Torque Analysis for v3 Design

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November 2021

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1 Abstract

The objective of this analysis is to determine the amount of torque required to pivot the upper joint around the motor's axis with the third version of the design. A torque of 0.4072 N-m is required due to the increased moment arm. As a result, a mechanical advantage of 1.434 is needed to have a factor of safety of 1.

2 Description of Component

The powered component I will perform a torque analysis on is the motor that will pitch the upper joint of the robotic arm. In figure 1, the motor will rotate a driving gear that rotates the driven gear on the linkage. This will allow the links forming a four-bar linkage to rotate about the axis of the driven gear. A gear ratio of 2:3 was used in the second version of the design to have a factor of safety above 2.

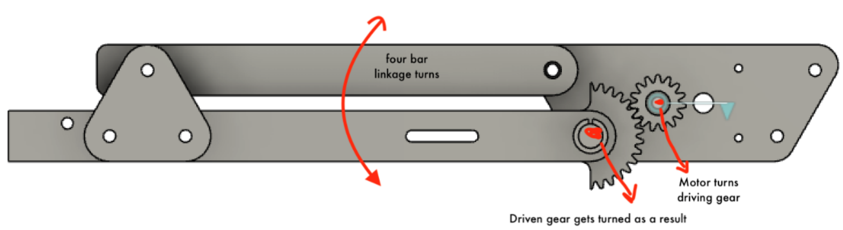

Figure 1: How My Part Works

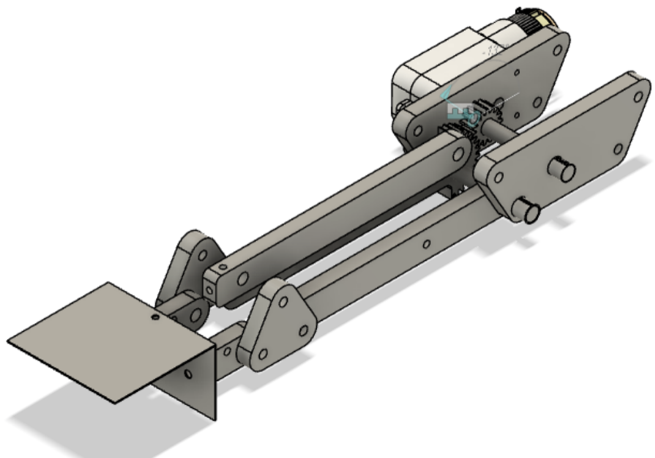

Figure 2: Isometric View of CAD

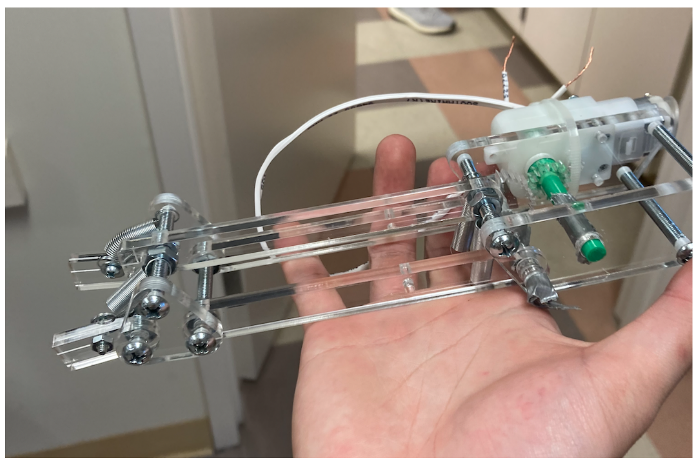

Figure 3: Physical Component

As I mentioned earlier, my design is based on four-bar linkage. The reason for this is because the gripper was designed in mind that it would be parallel to the ground when it was picking up boxes. The four-bar linkage allows the gripper to remain parallel at any height as shown in figure 3. The springs acts as a suspension system in order to make sure the body doesn't wobble too much during motion.

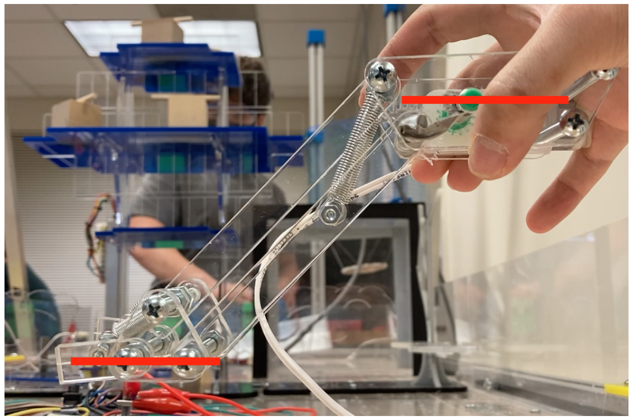

Figure 4: Red lines are always parallel

3 Torque Analysis

In figure 5, the worst case load scenario for the upper joint has been drawn as a free-body diagram. The reason for this is because the force of gravity will create the greatest torque opposing the rotation of the joint when it is horizontal. In the following calculations, this worst case scenario will be used to determine the amount of torque needed. The torque contribution of the wooden box will be included in this design; however, the torque contribution of the spring will be ignored for simplification.

3.1 Free Body Diagram

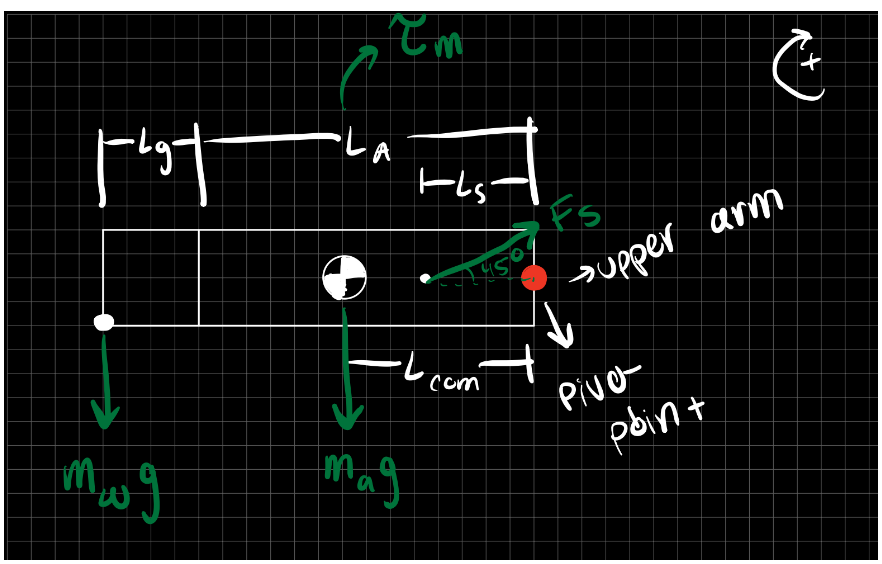

Figure 5: Free Body Diagram of Upper Arm

3.2 Assumptions

- Friction and air resistance is ignored

- Spring force contributes no torque

3.3 Calculations

Design Parameters:

Mass of Upper Joint	0.2 kg
Mass of Wooden Box	0.038 kg
Length from Pivot to Center of Mass	0.15 m
Length of Upper Arm	0.234 m
Length of Gripper	0.07 m
Stall Torque of Motor	0.284 Nm

$$\sum M = \tau_{motor} + R_1 \times F_s - R_2 \times m_{weight}g - R_3 \times m_{arm}g = 0$$
$$\tau_{motor} + F_s L_s sin(45) - m_{weight}g(L_g + L_A) - m_{arm}gL_{com} = 0$$
$$\tau_{motor} = m_{weight}g(L_g + L_A) + m_{arm}gL_{com}$$
$$\tau_{motor} = 0.4072Nm$$

The factor of safety for torque is $FOS_\tau = \frac{0.284Nm}{0.4072Nm} = 0.6974$.

4 Conclusion

With the new design, the torque required increases by 108%. This puts the factor of safety below 1. As a result, a mechanical advantage of at least 1.434 is needed.