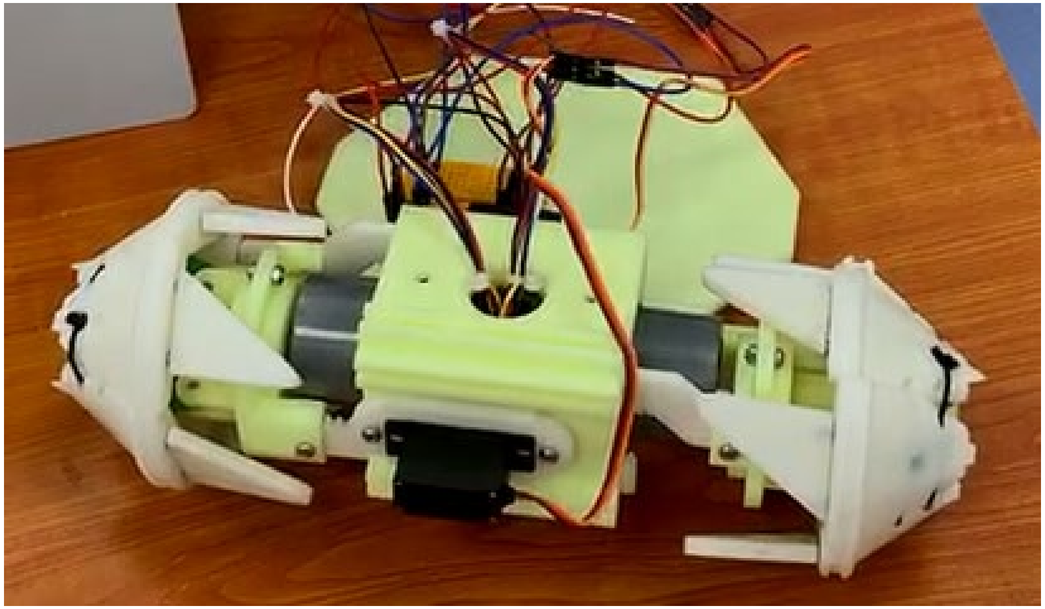
Introduction

Transformable wheels with sensors for different terrains (required situations)



Design Intro.

- Conventional:

1. Need different kind of wheels to adjust different terrains for the best performance.
2. Cannot adjust automatically, inefficient in complicated situations.
3. Impossible for climbing and creeping at the same time

- Transformable with sensors:

1. Applicable to different terrains with the best performance.
2. Adjust automatically and fast according to different situations.
3. Meet the two opposite needs for the gameday field

Objectives

- Can drive on sand.
- Can climb onto a 6cm stair.
- Can drive through a 9cm tunnel.
- Can drive fast on a flat surface.
- Can drive autonomously with sensors.

  Specific: 1. transform in front of the stair

  2. make a right angle turn at the corner

Project Plan

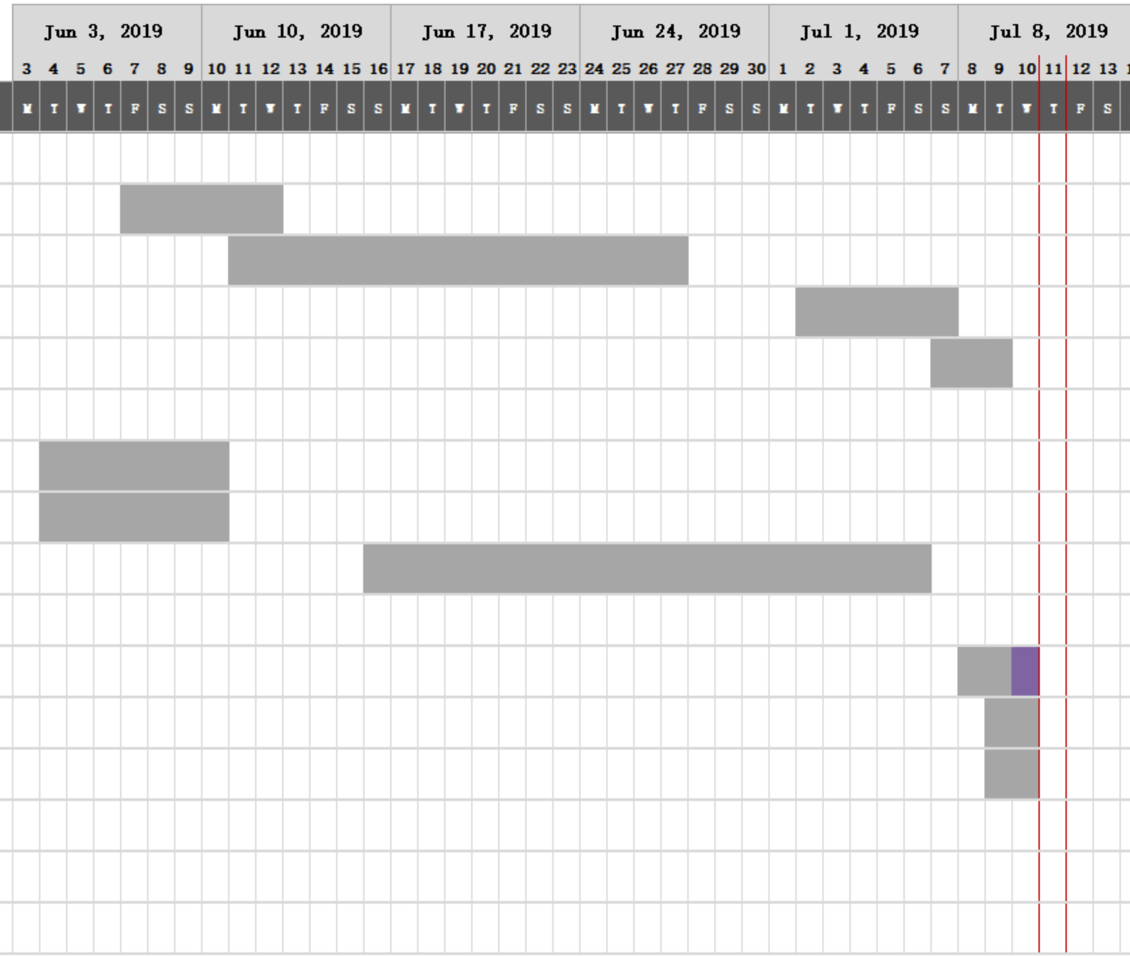
VM350 Final Project

Group 7

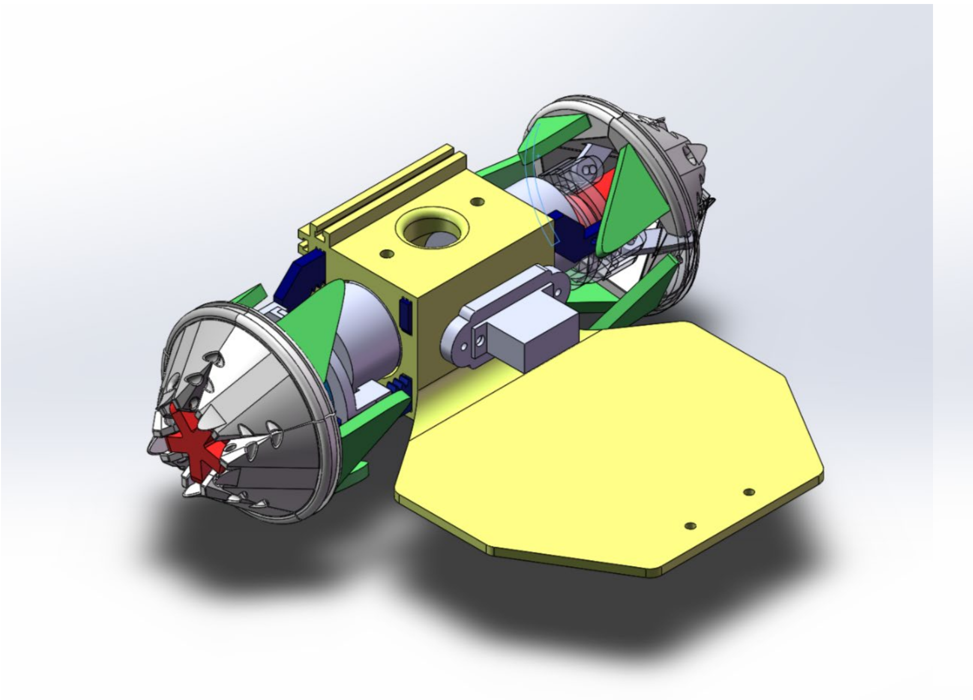
Project Start: 2019/6/3

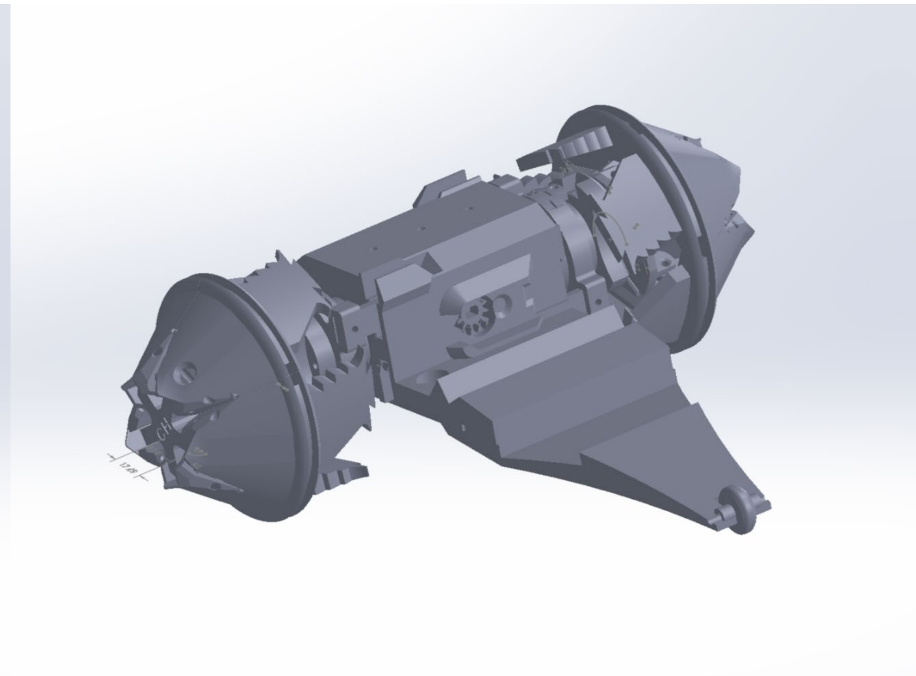
Display Week: 1

TASK	PROGRESS	START	END
Transformable Wheel (WuJiajin & LinYuechuan)			
Graphical linkage synthesis	100%	6/7	6/12
CAD drawing & simulation	100%	6/11	6/27
3D printing	100%	7/2	7/7
Analysis	100%	7/7	7/9
Controller (HeZhirui & SunTianxing)			
Selection of sensors	100%	6/4	6/10
Strategy for specific requirements	100%	6/4	6/10
Programming	100%	6/16	7/6
Assembly and Test (all members together)			
Assembly	90%	7/8	7/10
Test of the initial prototype	100%	7/9	7/10
Field test of the initial prototype	100%	7/9	7/10
Debugging	0%	N/A	N/A
Further modification	0%	N/A	N/A
Project Report	0%	N/A	N/A



Design Overview



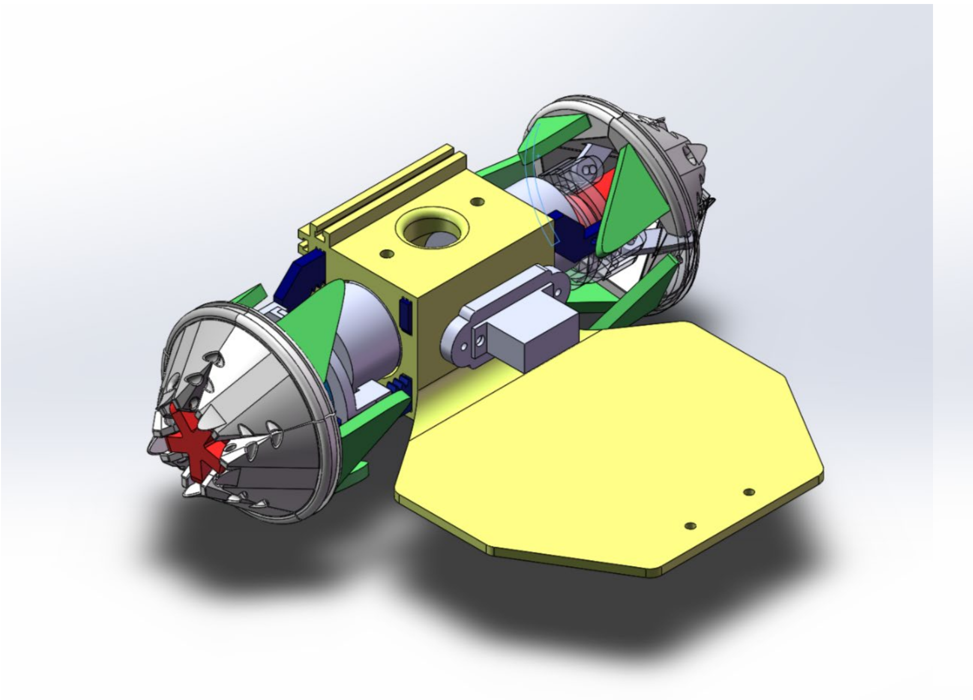


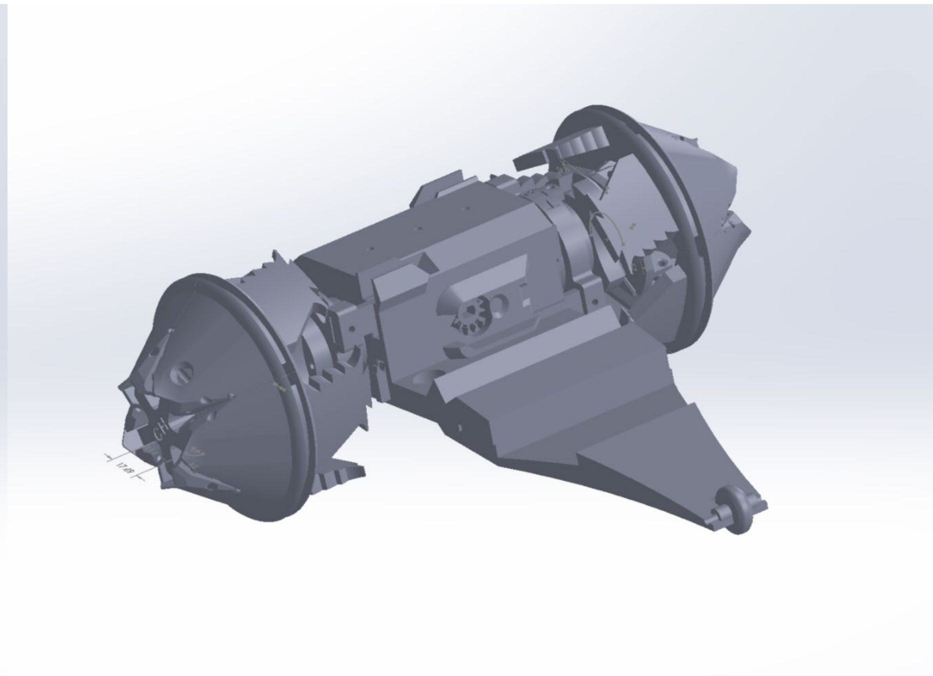
Why we emulate Ohio's car

Needed Improvements

- Design for sandy territories
- Locking mechanism that is suitable for 3D printed parts

Design Overview



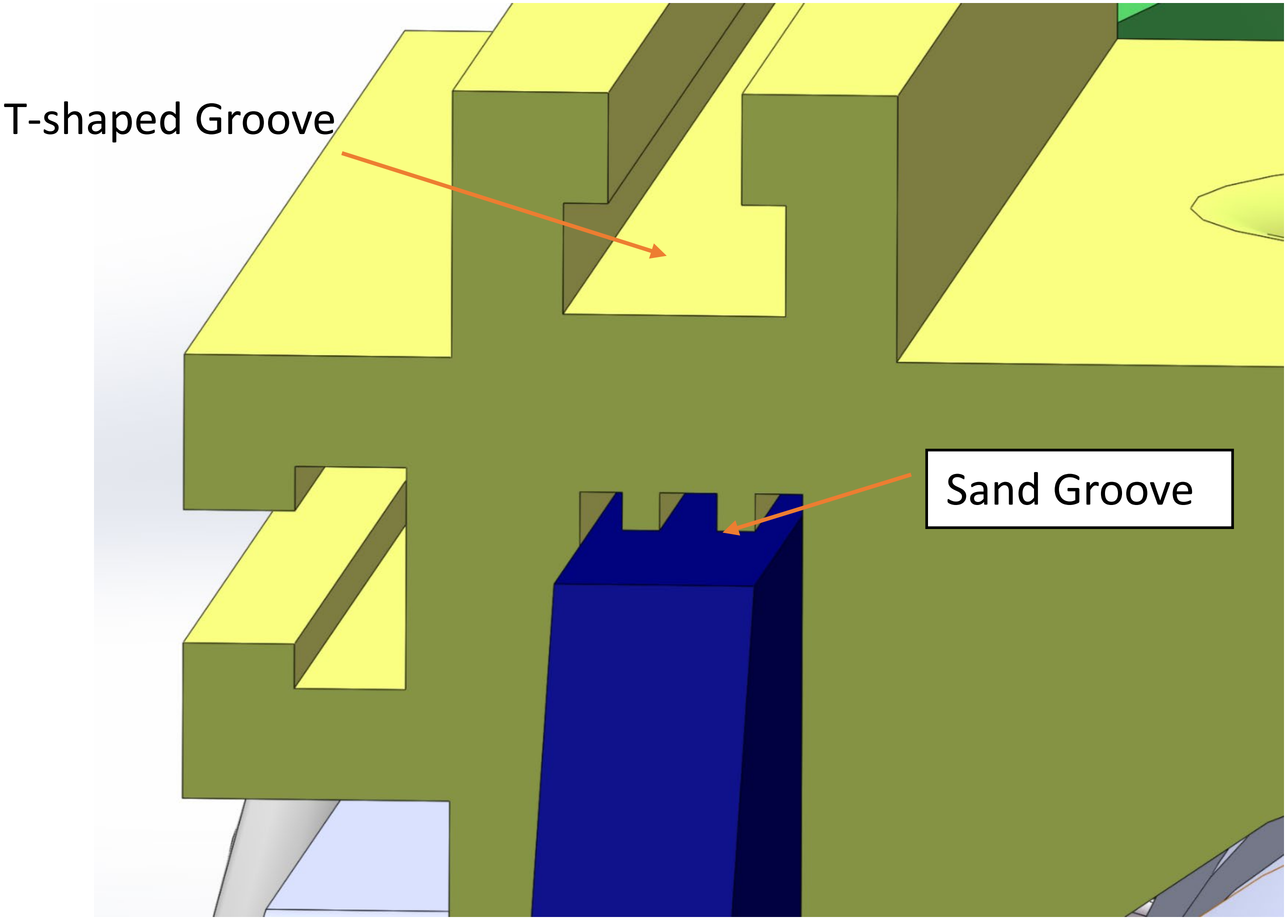


What's New?

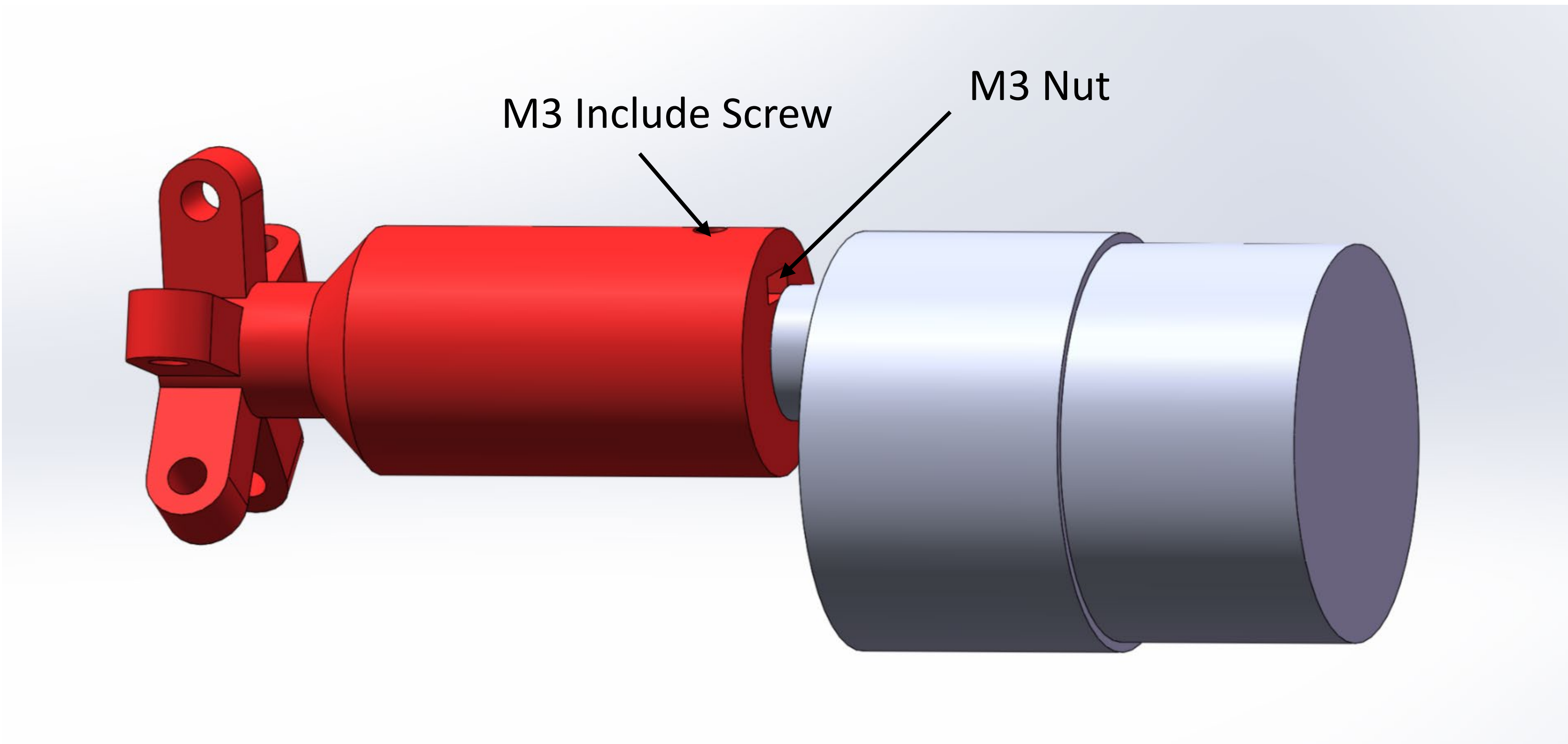
Creative Design

- Sand Groove and T-shaped Grooves
- Tight Locking Mechanism

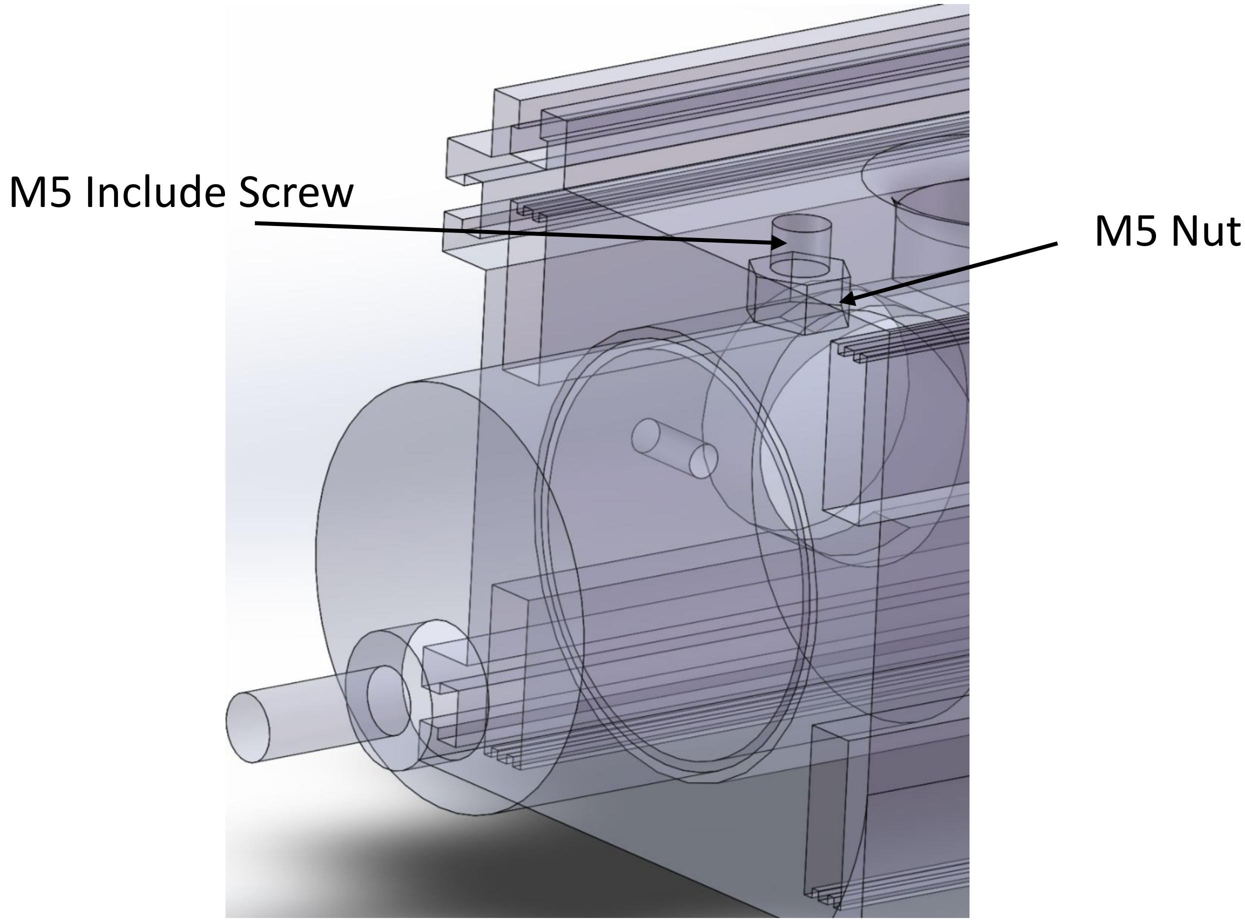
Sand Groove and T-shaped Groove



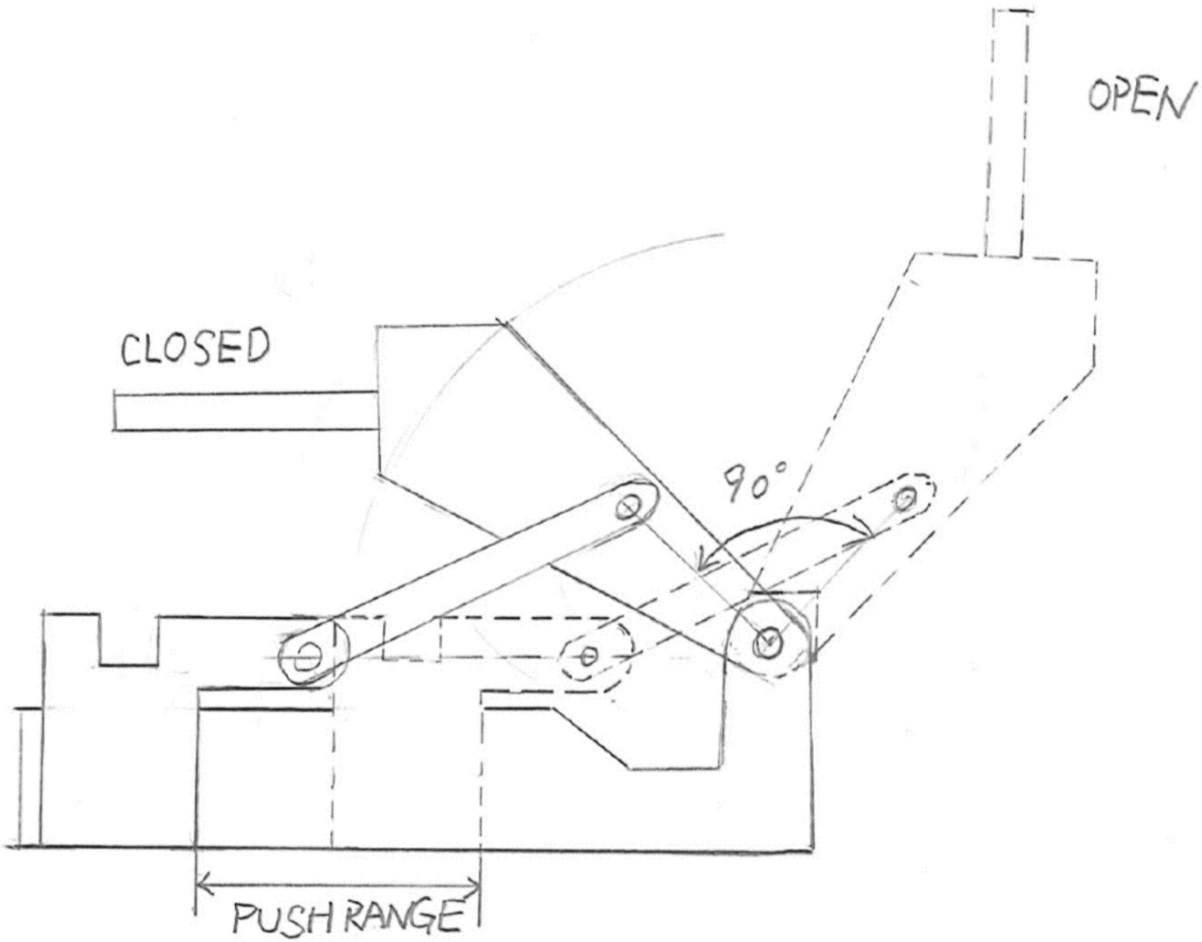
Tight Locking mechanism



Tight Locking mechanism



Linkage Synthesis



Material selection

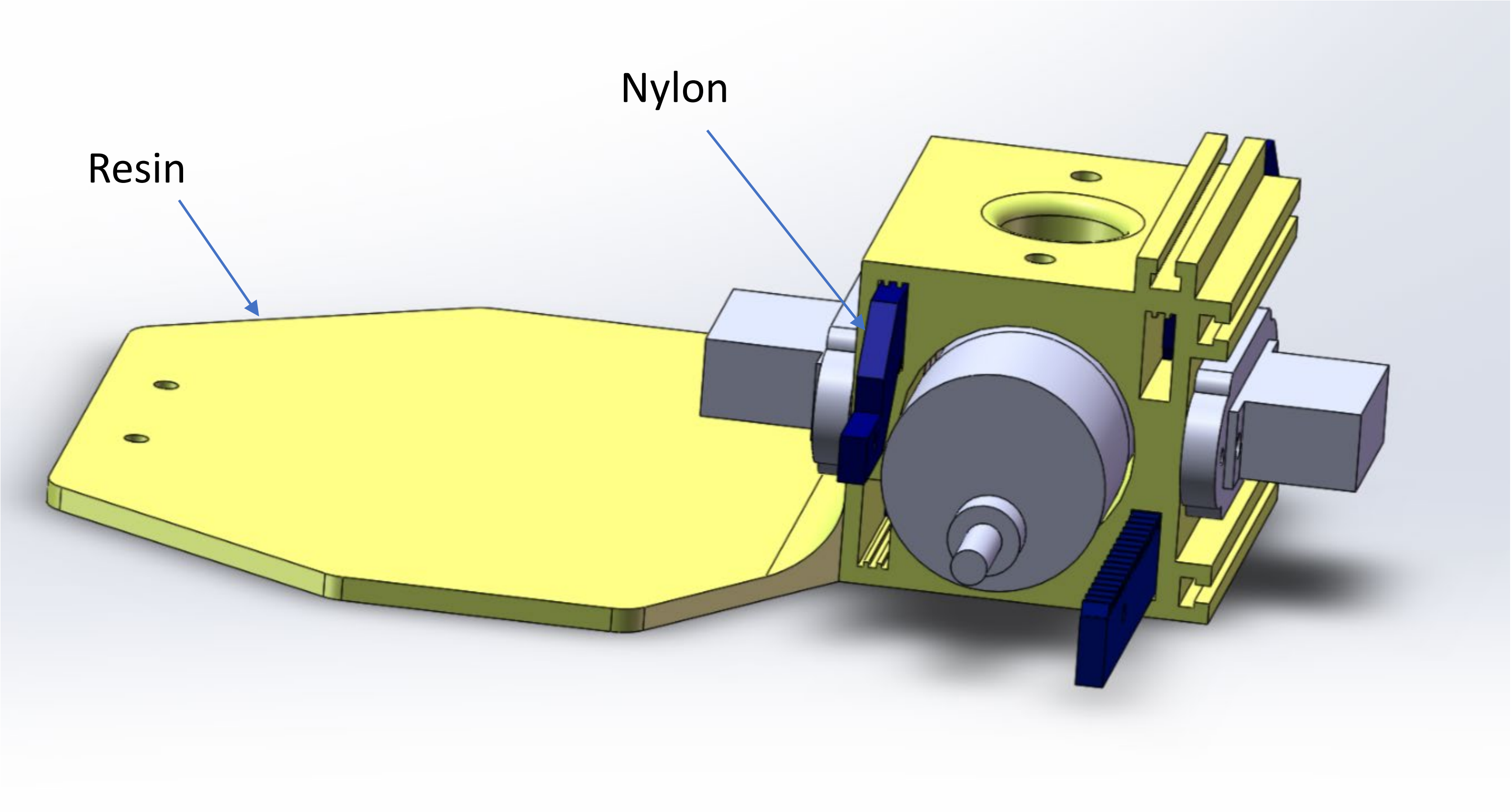
Material	Price	Fabrication	Surface finish	Strength	Resolution
PLA	Low	FDM	1	1	1
Resin	High	SLA	3	1	3
Nylon	Very-high	Multi Jet Fusion	2	2	3

Resin printing is specialized in Complicated geometry and Sliding mechanism

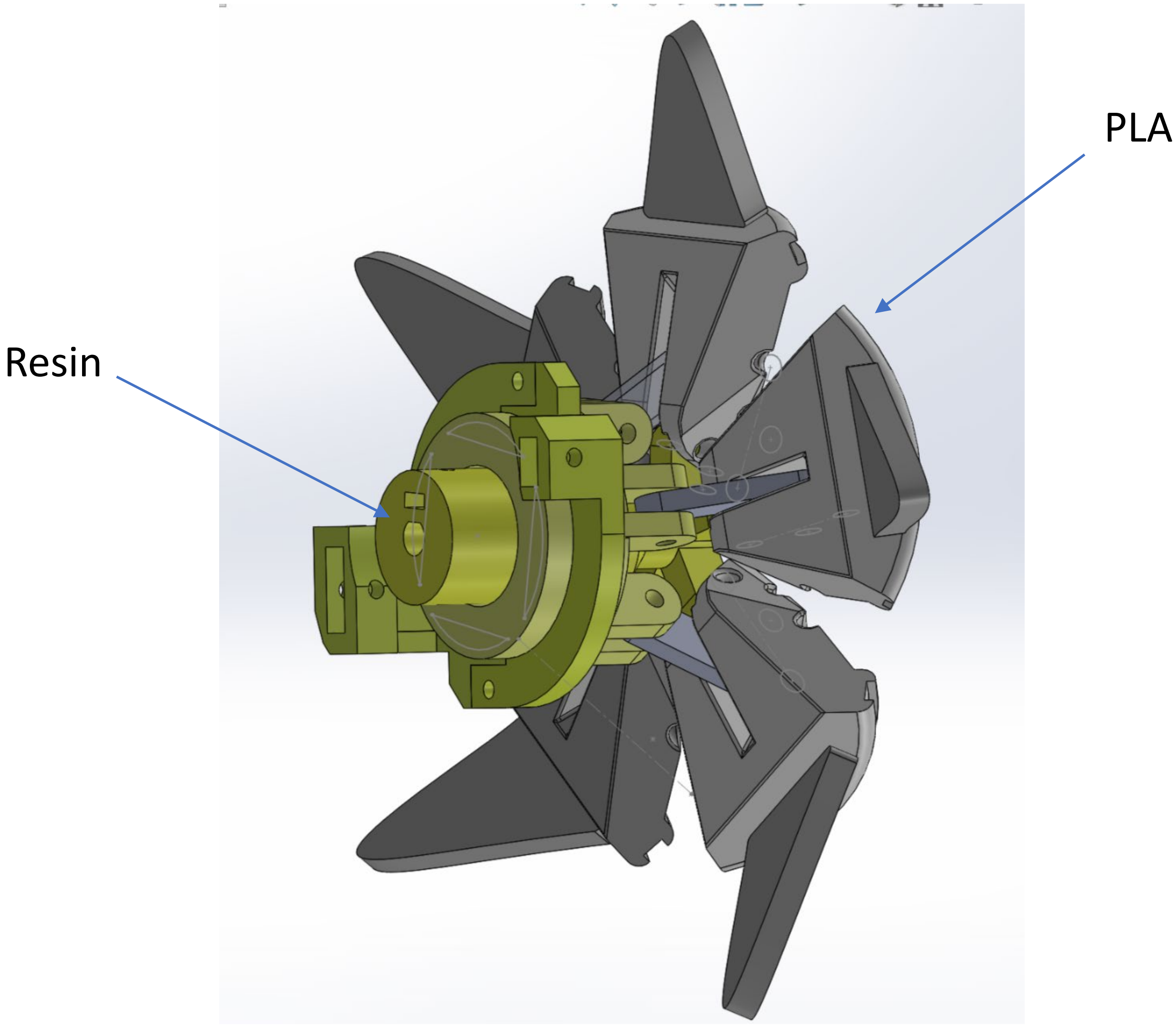
Nylon printing is specialized in High strength mechanical parts (Gears, Racks…)

PLA printing is specialized in Low price production

Material selection



Material selection



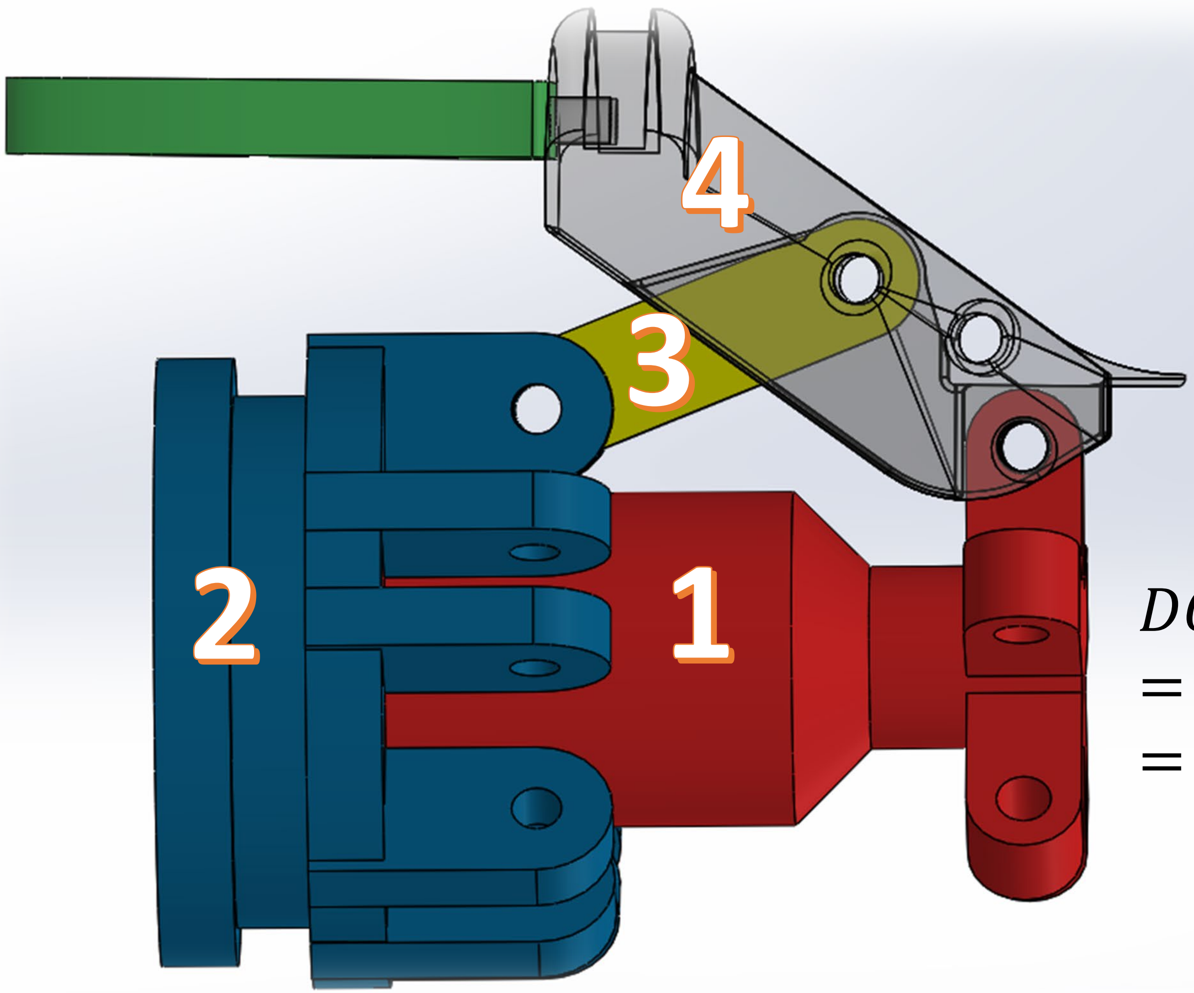
Analysis

- Classification of Linkage
- Position Analysis
- Force Analysis

Classification of Linkage

- DOF
- Type of Motion
- Grashof Condition

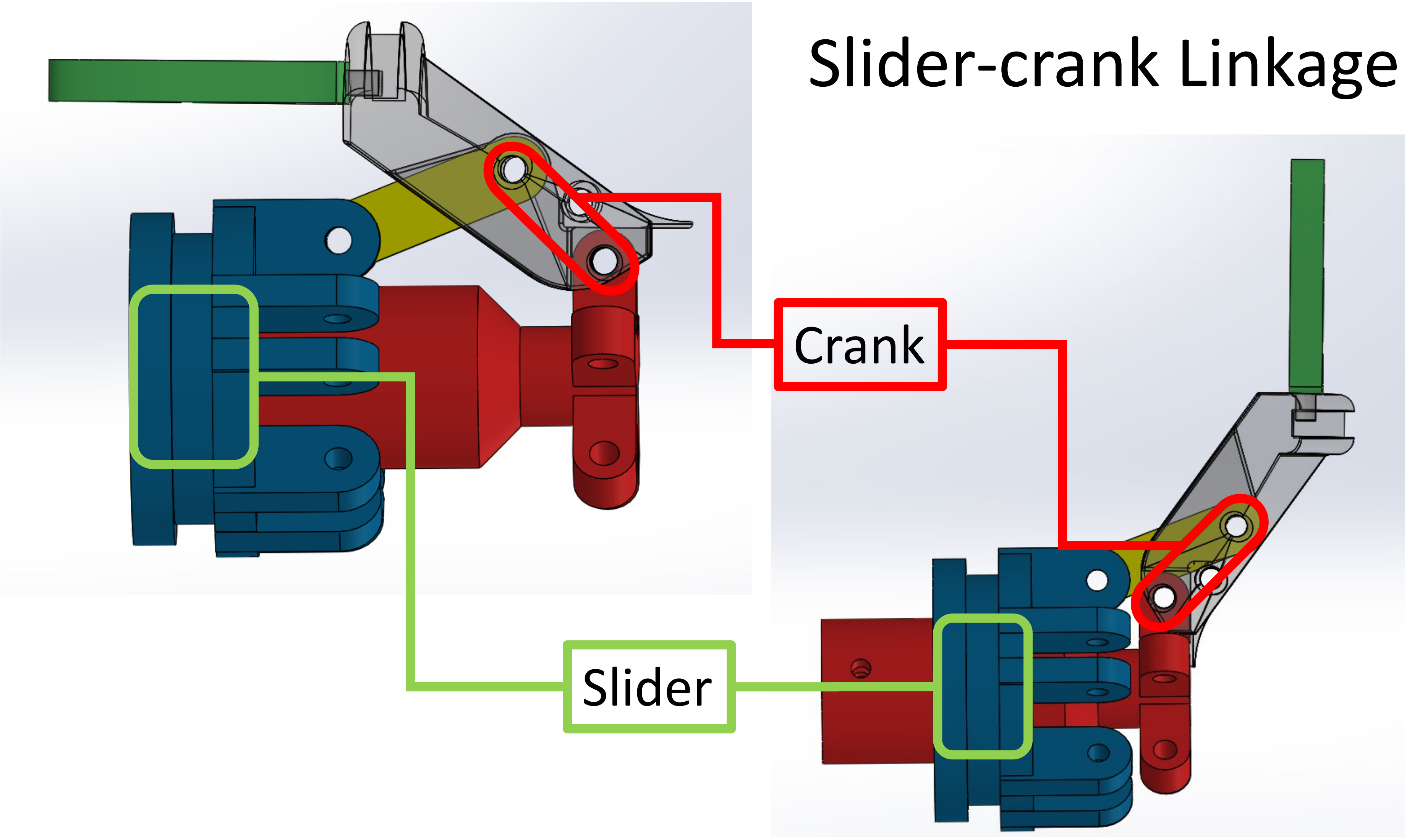
DOF



$$L = 4$$
$$J_1 = 4$$
$$J_2 = J_m = 0$$

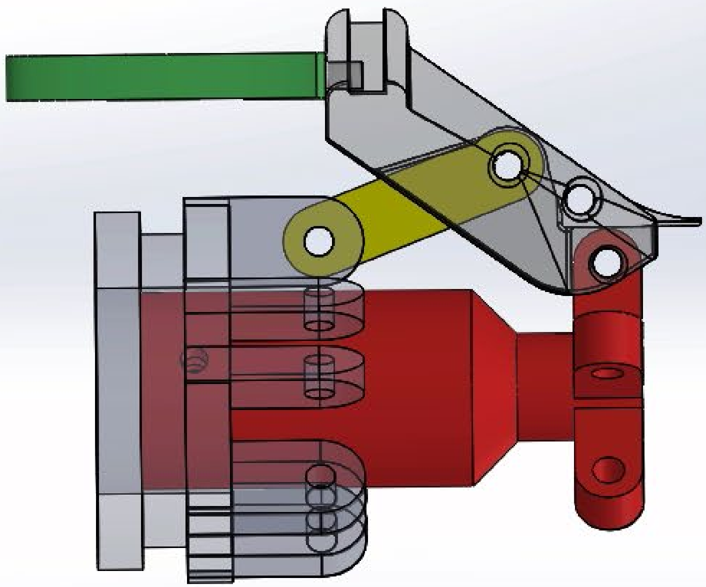
$$DOF = 3 * (4 - 1) - 2 * 4 = 1$$

Type of Motion

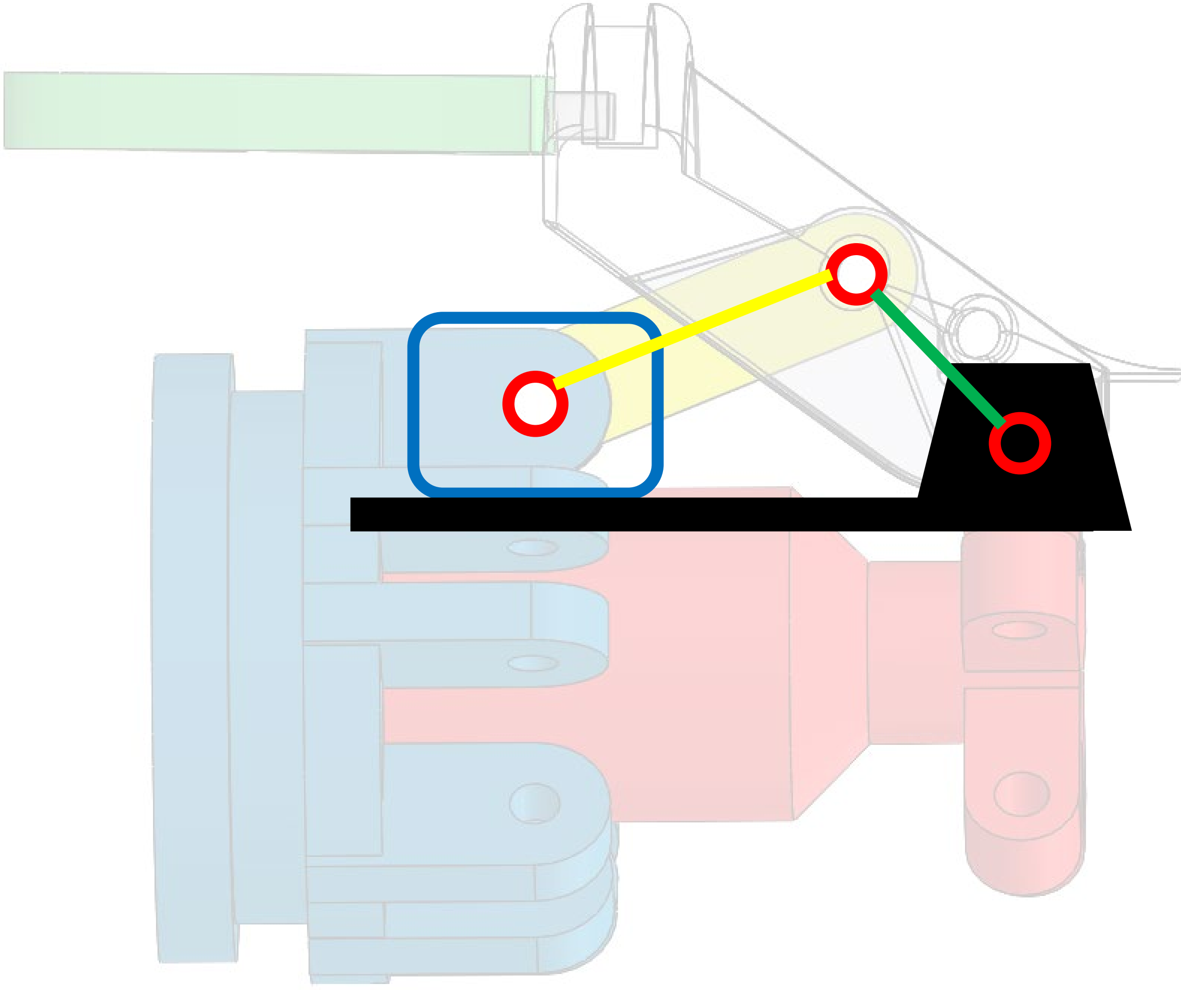


Grashof Condition

- Crank-slider linkage: RRRP



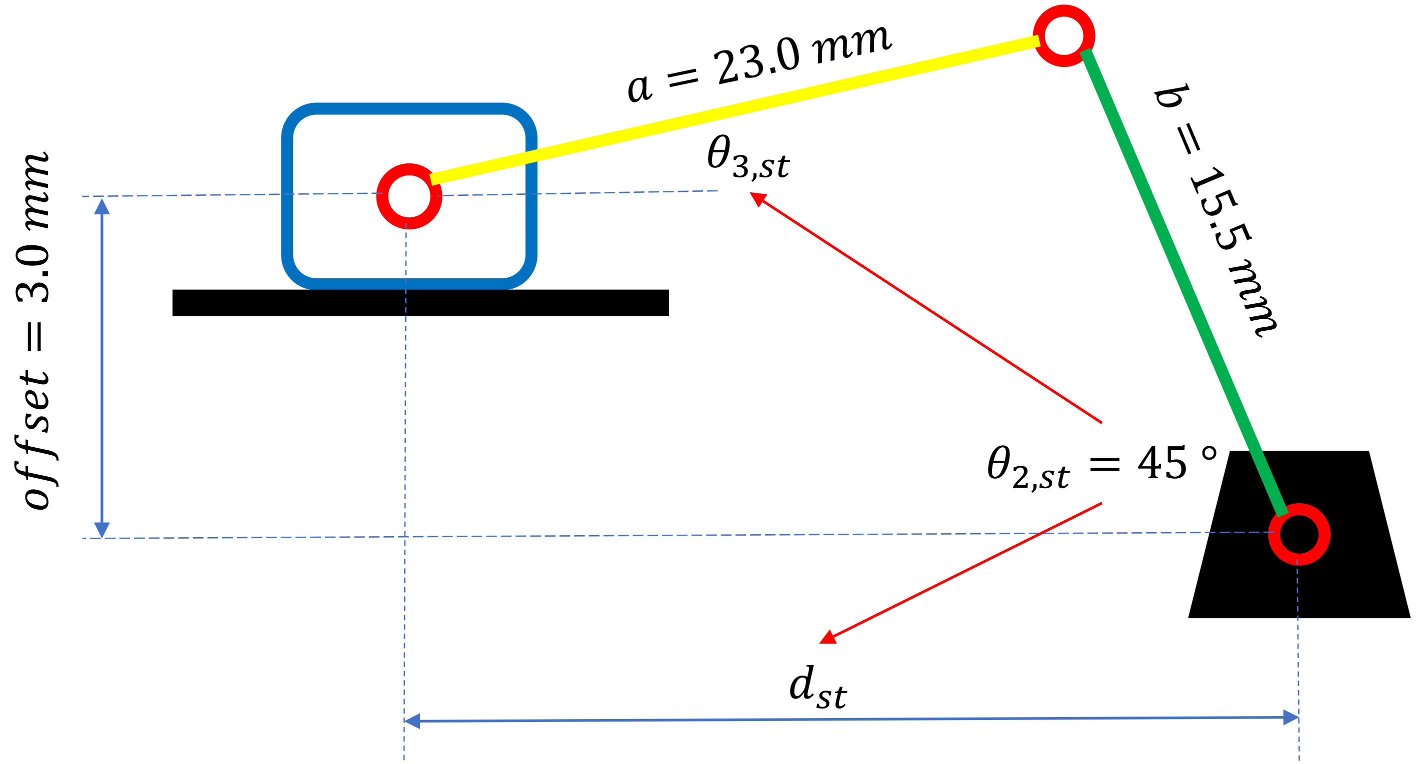
Position Analysis



Position Analysis

- Kinetic Diagram (start point)

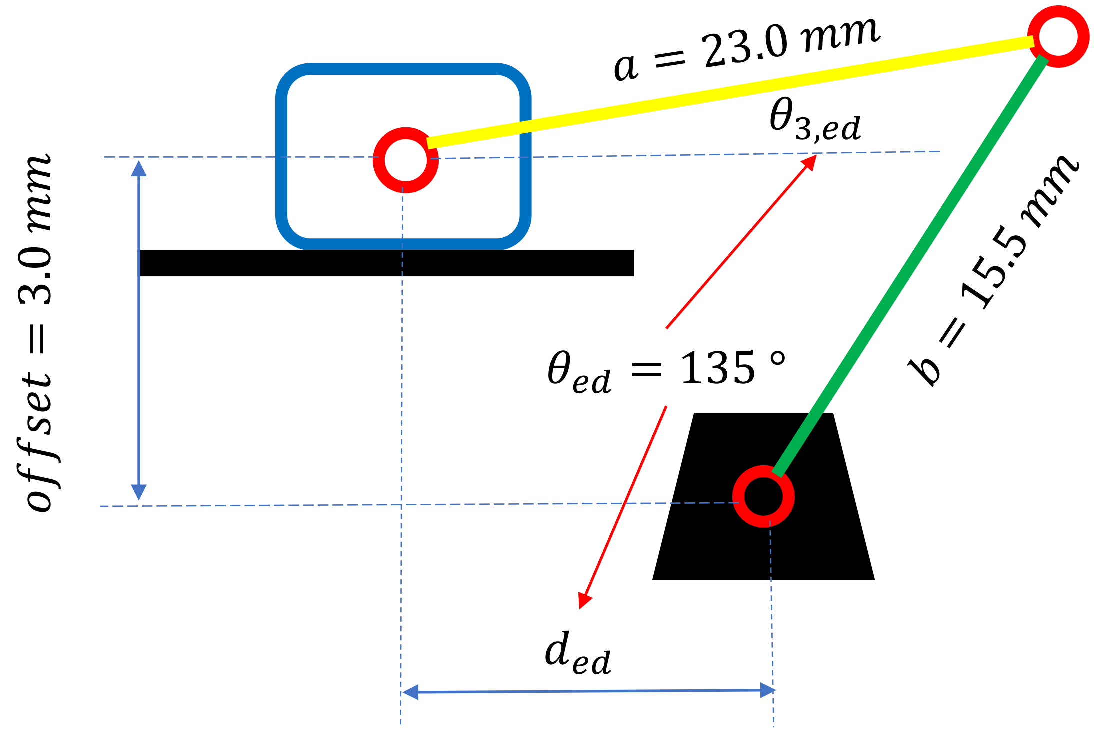
We know θ_2,
We want get θ_3 and d.



Position Analysis

- Kinetic Diagram (end point)

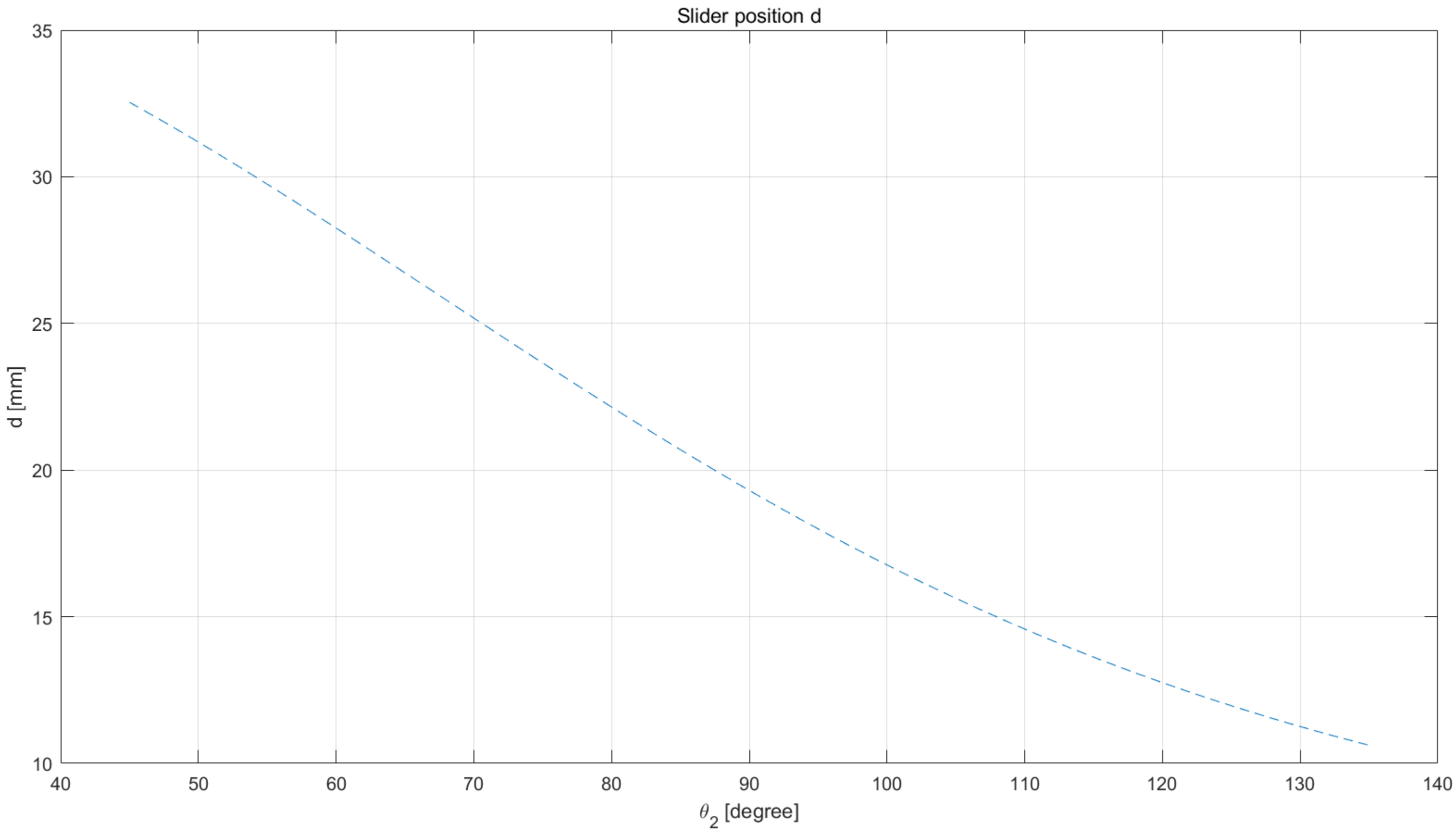
We know θ_2,
We want get θ_3 and d.



Position Analysis

Displacement =
$10.1 \sim 33.0\ mm$

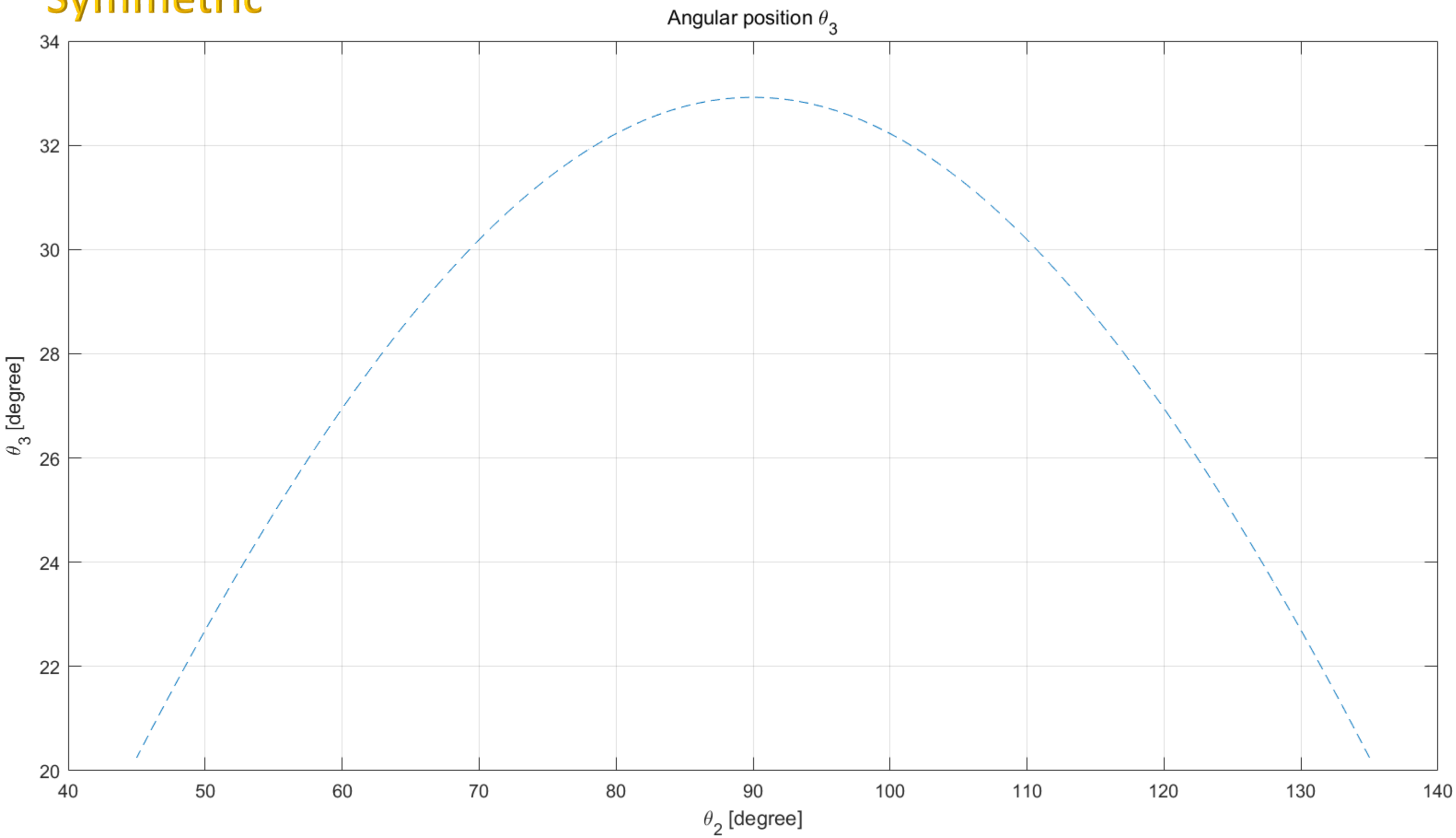
$$d\ v.s.\ \theta_2$$



Position Analysis

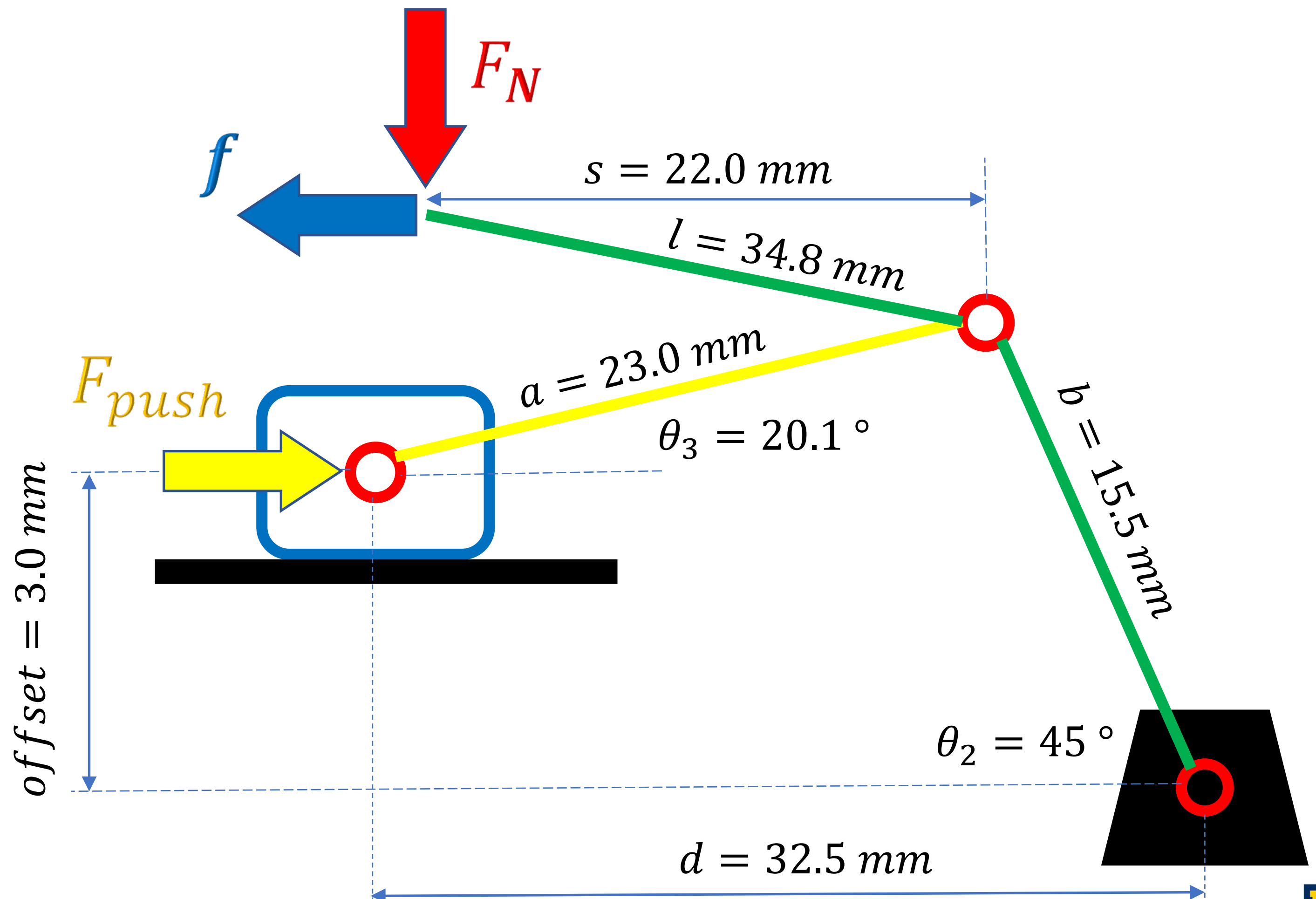
Angular Displacement =
$20.1°\sim32.9°$
Symmetric

$$\theta_3\ v.s.\ \theta_2$$



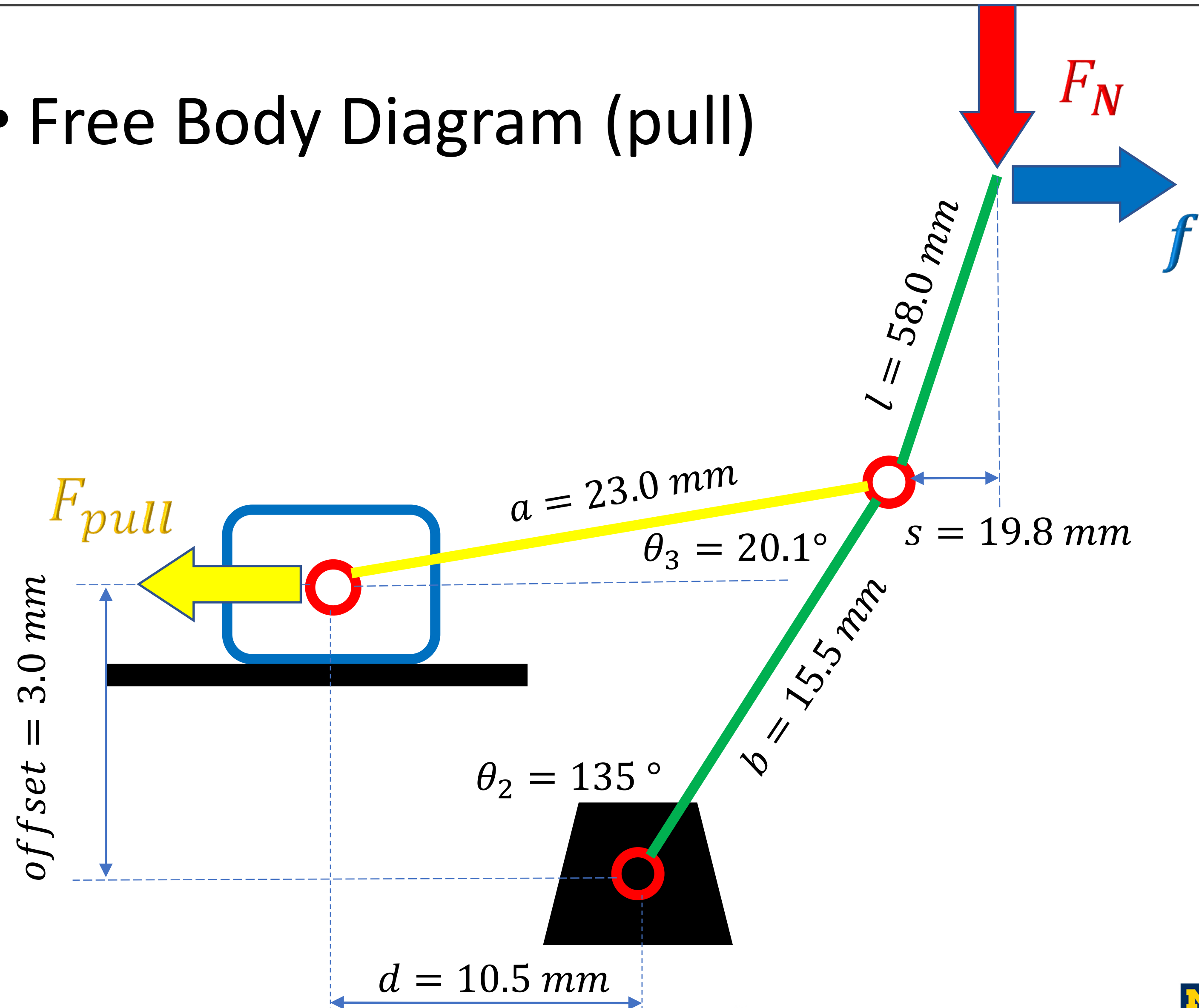
Force Analysis

- Free Body Diagram (push)



Force Analysis

- Free Body Diagram (pull)

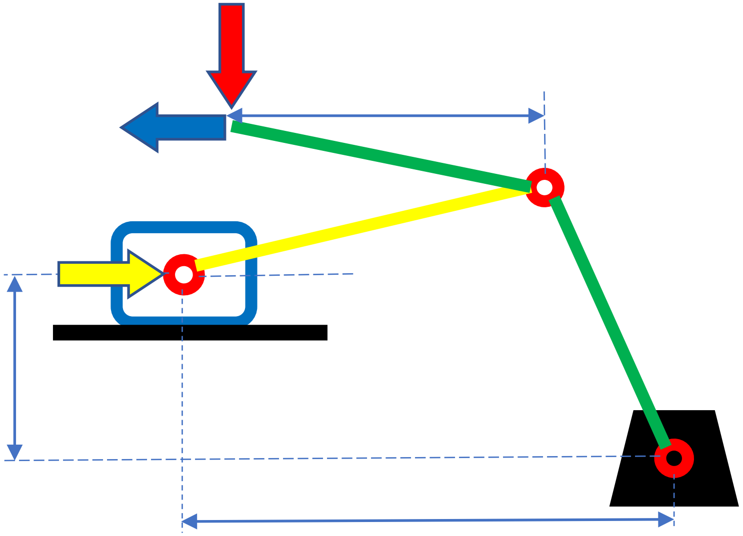


Input Torque (Push)

$$A = \begin{pmatrix} 15.5 * cos\theta_2 \\ 15.5 * sin\theta_2 \\ 0 \end{pmatrix}; B = \begin{pmatrix} 15.5 * cos\theta_2 + 34.8 * \cos(\theta_2 + 5.82°) \\ 15.5 * sin\theta_2 + 34.8 * \sin(\theta_2 + 5.82°) \\ 0 \end{pmatrix}; F = \begin{pmatrix} 2.4 \\ -4.9 \\ 0 \end{pmatrix};$$

$$T = r \times F = \begin{bmatrix} i & j & k \\ B_x & B_y & 0 \\ f & -F & 0 \end{bmatrix} = \begin{pmatrix} 0 \\ 0 \\ -4.9 * [15.5 * cos\theta_2 + 34.8 * \cos(\theta_2 + 5.82°)] \\ -2.4 * [15.5 * sin\theta_2 + 34.8 * \sin(\theta_2 + 5.82°)] \end{pmatrix}$$

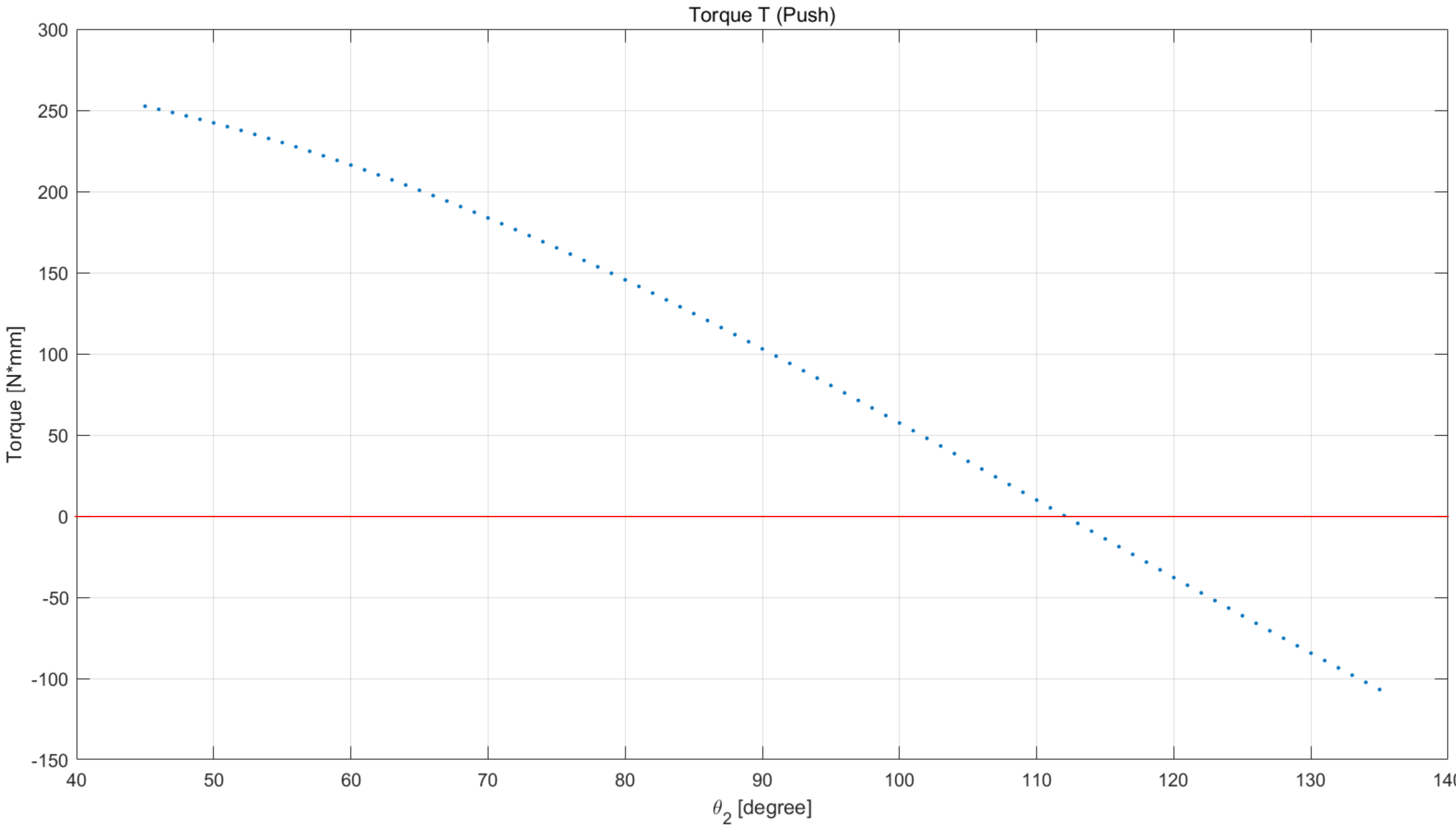
$$The\ required\ torque\ T$$
$$= 4.9 * [15.5 * cos\theta_2 + 34.8 * \cos(\theta_2 + 5.82°)] + 2.4 * [15.5 * sin\theta_2 + 34.8$$
$$* \sin(\theta_2 + 5.82°)]\ (N * mm)$$



Input Torque (Push)

Maximum Push Torque = 250 N*mm

$$T\ v.s.\ \theta_2$$

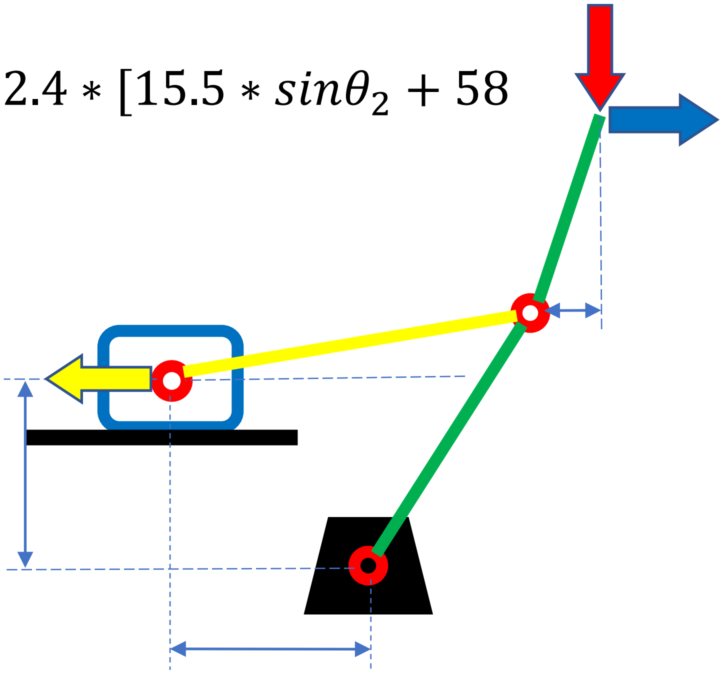


Input Torque (Pull)

$$A = \begin{pmatrix} 15.5 * cos\theta_2 \\ 15.5 * sin\theta_2 \\ 0 \end{pmatrix}; B = \begin{pmatrix} 15.5 * cos\theta_2 + 58 * \cos(\theta_2 - 29.13°) \\ 15.5 * sin\theta_2 + 58 * \sin(\theta_2 - 29.13°) \\ 0 \end{pmatrix}; F = \begin{pmatrix} -2.4 \\ -4.9 \\ 0 \end{pmatrix};$$

$$T = r \times F = \begin{bmatrix} i & j & k \\ B_x & B_y & 0 \\ -f & -F & 0 \end{bmatrix} = \begin{pmatrix} 0 \\ 0 \\ -4.9 * [15.5 * cos\theta_2 + 58 * \cos(\theta_2 - 29.13°)] \\ +2.4 * [15.5 * sin\theta_2 + 58 * \sin(\theta_2 - 29.13°)] \end{pmatrix};$$

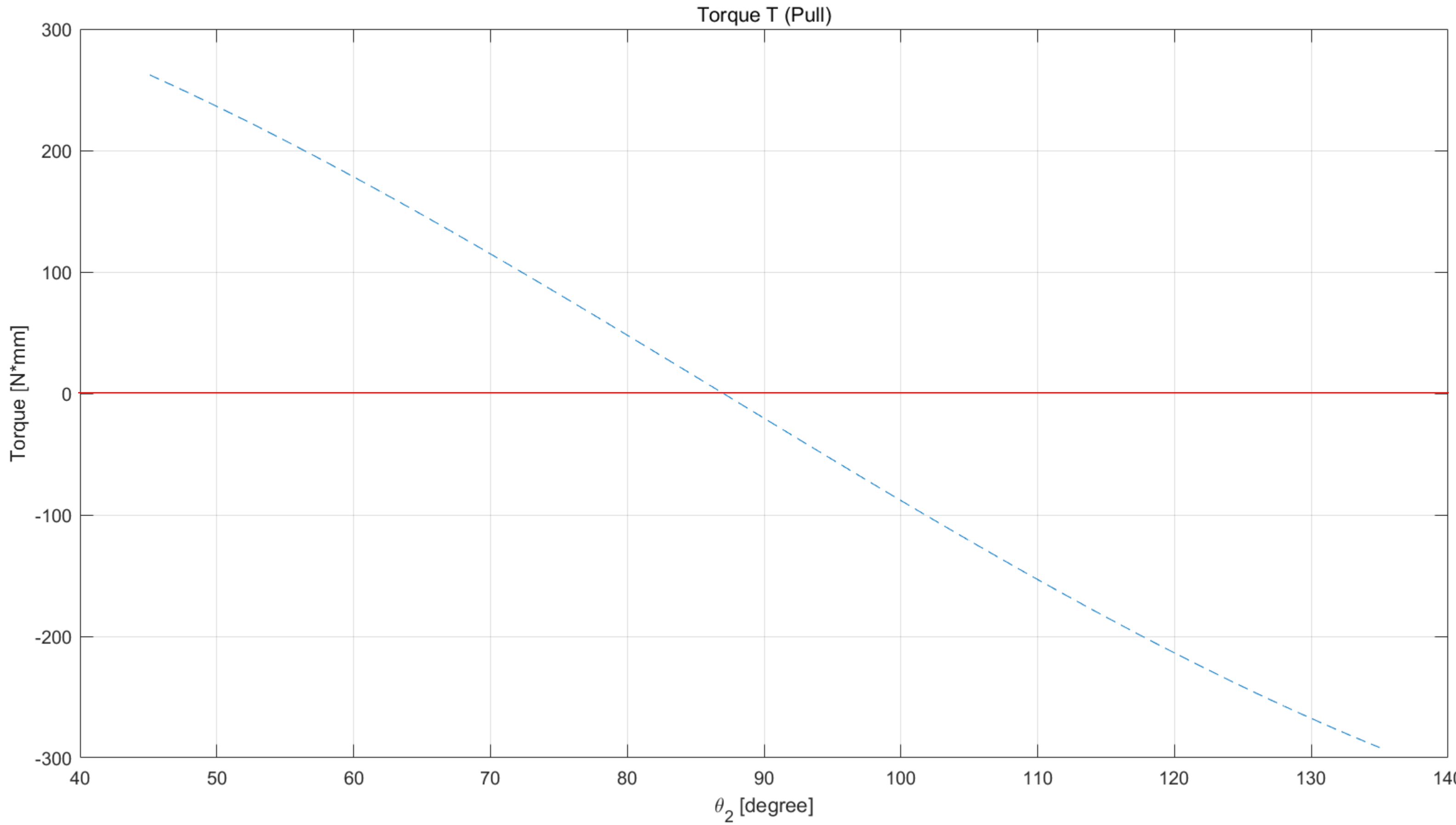
$$The\ required\ torque\ T = 4.9 * [15.5 * cos\theta_2 + 58 * \cos(\theta_2 - 29.13°)] - 2.4 * [15.5 * sin\theta_2 + 58 * \sin(\theta_2 - 29.13°)]\ (N * mm)$$



Input Torque

Maximum Pull Torque = 260 N*mm

$$T\ v.s.\ \theta_2$$



Servo Selection

- The servo we have chosen can provide a torque of 3.5 kg*cm (343 N*mm) at 6 V, which is bigger than the required torque 260 N*mm.

Datasheet

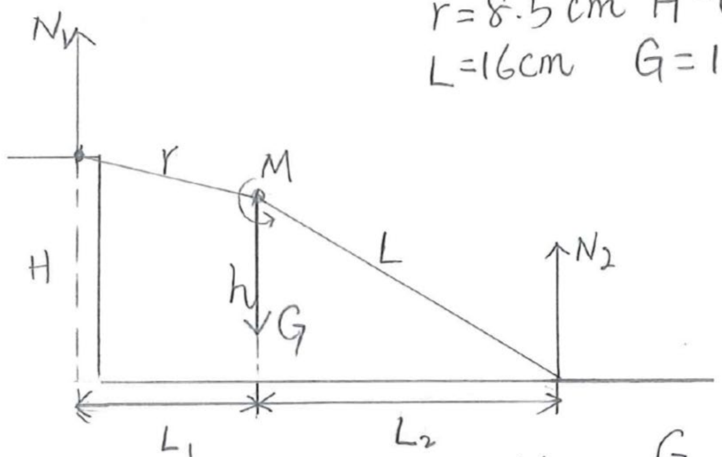
3018 Digital Servo			
Shell	Plastic	Max Speed	0.13 sec/60°
Gear	Metal	Min Speed	0.11 sec/60°
Controller	90-120°/900-2100us 120	Min Torque	3.0kg.cm
Panel	500-2500US 200°	Max Torque	3.5kg.cm
Dead Zone	2us	Size	28x13.2x29.6mm
Frequency	1500us/330HZ	Weight	17.5g
Motor	High Speed & Brush	Wine	JR 180mm
Bearing	2 ball	Guarantee	NON
Voltage	4.8-6v		

Motor Selection

- The two motors we have chosen can provide a total torque of 22 kg*cm at 25 rpm, which is sufficient to provide at maximum require torque of 5.8 kg*cm from our calculation

$r = 8.5\,cm \quad H = 6\,cm$

$L = 16\,cm \quad G = 1.1\,kg \cdot g$

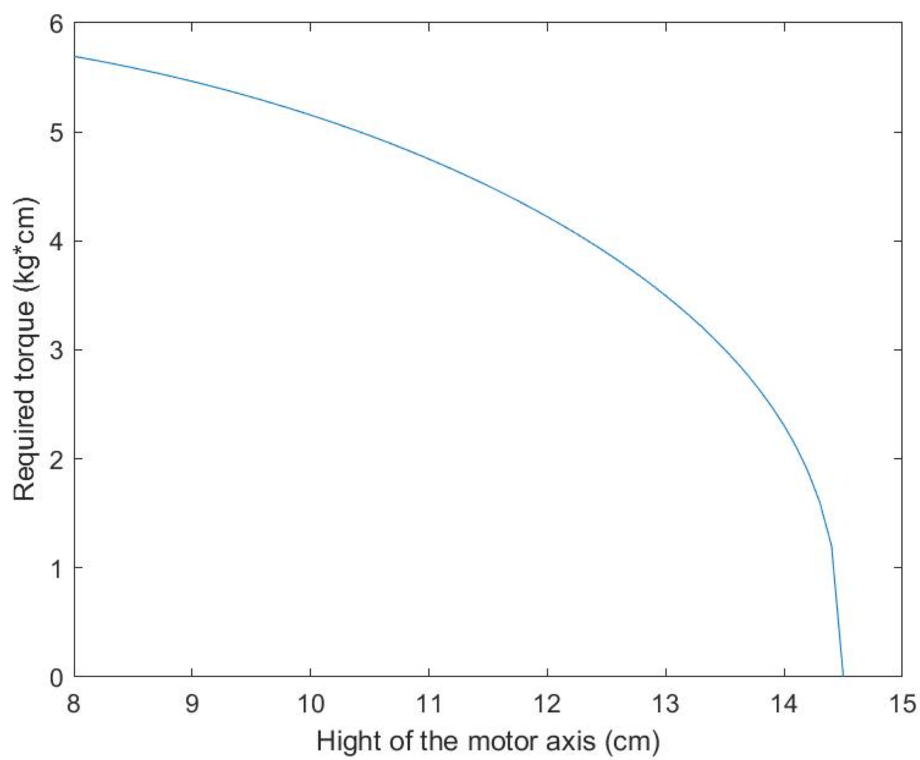


$$\begin{cases} N_1 + N_2 = G \\ M = N_1 L_1 = N_2 L_2 \end{cases}$$

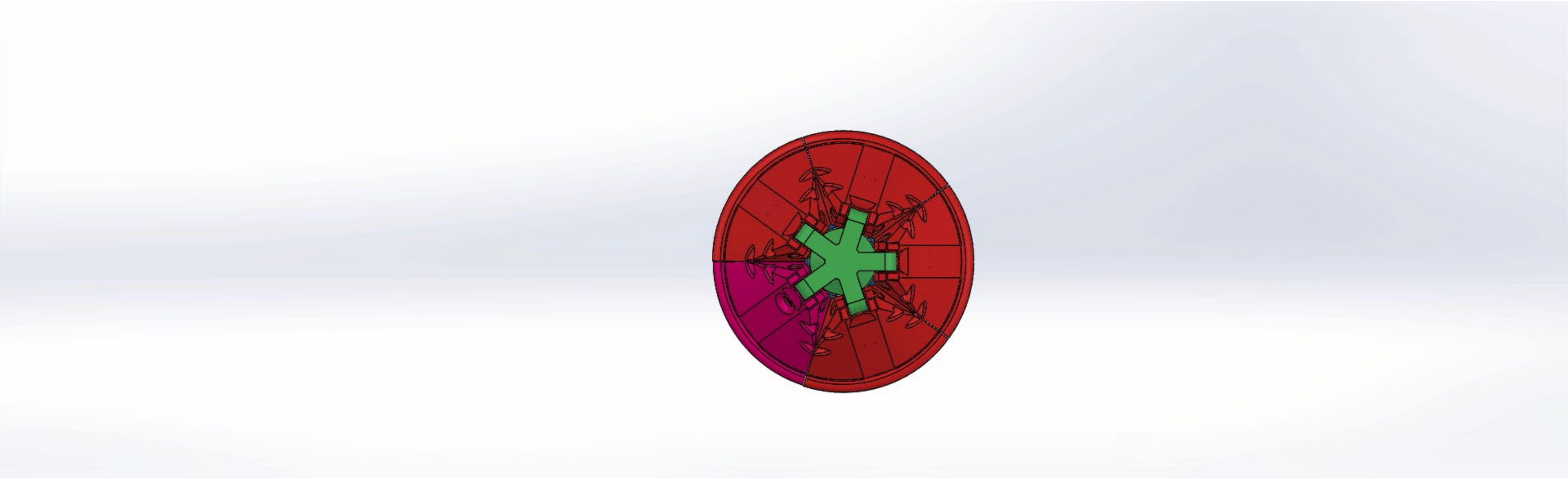
$$M = \frac{G}{1/L_1 + 1/L_2}$$

$$L_1 = \sqrt{r^2 - (H-h)^2}$$

$$L_2 = \sqrt{L^2 - h^2}$$



CAD Simulation



Initial Prototype