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BASE

The base measures at 7.5 inches tall and maintains the 6” x 6” floor with a width and length of 5 inches. We altered our truss structure into a 2 layered box configuration. To minimize the deflection we attached a 8.5 inch transverse support along each of the 4 sides of the base. To minimize total weight we only used one support per side since the desired stability was reached. Another major design consideration was that each beam was bent 90 degrees into an L-shape. The new bent members allowed applied forces to be better distributed and brought our base to the level of rigidity that we had desired. The final modification was the implementation of an extension from the base to the crane arm. We used triangular supports (4” x 5” 3.75”) to allow the arm to line up directly with the obstacle window.

CRANE ARM

We designed our lifting member with a triangular cross-section(3.5” x 3.5” x 3.0”) as opposed to our rectangular base. We expanded our transverse support modification in the base(8.5”) to a full-blown truss pattern throughout the arm(30.5”). As we found it necessary we added more cross-bars to distribute the forces and minimize the overall deflection created by the given weight and bearing. The trusses we decided to use for the greatest effect and material conservation for the arm are 30-30-120 degrees in measure. We didn't feel that the added strength for more trusses would be necessary and we were correct in our assumption. Initially our arm was too wide to make it through the small window on the playing field. We compensated by utilizing the flexibility of the aluminum and bending the arm as it extended so that its cross section became smaller(1.5” x 1.5” x 2.0”) towards the end near the weight. Like the base we only utilized bent L-shaped members throughout the arm's construction. We found that doing this allowed us to be more conservative with the amount of truss sections we created and the amount of material we used as well as producing a very strong frame that is significantly resistant to bending.
Here is a picture of the square base and the triangular truss we used to support the servo motor and lifting arm.

**LIFTING MEMBER**

For the actual lifting piece that makes contact with the weight we simply used a thin strip of aluminum that loops around the bolt that is attached to the weight. We also used an aluminum counterweight weighing about 5 ounces. The motor connects to the member at 3 inches away from where the ribbon attaches to the weight leaving 7 inches for the counterweight to create an opposing
moment. From the first design review we made adjustments to the counterweight and lifting member in order to reduce the failure rate when lifting the weight and bearing. On a minor note we also took a second look at our base's floor so that our project fits properly in the clamp. In conclusion our crane successfully lifted the weight under the specifications given to us.

Theoretical Predictions

2.5 inch arm

Given Stats: In a theoretical world. The maximum the motor could lift.

\[ \tau_{\text{servo}} = 72 \text{ oz/in}, \ m_{\text{weight}} = 16 \text{ oz}, \ h = 2'' , \ \Delta \theta = 90^\circ \]

Calculate distance of lever arm

\[ x = \frac{\tau}{F} = \frac{72}{16} = 4.5'' \]

\[ 4.5 \sin 45^\circ = 3.18'' \]

So the maximum theoretical lift would be \( \Delta h_{\text{max}} = 1.767 \cdot 2 = 3.53 \)

So assuming that the torque is linear throughout the lift, the percent of torque used to lift it 2” is \( \frac{2}{6.36} = 31.4\% \)

Real World Calculations
\[ \tau_{\text{servo}} = 72 \frac{oz}{in}, \ m_{\text{weight}} = 16oz, \ h = 2'', \ \Delta \theta = 90^\circ \]

We decided to use a lever arm of 2.5 inches to account for deflection, non optimal servo motor performance, and a general safety net.

\[ \tau = F \cdot x \]
\[ x = \frac{\tau}{F} = \frac{72}{16} = 4.5'' \]

So the maximum theoretical lift would be \( \Delta h_{\text{max}} = 3.18 \cdot 2 = 6.36'' \)

Our final lift result was 2.5” so it was a good thing we used a smaller lever arm.

The overall efficiency of our system compared to the theoretical value is fairly small.

We are technically using the full 90° to lift the weight, but we are only using 31.4% of the motors theoretical value. Significant amounts of energy are lost in the bending of the beams, inefficiency of the motor, and general bending of the lever arm and system.

The following are pictures of our overall crane and a close up of the lifting mechanism.