DISCUSSION

Design Concepts for Jib Cranes

Paper by JAMES FISHER and STEVEN THOMAS
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I thank the authors for a very thorough and informative article on jib cranes. To this, I would add the following regarding maximizing the crane's effect for column design.

For a single jib crane on a column, the position of the jib crane resulting in the maximum effect on the column can be calculated as follows. The position of the jib crane is described by the angle θ, defined as 0° for a wide-flange column when the jib is turned so as to maximize column minor axis bending and torsion, and 90° when the jib is oriented to maximize column major axis bending (i.e. parallel to the column web). For an HSS column, the major axis is defined (for the purposes of this discussion) as the axis bent by the jib positioned at θ = 90°. I hope the reader will forgive the circular definition. To clarify, if the jib brackets are mounted on the 10 in. face of an HSS 8 × 10 × ½, the major axis modulus S_x as used herein will be less than the minor axis modulus S_y.

Summarizing the notation of the article (to which reference should be made):

R_H	=	Horizontal reaction of the jib crane at the hinges.
P	=	Vertical load (lifted load and weight of hoist). Some allowance should be made by the designer for the jib selfweight as well.
A, B, C	=	Vertical dimensions along the column from upper hinge to roof framing, distance between hinges, and from floor to lower hinge respectively.
X	=	Maximum distance from the hoist to the hinge axis of the jib (essentially, the length of the jib).
D	=	Distance from the hinge axis to the face of the column.
d_c	=	Column depth.
t_f	=	Column flange thickness.

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For an HSS column, torsion manifests itself as a shear stress in the walls ($f_s = T/2bht$) and thus is not directly additive to axial and bending stresses. This shear stress should be evaluated separately by the designer and, if significant, should be checked along with bending and axial stresses using an interaction equation. We will begin with this case (HSS column), neglecting torsion and considering only bending.

Assuming service loads,

$$R_H = P \times e \,/\, (A+B+C) \tag{1}$$

where

$e = X$ for θ = 0°
$e = (X + D + d_c/2)$ for θ = 90°

For either axis of the HSS column, $M = R_H$ * (A or C). Then, the bending stress in the column is

$$f_b = P \times [(A \text{ or } C) \,/\, (A + B + C)] \times [\,(d_c/2 + D + X \sin\theta) \,/\, S_x + (X \cos\theta \,/\, S_y)] \tag{2}$$

when the jib is positioned at angle θ.

Differentiating to maximize f_b, $[X / S_x] \cos\theta - [X / S_y] \sin\theta = 0$; then,

$$\tan\theta = S_y \,/\, S_x \tag{3}$$

For square HSS shapes and box shapes, a value of θ = 45° results.

For wide flange columns, torsion manifests itself primarily as warping torsion, which can be evaluated as a minor-axis force couple acting horizontally on the column flanges. Depending on the relative dimensions of the jib bracket and the column cross section, torsion typically results in stresses several times that of maximum minor axis bending. Including torsion as an equivalent minor-axis moment, as suggested by the article, may be accomplished by adding a term "Y" to the "X" in the last term of Equation 2, resulting in the following equation:

$$\tan \theta = X\, S_y \,/\, (X + Y)\, S_x \tag{4}$$

The term Y is found from the equation $M_T = P\,(X/B)\,(d_c\,/2 + D) \cos \theta$. From this, the equivalent lateral flange force is found: $P_H = M_T \,/\, (d_c - t_f)$. Then, the moment acting on one flange of the column is $M_{fl} = P_H\, B\, (A \text{ or } C) \,/\, (A + B + C)$ (using the maximum of A or C), and $f_b = M_{fl} \,/\, (S_y\,/2)$.

Thus, if either or both ends of the column are torsionally pinned,

$$Y = X\,(2D + d_c) \,/\, (d_c - t_f) \tag{5}$$

If both ends of the column are torsionally fixed,

$$Y = [X\,(2D + d_c) \,/\, (d_c - t_f)] \times [1 \,/\, (1 + (A + B)/C) + 1 \,/\, (1 + (B + C)/A)] \tag{6}$$

For wide flange shapes used as columns (flange width approximately equal to depth), this results in a value of θ between 6° and 10° when substituted into Equation 4. Implicit in these equations is the assumption that the allowable bending stress is the same about both axes. For most wide flange shapes used as columns, this is close but not quite true, and thus the angle θ will be slightly overestimated by Equation 4.

For working stress design, the value of θ is then substituted into the equation

$$f_b = P \times [(A \text{ or } C) \,/\, (A + B + C)] \times [(d_c/2 + D + X \sin \theta) \,/\, S_x + [(X + Y)\cos \theta \,/\, S_y] \tag{7}$$

For LRFD, substitute the plastic modulus Z for the elastic modulus S in Equations 3 or 4 and use the resulting value of θ to calculate moments thus:

$$M_{UX} = P_U \times [(A \text{ or } C) \,/\, (A + B + C)] \times (d_c/2 + D + X \sin \theta) \tag{8}$$

and

$$M_{UY} = P_U \times [(A \text{ or } C) \,/\, (A + B + C)] \times (X + Y) \cos \theta \tag{9}$$

These equations will provide the critical angle causing maximum stress, to be used in checking against yielding and local buckling. When checking overall column stability, the designer should also check the cases of θ = 0 and θ = 90°.