



DESIGN TECHNOLOGY INTERNAL ASSESSMENT HIGHER LEVEL

International Baccalaureate

50 pages (3894words)

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Criterion A

Situation and problem

Cosmetic bottles leaking have been an issue due to its weak structure and material. People who frequently travel internationally by airplane with cosmetics in their hand luggage are restricted to bring a 100 mL plastic bottle per cosmetic item inside a 1 Litre plastic bag according to the European Union luggage restriction website. Cosmetic bottles which leak cause teenage girls particularly to become stressed because they prefer bringing their own favourite trusted cosmetic brands from their home country as opposed to buying cosmetics in a foreign country. Suitcases are a material staple item for travellers, so when they find that a cosmetic product leaks in their suitcase, it becomes an issue when the traveller arrives to their destination. The traveller may not be able to access supplies to clean the spill when they arrive to their destination causing stains and unwanted smells. My target consumer base will be focused for teenage travellers who frequently fly alone within the European Union. I will be focusing on preventing the cause of leaks and stains from cosmetic products for generic sized cosmetic bottles. The design will be developed to modify a generic 100 mL cosmetic bottle which is the most frequently bought online and in stores to become more protective and structured.

Primary and secondary research:

Fig 1.6 Damaged suitcase material from spilled cosmetics



Ineffective ways of how market currently protects cosmetic bottles



Questionnaire: Aimed to understand how teenage boarding girls around Europe who travel frequently within the European Union pack their cosmetics.



Fig 1.1 Evidence of hand luggage restrictions from European Union website

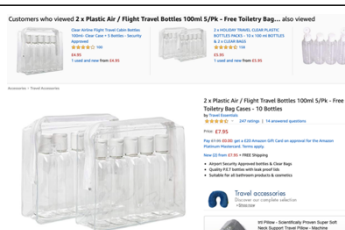
When travelling by plane from an airport in the EU, you should keep in mind certain security requirements when packing and boarding:

- **Liquids** carried in the aircraft cabin such as aerosols, drinks, toothpaste, cosmetic creams or gels must be carried in a transparent plastic bag - maximum capacity 1 litre - and no container may hold more than 100 ml. Liquid containers larger than 100 ml must be placed in checked baggage. The volume restriction does not apply to medicines and baby food.

Online survey: Answered by 50 teenage girls in boarding school who travel monthly



Top result Amazon search for generic travel size cosmetic bottles



All participants use same material of bottles for when travelling and found it difficult to fit their cosmetics into a 100 mL bottle without the bottle spilling/breaking in the travelling process. 6/7 participants all feel stressed about anticipating whether their cosmetic bottles are protected from spilling. 5/7 participants worry that their products will not fit inside the 1 Litre plastic bag at their airport. 4/7 participants have been stopped by airport security to be questioned/checked about their liquid items. 3/7 participants have experienced ruined suitcase material after a leak from travelling with hand luggage.

¹ (Your Europe - Citizens, 2020)

Design brief

Expected outcome

The product must protect a generic sized liquid cosmetic bottle from liquids spilling in luggage. It must be durable to use for multiple travelling experiences.

Broad requirements

Target audience: Teenage boarding girls who frequently travel within the European Union who can feel stress free in an airport security environment. My product will be focused on teenager girls because I have easy access to obtain personal detailed opinions and feedback in boarding school.

Target market: The travelling sector. The product should be readily available in airport shops, lounges, online travel sites.

Major constraints/parameters: The product needs to fit around a 100 mL cosmetic bottle. It must not consume too much space within a 1 L plastic bag according to European Union airport security regulations. There is a limited amount of time, skill and materials due to the purpose of this project being submitted for the IB.

The criteria: The product must protect a popular generic cosmetic bottle and it must be lightweight. It must be compatible to all European Union airport security regulations.

Feasibility:

The product is achievable to produce of the product dimensions being small. Protective airport approved materials are also accessible to me which is safe to use.

Persona map of target users



Design specification

Specification of the prototype	Requirement	Rationale
1. Function	1.1 The product must be able to cover and protect the total surface area of a generic 100mL plastic cosmetic bottle	According to my questionnaire, respondents experienced dents in the plastic material and the lid would pop open. To ensure certainty of protection for these areas of cosmetic bottle, the whole surface area should be covered.
	1.2 The product must be impact resistant to withstand intense forces and shocks of other hard objects in the suitcase	88.89% respondents from my survey said that they found that their cosmetic bottle products are damaged because of how they store in hand luggage it only using the plastic bag. This means that other objects which have impact on the bottle cause damage, and the bottle becomes unusable.
	1.3 The product should absorb the cosmetic in case of leakage	Suitcases are not handled delicately in the airport which is something users have no control over. Medical liquids and cosmetics with strong scents need to have a thicker barrier between the suitcase material and the lid. Preventing a spill from happening is easier than cleaning it up.
	1.4 The product needs to be able to fit inside a 1 Litre plastic bag	The product must fit inside a clear plastic 1L zip-lock bag according to the European airport regulations to "enable security staff to easily see what liquids you have without having to root through a cabin bag" ²
2. Size	2.1 The product must securely fit the surface area and circumferences of a 100mL generic cosmetic bottle	The total height of the 100 mL bottle is 12 cm. The height of the plastic body is 9cm and the lid is 3cm. Different heights radiuses must be accurately measured to fit curved edges, lid and the body of the bottle, ensuring an accurate design. These measurements follow the European Union airport hand luggage laws of liquid allowance.
3. Material selection	3.1 Material must be flexible	Flexibility on two axis is important according to the size and curved shaped edges of the generic size bottle.
	3.2 Material must be thin and lightweight	There is a certain weight limit of hand luggage depending on each airline ³ , so the material should not add any unnecessary weight which could be avoided. A restriction to 1 Litre volume of the plastic bag means that the product must be thin to fit the desired amount of user's essential items inside.
	3.3 Material must be impact resistant and durable	The product must be able to survive after using multiple times throughout the travelling process where objects inside the suitcase are impacting against each other.
		Shock absorbing shapes in a material can protect the cosmetic bottle from being compressed and could

² (Your Europe - Citizens, 2020)

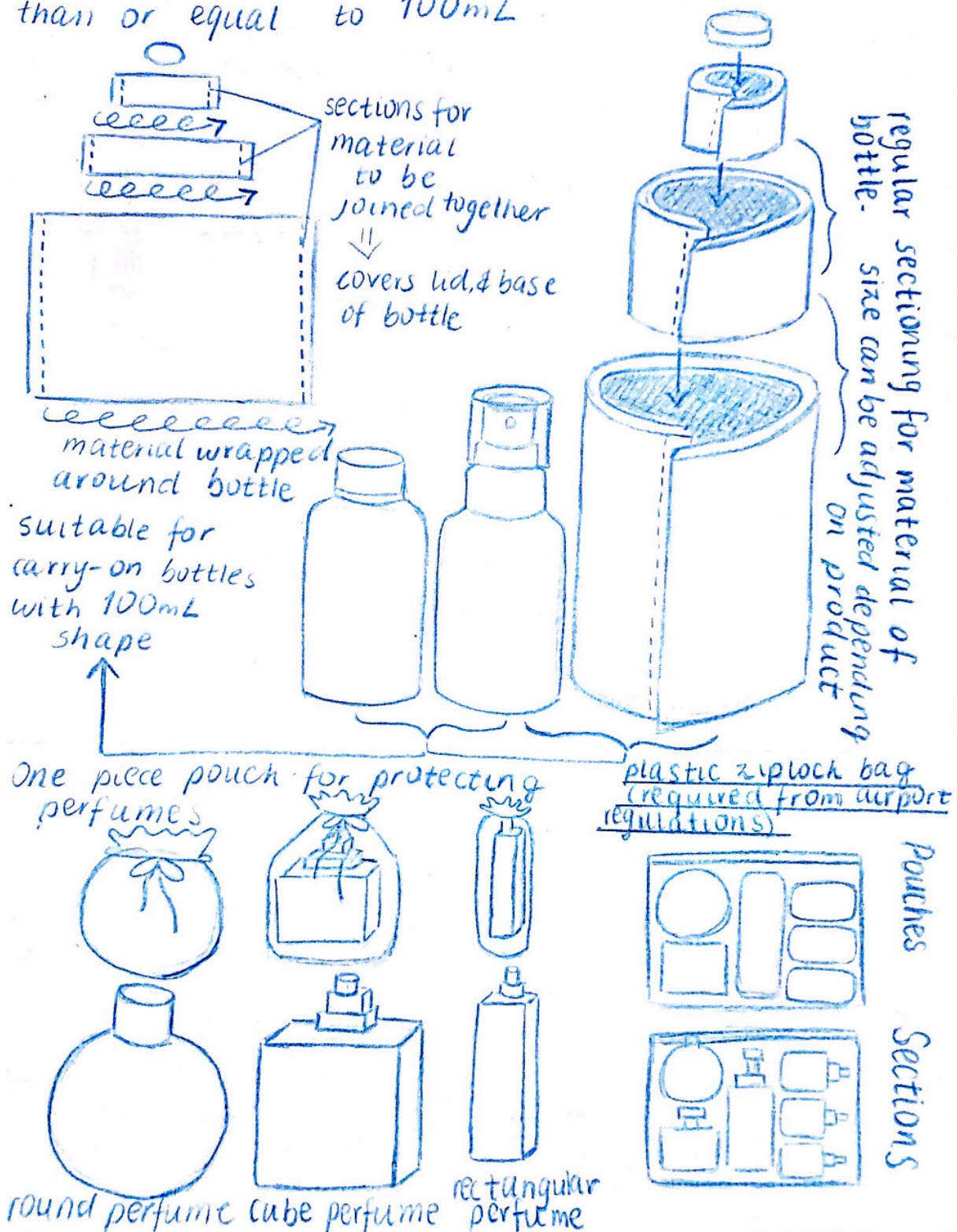
³ (TripSavvy, 2020)

4. Product constraints		prevent the lid from popping open. It provides structure and protection by trapping air.
	3.4 Material must be smooth	If the material is rigid and textured, it can be abrasive against the plastic bag causing tears.
	4.1 The product must not contain any chemicals which is against airport regulations	Banned materials and substances in the airport include: Flammables, oxidisers and organic peroxides, infectious materials, corrosives, magnetic materials, and radioactive materials. ⁴
	4.2 Knowledge and skill	I am limited in making the product because my knowledge is based from the IB design technology syllabus, guided by a design technology teacher. I am not an expertise in this field of knowledge.
	4.3 Lack of professional access to machinery	I am restricted to use machinery in school which affects the quality and accuracy of the product
5. Quantity	4.4 Time	There is a specified deadline which the IB requires in March of 2020. This means that designing, prototyping, testing and evaluating needs to be planned sufficiently to meet the deadline.
	5.1 Mass produced as a standardised product	The product should only be standardised because I am only making a prototype in a school using limited resources of machinery at a low cost.
	5.2 Mass produced – assembling individual components	Limited resources of materials means that materials need to be bought from other companies I should assemble the product.
	5.3 Mass produced – capital intensive process relying on automation	For maximum productivity, specialised machinery should be used to assemble individual components.
6. Target audience	6.1 International teenage boarding female students who travel within the European Union.	I can gain results quickly and easily from the girls in boarding school, which makes my market research feasible and accessible. It is also mostly teenage girls who reported to me that this as an issue for them.
7. Aesthetic requirements	7.1 Should use dark colours for materials	If any coloured cosmetic product spills onto the product, it should not leave a stain and should be easily hand washable. Dark colours appeal to a “grunge edgy vibe” which is currently what teenage girls find trendy. (data collected from questionnaire)
	7.2 Simple design	For the purpose of quickly and efficiently showing a security guard who needs to examine carry on liquids

⁴ (AirSafe.com, 2020)

Initial designs

- enough material must be required to wrap around cosmetic travel bottles that are less than or equal to 100mL

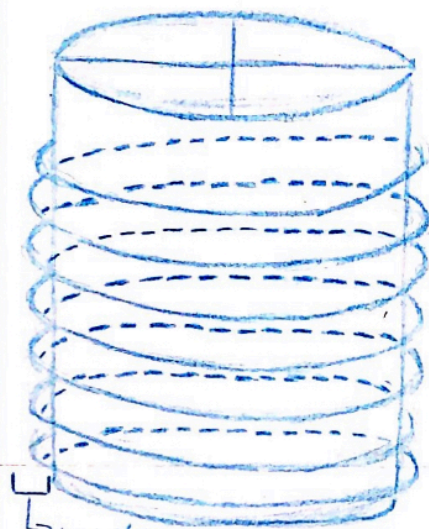


User Feedback: Users emphasised their need for protectiveness of the weakest parts which is the body of the bottle made from polyethylene terephthalate.

Fitting inside the 100Litre plastic bag is essential for accessibility of other products.

Multi layering and components seem like an unnecessary and may appear to slide out of place.

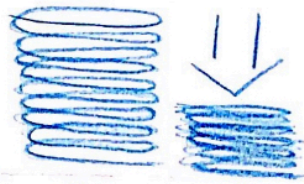
Adjustable spring for different size & shaped bottles



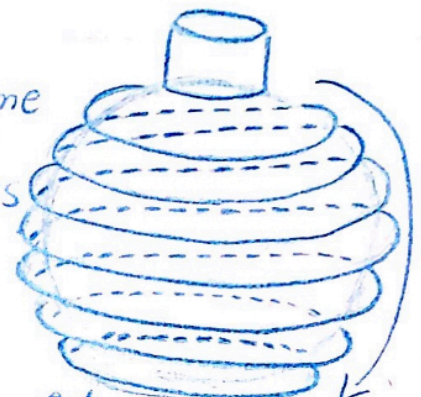
width for material shock absorption (protects crushing forces)

second lid - for protection & to absorb any spilled liquid

shape of spring is able to be compressed into different shapes



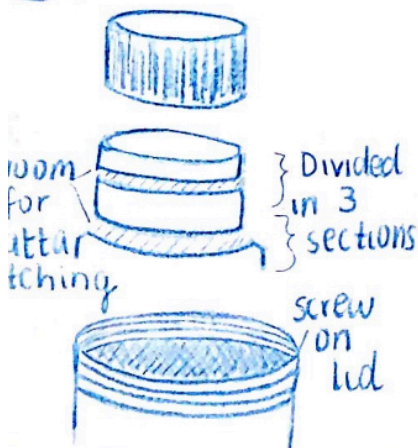
spring is the same width, can fit on shorter bottles



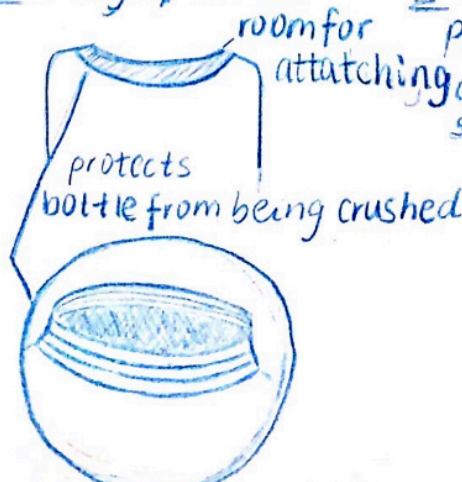
adjusted to different diameters

Sectioning pieces of the bottle to protect different parts

1. Bottle lid



2. Body of bottle



3. Bottom of bottle

Provides support when bottle is standing



User Feedback: Protectiveness is considered as a whole which is more desirable.

Detachable components using different (fast) methods needs to be explored.

Compressibility for long periods of time is desirable due to bottle being in a bag with many other items.

Packing/unpacking functionality for the bottle being adjustable was also well received.

Bottle in pouch

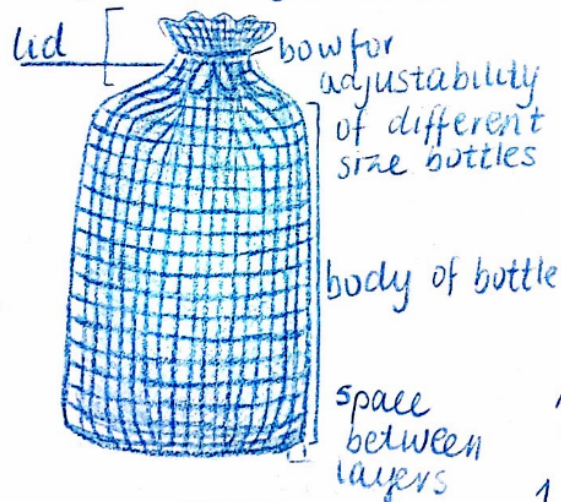


layering for extra protection

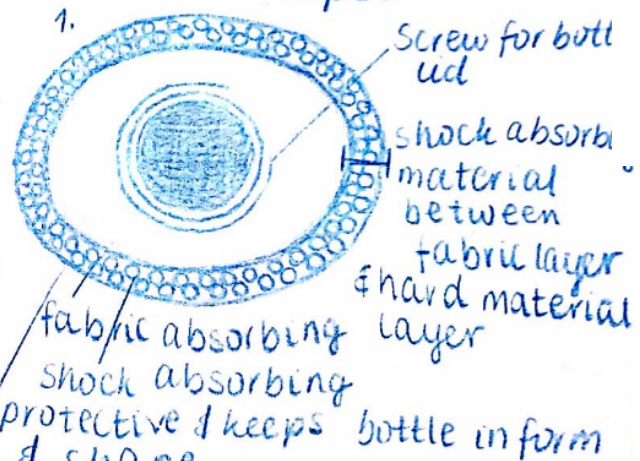
1. Outer layer - hard material - protects crushing forces
2. Inner layer - soft material - cushion & absorb liquid



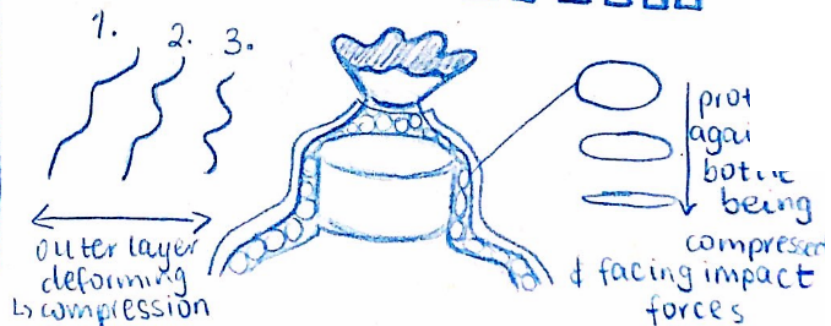
layering together



Shock absorbing materials, shapes

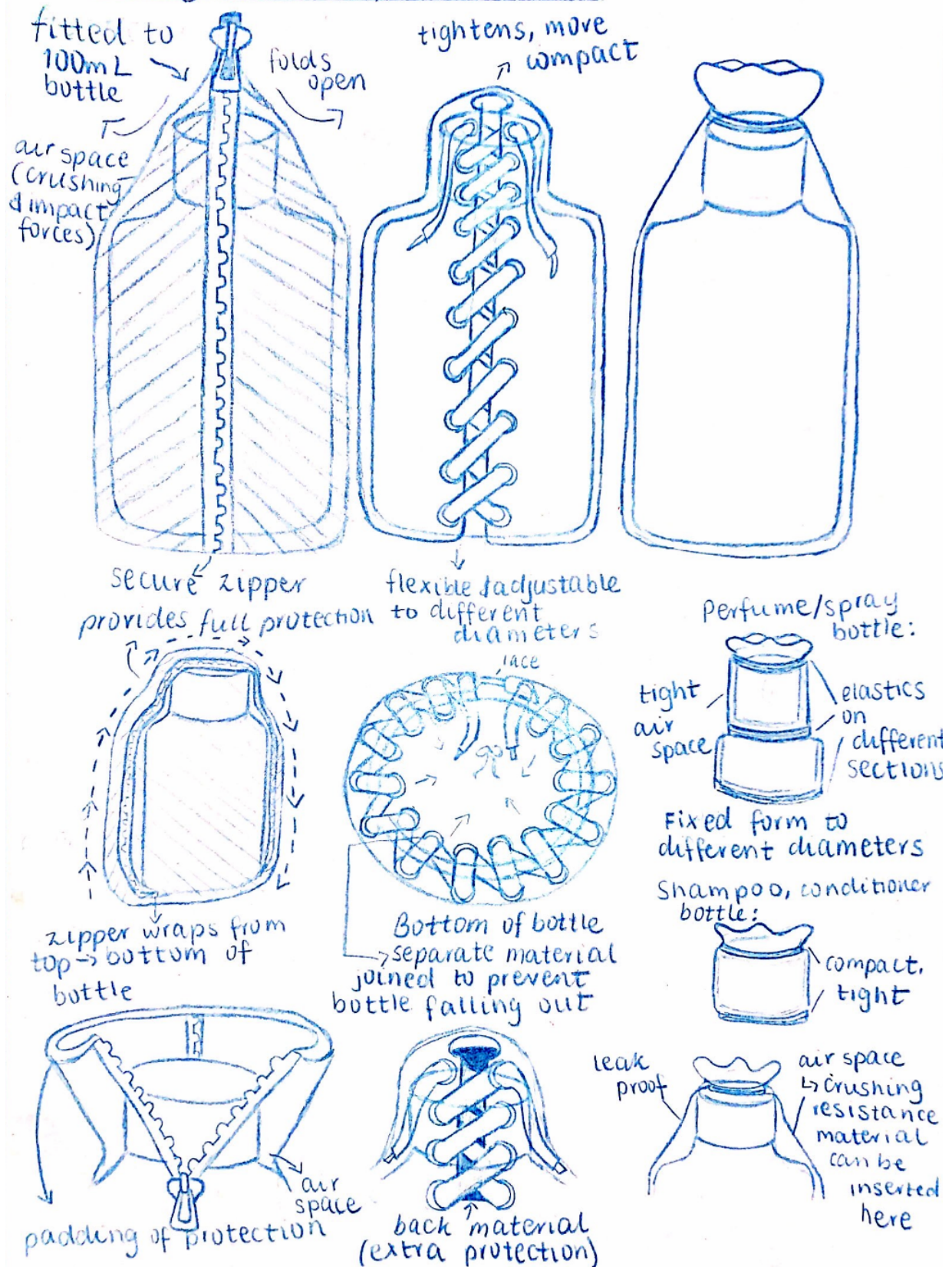


1. Material 1) [diagram of a layer with small circles]
2. Material 2) [diagram of a layer with wavy lines]
3. Material 2.2) [diagram of a layer with wavy lines]
4. Material 1.2) [diagram of a layer with a grid pattern]



User Feedback: Adjustable to the different diameters of the bottle and layered using shock absorbing shapes/materials. Drawstring has uncertainty of protection. It may not Layering materials was received well.

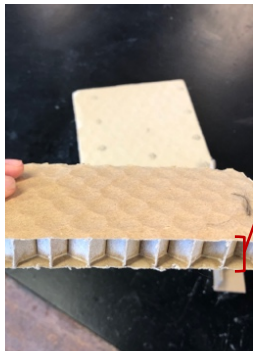
Joining Techniques



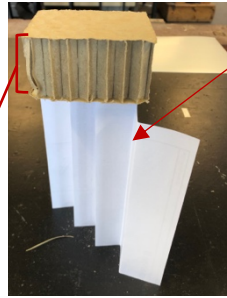
User Feedback: Zip is a simple one motion step to quickly detach prototype. Lace is too complex (doesn't fit simple design specification). Full protection is required but each section needs different level of protection due to material properties of the bottle. Body of the bottle is quite thin and the lid is impact resistant so it just needs something to absorb shock.

Criterion B

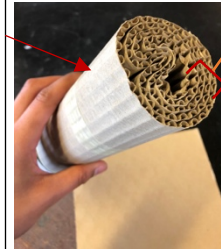
Different types of corrugated cardboard physical modelling



Thick for plastic bag, indentations provide shock absorption and lightweight



Folded paper - air trapping (provides structure and support for heavy objects)



Thin, adjustable layering of indented material (shock absorbing, protective)

Hot glue made fixed form around shape, but there were many bends



Won't protect different diameters of bottles, not adjustable

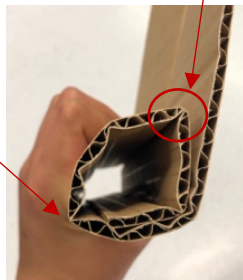


Wrapped cardboard around bottle causes unwanted dents

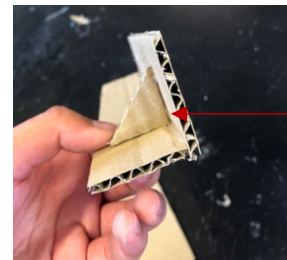


Sharp turning point is space restricting

Can cause abrasion against bag, not aesthetically pleasing



Material must bend on 2 axes to wrap around smoothly



Adhesive used to attain required form and structure

Foam with adhesive baking: smooth and scratch resistant against plastic bag



Neoprene, cut into many smaller pieces to cover curved surface area



Potential for sewn joining technique for aesthetic appeal

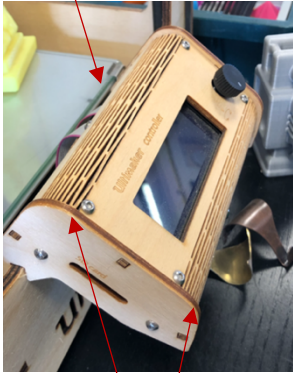
Wrapped around different sections in a fitted form



Cushioned shock absorbing material with air pockets allows impact and crushing forces to be resisted

Physical modelling using laser cut designs for MDF and acrylic

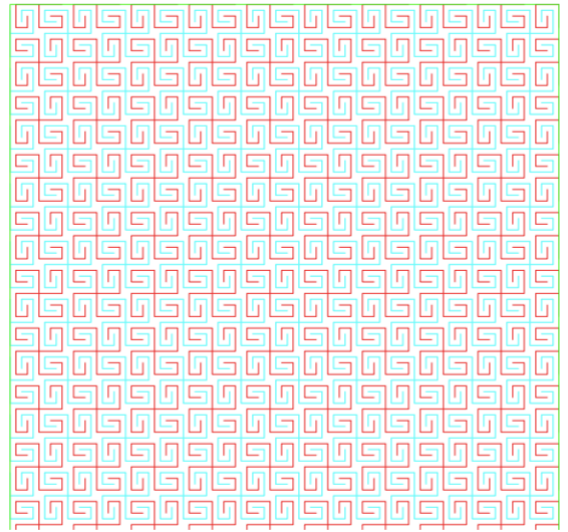
Plywood sheet is versatile, fixed formed and protective



Airgaps with acrylic is flexible on one axis and breaks easily

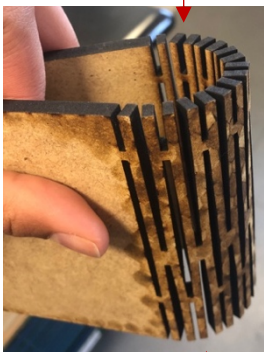


Design model of laser cut print – red space where gaps are is quite thin



Layered at 90 degrees with adhesive to make curved form

Protective and durable design



Slender elements that are easily twisted which are interconnected on fixed points

Solution to paying less for curvature surfaces with same amount of material in a simplistic way

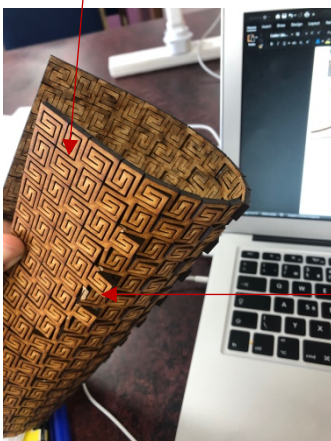
3 types of curved surfaces: neutral (cylindrical), double curved, negative (hyperboloid), positive (spherical)

Able to curve around main body, but not all sections of lid



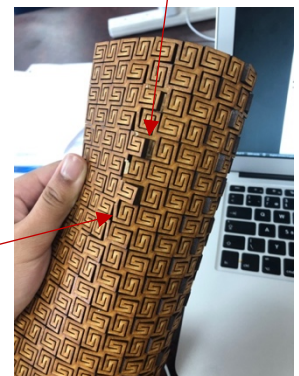
Make the distance of fixed points larger

The greater the distance between the fixed points, the greater the flexibility



Snaps on MDF board, use different material

Possibly combine woven elastic inside for a wider range of movement



Physical modelling using plastazote to fit the form of the bottle

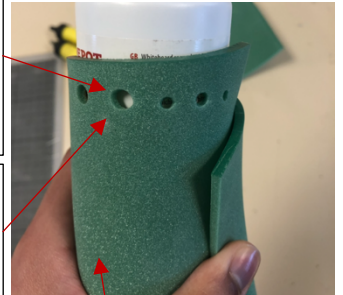


Thin and light enough, won't take up a lot of space within plastic bag



Holes punched to create a shock absorbing material

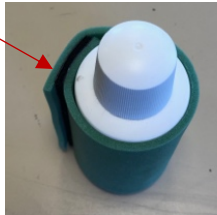
Creates protection against crushing forces



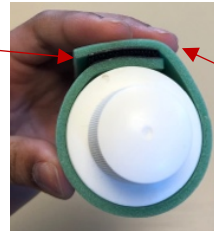
Protective and bends in one axis

Velcro comes off when being undone – need to consider new application

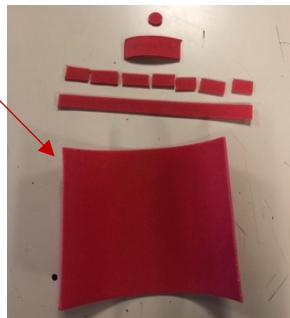
Joining technique: Velcro (attached to material with Velcro sticker)



Rough edge is inappropriate – can cause abrasion against plastic bag



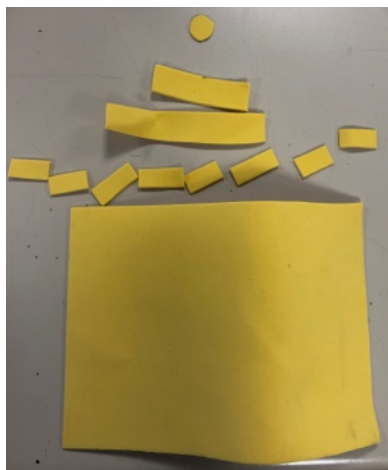
Does not appear tough for high impact forces



Perforated plastazote used, glued onto bottle - aesthetically pleasing but not protective



Flexible to bend around different circumferences



Flexible, thin, strong and durable

Staples maintain form of shape and keep it firm

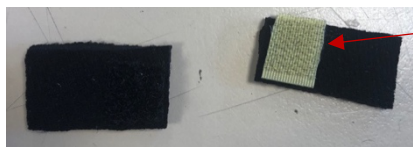
Not aesthetically pleasing



Covers entirety of bottle, elastics flexible to any diameter

Does not have protection against crushing forces

Velcro joining attached to material with adhesive



Joining Velcro at a certain point is bulky

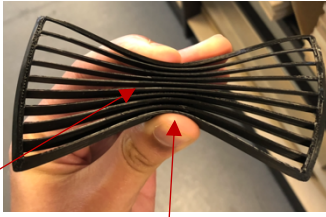


Material and structure slide off the bottle – doesn't meet purpose



CAD from thingiverse open source

Inspired model of 3D flexible printing with air space

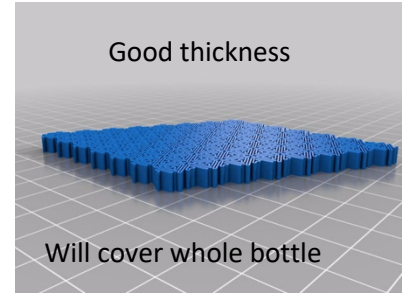


Different widths of design used for different types/sections of bottles

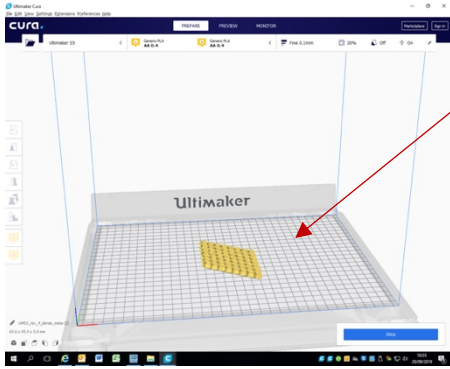
Bigger gaps mean more flexibility

Good thickness

Will cover whole bottle

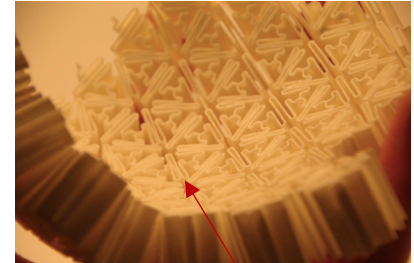
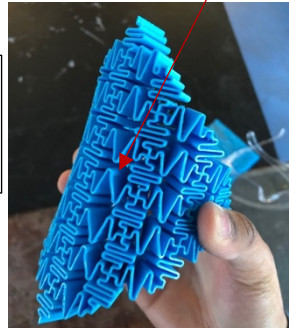


Able to withstand crushing forces



Limited space on 3D printing pad

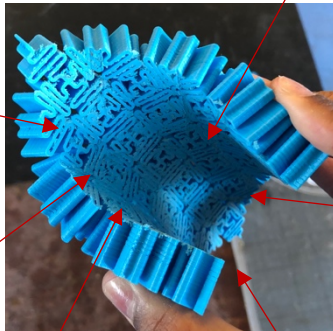
Printed PLA 3D print material be wrapped around bottle



Air space allows flexibility

Attempt to sand rough edges was unsuccessful

Will cause abrasion against plastic bag



PLA Material is not completely able to cover bottle



Form is still tough, protective and somewhat flexible

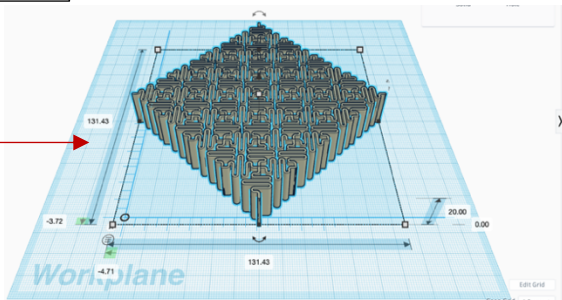


Printed onto PLA pad and peeled off for smooth finish

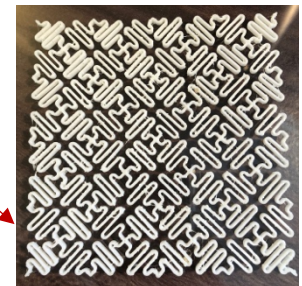
New testing material must be smoother

No breakage

Adjusting width and material using tinker CAD for fitting measurements



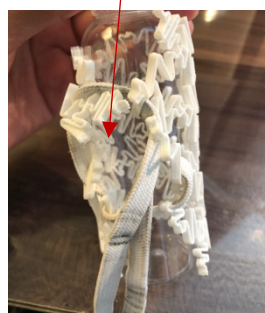
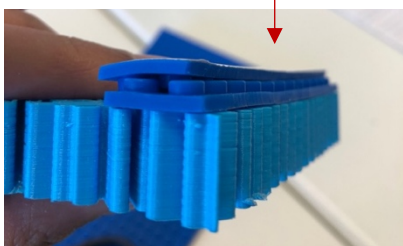
Measured to fit around circumference of 100 mL bottle



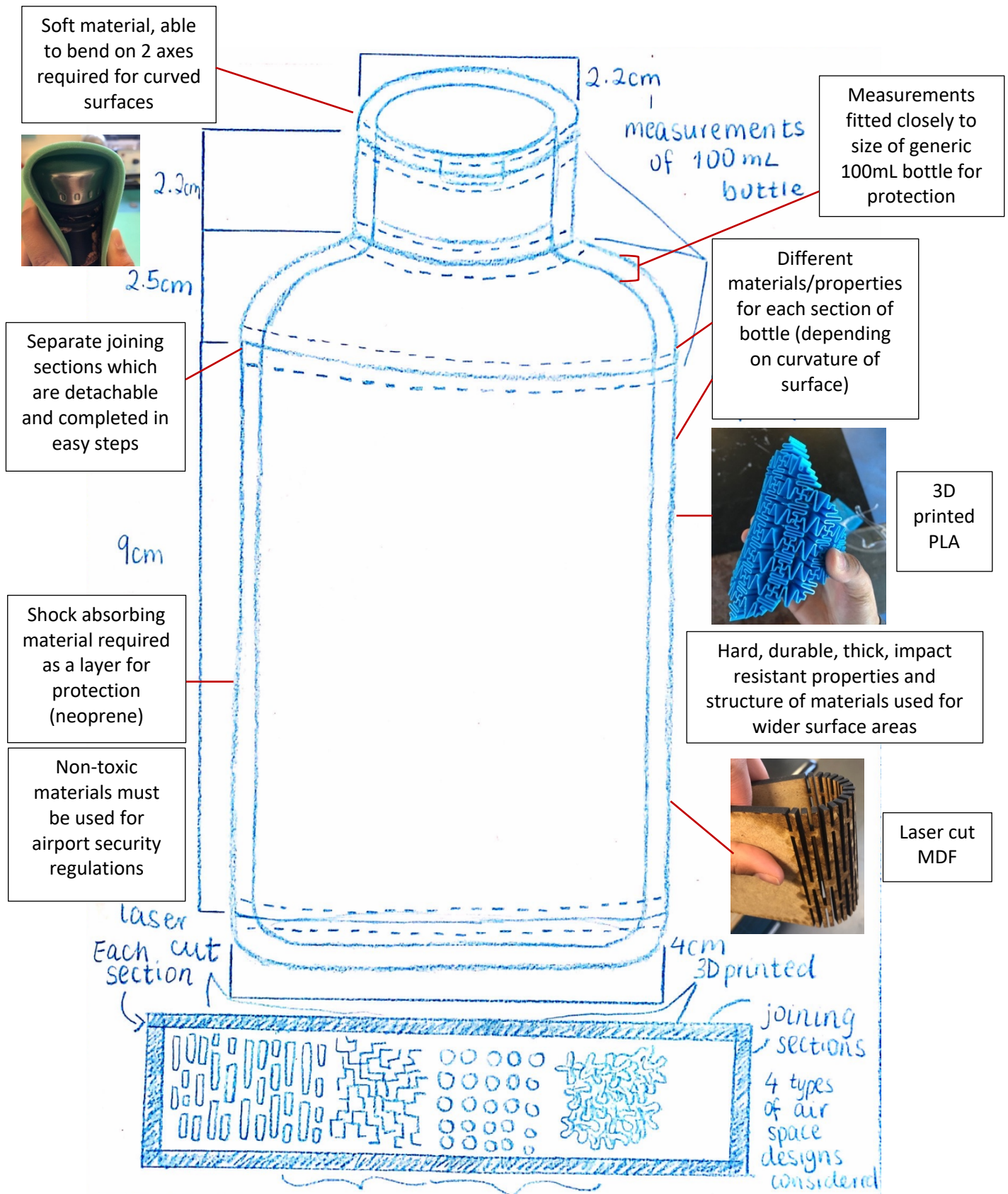
Soft absorbing material in between PLA for more protection

Adjustable joining techniques – clip on Lego (stuck with adhesive)

Many gaps mean less protection for leaks and crushing forces



Final design



Feedback: Joining techniques need to be simple and complete in one motion to fit user need of showing cosmetic product to airport security. Important properties include shock absorbency and impact resistance so layering of materials could be a possibility. Joining techniques which interlock are the best option because there would be no gaps. The more gaps there are in the material the less protective it is. The size must be fitted to the generic size 100 mL bottle, and flexible enough curved surfaces.

Justification of final design against the design specification

Function

The design must cover an area of a 100 mL cosmetic bottle which is taken aboard carry-on luggage. This size of the bottle is a legal requirement for European airport security regulations. The model must be secure, flexible, compact and shock absorbing so that the users do not experience leakages from their cosmetic products onto their other travel items.

Size

The thickness of the material covering the bottle cannot be more than 0.5 cm, otherwise each individual bottle will not be able to fit inside the 20 x 20 cm plastic bag. Availability for airspace within the bottle protection design is quite restricted due to the compact space of the plastic bag. Therefore, the design should fit perfectly around the 100mL bottle.

Material selection

The material selection will vary due to the different purposes of each section of the bottle. The lid should be an absorbing and crushing resistant section, so the cosmetic product doesn't spread to other items in the bag. The upper middle section of the bottle joins the body and the lid together, which is a flexible material on the curved surface. The body of the bottle is the toughest section which must be fitted and strong enough against impact and crushing forces which squash the product out of the bottle.

Product constraints and quantity

Machinery and manufacturing automated processes are not available in college grounds so I therefore will not be able to produce the design at the highest standard it could possibly be. I am also limited on the time frame which I am working within because this project has a deadline. I am limited to knowledge and my skills of many aspects because it is only my second year studying Design Technology, therefore I must learn about the positives and negatives of every aspect before making a decision at every point in my design process.

Target audience

The target audience for the product is specifically for teenage girls who travel internationally within the European Union. The people who travel frequently and for a time period of less than two weeks are in need of this type of product.

Aesthetics

The design of the product should look sleek and slim, similar to the cosmetic products and travel items that teenage girls currently purchase. From the feedback, boarding students said the colours which they prefer are dark and grunge such as black, blue or purple.

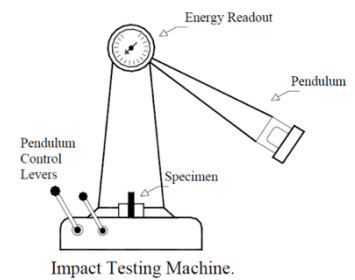
Criterion C

Material testing

Test must determine how effectively a shock absorbing material can resist impact forces. (Design specification 3.3)

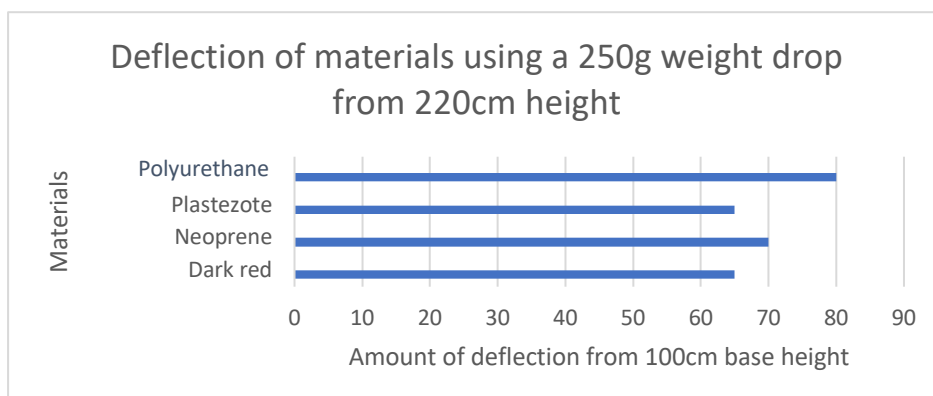
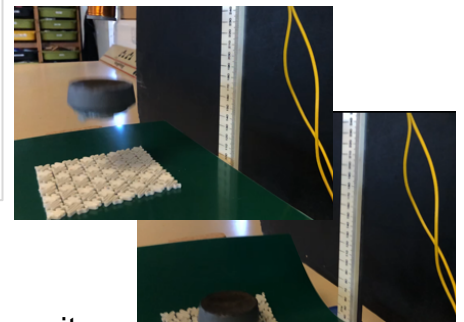
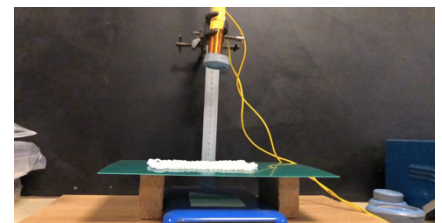
Izod test

Measuring the degrees which material can withstand impact forces and toughness to determine how shock absorbing a material is. A pointer shows the height of the follow through after breaking to determine energy absorbed in breaking the material⁵.



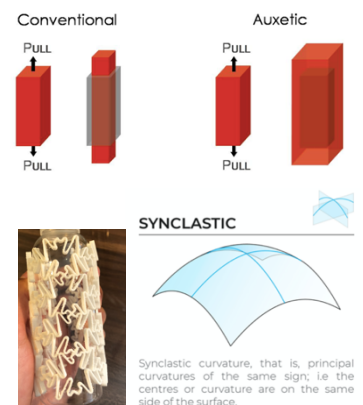
Electromagnetic weight drop test

The test measures the deflection of a material using an electromagnetic weight. Set up: A flexible base material that rests flat without a supporting base, constant variables are 250g weight and 220cm height. Decision: I chose to use the electromagnetic testing method because it takes into account the flexibility (Specification 3.1) of materials being tested.



Mesostructured cellular Polyflex TPU (Polyurethane)

It has a shore hardness of 95A and can stretch up to more than 3 times its original length. This mesostructure from open source 'thingiverse.com' has properties of synclastic bending and auxetic behaviour. It is able to form an elliptic paraboloid, meaning it can curve on two axis at the same time around the cosmetic bottle dimensions. When is compressed in one direction, the auxetic materials proportionally contract and when they are stretched they expand. However, it cannot be wrapped around the bottle because it does not provide enough surface protection when stretched.⁶



⁵ (Sites.google.com, 2020)

⁶ (Researchgate.com, 2014)

Justification of materials

PLA (Polyflex TPU95) (Polyurethane)

Was the most impact resistant out of the materials I tested. Elongation at break of the material is 330.1 ± 14.9 Mpa. It has a balanced strength to density ratio evidently shown in material selection chart 1. The material can comfortably stretch around the surface of the cosmetic bottle with a low density. 95A shore hardness means that it has a high resistance to indentation, therefore a good ability to protect the bottle against impact forces. It also flexible at the same time (material selection chart 3). The best suitable diameter size which is available is 1.75mm to save space inside the 1 Litre travel size plastic bag, to maintain a low density with less material.

Plastazote

A closed-cell flexible polyethene foam that is chemically friendly inert and non-irritant. It is airport friendly to airport security regulations. The low density 45 kg/m^3 that conforms to pressure. Restoring force will bring back the material back toward equilibrium (material selection chart 3). Low stiffness means I can use the material as the first layer around the bottle to provide shock absorption. Good adhesive and welding characteristics provides an opportunity to use adhesive to add an impact resistant outer layer PLA material. It is able to bend around the axis of the bottle as a secure and tight fit.

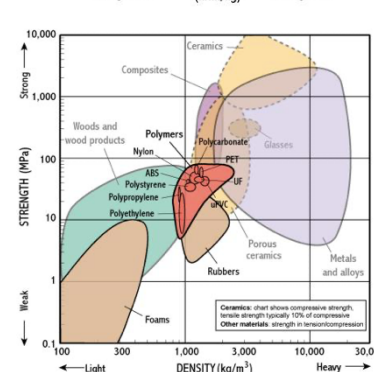
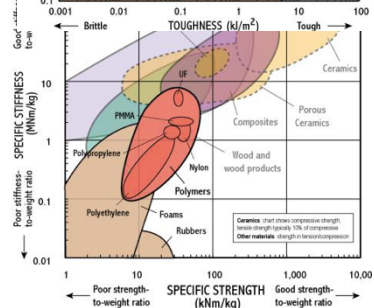
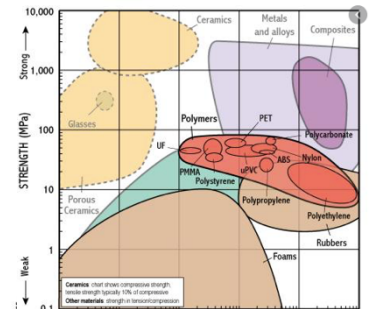
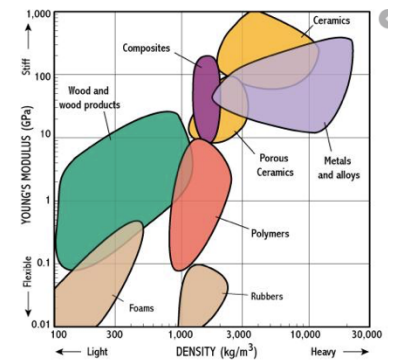
Neoprene

Is a synthetic rubber produced by the polymerisation of chloroprene. The limestone process of neoprene is more environmentally friendly however, the oil-based process is cheaper because it does not require as much technologies to be converted into neoprene. It can be recycled by being chopped up or blended with other synthetic rubbers to make a new material. Neoprene is able to stretch up to 6 times its original length which fits the requirement being able to stretch securely over the different diameters of the lid bottle

Justification of components

Adjustable toggle with drawstring

It is able to fit across all of the diameters of the bottle. It also provides one quick and easy hand movement for the user to remove this component which is beneficial for a stressful airport security situation.



Drawstring and toggle

Jigsaw edges

These components cover the whole surface body of the cosmetic bottle and form interlocking shapes which ensure full coverage and shock absorbing protection.

Justification of manufacturing techniques

Contact adhesive

For applying the mesostructured material to the plastazote. It is still able to have its mechanical properties and dries clearly, giving a clean aesthetic appeal.

Laser cutting plastazote

The laser cut jigsaw components needs to wrap around and join at one central meeting point of the bottle. I used foam for a first test, but it failed because of the circular edge became raised unevenly. On the second trial, I used plastazote and made triangular edges to see if they would fit into place. Oxidisation occurred in the joining section which led me to justify the final design interlocking together as a joining component. Laser cutting neoprene in my facility would be unsuitable because chlorine-based fumes would cause damage to the mirrors and lenses.

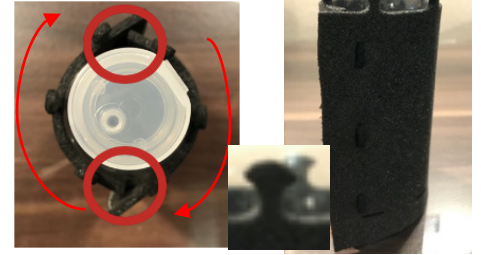
Sewing and cutting (scissors) neoprene

For safety precautions based on my research (appendices), I will cut neoprene using scissors. In order for the adjustable drawstring to be securely threaded through the neoprene, the circular components will need to be attached together using a black thread and the zigzag setting on a sewing machine. This component as a whole can be adjusted to any size and form of bottle caps providing secure, flexible protection against leakage.

3D printing

The material properties of Polyflex TPU95 is a suitable filament which I can use to 3D print the intricate design for a flexible and impact resistant form. The Robox 3D printer which is available at my facility has a high tolerance with accurate motion and positioning of materials. This will result in high quality for the prototype and allows the complex shape to be repeated with accuracy. Additive manufacturing techniques can create complex shapes without labour costs as the program can operate without supervision.

2 Interlocking jigsaw components



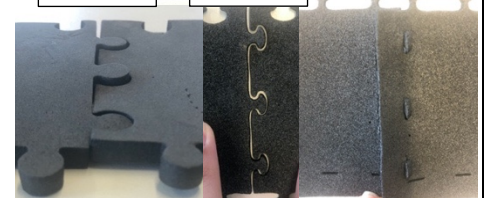
Thin contact adhesive layer



Test 1

Test 2

Test 3



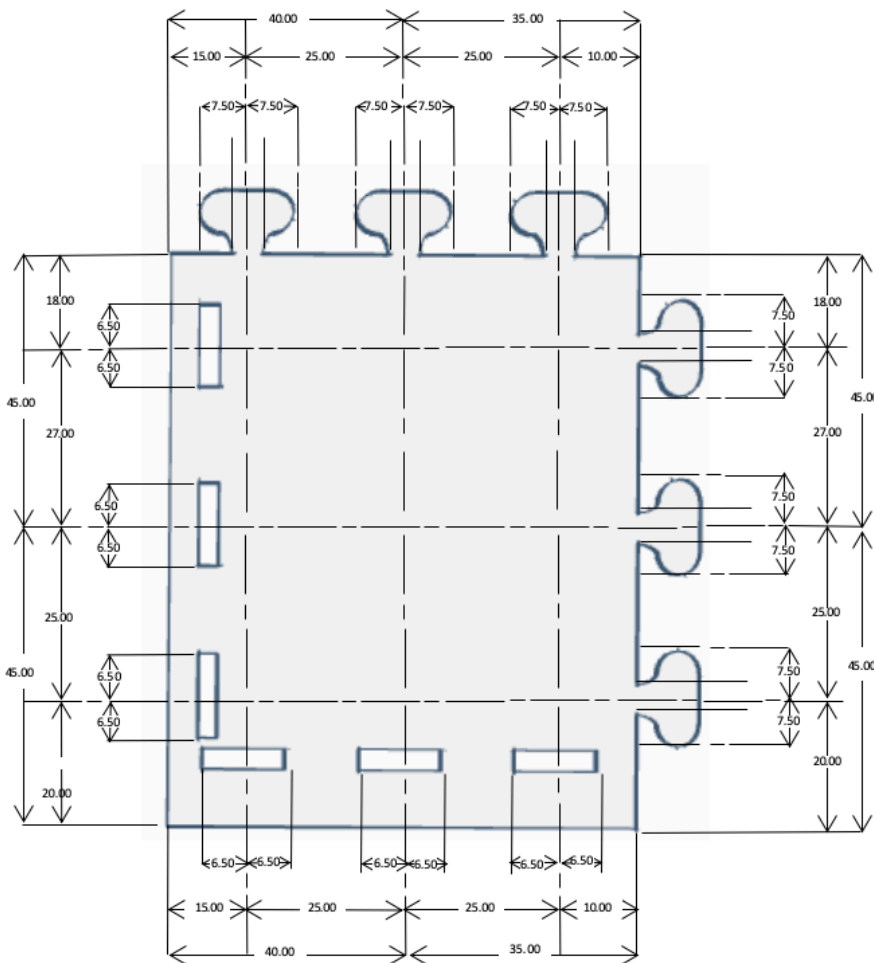
Gap for thread



Laser cut plastazote jigsaw component

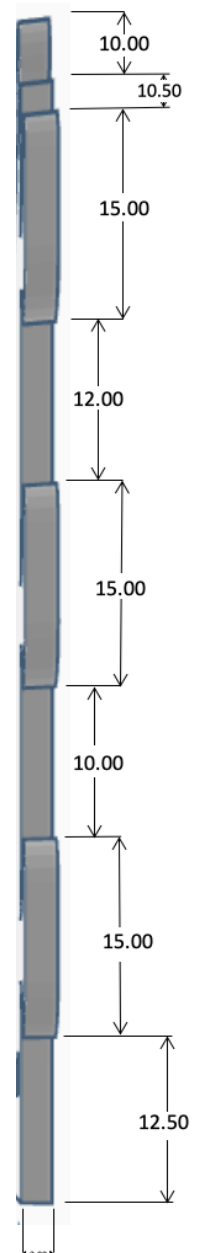
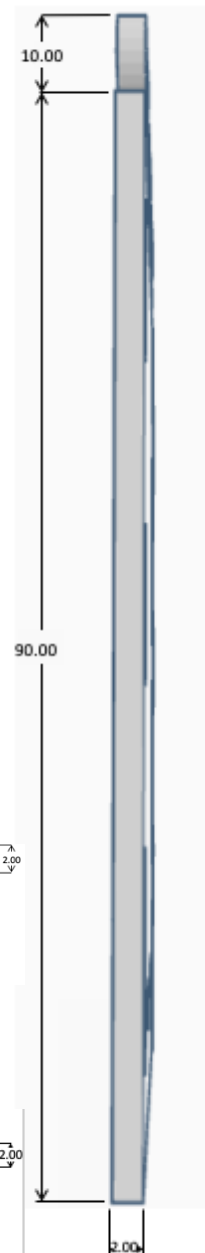


Plan view

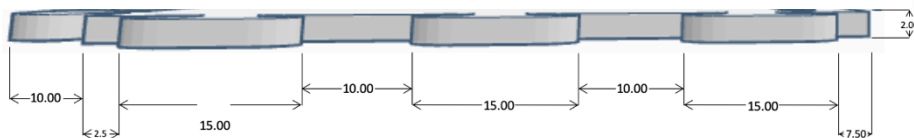


Left side view
(length)

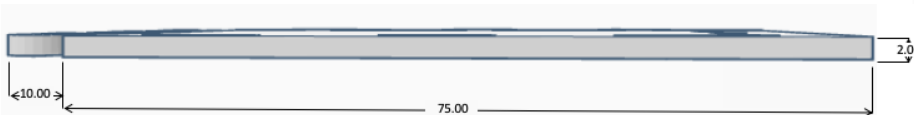
Right side view
(length)



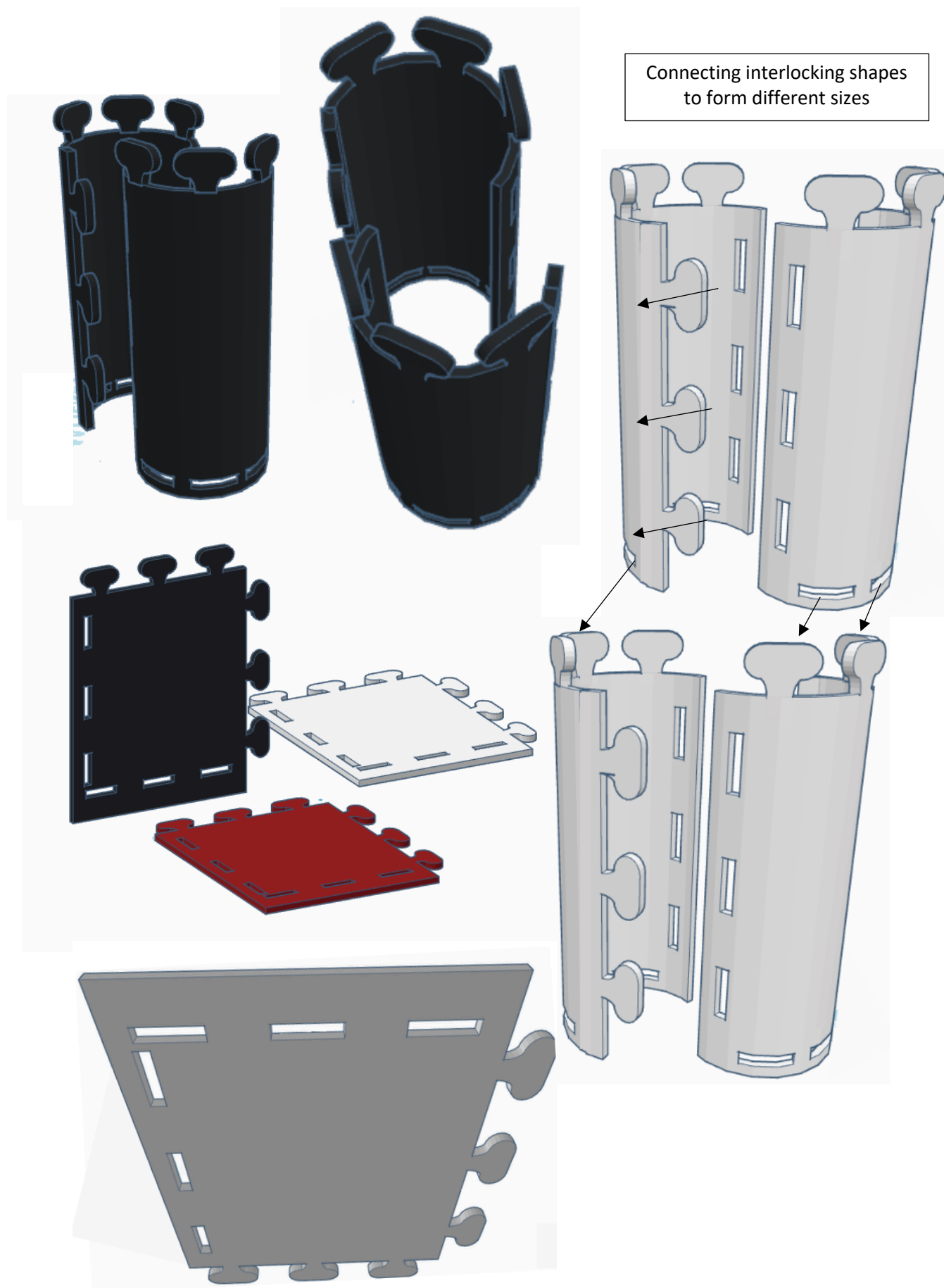
Front view
(width)



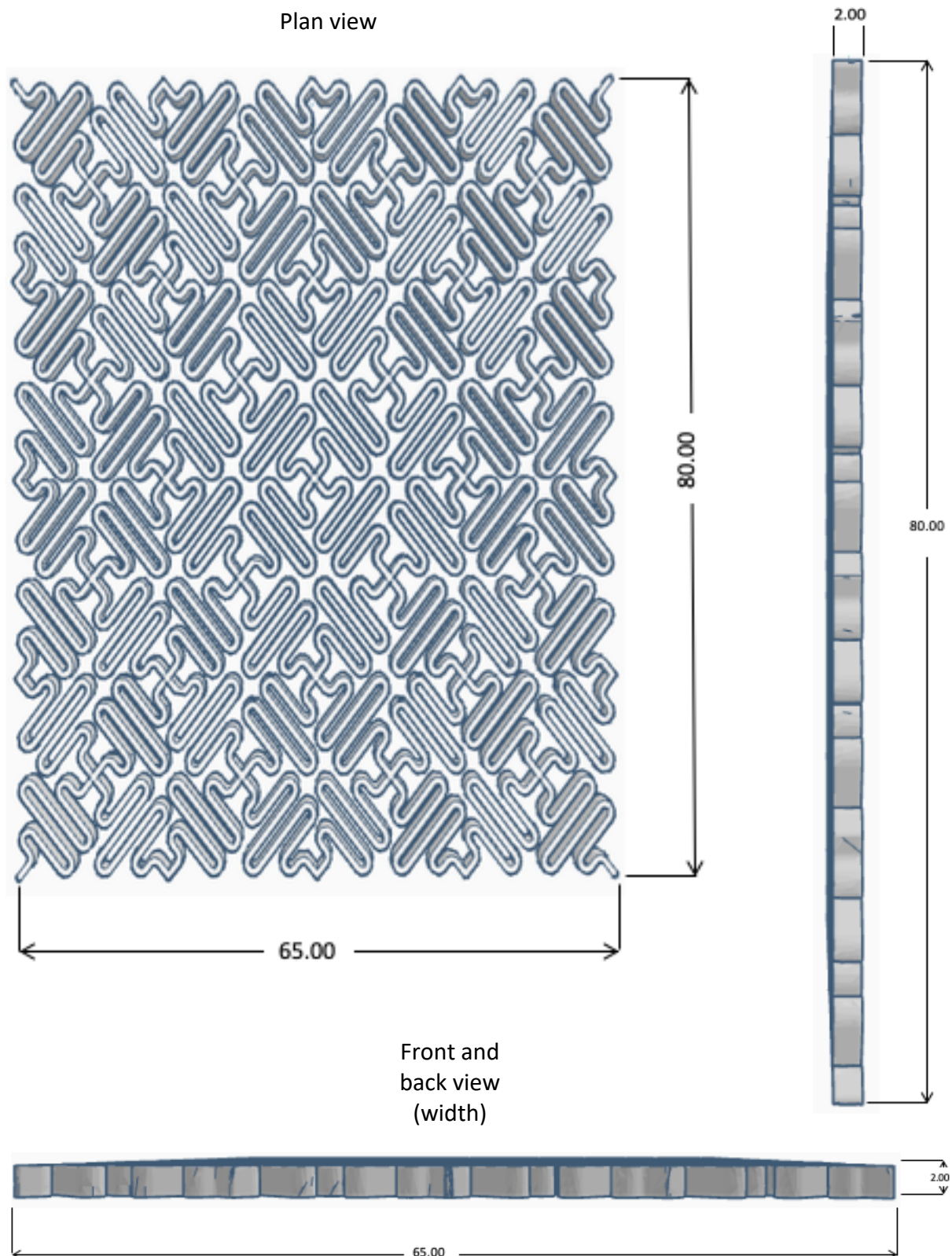
Back view
(width)



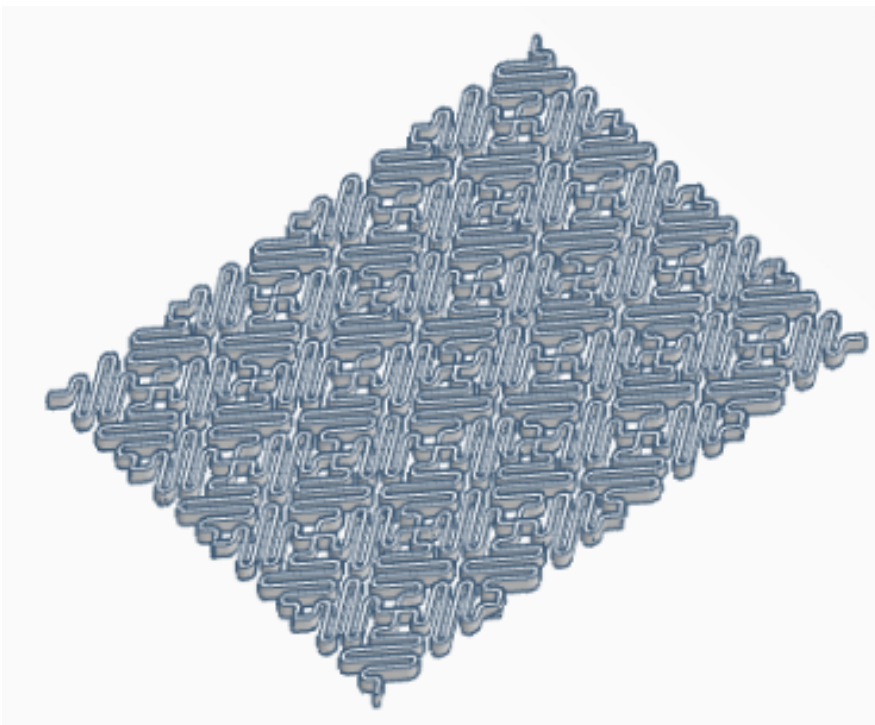
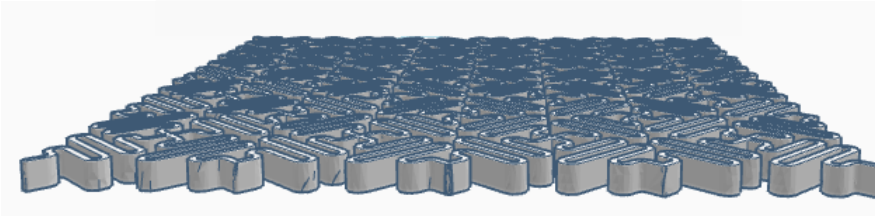
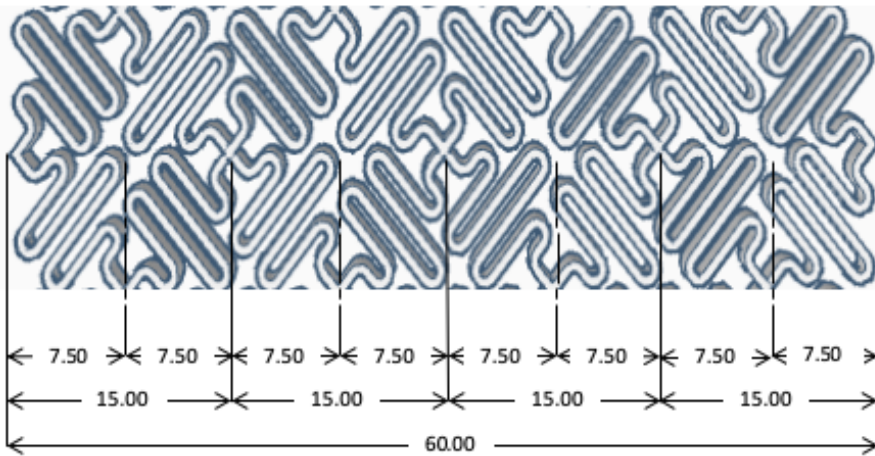
3D Designs of laser cut plastezote jigsaw form



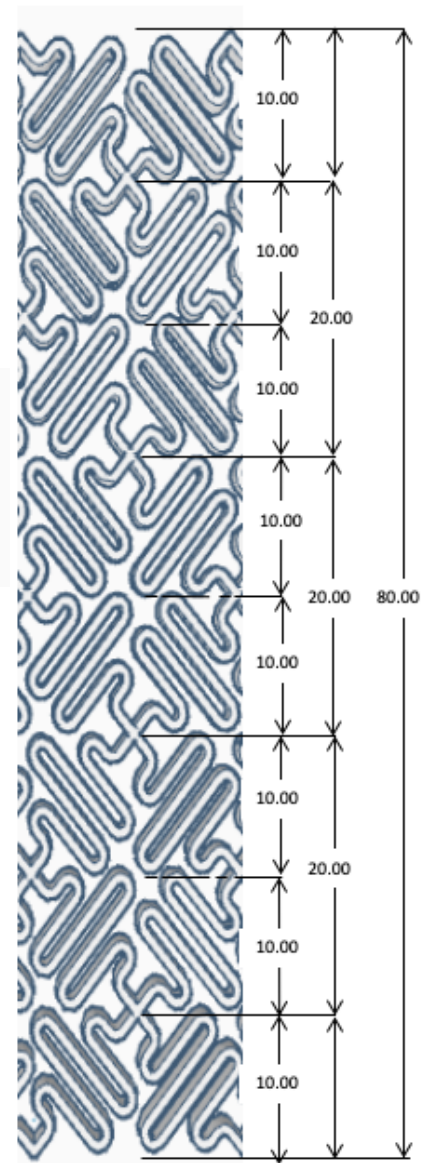
3D printed PLA mesostructure form

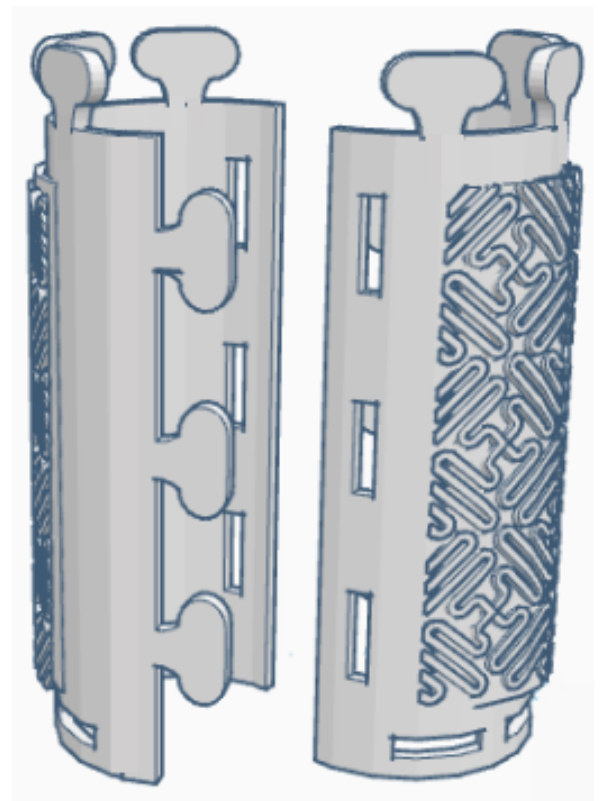
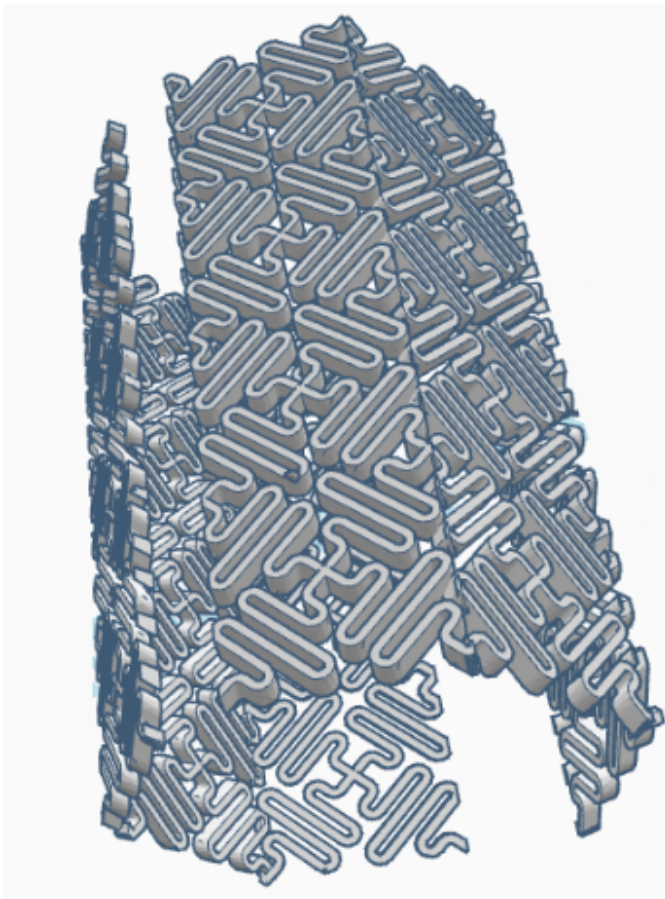
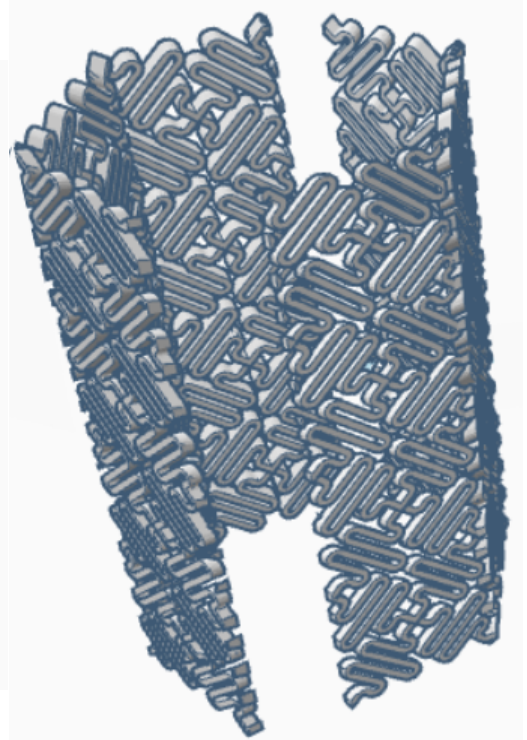
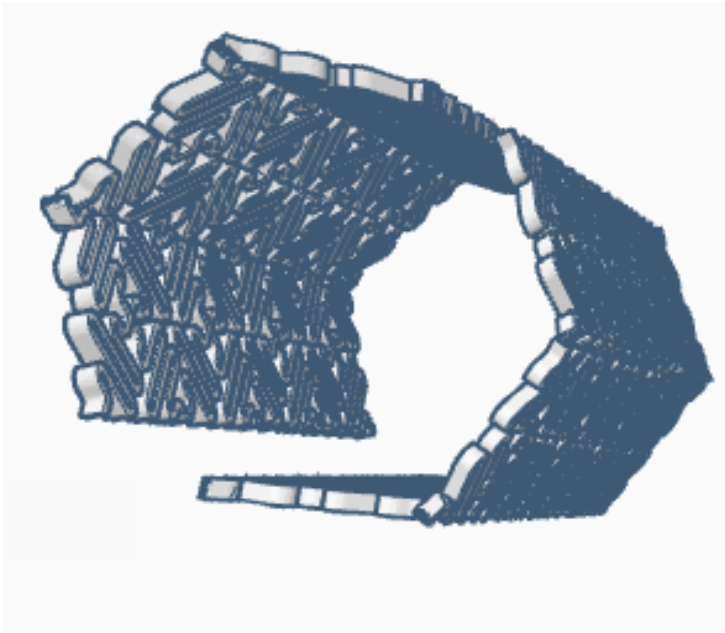


Close up section dimensions
of structure (width)



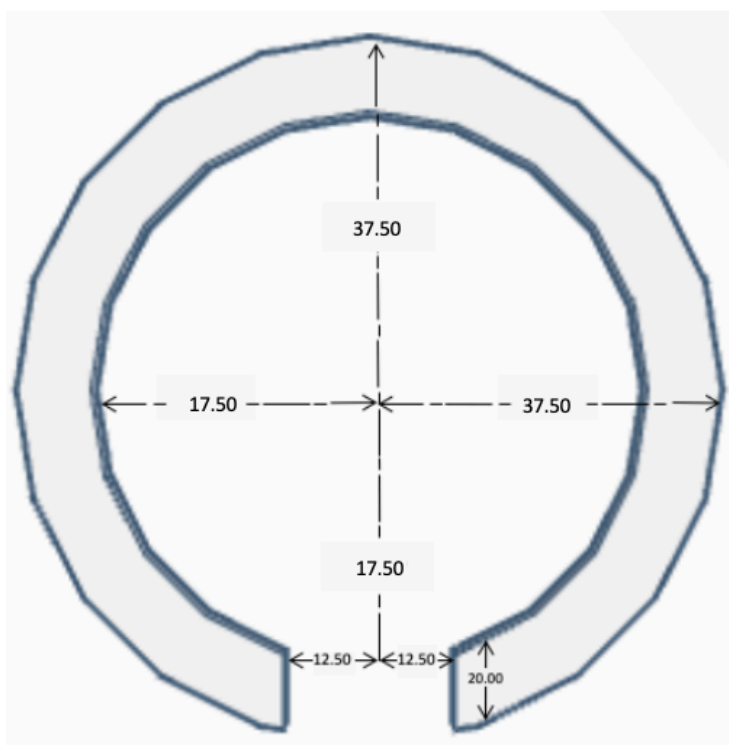
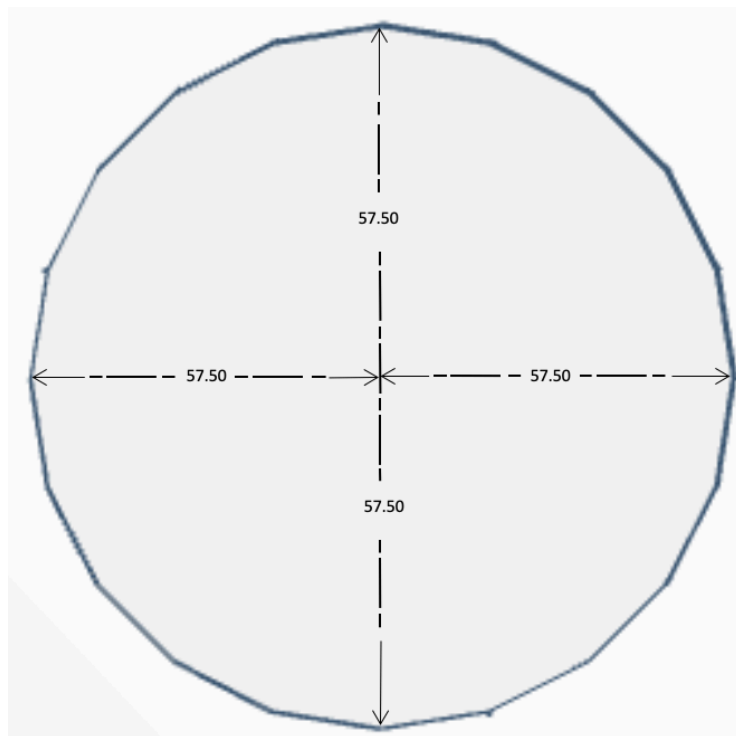
Close up section dimensions
of structure (length)





Lid attachment with adjustable drawstring component

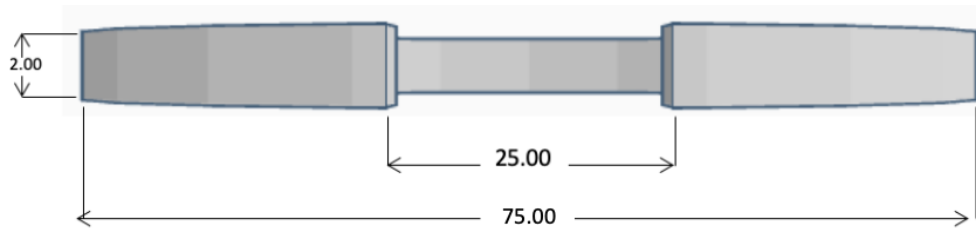
Plan view
Base circle



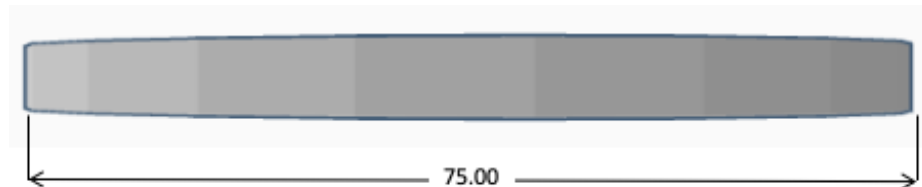
Plan view
Inner C shape

Lid attachment and toggle size

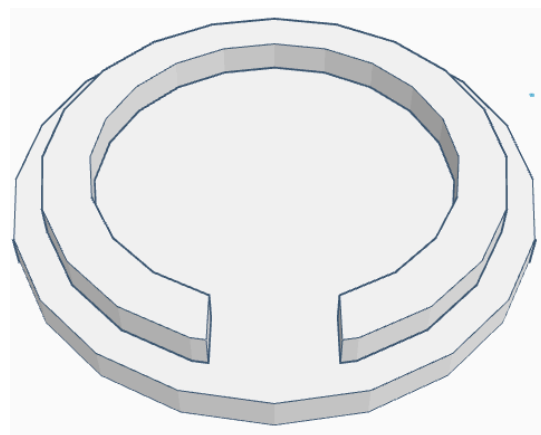
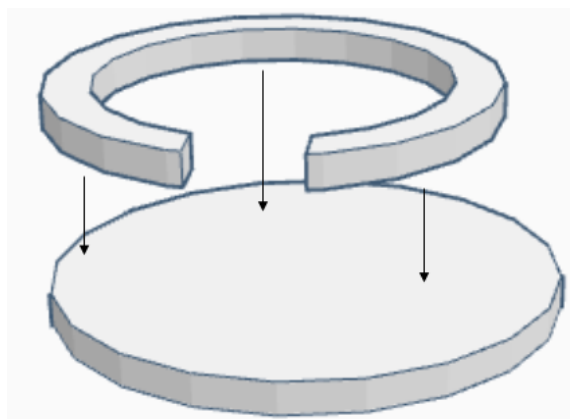
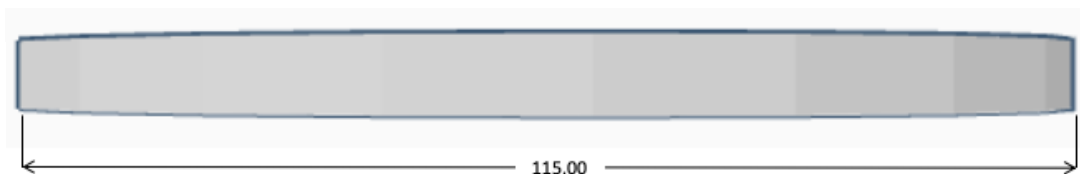
Front view of
inner C shape
(width)



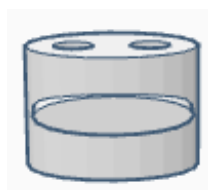
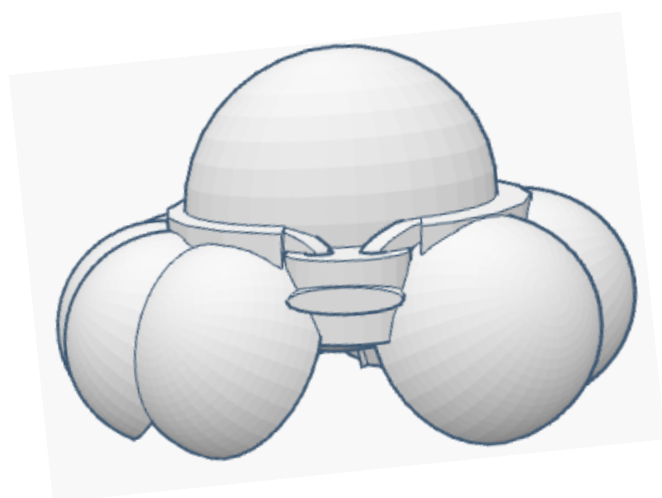
Outer diameter
of inner C
shape



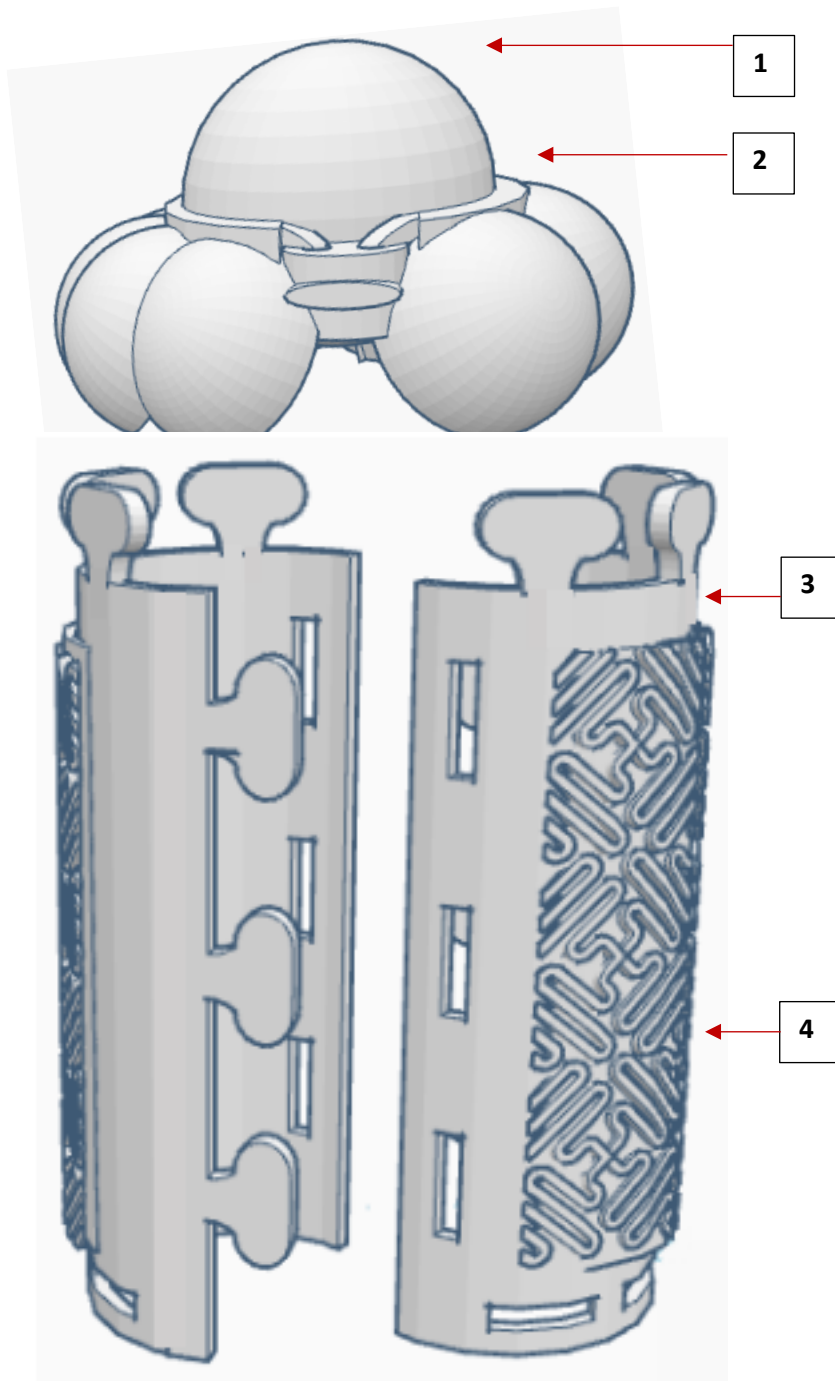
Outer diameter
of circle



Hole diameters = 2.6mm
(standard size available in
my school facility)



Final design



Bill of materials

Part	Reference	Part name	Height	Width	Thickness	No. off	Material	Colour	Unit cost	Machine	Unit cost	Total costs
1	ASTM D1056 - 00 AFNOR 99 - 211	Lid	(flat)	60mm	2mm	1	Neoprene	Black	£16.27	Laser cutter	£2500	£2516.27
2	K077-10P	Drawstring with standard toggle	8mm	20mm	15mm	1	Polyoxymethylene	Black	£5.98 £1.85	Sewing machine	£130	£137.83
3	MPC	Jigsaw components	90mm	75mm	2mm	2	Plastazote	Black	£2.99	Laser cutter	£2500	£2502.99
4	PM70108	Mesostructure	80mm	65mm	2mm	2	Polyurethane	White	£43.36	3D printer	£800	£843.36

Plan for manufacture of prototype

Laser cutting machine



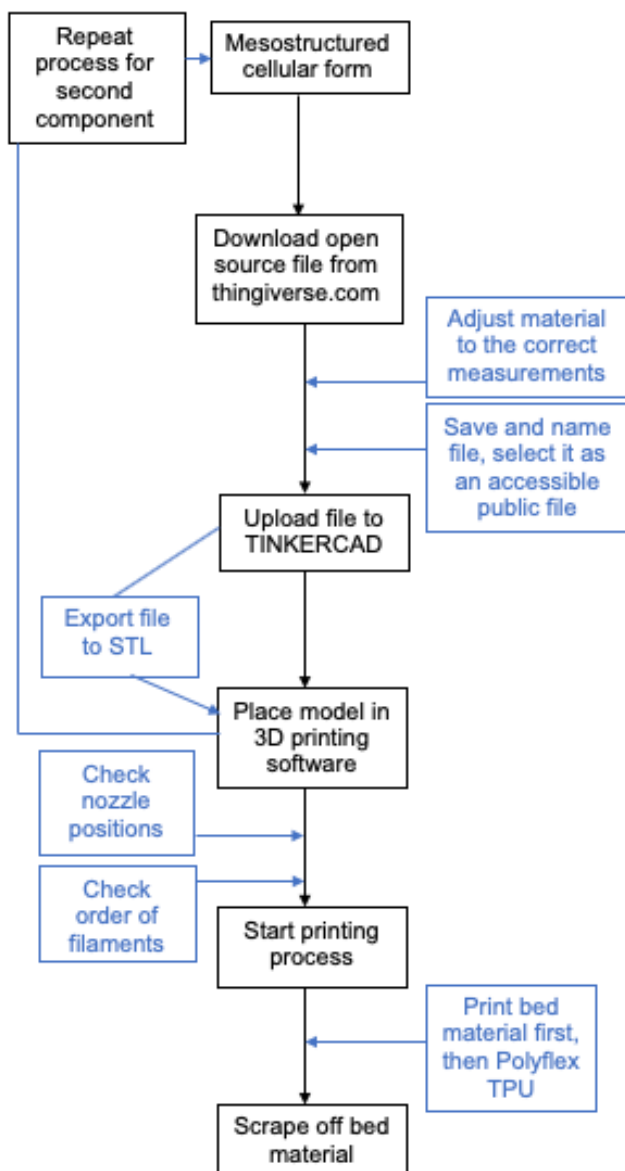
Sewing machine



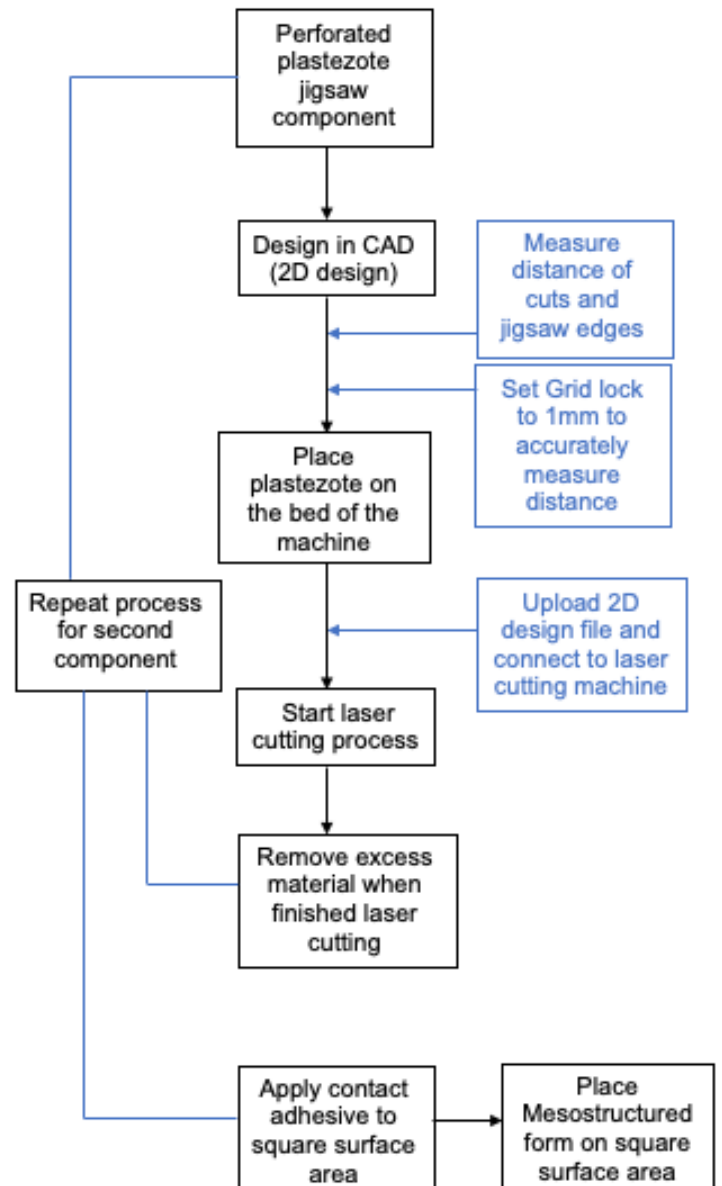
Robox 3D printer

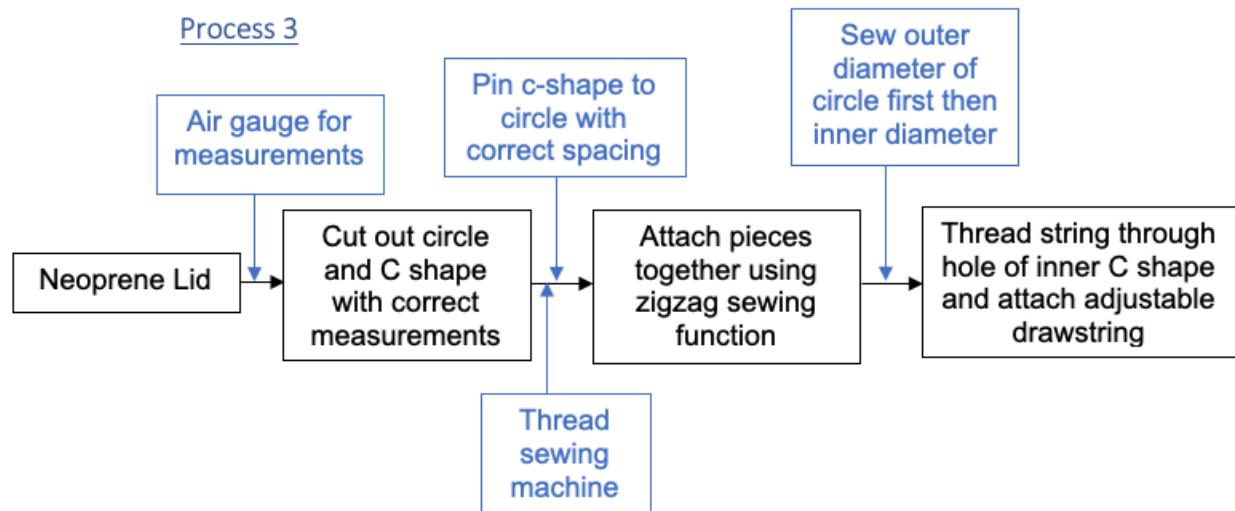


Process 1



Process 2





Construction plan

Part	Process	Materials	Equipment	Scheduling	Quality Control	Risk assessment
Jigsaw component	Laser cutting	Perforated plastazote	Laser cutting machine Perforated plastazote	20 minutes	Callipers to measure dimensions	Supervise laser cutter behind safety line. Wear gloves for contact adhesive
Mesostructured cellular material	3D printing	PLA (Polyflex TPU), Eastmann amphora 3D polymer	3D printer Computer	5 hours	Callipers (measure dimensions) Colour sensor (if all base material is scraped off)	Close 3D printer to reduce emissions
Lid	Cutting with scissors Sewing Threading	Neoprene	Scissors, Sewing machine	45 minutes	Air gage to measure internal and external diameters	Ensure fingers are 3cm away from the needle. Cut away from body when using scissors.

Criterion D

Testing Strategy for the prototype

Success parameters are measured against design specification using a field test. Specifically meeting the prototype function, size and material will assess good or bad user experience.

Step 1: Find teenage girls who struggle with protecting cosmetic products and are travelling internationally in the European Union.

Step 2: Ensure the user has two identical 100mL cosmetic bottles which contain the same amount of cosmetics. One bottle will be protected using my prototype and the other bottle will be unprotected.

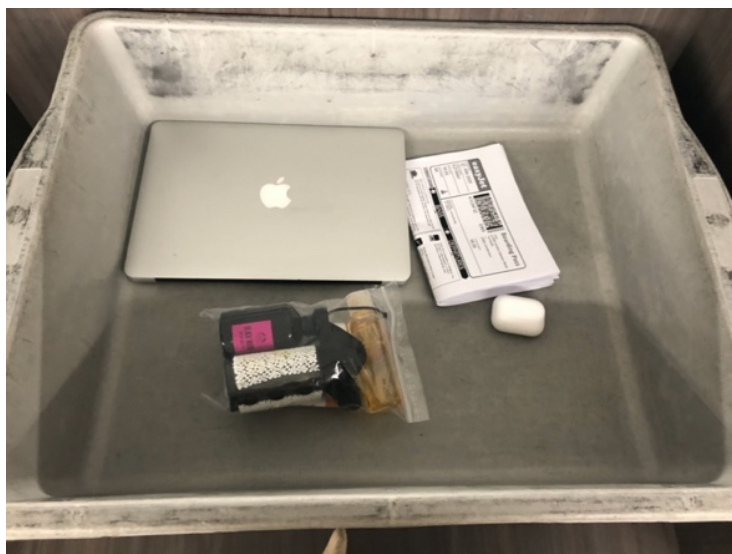
Step 3: Ask the client to photograph and write-up how the two bottles acted side by side while travelling.

Step 4: Interview the user to analyse and observe the difference between the two bottles survival of the travelling process and how well the product performed.

Justification:

It is difficult to form a focus group of several girls who are travelling within the European Union at the same time due to the clash of my product time constraint and when the holiday travel season occurs. I was reliant on three users to collect data for interaction of my product. The product is specified to work in an airport travel environment which I cannot re-create, so this test was suitable to obtain reliable data collection from photographs and write-ups.

Fig 4.1 Prototype prior to security scanning at an international airport



Evaluation of the prototype against the design specification

1. Function – specification met (1.2), partially (1.4), (1.3) but not (1.1)

(1.1) The user had an early date to depart for their travels, and a bottom section of the bottle was not designed due to time

constraints. This resulted in the prototype occasionally slipping downwards from the bottle because it did not have surface area cover for the bottom of the 100mL cosmetic bottle.

(1.2) The prototype is impact resistant and is able withstand intense forces and shocks because there were no dents or spills in the cosmetic bottle which used the prototype for protection, whereas the other bottle had these issues. User was not worried about cleaning spill from bottle 1.

(1.3) Plastazote is will not absorb water, it is buoyant. It can be washed, disinfected and wiped clean.⁷ The neoprene material's purpose protects environments that are in contact with oils and other chemical products.⁸

(1.4) The prototype is able to fit inside a plastic bag however the adjustable component was bulky.

2. Size – specification partially met (2.1)

(2.1) There was a gap in between the edge of the bottle and the prototype which meaning the prototype was not accurately measured in width and diameter. This resulted in the prototype sliding off the bottle. The height of the prototype fitted around the plastic body of the bottle perfectly.

3. Material selection – met (3.1), (3.2), (3.3) partially (3.4)

(3.1), (3.2), (3.4) Neoprene material is lightweight, smooth and flexible on two axis.

(3.1), (3.2), (3.3) Mesostructured PLA material is a thin and strong outer layer barrier against impact forces. It also has the ability to flex across multiples axis of curves.

(3.3), not (3.4) Perforated plastazote is rigid, has good moulding ability, is lightweight, tough, flexible.⁹

(3.3,) not (3.4) Perforated plastazote is rigid, has good moulding ability, is lightweight, tough, flexible.¹⁰

Fig 4.2 (Right = Bottle 1 with prototype, Left = Bottle 2 without



Fig 4.3 Evidence of spill (bottle without prototype)



Fig 4.4 Gap between prototype and bottle



⁷ (Polyformes.co.uk, 2020)

⁸ (Anon, 2020)

⁹ (Paulamar.co.uk, 2020)

¹⁰ (Paulamar.co.uk, 2020)

4. Product constraints – specification met (4.1)not (4.2)(4.4)

(4.1) Plastazote is chemically inert and resistant to oils, solvents and dilute acids.¹¹

(4.2) I was not able source someone for expert advice so I remained limited to my knowledge and expertise to only a student level.

5. Quantity – specification met (5.1), (5.2), (5.3)

(5.1) Automation included using a 3D printer, sewing machine and laser cutter. These processes are low cost because the prototype was created in a high school. These are all large-scale manufacturing processes for my standardised product.

(5.2) Each component used machinery to ensure an efficient production process and a high level of productivity. Plastazote and neoprene was bought from amazon. Polyflex TPU was bought from roblox 3D printing company because my school has a roblox 3D printing machine.

(5.3) 1. 3D printing machine was used for mesostructured material, 2. Laser cutting was used for cutting for jigsaw piece, 3. Sewing was used for the lid attachment, then components were assembled appropriately.

6. Target audience – specification (6.1) met

(6.1) The product was tested using a field to test to gain results to analyse specific issues in an airport security environment.

7. Aesthetic requirements – (7.1) partially met and (7.2) not met

(7.1) White printed PLA was not appealing because contact adhesive dried an 'ugly' yellow.

(7.2) User found that there were too many components and almost lost the lid component while travelling. She likes the concept but it would be better if it were a combined piece.

Fig 4.5 Prototype fits in 1 Litre plastic bag



¹¹ (Paulamar.co.uk, 2020)

Possible improvements for solution

1. Change in colour

Colours which were preferred from feedback suggested monochromatic colour: possibly as dark blue, dark purple and dark grey. They find set matching items more appealing. Renia Ortec¹² would be better for application to the 3D printed PLA because contact adhesive dried yellow. (see appendix)



Revised specification (7.2): Each component need its own separate dark colour tones which teenage girls find trendy.

2. Change in size

The jigsaw component needs to be smaller in width by 20mm so that the plastazote material does not slide off in the plastic bag or get lost. If the prototype slides off, this means that more plastic bottle material of the bottle shows affecting specification (1.1).

Revised specification (2.1): The product must tightly fit around the surface area of the 100mL generic sized bottle

3. Change attaching/detaching component for the lid to connect to the jigsaw piece

There was space revealing the bottle in between from the drawstring component and top edge jigsaw pieces. They required assistance to accurately fit the lid component back onto the lid of the bottle. Drawstring attachment was bulky and the strings were flimsy. Processes which can be completed in one step such as using a zip have been recommended by the user group. (Fig)

Revised specification (7.2): Simple design with a fixed attachment/detachment component which can be carried out in 1 step.

4. Adding a copy of the lid to protect the bottom of the bottle

To prevent possible dents at the bottom of the bottle and sliding, a second attachment at the bottom of the bottle is required.

Fig 4.6 Yellow dry patch of contact adhesive

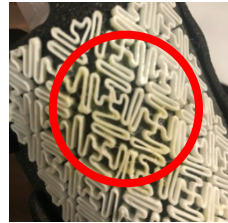
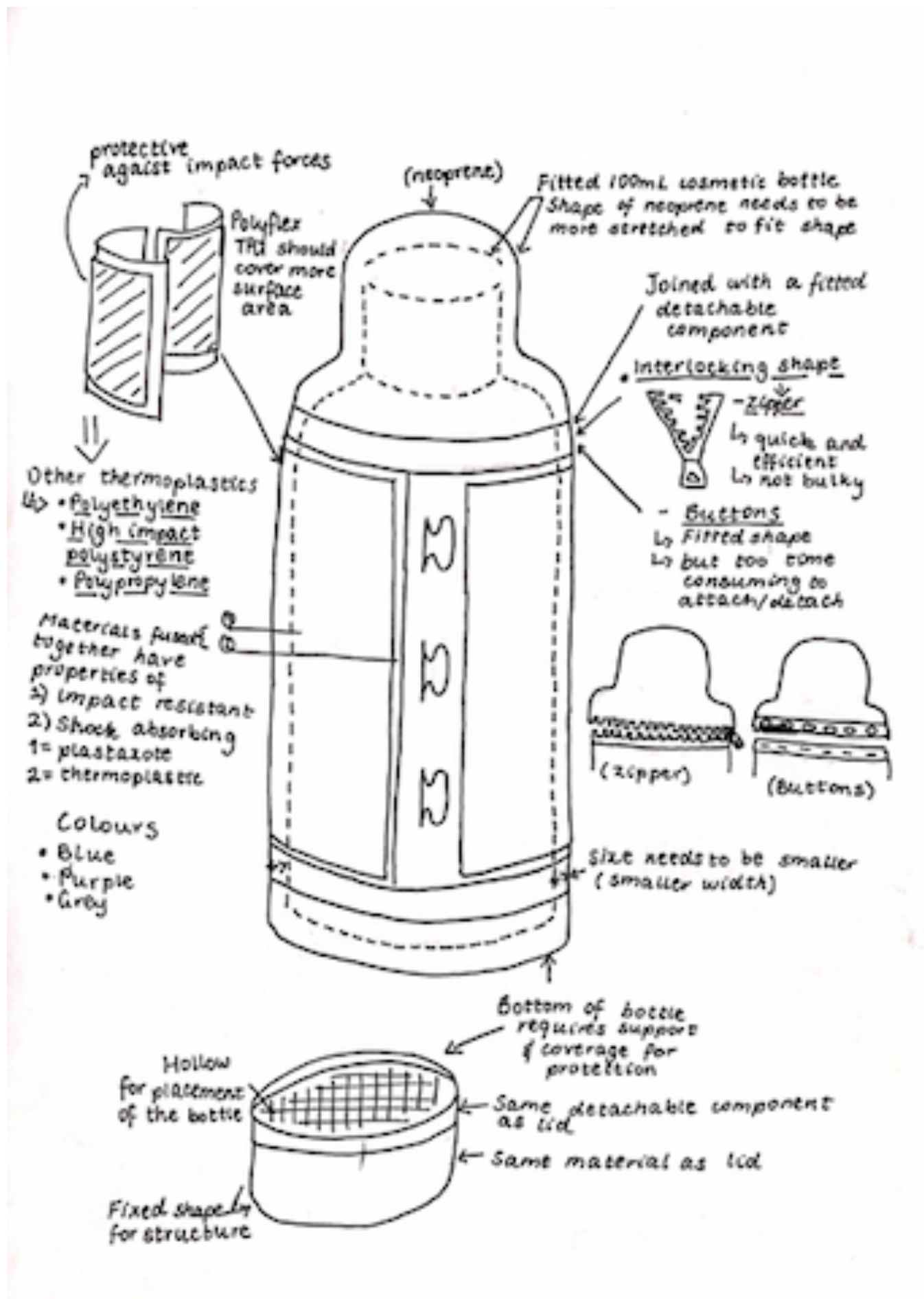


Fig 4.7 CAD model of purple colour



¹² (Algeos.com, 2020)

Drawings of possible improvements and modifications



Criterion E

Design Modifications for a commercial product

Aesthetics and planning modifications

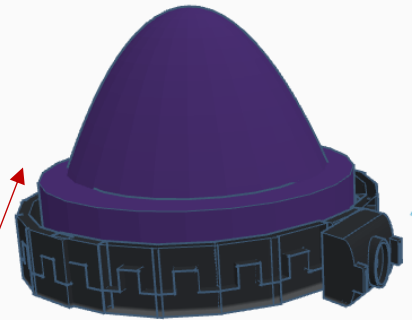
Fig 5.1 Boarding school girls adjusting and detaching prototype



Following aesthetic pattern of closing zips on suitcases

Development Fig 5.3, 5.6: Matching set of coloured components

Fig 5.2 Girls found drawstring attachment to be flimsy but looked 'cute'



Development of Fig 5.2: Dark embellishments for a zip component

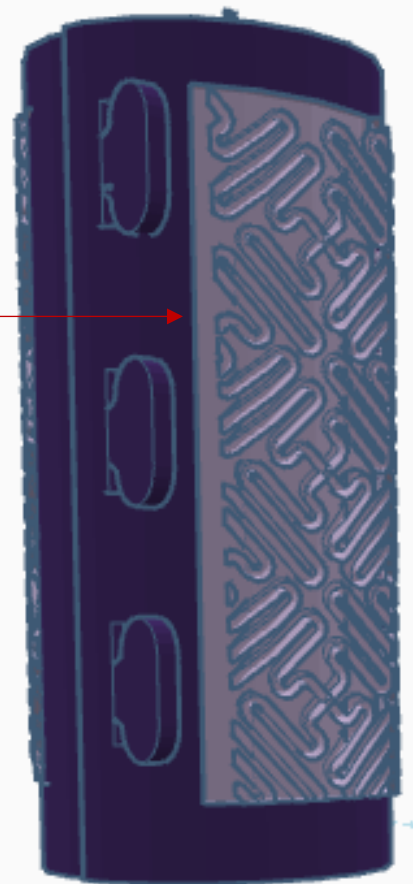


Fig 5.3 Current fashion trend is the Louis Vuitton suitcase travel set



Development of Fig 5.3, 5.4: Lighter shade of purple to show intricate details

Fig 5.4 Same colour as client's nails (common favourite colour in teenage girls)

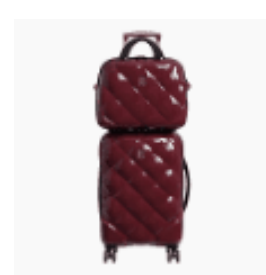


Feedback Fig 5.3: Girls admire details and logo as a different tone of colour to base material



Fig 5.6 Suitcases bought in a colour set makes travellers feel glamorous and organised

Examples:
affordable
suitcase sets
which teenage
girls own.



Design and planning modifications of prototype



**Lid: from
Criterion C**

Development of Fig 5.7:
Same concept but different
detachable component

Step 3.

Fig 5.7 Bulk causing wasted
space from drawstring
component needs to be
smooth and small



Development from Fig 5.7:
Thin zip to use less space
and material

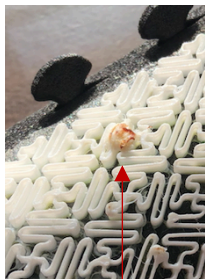
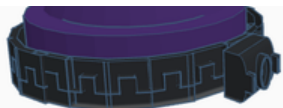
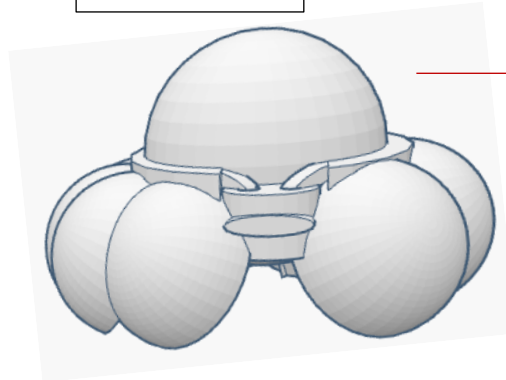
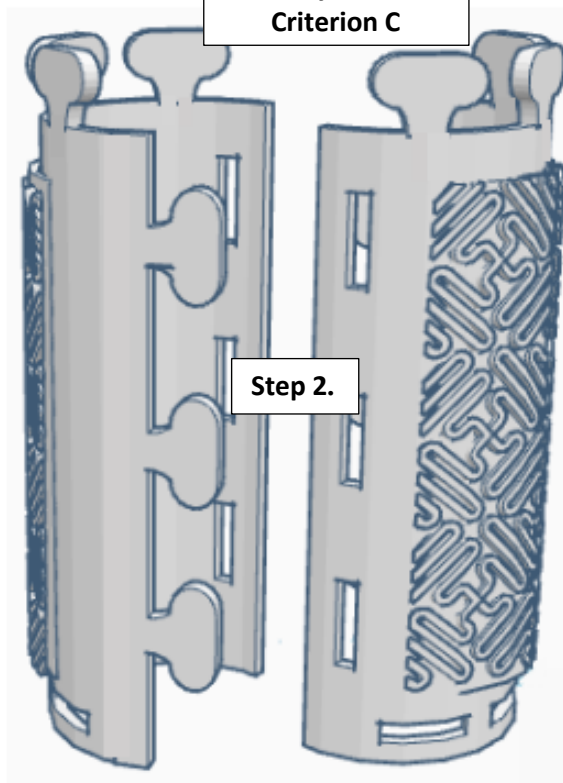


Fig 5.9 3D printing had
faults from material being
too thin and faulty machine

Development of Fig 5.9: New
positive and negative mould
for injection moulding



**Body: from
Criterion C**



Step 2.

Development of Fig 5.7:
Top zipper piece
attached to neoprene
material

Fig 5.10 Steps in order
in which user assembles
product

1. Zipping bottom piece
onto bottom of bottle
for stability

2. Interlocking jigsaw
component for
structure

3. Zipping top piece
connecting to plastazote
for protection

Step 1.

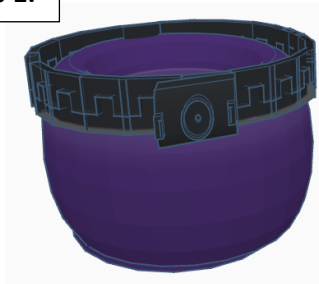


Fig 5.9 Additional component for
providing protection and stability

Feedback from Figs: Bottle looking
'dressed' in an outfit looked 'cute'

New manufacturing techniques

New measurements and materials for manufacturing as one whole piece (fused together because they are thermoplastics)¹³

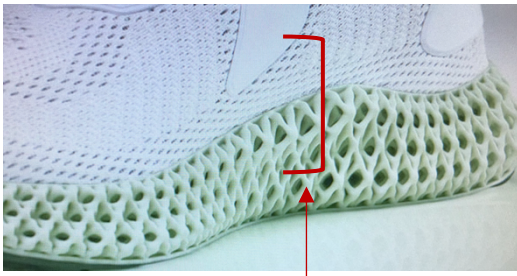


Fig 5.11 Shock absorbing, hard-wearing material one-piece injection mould reduces labour cost

Fig 5.12 Popular 21st century trainer which is injection moulded

Travel sector: no seasonal change, because it is a fixed international standard bottle.

NIKE FREE TRAINER 5.0

THE MEN'S NIKE FREE TRAINER 5.0 DELIVERS LIGHTWEIGHT COMFORT AND SUPPORTIVE LOCKDOWN WITH A DISTINCTIVE LOOK FOR TRAINING IN THE GYM, FIELD OR THE STREET.



Combining different material properties through one single injection moulding process could incorporate stiffness shock absorbency and durability

Fig 5.13 Screw type injection moulding machine to set all materials at once to be reproduced

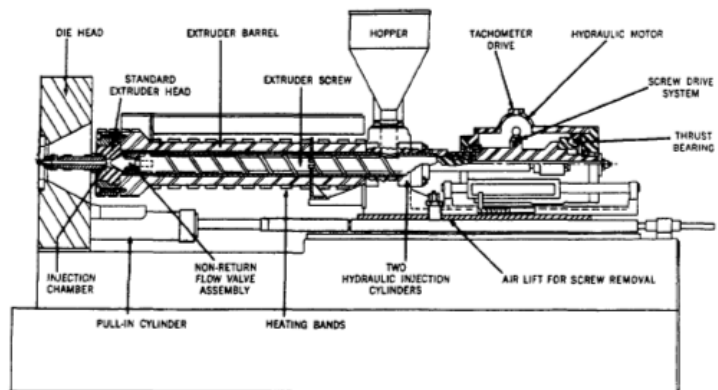
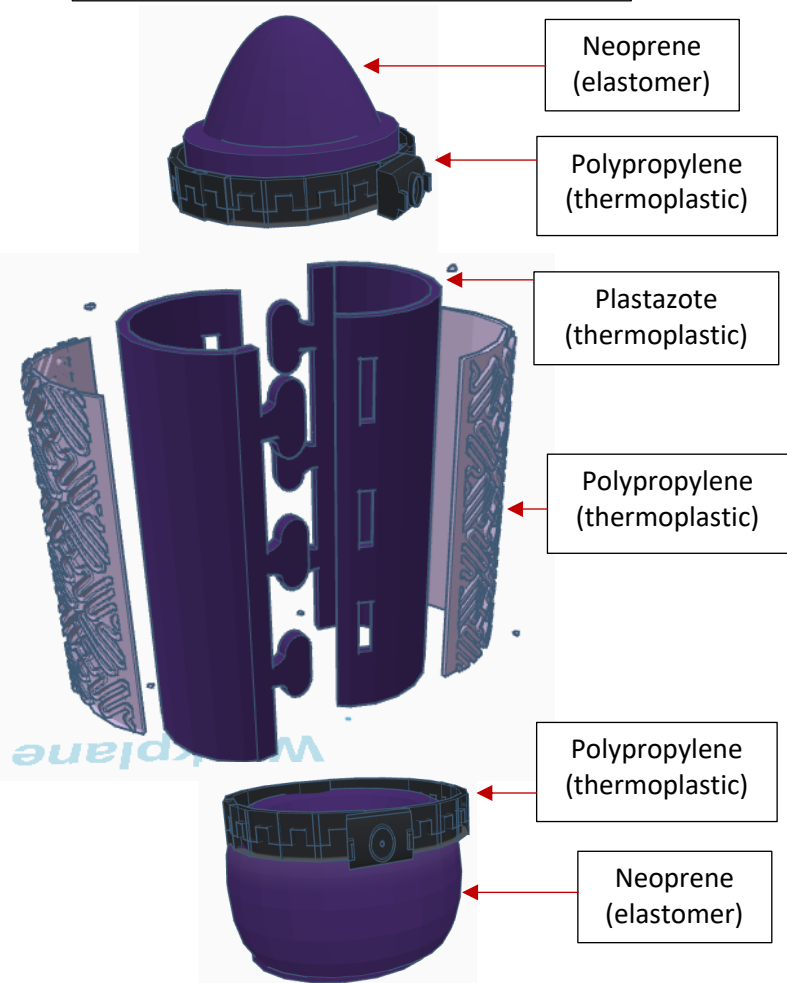


Fig 5.14 Thermoplastics and elastomers can fuse to one piece for an injection mould

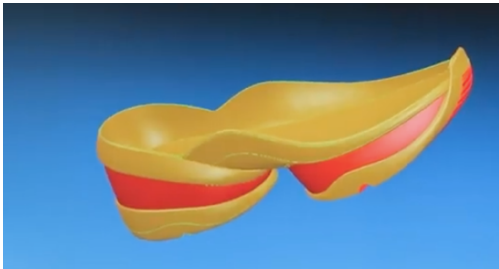


¹³ (Mold-technology4all.blogspot.com, 2020)

Injection Moulding Process (dye stamping, produced separately then combined)

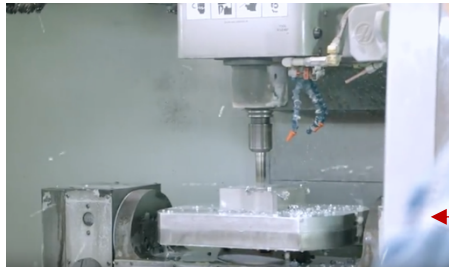
Research sourced from *'the ground up – How to make shoes'*¹⁴

Fig 5.15 Layering components to design mould



Development of Fig 5.15 Layering product components to design mould

Fig 5.16 CNC milling carves billet creating a positive and negative mould (20 hrs)



One-piece mould: Small components and good material properties



Fig 5.17 Mould fit for one size (generic 100mL bottle and size 7 shoe)

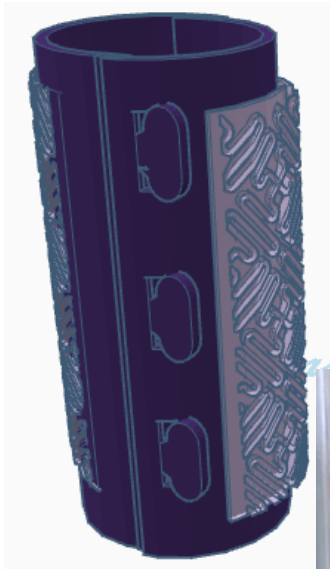
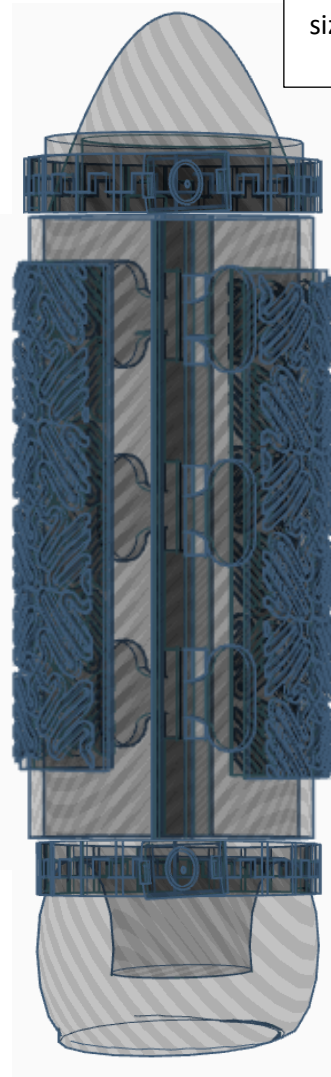


Fig 5.18 Injection moulding machine injecting material with pressure



Fig 5.19 Mould must be cured after being pressurised

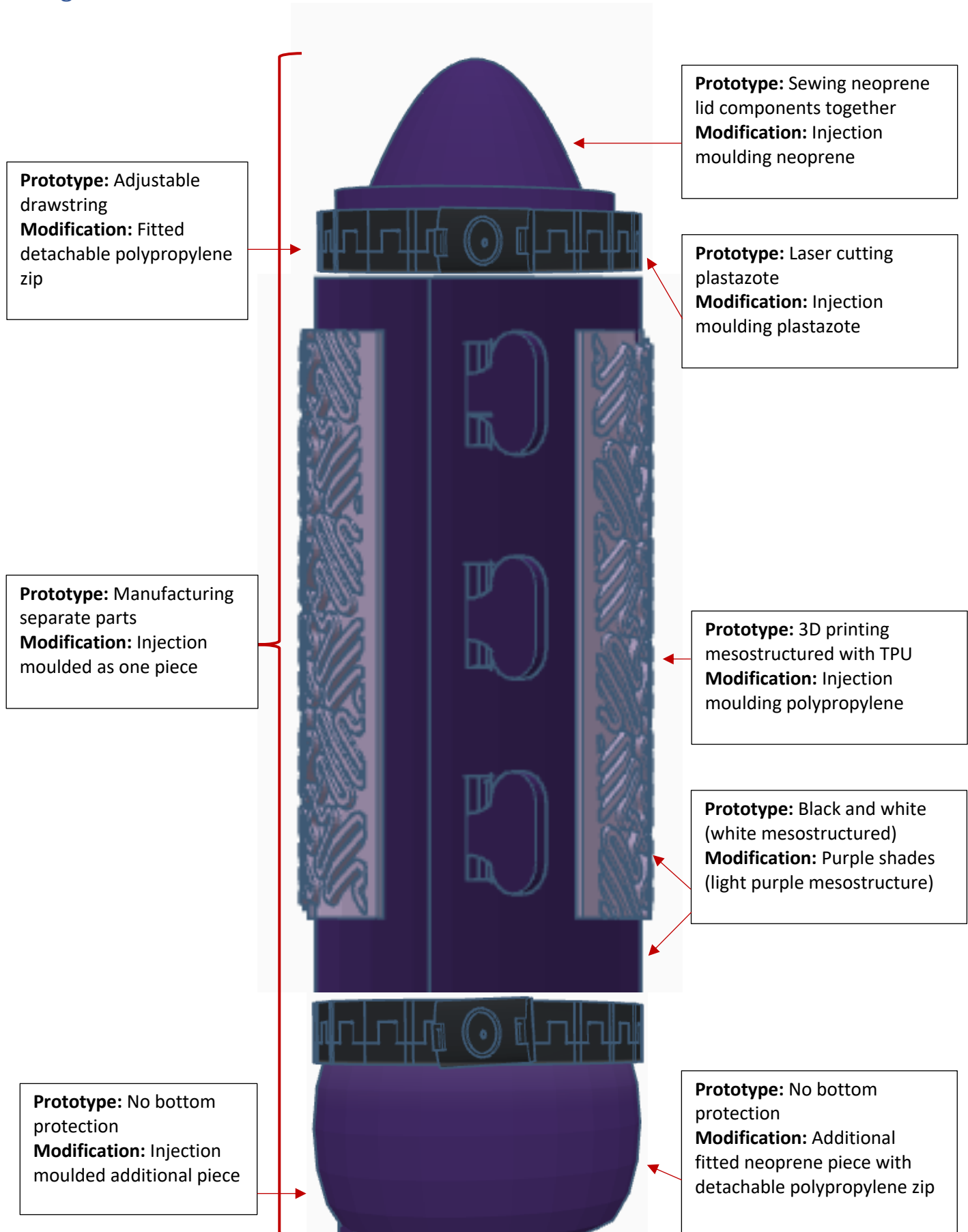


Mould is measured and inspected before process



¹⁴ (Santos, 2019)

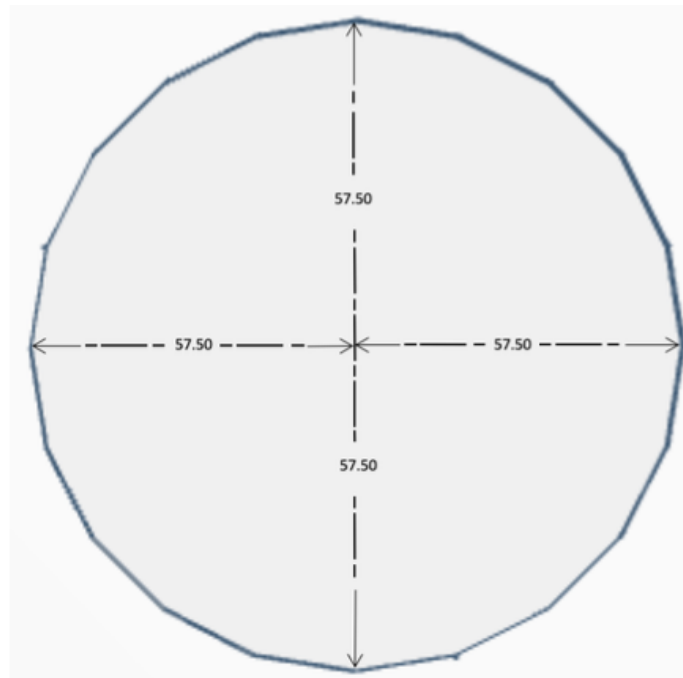
Design when fitted and stretched onto the bottle



Orthographic drawings

Top and bottom lid: Dark purple neoprene injection moulded

Plan view of
neoprene

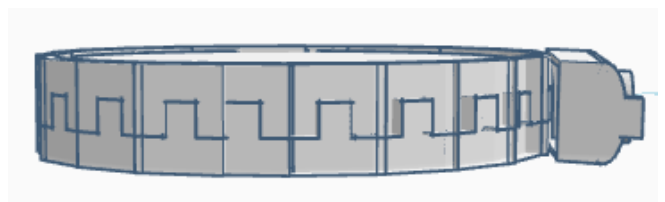


Front view

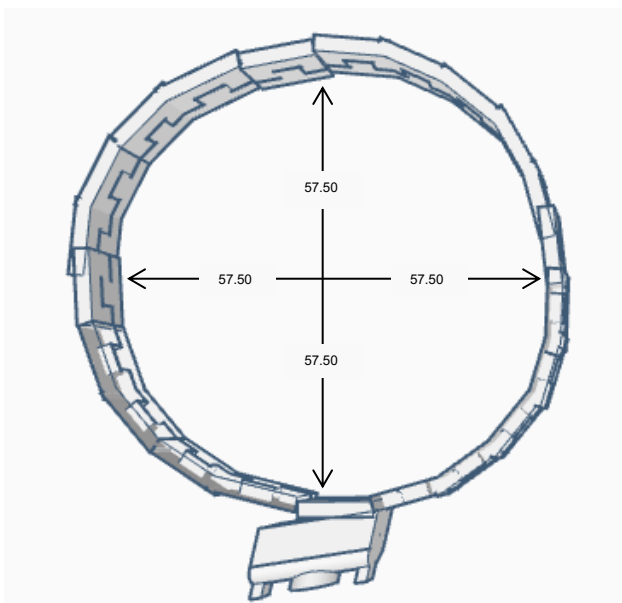


Section 1 of zipper (assembled with neoprene)

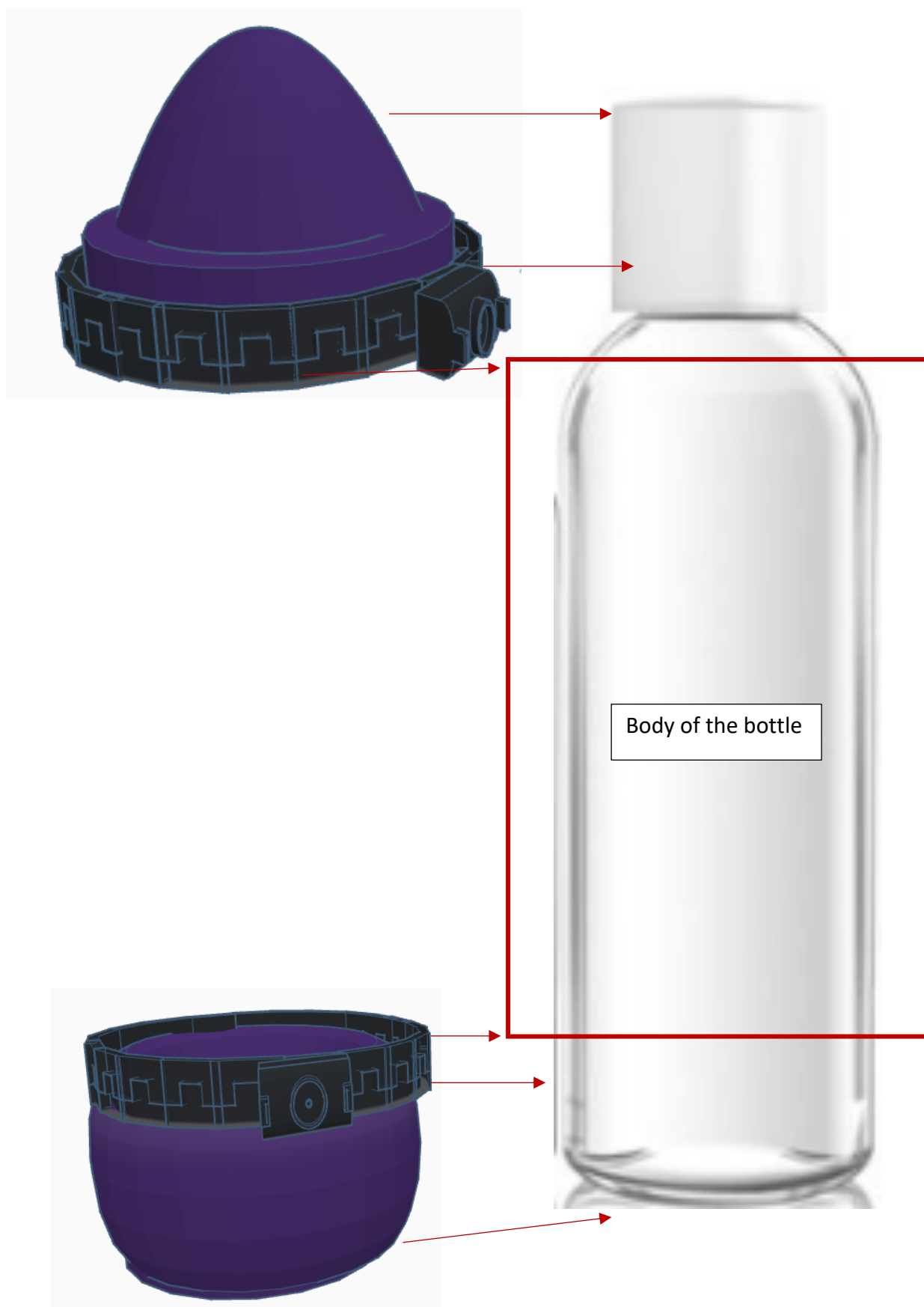
Side view



Section 2 of zipper (assembled to part 1 and 2 of
the body)



Neoprene and zip components when attached to bottle



Body part 1 and 2: Jigsaw pieces injection moulded using plastazote

Construction: Drawing is uploaded to CNC router to make positive/negative mould from in billet

Material: Purple neoprene

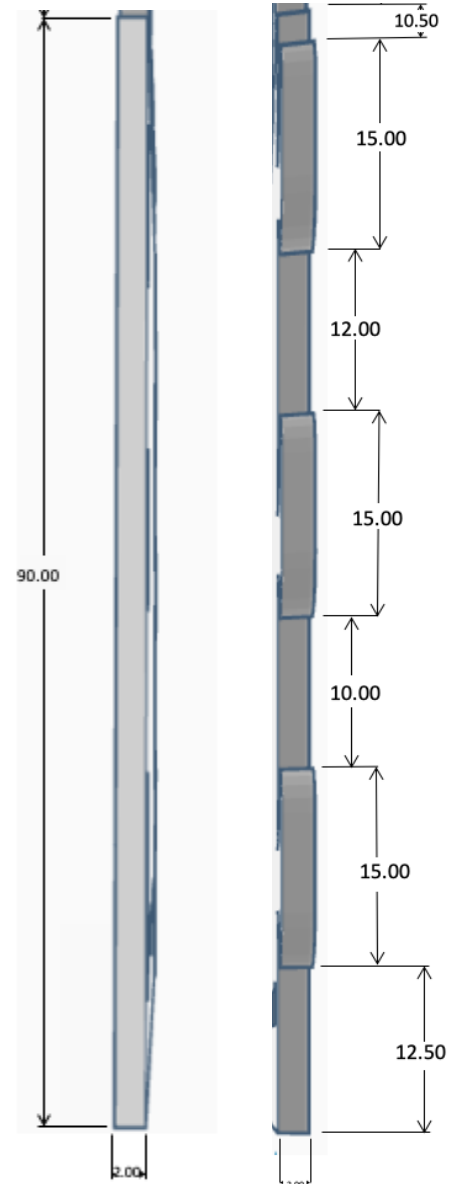
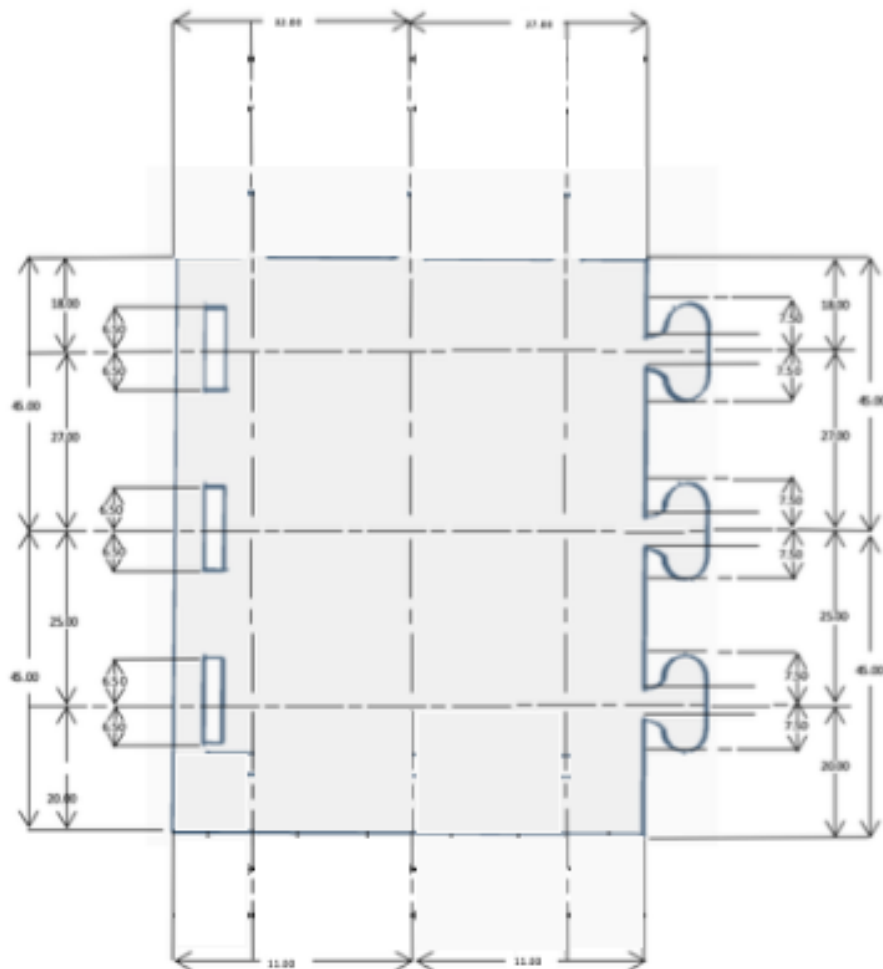
Components: Black zipper

Assembly and manufacturing: Injection moulded with all other parts

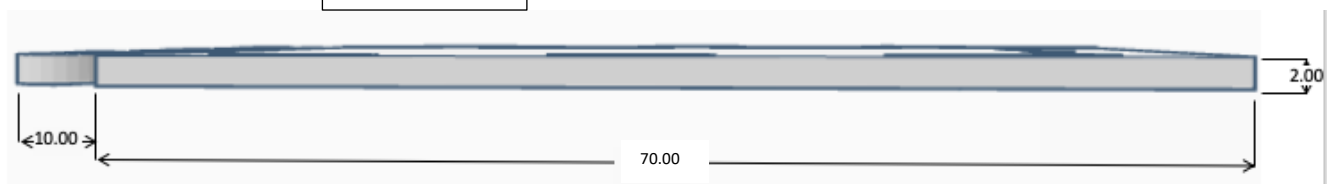
Left side view
(length)

Right side view
(length)

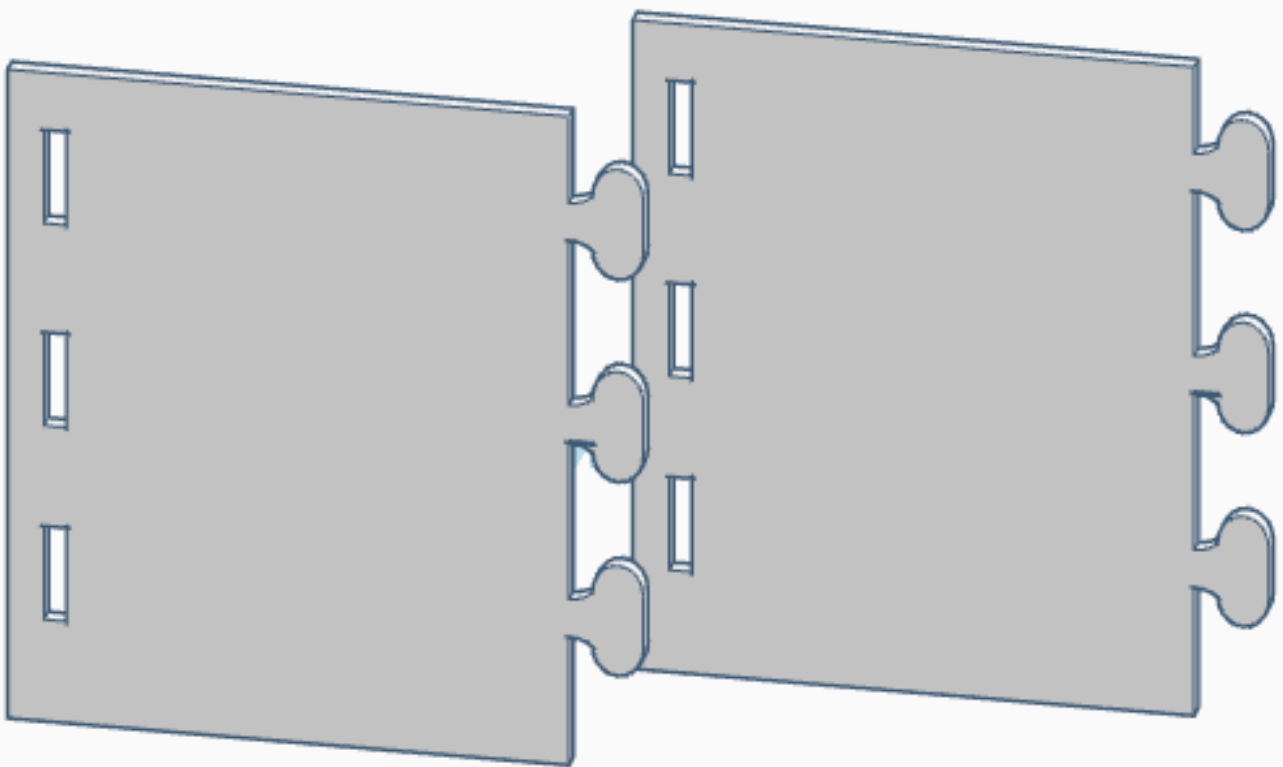
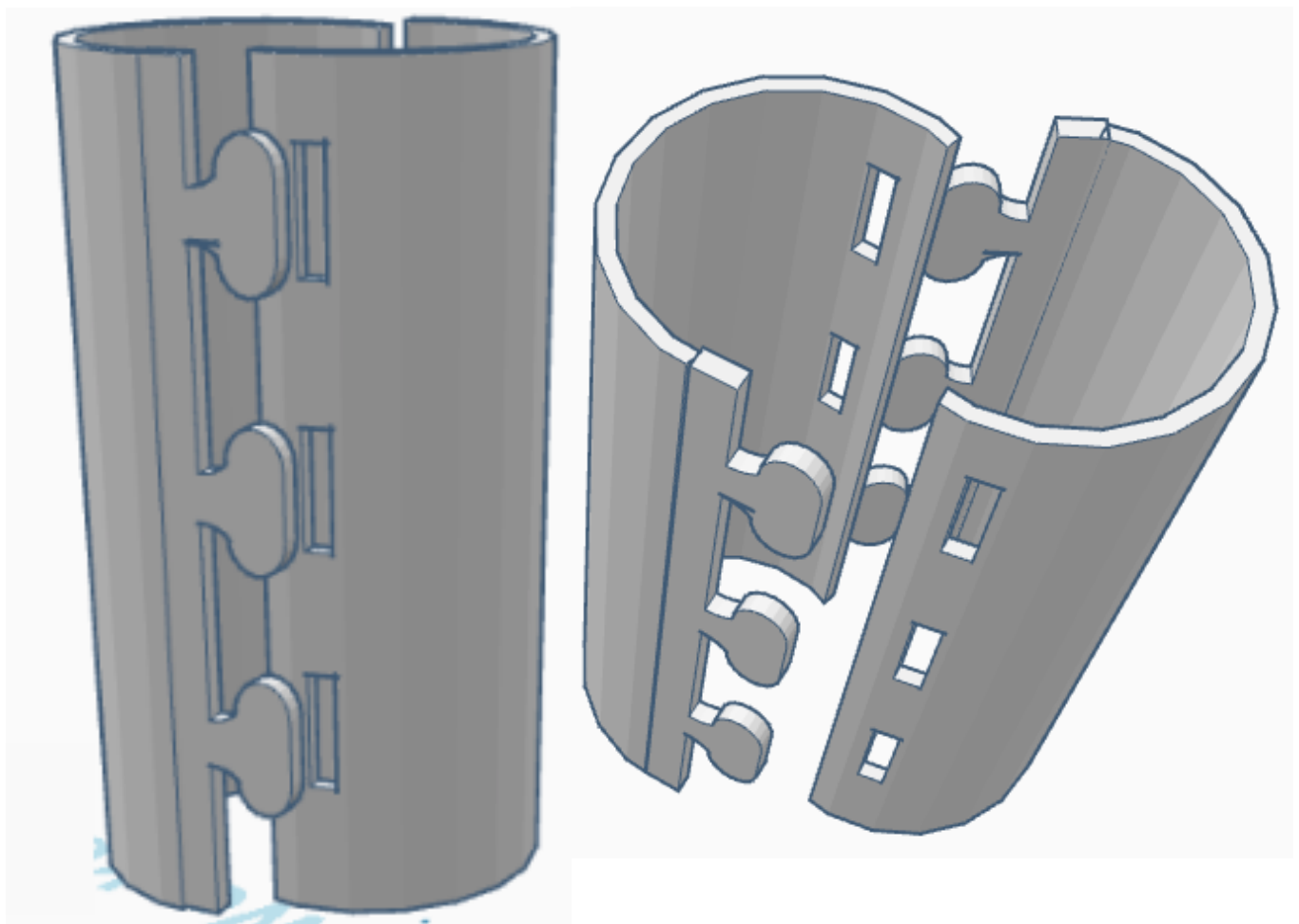
Plan view



Front and
back view

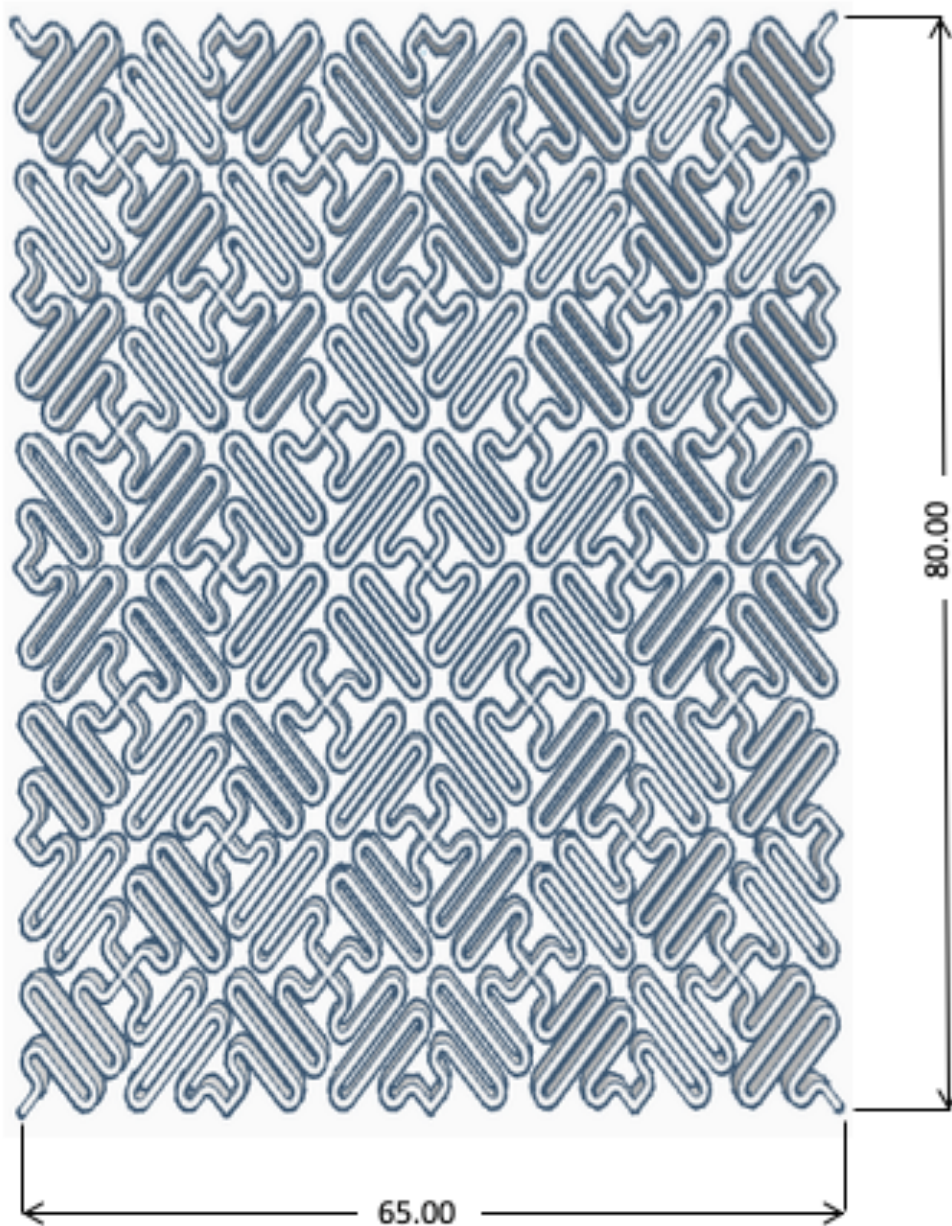


3D designs of both body components for bottle

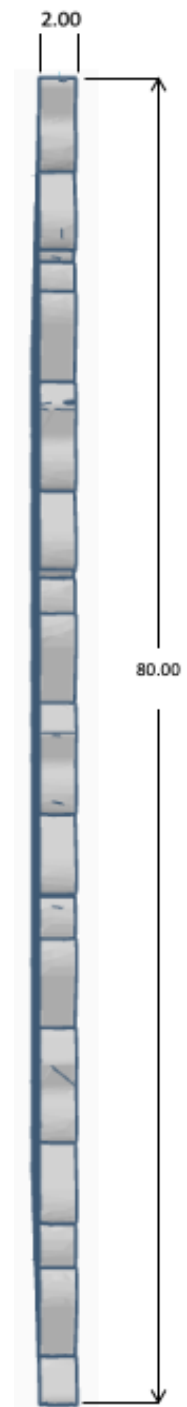


Mesostructure form injection moulded onto plastazote

Plan view



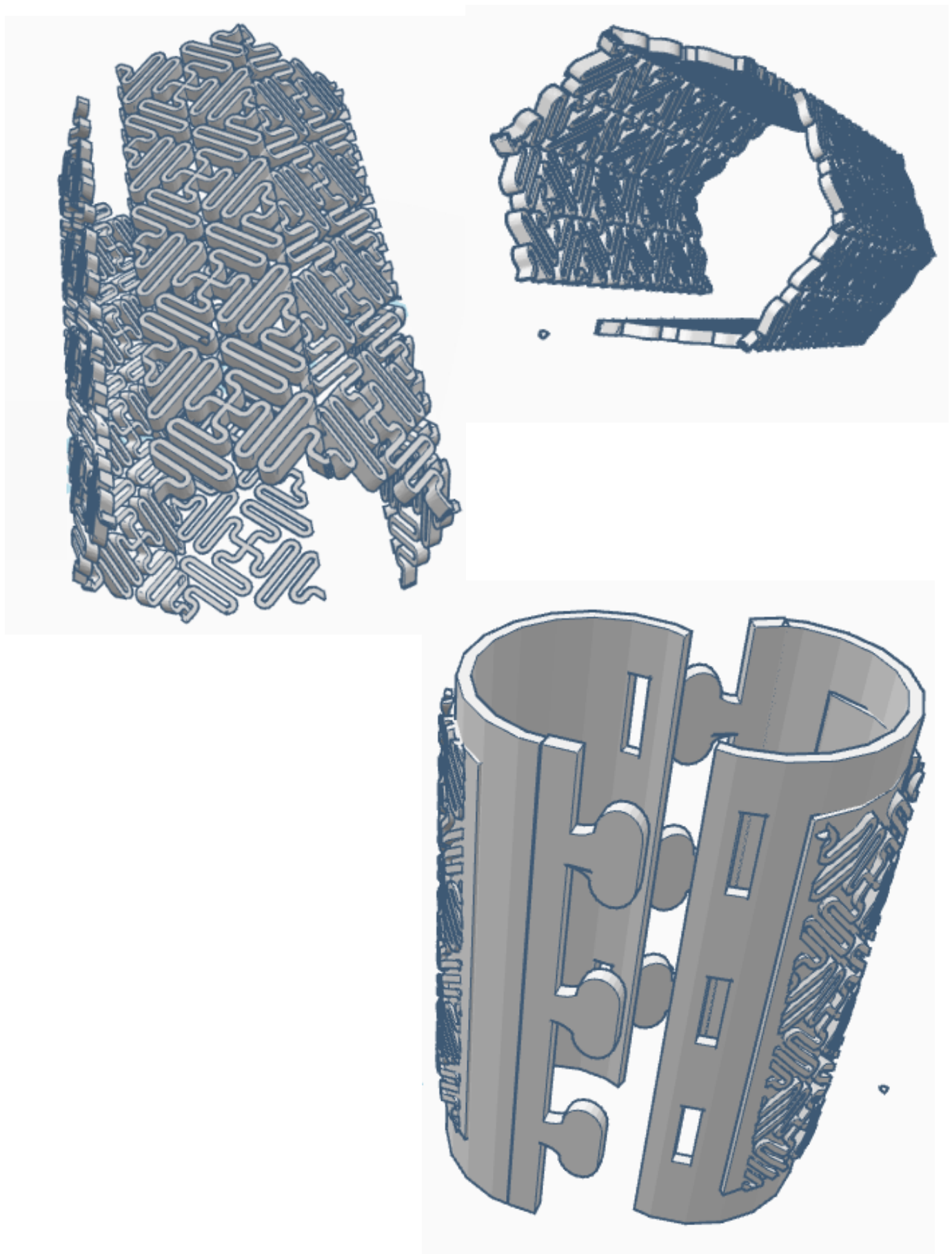
Side views(left and right)



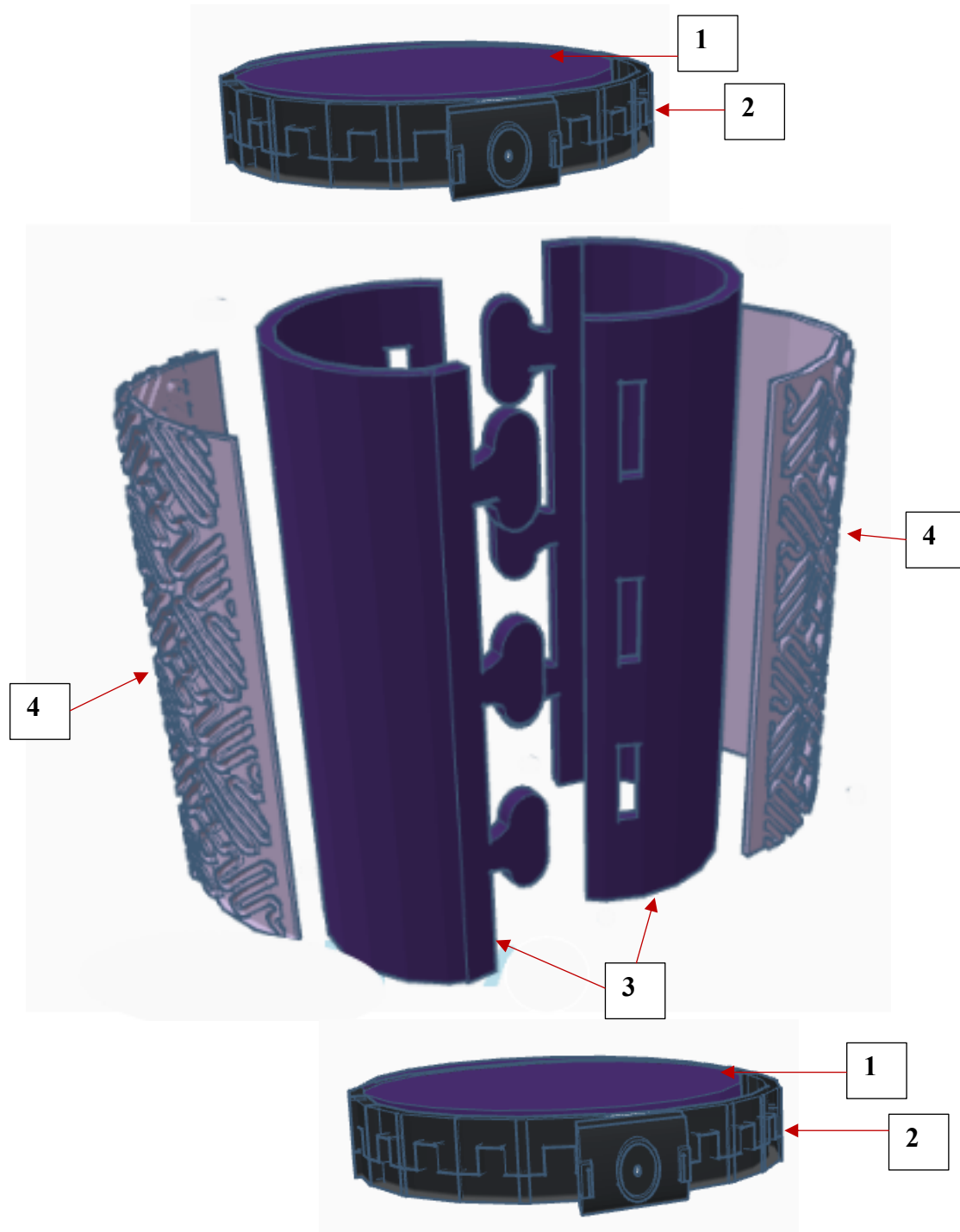
Front and back view



Mesostructure form attached to plastazote jigsaw component



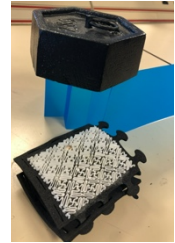
Assembly drawing of final design



Bill of materials

Part	Reference	Part name	Height	Width	Thickness	No. off	Material	Colour	Unit cost	Machine	Unit cost	Total costs
1	ASTM D1056 - 00 AFNOR 99 - 211	Lid	(flat)	60mm	2mm	2	Neoprene	Dark Purple	£16.27	Injection moulding machine	£2500	£2516.27
2	CZIS-BK6-DOLL	Zip	5mm	125mm	2mm	2	Polypropylene	Black	£8	Sewing machine	£130	£138
3	MPC	Jigsaw components	90mm	70mm	2mm	2	Plastazote	Dark Purple	£2.99	Injection moulding machine	£2500	£2502.99
4	PM70108	Mesostructure	80mm	65mm	2mm	2	Polyurethane	Light Purple	£43.36	Injection moulding machine	£2500	£2543.36

Justification of materials and components



1. Elastomer: Neoprene for lid and bottom

Characteristics	Resistant to chemicals, water, heat, flames, oxygen but more resistance against water, solvents and heat compared with natural rubber.
Properties	Good aging resistance, high tensile strength, durable.
Other applications	Padding for shoe insoles, elbow/knee supports, rubber tubing, wet suits.
Market	Tensile strength means that material can flex to supportively fit generic bottle without breaking.
Environment	Petroleum/limestone-based source is not eco-friendly. Eco friendly neoprene alternative: Natural based rubber 'NeoGreene' boosting properties and characteristics.
Costs	Synthetic rubber is more appropriate for size and thickness for protection and quantity being made.

2. Thermoplastics: Perforated plastazote for jigsaw part and component

Characteristics	Good moulding ability, washable, light weight, tough, flexible, easily cut, rigid, non-toxic.
Properties	Lightweight, tough, flexible, moisture resistant, shock absorbing.
Other applications	Plastic sheet used for orthopaedics, protective sports padding, packaging, anti-vibration mounts.
Market	Easily cut shape to form jigsaw component satisfies market needs for quickly detaching the product.
Environment	Basic foam which has no toxic or volatile chemicals such as solid chemical residues, CFC, HCFC or volatile hydrocarbons is environmentally friendly. Distilling crude oil to form plastic is not environmentally friendly.
Costs	Distilling crude oil is a cheaper and faster process to create material. It is the most suitable option for commercial production.

3. Thermoplastics: Polypropylene for zipper component and mesostructure form.

Characteristics	High resistance to cracking, acids, organic solvents, and is non-toxic compared to polyurethane. It can be moulded to be pliable above a certain temperature and when cooled, it returns to its solid state.
Properties	It is more shock absorbing, stiff, rigid, light weight, stable and good resistance to fatigue compared to polyurethane.
Other applications	Automotive industry and commercial packaging. Low density means it is light weight for distributors and manufacturers to injection mould.
Market	Light purple colour used for mesostructure to meet revised specification 7.2 (market research). Zipper is a fitted detachable component to generic sized bottle for travelling sector needs and European Union airport requirements.
Environment	Minerals in polypropylene are environmentally friendly because it is produced from natural polyolefin resins.
Costs	Polypropylene is more durable due to the fact that resist better in time, thermal and physical shock but has a higher price.

Justification of manufacturing

Injection moulding

Fused deposition modelling for commercial production is not suitable due to and the time-consuming process of the mesostructure part and the faults which were visible in the prototype. Additive 3D printing for the prototype was scheduled for 5 hours however, injection moulding can be scheduled for up to 40 seconds. Injection moulding is suitable because I am producing one generic standard sized product being made in a large quantity for the European Union regulated travelling sector. CNC machining is a faster method of prototype development and total costs are less expensive compared to Fused deposition modelling. All of the sections and components are able to be placed in a screw injection mould to produce the product as a whole because the materials are thermoplastics and elastomers.

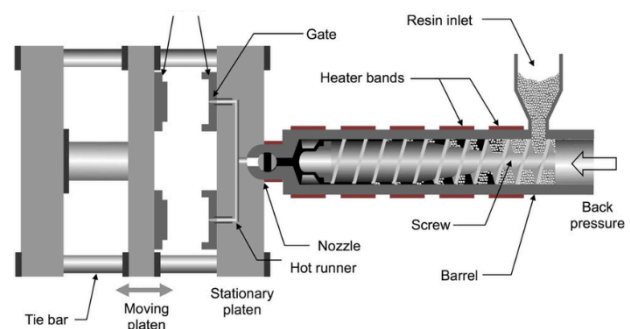
Die stamping

Die stamping the same size of material for two different components (the lid and the bottom) is the most suitable process providing a high-quality product. Neoprene is a rubber meaning it has low strength and the ability to be cut using a die cutting steel blade. (Neoprene I recommend is 2mm in thickness). The circle shape is cut is specifically fitted for the design which improves quality because the process is specialised in a single batch. Using scissors to cut the prototype was not accurate to the shape that was drawn on the material. It also takes a lot of time and money. There is opportunity to provide employment and profit through batch production however, my market is all across the European Union. Die cutting can be evolved to mass production using an automatic die stamping machines.

Fig 5.20 Practising die stamping in my school facility

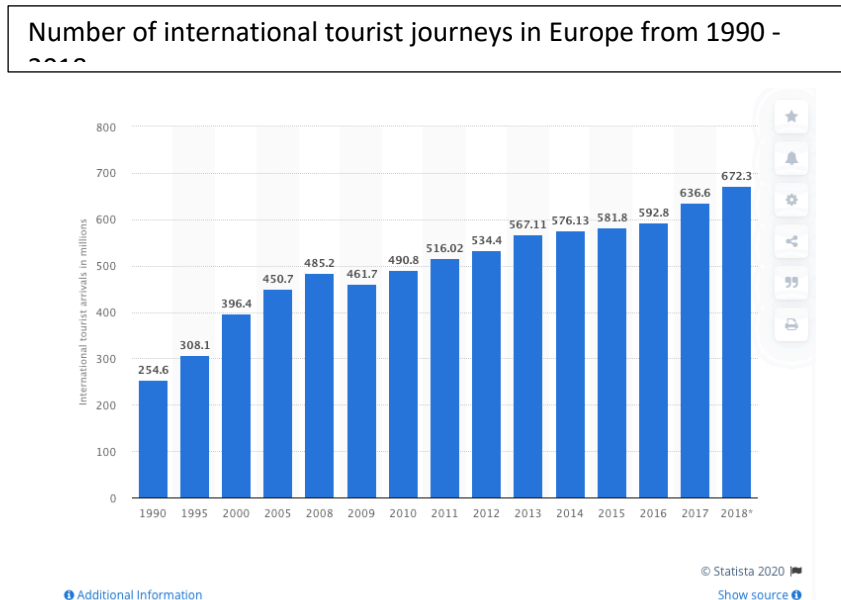


Fig 5.20 Screw injection moulding machine



Volume and scale of production

Tourism holds an important role within the European Union because of economic and employment potential. Travel is associated with tourism, meaning a large scale of production should be used to make my prototype for the travel/tourism industry. European tourism statistics from 'statista.com'¹⁵ shows the number of international tourist arrivals in Europe from 1990 – 2018. This measures the potential market size however; it doesn't account the whole travel industry.



$$\begin{aligned} \text{Potential market size for 2019 (based on tourism)} &= \begin{array}{l} \text{Percentage increase} \\ 672.3 - 636.6 = 35.7 \\ 35.7 \div 636.6 \\ = 0.05607 \\ 0.05607 \times 100 \\ = 5.61\% (35.7) \end{array} \quad \begin{array}{l} \text{Potential market size} \\ 672.3 + 35.7 \\ = 708 \text{ million} \end{array} \end{aligned}$$

To achieve economies of scale:

Batch production: Die stamping inexpensive materials such as the neoprene because it is partially reliant on automation, partly reliant on humans. This process is produced in quantities and completed for the next stage using the same machinery. The set-up costs are low but it requires human intervention for the whole process.

Mass production: Manufacturing as one whole injection moulded classic design where output is large scale at full capacity. Average fixed costs are reduced through technical economies of scale because production costs are spread over the high output volume. Machines work continuously to supply the large capacity of products needed. Machines could break down but they do not need wages, rests, breaks so it decreases production costs in the long run as no labour costs are reduced. Machines also maintain quality standards by using expert workers who can maintain quality control such as tolerances because of the repetitive accuracy of machines.

¹⁵ Statista. (2020)

Appendices

Smartwings.com forbidden items and substances in airports states that “Chemical and toxic substances that can be dangerous to passengers and crew or the aircraft and property, such as: Corrosive or bleaching substances, e.g. mercury, chlorine”

Dupont MSDS sheet and under Fire & Hazard states: burning neoprene produces noxious and toxic fumes.

Other sources say neoprene burns green, which means it contains chlorine and can damage your lungs. Sites such as Boston Laser, Polou and the Fashion industry are saying that neoprene is laser friendly and can be laser cut.

Criterion D referenced on, page 33

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- Algeos Educating Riyadh
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Renia Ortec

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Description



Renia Ortec is a Polychloroprene cement for bonding many materials used by orthopaedic shoe technicians, pedorthists, and foot orthotists. **Free of toluene and MEK.**

For use with:
Renia Ortec provides a strong bond on all materials used for repairing or producing shoes and orthotics/prosthetics like leather, rubber, PU, EVA, TR, felt, cork, compact PE/PP, metal, etc. (except plastified PVC, for which we recommend Renia Colle de Cologne All Purpose Cement).

Instructions for use:
Grind all materials and coat them with Renia Ortec until you can see a layer of cement. (Sometimes, you have to coat leather and other porous materials twice). Refer to additional preparation guidance below.

Preparation Guidance:
PE - PP: No special preparation necessary.
TR (Thermoplastic Rubber): Clean with acetone. Certain TR types need to be halogenated with Rehagol and bonded with Syntic-TOTAL or Colle de Cologne.
PUR (Polyurethane): After grinding, press the material with absorbent paper to remove the water. Then coat it with Renia-Primer for PUR and the adhesive without delay. Because of the long open time, this cement is ideal for use in larger series. The cement is also free from typical allergens.

Open time:
(Depending on the material): 5 - 60 minutes.
TR: 5 - 30 minutes.
Ortec can be dried with an infrared lamp or a heat gun: IR-Lamp 80 °C: 3 minutes, shock-activator: 3 seconds.