FABRICATION OF
MODIFIED SCOTCH YOKE MECHANISM

PROJECT REPORT

Submitted *in partial fulfilment of the requirements for the award of the degree of*

Bachelor of Technology

in

Mechanical Engineering

By

AISWARYA NAMBIAR T	**-**	**(B220132ME)**
S DEEPAK	**-**	**(B221168ME)**
SHRISTY SHARMA	**-**	**(B221211ME)**

ME3193D PRODUCTION ENGINEERING LABORATORY II

Under the guidance of

Dr. Vikash Kumar

Department of Mechanical Engineering

NATIONAL INSTITUTE OF TECHNOLOGY CALICUT

April 2025

CERTIFICATE

This is to certify that the report entitled: **“FABRICATION OF MODIFIED SCOTCH YOKE MECHANISM**” is a bonafide record of the **Project** presented by **AISWARYA NAMBIAR T (**Reg. No: **B220132ME)**, **S DEEPAK (**Reg. No: **B221168ME)**, **SHRISTY SHARMA (**Reg. No**: B221211ME)** under my supervision, in partial fulfilment of the requirements for the award of the degree of **Bachelor of Technology in Mechanical Engineering** from **National Institute of Technology Calicut** and this work has not been submitted elsewhere for the award of a degree.

Dr. Vikash Kumar
(ME3099D - Seminar)
Dept. of Mechanical Engineering

Dr. ML JOY
Professor & Head
Dept. of Mechanical Engineering

Place : NIT Calicut
Date : April 2025

ACKNOWLEDGEMENT

The success and final outcome of this project required a lot of guidance and assistance from many people and we are extremely privileged to have got this all along the completion of my project. All that we have done is only due to such supervision and assistance.

We are grateful to Dr. ML JOY (HOD, Mechanical Department), for providing us an opportunity to do the project work in the Mechanical Central Workshop and giving us all support and guidance, which allowed us to complete the project duly.

We owe our deep gratitude to our project in-charge Dr. Vikash kumar, who took keen interest in our project work and guided us all along, till the completion of our project work by providing all the necessary information for developing a good system.

We are also extremely thankful to and fortunate enough to get constant encouragement, support and guidance from all staff in the Central Workshop which helped us in successfully completing our project work. Also, we would like to extend our sincere gratitude to all Teaching Staff of the Mechanical Department for their timely support.

ABSTRACT

The Rack and Pinion with Scotch Yoke Mechanism is a mechanical system designed to convert rotary motion into precise linear reciprocating motion. This report explores its design, fabrication, assembly and real-life application in mechanical systems. The mechanism consists of two linear racks, a central pinion (spur gear), four rollers, a Scotch yoke, and a crank or actuator. When rotary input is applied to the crank, the Scotch yoke connected to the crank provides smooth reciprocating motion. While the pinion engages with the racks, moving them in opposite linear directions.

The design was meticulously developed through CAD modeling and simulated stress analyses, and subsequently fabricated in our production lab. This mechanism is widely used in cutting machines, presses, valve actuators, and automotive steering systems due to its efficient motion transfer and minimal backlash. The integration of the Scotch yoke ensures continuous, smooth reciprocation, reducing mechanical wear compared to conventional crank mechanisms. Additionally, the system can be optimized for force transmission and speed control based on rack and pinion size ratios.

The proper selection of materials, design, and installation is crucial to the successful operation of the scotch yoke mechanism. Maintenance and periodic inspection are also necessary to ensure the mechanism's continued performance and safety.

Components List:

1. Linear Racks
2. Central Pinion Gear
3. Scotch Yoke
4. Crank/Actuator
5. Rollers
6. Supporting Frame

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INTRODUCTION

The Modified Scotch Yoke Mechanism is an innovative design that enhances the conversion of rotary motion into precise linear reciprocating motion. This mechanism, fabricated using conventional manufacturing processes such as lathe, shaper, and welding, consists of a central pinion gear meshed with two parallel racks, a lever to drive the pinion, and a supporting frame to ensure stability. The system is particularly useful in scenarios requiring controlled linear actuation, such as in cutting devices, production lines, vehicle steering, etc. By leveraging the mechanical advantage of the lever and the precision of the rack and pinion arrangement, this mechanism provides a reliable and manually operated solution for transmitting motion and force in industrial settings.

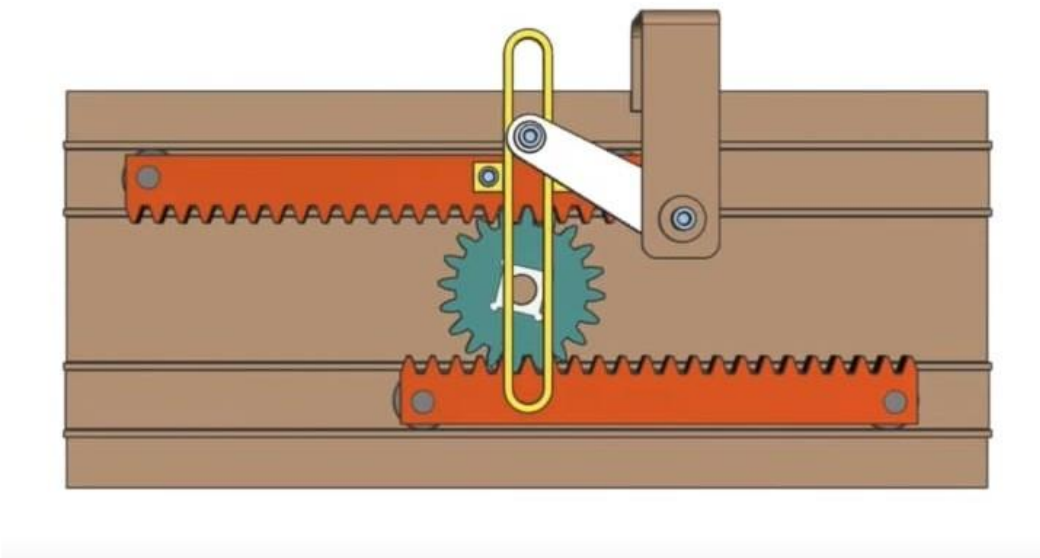


Fig 1: Modified Scotch Yoke Mechanism

Operations:

1. Lever Actuation: The process begins with the manual operation of the lever, which is rigidly attached to the pinion shaft. When the user applies a force to the lever, it rotates the pinion gear around its axis. The lever provides a mechanical advantage, allowing the user to apply a relatively small force to generate a larger torque on the pinion.

2. Pinion Rotation: As the lever rotates, the pinion gear, which is meshed with the teeth of the two parallel racks, also rotates. The pinion's teeth engage with the rack teeth, converting the rotational motion of the pinion into linear motion of the racks.

3. Linear Motion of Racks: The two racks, positioned on opposite sides of the pinion, move linearly in opposite directions due to the pinion's rotation. For example, if the pinion rotates clockwise, the upper rack moves to the left, and the lower rack moves to the right. This synchronized motion ensures balanced operation and can be used to actuate components attached to the racks.

4. Force Transmission: The linear motion of the racks can be used to transmit force to external components, such as pushing or pulling a load, clamping an object, or adjusting the position of a tool. The system's design ensures that the motion is precise and proportional to the angle of lever rotation.

5. Return Motion: When the lever is rotated in the opposite direction, the pinion reverses its rotation, causing the racks to move back to their original positions or in the opposite linear direction. This bidirectional operation makes the mechanism versatile for various applications.

The mechanism operates smoothly when the gear teeth are properly meshed, and friction is minimized through lubrication and precise machining. The frame ensures that the racks remain aligned and move within their designated slots, preventing misalignment or binding during operation.

Types of Mechanism

The mechanism depicted in the image is a specific configuration of a rack and pinion system with a lever, but it can be categorized and extended into various types based on design variations and applications. Below are the types of mechanisms related to this system:

1. Scotch Yoke Mechanism:

- The Scotch Yoke mechanism converts rotary motion into linear motion using a slotted yoke and a crankpin. As the crank rotates, the pin moves within the yoke slot, causing it to reciprocate. This mechanism is used in piston engines, valve actuators, and presses due to its smooth motion and high force output.

- Application: Valve Actuators, Cutting Machine, etc.

2. Basic Rack and Pinion Mechanism:

- This is the core mechanism in the system, where a circular pinion gear engages with a linear rack to convert rotational motion into linear motion or vice versa. In the given setup, the pinion is driven by a lever, and the racks move linearly in opposite directions.

- Application: Used in automotive steering systems, linear actuators, and sliding gates.

3. Bidirectional Linear Actuator:

- The mechanism can be classified as a bidirectional linear actuator because the racks can move in both directions (left or right) depending on the direction of the lever's rotation. This versatility allows the system to perform tasks like opening/closing or pushing/pulling.

- Application; Used in adjustable mechanisms, such as in furniture (e.g., recliner adjustments) or industrial tools requiring reversible motion.

Summary

The rack and pinion mechanism with a lever operates by converting the rotational motion of the lever-driven pinion into linear motion of the racks, with the two racks moving in opposite directions for balanced operation. The mechanism can be classified into various types, including a double rack and pinion system, lever-driven mechanism, guided rack mechanism, and bidirectional linear actuator, each offering specific advantages for different applications. This design highlights the versatility and practicality of combining simple mechanical elements to achieve controlled motion in engineering systems.

DESIGN OF THE MODEL

Determination of part dimensions:

In the initial CAD model, the parts were dimensioned according to dimensions. Later, changes were made owing to the material available in the workshop and module restrictions. All the links, disc and shaft dimensions were changed. Optimum lengths of the links , discs, shaft was obtained by constructing a 2D drawing of the mechanism and tracing its locus in the plane.

FABRICATION OF THE MODEL

Week 1:

- Decided the mechanism by shortlisting the ideas of each team member.
- We decided to work on Scotch Yoke mechanism and to increase the complexities modification is done by combining it with rack and pinion.

Week 2:

- Analyzed the mechanism and listed out individual components.
- Dimensions were finalized and fixed according to the availability of materials in lab.
- Finally prepared the CAD model of our selected mechanism and the mechanism worked successfully in CAD analysis.

Week 3:

- Production drawing of individual components and the assembly were prepared using SolidWorks.
- Dimensions were marked using smart dimensioning and required tolerances for each edges were also included.

Week 4:

- Materials are collected from the workshop.
- We collected a 50mm diameter blank for making the pinion.
- Calculated the number of teeth and outer diameter required of the gear using gear tooth equation.
- Performed facing, turning and drilling operations for initial preparation of workpiece.

- Then did milling operation and obtained the required gear.

Week 5:

- 2 mild steel square rod of dimension 16×16×200 mm was selected for making racks.
- Marked the tooth width on the square rod using a scriber by taking reference from the already made pinion.
- Cut the tooth on rack using shaper machine.
- Obtained 1 rack out of the 2 required racks.

Week 6:

- Material required for the rack was already chosen in the previous week.
- Marked the required tooth thickness on the square rod using scriber.
- Cut the tooth on the second rack with the help of shaper machine.
- Filing operation was done using triangular file on both racks for getting proper finishing of the parts.

Week 7:

- Sheet metal of 3mm thickness was selected from sheet metal shop for making the base plate of the mechanism.
- Required dimension of 400×200 mm was marked and cut out using sheet metal cutting instrument.

Week 8:

- Selected 10×10×400 mm steel square rods, four in number for making the guideways.
- Welded these 4 pieces onto the already cut base plate sheet metal after marking the distance between them on the sheet metal.
- A 10×30mm size mild steel cylindrical rod was also chosen for making the rollers.

Week 9:

- Shaped the 4 rollers for required dimensions of 14×10mm on the base and 16×6mm on the top part.
- Drilled 6mm hole on both racks to insert the roller.
- A 20×30mm cylindrical rod was selected for making the pinion support.
- Then shaped it to required dimensions with top part having 20×14mm and base of 15×16mm.
- 25×3mm mild steel flat were selected for making the slot and crank.

Week 10:

- 14×140×3mm slot was cut on the previously chosen steel flat with the help of milling machine using a 12mm drill bit after drilling a 14mm hole on both ends.
- Drilled a 6mm diameter hole on 25×130×3mm and 25×70×3mm MS flat for crank using a 6 mm diameter drill bit.
- Using a 14mm drill bit , we drilled a hole on the 25×70×3mm flat, on the opposite side of the already drilled 6mm hole.
- A 6×15mm cylindrical rod selected for connecting the flats.
- After selecting and cutting 25×130×3mm,25×60×3mm,25×100×3mm flats, we welded it together and onto the base plat to make the support for crank.
- Next we made a handle for providing manual rotation for the mechanism by cutting and welding MS flat and MS cylindrical rod of appropriate dimension.
- Drilled a 6mm diameter hole on MS flat of the handle using a 6 mm drill bit in order to connect it with the crank.

Week 11:

- Selected 2×10 mm metal sheet,16×6 mm metal rod.
- Welded the metal sheet behind the racks and proper meshing of gear and rack was confirmed before welding.
- The connecting shaft was made in such a way that can be removed or locate in its position.
- Painted all the parts before assembly.
- Assembled all the parts and checked the working of mechanism.
- Working model of modified scotch yoke mechanism is ready for submission.

➢ The following table gives dimensions of each part in assembly:

Part no.	Part name	Quantity	Dimensions	Material	Operations involved
1	Pinion	1	48mm diameter	MS Round	Facing, turning,drilling,milling, filing
2	Rack	2	16×16×200mm	MS square	Cutting , shaping, filing, drilling
3	Base plate	1	400×200×3	Sheet metal	Cutting
4	Guideways	4	10×10×400mm	MS square	Cutting , grinding, welding
5	Slot	1	25×180×3mm	MS flat	Cutting, drilling, milling
6	Crank	1	25×70×3mm	MS flat	Cutting, drilling, grinding
7	Rollers	4	10×30mm	MS round	Cutting, facing, turning, grinding
8	Pinion support	1	20×30mm	MS round	Cutting, grinding. Facing , turning
9	Connecting shaft	1	14×7mm	MS round	Cutting, grinding

ANALYSIS

FOR RACK:

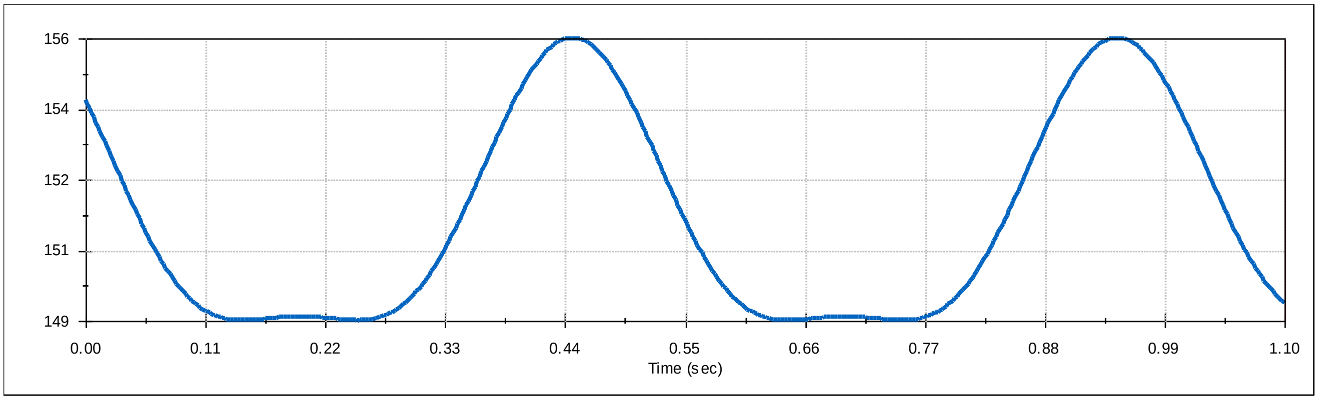


Fig: Displacement analysis

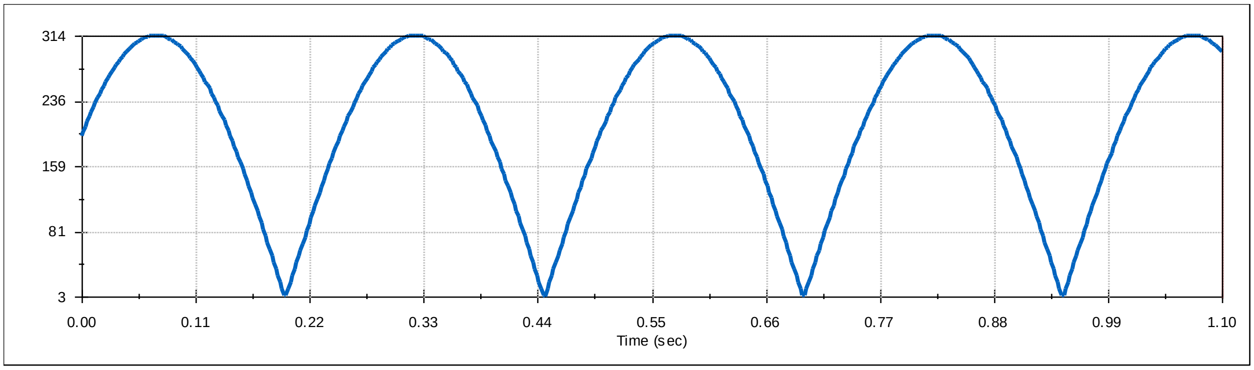


Fig: Velocity analysis

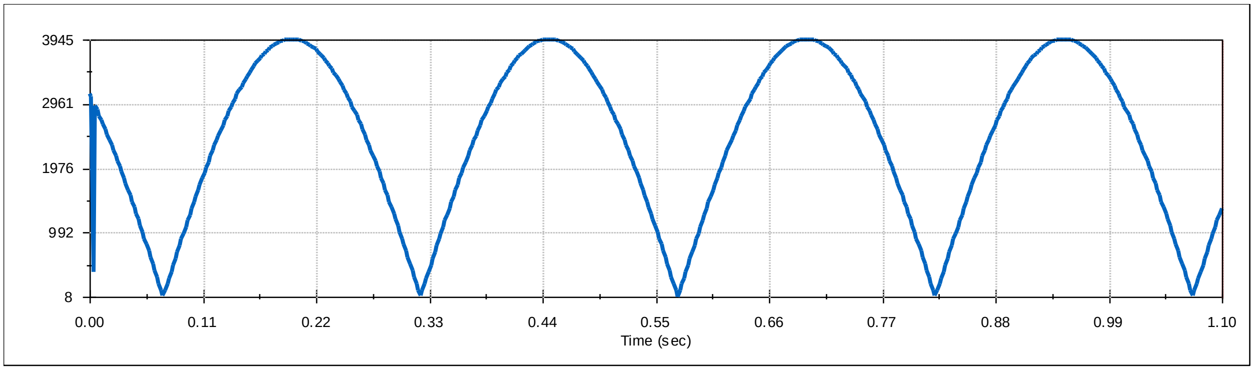


Fig: Accelaration analysis

FOR CRANK:

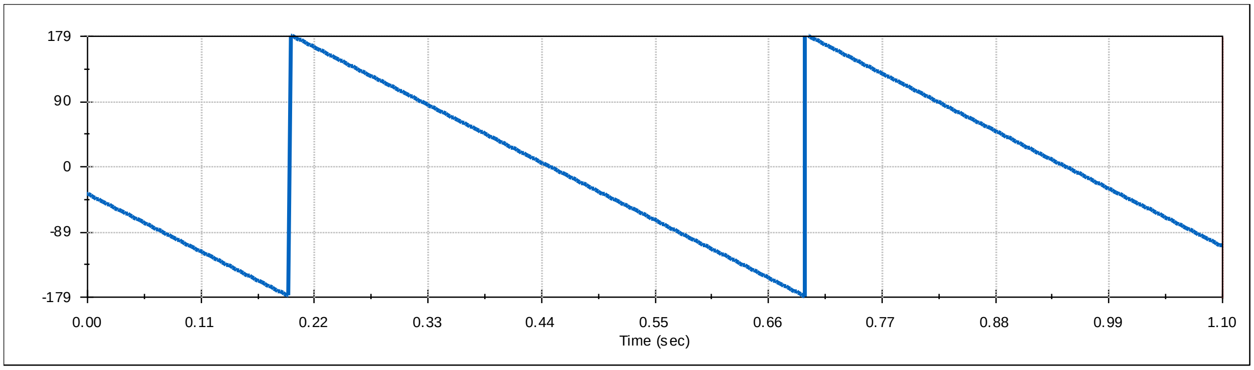


Fig: Displacement analysis

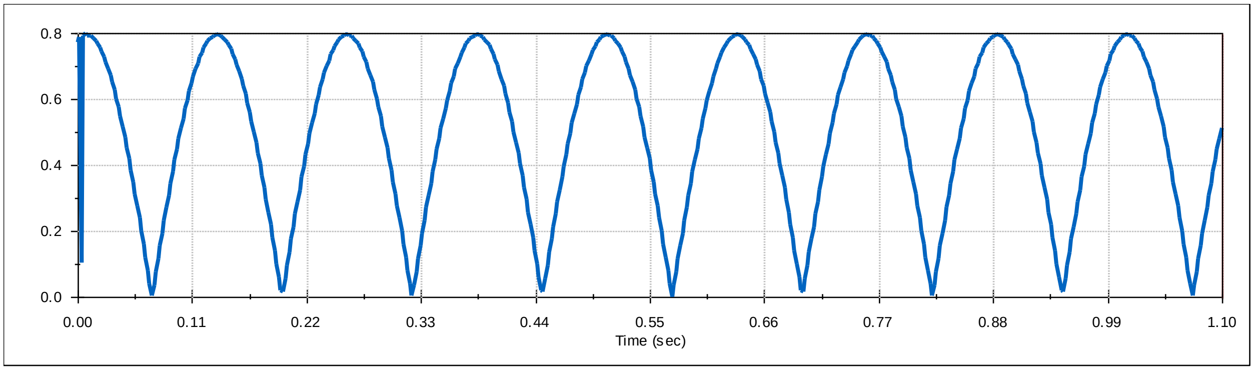


Fig: Motor Torque

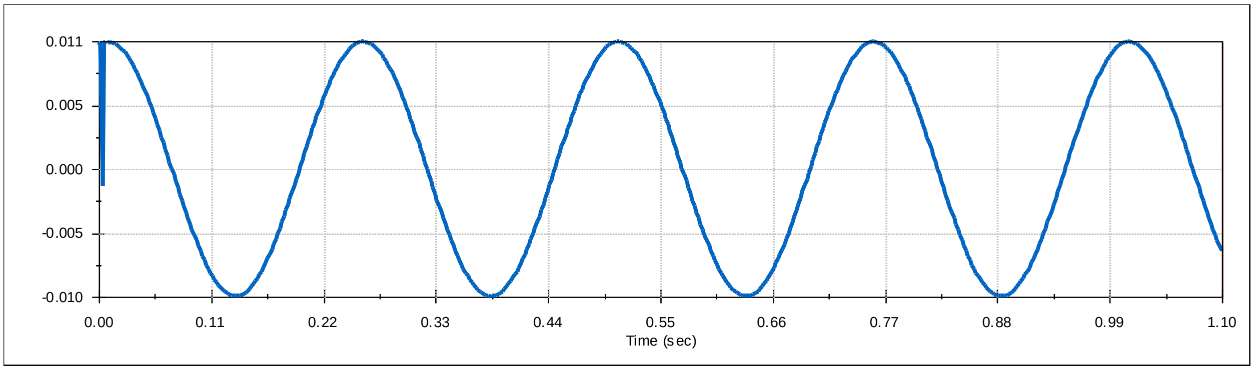


Fig: Power consumption

RESULT

The modified Scotch Yoke mechanism was fabricated using the above steps mentioned by 11 weeks. We used the following machines for the fabrication:

1. Lathe machine for facing, turning of rollers, pinion and shafts.

2. Drilling machines for drilling holes in links, slot, crank , and racks.

3. Power saw for cutting the MS flats, square rods and cylindrical rods.

4. Shaper machine for making racks .

5. Grinding wheel for grinding the edges of parts.

6. Welding machine for making base and support.

7. Milling machine for making pinion, slot.

We fabricated the following components for our model:

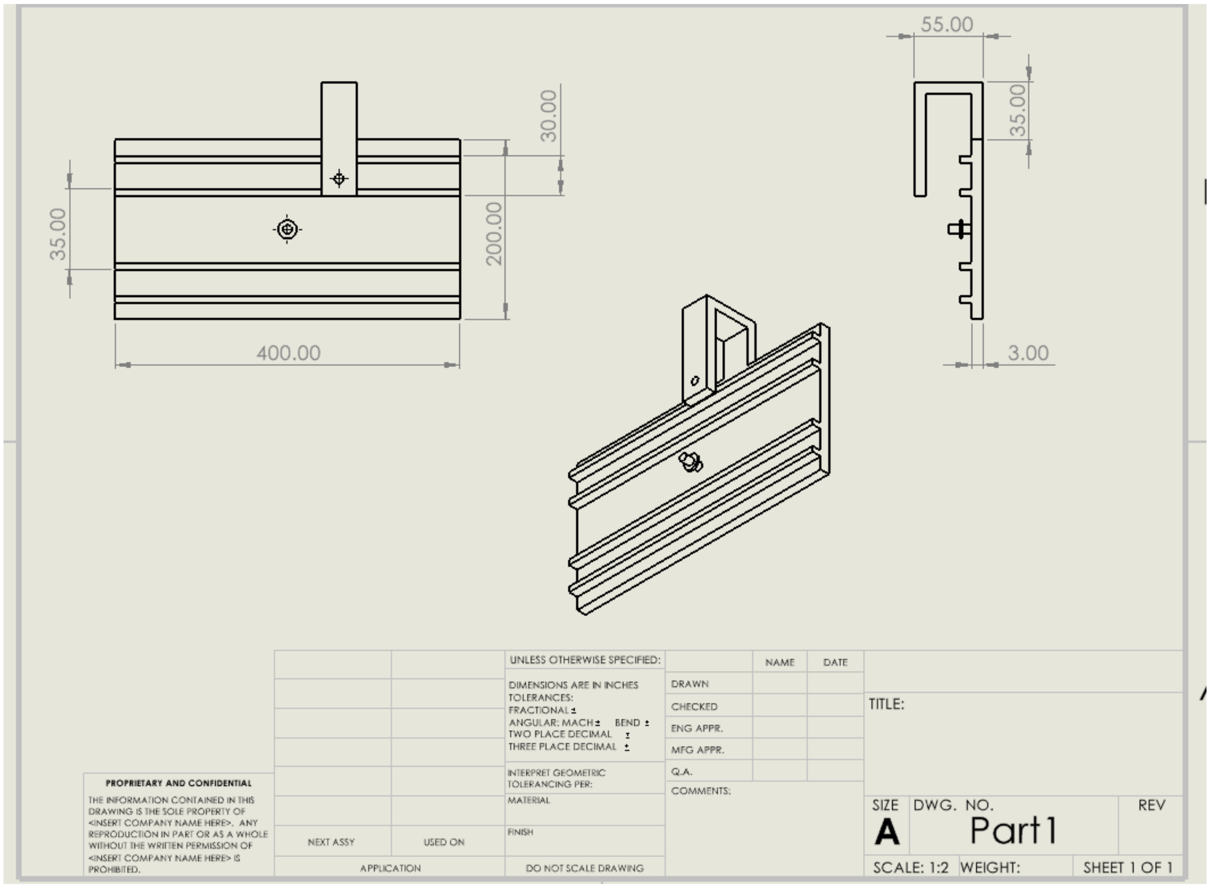
1) 1 pinion, 2 racks
2) Base plate with guideways for rollers.
3) Rollers, pinion support, connecting shaft.
4) Slot, crank.

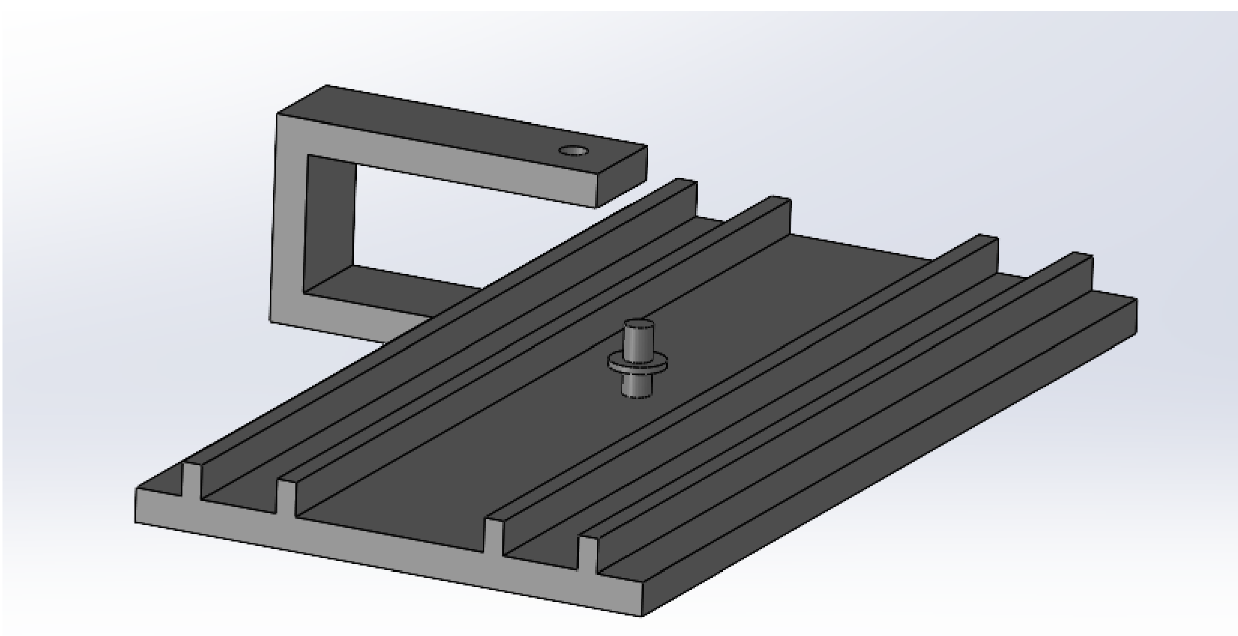
CONCLUSION

When given rotatory motion to the handle manually, the motion is transmitted to the crank and then to the slot, converting it to reciprocating motion. This reciprocating motion is converted to linear motion by the rack and pinion. The overall objective of the project fabrication is achieved.

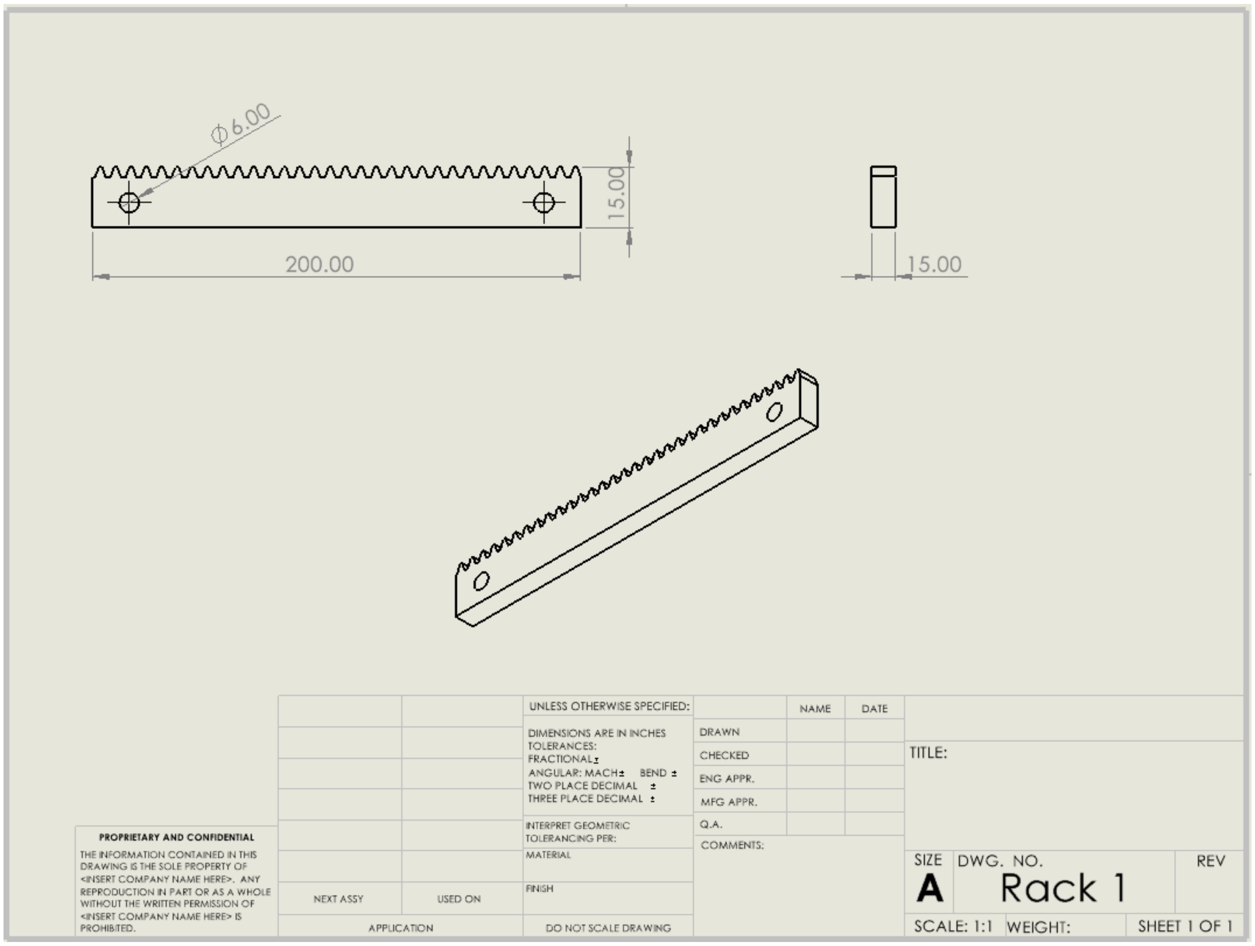
FINAL PARTS

BASE PART:





RACK:



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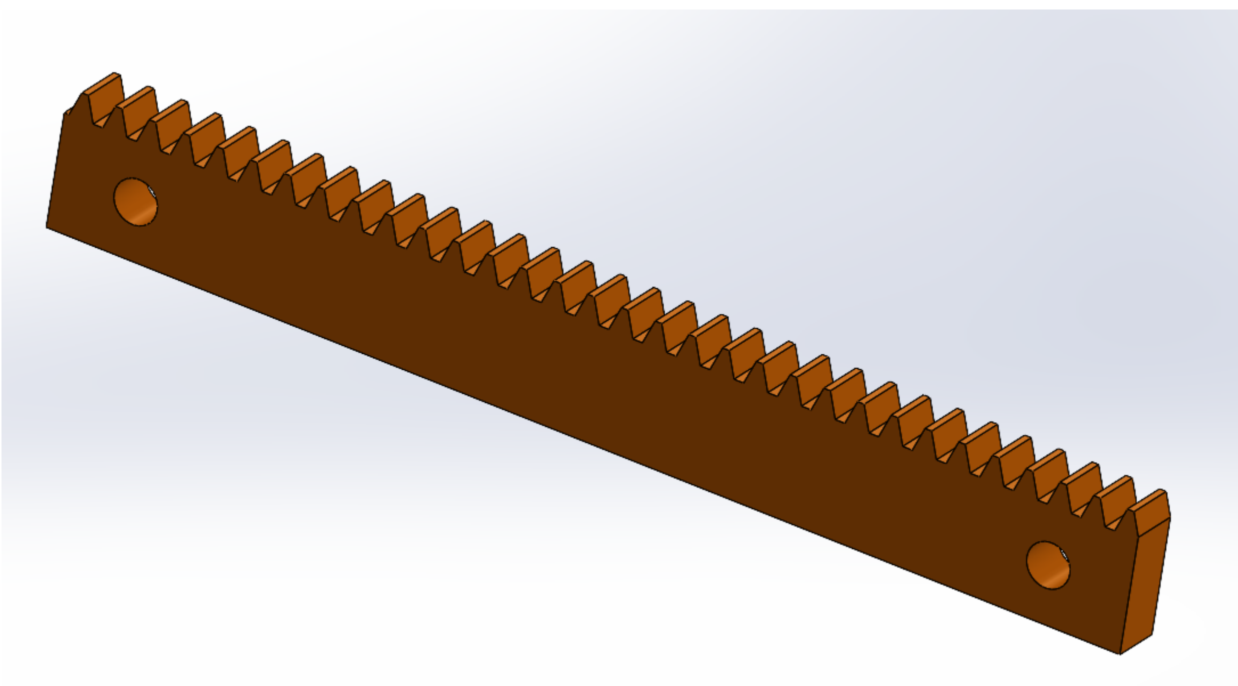
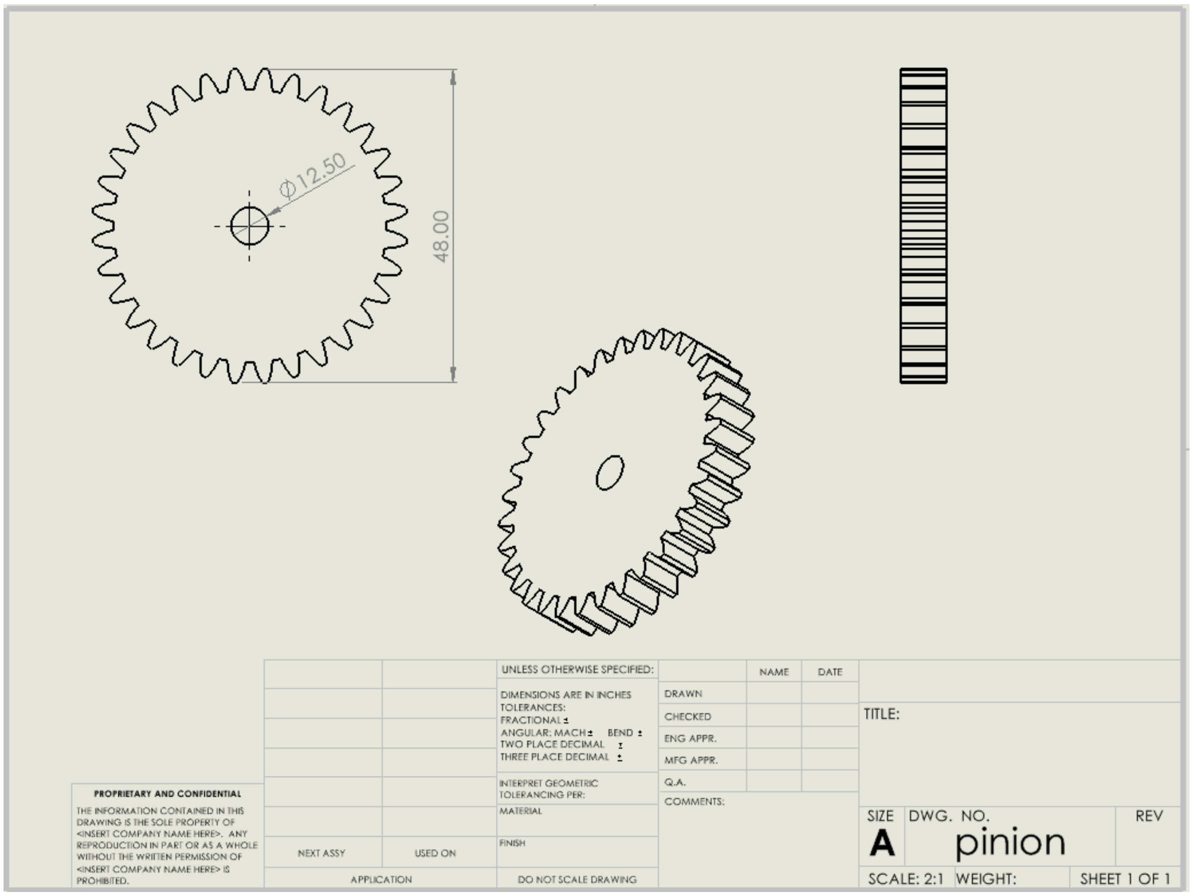


PINION: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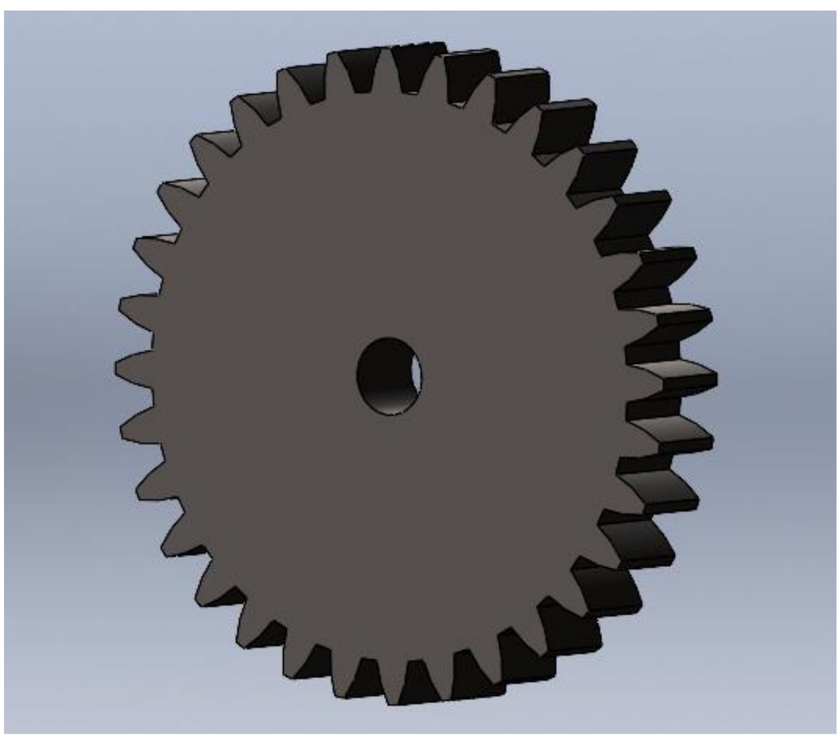
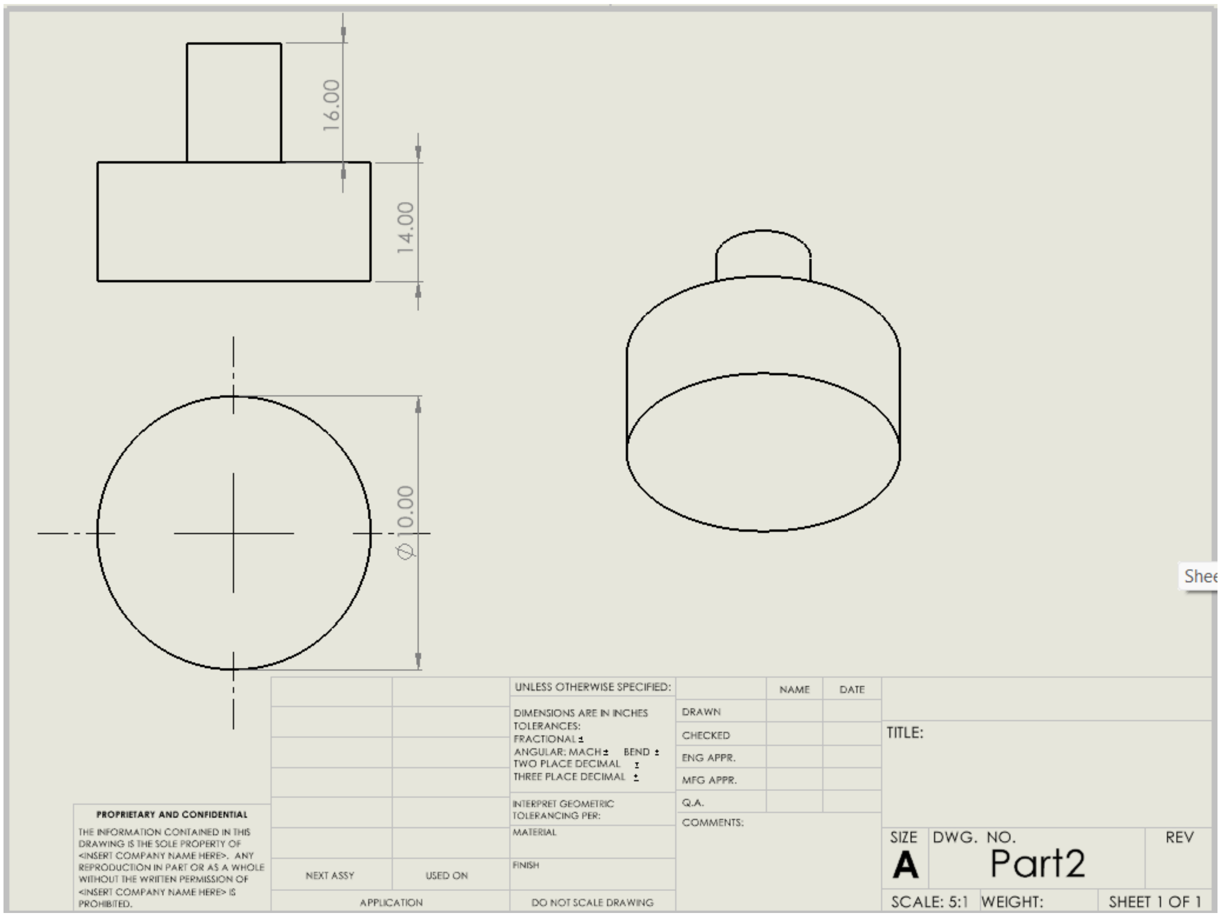


ROLLER: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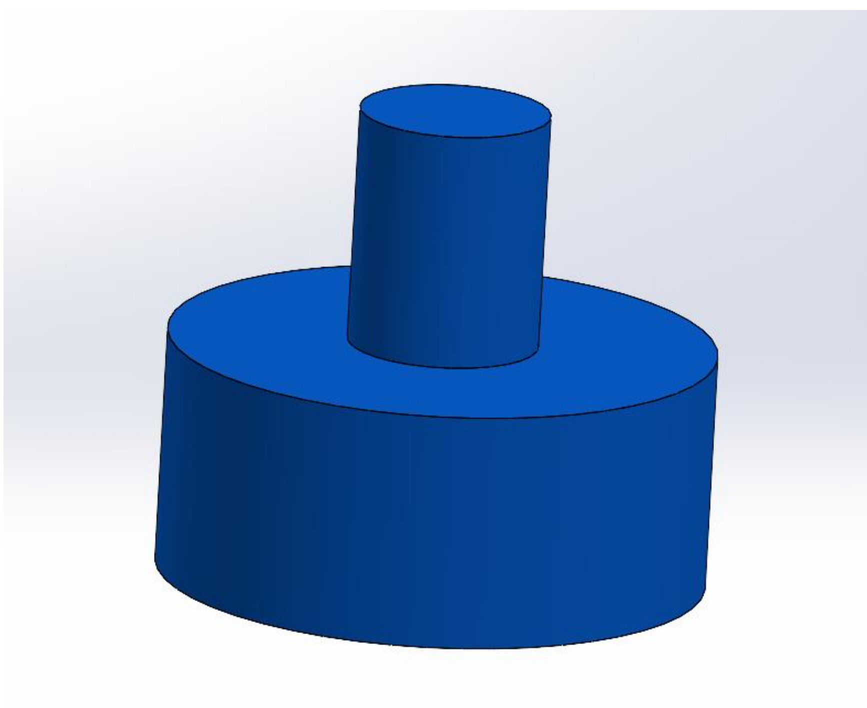

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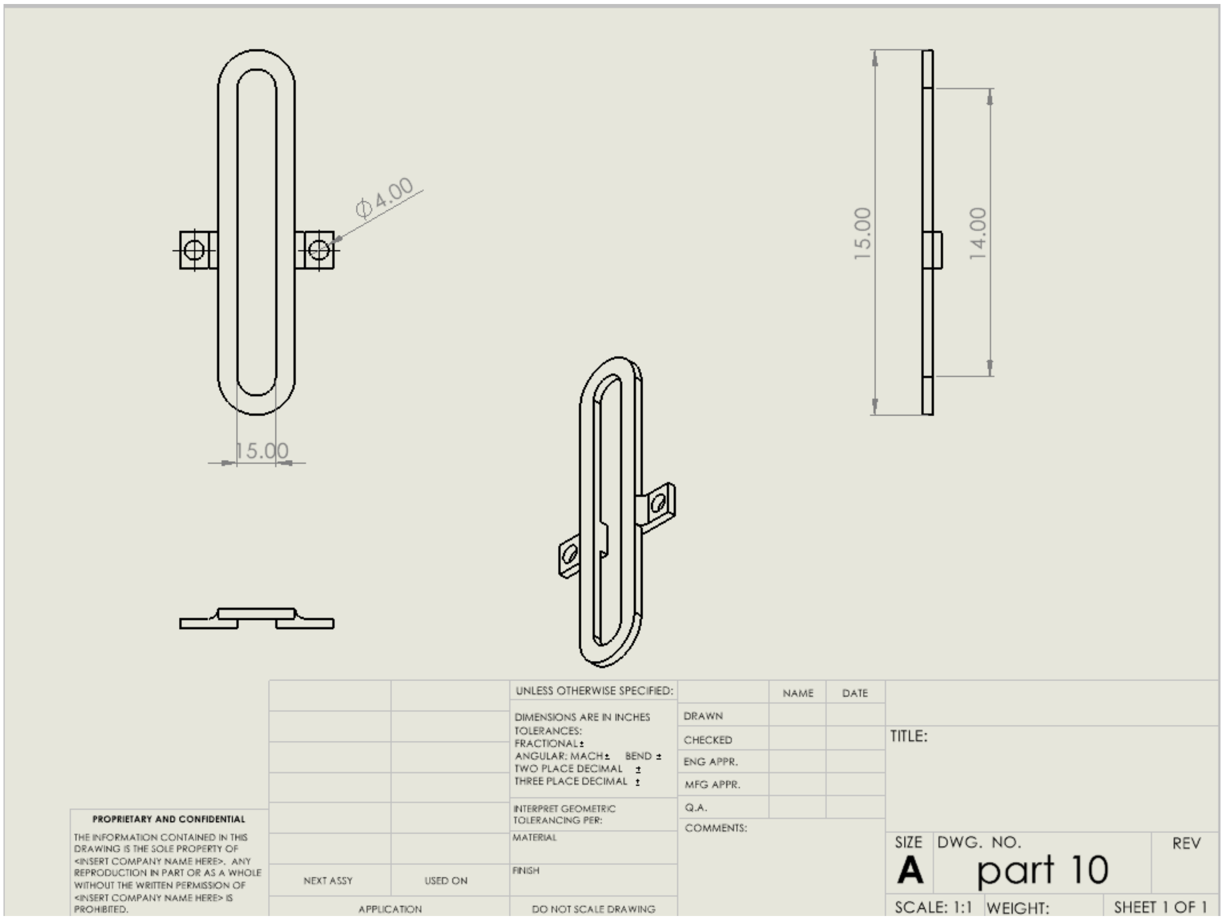

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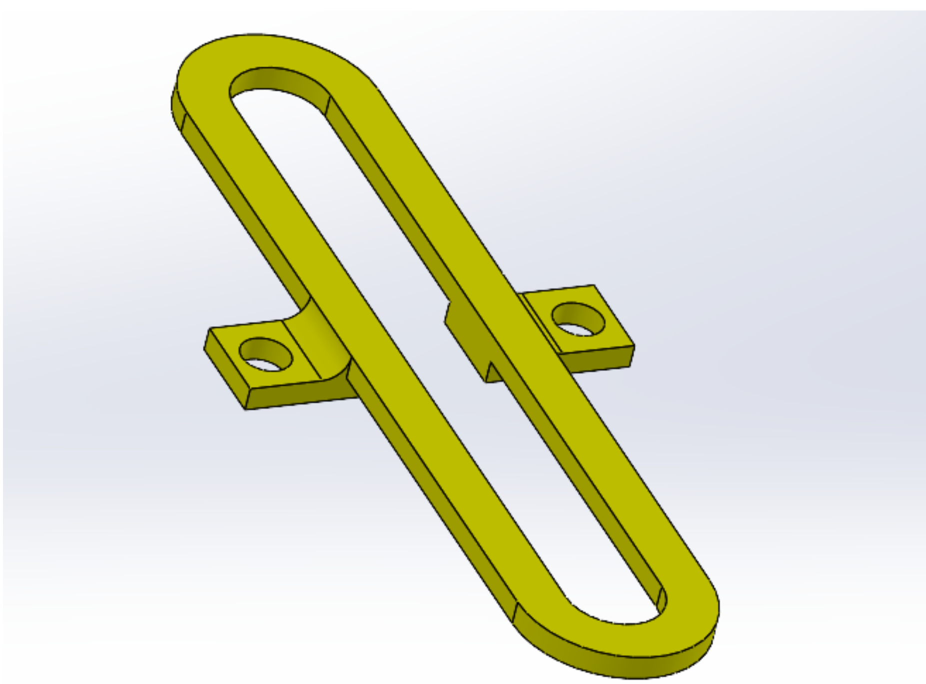

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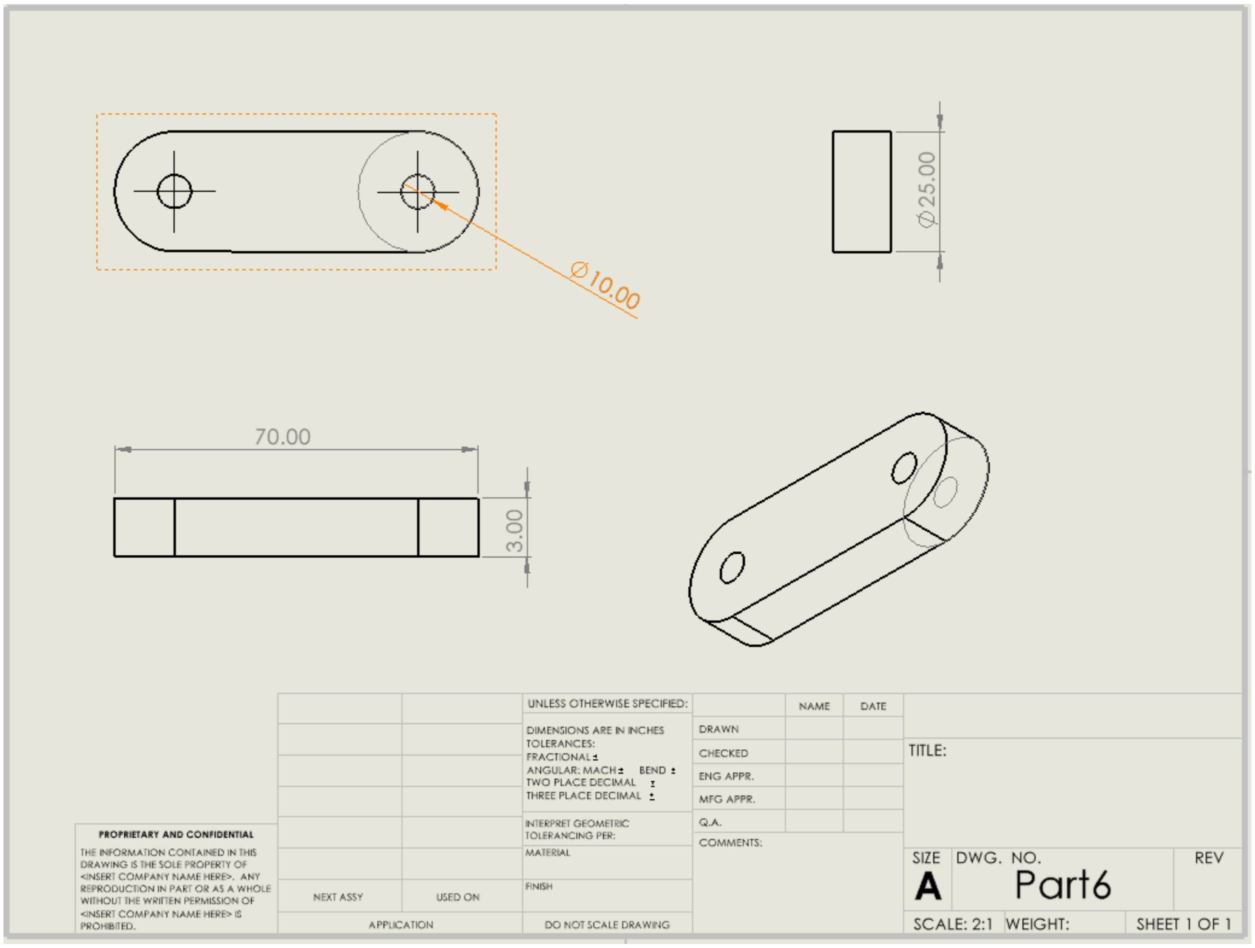

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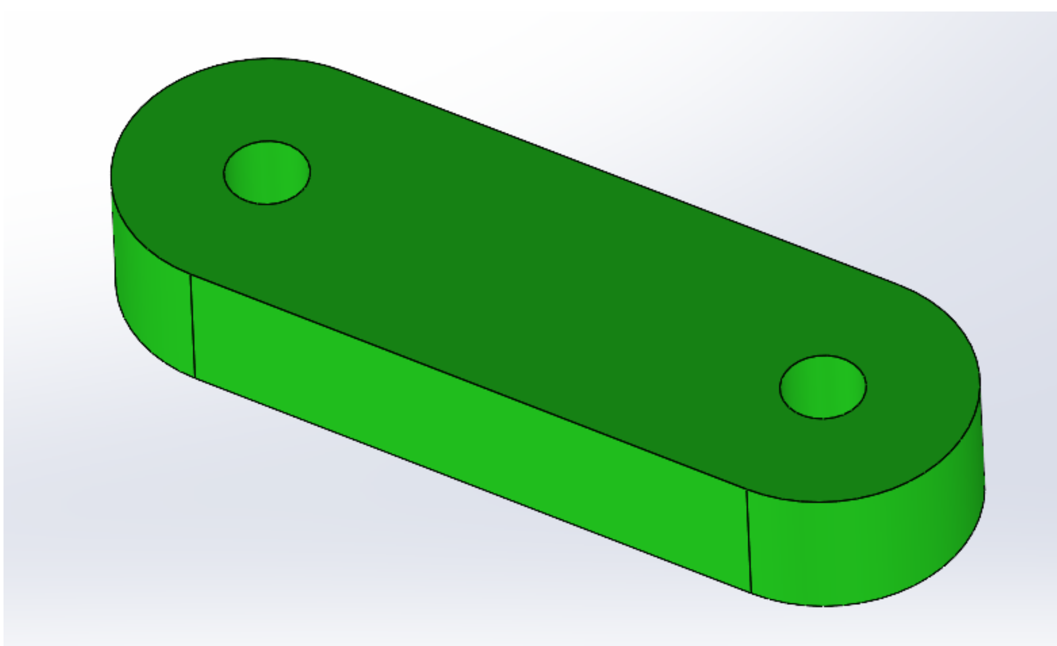
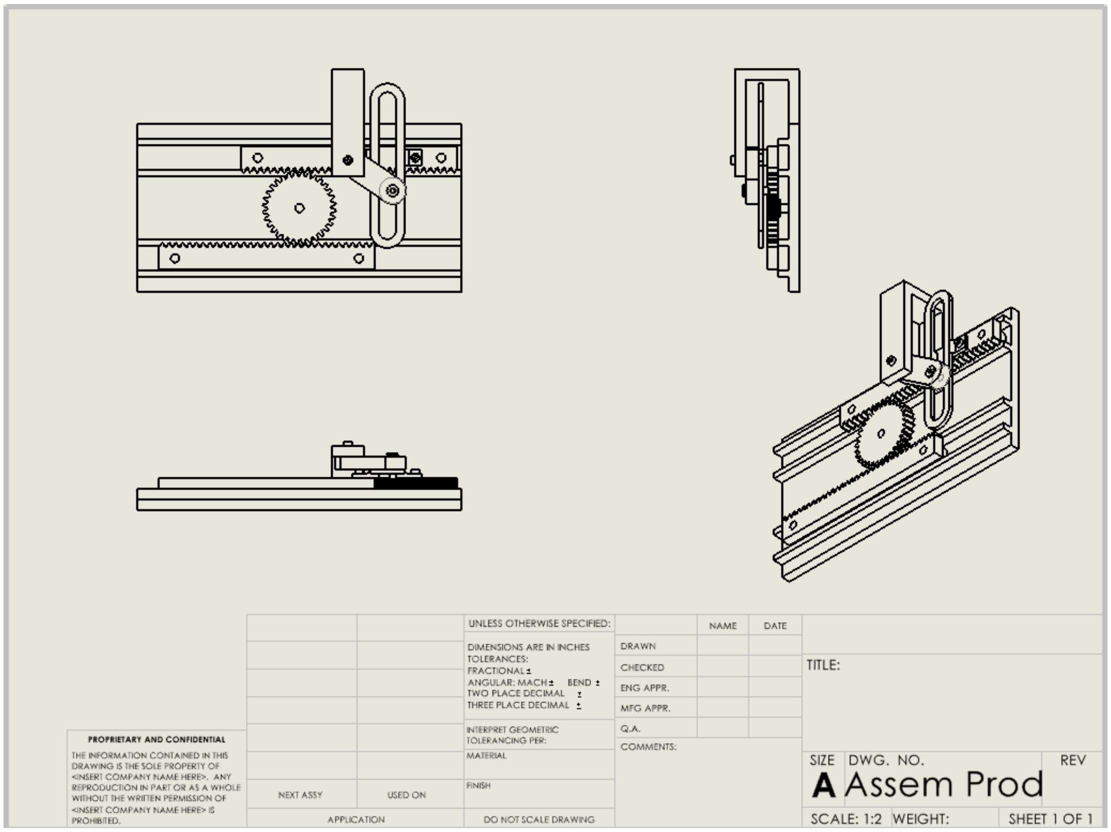
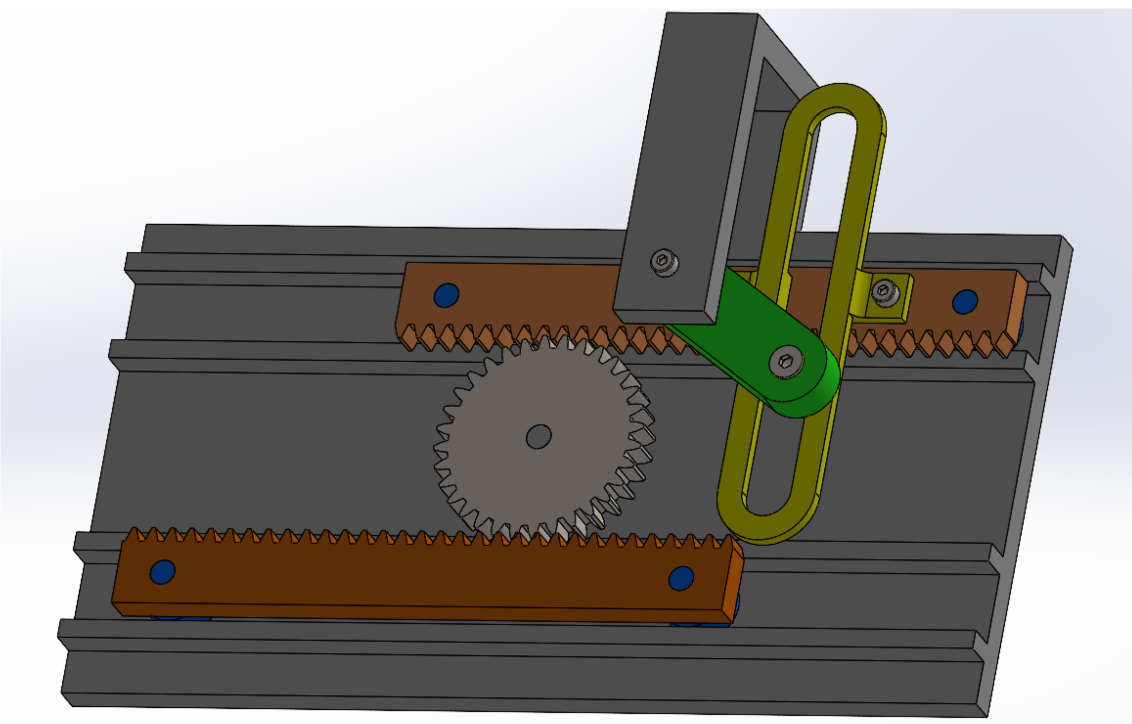
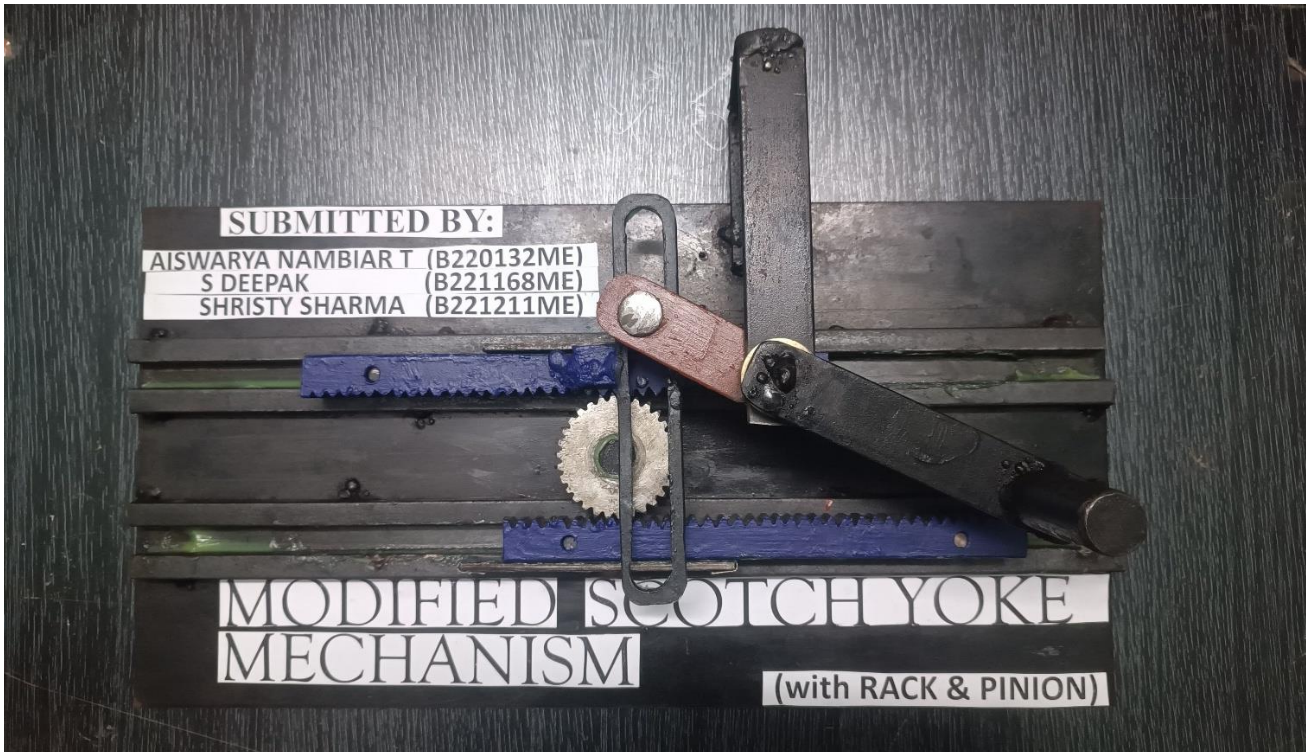


FINAL ASSEMBLY





WORKING MODEL



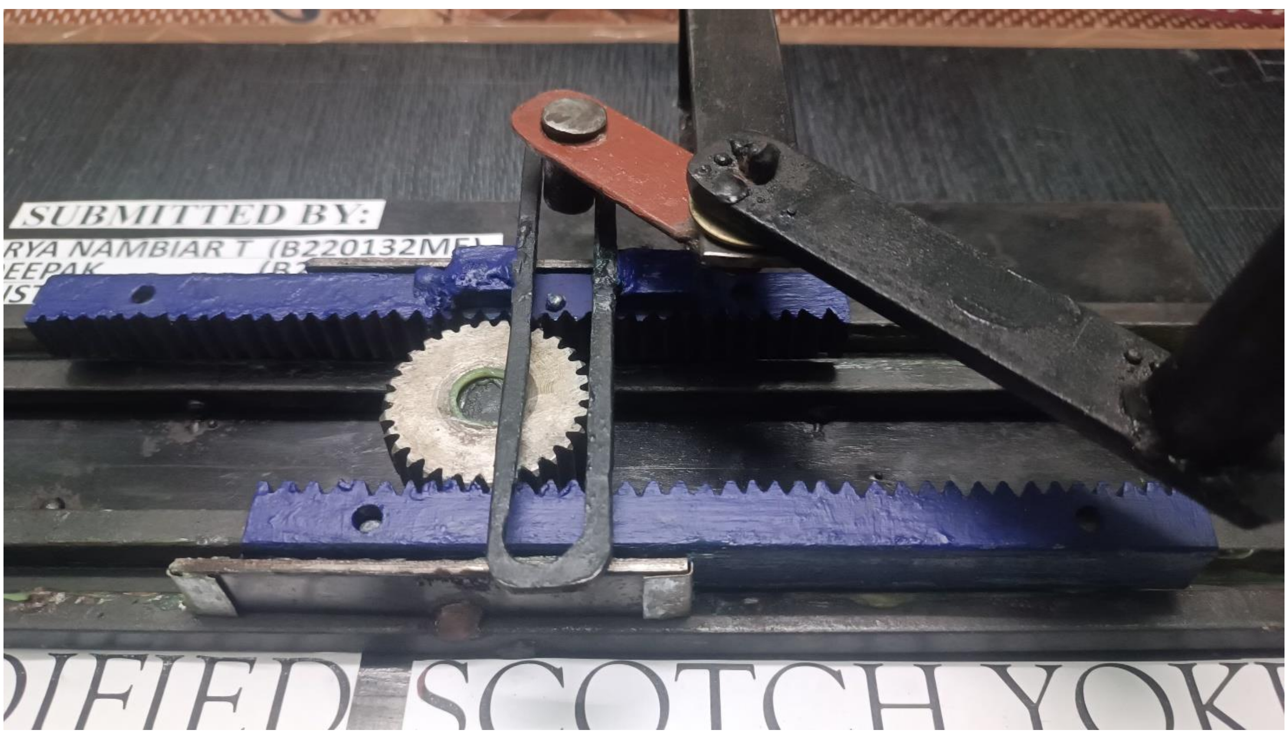


Fig: Finished model of Modified scotch mechanism