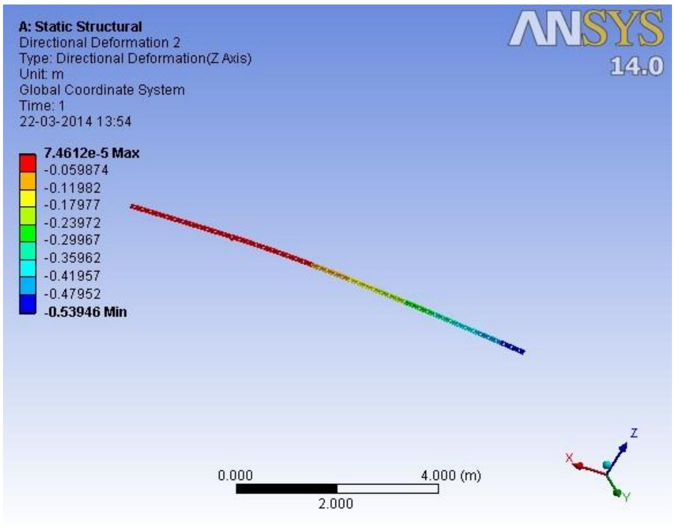


Fig 4. *Directional deformation in i section*



B. Vibration Analysis Results

The maximum equivalent stress developed in jib crane with triangular section is almost twenty times than the equivalent stress developed in the jib crane with I section. This result shows that when external force like wind acts on the jib wit triangular cross section a large amount of stress is developed as the stress cannot be equally distributed across the section. This can result large deformations and can cause the failure of the structure due to excessive vibrations.

Fig 5. *Equivalent stress developed for triangular tube section*

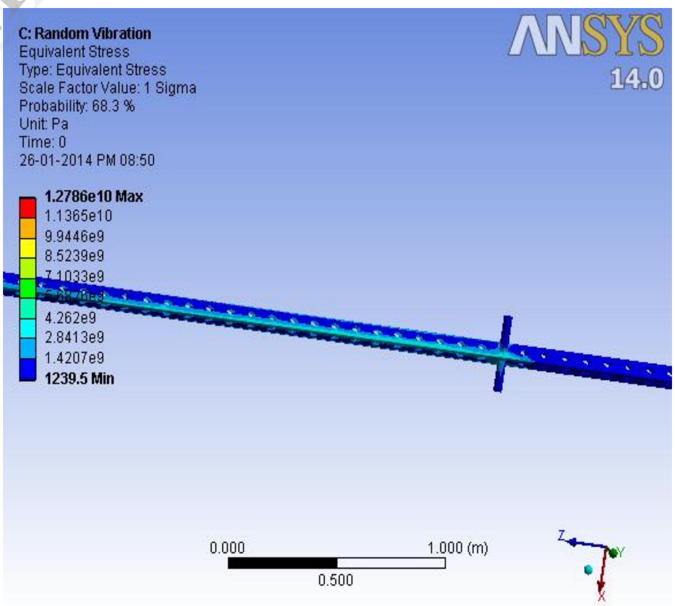


Fig 6. *Equivalent stress developed for i section*

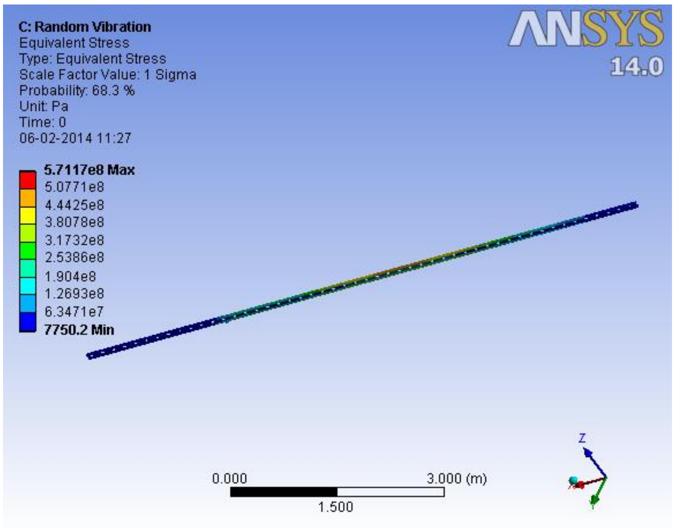


Fig 7. *Directional deformation in triangular tube cross section*

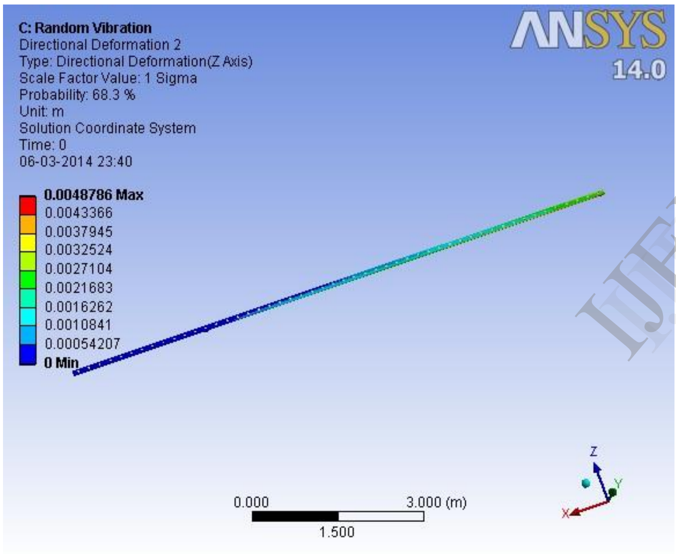
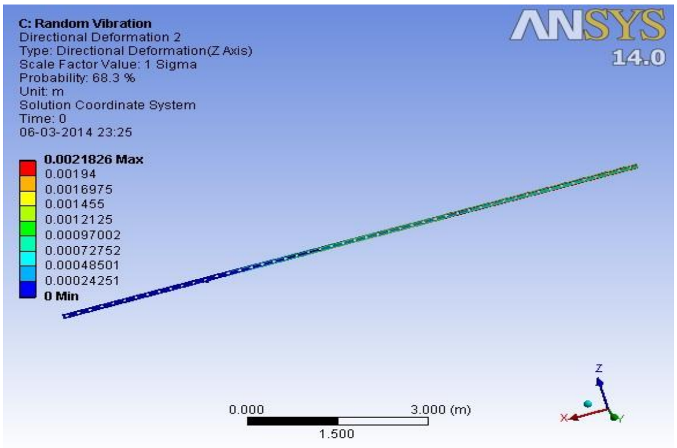
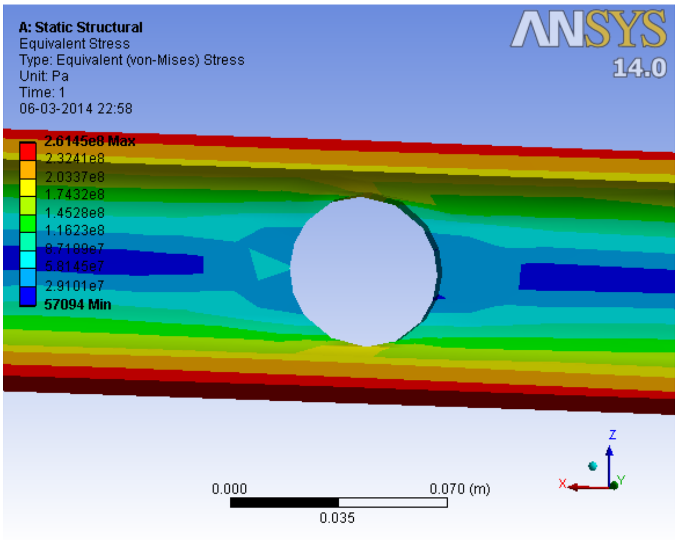


Fig 8. *Directional deformation in i section*



Due to the large stress developed and lower strength triangular tube section has got greater than deformation than the crane with I section. This makes it difficult to perform film shooting in areas of rough climatic conditions, whereas the crane with I section is more stable to vibrations and hence there will be less chances for jerks.

Fig 9. *Stress concentration around the holes*



The holes provided in the structure to reduce the material and weight can sometimes result in stress concentration. From the analysis it is clear that the stress developed around the hole will never result in the concentration of stress around it. The structure is safe even though fillets are not provided at holes to reduce stress concentration.

IV. COMPARISON OF RESULTS

Table III and Table IV shows the results about the stress developed and deformation occurred in each section during the analysis.

TABLE III. STATIC ANALYSIS

CROSS SECTION	EQUIVALENT STRESS (Pa)	DIRECTIONAL DEFORMATION (m)
Triangular tube	7.6411e8	8.958e-5
I section	2.5994e8	7.4612e-5

TABLE IV. VIBRATION ANALYSIS

CROSS SECTION	EQUIVALENT STRESS (Pa)	DIRECTIONAL DEFORMATION (m)
Triangular tube	1.2786e10	0.0048786
I section	5.7117e8	0.0021826

V. CONCLUSIONS

From the analysis it can be concluded that the I section has got better performance than commonly used triangular tube sections. The I section has got greater section modulus than triangular tube section even when the area of the I section considered is less than that of the triangular tube section. This makes jib with I section stronger than the present jib. This also makes the jib more economic and reduces the overall weight of jib crane as the amount of material used is less. From the static and vibration analysis it is clear that the I sectioned jib crane has got less deformation and stress developed is also less which makes it more suited in situations where there is harsh climate. Because of the lesser deformation and stress, the operating life of the jib is also improved. From the modal analysis it is clear that the values of mode frequencies are nowhere around natural frequency of vibration. Hence it is more resistant to the failure caused due to vibration. Therefore jib crane with cross section as I section can be used as an alternate for the existing jib crane.

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