

Automating the process of jib crane design



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Automating the Process of Jib Crane Design

Chapter 1

Introduction

1. 1 Introduction

In a jib crane horizontal jib is fixed to a pillar or to a wall and supports a movable lift. Jib crane mostly used in industries and for military purpose. The jib can also swing by the arc which corresponds to lateral movement (additional). These types of crane are used in warehouse stores to lift the goods to all floors.

In the materials handling industry workers are often required to do large payloads. In situations where large payload movements would require extra forces to be applied by the operator, the material handling devices are provided now with automatic or motorized power assists. These are basically designed such that they can reduce operator tiredness and damage. Such cranes are power assisted jib cranes with advanced design.

A jib crane consists of a pendulum like end line attached to a rota-table jib. Within this general cranes category there exist some devices with multiple degrees of freedom which includes variable load line length and jib length which is also variable. Point-point payload maneuvers with jib cranes are performed so as not to incite the spherical pendulum modes of the cable attached and payload assembly. In a typical way these pendulum modes yet time-varying, but shows low frequencies. That results in slow performance; hence high construction and transportation costs can occur. The figure below shows the different parts of jib crane. [Franklin, 1994]

Jib Cranes are industrial machines which mostly uses for materials movements in construction of buildings, production halls, assembly lines, storage areas, and power plants. The design features of jib crane vary widely according to their major operational and manufacturing specifications such as: crane structure according to motion, weight and type of the load, crane location, geometric features, and environmental conditions. However, a review of the available literature tells that technical design of jib cranes are highly saturated and standardized in many industrial companies and organizations independent of the jib crane type. [Marchese, 1974]

1. 2 Problems/Issues

Today most companies currently uses manual calculations to provide product design specification for their jib cranes for their customer's requirements. This job involves very hard work and the manual calculation. The reduced man work will efficient the company's process for design and manufacturing of the product. So it would be beneficial to automate this process which requires a software package in which all calculation can be done automatic.

1. 2. 1 Current Problems

The problems in jib crane design incorporate advance design for their different customers and their different purpose and the companies don't have a computer program which calculates the design specifications for manufacturing for their customers. [Erden, 1996]

1. 2. 2 Literature review

Current material handling systems exhibit anisotropic behavior. Their two planar degrees of freedom have requirement of different force inputs from

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the operator. For jib crane in generation of isotropic behavior there can be two directions, the first direction generates isotropy by floating the boom above the load. The second direction adds a power trolley and is capable of assisting by providing power to actually accelerate the given load. We can provide a cable angle sensor and ultrasonic distance sensor for the intelligence necessary to achieve isotropy. [A, Lorenz, 1999]

Consideration of the available technology that is mainly based on the accumulated previous experience is important for better performance, higher safety and more reliable designs. It is well known that generic features of jib crane components are similar for various different types of cranes. Since the jib crane design procedures are highly standardized with these components, main effort and time spent in jib crane design projects are mostly for interpretation and implementation of the available design.

In the figure below a rotatory jib crane is shown with degrees of freedom.

The crane considered here consists of a rotatable jib with a load line attached to the end. A mass, representing a payload, is attached to the end of the load-line. The figure (1) is shown for analysis. The three co-ordinate system (three vectors shown) attached to the jib and rotates about the hub with an angular rate (γ). The rotation angles are defined as rotation of the load-line about the two axes. The attachment point of the load-line to the jib is at a distance x from the centre of rotation of hub. The load-line has length L and the payload mass m .

Alternative Concepts:

Several concepts were evaluated:

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Single tension rod

A single-rod design is assumed during the initial calculations to determine reaction forces on the building column. Extra analysis explained that this design did not have enough power for its length and capacity.

Truss

A trussed beam is considered, as it would have provided a very light, strong crane. This design was shortly discarded because it would have proven very difficult to study and build.

Two tension rods

A two-rod design can be selected because it could be made strong enough to support the design load up to the length of 30 feet, yet be simple enough to analyze with a combination of manual calculations and computer-based analysis.

1. 2. 3 Objectives

- To understand design and analysis of jib crane
- To design jib crane in AutoCAD / Solid work
- To develop calculation of jib crane data using Microsoft excel

Chapter 2

Methodology

2. 1 Flow chart:

Start

Design and analysis for the jib crane (Existing Design) and a modified design

AutoCAD Design

Create Microsoft excel software

End

In the initial stage the project overview and scope of project is analyzed. Further on the literature based on the current design is reviewed. Next stage is examining the design advancement of the jib crane using sensors and control to automate the crane process and in lowering the operator stress and power. After that the software developed will be used in design and selection of major jib crane parts for the manufacturing. The design stated by software would be seen as in AutoCAD or solid work. In the final stage the further advancement and conclusion will be made.

The stages of the project are shown below.

2. 2 Description:

The project will consist of manual calculations of design specifications for the complex structures like Jib crane along with automated process. The use of Microsoft software along with some other package will be used so that it would be more users friendly. First the calculation will be done like moment of inertia, torque and transmission ratios etc. for the advanced mechanical design of the jib crane [Juvinal, 1991] then the number of variables will be included in software to give the product design specification for jib crane directly which will help in reducing the manwork. The simple advantage to get the all data which are required in jib crane design will come directly and this process will help in reducing time taken to produce a required jib crane. The work will be done with existing data and current methods of calculation.

At the end of project, a manufacturer should not calculate the various design data for the custom design of the jib crane for different purpose. The jib
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crane software itself will pick the most essential and important data and according to that will choose the simplified method to give design specification directly. Reader will be able to understand the various methods involved in jib crane design and advancement of design and the analysis of jib crane to make it effective. The practices followed and measures developed to make high-rise construction a safer job will be listed in report.

Some of the main benefits of the automated design include the following:

- Greater consistency of design; this makes manufacturing and field service easier.
- Ability to explore more alternatives; because design can be created in a shorter time, it allows designers to study more alternatives.

2.3 Gantt Chart

Gantt Chart: Project on “

Automating design of jib

crane”

	Oc	No	De	Ja	Fe
TASKS	t	v	c	n	b

Selection of
the Topic

Submission of
the Project

Proposal

Literature

survey on the

Topic

Submission of

the Interim

Report

Software

development

Conclusion

and

Recommendat

ions

Final Report

Submission

Chapter-3

Design and Calculation of Jib Crane

3. 1 Design Concepts for Jib Crane

Jib cranes, a free standing or portable jib crane is an economical solution for moving materials within an individual workstation, for transferring materials from work area to work area, or for use as an auxiliary lifting device under an overhead crane. Jib cranes are designed and manufactured in four styles:

- Free standing or portable jib cranes
- Wall bracket tie rod supported jib cranes
- Wall cantilever jib cranes
- Mast style jib cranes (top and bottom supported)
- Articulating jib cranes are also manufactured for positioning loads in those hard to reach places where most

Standard jib cranes cannot reach. An articulating jib crane can move loads around corners and columns, reach into machinery, and service an area from the closest pivot point to the end of the boom allowing 360° of operation. Another jib crane is the workstation jib crane. From self-supporting to wall mounted, workstation jib cranes provides economic, supplemental lifting coverage with 200° or 360° of rotation.

Features Standard jib cranes range in capacity up to 5 tons and spans to 20 feet. Jib cranes feature on unique trussed boom design, which offers longer spans for custom jib crane designs. Free standing and mast type jib cranes offer 360 ° rotations. Wall mounted offers 200° of rotation.

Design Factor

The standard capacity rating of a jib crane represents the net rated load of the hook at the hook of a hoist of the same rated capacity as the crane. 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. This was used all along with the average yield stress of the material to find out the type of the design. [Juvinal, 1991] 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.

Service Factor

The maximum weight of the application should match, NOT exceed, and design weight. The capacity rating is dependent and based on a design load. The jib crane design criterion allows the least amount of deflection so as not to hamper the performance of the jib crane.

3. 2 Design of a Jib Crane

The unit system of choice is normally SI. For this design, though, the BG (British Gravitational) system is chosen because the dimensions of most acquired components are in inches. We are doing analysis and design of a 30-foot, 1 ton jib crane.

Requirements

The crane must meet the following criteria:

- Should have a capacity of one ton (2000 lb).
- Should have a 30 feet length.
- Should be able to mount on the existing building structure.
- The design load is 2700 lb, defined as follows:
 - $P_d = 2000 \text{ lb} + 25\% \text{ overload} + 200 \text{ lb trolley weight}$

The length of the crane is taken as that of the main beam. The entire crane will arrive at approximately 372 inches from its pivot point. The alternative concepts are already evaluated earlier. We are taking the crane with two tension rods.

3. 2. 1 Reaction Force Calculations

Before detailed design could begin, it had to be determined whether the building structure could support the new crane. This can be accomplished by drawing a free body diagram of the overall crane structure, and calculating the forces that would act on it. The design load should be positioned in the worst-case position hence at the end of the main beam.

Since the weight of the crane makes a noteworthy horizontal reaction force, its main structural components were specified for this practice. A single 200-lb tension rod, attached at 20 feet from the root of the main beam

The weight of the vertical member (eight feet at 25 pounds per foot) was used in calculating the vertical reaction force, but was not deemed significant in calculating the horizontal reaction forces. Minor components e. g. mounting brackets and pin- fasteners, are not going to consider.

The calculations solved on paper, give the following results for The 10 Inch diameter S10at25. 4 the beam:

Horizontal reaction force: 12, 556 lb

Vertical reaction force: 3854 lb

3. 2. 2 Design of Main Beam

The main beam is the most structurally significant part of the crane, and thus was the first to be designed. The maximum stress of a crane has to be less than one fifth of the ultimate strength of the steel. The maximum deflection should be less than 600th part of the length of the crane.

Manual calculations proved that the 8-inch beam would buckle under the compression made by applying the design load at the end of the beam.

Buckling load

A Beam, 360 inches long, meets both stress and deflection guidelines when used with two tension rods. The maximum stress and deflection, when the load is on the end of the crane, are as follows

3. 2. 3 Primary Structure

With the main beam specified, the rest of the crane was designed around it. A model was constructed consisting of the main beam, the vertical member, and the tension rods, which were arbitrarily attached at 15 and 25 feet from the root of the main beam. Manual calculations performed later confirmed that these were appropriate attachment points.

For the sake of simplicity, the vertical member can be specified as the same cross section as the main beam and the vertical member is 96 inches long.

Rod tension

Assume main beam pinned at one end

3. 2. 4 Minor Components

Connecting the Tension Rods to the Main Beam

The tension rods are connected to the main beam using a clevis, which is pinned to a mounting plate welded to the main beam. This clevis is having a tensile load rating of 45, 600 lb which allows a considerable safety factor.

The clevis pin is protected with a 1/8" inch cotter pin. Double-shear calculations show it to be more than strong enough.

Clevis Pin

The clevis mount was designed over-large, to fill up the clearances provided by the clevis. The calculations show that the clevis mount, like the clevis itself, provides a significant margin of safety.

Clevis Mount

$$S_u = 58000 \text{ psi}$$

$$S_{us} = 33640 \text{ psi}$$

$$F = 21658 \text{ lb}$$

$$t_h = 2\frac{1}{2} \text{ in}$$

$$r_o = 2\frac{1}{8} \text{ in}$$

$$r_i = \frac{7}{8} \text{ in}$$

$$d = 1\frac{3}{4} \text{ in}$$

The tension rod is connected to the clevis through a turnbuckle and since the clevis has a rod diameter of $1\frac{1}{2}$ inches, the stud must be turned down from $2\frac{1}{4}$ inches to $1\frac{1}{2}$ inches. The lower end of the tension rod should be threaded for inclusion into the turnbuckle.

Specification of Bearings

Using the overall horizontal reaction force as the radial load, the bearings can be specified. The bolt holes in the flange of this bearing are placed in the identical position.

Design of Welds

The weld connecting the tension rod to the top of the vertical member requires individual explanation. The tension rod on the crane is bent, and then welded to the top of the vertical member of that crane

After placing one rod on top of the vertical member, welds 1 and 2 should consist of a groove weld, then a fillet weld. Weld 3 should use the same pattern subsequent to the second rod is being placed. At last, weld 4 is a groove weld. All welds should fill up obtainable clearances.

3.3 Design Modification:

For each handling device, the two horizontal DOF differ in feel. For the jib and gantry cranes, motion along the trolley's direction of travel requires relatively little force. Similarly, on the bridge crane, motion along the bridge is relatively easy. But for the jib crane, moving perpendicular to the boom's length is complicated by the boom's rotational inertia and the boom pivot's friction. For the gantry crane, this perpendicular motion is very difficult due to the large inertia of the crane, and as stated earlier, often requires power assist. Finally, for the bridge crane, it is the large inertia of the bridge and resulting increased rolling resistance in its trolleys that make the perpendicular motion more difficult.

Low speed power assist has been added to each of these difficult motions: rotation of the boom on a jib crane, translation of a gantry crane, and translation of the bridge along the fixed rails of a bridge crane. The control of this power has been limited to simple push button on/off switches and control algorithms which provide a slow start and stop to minimize load swing. The anisotropy exhibited in the different motions remains.

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This lack of isotropy makes it difficult for workers to move an object from point to point. The worker must constantly vary the applied force as the desired direction of motion changes. To think of this phenomenon in different terms, consider a round stick half immersed in a pool of water. It is very easy to move this stick through a curved trajectory. The forces resisting the motion are independent of the motion's direction. Now consider a paddle (which cannot be rotated) immersed in the pool. It is considerably more difficult to move this paddle through the same curved trajectory. The human must continually adjust to the changing resistance forces. Increasing the viscosity of the fluid will exacerbate the problem. This is analogous to increasing the size and/or load of a material handling system.[Franklin, 1994]

Hence thus, ideally, overhead material handing devices would exhibit isotropy. That is, the feel of the device would be independent of the direction in which it was pushed. So the next objective is to advance the design of jib crane which is intelligent power assist jib and making the design calculation by Microsoft excel itself.

For this design the drawing has been done for some parts and shown below. The rest of the analysis will be done in the final report. In the modified design we put some control sensor for the motion of the jib crane.

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