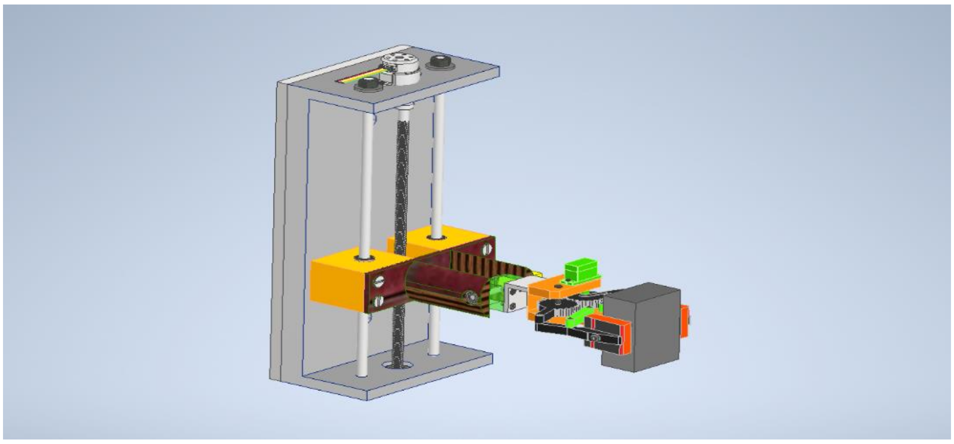
Report on

# Advanced 3D design on Automated Handling and Manipulation tool



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## ABSTRACT

In the framework of contemporary production, the goal of this project is to build an automated handling tool for lifting and rotating a block having a rough surface. The block is 350 g in weight and is 70 x 50 x 30 mm. Secure picking and placing of the block, as well as the mechanical setup required for movement and rotation, are the goals of this instrument. The manipulator has a lead screw mechanism for lifting by 250 mm, a parallel mechanical gripper for manipulation powered by an electric motor, and an MG 995 motor for a 90° rotation. The goal of this integrated strategy is to increase production automation and accuracy, which will improve the overall process' efficiency and quality.

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## LIST OF FIGURES

# 1 INTRODUCTION

## 1.1 Autodesk Inventor:

This is a program for 3D mechanical engineering, design, visualization, and simulation.Autodesk Inventor is a parametric, feature-based solid modelling program. It enables you toconvert a simple 2D graphic into a solid model using very basic modelling capabilities. By combining 3D data and 2D AutoCAD drawings into a single model, it creates a digital prototype as opposed to a physical one (which is expensive and time consuming). It is capable of producing spectacular presentations, animations, and visualizations that enhance communication fast and effortlessly. It enables manufacturing teams to swiftly produce and exchange production-ready drawings. The automated update feature makes switching between models straightforward. It provides a simulation environment for FEA (finite element analysis) of parts, assemblies, and moving systems as well as static and modal analysis, and load bearing frames.

## 1.2 DESCRIPTION OF PROJECT WORK

Task description and requirements: Task description:

A block (dimension 70 x 50 x 30 mm, mass 350 g) with very rough surfaces needs to be lifted by 250 mm and rotated by 90° during a production. The handling tool to be designed should fulfill the following requirements: Solution for picking and release of the block.Mechanical setup enabling the movement and rotation of the block.Evaluation and selection of suitable actuators

# 2 THEORITICAL DESCRIPTION

## 2.1 Robotic Grippers:

Robotic grippers play a pivotal role as end-effectors in the realm of robot manipulators. Functioning as the active connection between handling equipment and the workpiece, or the object to be acquired, grippers serve multifaceted purposes. They facilitate tasks such as maintaining precise position and orientation of the workpiece, holding static and dynamic forces, altering the object's position relative to the handling equipment, and enabling various technical operations. Grippers are indispensable not only in industrial robotics but also across automation domains like hard automation, NC machines, hand-guided manipulators, and even service robots. Their designs span a wide spectrum to accommodate the diverse range of tasks they undertake. While conventional jaw-type grippers and simpler open-close two-fingered grippers are common, specialized designs like magnetic devices, vacuum cups, and even miniaturized grippers are emerging to cater to distinct operational requirements.

## 2.2 Gripper Components:

Grippers are the most often utilized end effectors and are primarily made up of four components that have a direct impact on the gripper's physical characteristics. The functionality of the gripper is likewise impacted by these elements.  category for the components is

1.Transmission systems.

2. Actuators.

3.Joints and links

4. Sensors

## 2.3 Transmission Mechanisms:

Any mechanical system that requires the transmission of power from an actuator over a distance employs a transmission system. There are different types of transmission systems used in gripper mechanisms:

1. Chain-Belt Mechanism.

2. Mechanical Connection.

3.System of gear trains .

4.Rope and Pulley System .

5. A rack-and-pinion drive.

6.Harmonic Drive.

## 2.4 Gripper Drivers

Several potential primary movers can produce finger motion. To do this, a type of energy must be transformed into mechanical energy, which corresponds to the desired form of motion. Actuators used in grippers typically fall into one of three categories.which are

1. Pneumatic Actuators.
2. Electric Actuators.
3. Hydraulic Actuators.

## 2.5 Considerations and Selection:

Factors influencing gripper choice, such as object attributes, force, speed, environment, safety, and material compatibility.

# 3 Design of Gripper

components or parts Design one:

1.Base

2.a pair of fingers

3.Linkage between the base and the finger

4.Gear transmission

5.Basic Actuator/Motor

### 3.1.1 Base:

Base is the component in the gripper which joins the gripper fingers with the mechanical gears and also provides support to hold the actuator. To have proper parallel motion the base is connected to secondary linkages which is joined to the gripper fingers.

the 4 holes of diameter 4mm have position tolerance to make sure the holes are made in the correct position to have correct mating. The concentricity tolerance is to make sure the central axes of the holes are in line with the gear, finger, and secondary linkage.

### 3.1.2 Gears

The gear which I used have 15 gear teeth mating mechanically with similar gear at 1:1 gear ratio. The gear teeth are equally spaced for almost a semi-circle and the angular velocity of each the gears are in opposite directions. This makes the torque ratio negative .

### 3.1.3 Linkage:

The holes are made with a 4 mm diameter and are 32 mm apart.The geometric tolerances required for this hole to mate effectively with both the base and the finger include position tolerance to ensure that the hole is in the correct location and concentricity to ensure that the axis of this hole is concentric with holes at both the base and the finger.

### 3.1.4 Fingers:

Demonstrates that certain geometrical tolerances must be considered.To ensure that the fingers do not have a parallel linear angle between them, the surface of the fingers must account for parallelism.

To guarantee that the workpiece is maintained perpendicular to its center axis, the surface of the finger must also have a flatness tolerance.This will make it possible to charge the clamp and unload conveniently.The two holes' location tolerance and concentricity are the other geometrical tolerances that must be met in order for the links to fit snugly through them.

### 3.1.5 Gripper pads:

gripper pads play a crucial role in optimizing the performance and functionality of gripper systems across various industries and applications by improving grip reliability, protecting objects, and enhancing overall efficiency.

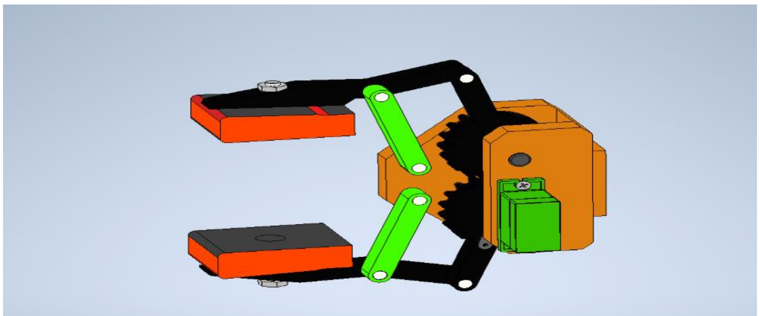


**Figure 1 Assembly of gripper components**

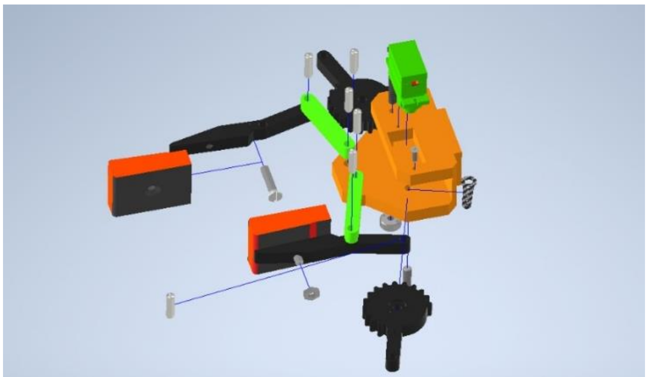


**Figure 2 Exploded view of gripper**

## 3.2 Designed Gripper Operation:

This design will function by the torque transmitted by the motor/actuator. The actuator will receive signals and power from the control system to transmit torque accordingly. The transmitted torque at the driving gear will rotate the driven gear at 1:1 torque ratio. The driven gear will rotate in opposite direction. So that both fingers move at equal and opposite displacements. As the gears rotate this causes the fingers to open or close.

## 3.3 Specifications Analysis for Design One

1.This design can have opening at a range of 60 mm to 50 mm.

2. In order to maintain the grip force 2 to 3 N the actuator is selected accordingly.

3. The maximum load carrying ability is 350grams

4. The minimum pressure is given by the selected pressure sensor.

5. Grip material is CFRP

# 4 Reasons for Choosing a Lead Screw Mechanism

First, I decided to use a pneumatic cylinder to lift and rotate simultaneously,it eliminate an extra accutor use for rotation.

**Figure 3 the first idea for a design**

However, the design's figure made it impossible to reduce the lifting force, so I decided to use a lead screw mechanism to raise the tool to the necessary height.

**Figure 4 Lead screw Assembly**

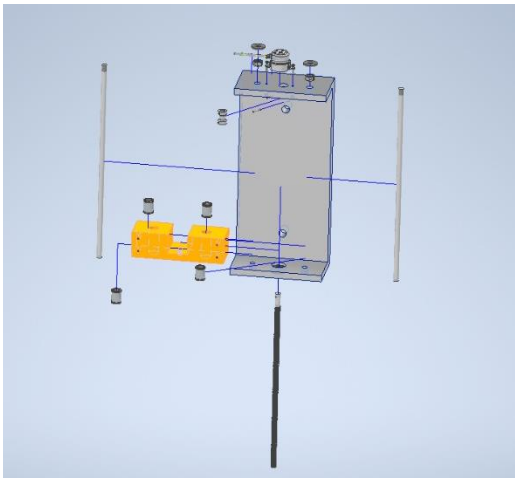


**Figure 5 Lead Screw Exploded view**

## 4.1 Working principle:

The Linear Slide Table's main job is to turn the exact linear movement produced by the stepper motor into rotational motion.The cooperation of various crucial components enables this.

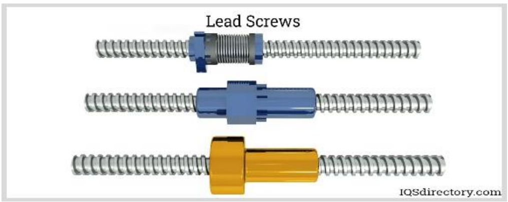



**Figure 6 technical principle of lead screw**

## 4.2 Lead Screw Design:

The components of a lead screw are the following:

### 4.2.1 Stepper Motor:

The stepper motor serves as the system's brain. It is created specifically to deliver precise and controlled motion. The linear slide table may be precisely positioned, discrete steps the stepper motor makes it possible. The efficiency of power transmission is increased by the use of stranded wires in the motor design.

**Figure 7 Motor for Lead screw**

## 4.3 Coupler for Lead Screw and Motor:

This part connects the lead screw to the stepper motor. It ensures a secure and reliable connection, enabling the transfer the lead screw to the rotational motion from the motor, enabling the transfer of rotational motion from the motor to the lead screw without loss of power or accuracy.

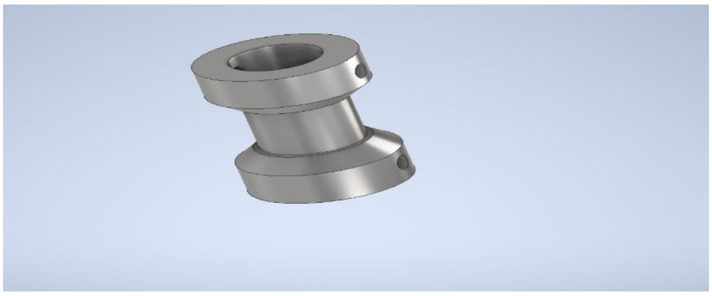


**Figure 8 Shaft Coupler**

## 4.4 Lead Screw:

The lead screw, which has trapezoidal threads and an 8 mm diameter, it is charge of turning the motor's rotating motion into linear movement. The lead screw converts the spinning of the motor into forward or backward motion along the linear axis. I chose to use threading with a trapezoidal pattern because it offers mechanical advantages that encourage efficient, regulated movement and less wear than alternative threading.

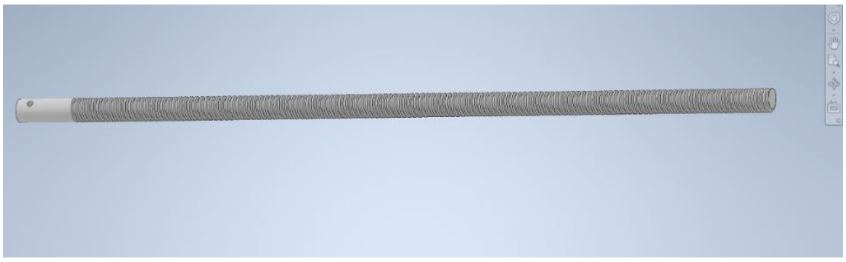


**Figure 9 Lead Shaft**

## 4.5 Lead Nut:

The lead screw is completed by the 8 mm lead nut. It is made to interface with the lead screw's trapezoidal threads, enabling smooth and accurate linear motion. The sliding table can be moved linearly by the lead nut moving along the threads, enabling precise positioning.

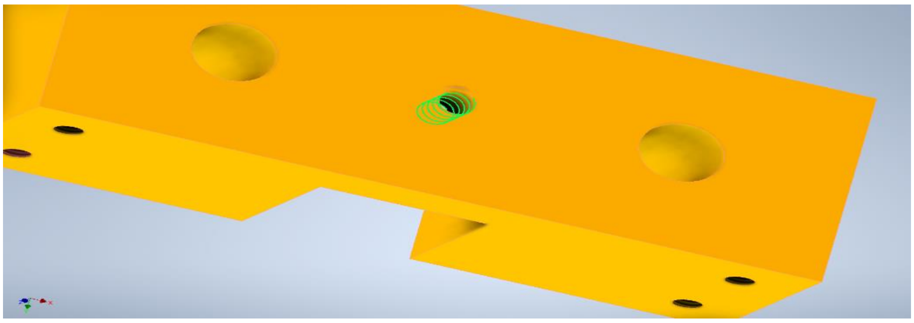


**Figure 10 Lead Screw Conversion Nut Seat**

## 4.6 Trapezoidal Thread :

Trapezoidal thread forms are screw thread profiles with trapezoidal outlines. They are the most common forms used for leadscrews (power screws). They offer high strength and ease of manufacture.

They are typically found where large loads are required, as in a vise or the leadscrew of a lathe. Standardized variations include multiple-start threads, left-hand threads, and self-centering threads.

The trapezoidal metric thread form is similar to the Acme thread form, except the thread angle is 30°. It is codified by DIN 103. While metric screw threads are more prevalent worldwide than imperial threads for triangular thread forms, the imperially sized Acme threads predominate in the trapezoidal thread form [1] .

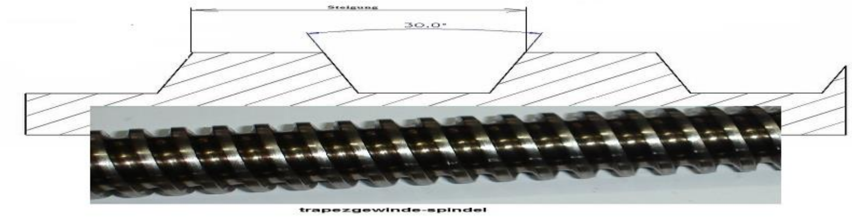
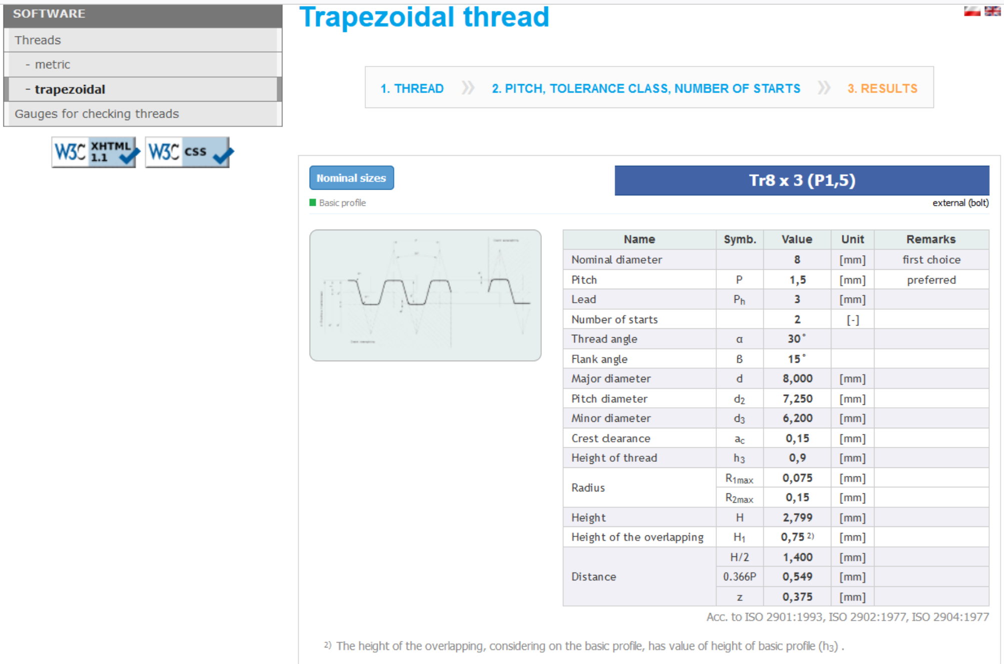



**Figure 11 schematic diagrams of trapezoidal thread**




| Name | Symb. | Value | Unit | Remarks |
|---|---|---|---|---|
| Nominal diameter | | 8 | [mm] | first choice |
| Pitch | P | 1,5 | [mm] | preferred |
| Lead | $P_h$ | 3 | [mm] | |
| Number of starts | | 2 | [-] | |
| Thread angle | α | 30° | | |
| Flank angle | β | 15° | | |
| Major diameter | d | 8,000 | [mm] | |
| Pitch diameter | $d_2$ | 7,250 | [mm] | |
| Minor diameter | $d_3$ | 6,200 | [mm] | |
| Crest clearance | $a_c$ | 0,15 | [mm] | |
| Height of thread | $h_3$ | 0,9 | [mm] | |
| Radius | $R_{1max}$ | 0,075 | [mm] | |
| | $R_{2max}$ | 0,15 | [mm] | |
| Height | H | 2,799 | [mm] | |
| Height of the overlapping | $H_1$ | 0,75 [2)] | [mm] | |
| Distance | H/2 | 1,400 | [mm] | |
| | 0.366P | 0,549 | [mm] | |
| | z | 0,375 | [mm] | |

Acc. to ISO 2901:1993, ISO 2902:1977, ISO 2904:1977

2) The height of the overlapping, considering on the basic profile, has value of height of basic profile ($h_3$) .

**Figure 12 Trapezoidal thread calculation sheet**

## 4.7 Specifications:

Thread Type: Trapezoidal-shaped thread.

Maximum Stroke Length: 230 mm.

Motor Selection: In order to maintain 1024 rpm motor torque is selecte the actuator accordingly.

Material: stainless steel

Voltage:12V

# 5 Actuators

All of the mechanisms are controlled by various actuator types that can move and rotate the block with the necessary accuracy from one location to the desired position. I have considered servo motors as actuators for the automated handling tool design. The following characteristics apply to the actuators I'm considering.

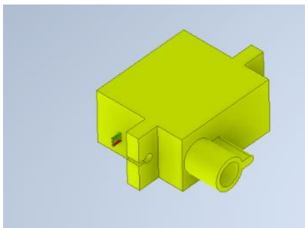
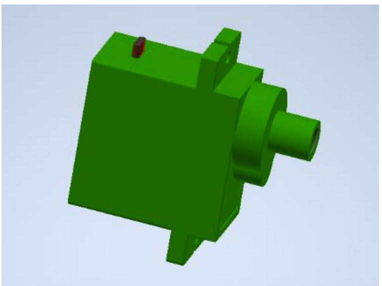
| Motor Design | Position | Model | Specification | Justification |
|---|---|---|---|---|
|  | Lead Screw Driver | NEMA 17 Stepper Motor With DRV8825 and A22 speed sensor | 12V with 3A adapter and 1000 RPM. with self-aligned pillow rotational bearing shaft. | High torque with relative precision control required. |
|  | Arm joint :use for ±90˚ rotation (Horizontal beam and gripper attacher) | TowerPro MG995 plastic Gear servo motor ±180˚ | ±180˚ approximation, 85 mm, 50-62.5 RPM, with self-aligned pillow rotational bearing shaft. | Low load, easy and precise control |
|  | Gripper Driver | a HerkuleX Robot Servo | 5mV ,a torque of 0.12 Nm. | Low load, easy and precise control |

**Table 1 Actuators information**

# 6 Assembly Sequence

## 6.1 Assembly of gripper

Step1: Two spur gear linkages are at first joined with the base by inserting 12mm connecting rod, by clearance fit.

Step2: Two linkages are joined with the base and by inserting 12mm connecting rod, also by clearance fit.

Step3: Two grip fingers are joined with the linkages and gearlinkages by inserting four12mm connecting rod, each by clearance fit.

Step4: gripper pads are joined with fingers by using nut and bolts

Step5: The actuator is joined at the base top with screws  to move the driving gearlinkage.

## 6.2 Assembly of Leadscrew Actuator:

Step 1: Attach two support shafts to the base frame using hex nuts.

Step 2: Install bearings into the housing frame or base frame.

Step 3: Secure the motor to the top of the base frame using screws and nuts.

Step 4: Join the lead screw conversion nut seat with the lead screw shaft.

Step 5: Attach the joined shaft and bearing to one side of the frame. On the opposite side, connect the motor shaft using a coupling shaft and the leadscrew conversion nut seat.

## 6.3 Final Assembly:

Step 1: Connect the gripper assembly to the frame by attaching it to a horizontal frame.

Step 2: On one side of the horizontal frame, connect it to the arm joint, and on the other side, attach it to the leadscrew actuator.

# 7 Assembly

Assembly: After integrating all the mechanisms and placing all the constraints, the complete assembly is shown below, along with an exploded picture of its requirements.

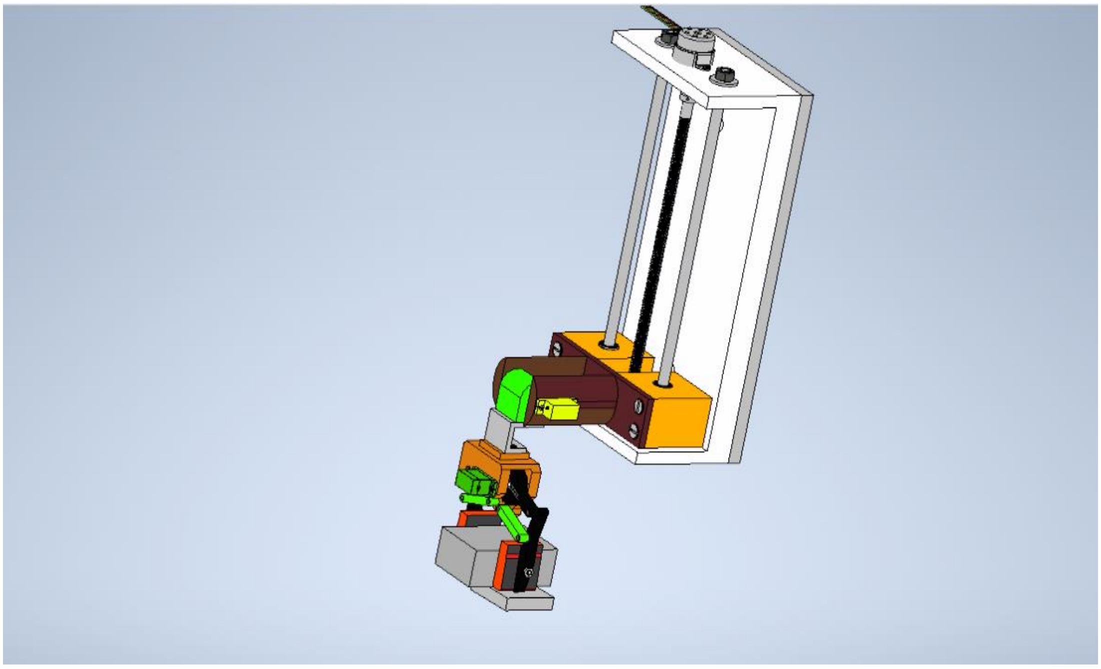


**Figure 13 Final Assembly picking position**

initial position: a tool or gripper mechanism that pick a block from the conver

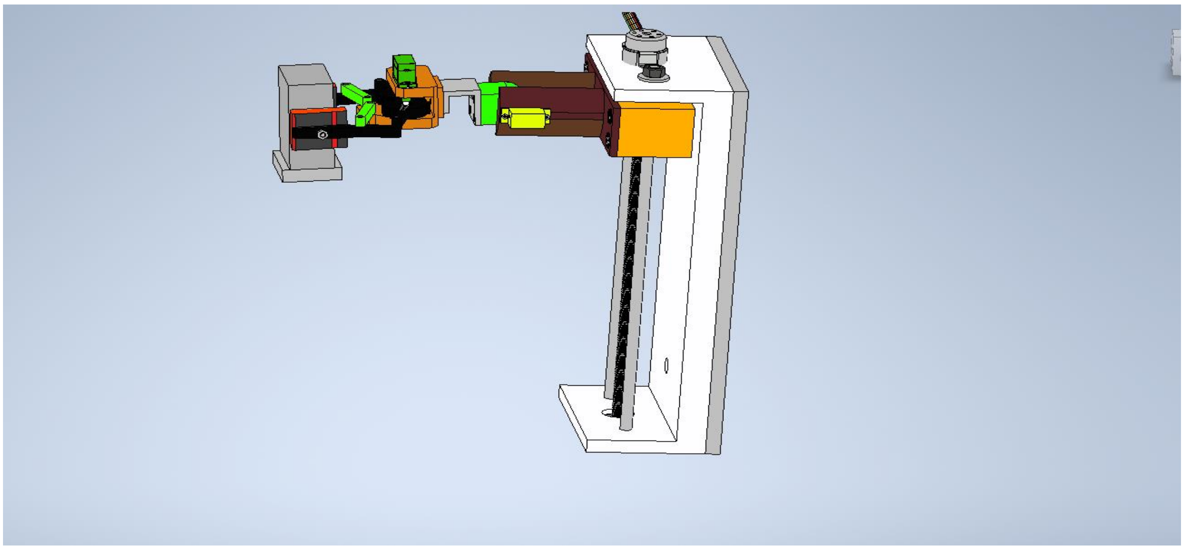


**Figure 14 Final Assembly placing position**

Final position:a tool or gripper mechanism place a block at required final position

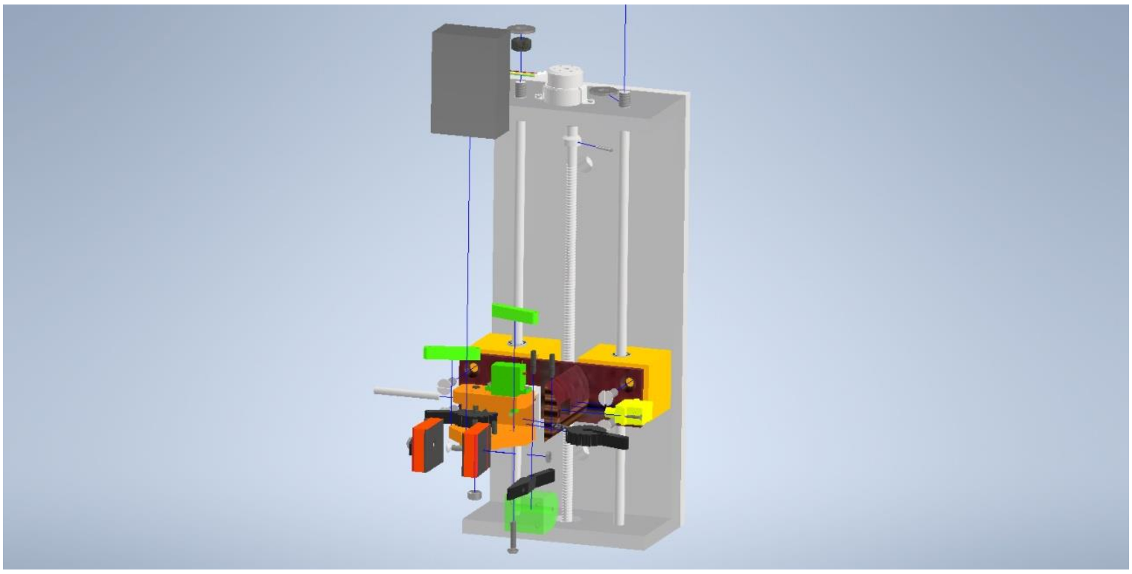


**Figure 15 Exploded view**

# 8 Mathematical Calculations

First, let's calculate the gripping force required to securely hold the 350-gram block. This force is determined by the weight of the block and the coefficient of friction between the gripper and the block's surface. Assuming a coefficient of friction (μ) of 0.6, which is a common value for metal-to-metal contact:

## 8.1 Gripping Force Calculation:

Gripping Force (Fgrip) = Weight of the Block × Acceleration due to Gravity × Coefficient of Friction Fgrip = 350 grams × 9.8 m/s$^2$ × 0.6 = 2058.6 mN (millinewtons)

### 8.1.1 Work Done in Gripping:

Work = Force × Distance Work = 2058.6 mN × 0.01 m = 20.586 mJ (millijoules)

### 8.1.2 Releasing Force Calculation:

Releasing Force (Frelease) = Gripping Force = 2058.6 mN

### 8.1.3 Work Done in Releasing:

Work = Force × Distance Work = 2058.6 mN × 0.01 m = 20.586 mJ (millijoules)

### 8.1.4 Total Work Done:

Total Work = Work in Gripping + Work in Releasing Total Work = 20.586 mJ + 20.586 mJ = 41.172 mJ (millijoules)

### 8.1.5 Power Calculation:

Power (P) = Total Work / Time Power = 41.172 mJ / 9 seconds = 4.575 mW (milliwatts)

### 8.1.6 Motor Selection - Torque Calculation:

Torque (τ) = Force × Distance Torque = 2058.6 mN × 0.072 m = 148.0992 mN·m (millinewton-meters)

## 8.2 Calculations Related to Lead Screw:

### 8.2.1 Calculate the lead screw efficiency:

Lead screw efficiency = (π * cos (pitch angle)) / (2 * tan (pitch angle))
Pitch angle (θ) = 15 degrees
Lead screw efficiency = (π * cos(θ)) / (2 * tan(θ))
Lead screw efficiency = (π * cos (15°)) / (2 * tan (15°))
Lead screw efficiency ≈ 0.866

**"I am assuming that the maximum total weight carried by the lead screw is approximately 4 kilograms, taking into account various components such as a 350-gram block, horizontal frame, lead nut block, and gripper."**

### 8.2.2 Calculate the axial force due to the weight to be lifted:

Axial force = Weight (4 kg) * gravitational acceleration
Weight = 4 kg
Gravitational acceleration (g) = 9.81 $m/s^2$
Axial force = Weight * g
Axial force = 4 kg * 9.81 $m/s^2$
Axial force ≈ 39.24 N

### 8.2.3 Calculate the effective axial force accounting for friction:

Pitch radius = Pitch diameter / 2
Pitch diameter = 7.25 mm
Pitch radius = 7.25 mm / 2
Pitch radius ≈ 3.625 mm = 0.003625 m

### 8.2.4 Let's assume a coefficient of friction (μ) of 0.2 for stainless steel surfaces.

Axial force due to weight = 39.24 N
Coefficient of friction (μ) = 0.2
Effective axial force = Axial force due to weight / (1 + μ)
Effective axial force = 39.24 N / (1 + 0.2)
Effective axial force ≈ 32.70 N

### 8.2.5 Calculate the linear speed of the lead screw:

Linear speed = Stroke / Time taken (9 seconds)
Stroke = 230 mm = 0.23 m

Time taken = 9 seconds
Linear speed = Stroke / Time taken
Linear speed = 0.23 m / 9 s
Linear speed ≈ 0.0256 m/s

### 8.2.6 Calculate the rotational speed of the lead screw:

Rotational speed = Linear speed / Lead screw pitch
Pitch = 1.5 mm = 0.0015 m
Rotational speed = 0.0256 m/s / 0.0015 m
Rotational speed ≈ 17.07 rev/s

### 8.2.7 Calculate the motor torque required (including efficiency losses):

Torque = Effective axial force * Pitch radius
Torque = 32.70 N * 0.003625 m
Torque ≈ 0.1184 Nm

### 8.2.8 Calculate the motor torque required (including efficiency and friction losses):

Motor torque = Torque / Lead screw efficiency
Motor torque = Torque / Lead screw efficiency
Motor torque = 0.1184 Nm / 0.866
Motor torque ≈ 0.1367 Nm

### 8.2.9 Calculate the required motor speed (RPM):

Rotational speed = 17.07 rev/s
Motor speed (RPM) = Rotational speed * 60
Motor speed (RPM) = 17.07 rev/s * 60
Motor speed (RPM) ≈ 1024.2 RPM
So, I need to select a motor that can provide at least 0.1367 Nm of torque at around 1024.2 RPM to achieve the desired sliding motion of the lead screw.

## 8.3 Movement in arm :

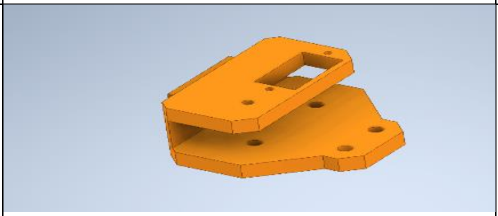
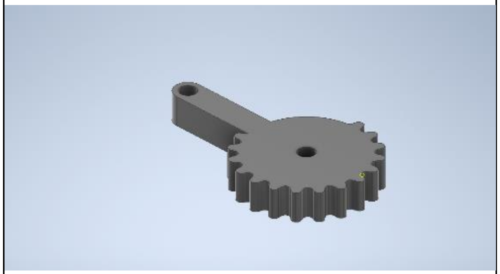
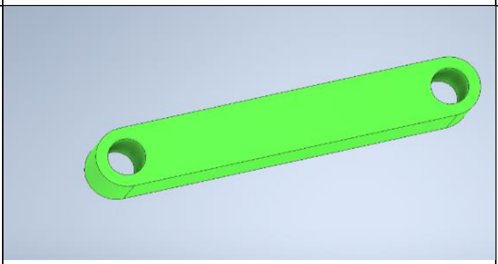
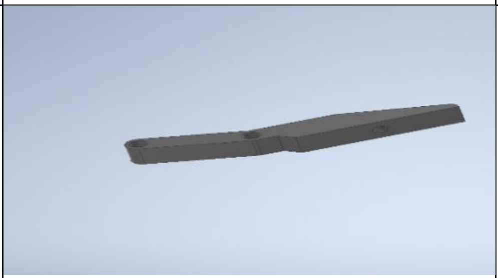
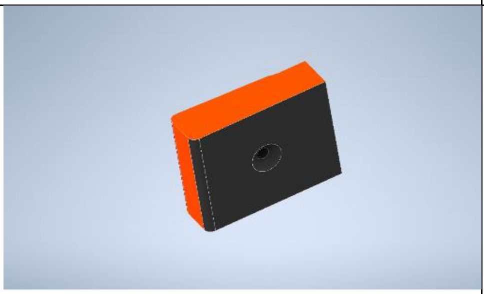
The rotational constrain for the arm motor is ±90˚.
90˚ rotation in one direction makes the arm vertical move and 90˚ rotation in another direction make arm horizontal.
A 30 RPM motor is used in case of Arm Rotation.
**Total angle covered:**
180 degrees (90 degrees for the initial rotation + 90 degrees for the return).

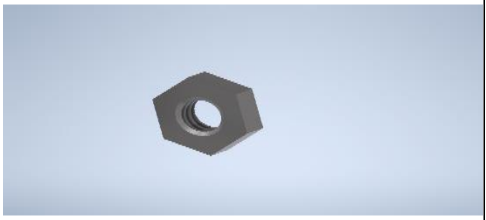
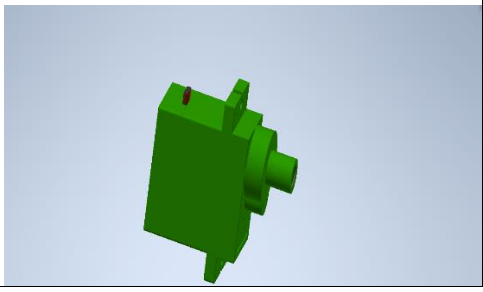
**Time taken:**
9 seconds for the initial rotation + 9 seconds for the return (total 18 seconds).

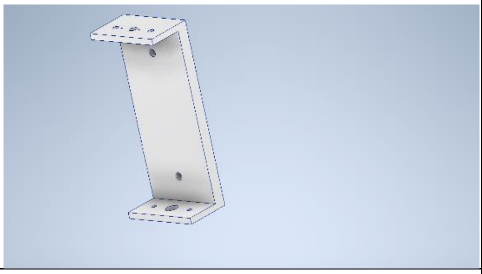
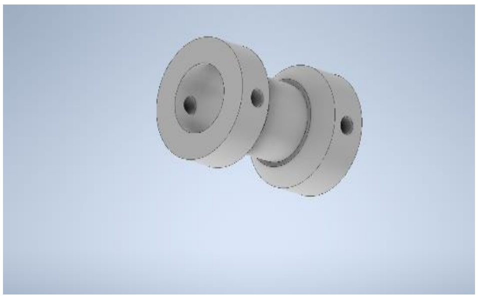
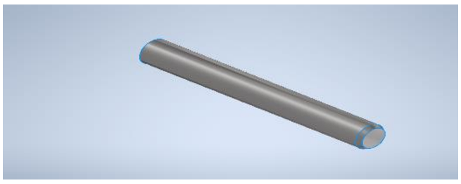
**Now, let's calculate the angular speed of the motor:**
Angular Speed (ω) = θ / t = 180 degrees / 18 seconds = 10 degrees/second.
**the linear speed at the end of the arm:**
Linear Speed (v) = ω × r = 10 degrees/second × (80 mm / 1000) = 0.8 mm/second.

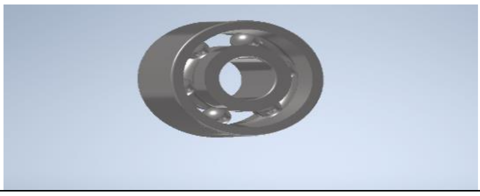
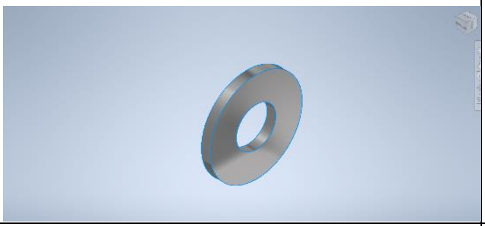
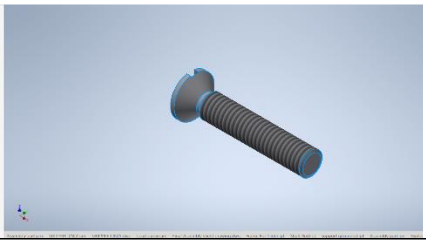
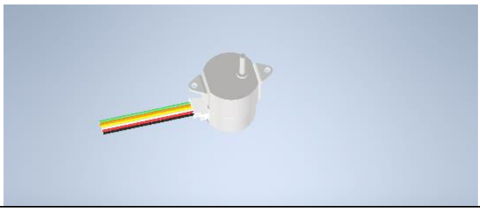
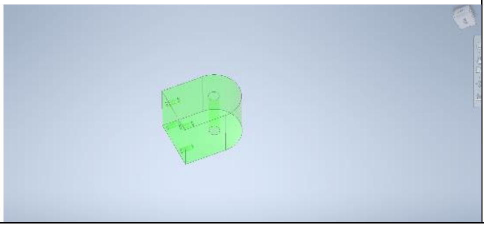
So, I used a 30 RPM motor, it will take 9 seconds to rotate the arm 90 degrees and then another 9 seconds to return to its original position, resulting in a total time of 18 seconds for a full 180-degree rotation. The linear speed at the end of the arm will be 0.8 mm/second.

# 9 BOM of Automated Handling and Manipulation Tool

| S.NO. | Part Name | Image | BOM structure | Quantity | Description |
|---|---|---|---|---|---|
| 1 | Base |  | Normal | 1 | which joins the gripper fingers with the mechanical gears and also provides support to hold the actuator. |
| 2 | Gear linkage |  | Normal | 2 | There are 15 gear teeth mating mechanically with similar gear at 1:1 gear ratio. |
| 3 | Linkage |  | Normal | 2 | Linkage between base and finger |
| 4 | Finger |  | Normal | 2 | Grasping and Holding |
| 5 | Gripper pads |  | Normal | 2 | protects object surfaces, prevents slippage |

| | | | | | |
|---|---|---|---|---|---|
| 6 | ISO 8734 - 4 x 16 - B3 |  | Purchased | 6 | Cylindrical pin |
| 8 | AS B194 - No. 2 x 3_8-CR1 B |  | Purchased | 2 | Counter sunk |
| 9 | AS 1474 - M2(1) |  | Purchased | 2 | Hex-Nuts |
| 10 | AS 1427 - M2 x 4(1) |  | Purchased | 2 | Counter sunk |
| 11 | ISO 2341 - B - 4 x 30DIN EN |  | Purchased | 1 | Clevis pins |
| 12 | Motor Gripper drive |  | Normal | 1 | To drive gripper |

| | | | | | |
|---|---|---|---|---|---|
| 13 | Frame |  | Normal | 1 | housing that supports and encloses the lead screw mechanism along with its associated components. |
| 14 | Shaft Drive |  | Normal | 1 | shaft drive is a mechanical power transmission system |
| 14 | Lead Screw Conversi on Nut Seat |  | Normal | 1 | systems used for linear motion and power transmission |
| 15 | Shaft Rod |  | Normal | 2 | Support for Lead Screw ConversionNut Seat |
| 16 | Linear Bearings |  | Purchased | 4 | provide smooth and controlled linear motion |
| 17 | Coupler shaft |  | Normal | 1 | Couple the drive shaft and motor shaft |
| 18 | BS 1804-2 - 2 x 16 |  | Purchased | 2 | pins |

| | | | | | |
|---|---|---|---|---|---|
| 19 | Rolling bearing B705 C GB_T 292-2007 |  | purchase | 2 | facilitate smooth and efficient rotation and movement |
| 20 | AS 1237 - 8 mm(3) |  | Purchased | 2 | Washers |
| 21 | ISO 8674 - M8 x 1DIN EN |  | Purchased | 2 | Nuts |
| 22 | AS 1427 - M3 x 16(1) |  | Purchased | 2 | ISO metric machine screws |
| 23 | Motor 2 |  | Normal | 1 | The motor provides the rotary motion necessary to drive the lead screw |
| 24 | Horizontal frame |  | Normal | 1 | To joint the leadscrew conversion nut seat one end and gripper at other end with motor it helps to rotate 90 ˚ |
| 25 | Gripper frame and horizontal frame attacher |  | Normal | 1 | To joint gripper frame and above horitontal frame |

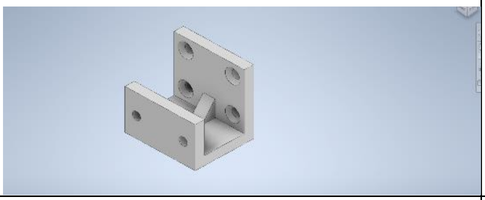
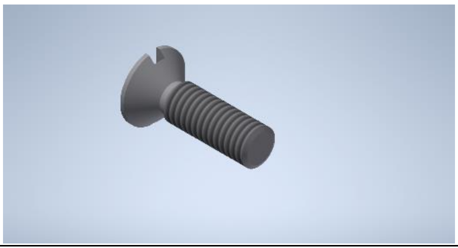
| | | | | | |
|---|---|---|---|---|---|
| 26 | Gripper and frame attacher |  | Normal | 1 | To join the gripper and above frame |
| 27 | ISO 2009 - M6 x 16 - 10.7 - ISO |  | Purchased | 4 | Pan head with type H or type Z cross recess. Product grade A |
| 28 | ISO 7046-2 H - M3x8 - 8.8 - H1 |  | Purchased | 6 | Pan head with type H or type Z cross recess. Product grade A |

Table (2): Bill of materials in assembly

# 10 Selection of Material

## 10.1 Carbon Fiber Reinforced polymer (CFRP):

Using Materials like Aluminium and steel are cheaper initially, they require more manpower due to the weight, so it is recommend to use CFRP material . In the design of the gripper,the major perference is lightness of the gripper,because this gripper is designed for 350 mm block lifting ,not for heavy load .for lightness beat choice is CFRP for construction. Carbon Fiber Reinforced Polymer (CFRP) was chosen for its exceptional strength-to-weight ratio, making it an ideal construction material for the gripper elements .

## 10.2 Rubber:

To hold the block, it utilized a rubber part at the gripper end because rubber improves grip, protects object surfaces, prevents slippage, offers flexibility, reduces vibrations and noise, and adds variety.

## 10.3 Stainless steel:

The major material for manufacturing the components in the lead screw actuator design is stainless steel. Stainless steel is useful for mechanical applications due to its strong corrosion resistance and durability. Stainless steel is used for the support shafts, motor coupling, lead screw shaft, and other vital elements. This option ensures lifespan and dependability in a variety of conditions.

Chromium is responsible for stainless steel's unique stainless and corrosion-resistant qualities. The ability of stainless steel to repair itself is unique. The alloying elements used form a thin, transparent coating on the surface. If the surface is scraped or otherwise damaged, this thin layer, which is only a few atoms thick, quickly reconstructs itself with the help of oxygen from the air or water. As a result, stainless steel retains its radiance and beauty even after decades of use without the assistance of a coating or other corrosion-prevention treatment.

Advantages:

Delivering times are short  because stainless steel pieces do not need to be finished.The stainless-steel parts are more corrosive-resistant and long-lasting. Even after years of use, the metal's surface is usually amazing and shiny. Even at high temperatures, stainless steel keeps its strength and shock resistance. Because of its smooth and slightly porous surface, it is hygienic.

I advocate using Carbon Fiber Reinforced Polymer (CFRP) for the horizontal frame and using this material to produce the remaining components aside from the lead screw actuator.

# 11 Manufacturability of the Design

"Manufacturability of the Design: Incorporating DOF and DFA Design for Manufacturability (DFM) and Design for Assembly (DFA) are pivotal strategies aimed at streamlining production processes and optimizing component manufacturing.

DFM concentrates on simplifying the production of individual parts that will eventually form the assembled product. This approach minimizes complexities in manufacturing by adhering to design principles that enhance ease of production. By utilizing DFM, manufacturers can curtail labor, overhead, and material costs. Furthermore, DFM contributes to expedited product development timelines.

DFA, on the other hand, emphasizes the reduction of assembly complexities. This involves creating designs that are inherently straightforward to assemble, thereby accelerating the assembly process and minimizing errors. Similar to DFM, DFA sets standards that aid in the reduction of expenses and the augmentation of overall manufacturing efficiency.

By harmonizing the principles of DFM and DFA, the design achieves optimal manufacturability. This not only mitigates production costs but also promotes efficient utilization of resources throughout the product lifecycle."

# 12 Conclusion

I was able to complete the following deliverables by completing this project: methodical device development; Detailed 3D models were created for all essential components and assemblies. These models were designed with careful consideration of both design for manufacture and design for assembly principles, optimizing production efficiency. Material recommendations for all components; standard-compliant drawings for all components and assemblies; and, finally, material recommendations for each part in the setup for the Automated Handling and Manipulation tool.

# 13 References

*1.*Bhandari, V B (2007), Design of Machine Elements, Tata McGraw-Hill, ISBN 978-0-07-061141-2.

2. ASM Material Data Sheet." ASM Material Data Sheet. ASM Aerospace Specification

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3. Smith, J. A., & Johnson, R. B. (2022). "Innovations in Gripper Design for Robotic Applications.