P2 Project Report

Design of Compliant hardwares for Plastic Doors

Guided by

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Submitted by

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अभिकल्प विद्यालय

Approval form

This is to certify that the Industrial Design Project entitled "Design of Compliant hardwares for Plastic Doors" by Infant Bibin is approved for partial fulfillment for the Master of Design degree in Industrial Design.

Prof . Avinash Shende
[Project Guide]

Signature of the
Chair Person

Signature of the
Internal Examiner

Signature of the
External Examiner
25.11.2022

Declaration form

I, declare that this written report represents my ideas in my own words, and where others' ideas or words have been included I have adequately cited and referenced the original sources.

I also declare that I have adhered to all principles of academic honesty and integrity and have not falsified, misinterpreted or fabricated any idea, data, facts or source in my submission.

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Signature:
Name of the student: Infant Bibin I
Roll No.: 216130007

Acknowledgement

I would like to express my heartfelt gratitude to my guide, Prof. Avinash Shende, for his essential assistance thoughout the project. Special thanks to the proffessors of Industrial Design Department for their critics and guidance . I am also grateful to all of the instructors, staff, and students at the Industrial Design Centre (IDC) for their assistance, advice, and suggestions.I would like to thank Sai Plastics,Ville Parle for their technical guidance. Finally I'd like to express my gratitude to my family and friends for their unwavering support.

Abstract

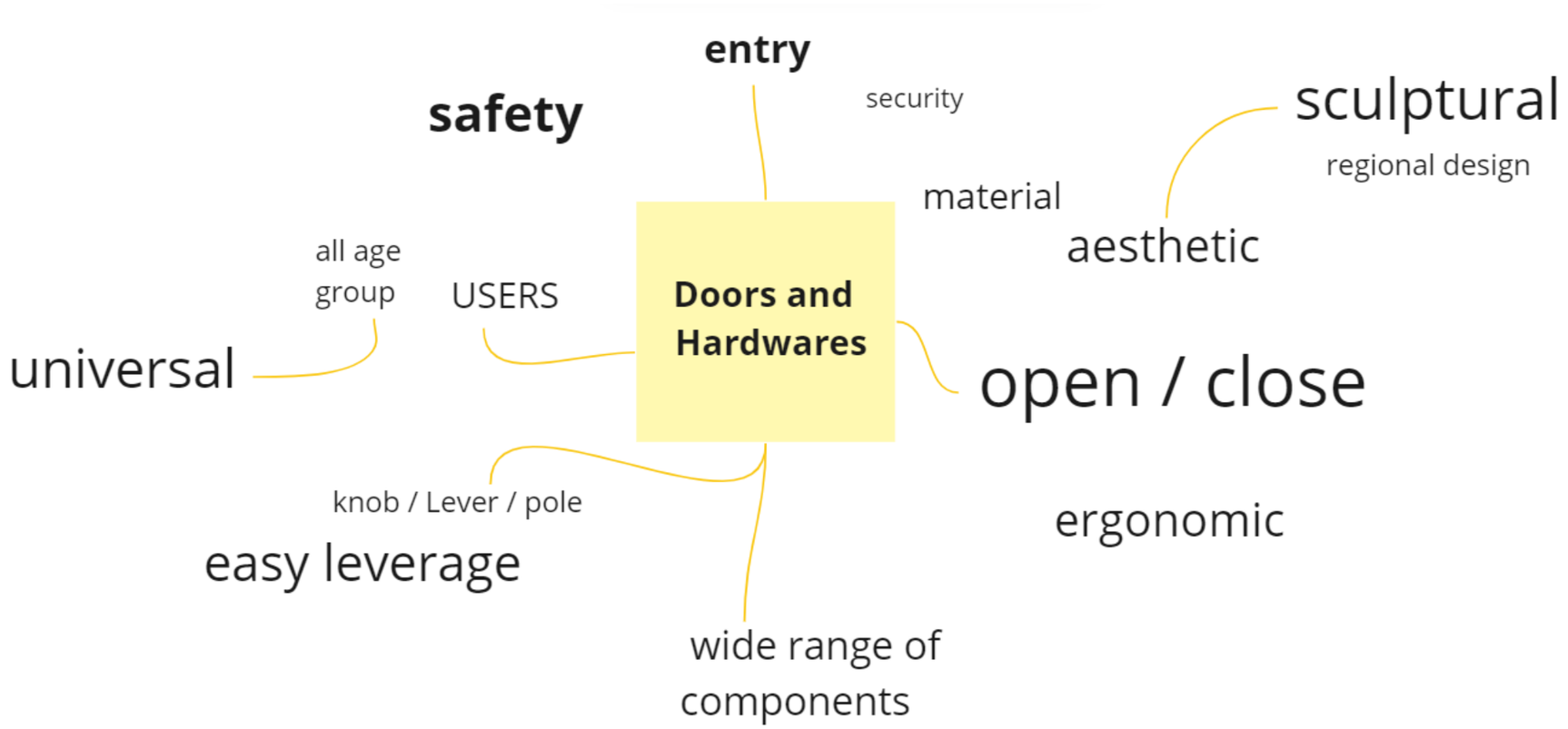
This increased building construction has resulted in increased production of doors and door hardware. Door Hardwares were essential components that makes any board or a plank into a usable and functional door and as a result there is an increasing demand for door hardware market on a global scale. Metal hardware industries are well developed and matured currently, having great designs and functionality. On the other hand, when it comes for Plastic Hardwares, it remains same over the years. This project tries to create a system to leverage the plastic hardware, especially for ***PVC/UPVC Doors*** *that are primarily used for lavatory spaces and temporary installations of enclosures.*

And also, the main objective of this project is to create an ***integrated system*** *for hardware designs that should be easily manufactured at the same time being* ***compliant****. The ideations were mainly driven with factors like creating the hardware with a smaller number of parts, easy to assemble and positively impacting user kinematics.*

Contents

1. Introduction Why Door Hardwares ?

This increased building construction has resulted in increased production of doors and door hardware. Door hardwares were essential components that makes any board or a plank into a usable and functional door and as a result there is an increasing demand for door hardware market on a global scale.



1.1 Current Market

Indian Doors Market size was valued at over USD 1.2 billion in 2016 and will surpass 9.5 million units by 2024 .Increasing consumer spending on construction and renovation of commercial & residential buildings will drive Indian doors market growth. Housing sector alone accounts for 5-6% of the Indian GDP. Private equity investment in real estate reached over USD 6 billion in 2016. Government initiatives across the countries for smart cities' development will support the Indian doors market penetration.

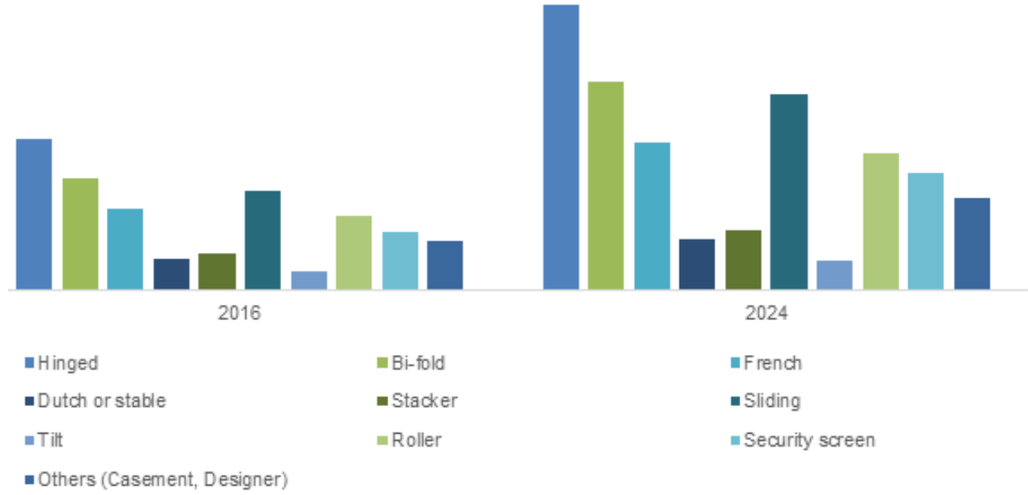
Increasing consumer spending on construction and renovation of commercial & residential buildings will drive Indian doors market growth. Booming demand for energy efficient and impact resistant housing infrastructure will lead industry towards more innovative product materials. As per IBEF, Indian real estate industry is expected to reach USD 180 billion by 2020. Housing sector alone accounts for 5-6% of the Indian GDP. Private equity investment in real estate reached over USD 6 billion in 2016. Government initiatives across the countries for smart cities' development will support the Indian doors market penetration.

Hinged doors market was valued over USD 300 million in 2016. Growing demand for see-through structures including doors induced with windows will propel the product market demand in commercial buildings. The product is most suitable for residential applications due to its easy fitting and lesser space consumption features.

Indian Doors Market Report Coverage

Report Coverage	Details
Base Year:	2016
Market Size in 2016:	1.2 Billion (USD)
Forecast Period:	2017 to 2024
Forecast Period 2017 to 2024 CAGR:	9.3%
2024 Value Projection:	2.8 Billion (USD)
Historical Data for:	2013 to 2016
No. of Pages:	430
Tables, Charts & Figures:	427
Segments covered:	Product, Material, Application and Region

Maharashtra Doors Market Size, By Product, 2016 & 2024 (Thousand Units)



Source : www.gminsights.com

1.3 TARGET AREA ?

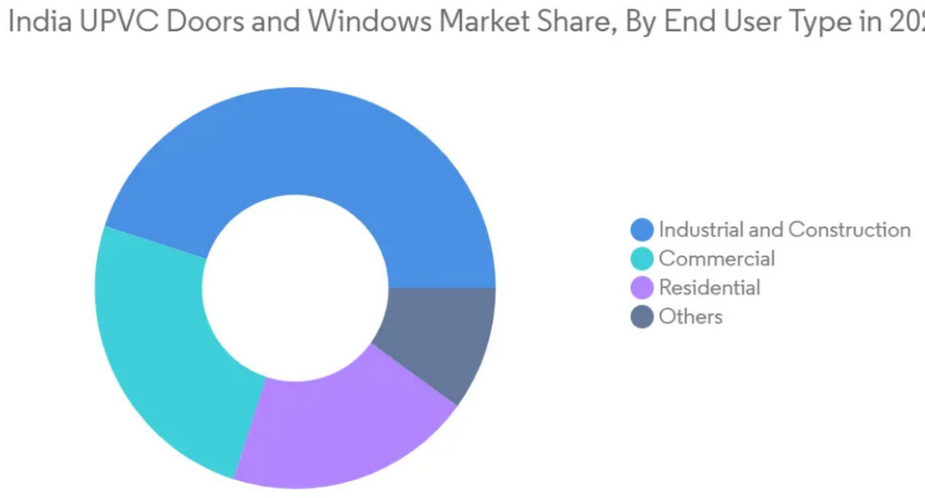
PLASTIC vs METAL Hardwares

Metal door hardwares are well explored and have established market. But on the other hand, Emerging demand for uPVC /Plastic doors and door hardwares due to their advantageous properties including enhancing strength, versatility, limited maintenance, high insulation against noise and resistance to moisture along at affordable prices.

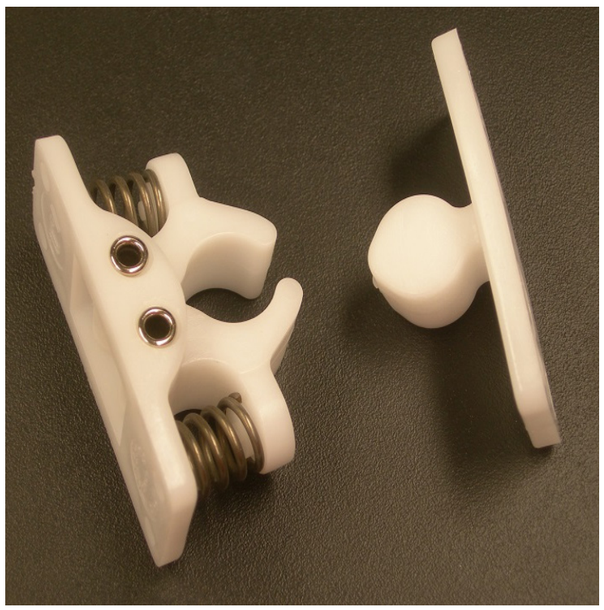
The Indian UPVC doors and windows market witnessed meteoric growth in the last few years, and it is estimated that the market may grow significantly at a CAGR of more than 7% during the forecast period, 2021-2026.

Factors contributing to market growth

- Rapid urbanization and industrialization.
- Booming residential and commercial construction.
- Increase in consumer spending on home remodeling & fittings.
- Consumer behaves to keep up with the trend.
- Improved and well designed products.



1.4 Current plastic hardware's for the Targeted segment



Plastic hardware for plastic doors, such as those made from PVC or uPVC, had made significant advancements and improvements over the years. The quality and performance of plastic hardware have been steadily increasing, making them more durable and reliable than earlier iterations. It is essential to note that the condition of current plastic door hardware may vary depending on factors such as manufacturing processes, materials used, and product design.

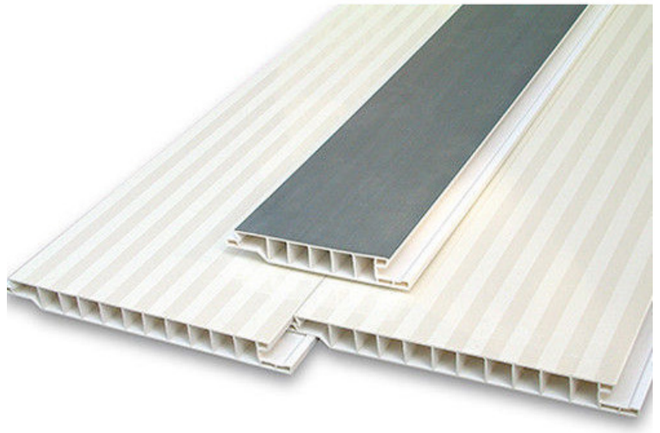
However, it's important to mention that plastic hardware, like any other material, has its limitations. In certain situations, such as heavy-duty or high-security applications, metal hardware might still be preferred due to its higher strength and load-bearing capacity. So Lavotary space doors and temporary doors installations(such as health care camps, refuge settlements, post disaster makeshift houses) are some application areas.

2 . Evolution of Plastic Doors in India

2.1 Multi panel door

Initially when plastic door industry started booming in India, industries invested in smaller moulds to reduce the risk. so with this smaller moulds they started producing panels of width 8 - 10”. These panels will come up with tongue and groove profile to join them. Initially these moulds were imported from China to reduce mould making costs.

- Extrusion moulding Process
- 8” width panels - PVC
- Aluminum A-Section and H- Section for framing
- Tongue and Groove for joining the panels
- Adaptation to Indian Context



2.2 Single panel door

Later as technology advances bigger dies are made, in which the entire panel is extrude and ready to assemble to the frame

- Extrusion Moulding process
- 21″ 24″ 30″ width panels - PVC/UPVC
- Aluminum A-Section frame 24MM/30MM Thickness
- Availability of Bigger and wider moulds

2.3 PVC Flush door

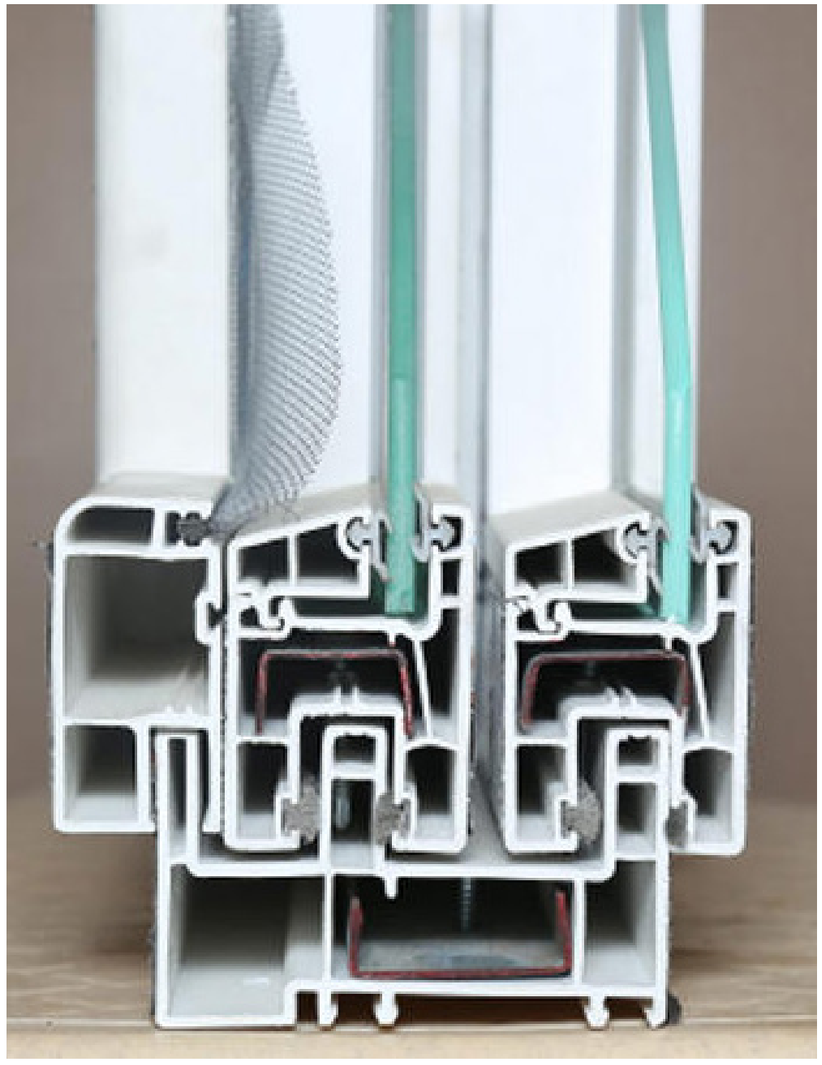
Later evoloution of plastic doors came up with good structural improvements, so as to avoid the use of frames. And the quality of aesthetics of plastic doors also started improoving at the same time. Better textures and prints started evolving during this phase

- Extrusion moulding process
- 21" 24" 30" width panels - PVC/UPVC
- PVC/UPVC Side caps to cover four sides
- Single doors
- Seamless look and better aesthectics

2.4 Advanced Frame section

Currently frames with better structural and better resistance to all affecting factors are being produced with the help of advanced tooling to make intricate dies.Also the door industry is systemised and the dimensions are standardised to make it ready to assemble onsite. Door is ready made from the factory, to avoid human errors while assembling on site.

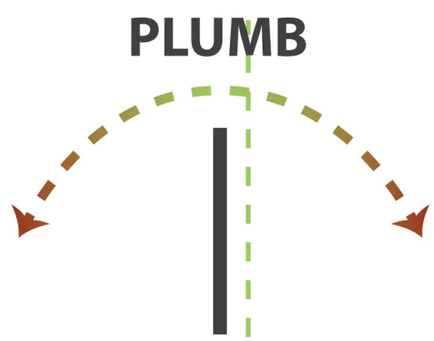
- Extrusion moulded
- L- frames - UPVC
- Smaller and heavier versions of frame sections
- UPVC frames are hard to achieve Plumb and Square, so the idea of factory welding started to be in practise
- Started using extensively cost of minimal deployment time



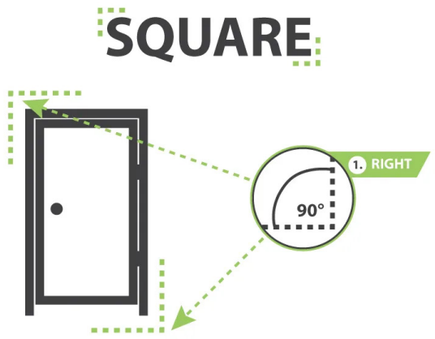
3.Technical aspects of a plastic door

3.1 Instability OF PLASTIC DOORS Due to bad fixing

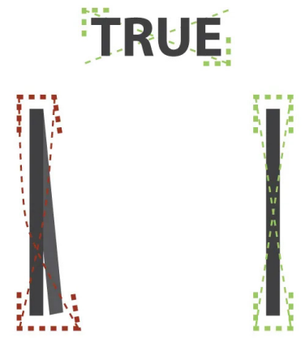
The best way to describe LEVEL is to imagine a straight line that is perfectly horizontal. Take a look at the picture above, the dotted green line represents LEVEL. If a door or window is installed out of LEVEL, it will tend to rub on the jamb and it will be hard to get the reveal (spacing between the door and frame) to line up.



PLUMB is the term used to refer to a perfectly vertical line, thus why the clever tool used to find PLUMB is called a plumb-bob. If a door or window is installed out of PLUMB, it will cause a host of issues. Such as: sagging open in the corner, unwanted opening or closing doors, and binding during operating.



The definition of SQUARE is a 90 degree corner. Installing a door or window SQUARE involves being both LEVEL & PLUMB at the same time. This is important to prevent: binding during operation, springing open on the corners and again to insure proper sealing between the sash and frame.



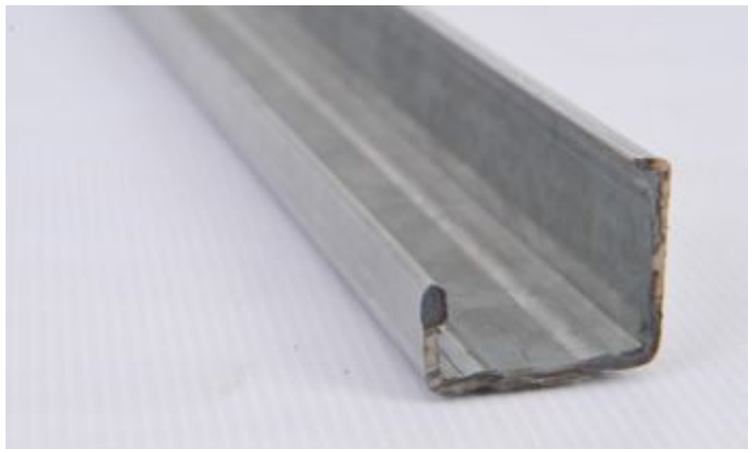
TRUE represents being SQUARE on both the LEVEL & PLUMB axis at the same time on all sides of the unit being installed. The picture above describes TRUE. A door or window can be installed perfectly LEVEL, PLUMB & SQUARE on one side, but if the other side's aren't LEVEL, PLUMB & SQUARE, the unit will not be TRUE and will create many of the problems.

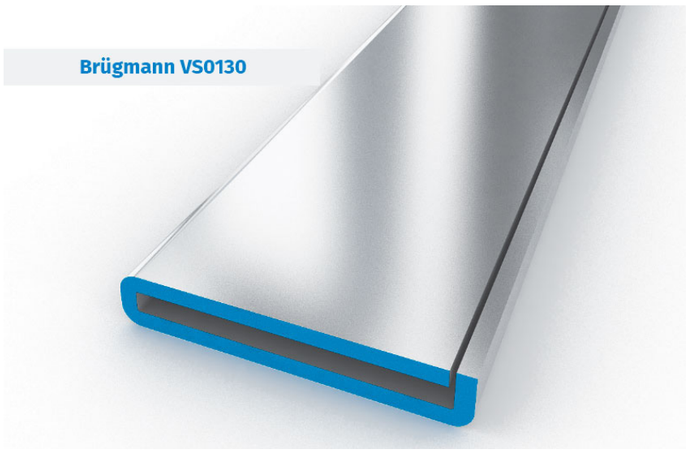
3.2 Reinforcement MS / Galvanised Iron

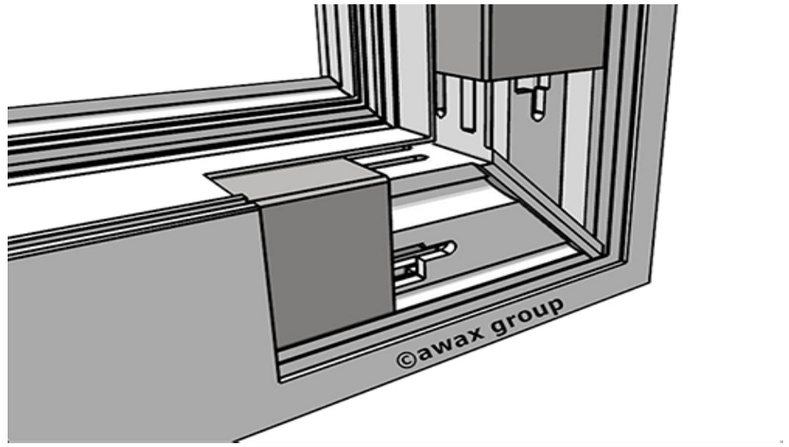
(Mostly on Window frame and Main doors)

Doors and windows on the building are subject to environmental impacts, mainly wind pressure and rain and snow, and they must also withstand the use of switching forces and their own gravity. Among them, wind power is the main reason for the bending of bars and bars of windows and doors (as cross bars, vertical bars and windows), and whether doors and windows are safe depends on their ability to withstand wind power, usually on a unit basis.

uPVC doors are steel reinforced and come with high security locks & hinges to help prevent easy entry by thieves. These doors are highly durable, strong and create a lasting first impression.

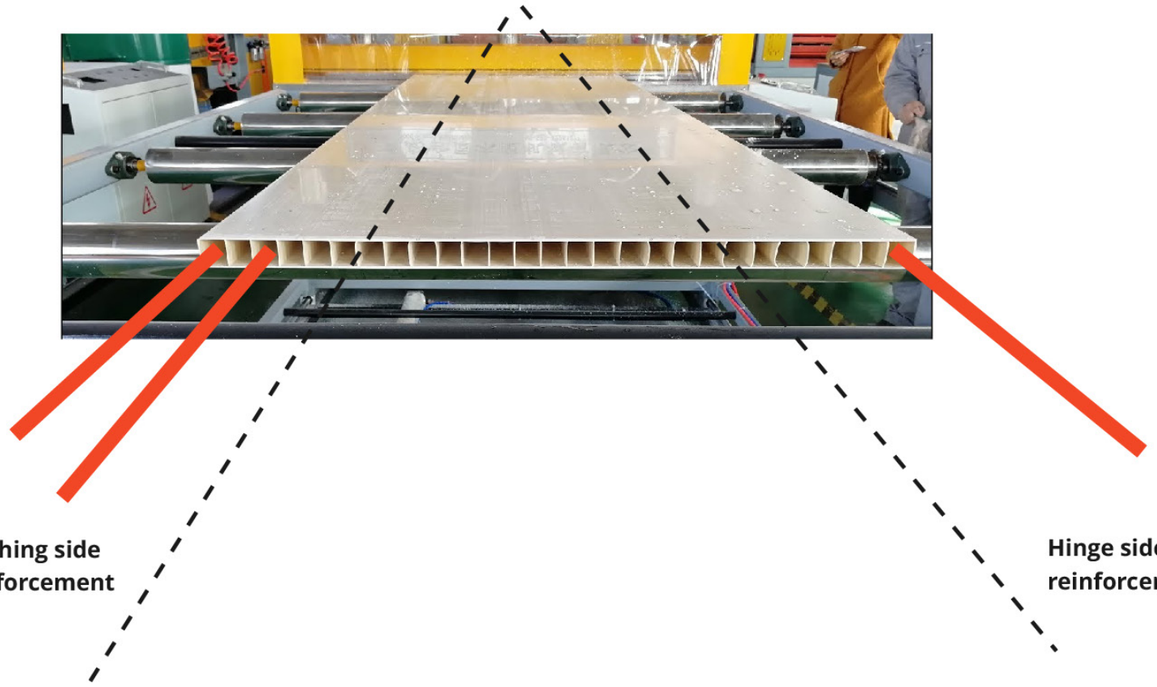






3.3 Reinforcement

NYLON / Recycled Solid Polymers **(Mostly on PVC doors)**



These doors and reinforcement are fixed and marked for screws on reinforcement areas, since screws cant be placed on 1mm thick sheet

Adhesive called **PD99** used for (becomes a permanent bond)

3.3.1 Assembly

Skill Labours needed

1 carpenter + 1 helper (7 - 10 doors can be assembled in a day by two labours)

7-10 kgs depends on the door dimension (light enough for one person to take the door)

3.4 Industrial welding of Complex PVC / UPVC frames

Welding processes for joining plastics are numerous and the right selection of welding machines plays an essential role in getting high-quality and reliable results. Ultrasonic welding is the most commonly used methods of PVC / UPVC Welding.

Ultrasonic Welding

Ultrasonic plastic welding is a commonly method that has been in use for a long time. It uses the heat generated from high-frequency mechanical motion to join thermoplastics. It happens by transforming high-frequency electrical energy into a high-frequency mechanical movement

Plastics welding is achieved in three phases, surface preparation, application of heat and pressure and cooling.

Many plastics can be welded such as acrylic or polymethyl methacrylate (PMMA), polycarbonate (PC), polyethylene (PE), polypropylene (PP), polyethylene terephthalate (PETE or PET), polyvinyl Chloride (PVC), acrylonitrile-butadiene-Styrene (ABS).

3.5 The extrusion process of PVC door and window profile

Production process

The production process of PVC door and window profile mainly includes single screw extrusion process and twin screw extrusion process. The raw materials used in the two processes are the mixed powder prepared in the previous process according to a certain formula. At present, the extrusion line of hard PVC door and window profile mostly uses conical screw.

1. Single screw extrusion

The single screw extrusion process is especially suitable for the production of small batch and small size profile. The process flow is as follows:

Mixed powder- single screw extrusion granulation-single screw extrusion molding-setting - traction-cutting -turntable-finished product

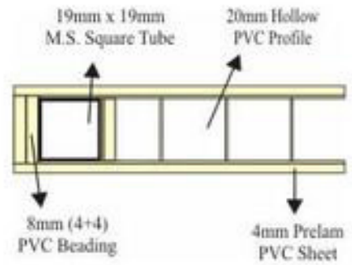
2. Twin screw extrusion

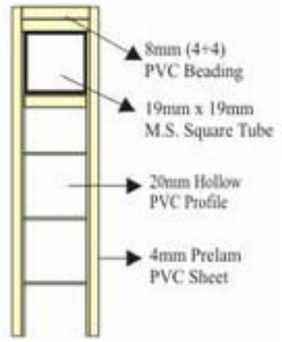
The twin-screw extrusion process can be directly molded with powder, with large production capacity, especially suitable for the production of large quantities of conventional profiles and large specifications of different profiles. The process flow is as follows:

Mixed powder-twin screw extrusion molding- setting -traction-cutting -turning table- finished product

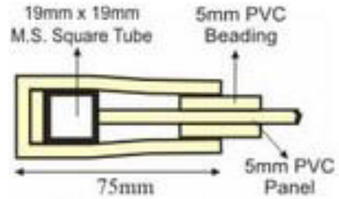
3.6 Typologies and detail

Internal PVC Flush Doors

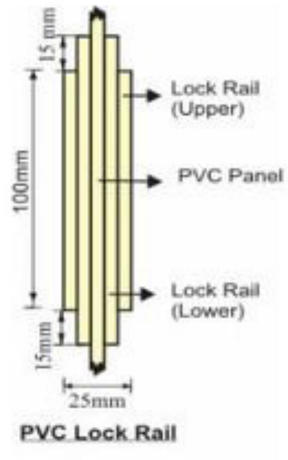




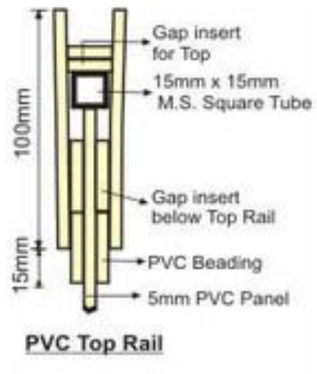
Solid Panel PVC Door



PVC 'C' Channel



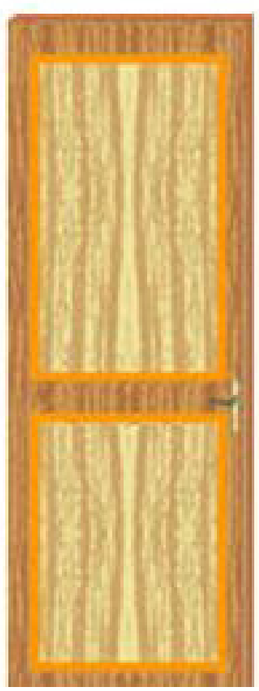
PVC Lock Rail

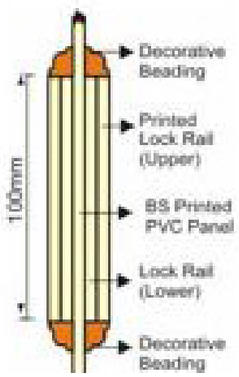


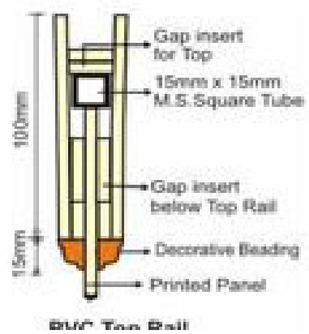
PVC Top Rail

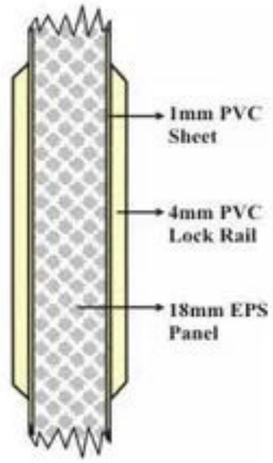
28mm thick Vikas Plasticply PVC Flush Door is unique substitute of wooden flush door. 4mm Plain / Prnted / Prelam Vikas Plasticply PVC sheets are used on both sides of 20mm multi-channel hollow PVC panel infill material to cover the panel. These doors are reinforced with 19mm x 19mm MS tube welded frame. These doors have unmatched screw holding capacity, strength & dimensionally stability. These doors are lightweight, which do not give much stress on hinges. These doors are 100% environmental friendly.

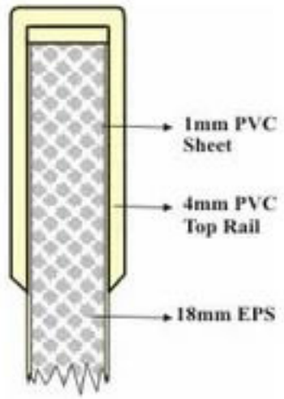
3.6 Typologies and detail











PVC Doors are made from 5mm prelam PVC Sheet and are equivalant to expensive teak wood doors. Vikas Plasticply Both Side Prelam Solid Panel PVC Doors have a decorative wood like veneered look and are ideally suitable as internal doors in bedroom, living room etc. The available wide range of laminated finish, provides the choice to select the door most suitable as per the interior decor and finish of the room.

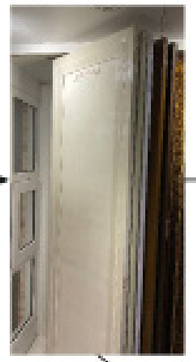
4. Current Market Analysis

4.1 Sai Plastics , Ville Parle

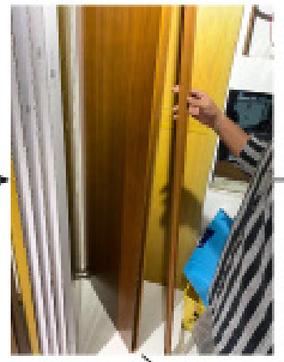
Door

Multi panel door

Single panel door



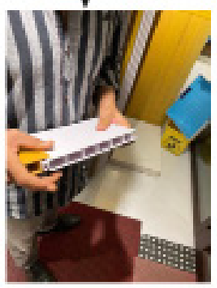
Single panel flush door



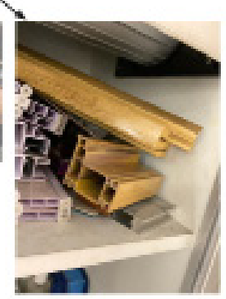
STANDARDS

SIZES(Only shutter)	
Length (feet)	**Width (feet)**
6.5	2.25
6.75	2.25
6.5	2.50
6.75	2.50

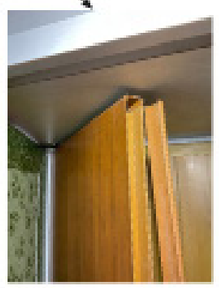
Details



Multi panelS



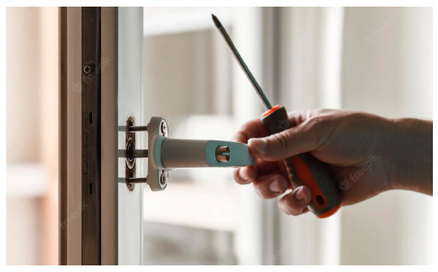
FRAME Sections



Single panel flashing

Hardwares

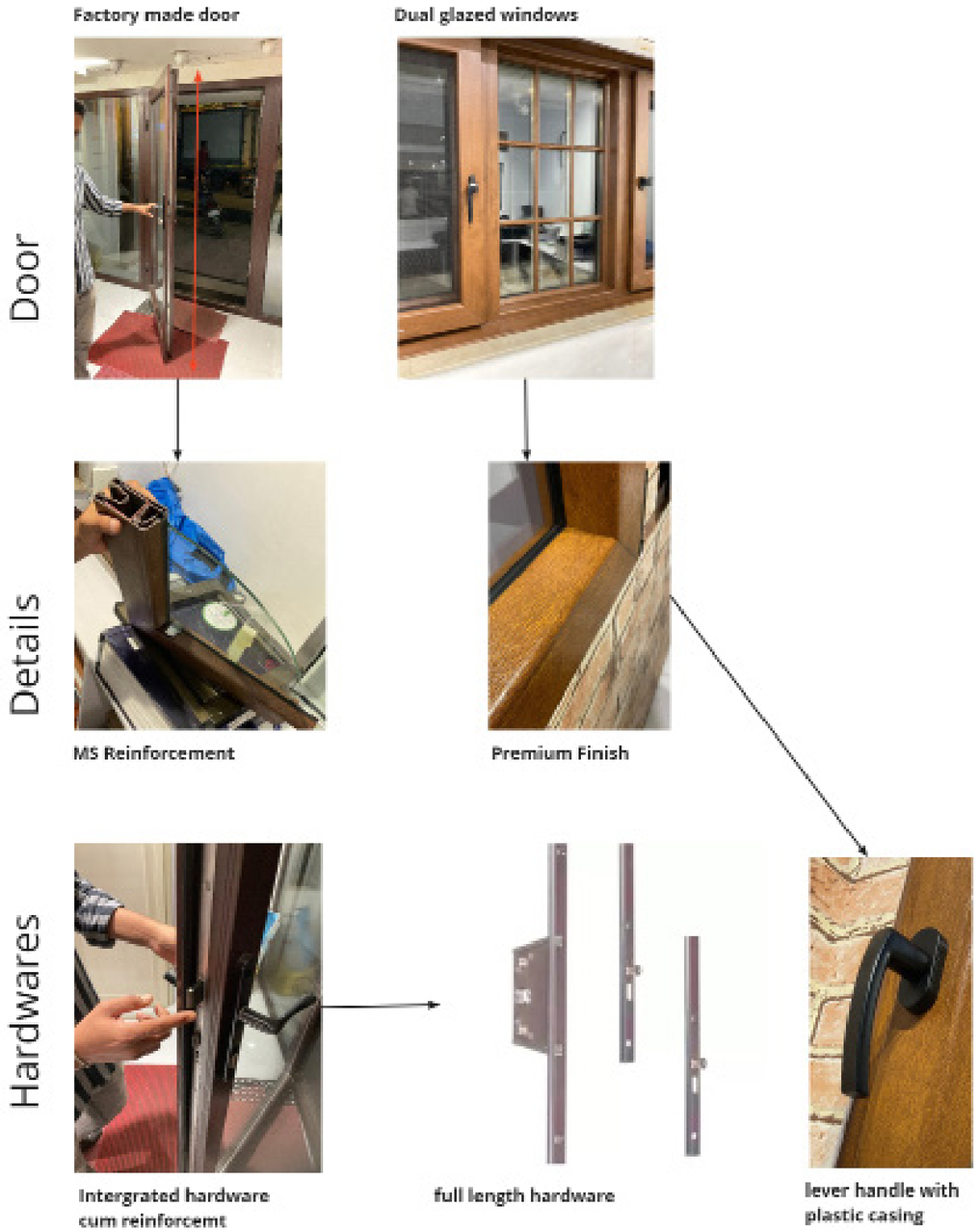
SS Hardwares



Sintex Plastic Doors:

- The Sintex doors were constructed from PVC, which made them lightweight and easy to handle during installation.
- The doors came in various designs and finishes, catering to different aesthetic preferences.
- The doors were known for their resistance to moisture, making them suitable for areas prone to humidity.
- The representative emphasized that Sintex doors were an economical choice, ideal for budget-conscious customers.
- However, one noticeable aspect was that the hardware, such as handles, hinges, and locks, needed to be attached separately after installation.

4.2 Market Visit- Fenesta Mumbai



Fenesta Plastic Doors:

- Upon entering the Fenesta showroom, I noticed a more contemporary and sophisticated ambiance. The doors on display had a sleek and modern design, appealing to customers who valued aesthetics and quality.
- The sales representative informed me that Fenesta doors were crafted using uPVC, a more durable and robust variant of PVC.
- Unlike the Sintex doors, Fenesta doors came with integrated hardware, which meant that handles, locks, and other components were seamlessly incorporated into the door's design during manufacturing.
- The integrated hardware provided a streamlined and polished look to the doors, enhancing their visual appeal.
- Fenesta doors were not only aesthetically pleasing but also boasted advanced technical features, such as enhanced insulation properties, which contributed to energy efficiency.
- Additionally, the doors were designed to be soundproof, making them an excellent choice for areas with high noise pollution.
- The representative mentioned that Fenesta doors were ideal for both residential and commercial applications, as they offered excellent security and weather resistance.

4.3 Finding the Gap - Product placement

After visiting both showrooms, I reflected on the differences between the two brands. Sintex doors were a practical and economical choice for customers seeking affordable options, but they required additional efforts for attaching hardware. On the other hand, Fenesta doors were a premium choice for those who valued innovation, integrated hardware, and advanced technical features.

Overall, the market visit provided valuable insights into the plastic door industry, the technical details of the doors, and their various applications. It was evident that the industry had evolved significantly to cater to diverse customer needs, whether it be budget-friendly options or high-end, technologically advanced solutions. Armed with this knowledge, I felt better equipped to make informed decision of placing the product on the more budget side yet to try achieving the integrated technology through compliant mechanisms.

Brand Example

Sintex
SINCE 1975

Average - **Rs 230 /square feet**

PVC / UPVC
Not end to end assembly
Plastic Reinforcement
No mechanism just comes as in
Both industrial welded and Onsite assembly
Digital UV print
Seperate hardwares need to be used (Plastic / SS)

SCOPE FOR PLASTIC INTEGRATED HARDWARES

SCOPE FOR COMPLIANT MECHANISM INTEGRATION

Brand Example

Fenesta™
Better by Design

Average - **Rs 850/square feet**

UPVC
End to end assembly
MS Reinforcement
Flushed in mechanism
Industrially welded
Vinyl skin
Integrated hardwares (Plastic and Metal)

4.4 Application of these Panel doors

Current Residential Usage

Previously there is no concept of dry area in Indian toilet, everything was wet, flush door is used by all. Currently everything the between MIG to HIG groups have the concept of having dry areas and also big openings , so flush doors are mostly used by MIG to LIG (There is where the mass consumers are)

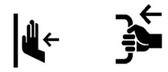
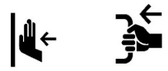
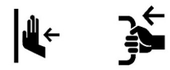
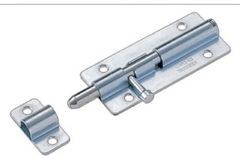
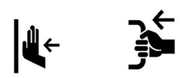
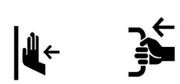
Other Usage

Used as Partition Doors in few commercial and public building mostly with steel (maintenance free).

Any kind of temporary partition and enclosure. (Exhibitions , Events , Security cabin, Temporary Covid center, Outdoor temporary toilets)

Costal areas (high humidity areas) degrades the wood or metal doors due to high humidity and high salt content in atmosphere. So in sunch areas Plastic doors are often prefferred.

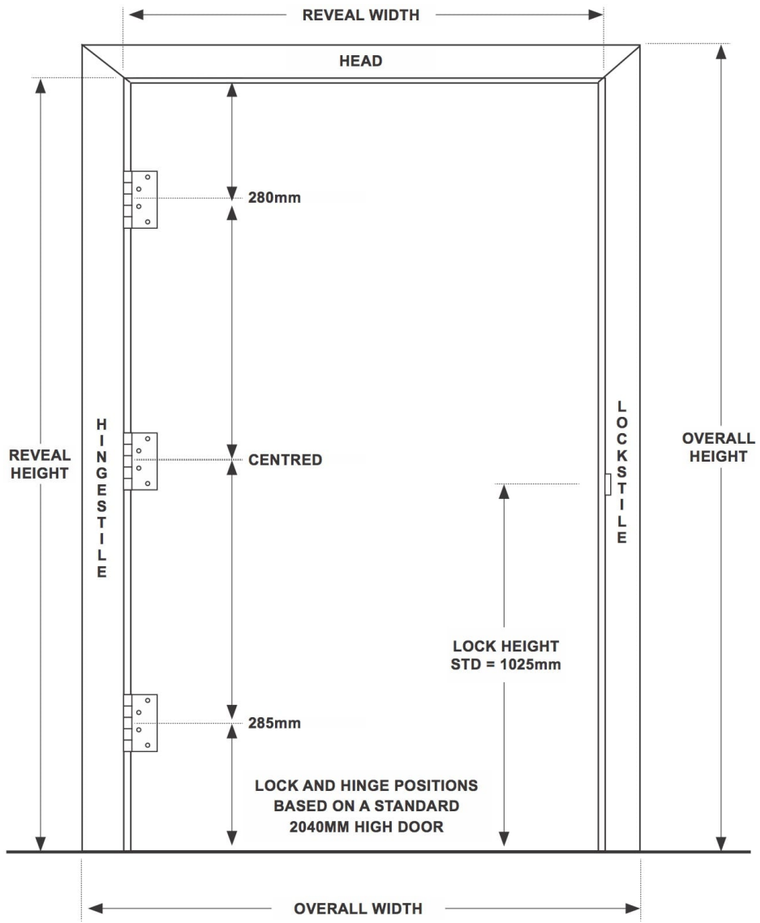
4.5 Detailed Study on widely used Existing hardwares for the selected range

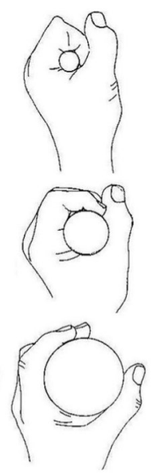
TYPE OF LATCH / HANDLE		MAJOR USAGE / Limitations	PARTS COVERED IN THE HARDWARE	COMPONENTS COVERED	ADDITIONAL SUPPORT COMPONENTS NEEDED AFTER USE	BEHAVIOUR OF OPERATING	BEHAVIOUR WITH THE DOOR AFTER OPERATING	SUITABILITY WITH PLASTIC DOORS
HASP PADLOCK LATCH (hasp and staple)		Arresting the door (2/5) Ergonomics (3/5) Latch fasening (1/5) Needs pin/picklock to lock in place	4 + 8 screws	**1**	**Door handle**	REMOVES THE PIN/LOCK FLIPPING THE HASP FROM STAPLE OPEN THE DOOR		**Self Tapping Screws NEEDED** **THIN WALLS OF EXTRUDED SECTIONS MAKES THE SCREWING PROCESS COMPLICATED**
HOOK EYE LATCH		Arresting the door (4/5) Ergonomics (2/5) latch fastening (3/5) Lock on its own	5 + 4 screws	**2**	**Door handle**	FLIPPING THE HASP FROM STAPLE OPEN THE DOOR		Self Tapping Screws NEEDED THIN WALLS OF EXTRUDED SECTIONS MAKES THE SCREWING PROCESS COMPLICATED
FLIP LATCH		Arresting the door (4/5) Ergonomics (1/5) latch fastening (4/5) Lock on its own	5+ 4 screws	**2**	**Door handle**	FLIPPING THE HASP FROM STAPLE OPEN THE DOOR		Self Tapping Screws NEEDED THIN WALLS OF EXTRUDED SECTIONS MAKES THE SCREWING PROCESS COMPLICATED
SLIDING BARRELL BOLT LATCH WITH PADLOCK		Arresting the door (4/5) Ergonomics (3/5) latch fastening (5/5) needs pin / picklock to lock	5 + 8 screws	**2**	**Door handle**	REMOVES THE PIN/LOCK FLIPPING THE HASP MOVES THE BARREL TO SIDE OPEN THE DOOR		**Self Tapping Screws NEEDED** **THIN WALLS OF EXTRUDED SECTIONS MAKES THE SCREWING PROCESS COMPLICATED**
SLIDING BARRELL BOLT LATCH		Arresting the door (4/5) Ergonomics (2/5) latch fastening (5/5) preferred latch	4 + 6 screws	**2**	**Door handle**	FLIPPING THE HASP MOVES THE BARREL TO SIDE OPEN THE DOOR		**Self Tapping Screws NEEDED** **THIN WALLS OF EXTRUDED SECTIONS MAKES THE SCREWING PROCESS COMPLICATED**
SLIDING SQUARE BOLT LATCH		Arresting the door (4/5) Ergonomics (1/5) latch fastening (5/5) difficult to use because of it square surface friction	4 + 6 screws	**2**	**Door handle**	MOVES THE BARREL TO SIDE OPEN THE DOOR		**Self Tapping Screws NEEDED** **THIN WALLS OF EXTRUDED SECTIONS MAKES THE SCREWING PROCESS COMPLICATED**
MORTISE LATCH		Arresting the door (4/5) Ergonomics (5/5) latch fastening (3/5) better handling comparing other latches	6 + 3 fasteners	**3**	**Door handle**	TURN THE LEVER HANDLE PUSHES THE LEVER HANDLE TO OPENS THE DOOR		**FASTENERS NEEDED FOR THE FIXING**

5. Ergonomics

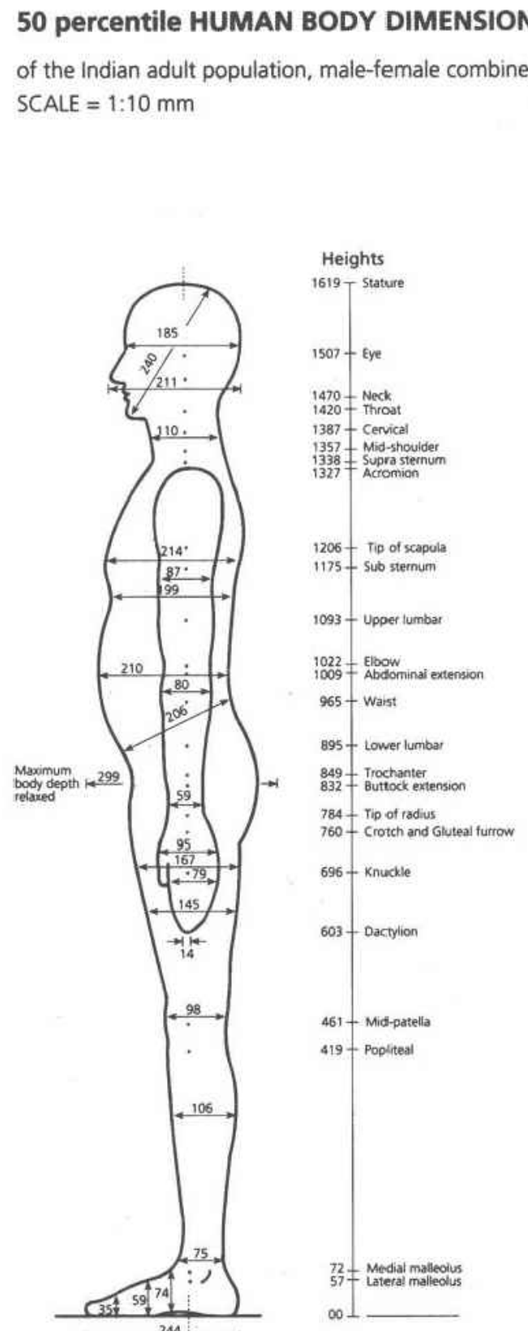
Other than ensuring that the handle height will be suitable for the full range of users, some other important ergonomic design parameters, when specifying a handle are described below:

1. Position: Well within reach
2. Shape: No sharp edges, grooves, seams or corners
3. Surroundings: Clearance if it needs to be held
4. Fixings: Ease of assembly, strength, repair-ability
5. Clean-ability: Surface, resistance to cleaning





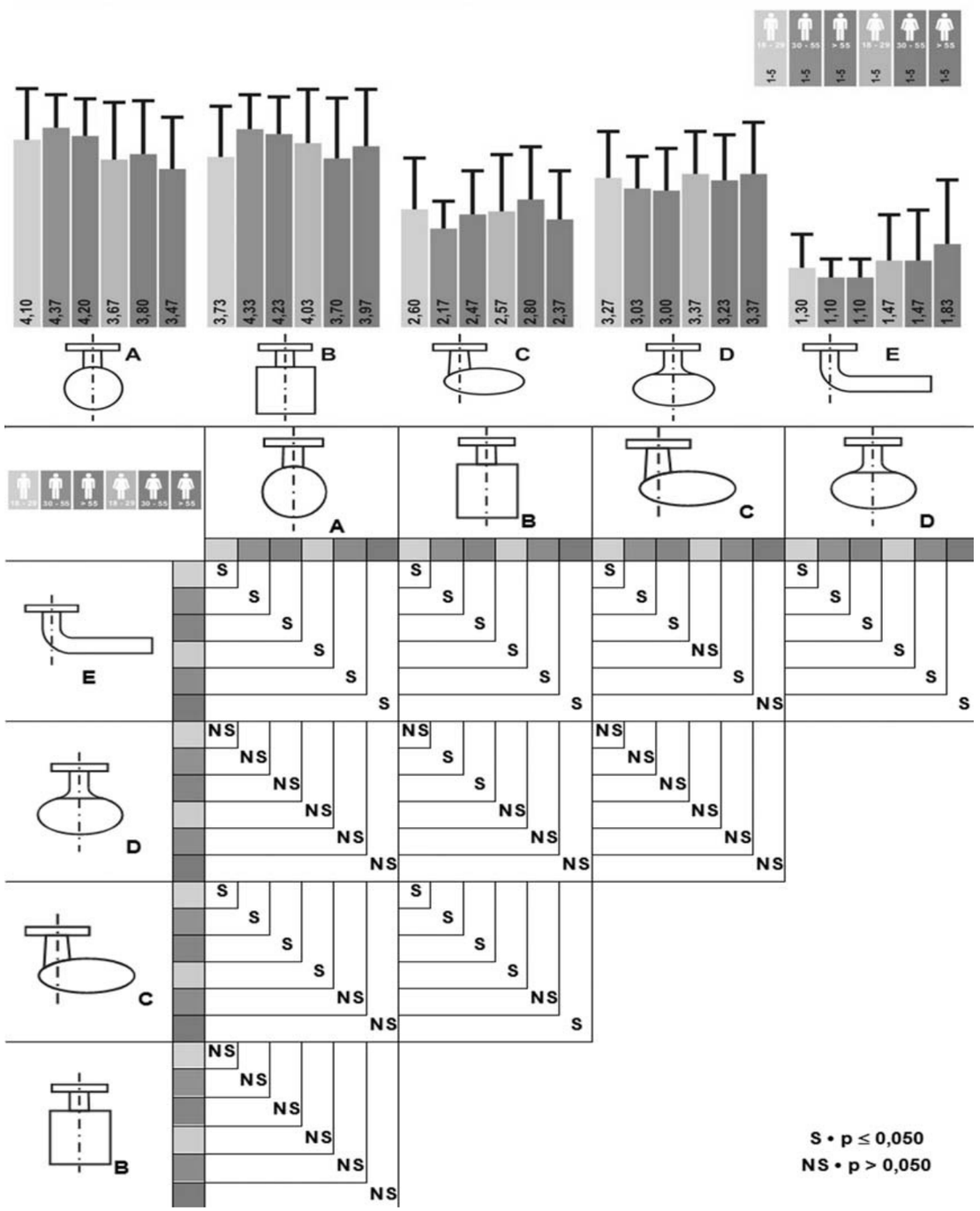
Description	Guidline	Reason
shape	Slightly contoured	Easy grip
Handle length	> 100 mm	Keep contact out of palm
Handle diameter (power grip)	30-50 mm	Greater force and stability
Handle diameter (precision task)	8-16 mm	Greater control
Material and texture of handles	Non-slip non-conductive materials	For comfort and reduces effort required to use



5.1 Influence of door handles design in effort perception: Accessibility and usability

Regarding effort perception among different door handles, there weren't significant differences between door handles "A" and "B", "A" and "D" and "D" and "C", and the knob "E" stood out from the others, with lower means of effort perception, compared to most interactions.

In general, there's an inverse relationship between the results of biomechanical studies and the effort perception of the same task activity. This shows that door handles design influence directly these two variables and can interfere in the accessibility and usability of these kinds of products.



6. Design brief

To design an Integrated Compliant Door Hardware system for Affordable range Plastic (PVC/UPVC) doors, which can be primarily used for lavatory spaces.

Key Objectives

Consider ease of manufacturing

Reduce part count - easy assemby

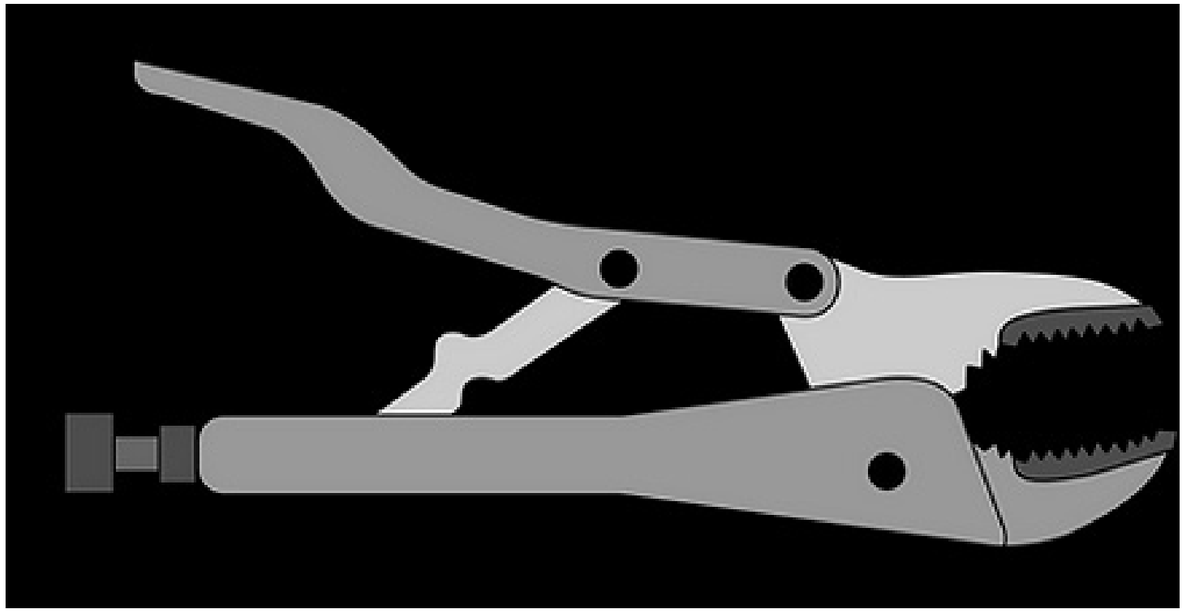
Consider mechanical movements

Positively impact users kinematics

Incorporating Compliant mechanism to achieve this.

7. Compliant Mechanisms

A compliant mechanism is a mechanism that gains at least some of its mobility from the deflection of flexible members rather than from movable joints only. An example or a compliant crimping mechanism is shown below.



1.Number of parts

The possibility for a significant decrease in the overall number of pieces needed to complete a specific operation is one benefit of compliant mechanisms. By using flexible components in place of standard inflexible hinges, springs, and pins, the number of parts can be decreased. In comparison to a rigid version of the same mechanism, the amount of components needed for a compliant mechanism may be significantly lower.

2. Production methods

Because they adapt themselves well to various manufacturing methods, compliant mechanisms can be easily produced. Many compliant devices can be made flat from planar sheets of material because they obtain their motion from flexible regions. For instance, the conforming grippers displayed above might be made from a single polypropylene sheet.

3. Price

Compliant mechanisms can be produced for a very low cost due to their simplicity and lack of moving parts. Assembling products could be made more efficiently and at a lower cost thanks to a lower part count. Because they adapt themselves well to various manufacturing methods, compliant mechanisms can be easily produced. As seen in the image below, some mechanisms, for instance, may be made of an injection-moldable material and assembled as a single unit.

4. Accurate motion

Due to wear and backlash, conventional mechanisms can lose their precision. By minimising or eliminating backlash and wear, compliant mechanisms can enable precise motion. Physical pins and hinges rubbing against one another provide the motion for rigid-body devices. When components move in close proximity to one another, mechanical wear occurs. Over time, this may wear out or change the material, which will alter the geometry and motion of the mechanism. Wear can be significantly decreased by using compliant mechanisms rather than conventional pins and rigid hinges (because no parts are rubbing on each other).

5.Performance

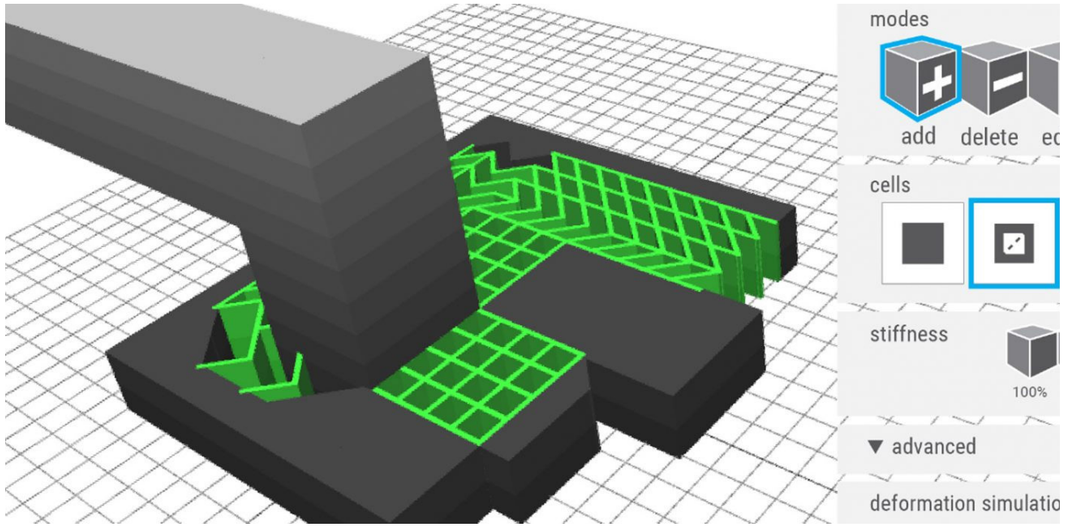
Less movable joints, such pin (turning) and sliding joints, are found in compliant mechanisms. Because of this, there is less friction and less need for lubrication. These are useful qualities for applications where the mechanism is difficult to reach or for use in severe locations where joints may suffer. Because lubricants tend to “outgas” (essentially evaporate) in a low-gravity environment, this is particularly crucial for space applications. The compliant pointer device is a tool that was created especially for usage in space and is displayed below.

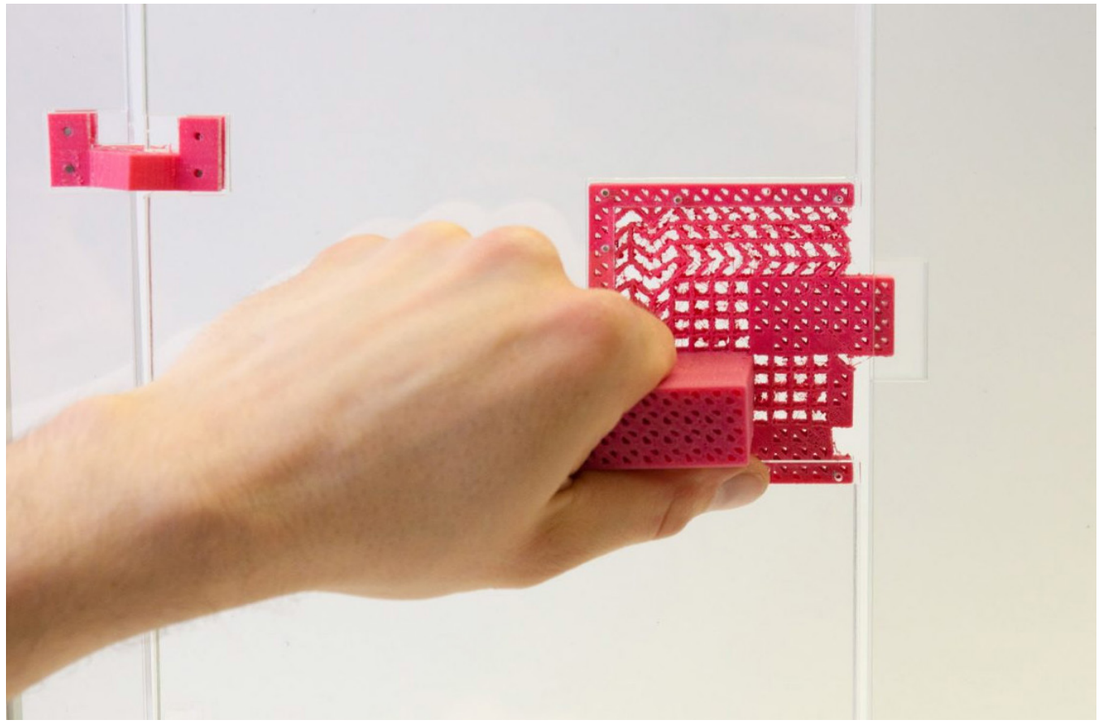
6. Predictability

Energy is stored in the form of strain energy in the flexible components because compliant mechanisms rely on their deflection. The effects of springs can be incorporated into the design of a compliant device since this stored energy is comparable to the potential energy in a deflected spring. This makes it simple to alter and/or store energy for release at a later date or in a different way. An easy illustration of this is a bow and arrow system. As the archer draws the bow, energy is stored in the limbs. The kinetic energy of the arrow is then created from this potential energy.

7.1 Door handles made with Metamaterials

Hasso Plattner Institute's Human Computer Interaction Lab





A door latch and a pair of pliers are among the mechanisms created without screws, bolts or other fixings by researchers working with a new technology called metamaterials. The team at the Hasso Plattner Institute's Human Computer Interaction Lab design objects that move despite being 3D printed as one single part.

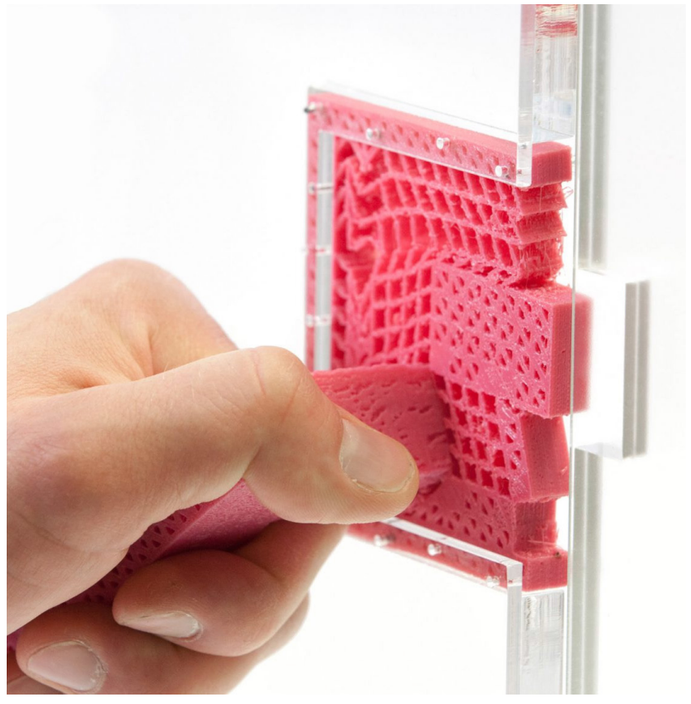
Turning the handle creates a rotating movement that causes the adjacent cells to shear.

The mechanisms are 3D-printed as a single part in flexible silicone, alternatively ABS or PLA plastic.

Because they are made of a single part, they do not require assembly, nor do they need lubrication to move – which the team claims will reduce or eliminate the need for maintenance.

They are made up of a grid of silicone cells with different patterns creating different levels of rigidity

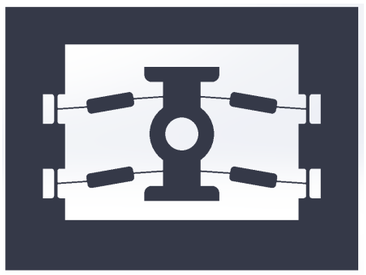
"Since these objects allow each cell to be designed differently, the resulting objects literally offer thousands of degrees of freedom," said the research team in a paper.

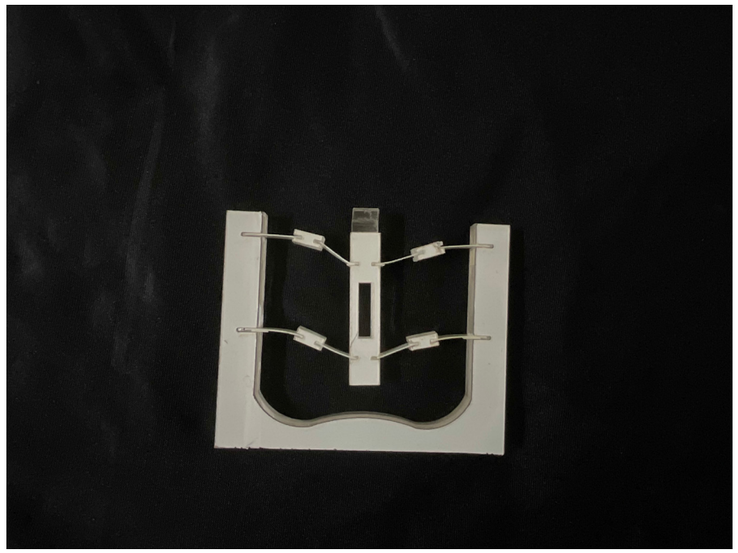


8. Compliant Mechanism exploration and Ideations

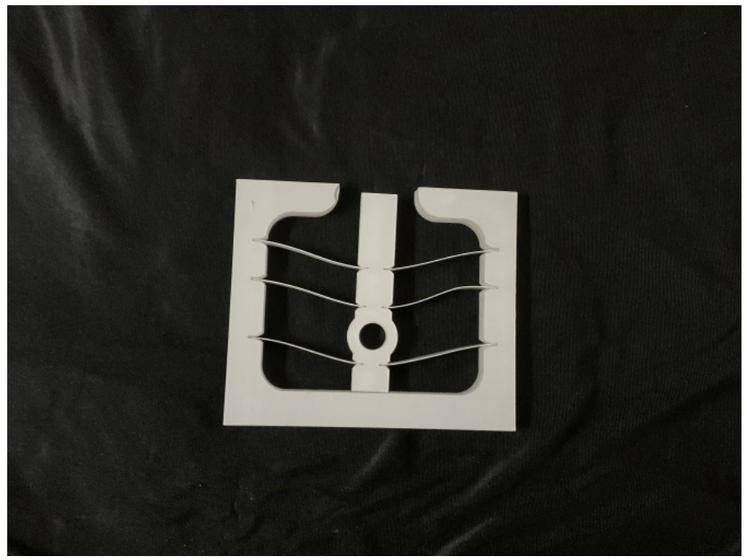
8.1.1.Compliant Mechanism Exploration

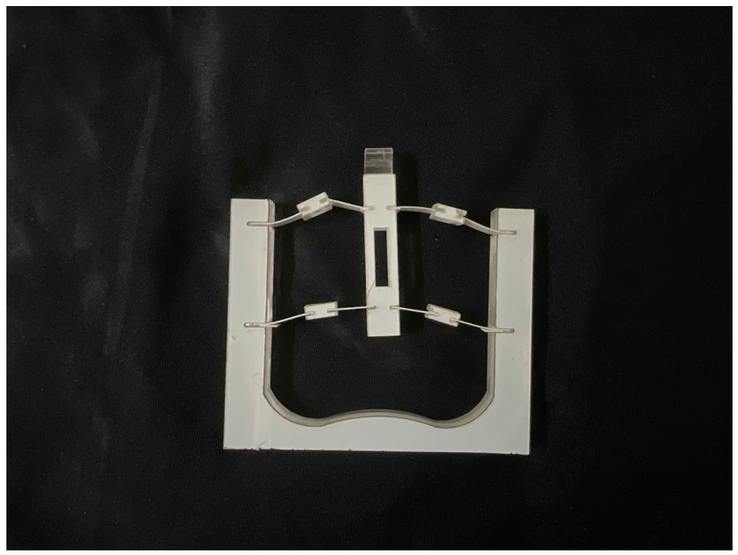
AIXIAL BISTABILITY Mechanism - Existing



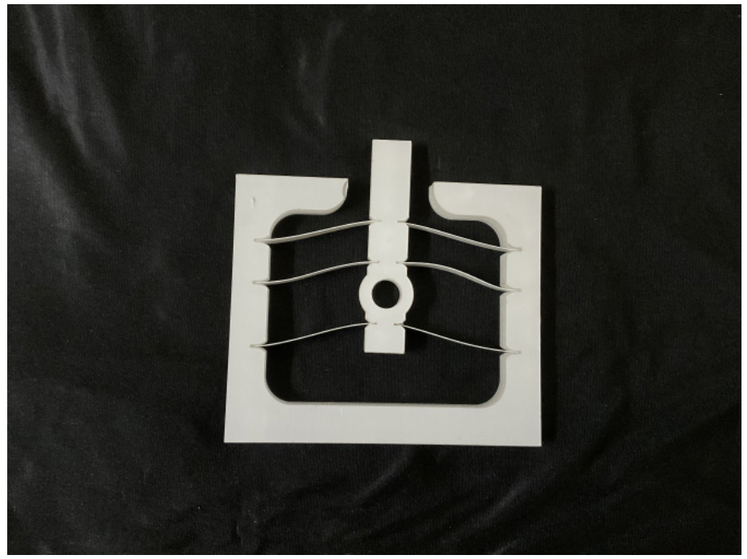


open





close

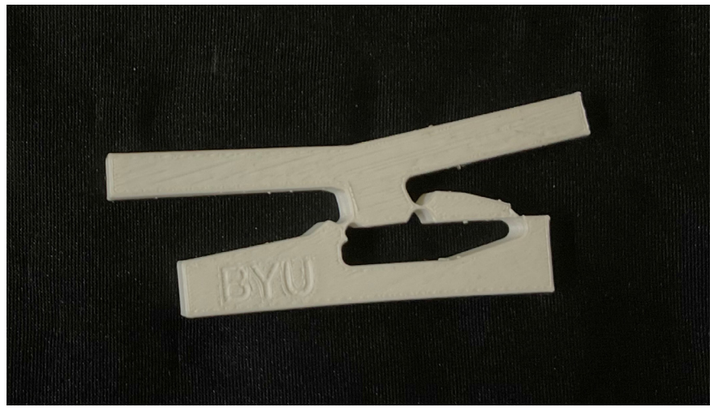


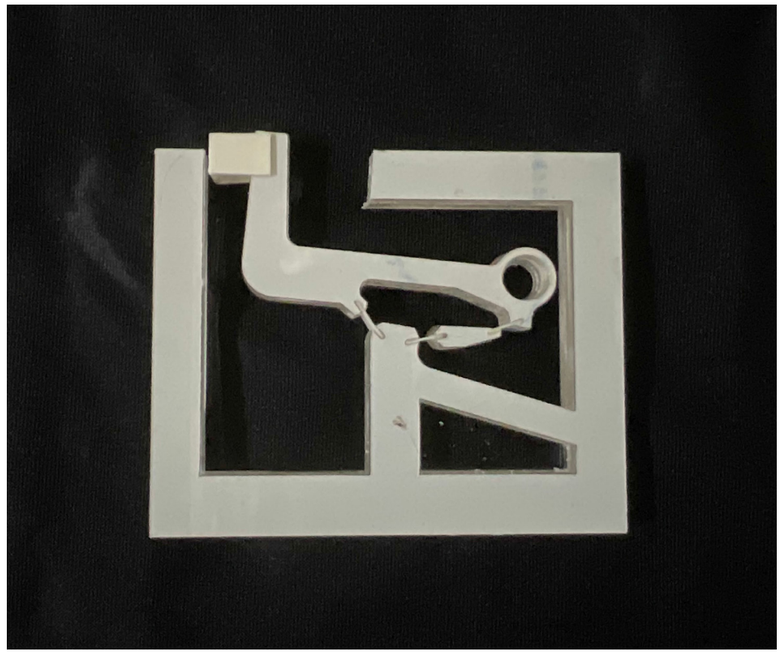
Potential application

It has good latching behaviour and produces haptic feedback for the users confirmation. And reduces the efforts comparing the conventional latch.

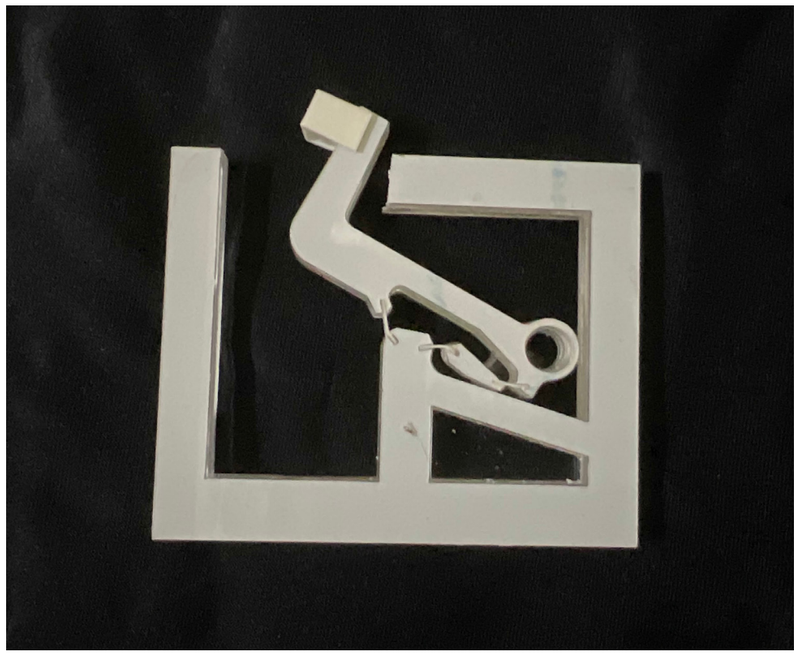
8.1.2.Compliant Mechanism Exploration

BISTABILITY Mechanism - Existing





open



close

Potential application (MODIFIED)

This also has good latching behaviour and produces haptic feedback for the users confirmation.

But this has an inverted action which may confuse the user.

8.1.3.Compliant Mechanism Exploration

BISTABILITY Mechanism- Existing

close

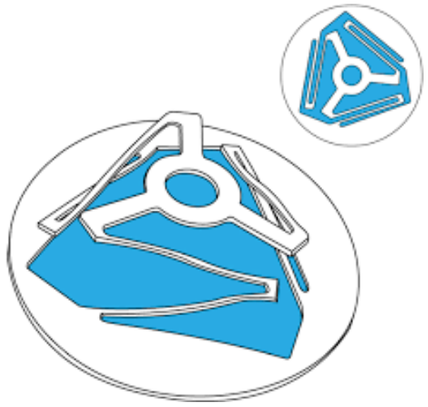
open

Potential application

This also has good latching behaviour similar to top latch of the door and produces haptic feed-back for the users confirmation.

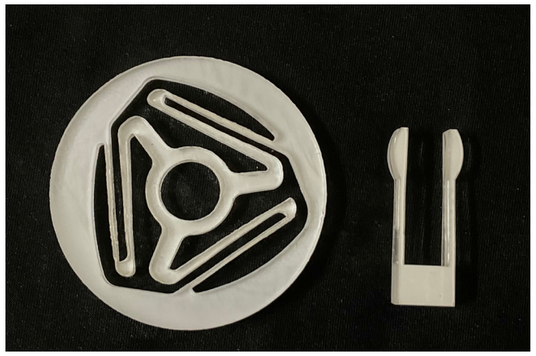
8.1.4.Compliant Mechanism Exploration

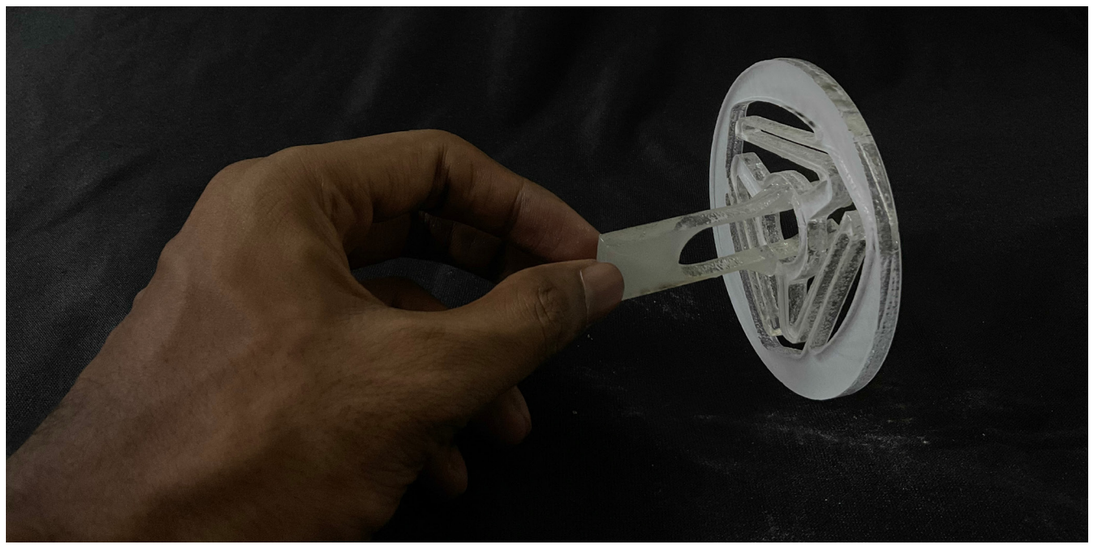
Ortho Spring - Existing



Potential application

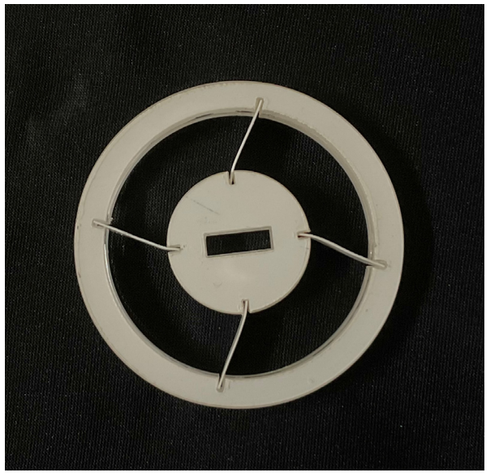
The spring action of this mechanism can be potentially applied to door catcher, where instead of making a bashing sound this smoothens the snaping and catching the door.

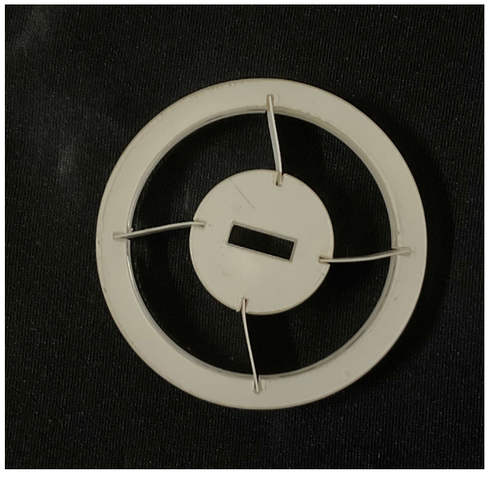


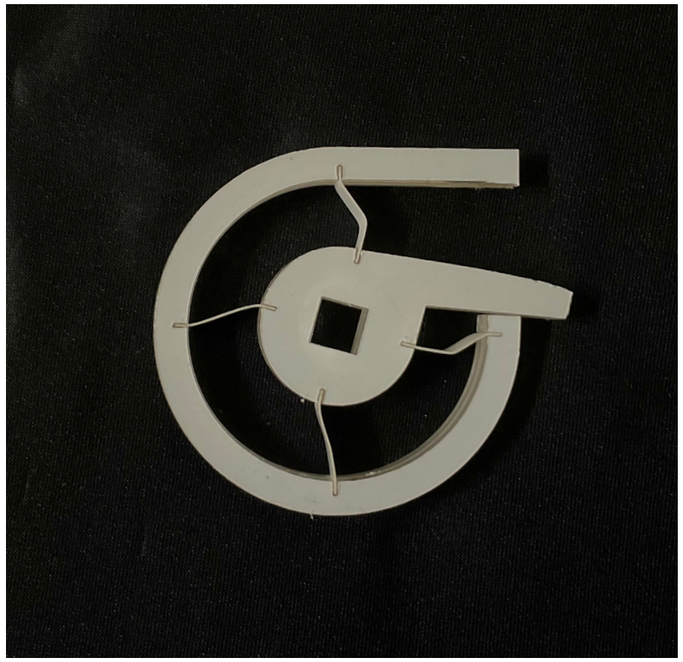


8.1.5.Compliant Mechanism Exploration

Rotational Bistability







close

open

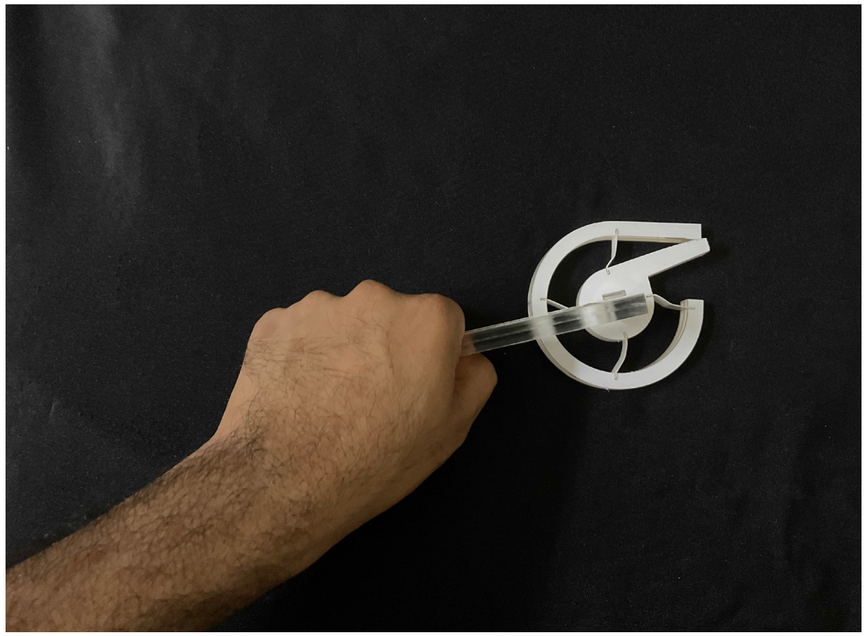
Potential application (MODIFIED)

This has a similar behaviour of lever handle and produces haptic feedback for the users confirmation.

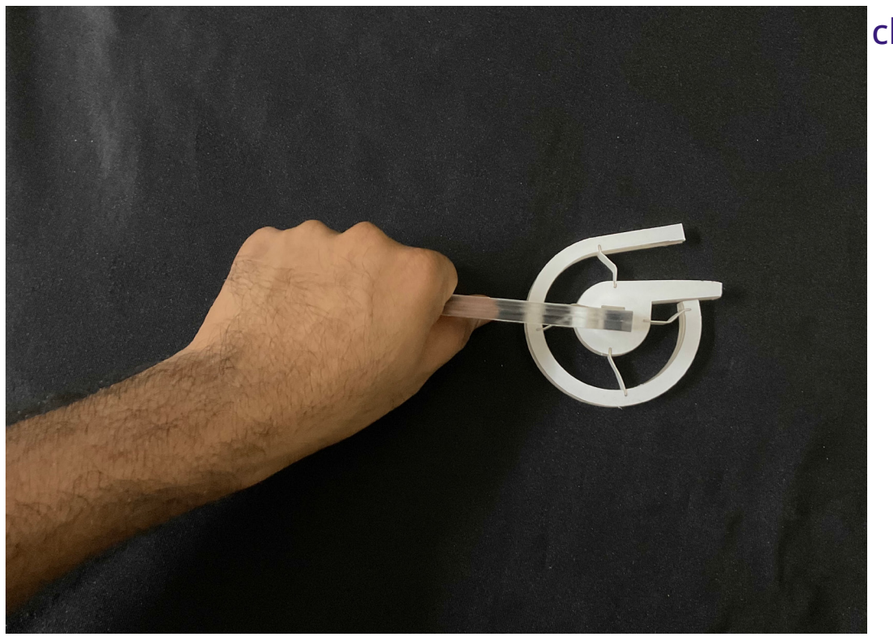
8.1.5.Compliant Mechanism Exploration

Rotational Bistability

open



close

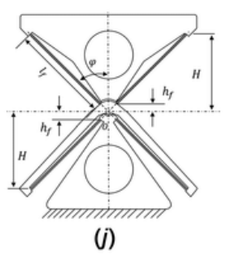


Potential application (MODIFIED)

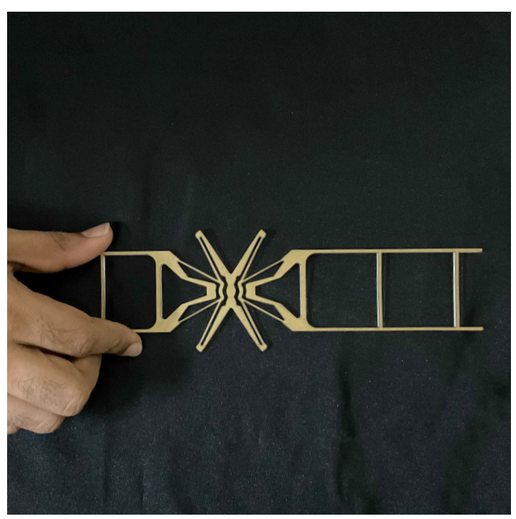
This has a similar behaviour of lever handle and produces haptic feedback for the users confirmation.

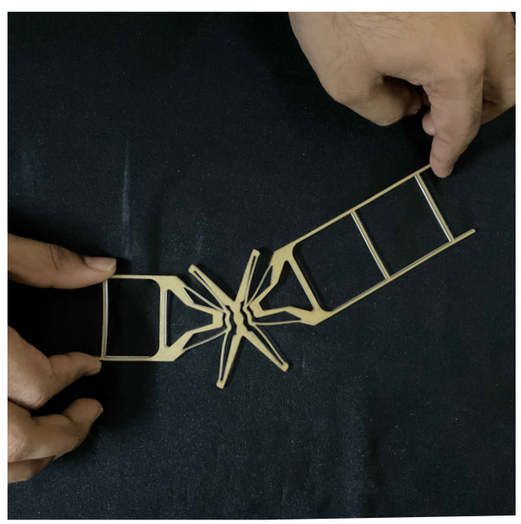
8.1.6.Compliant Mechanism Exploration

Flexural Hinge



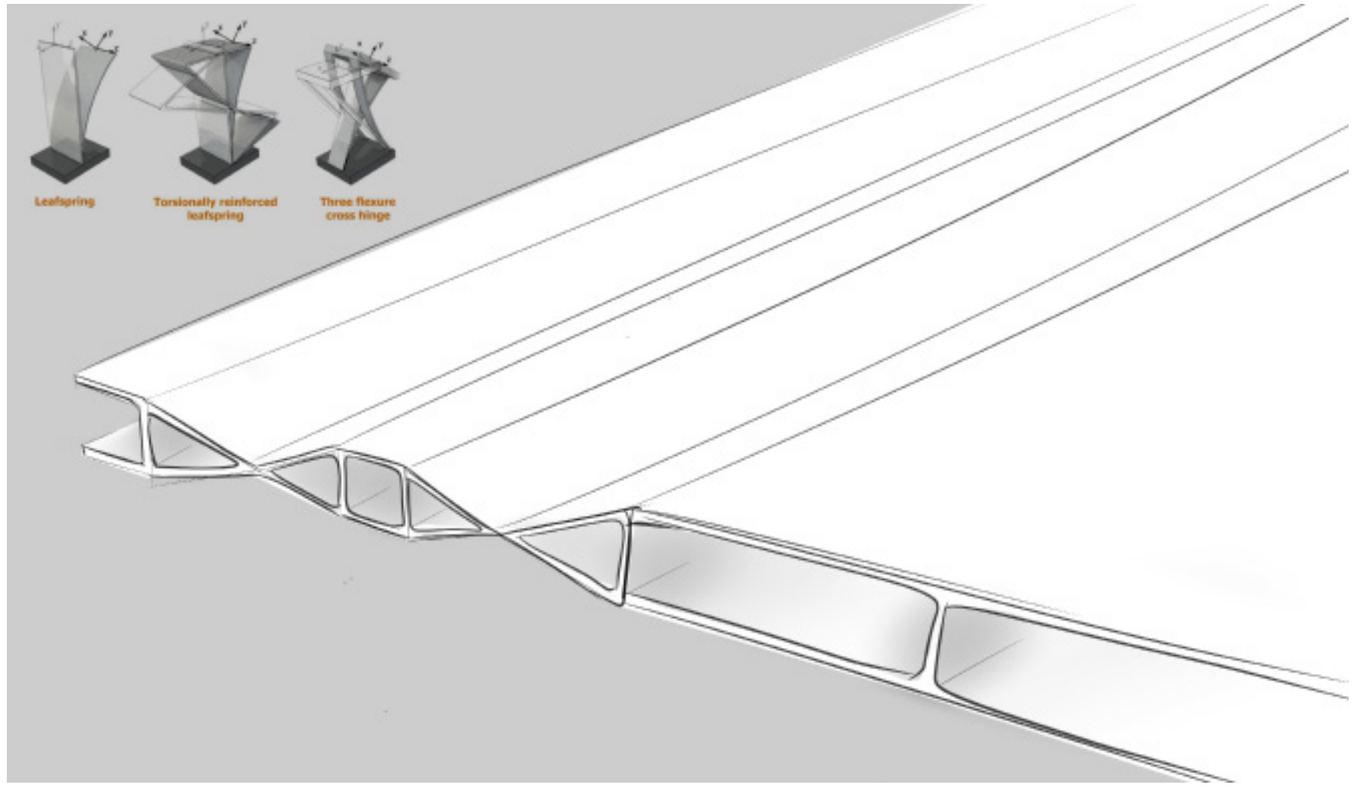
(j)





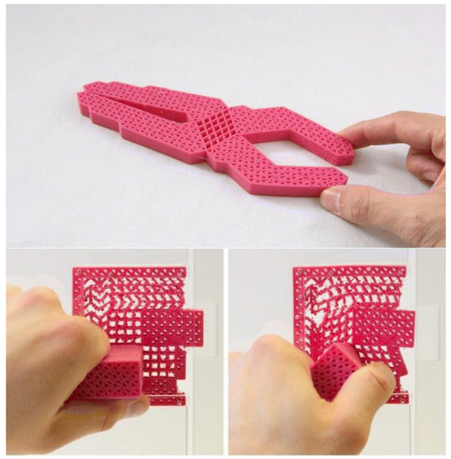
Potential application (MODIFIED)

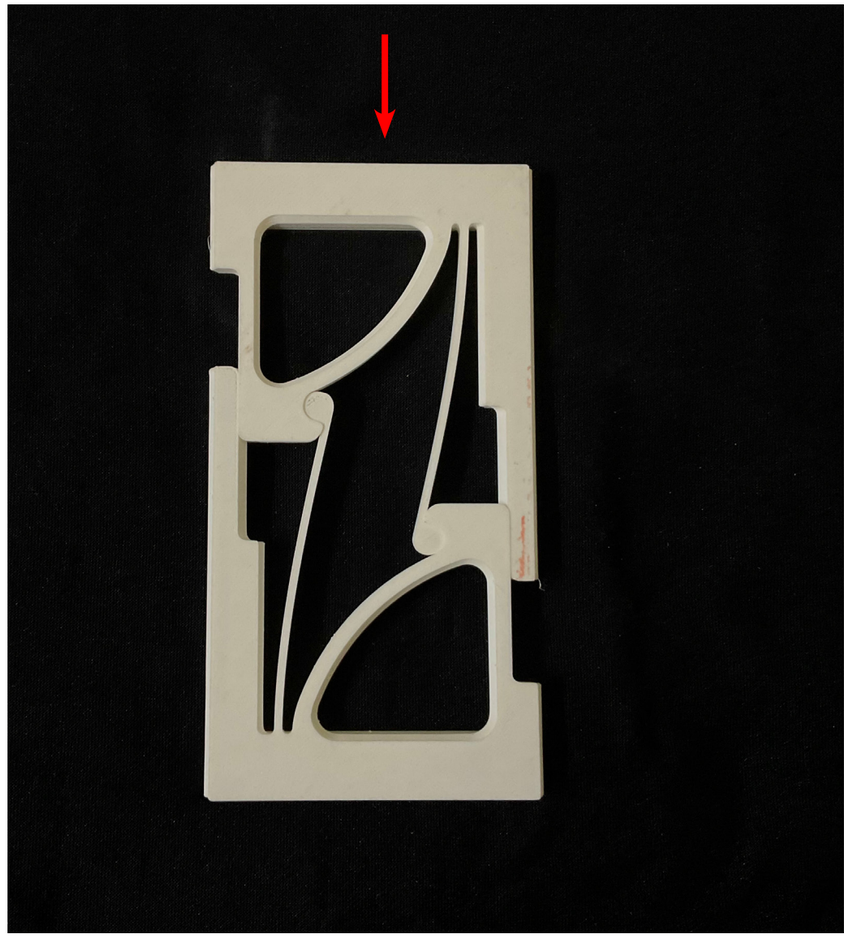
The idea is to incorporate this flexural hinge incross section of a plastic door to make it flexible and spring back to its position.

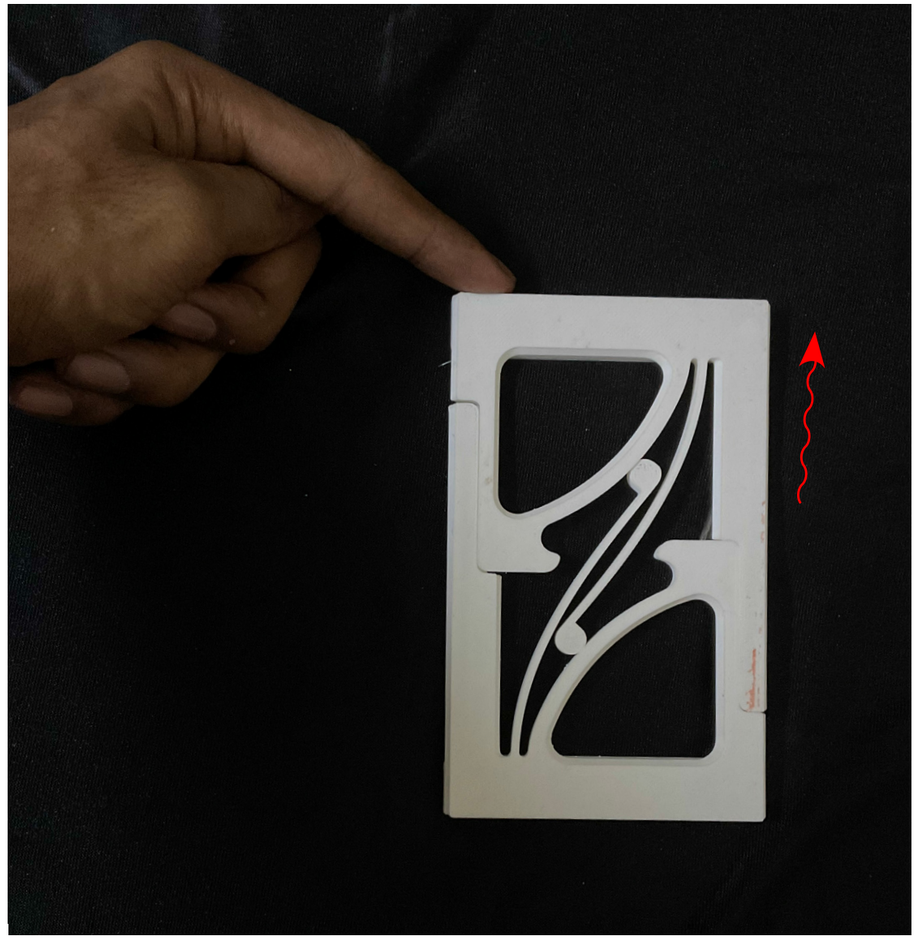


8.1.7.Compliant Mechanism Exploration

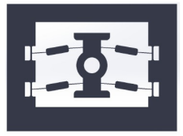
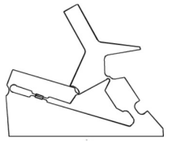
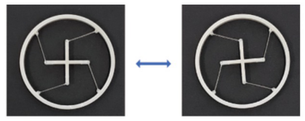
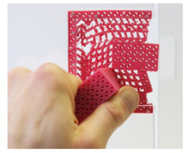
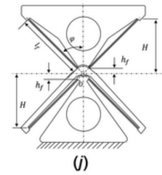
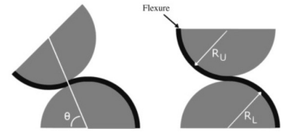
Constant force mechanism.







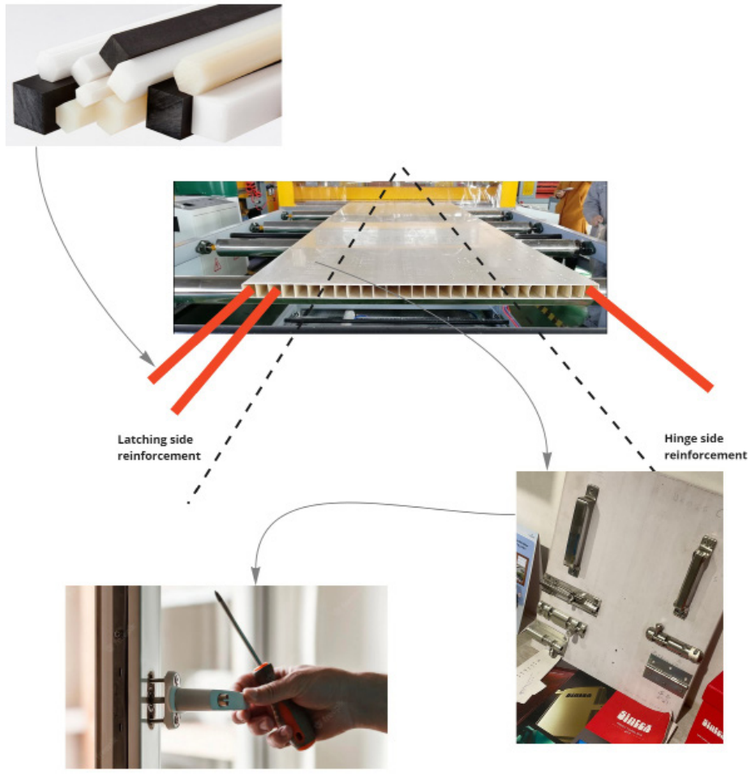
8.2 .Mapping of potential mechanisms as a hardware after Exploration

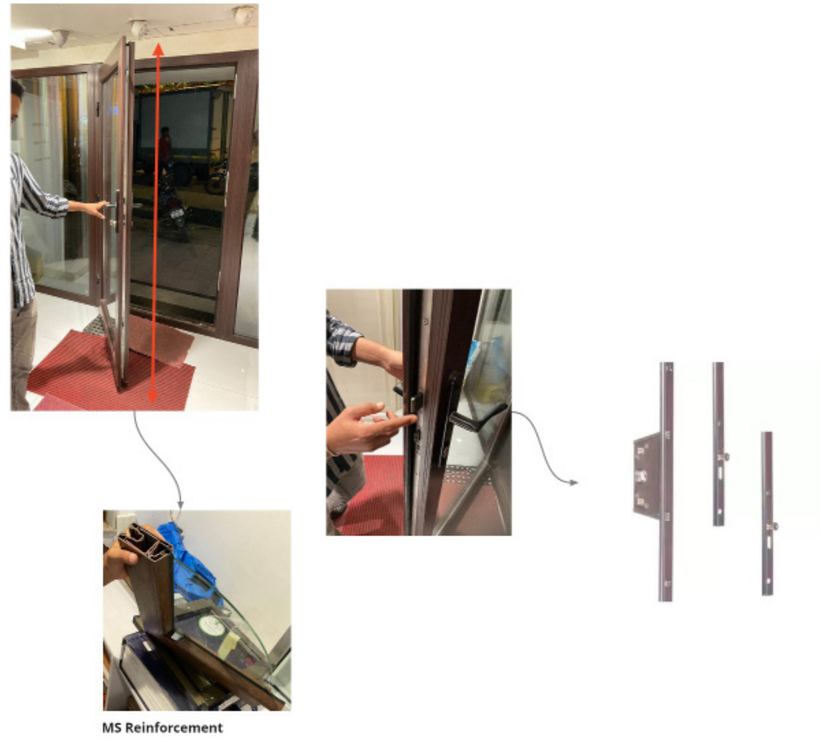
	BISTABILTY			CONSTANT FORCE			FLEXURE	
	AIXIAL BISTABILITY	**BISTABLE SWITCH**	**ROTATIONAL BISTABILITY**	**COMPLIANT ORTHO PLANAR SPRING**	**CONSTANT FORCE MECHANISM**	**METAMATERIAL LATTICE**	**FLEXURAL HINGE**	**CORE JOINT**
MECHANISMS THAT ARE HAVING POTENTIAL FOR DOOR HARDWARES AND EASY MANUFACTURING PROCESS								
HANDLE		**Behavioral Similarity 2/5** **Application Possibility 3/5** Motion can be used for handle latching	**Behavioral Similarity 4/5** **Application Possibility 3/5** Rotational motion of lever handle is seen		**Behavioral Similarity 2/5** **Application Possibility 3/5** Motion can be used for handle latching	**Behavioral Similarity 5/5** **Application Possibility 4/5** Rotational motion of lever handle is similar in this case		
LATCH	**Behavioral Similarity 5/5** **Application Possibility 4/5** • Similar motion of the barell bolt latch • Good haptics • Reduced motion	**Behavioral Similarity 4/5** **Application Possibility 4/5** • Similar motion of the barell bolt latch • Good haptics • Reduced motion	**Behavioral Similarity 2/5** **Application Possibility 3/5** • Motion of the barrell bolt latch NO NOT SEEN • Good haptics		**Behavioral Similarity 4/5** **Application Possibility 3/5** • Motion of the barell bolt latch NO NOT SEEN • Good haptics and motion • best suits for handle latch	**Behavioral Similarity 2/5** **Application Possibility 2/5** • Motion of the barrel bolt latch NO NOT SEEN • bad haptic		
STOPPER	**Behavioral Similarity 3/5** **Application Possibility 2/5** • motion is different • Good haptics • strenght is doubtful as a stopper	**Behavioral Similarity 2/5** **Application Possibility 2/5** • motion is little similar • Good haptics • strength is doubtful as a stopper		**Behavioral Similarity 4/5** **Application Possibility 4/5** • similar application to that of a magnetic stopper • Good haptic • spring provides suspension	**Behavioral Similarity 4/5** **Application Possibility 4/5** • spring force can be used for seamless stopping • bad haptic		**Behavioral Similarity 2/5** **Application Possibility 3/5** • spring force can be used for stopping • bad haptic	
HINGE							**Behavioral Similarity 4/5** **Application Possibility 3/5** • motion is little similar • flexural • strength is doubtful as a hinge	**Behavioral Similarity 5/5** **Application Possibility 4/5** • motion is similar • easy assembly
DOOR SPRING				**Behavioural Similarity 4/5** **Application Possibility 2/5** • motion is little similar • flexural • remodelling is needed for using a spring	**Behavioral Similarity 4/5** **Application Possibility 3/5** • motion is similar • flexural	**Behavioral Similarity 3/5** **Application Possibility 2/5** • motion can be achieved • flexural	**Behavioral Similarity 4/5** **Application Possibility 3/5** • motion can be achieved • flexural	**Behavioral Similarity 3/5** **Application Possibility 2/5** • motion can be achieved • strength is less compairitively to generate force to operate

Bad potential as particular hardware moderate potential to be that particular hardware Good potential to be a hardware

8.3 Concept

The first concept is generated from the extisting framework of the door, where the plastic door will have reinforcement . And the hardwares are screwed to bind with the door.





- Seperate PLastic reinforcement
- Hardwares are to be screwed to the door

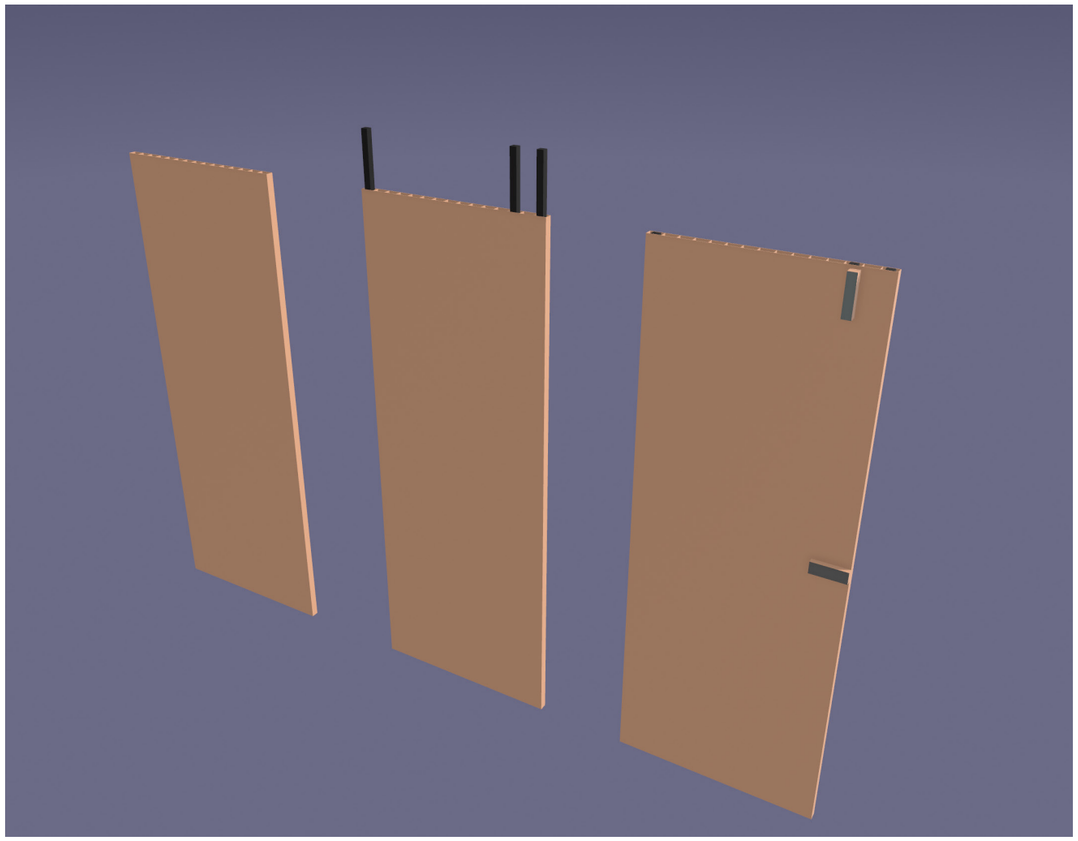
Concept from Existing product Gap

Creating an integrated plastic reinforcement cum hardware for affordable range door.

- Metal Reinforcement cum hardware
- Integrated hardware

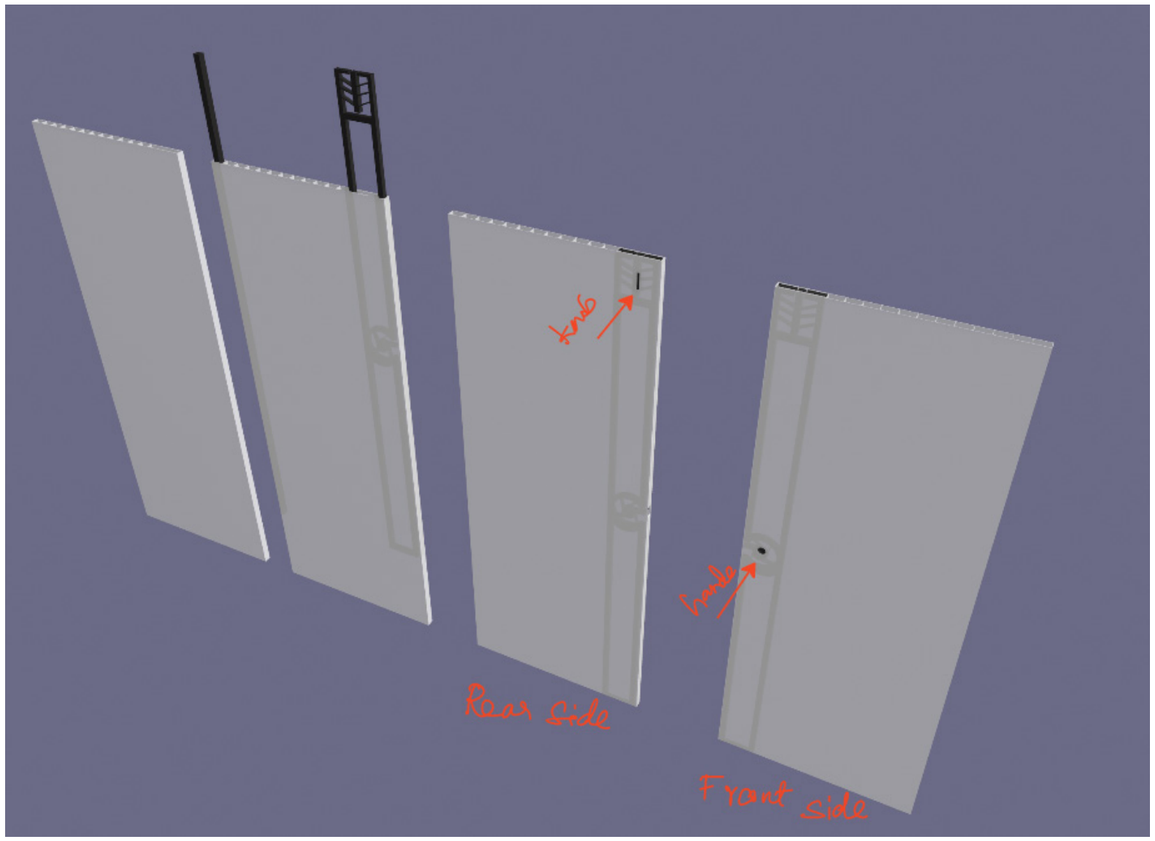
8.3 Concept from Existing product Gap-

Creating an integrated plastic reinforcement cum hardware for affordable range door.



EXISTING METHOD

Plastic rods are inserted on ther hollow PVC Panels and the the hardwares are then screwed through the surface and through the reinforcement insert.



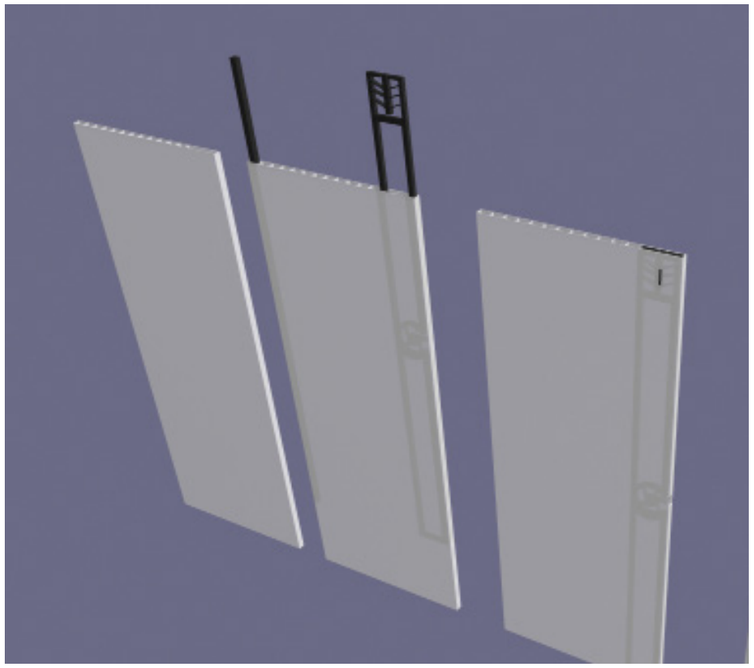
PROPOSED METHOD - 1

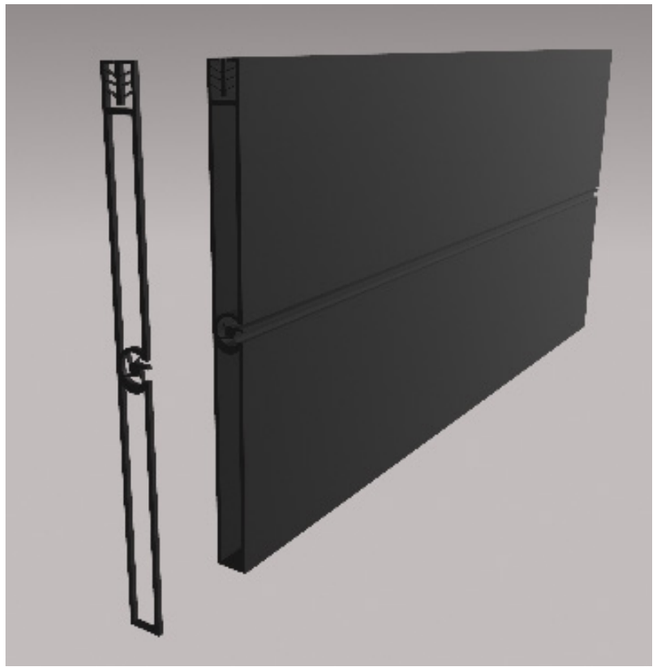
Hardware cum reinforcement which are made of PP Plastic, manufactured as a single block through extrusion moulding.

These hardwares are then integrated in the custom hollow profile door and the handle and the knob are fixed externally. the design of an integrated hardware system with a top-inserted reinforcement for plastic doors

8.3 PROPOSED METHOD - 1

Hardware cum reinforcement which are made of PP Plastic, manufactured as a single block through extrusion moulding. These hardwares are then integrated in the custom hollow profile door and the handle and the knob are fixed externally.





CONS OF THIS METHOD

Doesnot uses the existing Door section profile.

Hardware manufacturing should have given a extra thought.

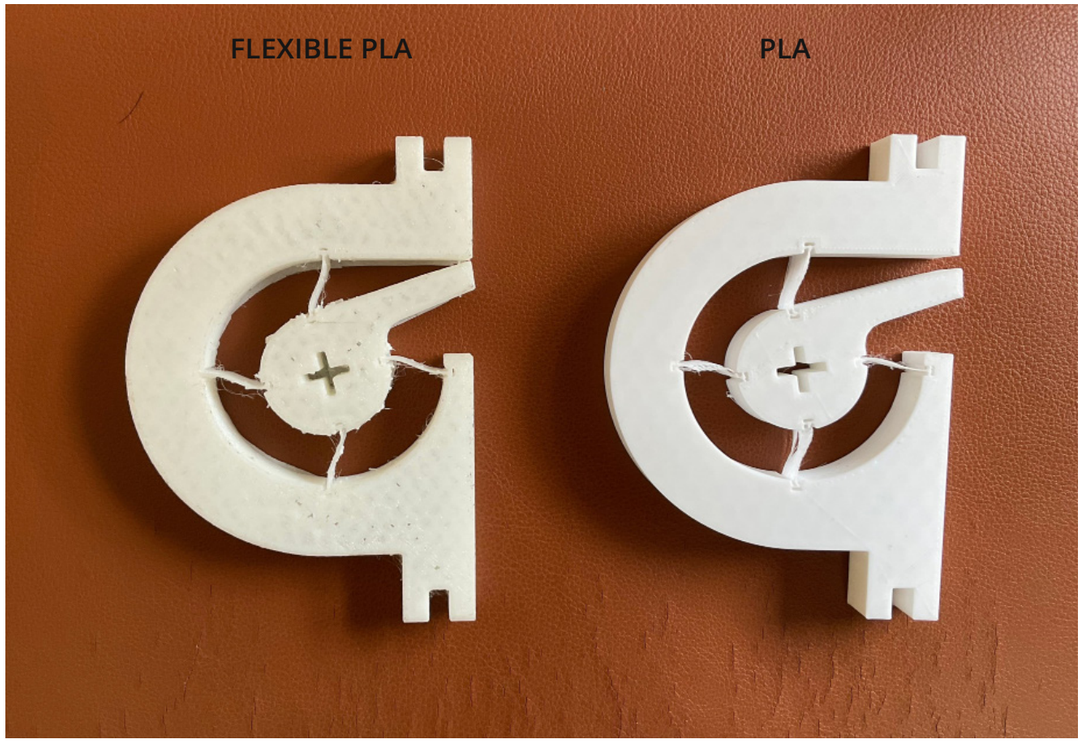
8.4 Initial Prototyping with different Materials for testing.

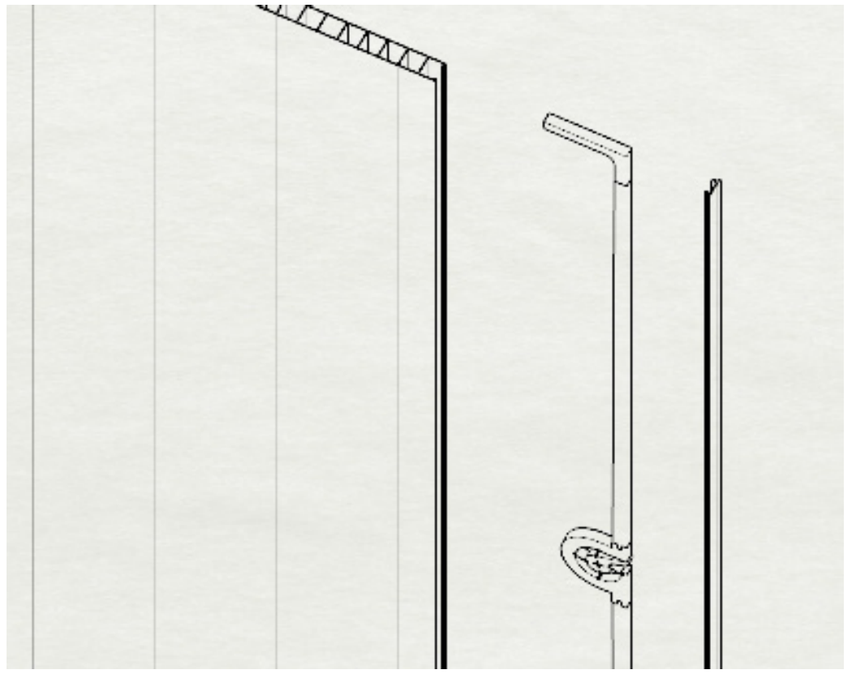
NOTE:

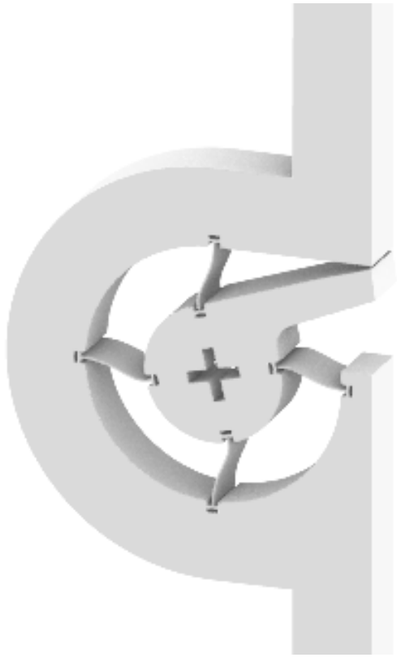
The thickness of the flexural member to be increased.

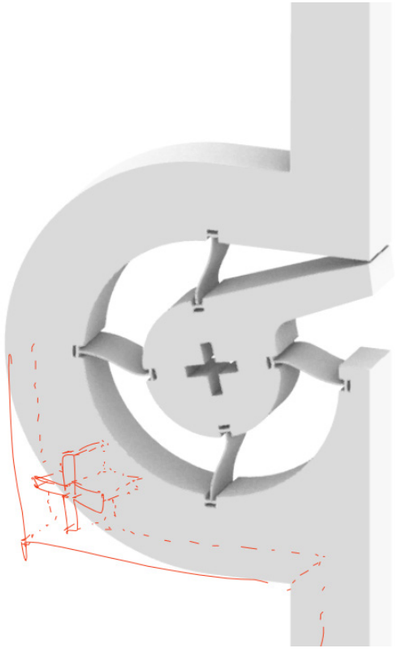
Both the flexible and normal PLA suits for prototyping

Joinery groove to be reworked.









8.5 Development of hardware integrated System

Designing an integrated hardware system for plastic doors with a reinforced insert is a feasible approach that can offer several benefits. Few criterias to make it really feasible are

Material Selection: Choose a suitable high-quality high elastic modulus plastic material for compliant hardware and recycled hard plastics for the reinforcement insert. This ensures compatibility and consistent performance.

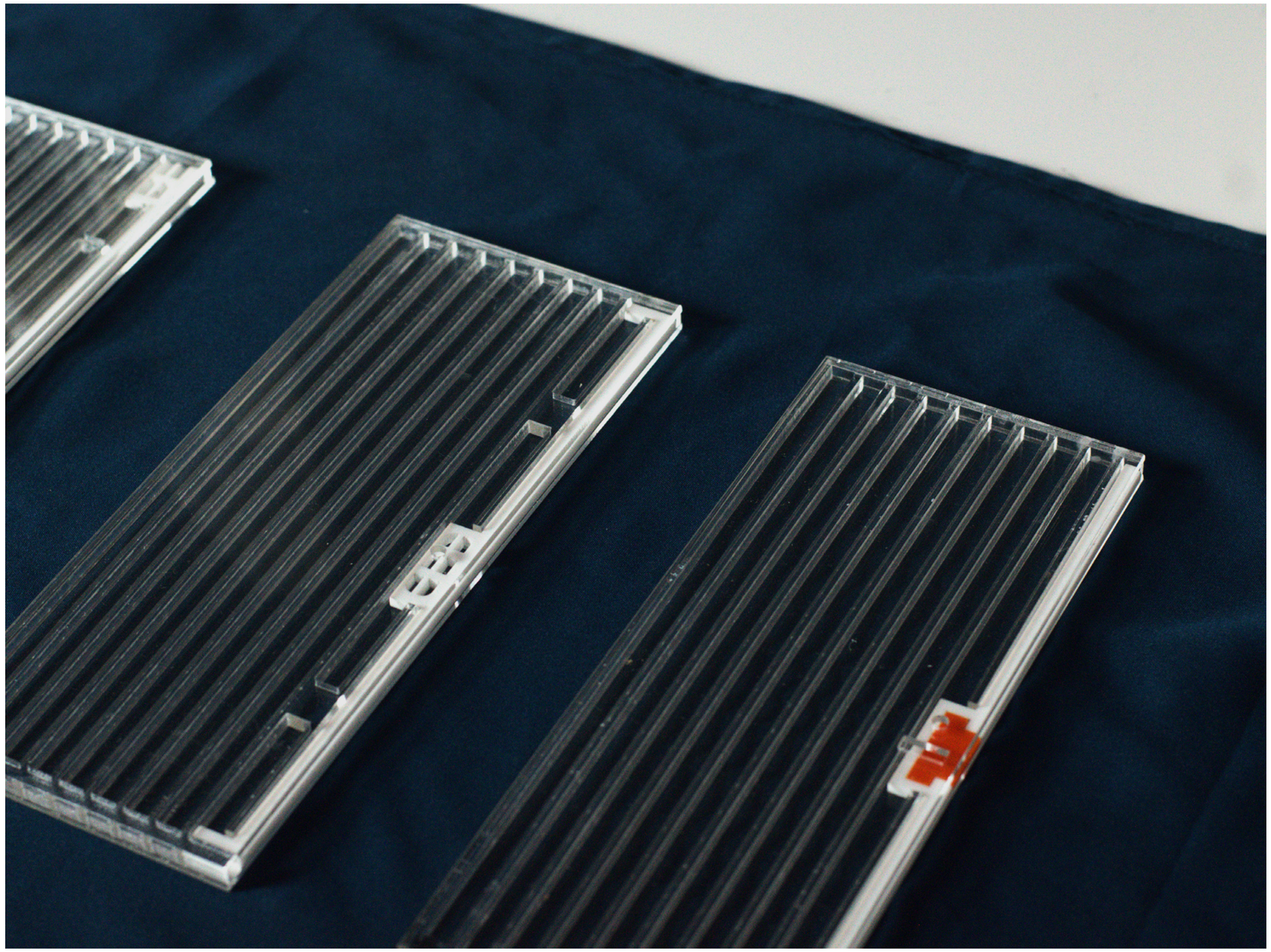
Reinforcement Shape: Design the reinforcement insert to match the door's shape and dimensions, allowing it to be easily inserted into the door's core.

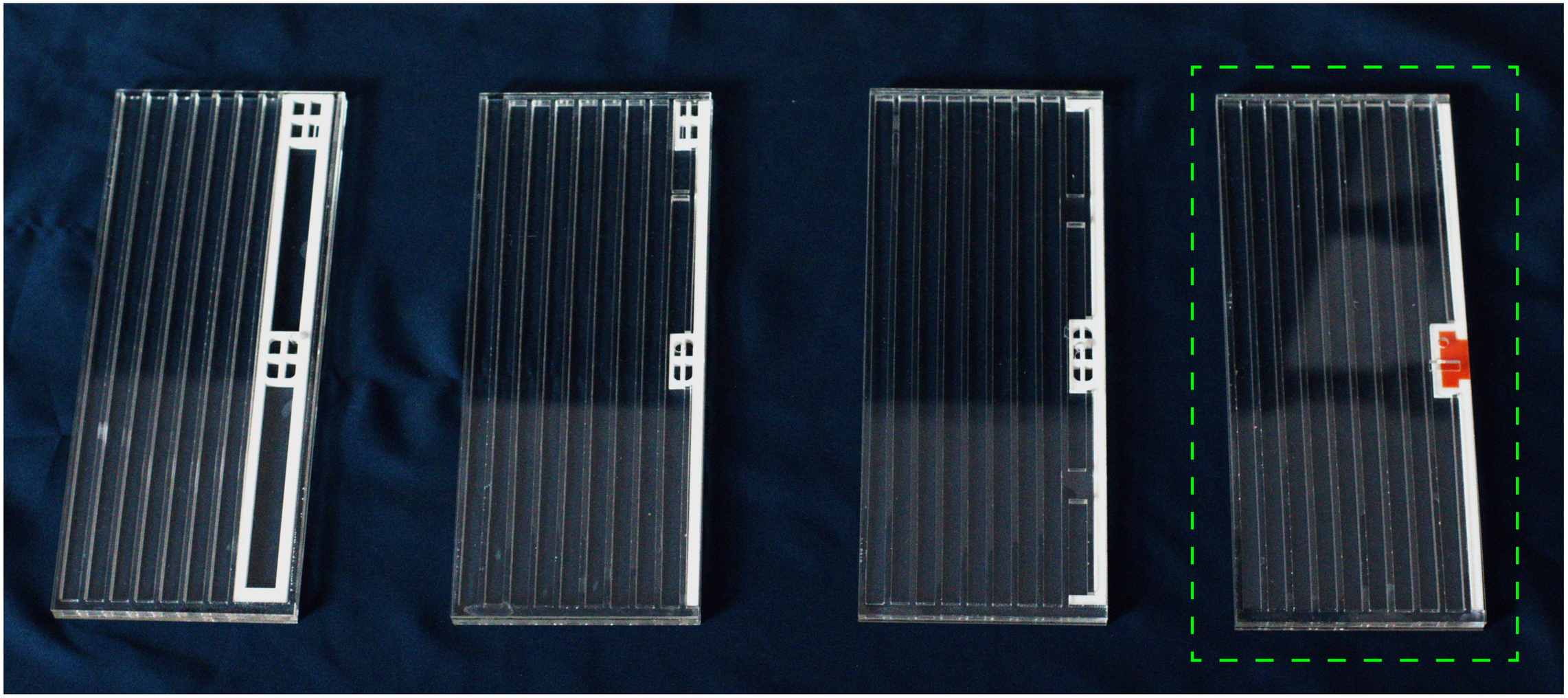
Easy Insertion: The top insertion method simplifies the assembly process. By inserting the reinforcement from the top or Side we can avoid complex installation steps and potential damage to the door's surface.

Integration with Hardware: Ensure that the reinforcement insert has pre-designed slots and anchor points to seamlessly integrate the comploant door hardware component. This integration will give the door a clean and modern appearance.

Distribution of Forces: The reinforcement insert should be strategically designed to distribute forces evenly throughout the door, providing stability and preventing localized stress points.

Consideration for Weight: Take into account the additional weight of the reinforcement insert to ensure that the overall door remains lightweight and easy to handle.





Initial Proposed Idea

Integrated hardware system manufactured with a top-inserted reinforcement for plastic doors as a single block with single material.

This system needs completely new door panel design which is less feasible, So jury suggested to design hardware to fit the existing door panel design in market.

Development 2

Integrated hardware system (top latch and mid latch not combined) manufacture along with a side-inserted reinforcement for plastic doors with same material

This system has manufacturing dificulties.

Development 3

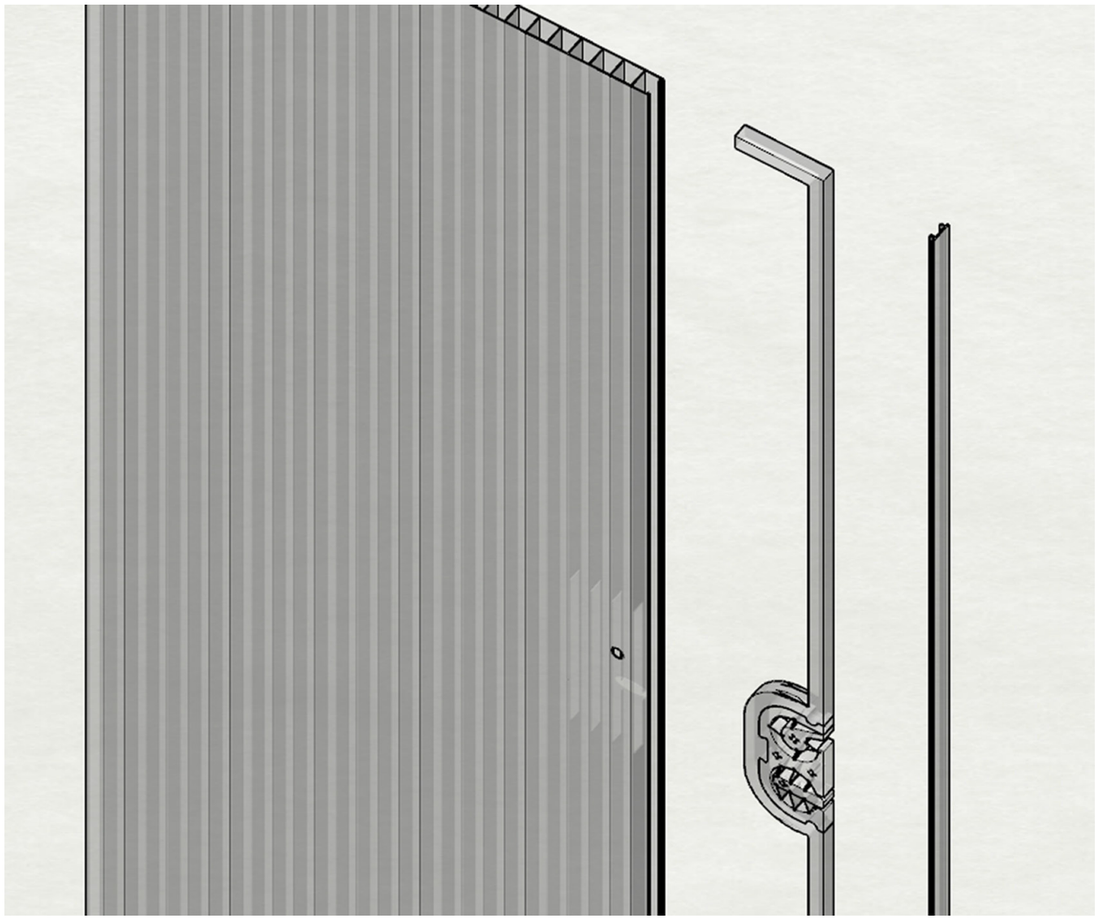
Integrated hardware system (with top latch and mid latch combined at middle) with a side-inserted reinforcement for plastic doors

This system has both the reinforcement insert and the compliant hardware of same material, which is not very functional and maerial wastage is an issue.

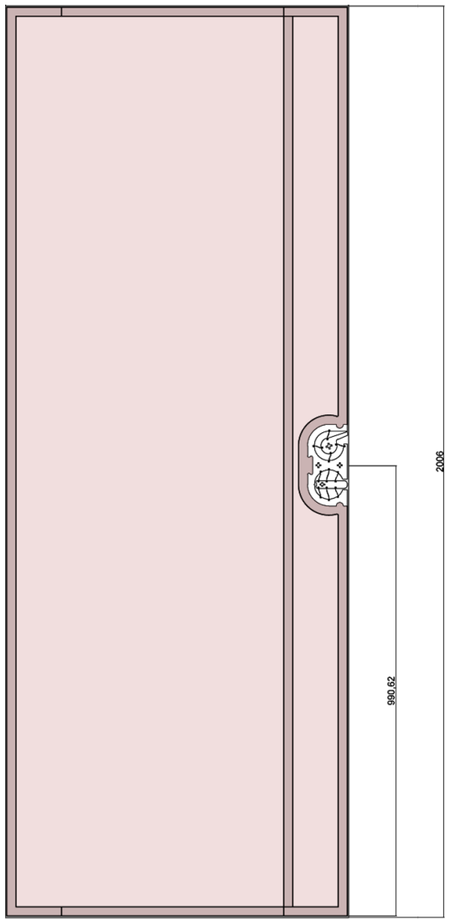
Final System Development 4

Integrated hardware system (combined hardware manufactured seperately with its champion material) and plastic doors reinforcement insert has pre-designed slots and anchor points to seamlessly integrate the door's hardware component at the mid height.

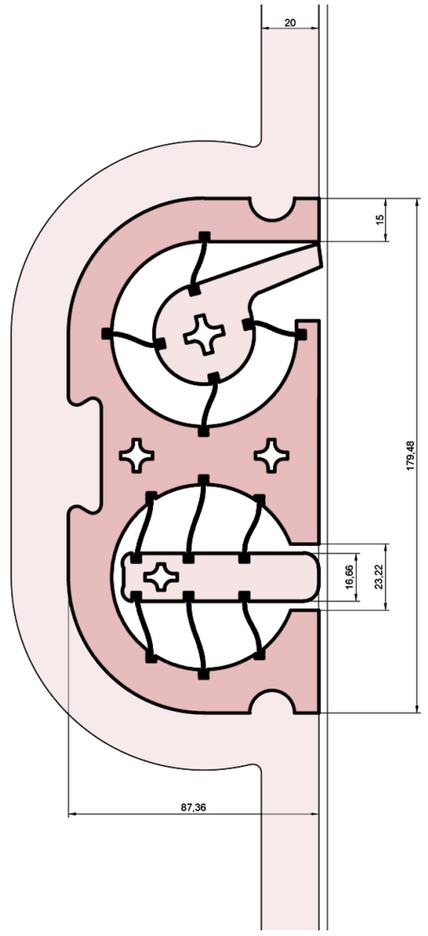
9 Final Hardware system Plan Iteration 1



Newly design reinforcement houses the compliant mechanism at desired height in the middle and also fits along the door side.



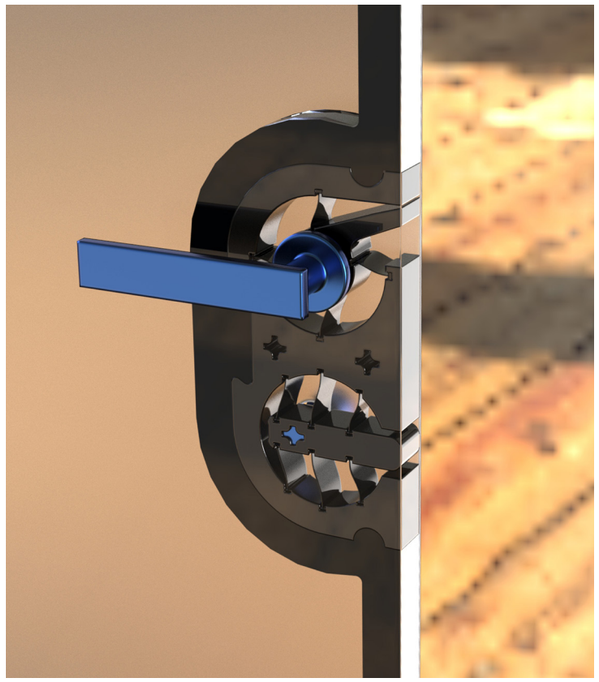
Compliant mechanism based hardware is Intergrated along reinforcement. which is not visible from the outside.

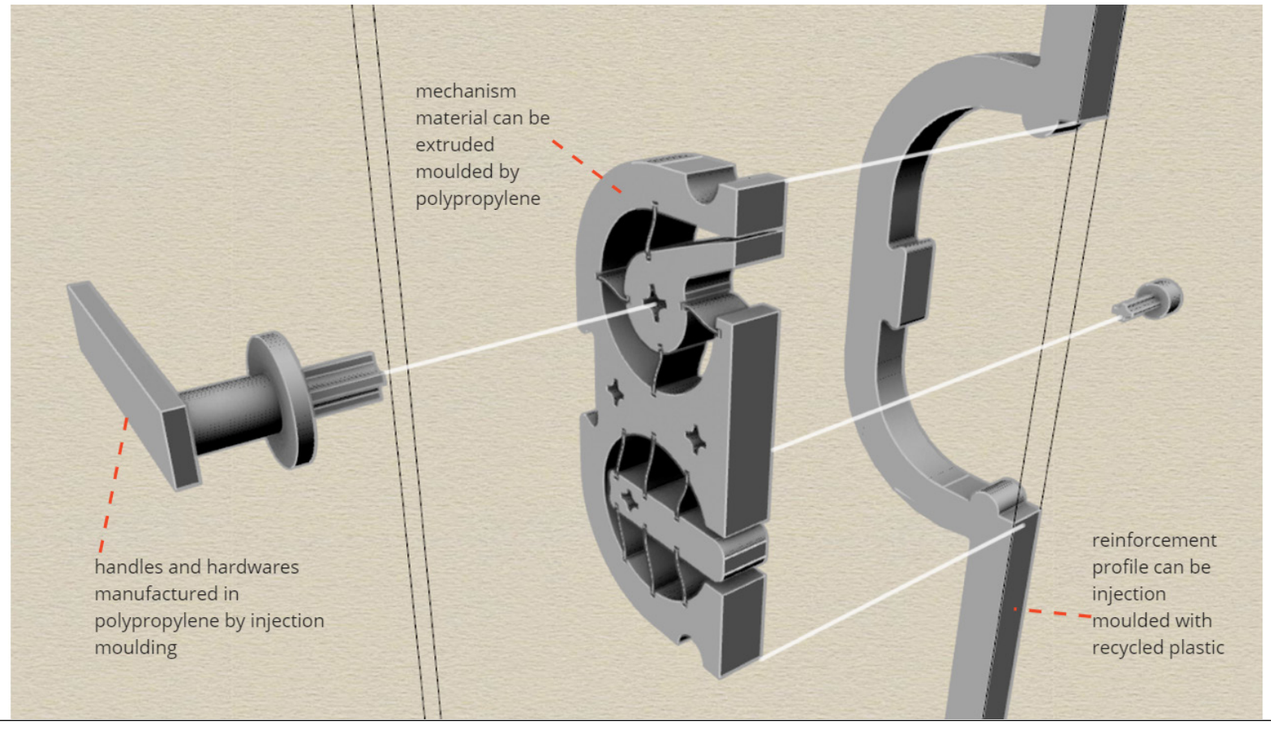


Hardware mechanism will be pluged in the speacially designed reinforcement bar with groove.Hardware is manufactured seperately with high tensile strength Polypropylene.

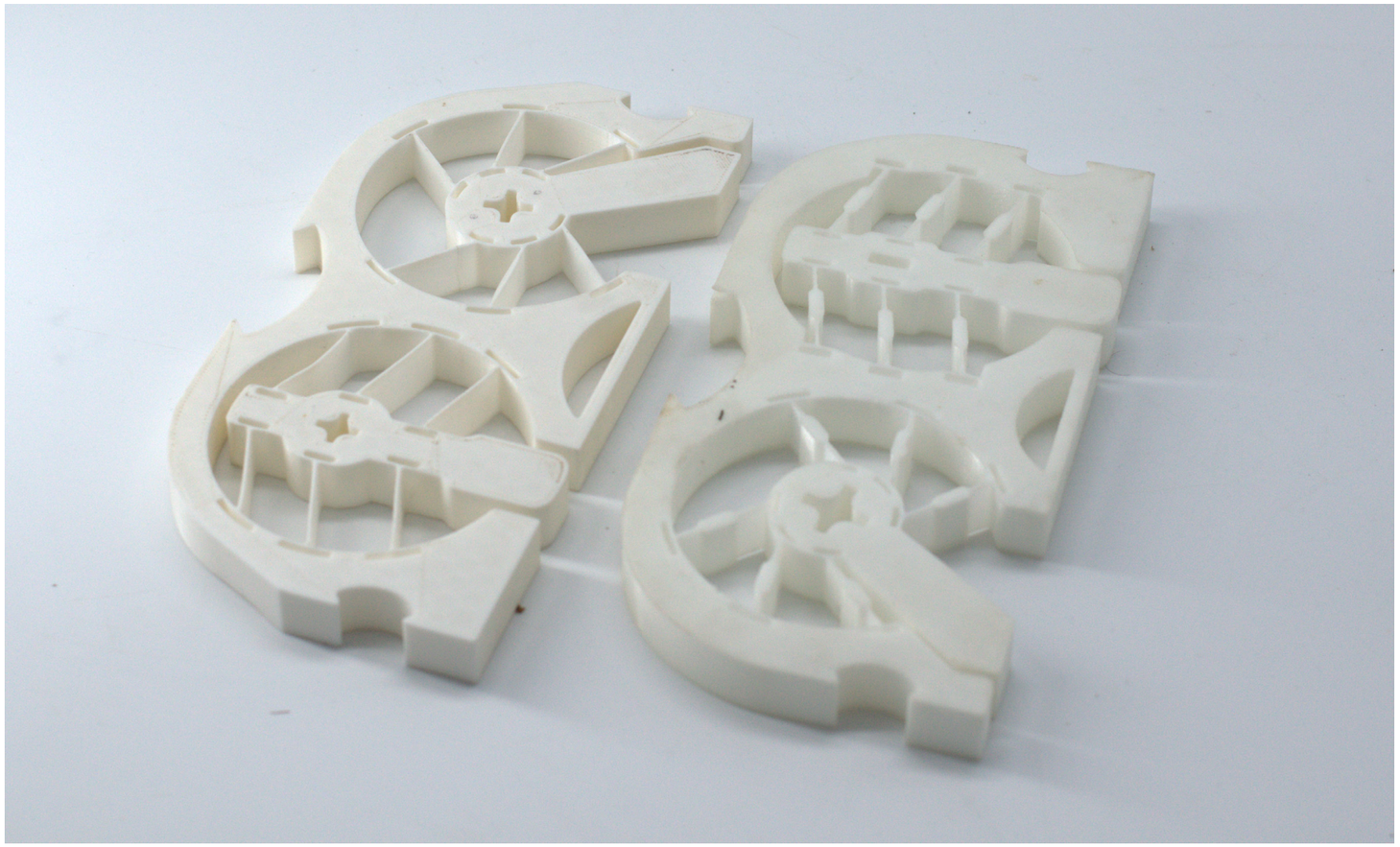
9.2 DETAILS OF Iteration 1

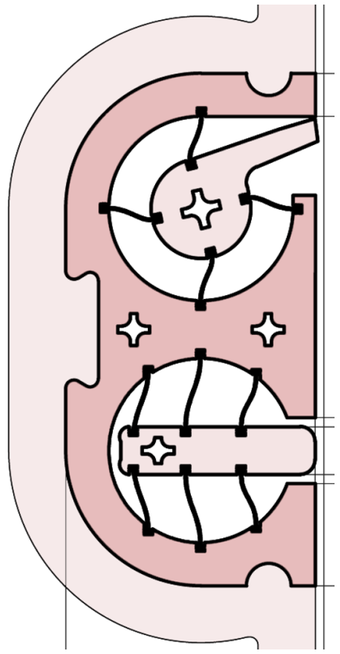
From the first iteration it was noted that it had some revision on the hardware layout as well as some revision in flexural members to make bistable function more efficient.



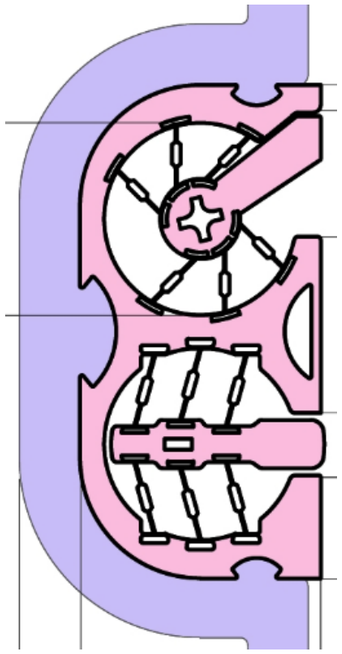


9.3 Final Design





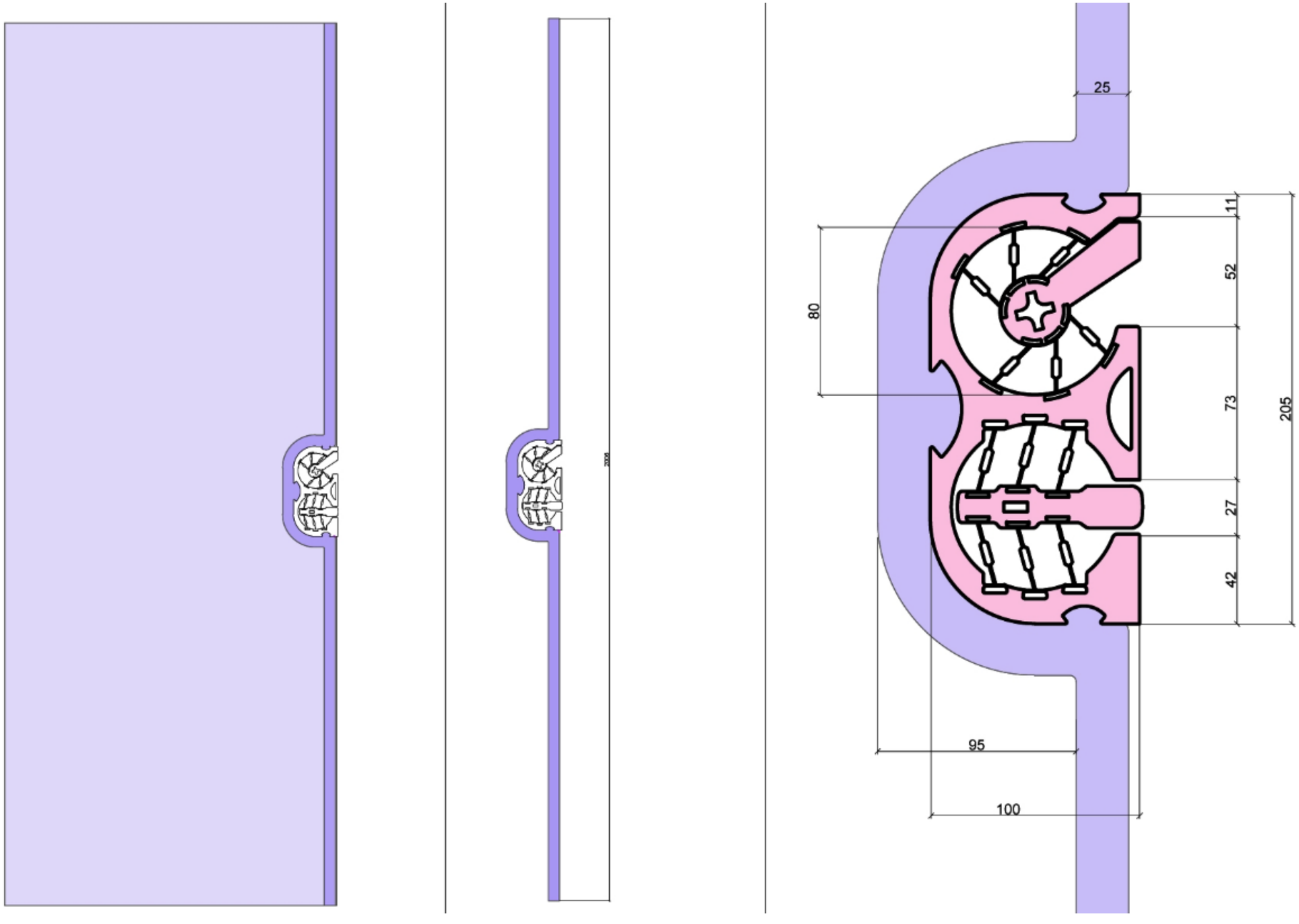
Previous iteration



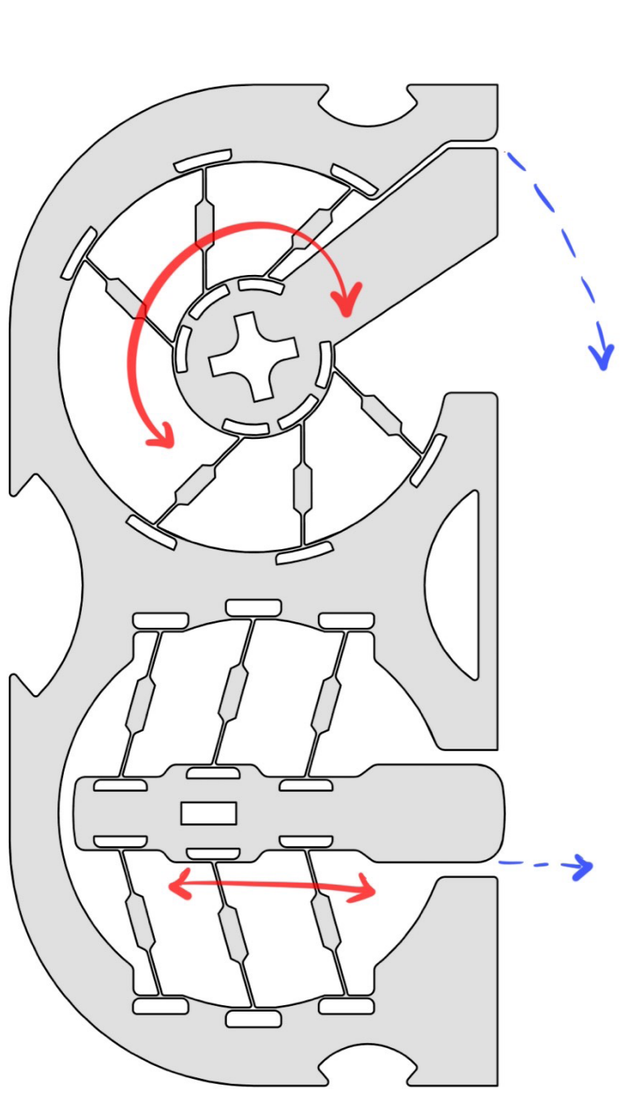
Final Design

Flexural members are revised and redesigned with rigid members inbetween for better bistabilty.

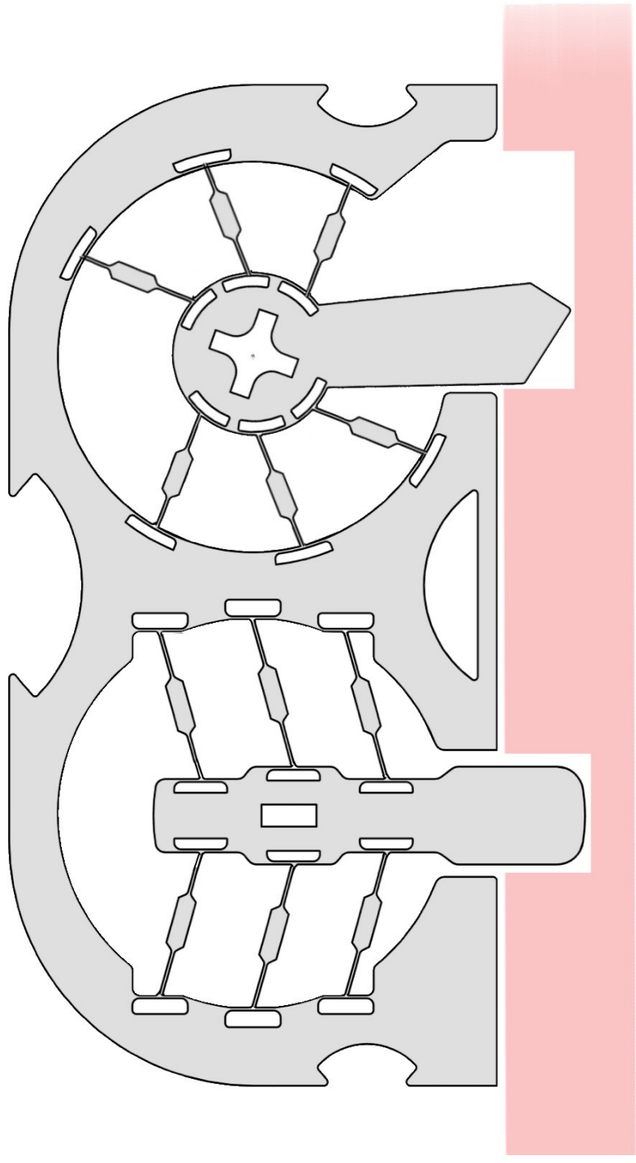
9.3 Final Design _ Dimensions



9.3 Final Design _ Bistable positions

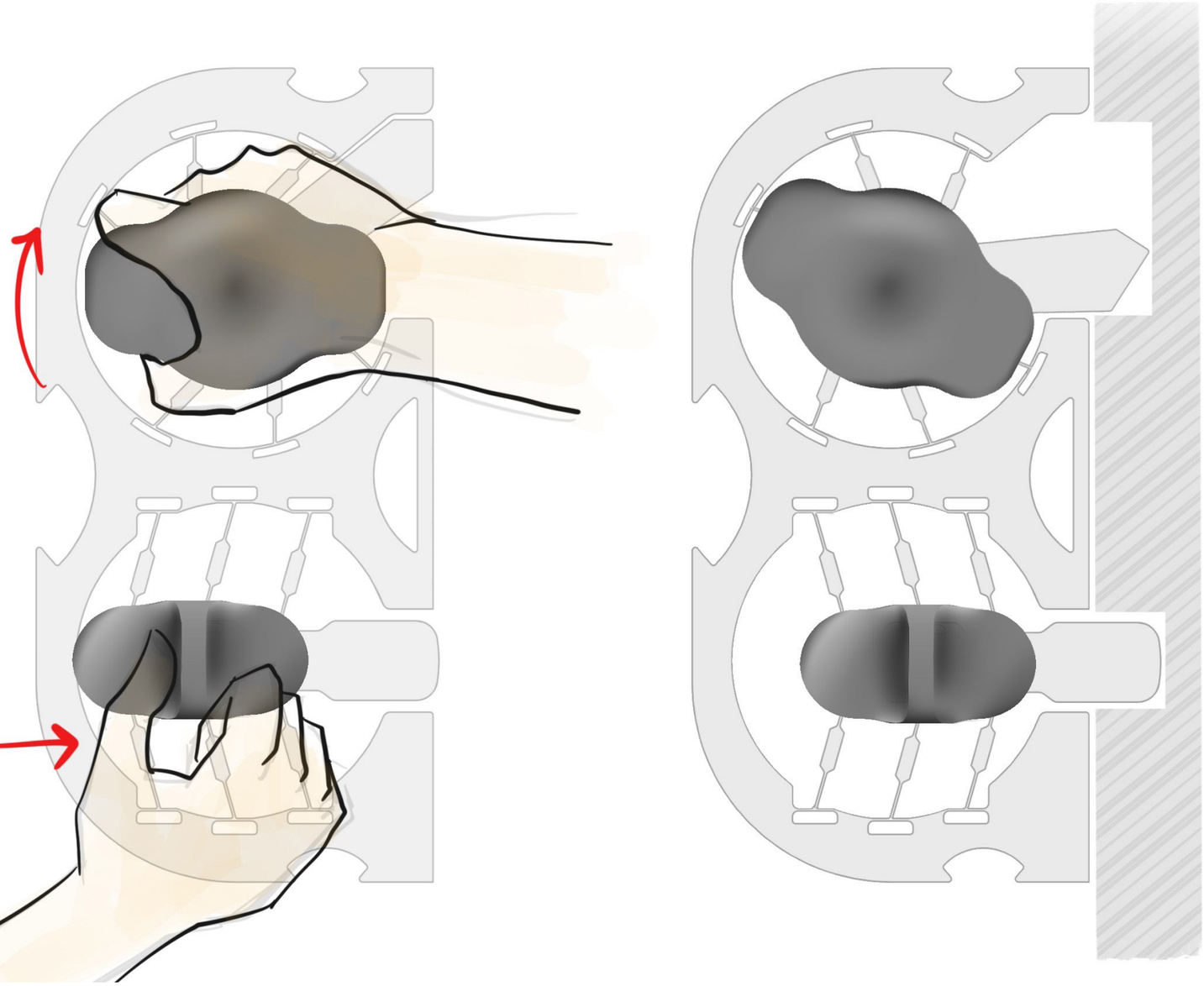


Both lever handle and latch in open position



Position of Both lever handle and latch in closed/ locked with door frame

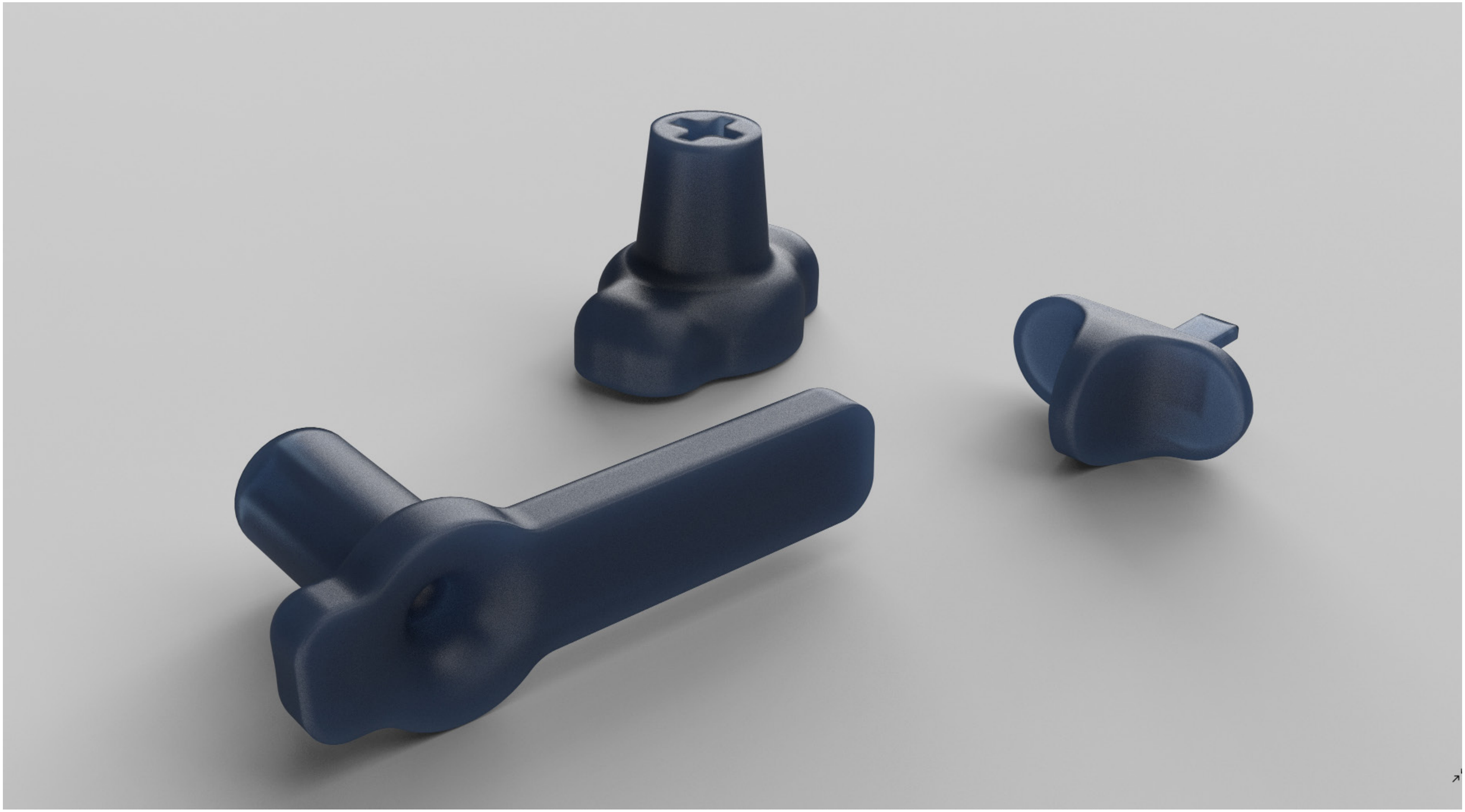
9.3 Final Design _ Operation



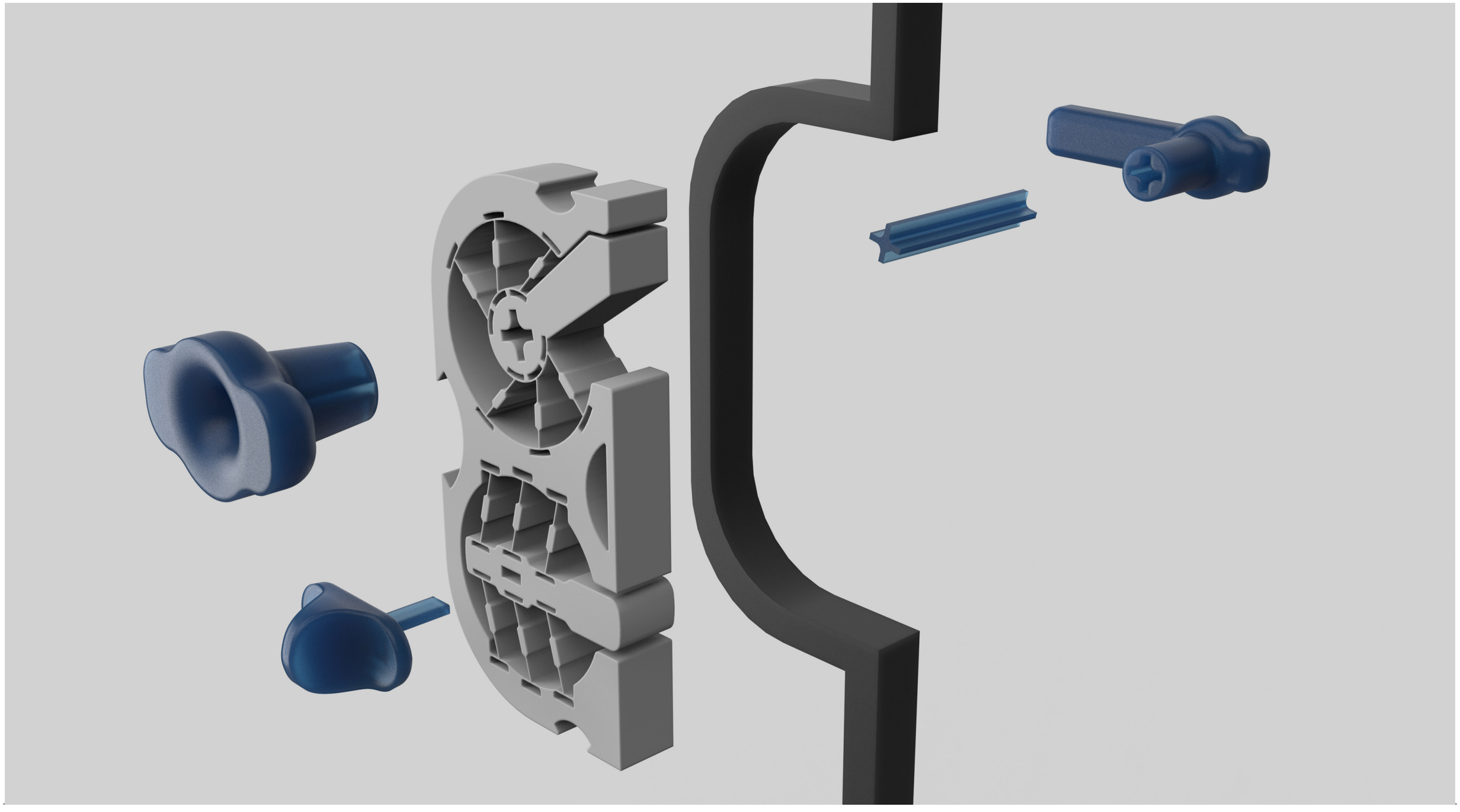
Door open position

Door closed position

9.3 Final Design_ knob and handle design

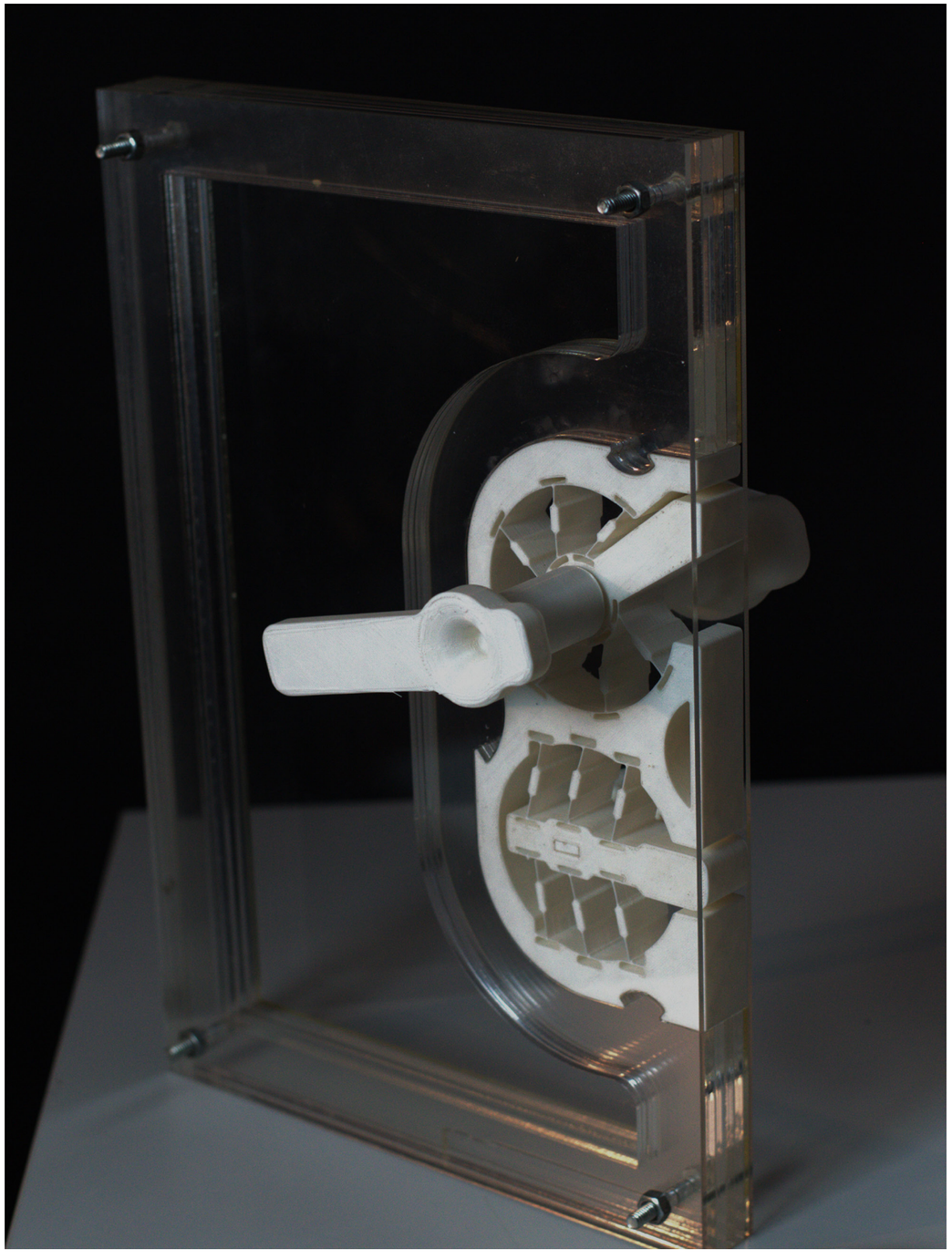


9.3 Final Design_ Exploded View

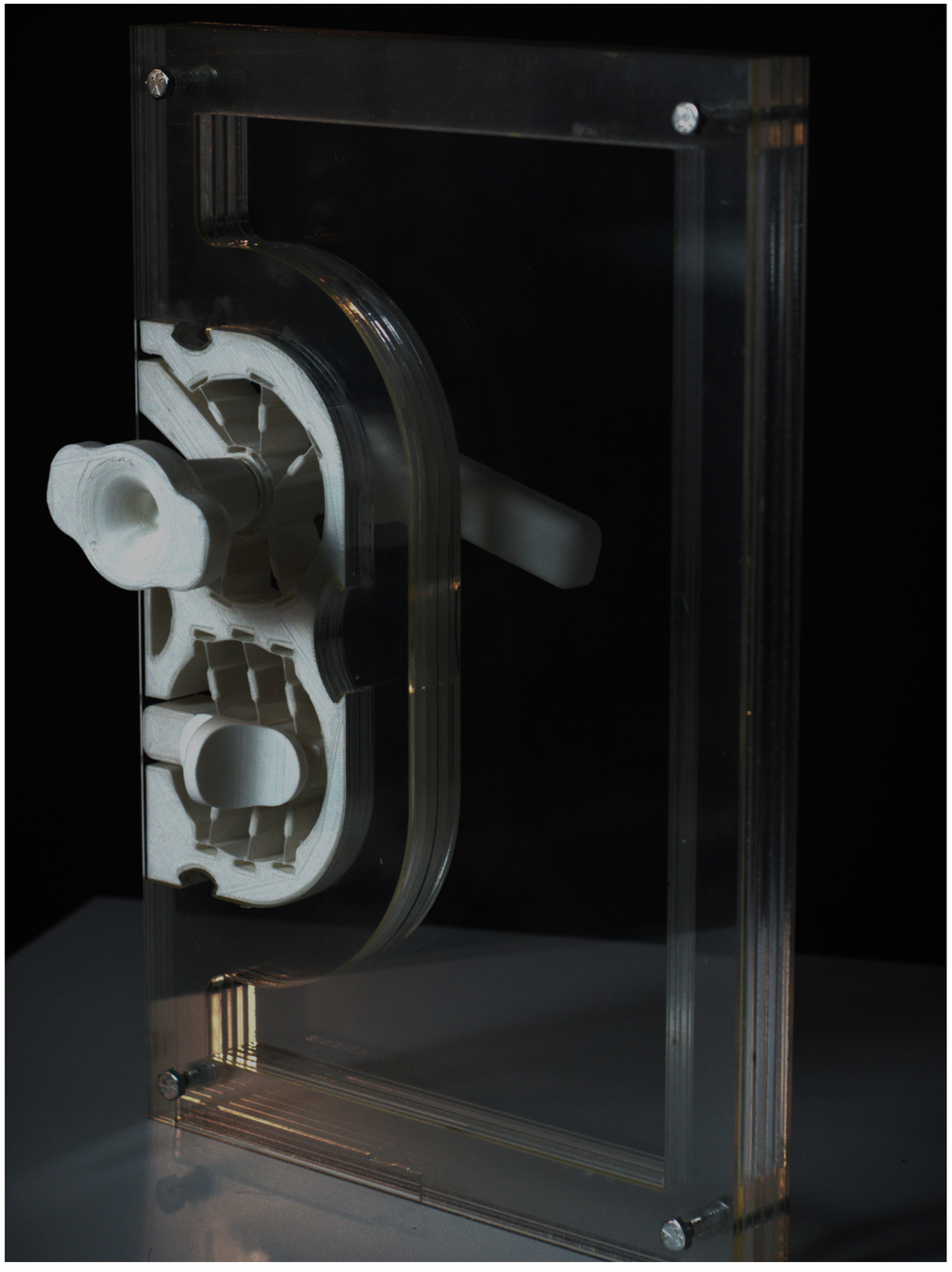


9.3 Final Design_ After Installation

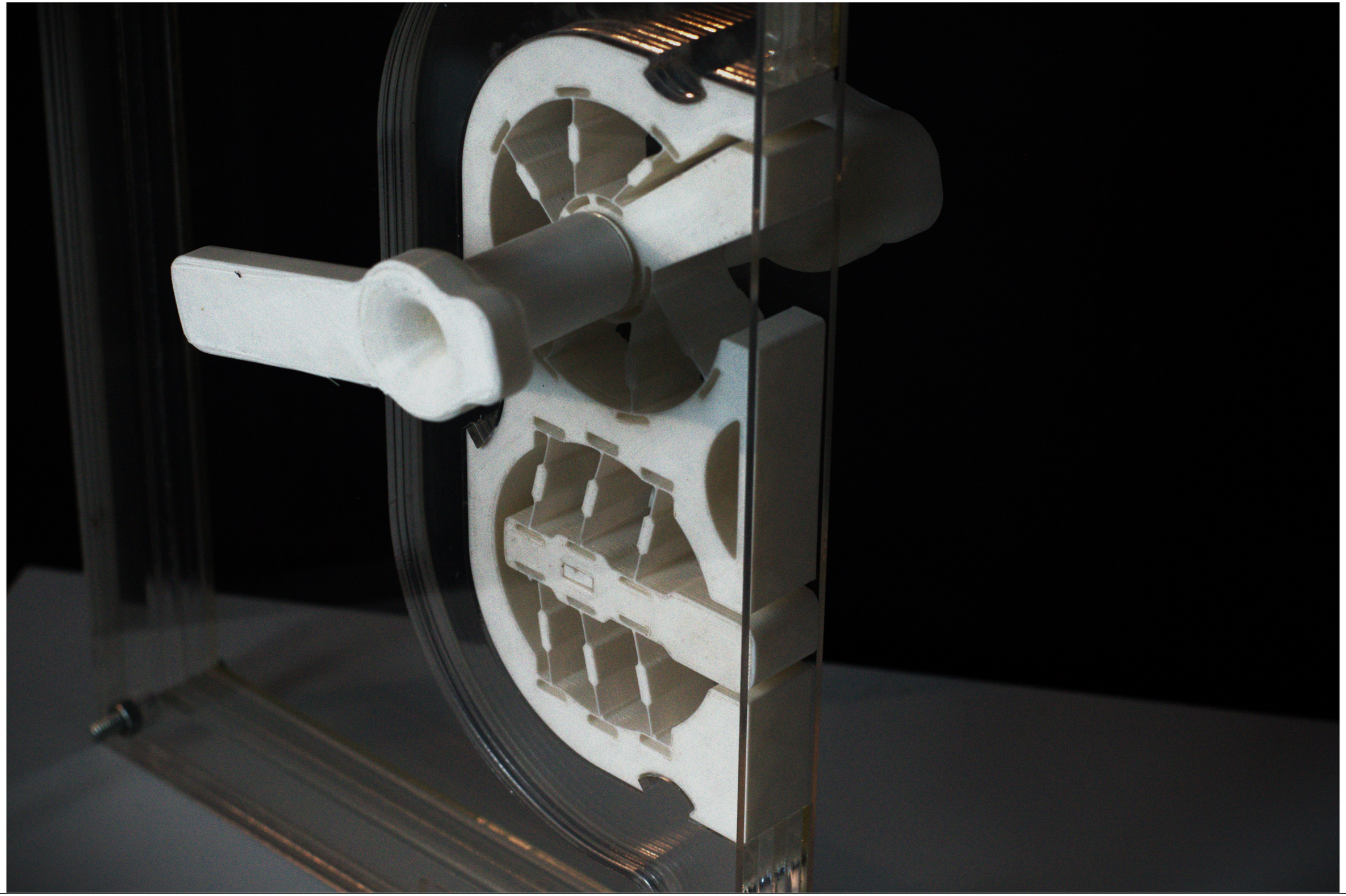
9.3 Final Design_ Prototyping

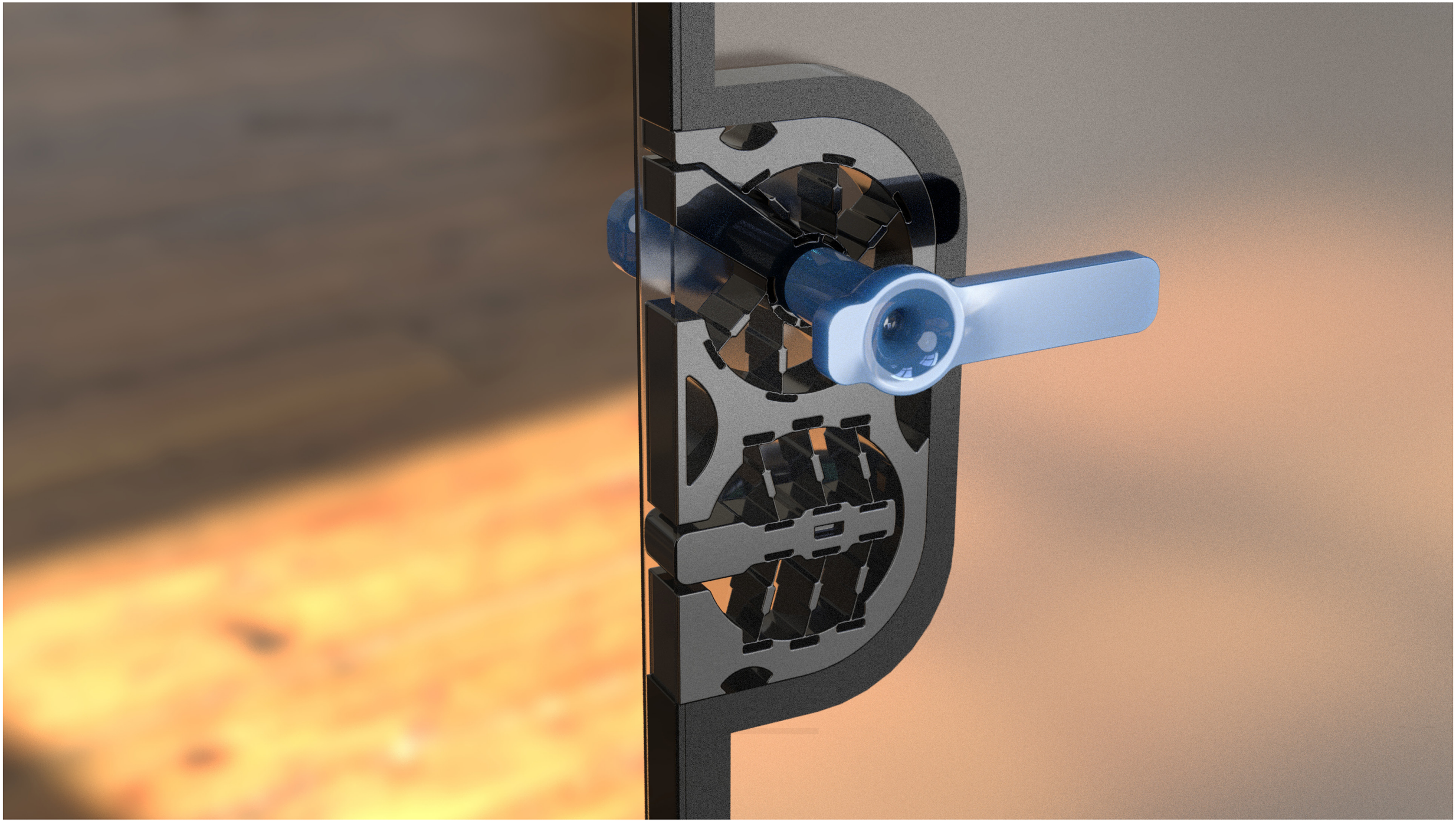


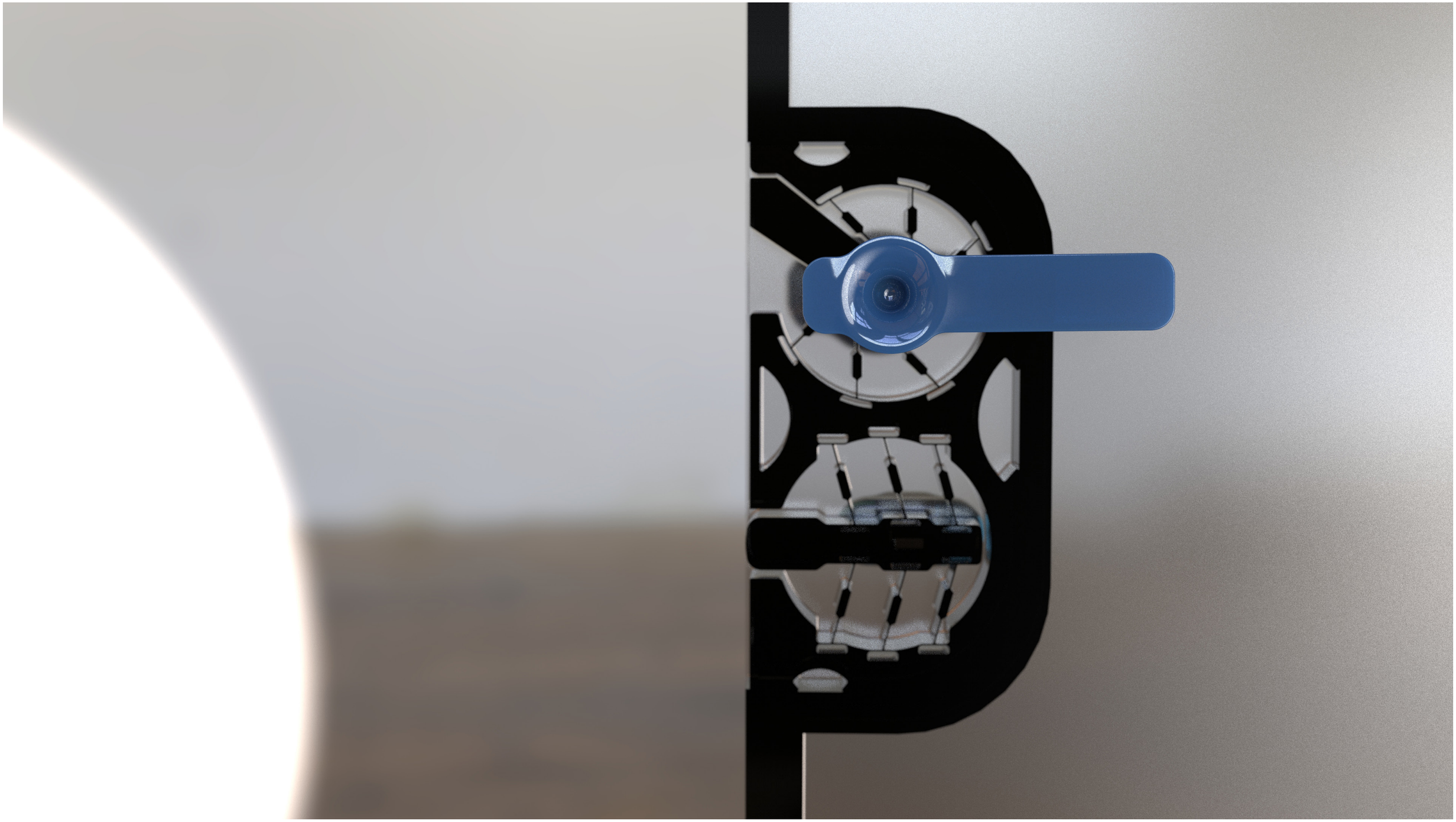
FRONT SIDE OF DOOR (Facing outside the lavotary space)



REAR SIDE OF THE DOOR (Facing inside the lavotary space)







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