

FESTO Collaborative Robot Gripper Design Development

ACMA5002

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1.0. Introduction

1.1. Assignment Overview

This project involves the design and implementation of an end-effector gripper for a UR3 collaborative robotic arm, specifically tailored for automated mobile phone handling. The goal is to develop a lightweight, precise, and reliable gripper capable of safely picking, moving, and placing mobile phones in an industrial or laboratory setting.



Figure 1: UR3 set up alongside output station

1.2. Application Background

Robotic automation has become essential in industries requiring high-speed, precise handling of delicate objects, such as consumer electronics manufacturing, logistics, and laboratory automation. Mobile phones, with their sensitive screens, variable sizes, and lightweight construction, present a unique challenge for robotic systems.

Traditional grippers used in heavy industrial settings often lack the dexterity, force sensitivity, and adaptability needed to manipulate these fragile items without damage.

The UR3 collaborative robot (cobot), with its compact size, 6-axis flexibility, and force-limited safety features, is an ideal platform for this task. However, its standard end-effectors are not optimized for delicate operations, necessitating a custom gripper design that meets the critical requirements needed such as gentle grasping to avoid damaging the product and high speed precision for efficient automation.

By developing a UR3-compatible gripper tailored to these needs, this project addresses a growing demand for small-part automation in electronics manufacturing, while demonstrating the versatility of collaborative robots in delicate tasks.

1.3. Key Design Objectives

The following are the key design objectives for the UR3 robotic gripper, derived from the assignment brief:

- Safe and damage free grasping – apply a controlled force to screen/casing and use soft contact materials to avoid damage on the mobile phone.
- Lightweight and payload compliant – keep the total mass of the gripper under 0.5kg to preserve the UR3's max payload.
- Precision and repeatability – aim to achieve a $\pm 0.5\text{mm}$ positioning accuracy for consistent gripper alignment.
- Power and control integration – operate within UR3's 24V 2A tool I/O limit or account for an external power supply.
- Durability and maintenance – design for approximately 10000+ cycles with minimal wear and have components be easily replaced if needed.
- Design for manufacturing – design for high volume, cheap manufacturing that is easy to assemble.

2.0. Design Requirements and Specifications

2.1. Functional Requirements

2.1.1. Grasping Performance

- Must securely grip mobile phones weighing 50-300g without any slipping.
- Apply adjustable grip force of 5-10N to prevent damage to the screen or casing.

2.1.2. Motion and Control

- Open/close time of 1 second or lower.
- Compatible with UR3's Tool I/O (24V, 2A maximum) or external power with UR3 control signals.
- Support real-time force feedback to control to minimize deviation in grip force.

2.2. Manufacturing Requirements

2.2.1. Materials

- Gripper contact points should ideally be made of silicone or rubber coated aluminium for soft contact.
- The gripper frame should be made from a strong lightweight inexpensive material such as aluminium.
- The manufacturing methods needed to create the parts should not be complicated or expensive or require overly expensive equipment and machinery.
- The parts should be able to be produced quickly.

2.2.2. Tolerances

- $\pm 0.04 - 0.16\text{mm}$ for critical alignment features.
- For other assembly components, follow ISO tolerances.

2.2.3. Cost

- Excluding UR3, the gripper mass produced total cost should be £150 or lower ideally.

2.3. Assembly Requirements

2.3.1 Modularity

- Assembly time should be below 30 minutes with standard tools.
- Should be fewer than 10 discrete components for ease of maintenance and assembly.

2.3.2. Safety and Compliance

Must comply with ISO/TS 15066, collaborative robot safety standards.

No exposed sharp edges or pinch points.

3.0. Design Methodology

3.1. Design for Manufacture

Design for Manufacture (DFM) is a set of guidelines aimed at optimizing product design to make manufacturing easier, faster, and more cost-effective while maintaining quality. Below are key DFM principles:

Simplify the Design

- Reduce part count by combining features where possible.
- Eliminate unnecessary complexity (e.g., avoid over-tolerancing).
- Use standard components to minimize custom parts.

Choose the Right Manufacturing Process

- Select the most efficient process (e.g., injection moulding, CNC machining, sheet metal fabrication, 3D printing).
- Design parts to suit the chosen process (e.g., draft angles for moulding, uniform wall thickness).

Standardize Components & Materials

- Use common materials to reduce costs and lead times.
- Avoid exotic materials unless absolutely necessary.
- Standardize fasteners, threads, and hardware.

Minimize Machining & Finishing Operations

- Reduce secondary operations (e.g., drilling, tapping, polishing).
- Design features that can be produced in a single setup.
- Avoid tight tolerances unless critical.

Design for Tolerance & Fit

- Apply tolerances only where necessary to avoid costly precision machining.
- Use loose fits where possible to ease assembly.

Consider Material Waste & Yield

- Optimize nesting for sheet metal or CNC cutting.
- Minimize scrap in moulding or casting processes.

Test & Validate Early (Prototyping & DFM Analysis)

- Use prototypes to identify manufacturing challenges.
- Conduct DFM reviews with suppliers and engineers.

3.1.1. Benefits of DFM:

Lower production costs – reduced material waste, fewer operations,

Faster time-to-market – fewer redesigns, smoother production,

Higher quality & reliability – fewer assembly errors,

Easier scalability – optimized for high-volume production.

3.2. Design for Assembly

Design for Assembly (DFA) focuses on simplifying product assembly to reduce cost, time, and errors. The goal is to minimize part count, ease handling, and streamline assembly operations. Below are key DFA principles:

Minimize Part Count

- Combine functions (e.g., snap-fits instead of screws).
- Use multi-functional components (e.g., a single moulded part instead of multiple fastened pieces).
- Eliminate unnecessary fasteners (use adhesives, welding, or clips where possible).

Standardize Components

- Use common fasteners (e.g., same screw type throughout).
- Avoid custom parts unless absolutely necessary.
- Prefer modular designs (e.g., interchangeable sub-assemblies)

Design for Easy Handling & Orientation

- Make parts symmetrical (so orientation doesn't matter).
- If asymmetry is needed, add clear alignment features (notches, chamfers, pins).
- Avoid tangled or flexible parts (e.g., springs, wires) unless necessary.

Optimize Fastening Methods

- Snap-fits for plastic parts (no tools needed).
- Press-fits for bearings/shafts (eliminates screws).
- Adhesives for permanent bonds (e.g., thread locker instead of lock washers).

Ensure Access for Assembly Tools

- Leave clearance for screwdrivers, wrenches, or robots.

- Avoid deep recesses where tools can't reach.
- Use self-locating features (e.g., tapered guides).

Mistake-Proofing (Poka-Yoke)

- Unique connectors (so parts can't be plugged in wrong).
- Colour coding for wires or components.
- Asymmetric screw patterns (to prevent incorrect assembly).

Prototyping

- Build physical prototypes to test assembly steps.
- Use DFA software (e.g., Boothroyd-Dewhurst method).
- Consult assembly line workers for feedback.

3.2.1 Benefits of DFA

Lower labour costs – faster assembly,

Fewer defects – mistake proofing,

Reduced part count – cheaper BOM,

Faster production – simpler workflows.

By following these principles for design for manufacture and assembly, engineers and designers can create products that are efficient to manufacture, assemble, and maintain.

4.0. Design Research

4.1. Motor Type Research

When designing a gripper for a UR3 robotic arm, you need a compact, lightweight, and powerful enough motor that can be powered by the UR3's 24V/2A (48W max) Tool I/O. The following are some considerations that would be compact enough to work into a gripper design.

4.1.1. DC Brushed Motors

These low cost motors are simple and effective for moderate force applications. They are ideal for simple gripper designs however most typically need replacing after excessive use due the brushes wearing over time.

Some example motors:

Pololu 37D Metal Gearmotors (6V, 12V and 24V versions) – compact, with encoders for position feedback and an RPM of 50-150.

Faulhaber 2642W Series (24V) – used in medical/robotic grippers, offering very smooth and high precision performance.

4.1.2. Brushless DC (BLDC) Motors

These motors offer high speed performance whilst maintaining efficiency. They also boast a much longer lifespan; however, they require a BLDC driver to operate.

Some example motors:

Maxon EC-I 30 (24V, 50W) – lightweight with a high torque output and allows for encoder options.

T-Motor MN5208 (24V, KV100) – often used in drones and is very compact.

4.1.3. Stepper Motors

Allows for precision positioning control, ideal for automated set ups without the need for an encoder for positioning. However, these motors do vibrate more and are less efficient than DC/BLDC options.

Some example motors:

NEMA 11 or NEMA 14 Stepper (24V, 0.5-1.5A per phase) – compact with high torque control.

4.1.4. Linear Actuators

Uses direct motion to move in a straight line, great for push and pull set ups. Simplifies the design as no other mechanics are needed, however the speed is very limited and has a fixed stroke length.

Some example actuators:

Firgelli L12 (24V, 50-100mm stroke) – has a built in potentiometer for position feedback.

Actuonix PQ12-P (12V, 24V with PWM) – very small, good for lightweight grippers.

4.2. Chosen Motor

Dynamixel XL430-W250



Figure 2: New XL430-W250 (Released in 2018)

4.2.1 Motor Choice Reasoning

When factoring in all other requirements for the motor other than size, the Dynamixel XL430-W250 ended up being the best choice. It alleviates design hassle by having integrated control, not needing to include an external driver in the design. It features position and torque feedback which will prevent excessive force being applied to the mobile phone, preventing them from being crushed. The device is incredibly lightweight, weighing only 57.2g, this should allow for less structural support to house the motor. This motor however does run at 12V, therefore will require a method to reduce the input voltage such as a buck convertor, to reduce the 24V from the arm.

Item	Specifications
MCU	ARM CORTEX-M3 (72 [MHz], 32Bit)
Position Sensor	Contactless absolute encoder (12Bit, 360 [°]) Maker : ams(www.ams.com), Part No : AS5601
Motor	Cored
Baud Rate	9,600 [bps] ~ 4.5 [Mbps]
Control Algorithm	PID control
Resolution	4096 [pulse/rev]
Operating Modes	Velocity Control Mode Position Control Mode (0 ~ 360 [°]) Extended Position Control Mode (Multi-turn) PWM Control Mode (Voltage Control Mode)
Weight	57.2 [g]
Dimensions (W x H x D)	28.5 x 46.5 x 34 [mm]
Gear Ratio	258.5 : 1
Stall Torque	1.0 [N.m] (at 9.0 [V], 1.0 [A]) 1.4 [N.m] (at 11.1 [V], 1.3 [A]) 1.5 [N.m] (at 12.0 [V], 1.4 [A])
No Load Speed	47 [rev/min] (at 9.0 [V]) 57 [rev/min] (at 11.1 [V]) 61 [rev/min] (at 12.0 [V])
Operating Temperature	-5 ~ +72 [°C]
Input Voltage	6.5 ~ 12.0 [V] (Recommended : 11.1 [V]) (lithium-ion battery 3 Cell)
Command Signal	Digital Packet
Physical Connection	TTL Multidrop Bus (5V Logic) TTL Half Duplex Asynchronous Serial Communication (8bit, 1stop, No Parity)
ID	253 ID (0 ~ 252)
Feedback	Position, Velocity, Load, Realtime tick, Trajectory, Temperature, Input Voltage, etc
Case Material	Engineering Plastic
Gear Material	Engineering Plastic
Standby Current	52 [mA]

Figure 3: XL430-W250 Product Specification Sheet

5.0. Design Iterations

5.1. Design Iteration 1

5.1.1. Design Breakdown

Design 1 uses mechanical gearing, powered by the chosen motor to grasp the mobile phone on each of its corners. It features a compact and sleek design that shouldn't require complex manufacturing techniques or machinery which should allow for quick manufacture. It also has a very simple assembly structure, which will also allow for swift assembly.

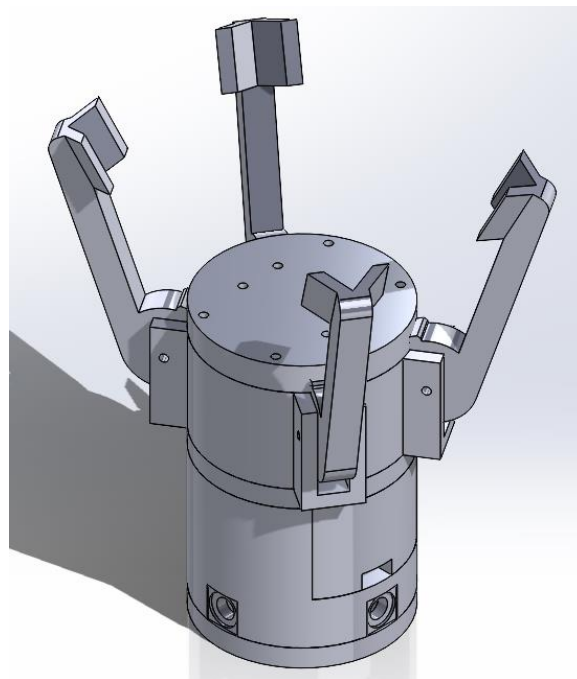


Figure 4: Design 1

The design thought process when designing was initially to create simple shapes and have them work together to form the structure, however as the design progressed to the mechanism, it began difficult to follow. The most notable challenge during this design was forming ideas for the mechanism and making it work within the current limits of the design. Many ideas were quite ambitious but lacked the structure for the design or simply would increase manufacturing costs or not agree with the design brief. Of all the on paper mechanism concepts, the chosen one that would fit and work under the constraints of the design was using worm gears to change the rotational force from horizontal to vertical and at an angle. The mechanism can be seen in the following images.

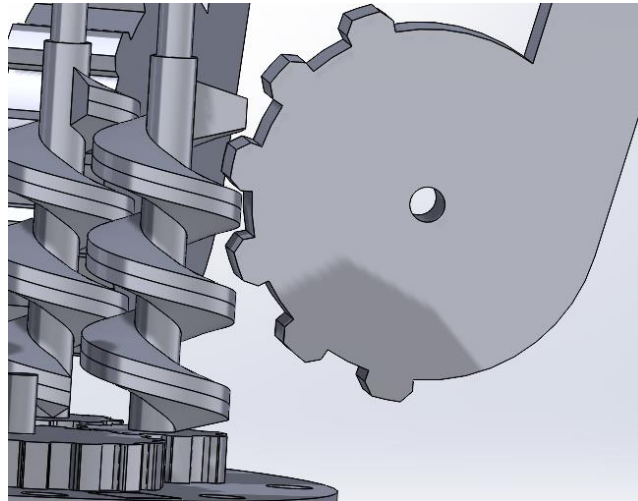


Figure 5: Design 1 Arm Mechanism

The worm gears were the simplest method to transfer the rotational force perpendicularly. However, this did have its challenges of implementing into solid works.

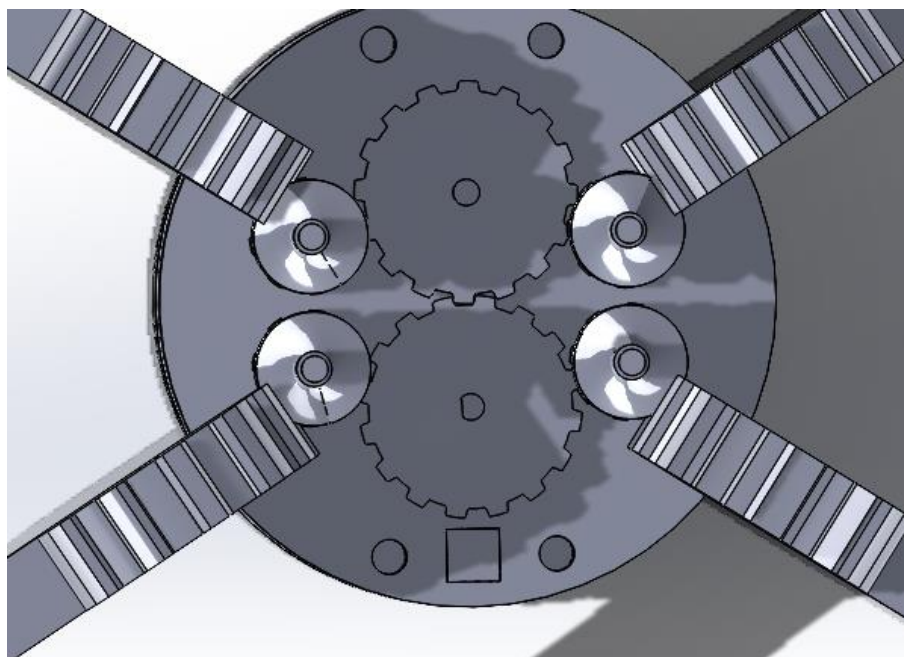


Figure 6: Drive to Worm Gear Mechanism

To connect the worm gears to the motor, 2 gears were needed, one would have been sufficient but based on the size and the positioning of the motor and where it was placed within the design, a second gear was necessary to cover more and reach the other worm gears. However, having a second gear meant needing opposing worm gears, meaning two different worm gears would need manufacturing, which is unfortunate. A second set of worm gears is needed since they aren't directly connected to the main motor gear like the other two, they would spin in the opposite direction, therefore 2 sets of anticlockwise and clockwise worm gears were designed.

The following image shows the components and arrangements below the cover the gears slot in above. On the main casing, there is small notch which allows for quick and easy assembly by having the components slot into or around each other to reduce the likelihood of the device being assembled incorrectly. The side panels also do not require fastening and are held in place by the constraints of the design and by other components being screwed in such as the motor top cover. They also hide access to the small screws that attach the motor. The side panels have so many cut outs to preserve material usage and to still provide structural support.

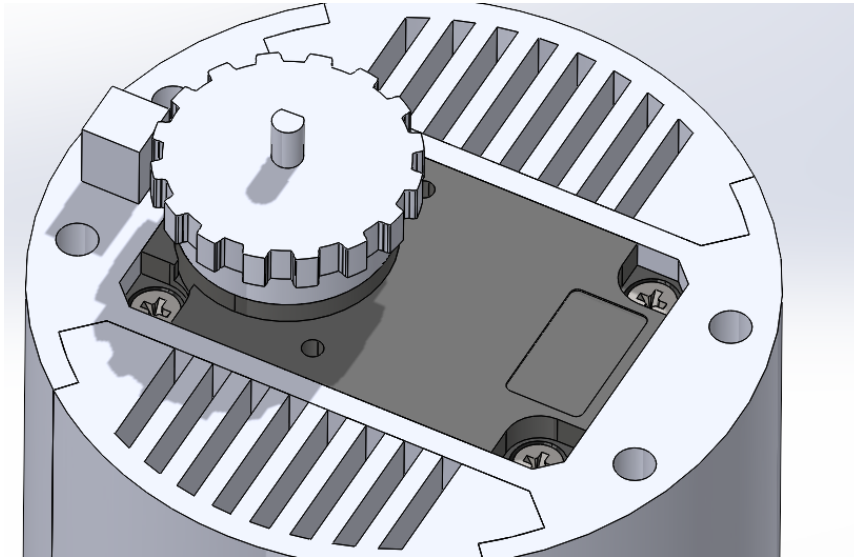


Figure 7: Motor without top cover

This next image shows the design for how the motor to gear adaptor is connected to the motor. The motor output features 4 screw holes which are used to connect it to the gearing mechanism. The adaptor and one of the gears each have a notch that prevent gear slipping.

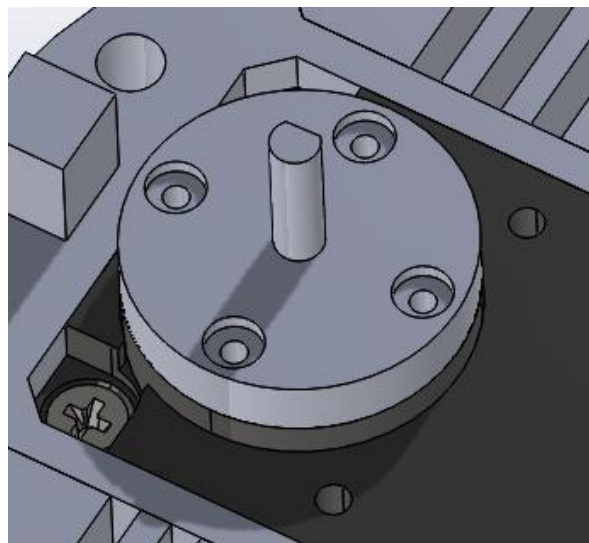


Figure 8: Motor to Motor Gear Attachment

The motor is held in place by the top motor cover and by small screws on the sides of the motor. The main motor mount and the side panels both feature a hole that allows space for a power supply wire to connect to the motor and provide power and with the addition of the removable side panels, it is easy to plug in and then place the side panels back on.

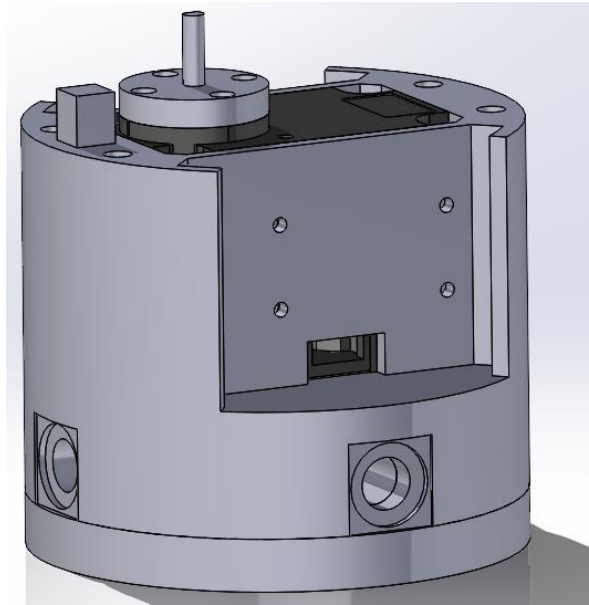


Figure 9: Main Motor Mount Side View

To always make sure the motor is installed in the correct orientation, the motor features an indent on all but one of its 4 corners, using this, the design features protrusions in all but one of the corners of the housing that the motor sits in, making it so the motor can only be installed in one orientation. This is visible in the image below.

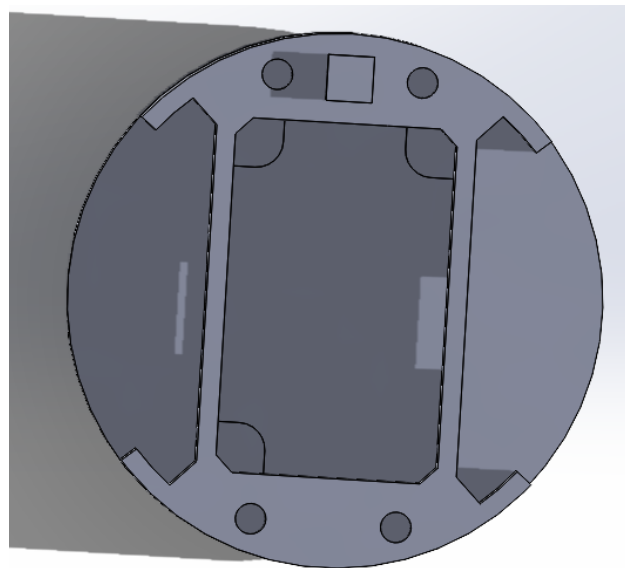


Figure 10: Motor Mount Notch Arrangement

The device connects to the UR3 with the bottom component. It attaches to the UR3 first as an adapter that allows the rest of the device to be screwed into the adapter. The adapter also has a slot in feature to allow for easy orientation for the screw holes.

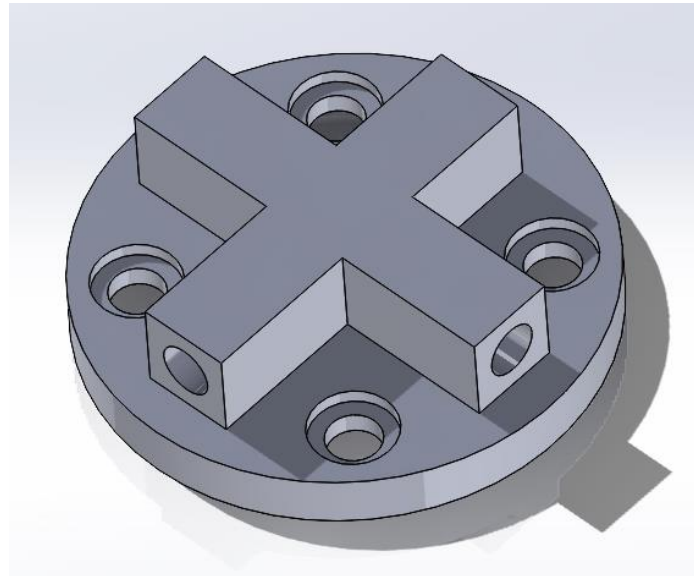


Figure 11: Device Adapter

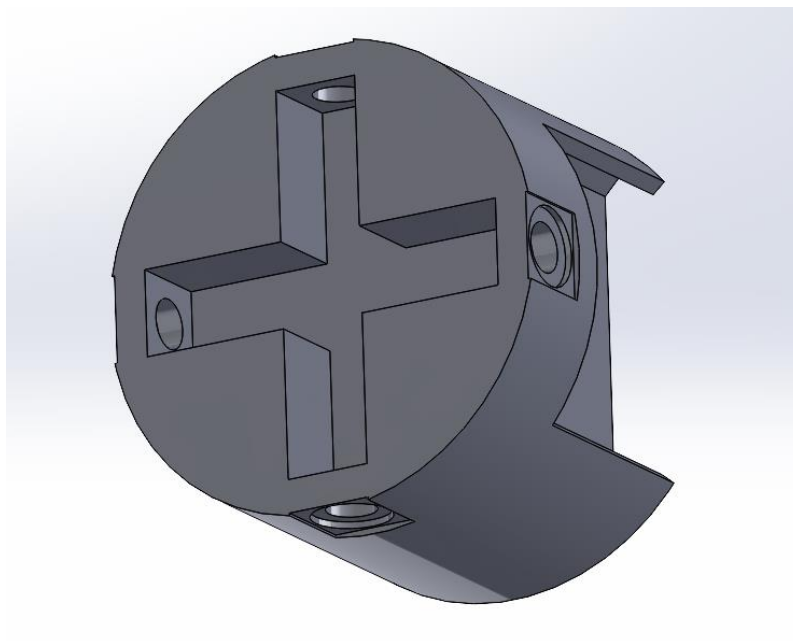


Figure 12: Adapter to Motor Mount Slot In

5.1.2. Design Review

The design functionally appears to work and looks aesthetically pleasing however there are some areas that could use improvement. The mechanism is overly complex, a much more efficient and reliable mechanism could be achieved with few parts. Some gear designs are mathematically incorrect and occasionally causes the gears to mesh

together, in actual application this would cause the arms to work misaligned and fail in its operation, potentially damaging surrounding machinery or products. The design strategy for the arms is also quite poor, having to collect the mobile phone at the corners is good to reduce potential unbalance when transporting but it has the risk of adding additional misalignment issues, especially if an anomaly occurs where the mobile phone is not in an expected position.

Aside from the mechanism, the design has many good features to try and carry over into future designs, such as the design methodology for the assembly and manufacture of the components. The limited use of required fasteners such as how the side panels are incorporated into the design.

5.2. Design Iteration 2

5.2.1. Design Breakdown

Design iteration 2 is ultimately unfinished but it generated ideas for future designs and shows more design progression therefore seemed appropriate to include. It has an identical connection to UR3 as design 1. The main changes compared to design 1 is the mechanism, using a rack and pinion system to convert rotational force from the motor into linear motion to move one arm inward or outward. It would be accompanied by another arm that would be fixed to the structure, needing two moving arms using this type of system seems unnecessary, so to reduce part count, manufacture costs and assembly complexity, it was best to only include one actuated arm. To note two arms were considered, with both being a rack pinion system connected to the same pinion on parallel sides but as previously mentioned was a waste.

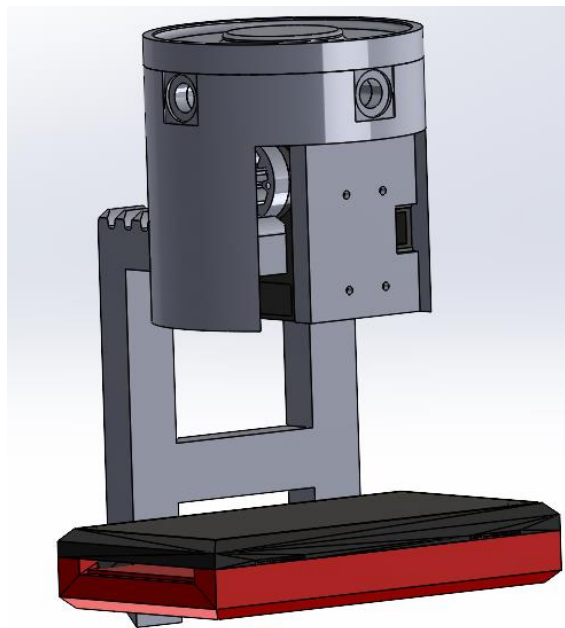


Figure 13: Design Iteration 2

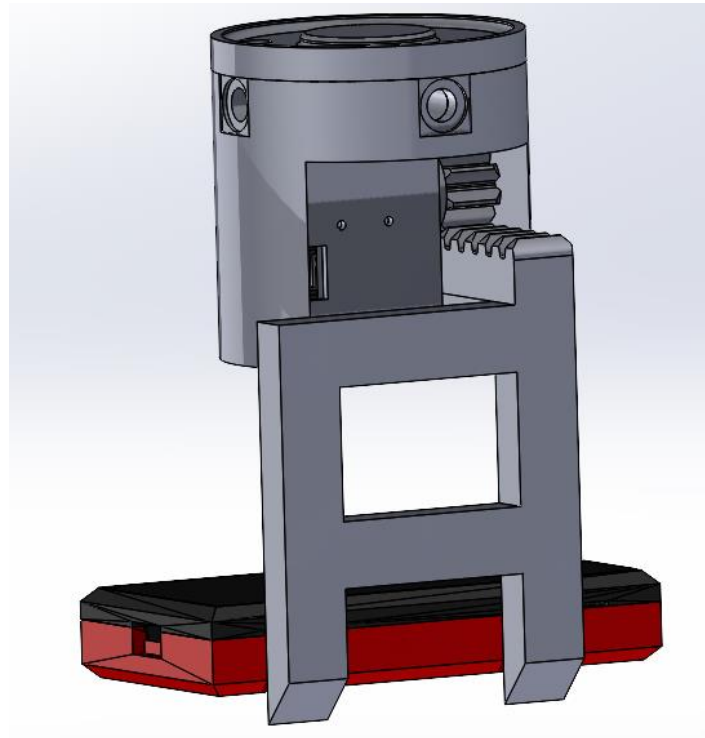


Figure 14: Design Iteration 2, view 2

The method to house the motor is largely the same, with the motor orientation changed to comply with the mechanical system efficiently.

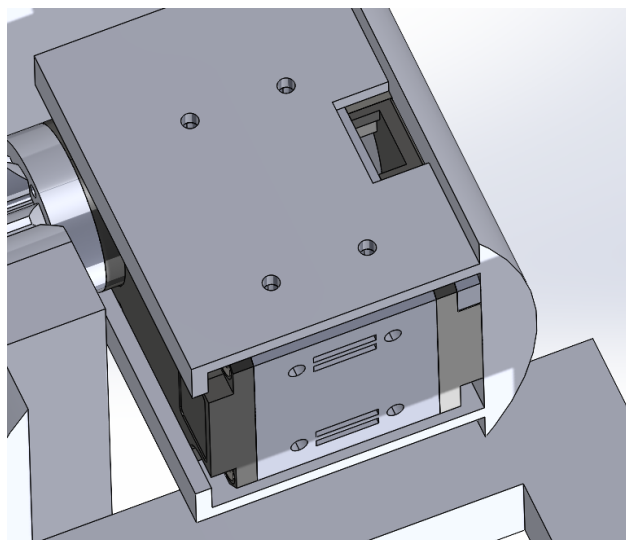


Figure 15: Design Iteration 2 Motor Housing

Actual gear theory was applied when designing this iteration, which provided reliable motion and visual analysis of the design and how it would work in a real setting. Initially gear design theory was difficult to implement well but the use in in design 2 was good practice for future iterations.

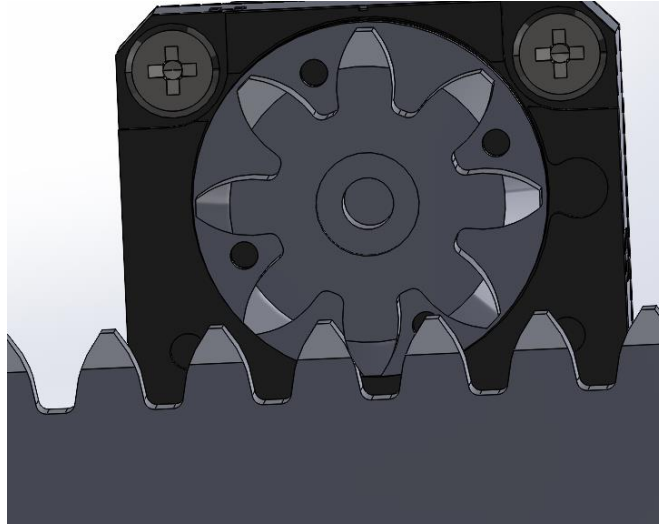


Figure 16: Rack and Pinion Design

5.2.2. Design Review

Ultimately this design has no major flaw and may even be included or referenced for future designs, however the choice to abandon it to move onto design iteration 3 was due to the method for the mechanical system, it began apparent; to reduce workload and design complexity, it would be best to have a more standardised simpler mechanical system for the gripper. The methodology of removing unnecessary actuation is great takeaway from this design which will help comply with the design objectives easier by having less parts and reducing assembly complexity.

5.3. Design Iteration 3

5.3.1. Design Breakdown

Design 3 features a more standardised mechanism for the gripper and unintentionally moves away from the smooth design of the previous designs to accommodate the gearing mechanism. Compared to the previous designs, the full focus when designing was the gripper mechanism and then building around it, which caused some issues which will be highlighted later, however the mechanism is incredibly efficient and works perfectly as intended. So far this iteration has had the most time and effort into it, therefore there is a lot more to critique about the design compared to the previous ones.

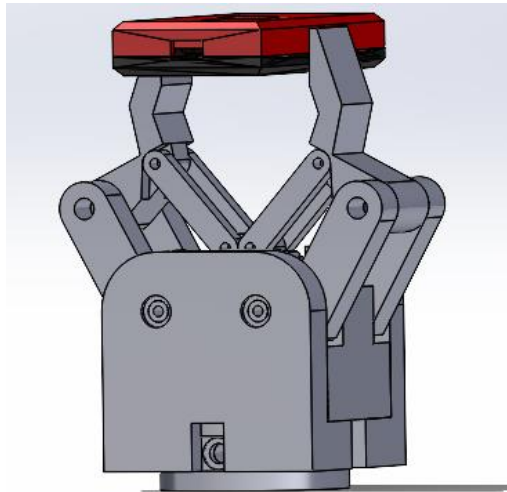


Figure 17: Design Iteration 3 Closed

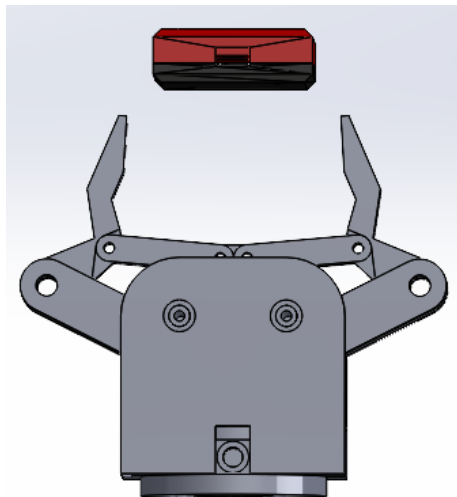


Figure 18: Design Iteration 3 Open

The mechanical system again uses gear design theory to achieve perfectly aligning gears, more refined after the practice in design 2. The drive motor connects to one arm which then connects to another adjacent arm with a gearing offset of half a tooth to account for arm alignment.

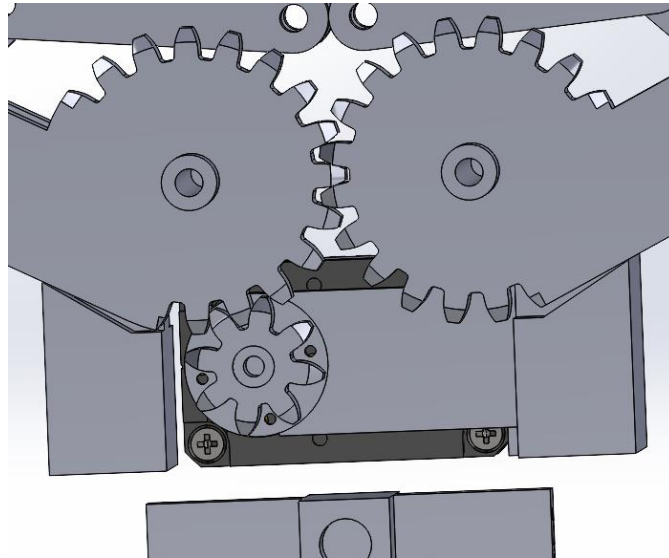


Figure 19: Design 3 Gearing Set Up

The end arms are connected to the main body with two free joints, one connected to the gearing, and one connected to hinges that connect to the main body. This allows for the end of the gripper arm to stay perpendicular to the main body to achieve greater support and to allow variability when anomalies occur to still be able to be pressed into the mobile phone to transport if the phone and gripper are misaligned.

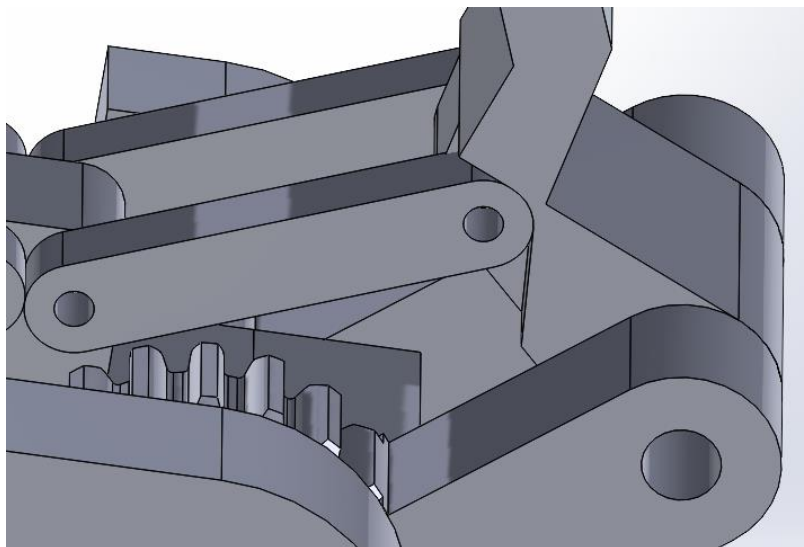


Figure 20: Design 3 Hinges

The gearing and hinged parts in previous designs potentially would not have worked if they required to be fastened, therefore to fix this issue in design 3, a hollow rod like component is inserted in the holes to allow for the moving parts to move around it and then the rod can be fastened in place with a screw into its hollow section, allowing for the gears to freely move whilst maintaining their concentric alignment on the main body.

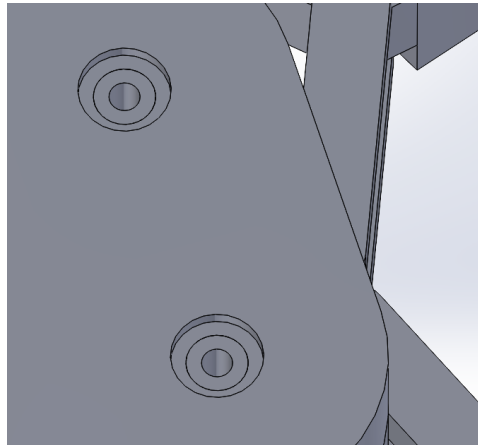


Figure 21: Gearing Rod Placement

Unfortunately, due to the placement of the motor early into the design the power supply slot is quite deep within the model and may be difficult to install the power supply connector to it. This is an unfortunate circumstance of designing around the mechanism, future iterations will have to either fix this issue or find a balance during the design process between the mechanical system and the design goals of the main body.

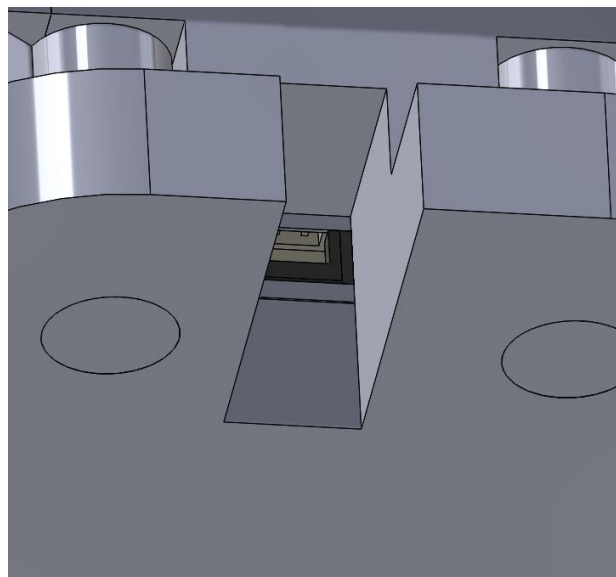


Figure 22: Design 3 Power Supply Placement

Below one of the side covers is the slot where the motor is inserted, kept in place with screws on either side of the motor. On the side where it slots in, there is an additional component that acts a cover for the remaining visible parts of the motor, this is necessary because the motor wouldn't be secure enough with just screws on the one side, so cover adds additional security.

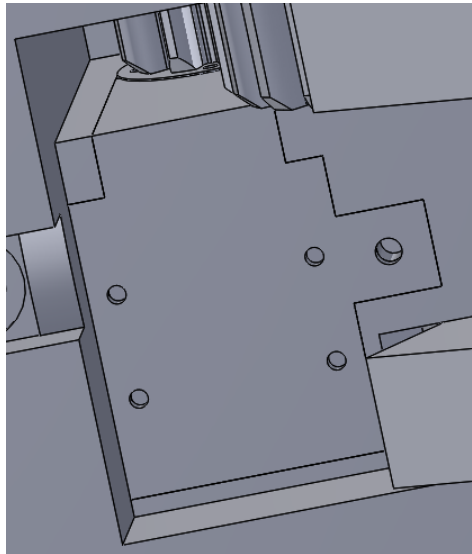


Figure 23: Design 3 Motor Cover

The design stays relatively low on individual parts usage, requiring only 11 unique parts to be manufactured. This was a design goal to keep the part count low to save time and money manufacturing the components, however this has caused a potential issue where the main body is very complex and may cost more money and time manufacturing it as one piece rather than separate pieces. This component would require extensive manufacturing, requiring work to be done on nearly every side of each plane. A good potential reasonable design goal for a future iteration may be to break this component down into two parts for easier manufacture and potentially easier assembly. It is also rather bulky aesthetically, which has no conflicts with the design goals, however reducing material usage should provide a benefit.

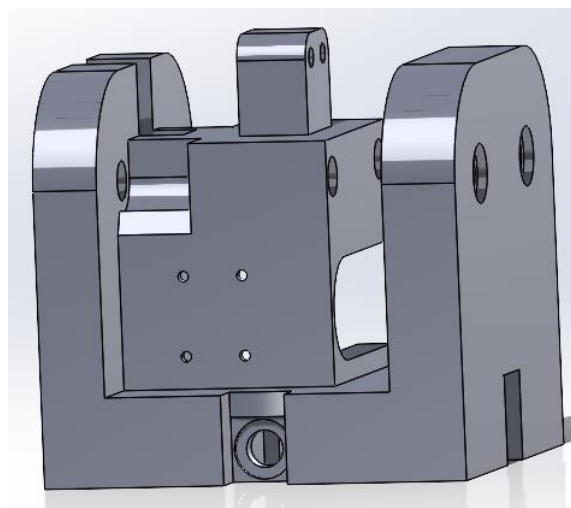


Figure 24: Design 3 Main Body

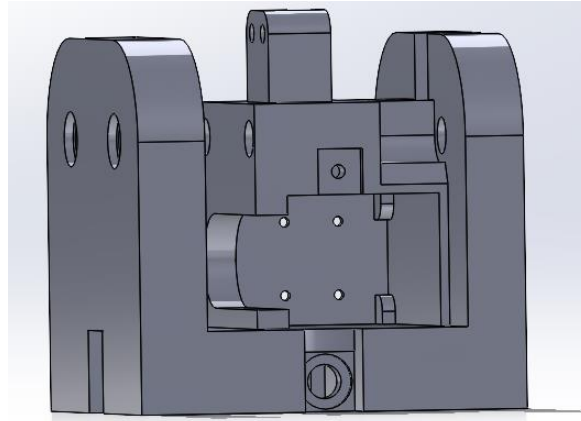


Figure 25: Design 3 Main Body View 2

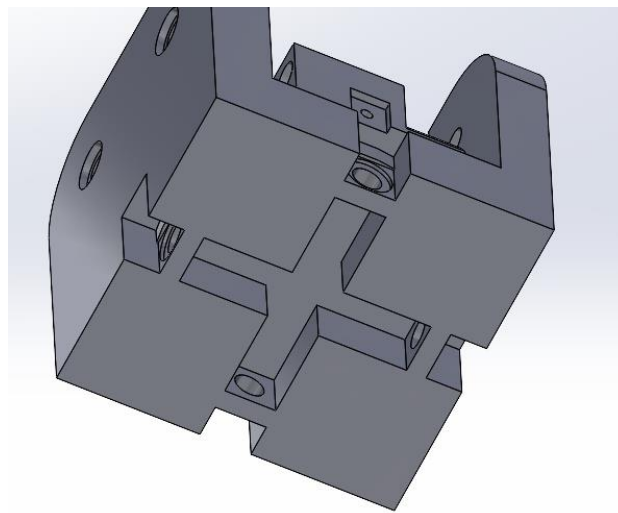


Figure 26: Design 3 Main Body View 3

5.3.2. Design Review

This design offers a lot, however there are glaring issues with the design, especially with the layout and geometry of the main body. Luckily there is no major issues that would require a full redesign, which would likely be the case if there was an issue with the arm mechanism, all current issues should be able to be addressed by simply editing the current geometry and arrangement. Future iterations should aim to address these issues whilst maintaining the gearing mechanism.

5.4. Design Iteration 4

5.4.1. Design Breakdown

The goal of iteration 4 was to fix any major issues highlighted in the previous design and prepare the model for finite element analysis by assigning materials. The main issues the previous design faced was the installation of the power connector into the motor and the complexity manufacturing the main body.

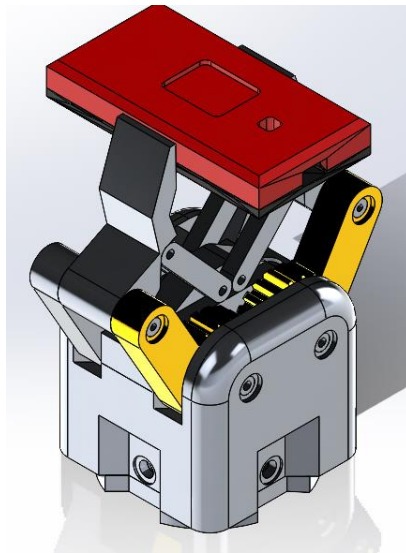


Figure 27: Design Iteration 4

The space made to connect the power connector could prove difficult to actually insert during set up and to save on manufacturing time and complexity, it seemed more reasonable to separate the main body into 2 different components. This is achieved by editing the middle of the body to functionally separate from the outer body. This then required adjusting the middle body that houses the motor to be able to safely hold it and slot in the outer body, this can be seen in the following images.

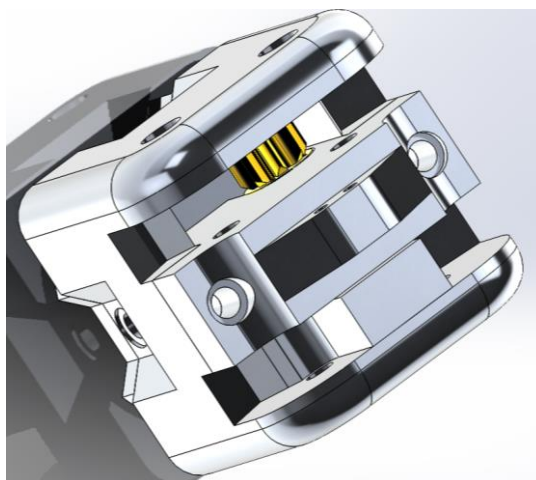


Figure 28: Mid and Outer Body Separation

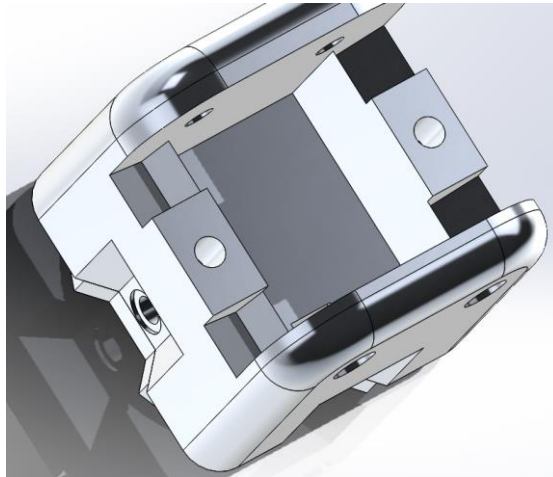


Figure 29: Outer Body with Space for Inner Body

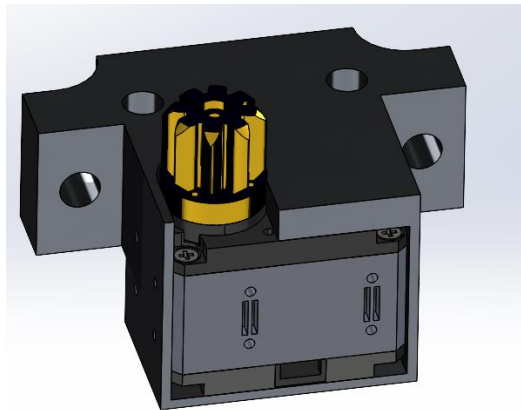


Figure 30: Inner Body Housing Motor

The design strategy for fixing the motor power connector was to use the one on opposite side of the motor and have the wire feed through the back. This was achieved by removing material from the UR3 attachment component and feed out the bottom, which will allow for easy installation before being attached to the UR3 attachment component.

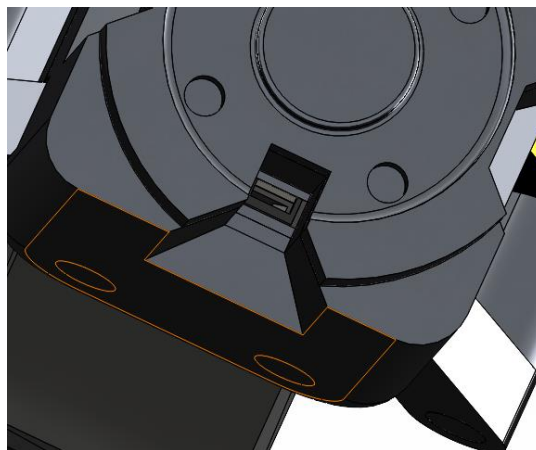


Figure 31: Design 4 Rear View Showcasing Power Supply Slot

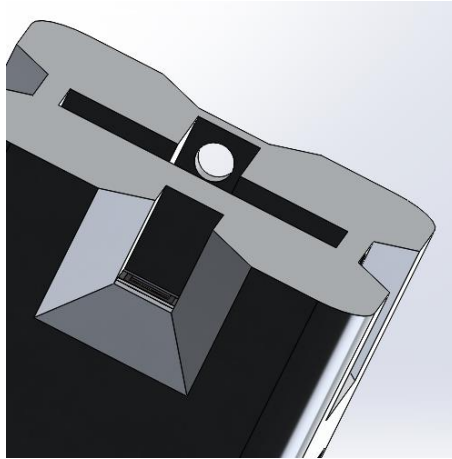


Figure 32: Design 4 Rear View Showcasing Power Supply Slot view 2

5.4.2. Material Choices

The main body and most components will be made from aluminium as offers a lot of benefits to the structure and manufacturability. Due to the size of the gripper, aluminium offers a high strength to weight ratio, maintaining structural integrity with minimal bulking. Aluminium is also relatively soft and easy to machine, allowing for high-precision, intricate designs with tight tolerances and is 100% recyclable without losing quality, making it an eco-friendly option.

However, for the gears, it was an appropriate choice to select brass as the material as it offers many advantages over using aluminium when it comes to gearing. Brass has self-lubricating properties, reducing the wear between meshing gears, ideal for low-load small mechanisms. It also is one of the easiest metals to machine, allowing for tight tolerance and intricate gear tooth profiles and a lot cheaper than steel and bronze for low stress applications, producing smooth finishes without burrs, reducing post processing. Compared to brass, aluminium shares many of the positive material characteristics, however aluminium wears much faster than brass and would require more maintenance, therefore increasing the costs.

5.5. Finite Element Analysis

Finite Element Analysis (FEA) is a powerful computational tool used to simulate and predict how products and structures behave under real-world forces, vibrations, heat, fluid flow, and other physical effects. It was used on the design iteration 4 to identify stress concentrations, weak points and potential failures, this is incredibly beneficial as it somewhat skips the prototyping phase of the design process, offering a much cheaper and faster alternative.

The following images show the results of a static study conducted emulating the gripper carrying the mobile phone from above in a vertical position, this is believed to be the

position with the most stress in the body. The following images are the results, showing the stress, strain and displacement on the structure.

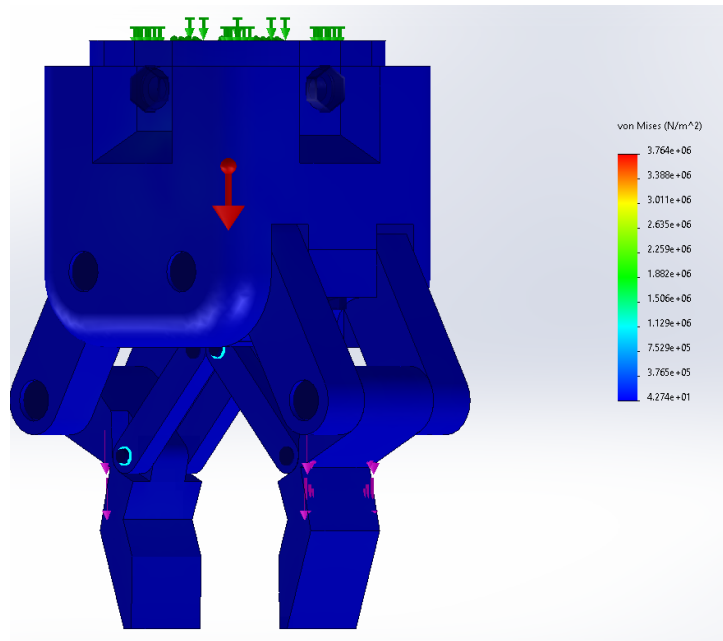


Figure 33: Stress FEA Results

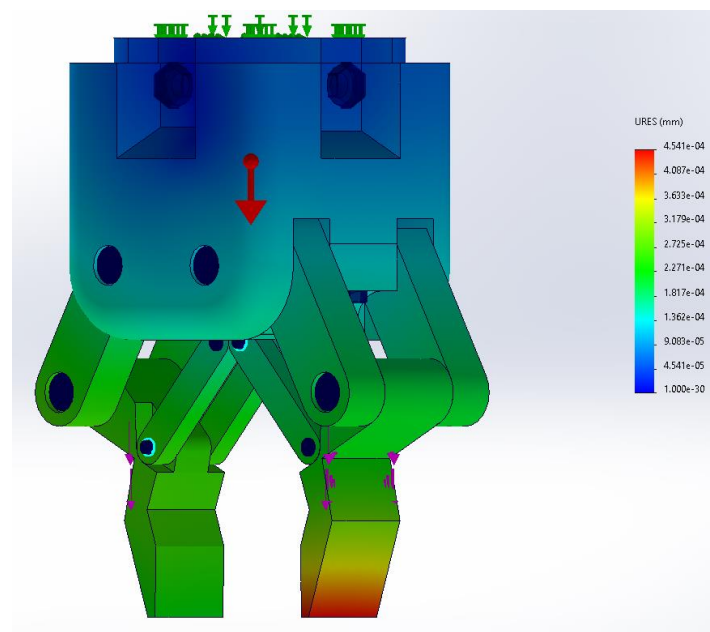


Figure 34: Deformation FEA Results

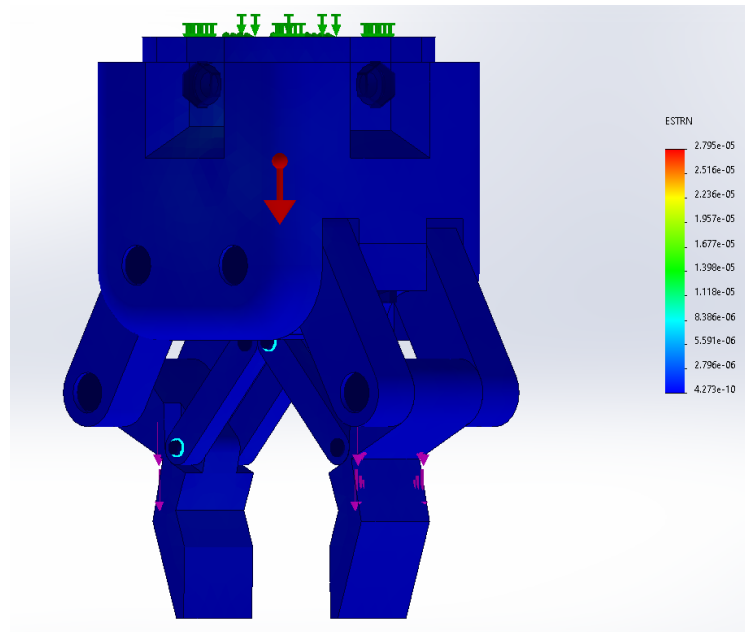


Figure 35: Strain FEA Results

These results don't show any issues with the current design, this means material can be removed from the current design and make it more compact. However, it would be wise to test the current design under exaggerated conditions with the aim to detect areas of potential failure and high stress and reinforce those areas by adjusting the design. The following are the results of the exaggerated tests.

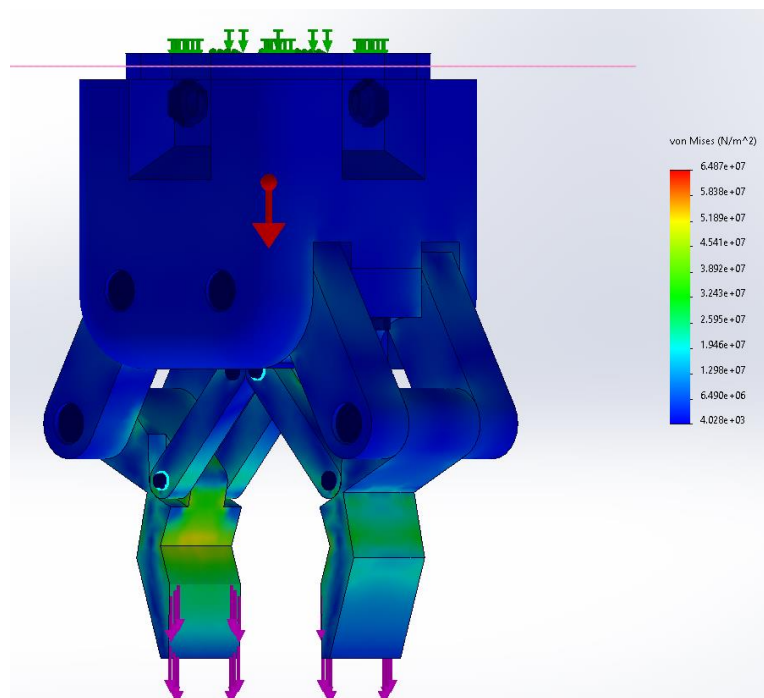


Figure 36: Exaggerated Stress Results

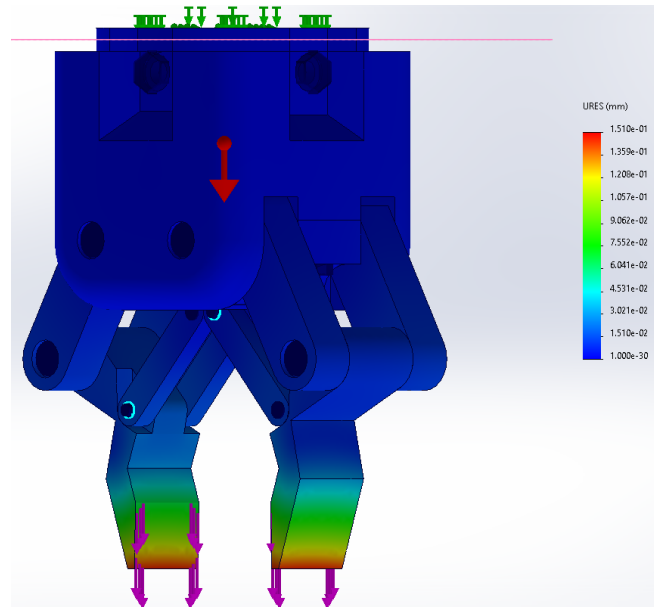


Figure 37: Exaggerated Displacement Results

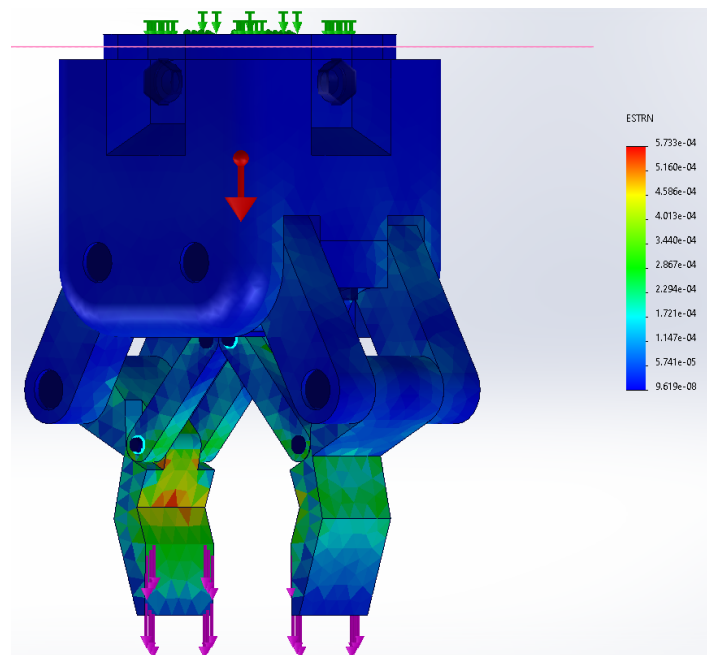


Figure 38: Exaggerated Strain Results

From these results, a key area that that would benefit additional reinforcement is the mid area of the end gripper component, just below where the brackets connect. In future iterations, addressing the areas of potentially problematic stress and strain would benefit the product to reduce potential wear in future.

6.0. Final Design

6.1. Design Breakdown

For the final iteration of the mobile phone gripper, the goal was to reinforce the areas of potentially problematic stress and strain, identified by the previous FEA results.

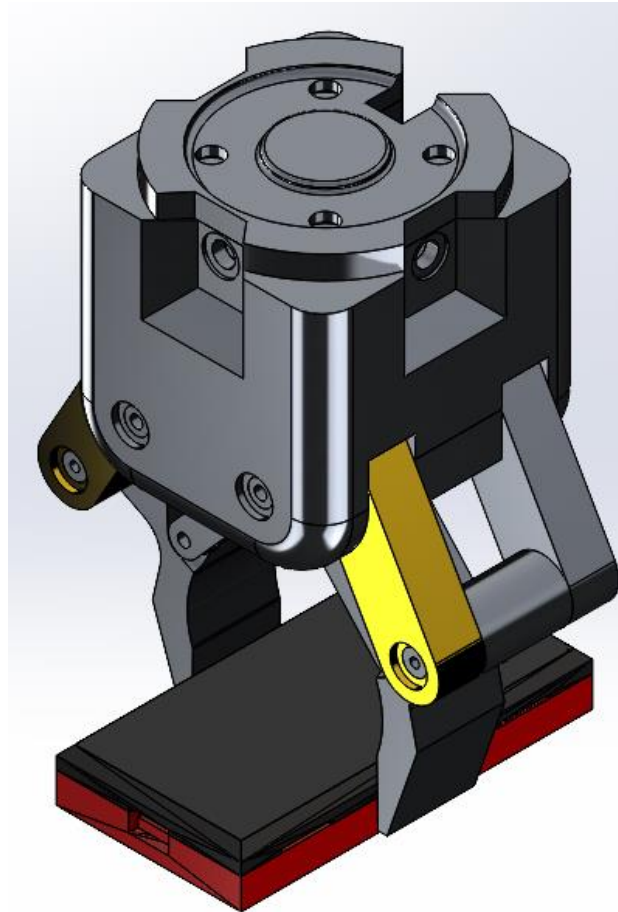


Figure 39: Final Design

The key area that required reinforcement was the end component that interacts with the mobile phone. To add to reinforce this, the only viable solution was to add more material to the area, as other reinforcement options wouldn't be space efficient. Additionally, around where the bracket connects, additional material has been added to avoid tearing that appeared in the FEA report. The changes can be seen in the below image.

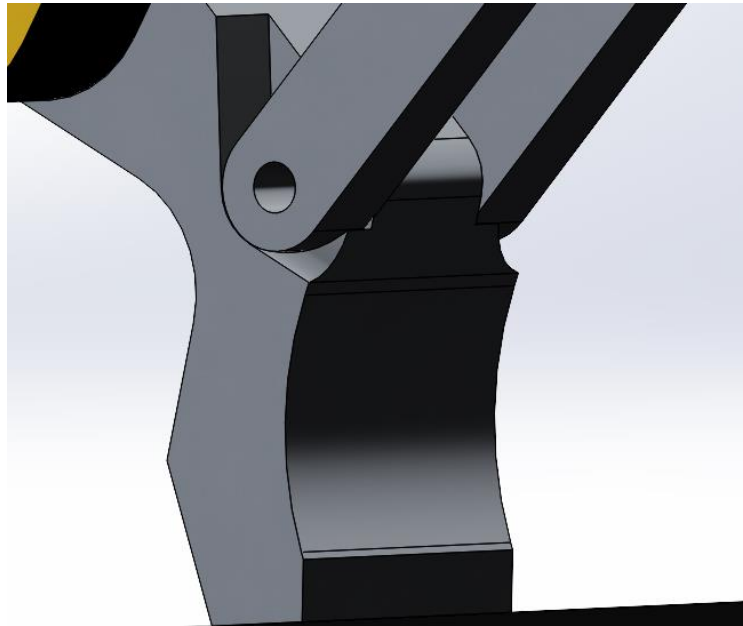


Figure 40: Changes to the Gripper Arms

With these changes another FEA should result in the stress and strains in these areas to be minimal or greatly decreased.

6.2. Finite Element Analysis

To test whether the design changes are successful in combatting the high stress and strain, another FEA will be necessary. The following images are the results of the FEA with the new design changes.

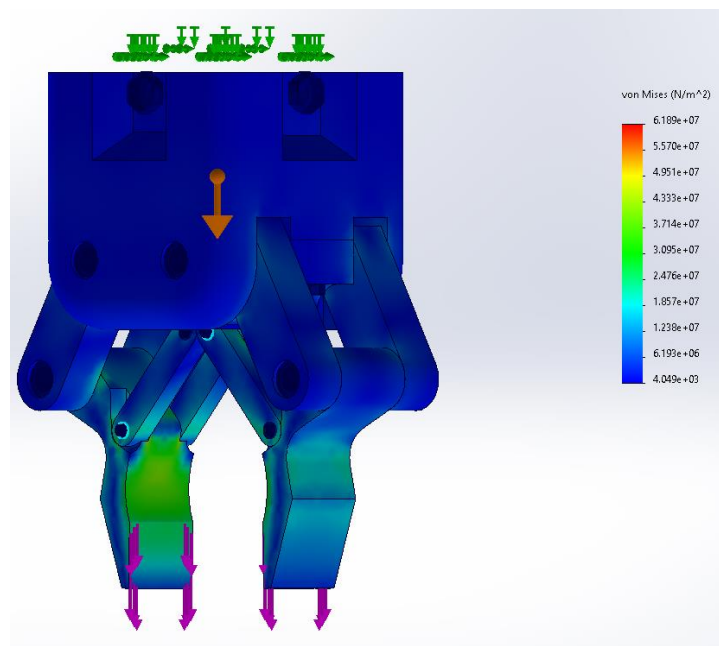


Figure 41: New Stress Results

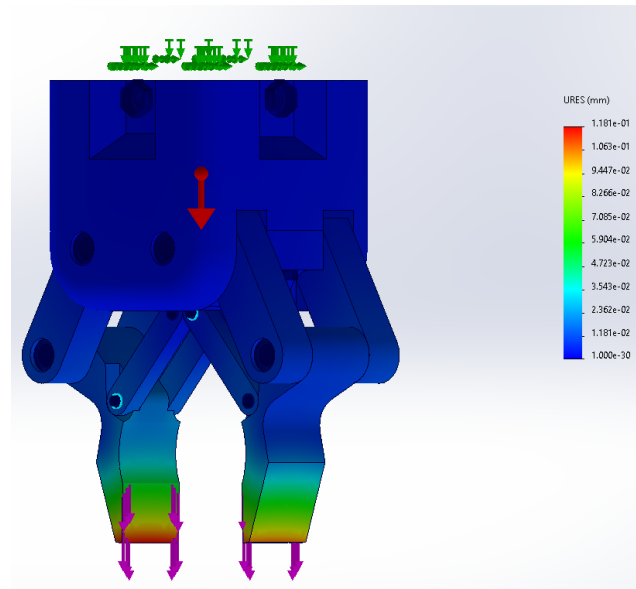


Figure 42: New Displacement Results

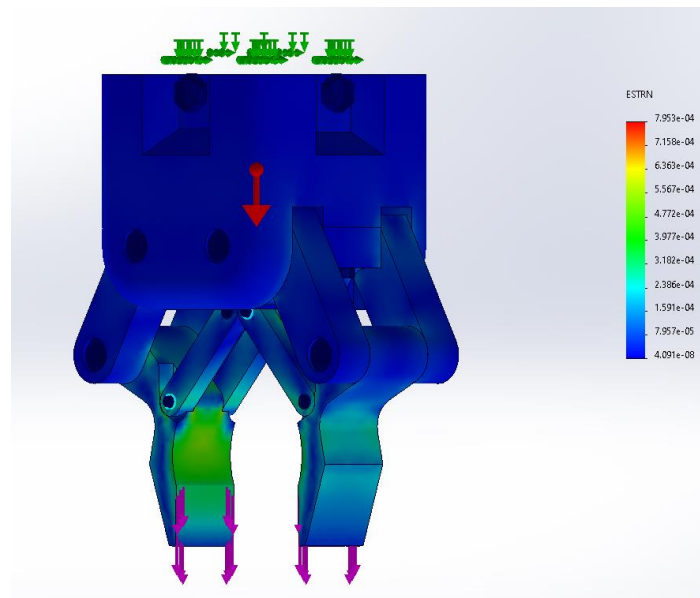


Figure 43: New Strain Results

The results show the success of the new design changes, the design now features no major stress or strain clusters that could cause the device to fail.

Each part is made from an easily machinable material as previously mentioned, therefore the ideal manufacturing method for all components should be CNC machining. Each parts shape is also not complex and should be easily mass produced with 2.5 axis CNC machining. With CNC machining, key critical alignment features such as the gears should be able to be machined with tolerances of 0.04 - 0.16mm, a major misalignment could cause one arm to exert more force on the mobile phone than intended and damage the product. It would also cause the feedback system in the

motor to be inaccurate. Other components can be subject to standardised tolerances following ISO standards or follow the CNC machine tolerance.

6.3. Design for Manufacturing

Where necessary, design for assembly principles have been considered for this design, including but not limited to:

- reducing part count where possible,
- limiting unnecessary complexity,
- leaving space to allow for the CNC tooltip,
- the use of common, easily recycled materials,
- the use of loose fits where possible,
- reduce the use of secondary operations such as drilling.

However, there are processes that could further enhance the product to align more with design for manufacturing principles. The following are some potential considerations for continued iterations:

- the use of standard components to minimize custom parts,
- design features that be produced in a single set up,
- optimise nesting for CNC machining
- the use of prototypes or software to identify manufacturing challenges.

6.4. Design for Assembly

A key methodology when designing the product was to follow design for assembly principles. Some principles to highlight in the design are:

- making parts symmetrical so orientation doesn't matter,
- the use of alignment features for asymmetric components,
- avoided the use of flexible parts,
- the minimal use of fasteners,
- allowing space for assembly tools in the design,
- the same common fasteners throughout the design where possible,
- easy to disassemble for servicing.

However, there are some more principles that could be considered for the design or future iterations:

- the use of snap fits or clips instead of fasteners,
- asymmetric screw patterns where possible
- prototyping or DFA software

7.0. Conclusion

The goal of this assignment was to create a robotic gripper head attachment for a UR3 robotic arm to be used in an automated setting to transport assembled mobile phones. An aspect of the assignment was to showcase knowledge and demonstrate use of design for manufacture and assembly principles. The current design is able to meet all design requirements and goals set and is operates successfully with the UR3 robotic arm to perform its intended task. In hindsight, there are some noticeable shortcomings in the design process, such as a lack of market research to produce a QFD or equivalent specification, which hasn't negatively affected the design but would have been beneficial, nonetheless. Also, some components such the brackets could have been combined into a single component to reduce the part count and comply more with the design for manufacture and assembly principles. Also due to the word count some design analysis has been reduced to accommodate. To conclude, the design works sufficiently well, with some minor room for improvements to decrease cost and increase mass production and assembly times but as it, it is a very good design that heavily complies with the said principles.