Crane Project Report
ME 201

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Figure 1: A Crane

What's a crane's favorite type of music?
Heavy Metal.
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Noted Philosopher

1 Introduction

The goal of this project was to make a crane capable of lifting a heavy object as fast as possible using as little mass as possible. We were given a chassis, motors, pulleys, and a micro-controller, everything else we had to make ourselves. This includes several aluminum scaffolding components, a base made of HDPE, structural braces, and a wooden support implement.

2 Design: Warner

2.1 Pulley System

We decided early on make a simple crane, so that we could focus our efforts on optimization. We wanted to lift 2.1 kg, and we designed the crane around it. We did some quick math and determined that a block and tackle system that split the tension in half would be best. Using a spreadsheet, we came up with an equation for the relationship between torque and rotational speed of a motor. This equation was then multiplied by two to account for the fact that two motors were being used. This equation was then put into EES along with an equation that related the torque to the radius of the pulley and the weight of the object being pulled up.

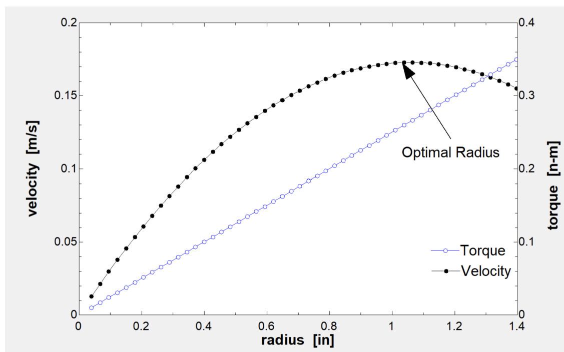

Figure 2: A graph of the relationship between the radius of the drive pulley and the vertical velocity of the object being lifted. Torque delivered from the motors is also included for reference.

We derived the vertical velocity of the object using equation 1.

$$\text{Velocity} = \frac{2 * \pi * \text{Radius} * \text{Rotational Speed}}{\text{Number of Lines connected to bucket}} \tag{1}$$

Where:

$$\begin{aligned}
&\text{Velocity is the vertical velocity of the object being lifted}\\
&\text{Radius is the radius of the drive pulley}\\
&\text{Rotational Speed is the rotational speed of the drive pulley}\\
&\text{Number of Lines connected to bucket is the number of lines connected to the bucket}
\end{aligned} \tag{2}$$

The subsequent parametric study and graph showed that 1 inch was the idea drive pulley radius because it maximized the vertical velocity of the object being lifted. This can be seen in Figure 2.

2.2 Counterweight

We then moved on to calculating both the mass and the position of the counter weight. First we repeated an earlier lab procedure to find the center of mass of the crane using equations 3 to 6.

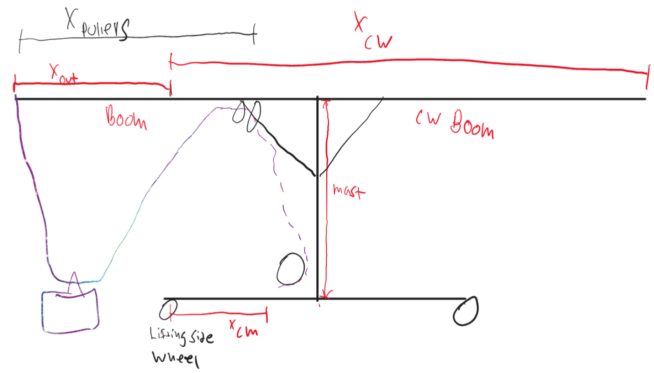

Figure 3: A diagram of the crane

$$\begin{aligned} w_{\text{tip}} &= m_{\text{tip}} * 9.8 && (3) \\ t_{\text{tip}} &= w_{\text{tip}} * x_{\text{out}} && (4) \\ t_{\text{tip}} &= w_{\text{crane}} * x_{\text{cm}} && (5) \\ x_{\text{cm}} &= \frac{t_{\text{tip}}}{w_{\text{crane}}} && (6) \end{aligned}$$

Where:

m_{tip} is the mass of the object that makes the crane tip
w_{tip} is the weight of m_{tip}
x_{out} is the x from the lifting side wheel to the where the mass is hung
t_{tip} is the torque from the object that makes the crane tip
w_{crane} is the weight of the crane without the counterweight
x_{cm} is the x from the lifting side wheel to the center of mass of the crane.
Note: Check figure 3 for a diagram of the crane. (7)

Equation 4 and 5 are made possible by the fact that at the moment of tipping the sum of the moments must be zero because nothing should be moving.

Once the center of mass was found, we could then calculate the mass of the counterweight. A free body diagram of the pulleys can be found in figure 4. This helps

$$\begin{aligned} w_{\text{lift}} &= m_{\text{lift}} * 9.81 && (8) \\ t_{\text{lift}} &= \frac{w_{\text{lift}}}{2} * x_{\text{out}} + w_{\text{lift}} * (x_{\text{out}} - x_{\text{pulleys}})^{1} && (9) \\ t_{\text{lift}} &= x_{\text{cm}} * w_{\text{crane}} + x_{\text{cw}} * w_{\text{cw}} && (10) \\ m_{\text{cw}} &= \frac{w_{\text{cw}}}{9.81} && (11) \end{aligned}$$

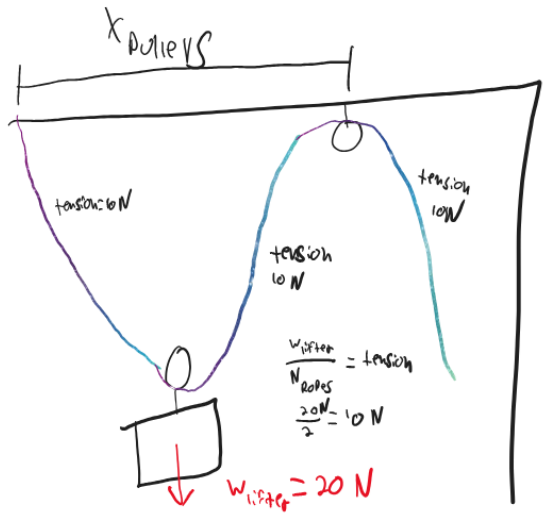

Figure 4: A free body diagram of the pulleys

Where:

$$
\begin{aligned}
&x_{\text{pulleys}} \text{ is the distance betweens the pulleys and the anchor of the string on the boom}\\
&x_{\text{cw}} \text{ is the distance of the counterweight from the crane side wheel}\\
&t_{\text{lift}} \text{ is the torque from the object being lifted}\\
&m_{\text{lift}} \text{ is the mass of the object being lifted}\\
&w_{\text{lift}} \text{ is the weight of the object being lifted}
\end{aligned}
\tag{12}
$$

Equations 9 and 10 are made possible by the fact that at the moment of lifting the sum of the moments must be zero because nothing should be moving.

This equation allowed us to perform a parametric study to find the ideal position and mass of the counterweight. The resulting graph can be seen in Figure 5.

[1]Equation 9 was created when we only had one pulley attached to the boom. Luckily the calculated counterweight still worked when we added the second pulley.

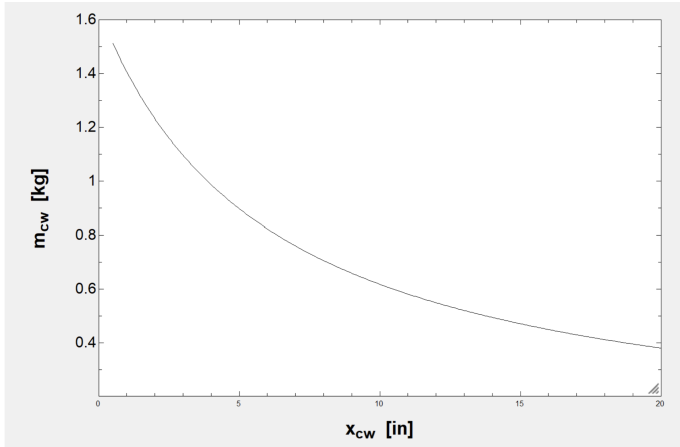

Figure 5: A graph of the relationship between the mass of the counterweight and the vertical velocity of the object being lifted.

Figure 5 came in quite handy as we had to adjust the counterweight several times during the project. Eventually we ended up making our counterweight boom 13 inches long[2] which translated to a m_{cw} of 0.7 kg.

3 Construction: Sam

4 Testing: Malini

5 Future Work

[2]This distance refers to the distance from the center mast of to the end of the counterweight. This translates to a x_{cw} of around 9.969 inches