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Automated Power Controlled Jib Crane Design for its Degree of Freedom

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***Abstract*: The movements of most of the cranes are hindered by their own limitations and non-synchronic movement of parts while working. The research focuses on two aspects, first being the jerking on the load during tangential movement or the inertial force applied on the load. Second being the possibility to provide four degrees of freedom to the crane where the boom has two degrees of freedom, trolley with rope and pulley arrangement would have remaining two degrees of freedom. Research tries to implement few new parts into the system and replacing few mechanical systems with new customized system. A typical jib crane has three degrees of freedom with one rotatory and two lateral motions. And the lateral motion on the trolley needs dual power supply in operation for two different motions. This research offers two solutions for this anomaly, first adding a powered trolley that can accelerate the weight, second changing the motion style by using modified level-luffing method into the jib crane design. The agenda behind all these steps is to make the crane more efficient and increase it's scope.**

***Keywords*: Concurrent movement, Degree of Freedom, Motorised movement, Circular motion, Translation.**

1. Introduction

In a traditional jib crane there are three degrees of freedom which are distributed on lateral motion of trolley and boom rotation around the mast/pillar/pole.

The lack of concurrency in motion of the parts of the crane creates a continuous need for variation in force applied. The changing load increases inertial forces in different directions. At all times a trolley moves linearly along the boom and a rope system hangs the load in concurrence with an elevator.

Ideally, overhead material holding instruments exhibit concurrency. That is, the force acting on the device would not depend on the direction in which it was dragged. This creates the purpose of the research, to design a structure that allows automated power controlled crane which exhibit concurrent dynamic response throughout its work domain. This research would also try to put light on the possibility of increasing the degree of freedom of the crane.

The dominance of the articulating arm in comparison to a standard jib is basically due to following factors; the moment of inertia of a dual arm system is lower than that of a standard or fixed boom therefore requiring lesser force for horizontal movement across boom. But forces along a standard boom are lower due to lower inertia of a trolley.

The cantilevered jib cranes have lower load capacity as compared to Gantry crane or Bridge crane but occupies less space.

The D.O.F for every device varies despite being in same plane and axis due to design constraints. In a jib crane boom's length is perplexed by the rotational motion creating rotational inertia. A power support of low-speed is added for rotational motion of the jib but it doesn't solve the non-concurrency in the movement.

Other way to completely remove the inconsistency during rotational motion and trolley movement is by supporting the boom using a single truss like arrangement below the boom, attached to mast from one end and assisting the rotational motion. If this arrangement is combined with a Level-Luffing system, then the issue of increased inertia can be resolved and three separate movements can be executed at the same time

2. Methods

In a jib crane the non-concurrency is basically due to swing in tangential movement which can be resolved using a power assistance at the pivot, to accelerate upper pivot, boom mount and linear acceleration to the trolley. Accelerating weight would be followed by boom and other components reducing the feel of swing.

The total inertia developed with the new acceleration on tangential direction is calculated using following equation.

$I_{total} = I_{pivot} + I_{mount} + I_{boom} + I_{trolley} + I_{load} = 0.0299 + 0.0759 + 39.7 + (6.33x10^{-3} + 0.171r^2) + (W / 32.2) \times r^2 = (39.8+r^2 (0.171+ W/32.2))$slug.ft^2

An accelerometer is connected to the weights. They are accelerated back and forth at a maximum desired rate. Data collected from the accelerometer shows the maximum acceleration to be 0.15g or 4.83 ft/s2. It is set as the design goal for the maximum linear acceleration of the trolley in the tangential direction.

To evaluate the desired maximum velocity, the weights are moved along the rail again at the maximum desired speed. A stopwatch and marked off distance discover this velocity to be 3.3 ft/s.

Maximum speed times its continuous stall torque gives the continuous power rating of 2.45 hp.

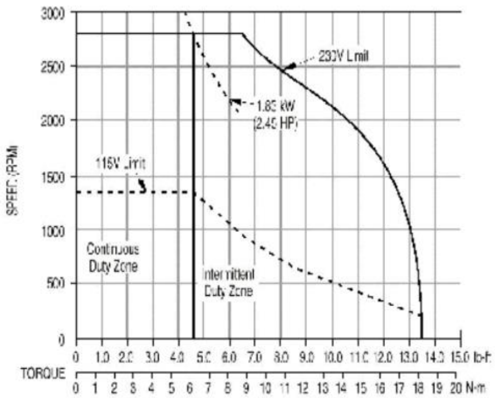


Fig. 1. Torque Curve for the Selected Motor

The stall torque, which is the torque amount that can be built when the rotor is locked in its position, is the normal design parameter.

3. Results

Once the weight attains the commanded speed, the amplitude of higher frequency current input drops to nil. Due to the swing in the load there's a low frequency oscillation around 3 seconds.

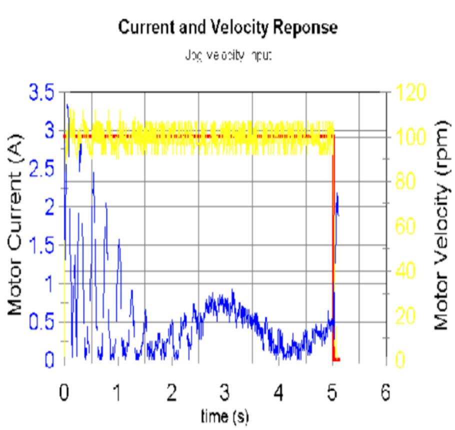


Fig. 2. Motor Angular Speeds and Motor Current in Answer to a Velocity Step Input of 100 RPM

High-frequency oscillations of the current correspond to an oscillation in the actual velocity. As the load attains commanded speed the amplitude of the high frequency current input dies out. Due to the swing in the load there's a low frequency oscillation around 3 seconds. The detected response to the torque command is very smooth acceleration, as expected.

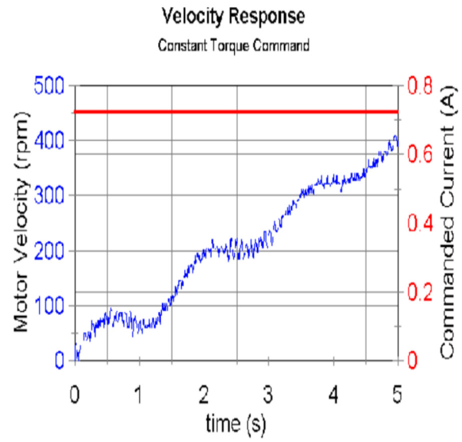


Fig. 2. Velocity Responses to a Continuous Torque (Current) Command

When the roller chain is disengaged, 25kg weight is suspended from the trolley and motion develops. The weight is stabilized by moving it in the radial and tangential direction.

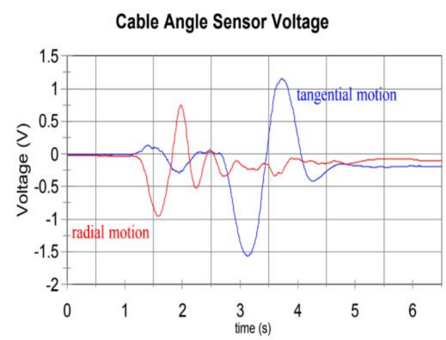


Fig. 4. Cable angle sensor voltage

It is advisable to apply more thrust for motion in this direction considering the higher amplitude. The higher amplitude of the tangential curve is indicative of the more significant force necessary for motion in this direction. The tangential curve flattens indicating the pivot damping effect.

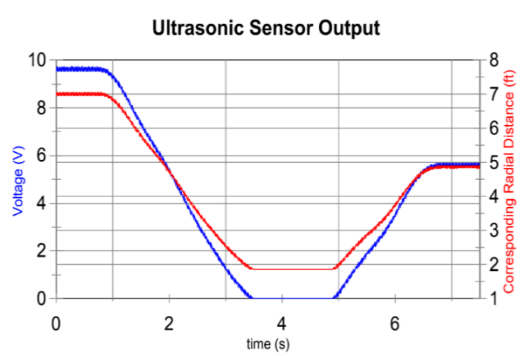


Fig. 5. Ultrasonic sensor output

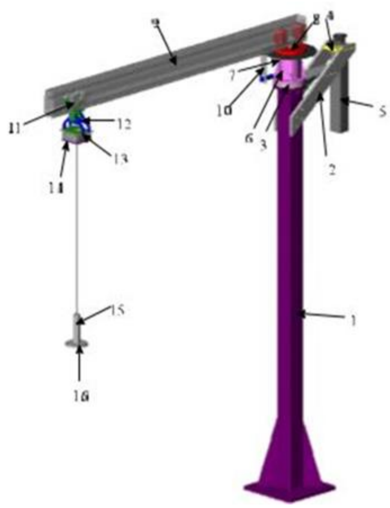
Ultrasonic sensor is used for end verification. As desired the sensor appears linear. As mechanical and electrical parts show correct outputs a conclusion can be derived out of it.

4. Conclusion

The construction and design of a platform for an automated power jib crane are finished. Acceleration of a 100kg weight tangentially with 0.15g at 1m/s, could be achieved using a servo motor, motor drive, gear-head and roller chain. For emergency halt and for smoother movement a dead man's joystick shall be installed. The angle of the suspended cable is determined using the sensor mounted on the trolley. Radial position is of the trolley is measured using an Ultrasonic sensor.

The summation of these components gives a platform capable of providing the jib crane concurrence feel throughout its workspace.

Appendix



Component drawing reference

Table
Conversion factors

density	$\frac{515.4\frac{kg}{m^3}}{\frac{slug}{ft^3}} = 1$
force	$\frac{4.448N}{lb} = 1$
length	$\frac{0.3048m}{ft} = 1$
mass	$\frac{14.59kg}{slug} = 1$
mass moment of inertia	$\frac{1.355kg \cdot m^2}{slug \cdot ft^2} = 1$
power	$\frac{745.7W}{hp} = \frac{550\frac{ft \cdot lb}{s}}{hp} = 1$
torque	$\frac{1.356N \cdot m}{lb \cdot ft} = 1$

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