FBP-Report
Industrial Design

AEG-X

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Crafting Wearable Senses

ABSTRACT

This design project addresses the lack of **comfort, personalization, and modularity** in motorcycle protective gear while maintaining high safety standards. Utilizing a non-linear Double Diamond design process with integrated design sprints, it introduces Aeg-X; a novel fractal-based design inspired by the Sierpinski pyramid, engineered for its unique balance of flexibility and impact absorption. The structure is applied to create motorcycle body armor for the shoulder, morphing the fractal geometry into a rounded form that tapers toward the edges to ensure an ergonomic fit and seamless integration with existing gear. To enhance usability, a modular Velcro attachment system is incorporated, allowing users to easily remove and attach the armor as needed.

The project evaluates the design's structural properties through dynamic impact and flexibility testing using six TPU samples with small structural adaptations, supported by feedback from an expert and seven motorcycle drivers aged 18–28, to ensure alignment with real-world market demands.

The results demonstrate that the new fractal structure meets Level 1 CE safety standards for dynamic impact absorption while maintaining lightweight and flexible features. The on-top modular placement introduces unexpected benefits, offering enhanced personalization and modularity that appeals to a broader range of users than initially envisioned. This success inspired the inclusion of a wide colour range and services aimed at improving the usability of the customization and modular features.
Aeg-X contributes to the field by demonstrating its potential for modular, user-friendly safety gear. It opens new opportunities for innovation in motorcycle armor and safety-critical industries such as sports and military equipment. Future work focuses on exploring alternative materials, testing long-term durability, and developing scalable manufacturing methods to address production challenges. This project marks a meaningful step toward customizable, lightweight, and effective protective technologies.

TABLE OF CONTENT

INTRODUCTION

Motorcycle gear typically consists of several essential items: a helmet, which is mandatory in most EU countries, along with gloves, boots, and either a suit or a combination of a jacket and pants, collectively referred to as "gear." This gear protects riders from weather conditions, as well as abrasions and penetration injuries during a crash. A key component of this gear is the armor worn underneath the suit, which consists of strategically placed padding on the back and joints designed to absorb crash impact, playing a critical role in rider safety.

The motorcycle gear industry is valued at €13.53 billion globally, with an annual growth rate of 6.6% (Motorbike Riding Gear Market Size Report, 2023). This growth reflects increased awareness of the importance of safety gear and the rising number of motorcycle riders worldwide. However, despite the expanding market, the motorcycle gear industry faces significant challenges in balancing safety, aesthetics, and user needs. While protective gear is designed to meet stringent impact resistance standards, it often compromises on comfort and ease of use. Current solutions rarely address the users needs and ability to accommodate diverse body types, leaving many riders unable to find gear that fits well or feels comfortable. This lack of attention to comfort creates a critical problem: many motorcyclists choose to forgo wearing protective gear, citing discomfort during use, the inconvenience of carrying bulky equipment, or the hassle of putting it on.
These challenges are particularly pronounced in the rapidly growing female motorcycle market. In 2009, women represented just 10% of the market, but by 2018, this figure had doubled to 19% (Women Motorcyclists: Driving Change on Two Wheels, n.d.). Despite this growth, the male-dominated industry offers women only a fraction of the gear choices available to men, exacerbating issues related to comfort and fitment for female riders.
The importance of motorcycle gear cannot be overstated, as motorcycle riders are 9 to 30 times more likely to be killed in traffic compared to car occupants (Slootmans Freya, 2023). Addressing these challenges requires innovative solutions that prioritize safety while improving user comfort and accessibility.

This project focuses on the armor component of motorcycle gear, offering a 3D printed design that retains high safety standards while increasing comfort through added mobility and a lighter weight. Additionally, it introduces modularity, allowing users to adapt the gear to their needs, which addresses the limited selection for female riders and responds to various other identified user needs. By combining these elements, the design aims to provide a more user-friendly and adaptable solution to protective motorcycle armor.
This report will discuss the concept and design methodology employed across three iterations, outlining a design process that integrates research from multiple fields and extensive testing. It concludes with a discussion of the findings and a summary of the project’s contributions and implications.

CONCEPT

Aeg-X is an innovative motorcycle armor, aiming to combat the lack of comfort, personalization, and modularity in motorcycle gear, while maintaining a CE-certified Level of impact absorption. To achieve this, it uses both its unique custom structure and its positioning.
Aeg-X (Figure 1) is created using a TPU 3D-printed structure, based on the sierpinski pyramid, a fractal type structure. The structure is lightweight and bends easily along the side the body moves in, while being sturdier in the other direction to keep impact absorption as high as possible.

Figure 1, Photo of Aeg-X from various angles

Figure 2, Various Aeg-X colorways

This armor boasts its own logo, comes in various colours (Figure 2) and can easily be worn on top of your gear through a Velcro attachment, making them easy to switch out or take off. This gives riders the option to easily replace armor after a crash, switch to other colours, and take the armor off for other activities. Wearing the armor on the outside of the gear also increases mobility (figure 3).

The Armor can be bought in physical and online motorcycle gear stores as either a full body set (8 pieces for around 100 to 200 euros) or individually (for around 20 to 40 euros).
Aeg-X can be bought together with the accompanying gear, like a jacket or suit, from a partnering motorcycle gear brand. These come with the necessary Velcro attachment applications and flat leather Velcro patches to cover the exposed Velcro when no armor is attached.

Figure 3, Aeg-X Orange and Black, worn on a leather motorcycle jacket.

PROCESS METHODOLOGY

To create Aeg-X, a **non-linear Double Diamond design process with integrated design sprints** was used to cover three iterations (Figure 4). The design sprints are adapted to this project by changing the "Sketch" step to a wider "Explore" version as sketching does not suit some of the explorations in this project. A more in-depth visual on the integration of this process is seen in Figure 5, and throughout the document (Figure 6, 11, 12, 20, 27, 34, 60, and 77). During the project, all activities were documented in a physical workbook (Appendix 1) at the end of each week, simultaneously acting as a feedback session on the activities of that week.

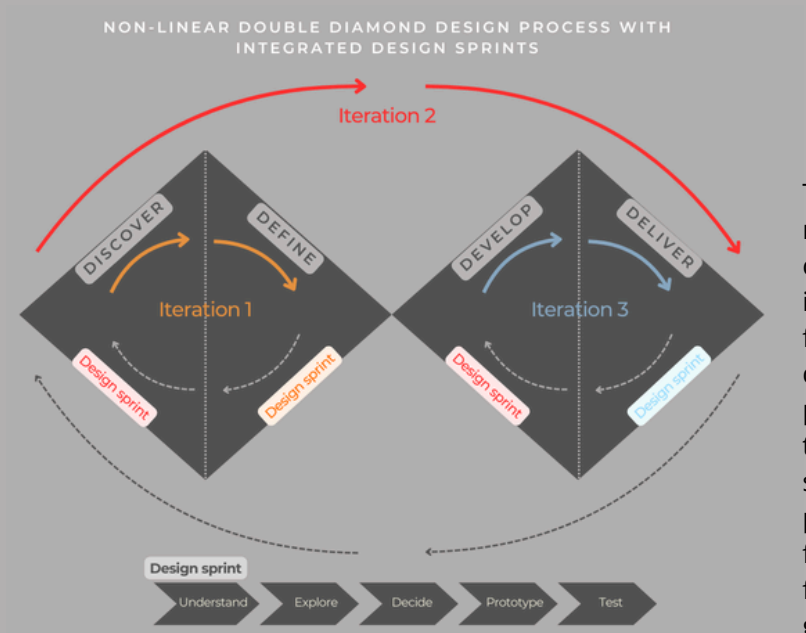


Figure 4, Design process visualization

This process is well-suited for the technical nature of this project, which involves combining multiple distinct components into a cohesive final design. Its structured framework, balancing exploration, definition, development, and delivery, provides the flexibility needed to address the technical challenges of integrating separate elements, such as structural properties, Aesthetics, and usability features. The non-linear approach, makes for built-in feedback loops. Emphasizing gathering and integrating insights throughout the design stages.

The addition of design sprints enhances this by enabling rapid prototyping and testing, providing opportunities to quickly validate and implement ideas.
This combination ensures that the final design balances its multidisciplinary nature to create one fully coherent design.

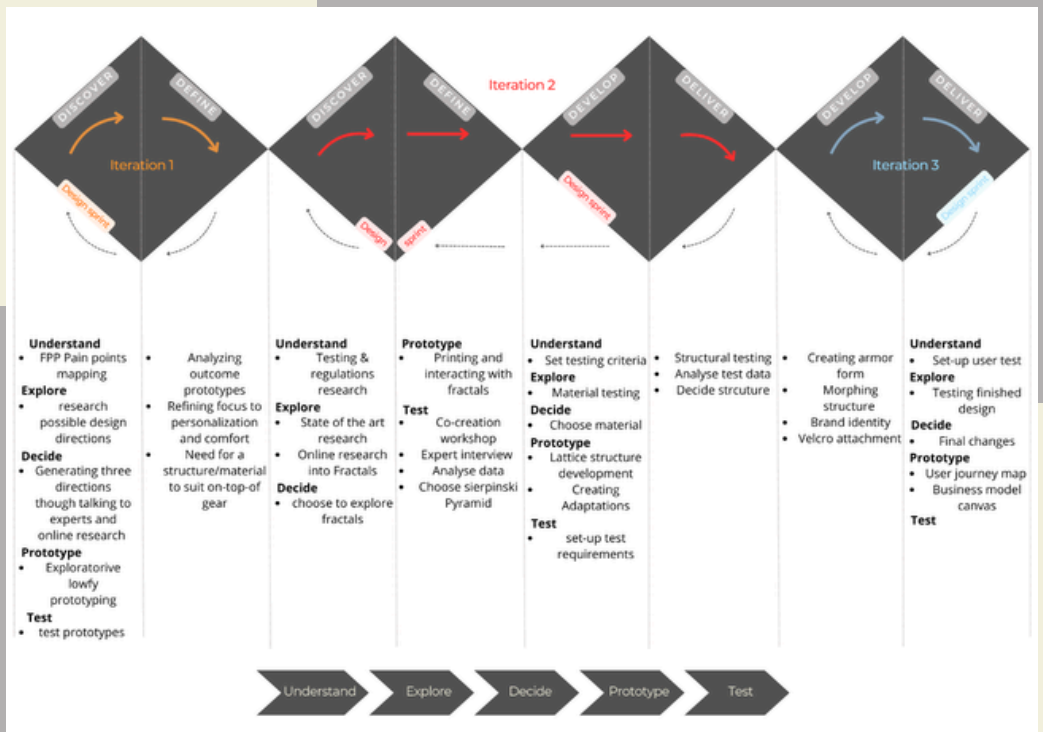


Figure 5, Visualization on the design process integration

ITERATION 1

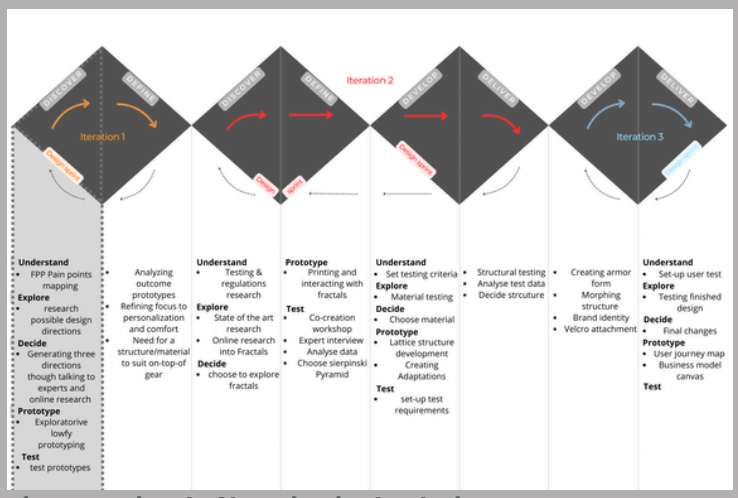


Figure 6, Visual of location in the design process 1

Drawing from the first-person perspective (FPP) of a female motorcycle rider, half a Value Proposition Canvas (VPC) was created to understand user needs and challenges with motorcycle gear (Figure 7).

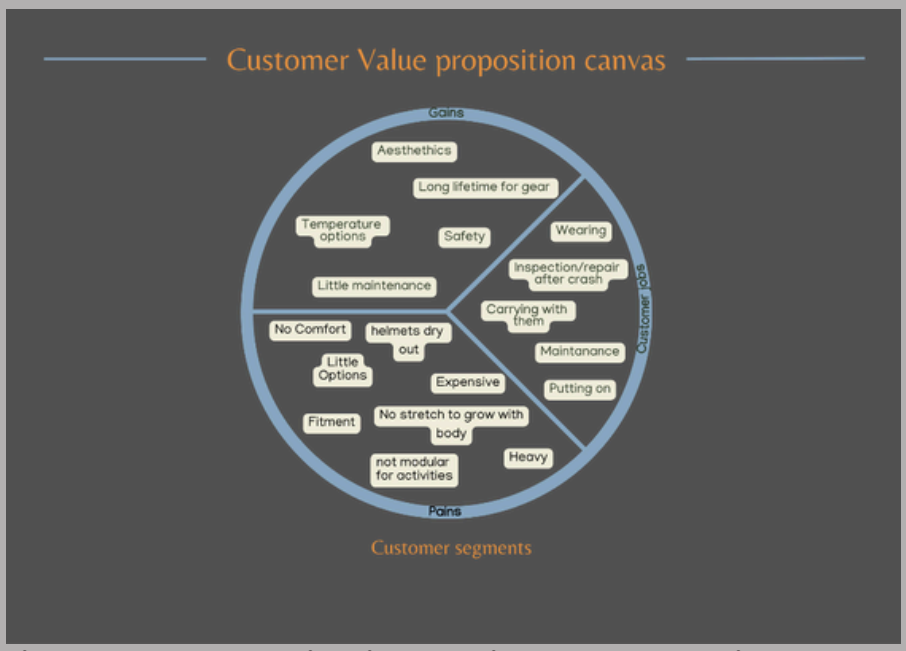


Figure 7, Customer VPC filled in from a first person perspective

This analysis highlighted key pain points, which guided the exploration of three design directions: Coiling, Auxetics, and On-Top Gear Placement.

1.2 Three design explorations:

Coiling

This concept explores a 3D printing technique inspired by the work of (Amorim et al., 2019). The hypothesis being that a coiled structure can offer interesting shock-absorbing qualities. For this to work on 3D objects, the print plate needs to rotate beneath the nozzle. A pre-build Stewart platform was used (Figure 8), which was programmed to move according to specific inputs based on existing code (ThomasKNR, n.d.).

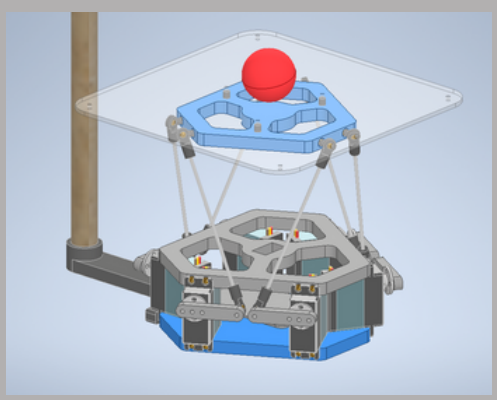


Figure 8, Steward platform set-up (Stewart Platform – Aaed Musa, n.d.)

Auxetics

these are structures that harden/expand on impact (figure 9) with proven impact absorbing qualities (Bohara et al., 2022). To explore this concept, research was conducted into auxetic structures, and their implementations like shoe soles (Sun et al., 2024), vehicle bumpers (Y. Wang et al., 2017), or seismic applications (Zhang et al., 2021). The research also highlighted the potential of hybrid auxetics, which offer a better balance between flexibility and stiffness (Bohara et al., 2022).

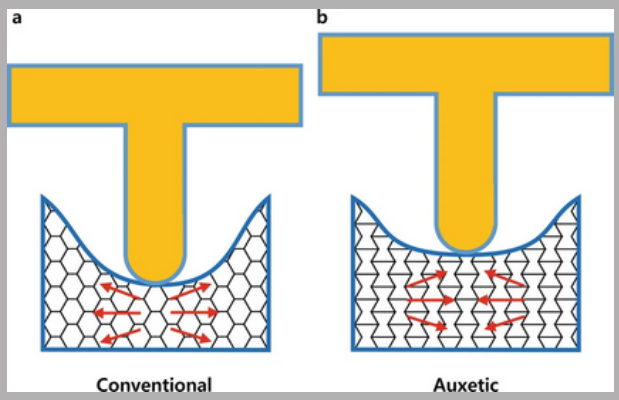


Figure 9, Auxetics expanding properties (Cho Hyeonhoand Seo, 2019)

On-top

This concept tests whether placing armor on top of motorcycle gear can improve rider mobility. To explore, two identical gloves were modified using egg cartons and hot glue simulating armor placement, one with armor on the outside and one underneath (Figure 10). Gloves were chosen because hands have many moving parts, making them ideal for evaluating mobility differences. Eight participants tested the gloves, and all reported greater comfort and freedom of movement with the armor on top.

Figure 10, On-top placement evaluation through wear trials with gloves

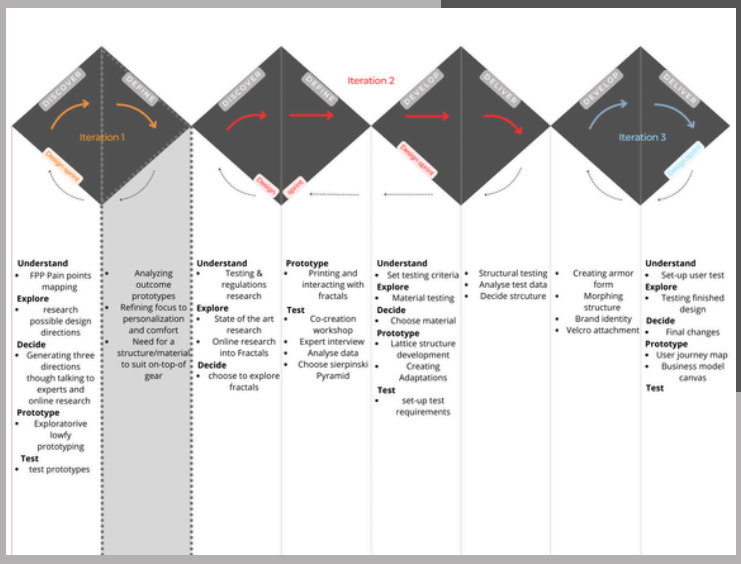


Figure 11, Visual of location in the design process 2

1.3 Analyse explorations:

the outcomes of the initial explorations and prototypes were analyzed for feasibility, innovation, and alignment with user needs.

The **Coiling** concept, while promising in theory, proved too technically complex, requiring advanced programming, precise calculations, and resources beyond this project's scope, leading to its dismissal.

Auxetics with proven impact absorption properties, revealed significant challenges. The field is highly saturated, making it difficult to bring meaningful innovation. Given the absence of auxetics in current motorcycle gear, it is likely that manufacturers have explored and ruled out this approach, reducing its viability as a direction.

The **On-Top Gear Placement** concept delivered expected results of greater comfort and mobility with armor placed externally. However, its standalone impact was minimal, requiring integration with a structure or material to enhance comfort and mobility. Since the armor is visible, aesthetics also become a key factor to address.

With this on-top concept in mind, reflecting back on the initial VPC highlights a broader issue of personalization, especially for female riders with limited gear options. Personalization, alongside comfort and mobility, now becomes a central goal in designing the accompanying structure or material, to create a solution that is both functional and emotionally resonant for riders, ensuring it stands out in the market.

ITERATION 2

Motorcycle armor is essential for rider safety. Advances in material science, additive manufacturing, and innovative design methodologies now enable the development of lightweight, durable, and customizable protective gear. This section explores the current state of motorcycle armor technology, the application of 3D printing, and the potential of impact-absorbing structures to improve both safety and aesthetics.

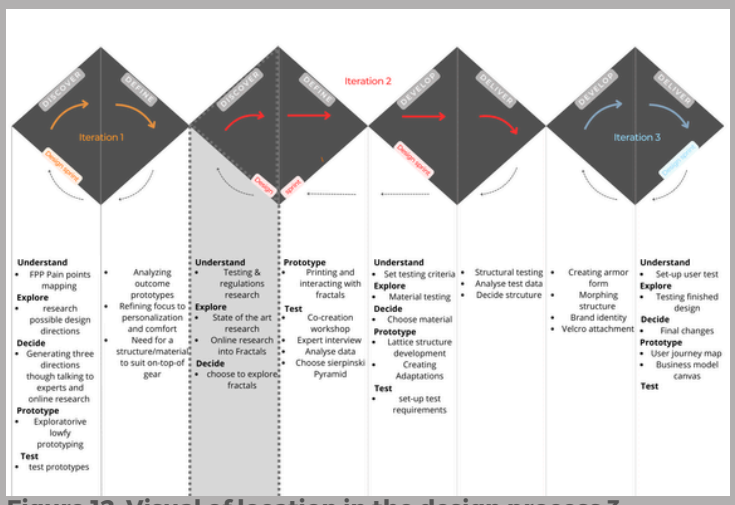


Figure 12, Visual of location in the design process 3

2.1 State of the Art:

Existing motorcycle armor:

Modern motorcycle armor combines various materials and technologies to achieve protection, durability, and flexibility. Traditional armor inserts (Figure 13), used by brands like Dainese and Alpinestars, integrate flexible, impact-absorbing materials like D3O® (D3o, n.d.) with rigid shells to meet safety standards.

Most armor is mass-produced and intended for a wide range of users, limiting customization for fitment or aesthetic preferences. Armor is typically placed in fixed areas underneath the garment , held in place by a pocket in the fabric (Figure 14 and 15) or fixed to a lightweight undergarment, typically sewn on (Figure 16).

Figure 13, Traditional armor inserts (Martin, 2024)


Figure 14, Armor insert pockets hip(Highlights | SEESMART Hip Protectors, n.d.)


Figure 15, Armor insert pocket back(Highlights | Prepared for SEESOFT CE-Level 2 Back Protector Insert, n.d.)


Figure 16, Dainese under garment (RHYOLITE SAFETY JACKET LITE, n.d.)

3D printing has opened new possibilities in protective gear, enabling manufacturers to create custom-fit solutions and integrate complex geometries for optimized impact absorption. Companies like HEXR and EOS have applied these technologies in helmets and padding (Hexr — Curventa, n.d.; EOS, n.d.), enhancing safety and user experience. Research by Tilley et al. (2024) shows that 3D-printed impact-absorbing structures can reduce weight and cost compared to traditional materials. However, personalization and comfort remain underdeveloped.
Innovations like modular climate-adaptive gear (Release, 2018) and comfortable airbag vests (International, n.d.), are costly but show promise. However, current designs often sacrifice flexibility for impact resistance and still rely on one-size-fits-all solutions that fail to address the diverse riders' needs, leaving room for innovation.

Rules and Regulations:
In the European Union, motorcycle armor is governed by stringent safety standards set by the European Committee for Standardization (European Standards - CEN-CENELEC, n.d.). These regulations establish testing protocols, performance thresholds, and labeling requirements. Impact protection is classified into two levels based on transmitted force during dynamic impact tests: Level 1 allows up to 35 kN, while Level 2 restricts it to below 20 kN. For back armor, these limits are 18 and 9 kN, respectively (Figure 17).

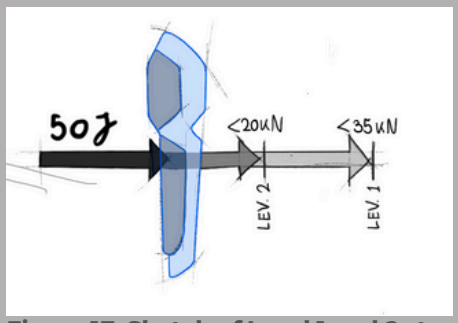


Figure 17, Sketch of Level 1 and 2 standards

Testing simulates real-world crash conditions, measuring transmitted forces and evaluating armor performance under various environmental conditions. Certified armor must display labels indicating protection level, size, and type (Figure 18). However, these regulations focus solely on impact resistance and abrasion performance, neglecting comfort, ventilation, and customization. This regulatory emphasis on compliance over user experience limits innovation in non-safety areas, creating a gap in the market for designs that combine safety with comfort and aesthetics.
appeal.

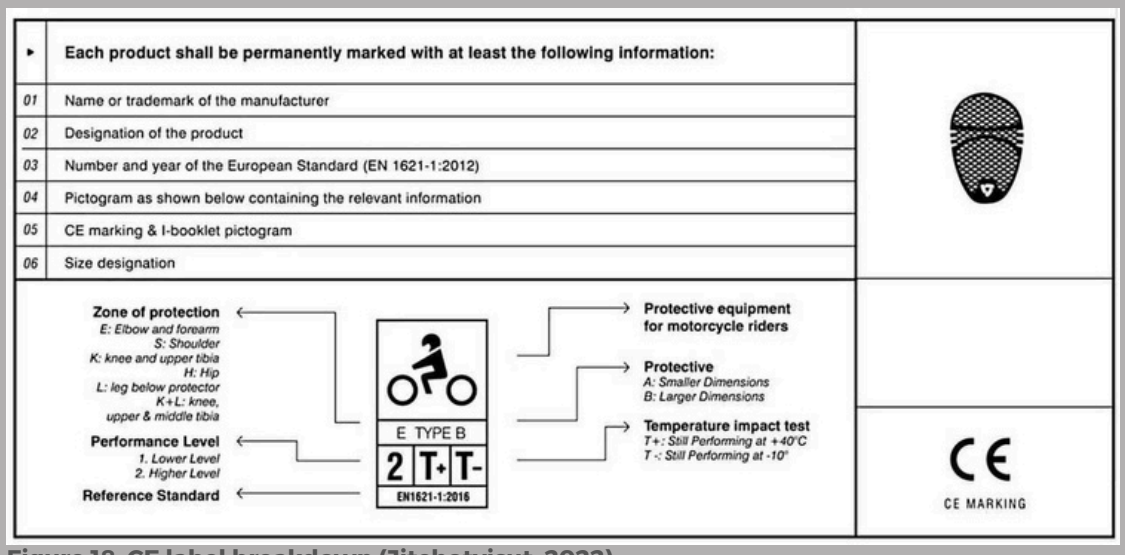


Figure 18, CE label breakdown (Jitchotvisut, 2022)

Impact-Absorbing Structures

Impact-absorbing structures efficiently dissipate energy during impacts, reducing the force transmitted to the rider. Recent advancements include honeycomb structures, nature-inspired geometries, and gradient designs.

Lattice and honeycomb geometries, often produced using 3D printing, are renowned for their lightweight and robust properties. Studies by Bohara et al. (2022) and Mazaev et al. (2020) highlight auxetic lattices, which expand perpendicular to applied forces, as particularly effective in energy dissipation. Honeycomb structures, inspired by natural patterns, are widely used for their high strength-to-weight ratio and ability to absorb energy across multiple points (Mohammadi et al., 2022). Meyers et al. (2008) also emphasize other nature-inspired designs with similar impact-absorbing qualities, which Siddique et al. (2022) attributes to mechanisms such as high strength-to-weight ratios, deformation modes that slow force transfer, and hierarchical designs that reduce stress concentrations.

Fractals, self-replicating patterns found in nature, distribute stress across multiple scales, enabling controlled deformation crucial for mitigating impact energy (Ha et al., 2024). These structures are increasingly applied in fields like architecture (Upadhayay & Maru, 2021) and automotive safety (J. Wang et al., 2018), with additive manufacturing enabling complex, multi-level geometries previously unattainable (Viccica et al., 2022). Fractal structures such as the 3D Greek cross (Figure 19) and tree-like fractals (Figure 20) demonstrate strong energy absorption capabilities (Viccica et al., 2022; Wu et al., 2021). While most tests focus on quasi-static axial crushing, findings by Yulong et al. (2022) underscore the effectiveness of fractal geometries in crash protection systems, suggesting significant potential for dynamic impact applications in motorcycle armor.

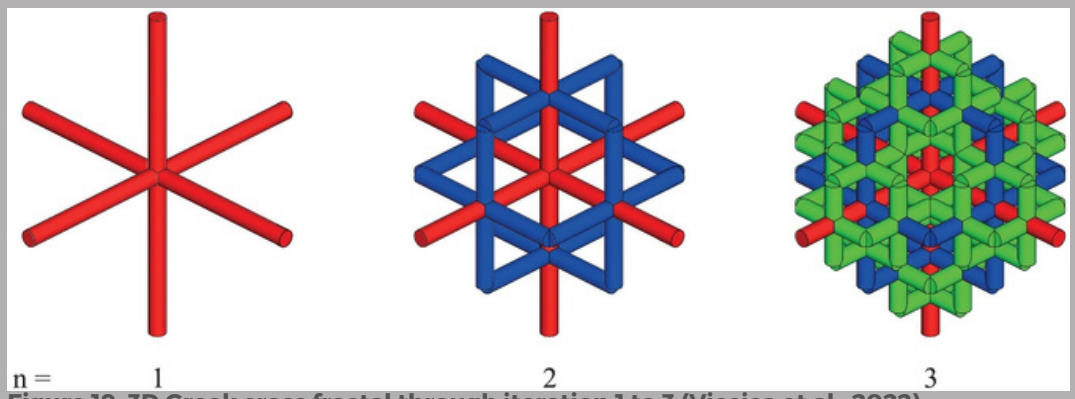


Figure 19, 3D Greek cross fractal through iteration 1 to 3 (Viccica et al., 2022)

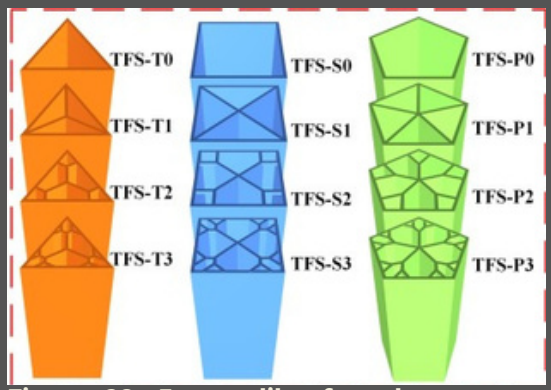


Figure 20, 3 tree like fractal structures through 4 iterations (Wu et al., 2021)

These impact-absorbing structures not only enhance safety but also address comfort and aesthetic limitations in current designs. By leveraging these advancements, motorcycle armor can meet safety standards while offering improved comfort.

Despite advancements, current motorcycle armor often sacrifices comfort and flexibility to meet safety standards. One-size-fits-all solutions limit customization, neglecting diverse rider needs such as fitment and aesthetic preferences. This presents an opportunity to integrate advanced impact-absorbing structures, like fractals and nature-inspired designs, to enhance the user experience. With 3D printing, manufacturers can create scalable, personalized solutions that combine protection, comfort, and visual appeal

2.2 Fractal research

Fractal geometries were chosen as the focus for the accompanying structure in the on-top placement concept due to their promising impact-mitigating properties and unique aesthetics. Despite their potential, the lack of dynamic impact testing on fractals offered little guidance for selecting specific designs. To address this, five distinct fractals, four 2D and one 3D, were created to explore their printability, aesthetics, and structural properties (Figure 22).

Among the 2D fractals, one sample was extruded vertically and another horizontally, enabling a basic comparison of how extrusion orientation affects structural performance and aesthetics. The Sierpinski pyramid was the only successfully printed 3D design, as other fractals' geometries exceeded the limits of FDM printing. For the pyramid instead of an extrusion in another direction, a structure was created by pasting multiple pyramids next to each other.

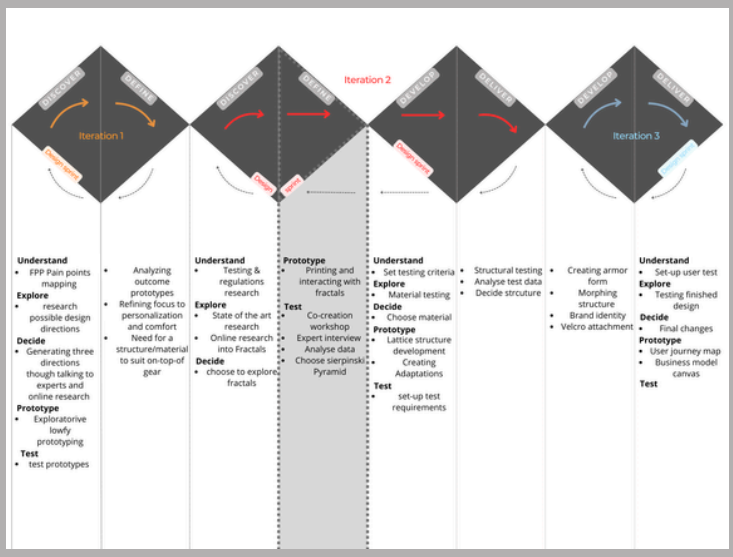


Figure 12, Visual of location in the design process 4

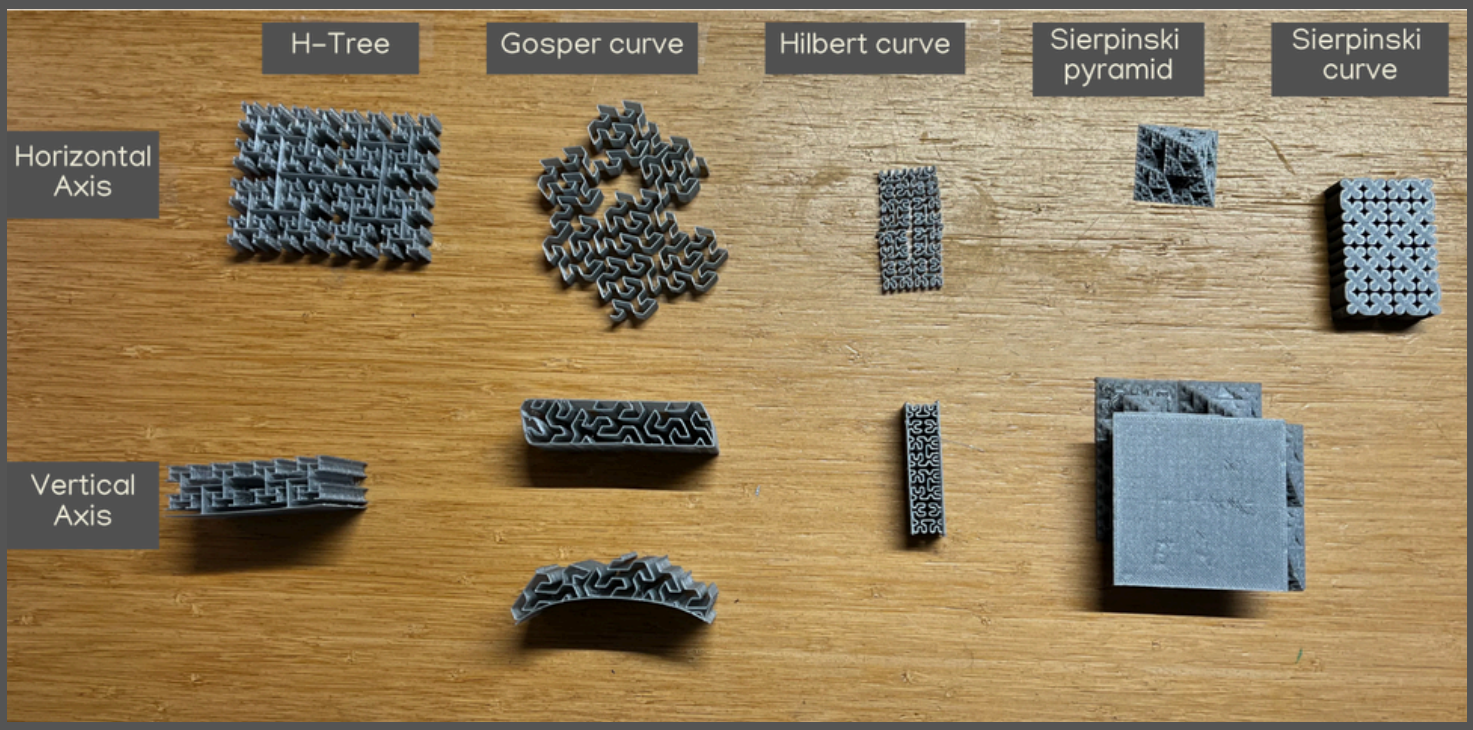


Figure 21, Fractals printed in in extrusions along both the horizontal and vertical axis

The printed fractals were assessed on three key criteria (Figure 23):

- Printability
- Aesthetics
- Structural Properties

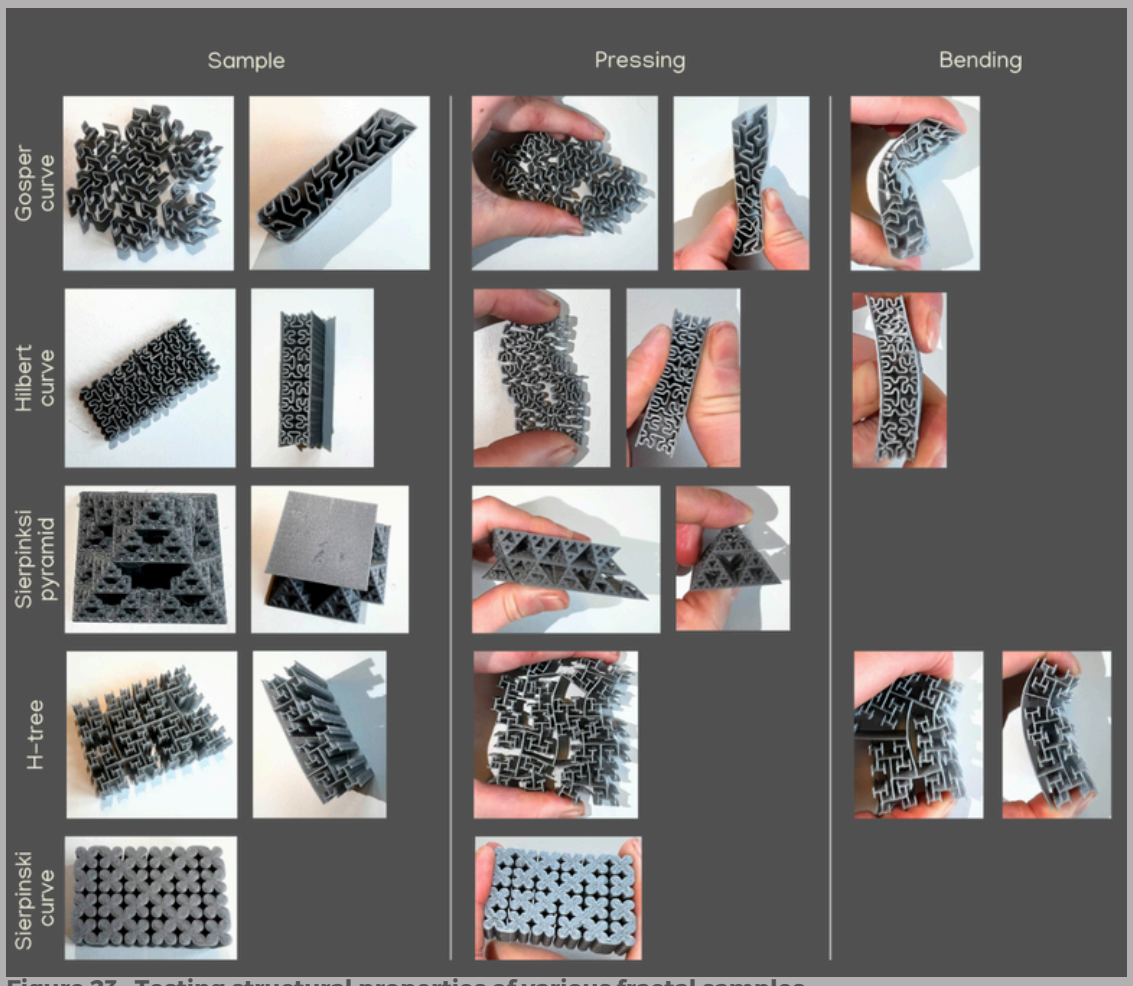


Figure 23, Testing structural properties of various fractal samples

The **key insight** to take away from this assessment are:

- Most 2D fractals, exhibited internal shifting when subjected to pressing or bending forces. This diminishes the ability to evenly distribute impact forces, particularly angular forces common in motorcycle accidents.
- Many fractal designs were not feasible to print in 3D with the limitations of FDM printing. For 2D structures, extruding them as the height component removes any structural properties for impact absorption and extruding horizontally often results in flat, visually unappealing surfaces and reduced ventilation.
- The Sierpinski-pyramid and -curve demonstrated promising results, not deforming under pressing forces.
- The Sierpinski pyramid is printable in 3D and allows for the creation of structures that are flat on both sides. However, it lacks aesthetic appeal with its flat surface and is not bendable.

The Sierpinski-pyramid offers most promise for impact absorption and printability, but further developing must make the structure bendable and aesthetically pleasing while maintaining its mechanical properties.

2.3 User and Expert validation

To refine the Sierpinski structure, the focus shifted to validating the concept and structural requirements through user feedback and expert consultation. A co-creation workshop was conducted with end-users to gather insights on practical preferences and usability. Additionally, a Design Engineer from the motorcycle gear company Rev'it was interviewed to assess the design's feasibility.

The co-creation workshop involved seven motorcycle riders aged 18 to 28, all riding Naked or Sport bikes and frequently wearing leather sport gear. The session included a workshop and group interview (Figure 24), with the schedule and presentation details provided in Appendix 2.1.

Figure 24, Workshop photos

Key insight from the workshop were:

1. All participants reported **comfort-related issues**, including weight, poor fitment, restricted circulation, overheating, and outgrowing their gear.
2. Many participants (would) **reuse their armor after a crash** due to high price tags or the effort required to replace them.
3. While participants claim protection is their top priority, their gear choices and workshop designs show prioritized comfort and aesthetics instead (**Cognitive Dissonance**).
4. Riders **prefer modular functionality** for different types of use like normal wear and road VS track riding, over aesthetic customization. The need for aesthetic options is hypothesized to be higher among women due to fewer design and colour choices.
5. Aesthetics play a significant role in whether participants would buy the concept, though preferences varied widely among individuals. While participants expressed no strong desire for aesthetic personalization, this might stem from **unarticulated needs,** which are customer desires that they may not even be aware of themselves. Providing personalization could address diverse aesthetic preferences and enhance the product's appeal.

Full workshop results and the consent for can be found in Appendix 2.2 and 2.3

To complement the insights from the workshop, an interview was conducted with Davide Amorim, a Design Engineer and Innovator at Rev'it, one of the world's leading motorcycle gear companies (Learn about the History of REV'IT! | Driving Innovation Forward. – REV'IT! Sport International, n.d.). The interview provided professional insights into both practical and theoretical aspects of the concept.

- FDM 3D printing of lattice structures performs best when walls (lines) are printed like extrusions along the height instead of studs (dots) (Figure 25), like the 3D Hilbert curve (Figure 26). **Printing the Sierpinski structure at an angle** is recommended to optimize print quality as this prints less overhangs and studs.
- Large companies face many restrictions in producing gear that prioritizes comfort and aesthetics due to harsh safety regulations. Placement on top of garments could **conflict with abrasion resistance** standards.
- In theory, fractals have potential for impact absorption, however experience suggests that performance in actual testing may not always align with theoretical expectations. **Testing is essential** to validate the concept, and Rev'it offers the facilities to conduct such evaluations.
- The **base material** currently often plays a larger role in impact performance than the structure.
- "You can make something very safe, but if people don't wear it, it doesn't matter." **Aesthetics are a crucial factor** in encouraging riders to adopt and consistently use protective gear.

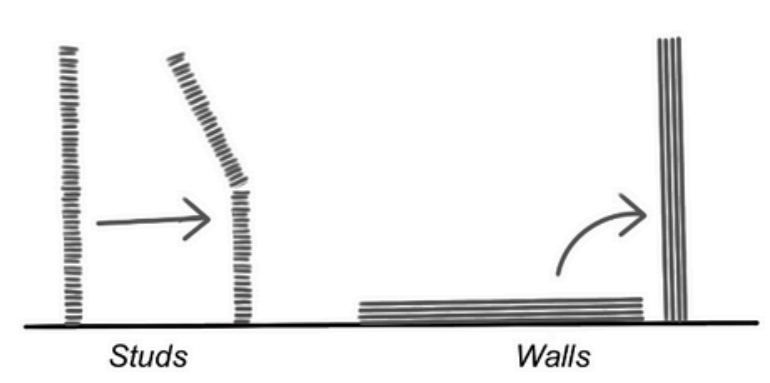


Figure 25, Sketch FDM printing studs vs walls

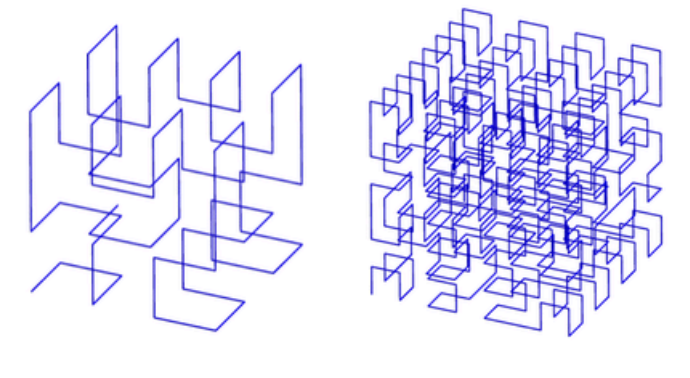


Figure 26, 3D Hilbert curve across 2 and 3 generations (Borrell et al., 2018)

The Sierpinski structure will be refined to enhance comfort and aesthetics. Customization options will be expanded to accommodate different use cases, such as riding versus everyday wear, alongside aesthetic variations. To improve structural performance and print quality, printing angles will be adjusted to minimize studs and overhangs. Real-world testing will be conducted at Rev'it's facilities to ensure the designs meet practical performance standards.

2.4 Custom structure

The material used for the structure is TPU 95A, widely recognized for its flexibility and strength. Three brands of TPU 95A were tested using a fractal printed with the same temperature (220°C) and print speed (40 mm/s) (Figure 28), with Overture emerging as the best option based on print quality and material properties.

Only the outline of the Sierpinski pyramid was used, instead of a solid version. This approach reduces weight and enhances flexibility, ventilation, and aesthetic appeal (Figure 29).

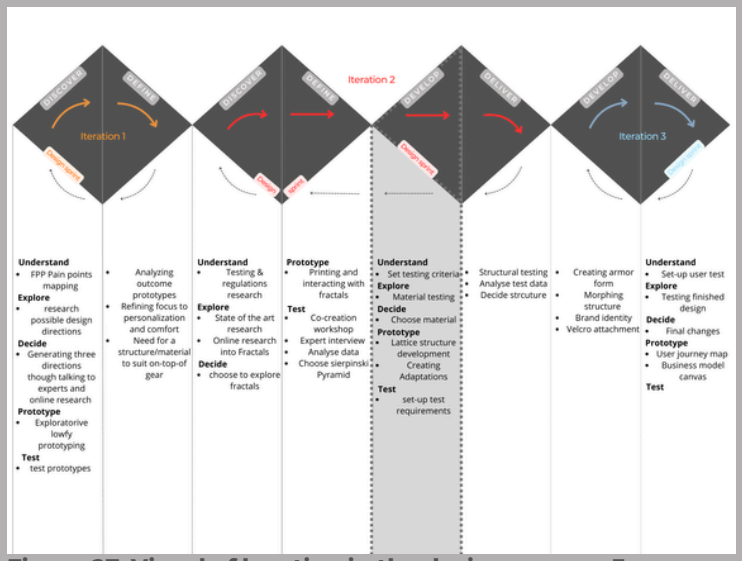


Figure 27, Visual of location in the design process 5

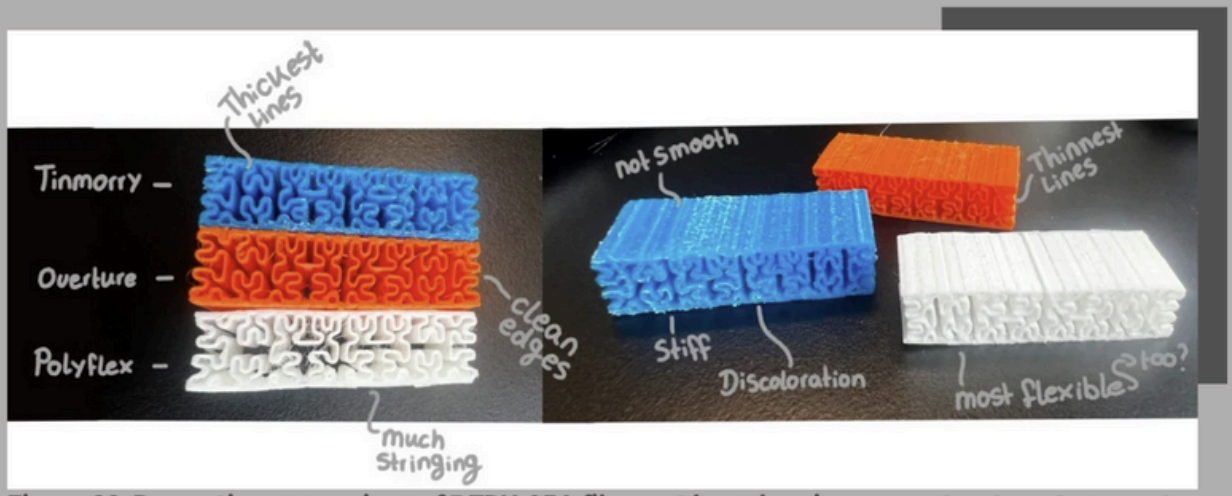


Figure 28, Properties comparison of 3 TPU-95A filament brands using same structure, temperature, and speed

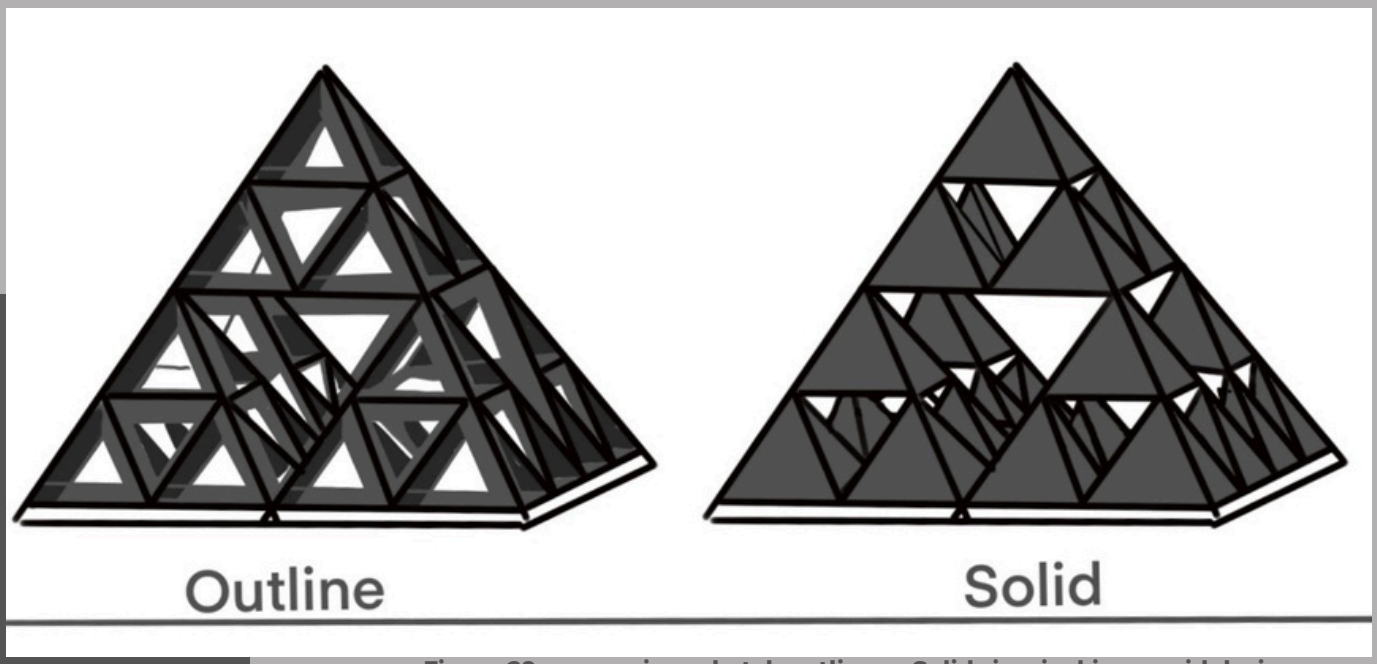


Figure 29, comparison sketch outline vs Solid sierpinski pyramid design

To refine the structure, a sheet-like configuration was created by repeating the Sierpinski pyramid side by side (Figure 30a). Upside-down pyramids were added to the sheet (Figure 30b) to form a flat surface on both sides. To enhance bendability along the x-axis, the upside-down pyramids were aligned with the bottom row along this direction (Figure 30c), a modification theorized to improve flexibility. The resulting structure features a geometric grid of small squares with crosses inside on both sides (Figure 30d).

Six iterations were developed using Rhino 8, Grasshopper, and Blender to create a 3D model of this base structure. Details of all iterations are in Appendix 1. The final design combines 3D modeling with Grasshopper, incorporating Python scripting (Figure 31).

The Grasshopper code begins by creating a Sierpinski pyramid using Python to generate a solid version. This output is baked and joined, and its borders are extracted to form an outline version. The outline is flipped upside down and paired with the original, then repeated along the x and y axes using a loop function. The lines are given thickness to produce a SubD output (Figure 32).

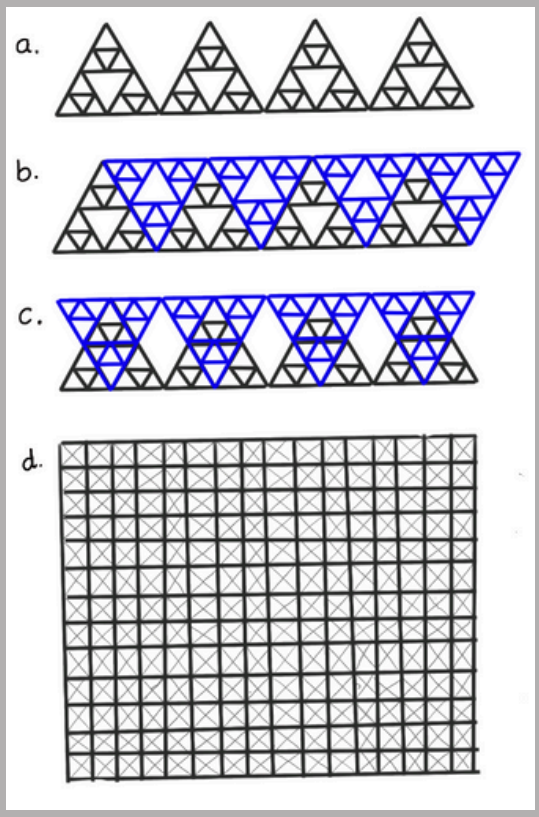


Figure 30, Structural explanation sketch

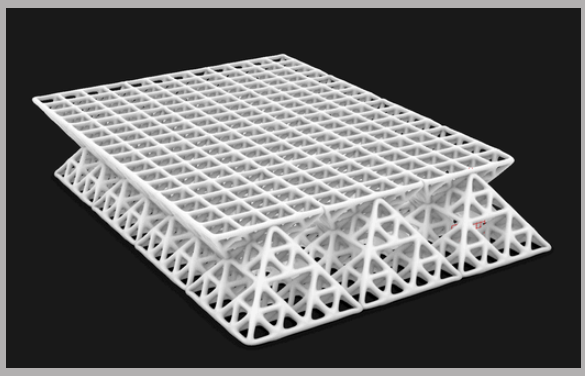


Figure 32, Structural explanation sketch

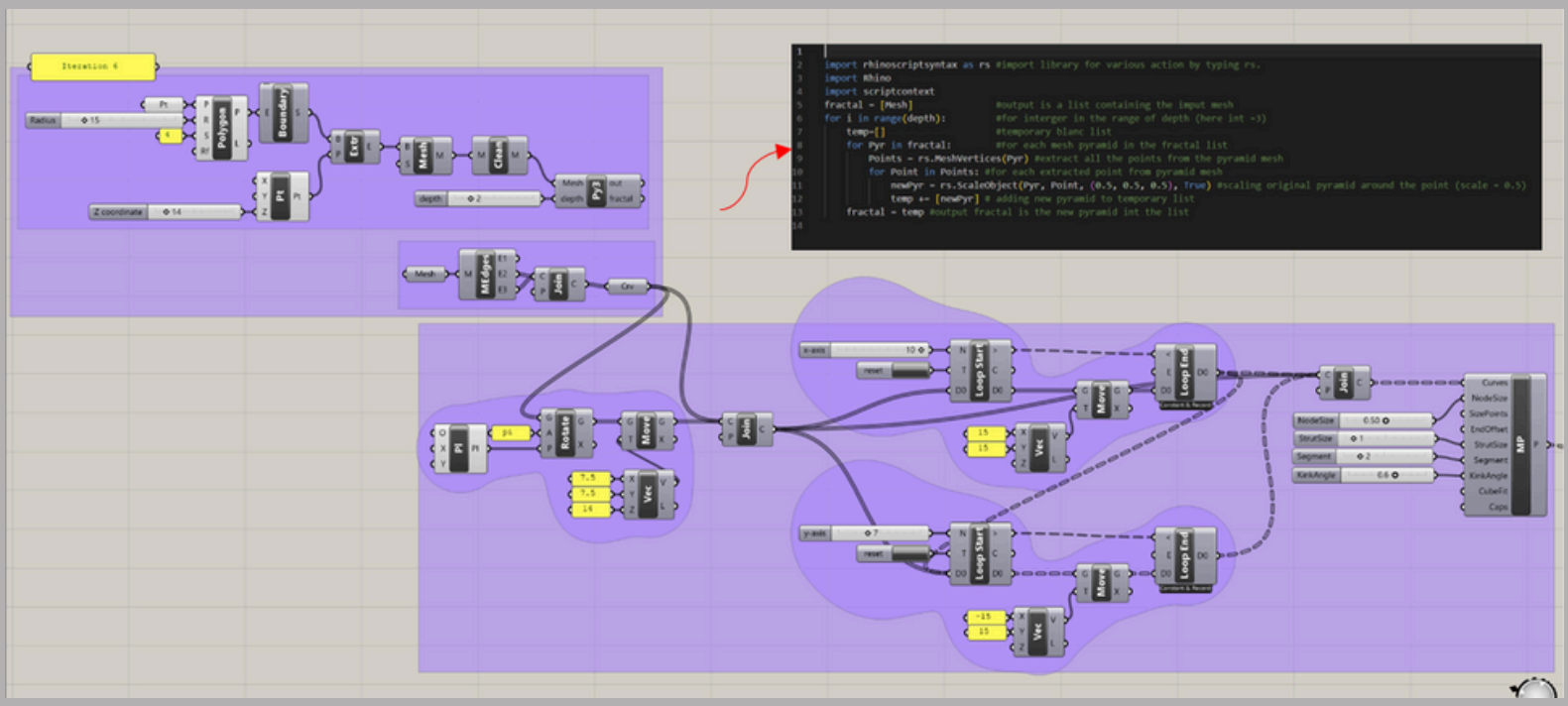


Figure 31, Grashopper code sierpinski structure sheet.

2.5 Structural adaptations

To explore variations and test performance differences, five adaptations of the custom lattice structure were developed, varying in line thickness, top and bottom surfaces, pyramid size, and structural modifications (Table 1). These variations were easily adjusted using sliders in the Grasshopper code (Figure 31). The original structure (Sample 5) features a line thickness radius of 0.55 mm and pyramids sized at 15x15x14 mm, with a total height of 14 mm.

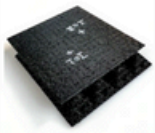
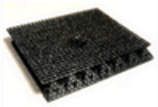
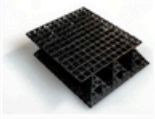
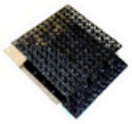
	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6
Z-axis						
X-axis						
Y-axis						
Three quarter view						
Sample size	90x90x14 mm	90x90x10 mm	90x90x14 mm	90x90x14 mm	70x70x14 mm	70x70x14 mm
pyramid size	15x15x14 mm	10x10x10 mm	15x15x14 mm	15x15x14 mm	15x15x14 mm	15x15x14 mm
line thickness (radius)	0.55 mm	0.35 mm	0.45 mm	0.55 mm	0.55 mm	0.55 mm
Top/bottom surface	solid	Squared	squared	lines	squared	lines
material	TPU 95A	TPU 95A	TPU 95A	TPU 95A	TPU 95A	TPU 95A
Weight	38 g	25 g	25g	31	17 g	17 g

Table 1, All structure sample properties

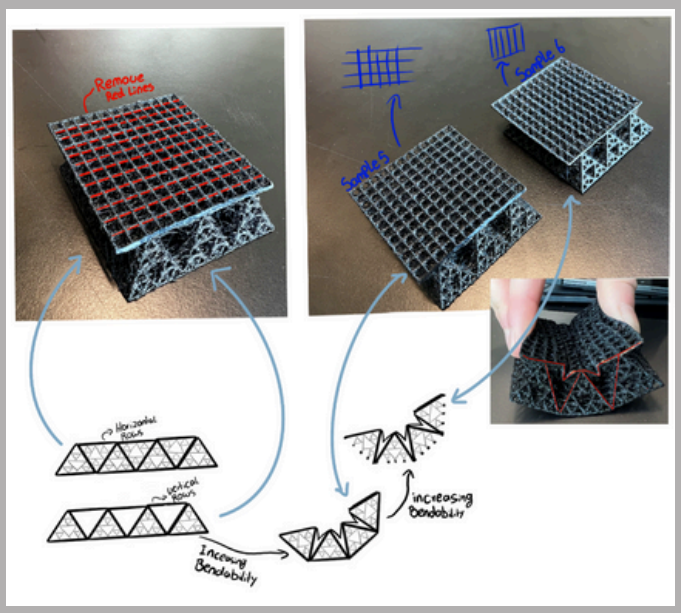


Figure 33, Hypothesis sketch structural adaptation incleased flexibility in sample 4 and 6.

Sample Variations:

- **Sample 1:** The structure includes solid surfaces of 0.7 mm thickness on the top and bottom, hypothesized to improve aerodynamics and impact absorption while appealing to users seeking simpler aesthetics.
- **Sample 2:** Line thickness is reduced to 0.35 mm, and pyramid dimensions are adjusted to 10x10x10 mm. This sample creates a thinner sheet while maintaining impact absorption through a denser arrangement of smaller pyramids.
- **Sample 3**: The original pyramid dimensions, line thickness is decreased to 0.45 mm, assessing the impact of thinner lines on flexibility and performance.
- **Samples 4 and 6:** Lines along the X-axis on one surface were removed to enhance bendability along this axis (Figure 33) while minimizing any compromise to impact absorption.

These samples are designed to explore how modifications to the lattice geometry affect impact absorption and flexibility. Real-world testing will assess their suitability for motorcycle armor applications using two primary criteria: dynamic impact absorption and flexibility.
To establish a benchmark, the performance of these samples will be compared to another structure made from the same material. Additionally, impact absorption will be evaluated at various x-axis locations to determine whether the uneven distribution of pyramids causes inconsistencies in performance.

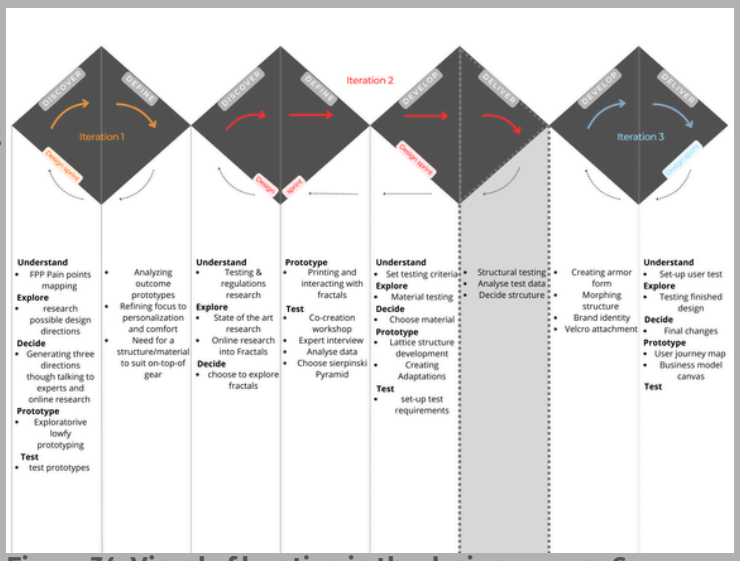


Figure 34, Visual of location in the design process 6

2.5 Structural testing

2.5.1 Three-point bend test

Flexibility was evaluated using a three-point bend test. Each sample was placed on two supports 40 mm apart (L) (Figure 35), and a downward force of 100 N was applied at the midpoint (½L) using a custom 3D-printed PLA rod (Figures 35–37). The rod, designed in Rhino 8, measured 90 mm in width, with a rounded top (10 mm diameter) and two 65-mm-apart holes for attachment to the base (Figure 38). Flexibility was measured as the deformation distance (d) in mm under the 100 N load (Figure 35).
Each sample underwent four tests: two along the X-axis and two along the Y-axis. For Sample 6, additional tests were performed along the X-axis, with two tests conducted with removed rows on the top and two with removed rows on the bottom

To see the test in action klick here or go to Appendix 4.1.

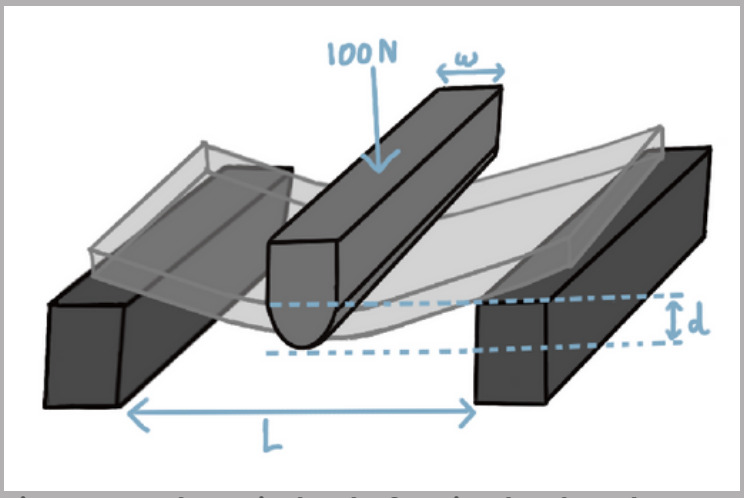


Figure 35, 3D shematic sketch of 3 points bend-test layout

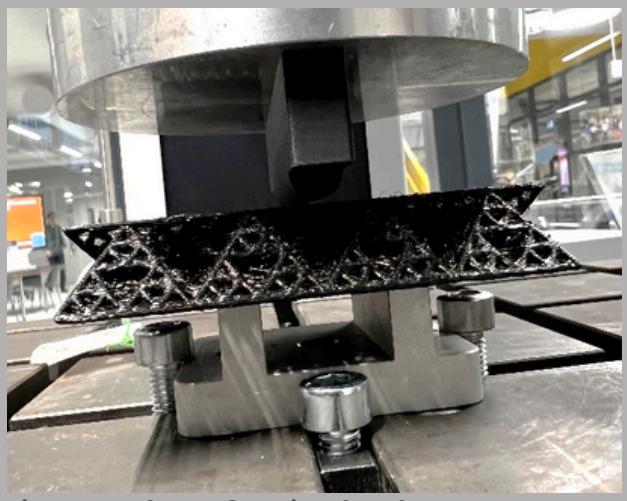


Figure 36, Photo of 3 points bend test set-up

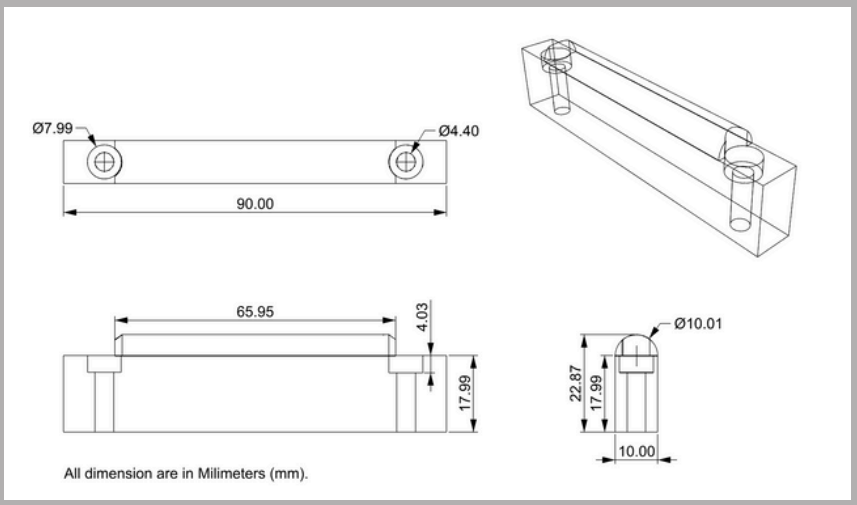


Figure 37, Rhino 8 2D layout schematic of force applying rod used in 3 points bend test.

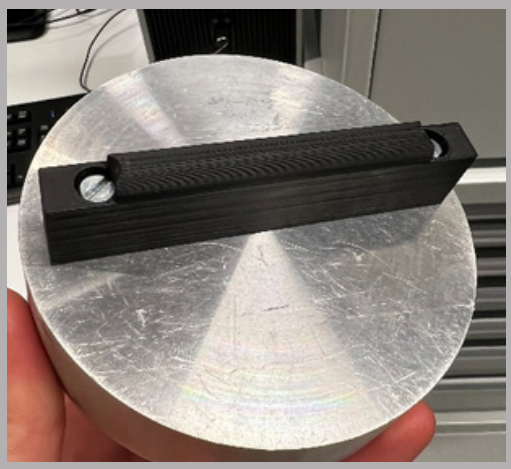


Figure 38, 3D printed force applying rod, screwed on to base

Results:

The raw test data, including time (s), load (N), and deformation (mm), was imported into Excel for analysis (Figure 39). Extension columns were grouped by sample and axis direction (Figure 40), and the deformation at a load of 100 N was extracted using the formula =MAX(column cells) (Figure 41).

Time (s)	Load (N)	Extension (mm)
0,9234	0,01341	0,83041
1,026	0,18349	1,001
1,129	0,45495	1,1723
1,231	1,7753	1,3432
1,334	4,0828	1,514
1,436	5,6536	1,6849
1,539	5,9059	1,8559
1,642	6,2572	2,0269
1,744	8,0906	2,1979
1,847	10,981	2,369
1,949	13,872	2,54
2,052	16,492	2,711
2,155	18,848	2,882
2,257	21,203	3,053
2,36	23,328	3,224

Figure 39, Raw bend test data from test 30 loaded into excel.

Sample 5 extentions			
x1	x2	y1	y2
0,88004	0,78898	0,34368	0,65087
0,9458	0,84475	0,40317	0,69841
1,012	0,90054	0,46263	0,74594
1,0783	0,95675	0,52262	0,79385
1,1441	1,0123	0,58235	0,84137
1,2104	1,0683	0,6419	0,88893
1,2762	1,1247	0,70184	0,93682
1,3423	1,1805	0,76161	0,98462
1,4084	1,2364	0,82158	1,0323
1,4741	1,2923	0,88159	1,0797
1,5403	1,3482	0,94116	1,1277
1,6065	1,4042	1,0011	1,1754
1,6726	1,46	1,0611	1,2229
1,7386	1,5159	1,1206	1,2704
1,8047	1,5717	1,1806	1,3181
1,8707	1,6277	1,2403	1,3657
1,9368	1,6837	1,3	1,4133
2,0029	1,7397	1,3601	1,461
2,0689	1,7957	1,4201	1,5087
2,135	1,8517	1,48	1,5564

Sample 1 extensions			
x1	x2	y1	y2
0,81002	0,9094	0,88265	0,76412
0,85187	0,95284	0,92949	0,80582
0,8943	0,99667	0,97562	0,84763
0,93685	1,0407	1,0221	0,88945
0,97889	1,0847	1,069	0,93072
1,0205	1,1279	1,1155	0,97245
1,0632	1,172	1,1613	1,0142
1,1058	1,216	1,2082	1,0559
1,148	1,2596	1,2551	1,097
1,1902	1,3031	1,3013	1,1389
1,2324	1,3471	1,3475	1,1807
1,2746	1,3912	1,394	1,2225
1,3168	1,435	1,4406	1,2637
1,3591	1,4785	1,4872	1,305
1,4013	1,5224	1,5339	1,3467
1,4435	1,5663	1,5805	1,3885
1,4857	1,6101	1,6271	1,4302
1,5279	1,6539	1,6736	1,4718
1,5701	1,6977	1,7201	1,5135
1,6124	1,7415	1,7666	1,5552

Figure 40, extension data divided by sample and axis , here sample 5 and 1.

Max	Max	Max	Max
5,7021	4,7618	5,1304	3,9408

Max	Max	Max	Max
3,9467	3,5382	3,9984	3,5523

Figure 41, Max row at bottom of each column in divided data, (sample 5 and 1).

To compare the axes and samples, the average maximum deformation for the X-axis and Y-axis of each sample was calculated and visualized in a bar chart (Figures 42 and 43).

Sample	X max (mm)	Y max (mm)
Sample 1	3,74245	3,77535
Sample 2	8,3444	9,00995
Sample 3	16,383	17,0645
Sample 4	6,32625	4,86315
Sample 5	5,23195	4,5356
Sample 6	8,4683	4,92945

Figure 42, Bar chart comparing flexibility among samples and axes.

The bar chart reveals that Samples 1, 2, and 3 exhibit consistent flexibility across both axes, while Samples 4 to 6 show increased flexibility along the X-axis. Additionally, Samples 1 to 3 demonstrate significantly different flexibility levels compared to Samples 4 to 6. These findings suggest that X-axis structural are effective but only if the starting structure (y-axis structure) is not too stiff or flexible.

Further analysis (Figure 44) compares the Y-axis flexibility of Samples 4 to 6, the X-axis adaptation in Sample 5, and the X-axis adaptation with removed horizontal rows in Samples 4 and 6. Since these samples share the same line thickness and pyramid sizing, they allow for direct comparison. The graph indicates that the X-axis structure with removed rows offers superior flexibility compared to the Y-axis structure.

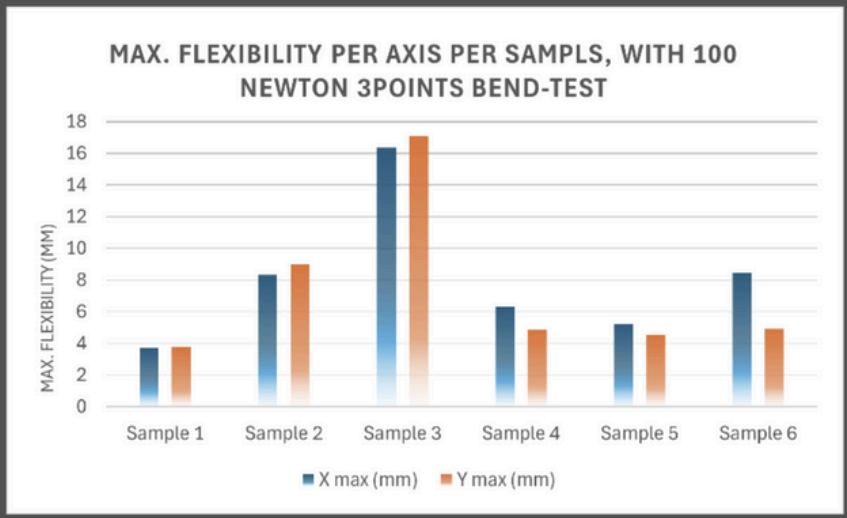
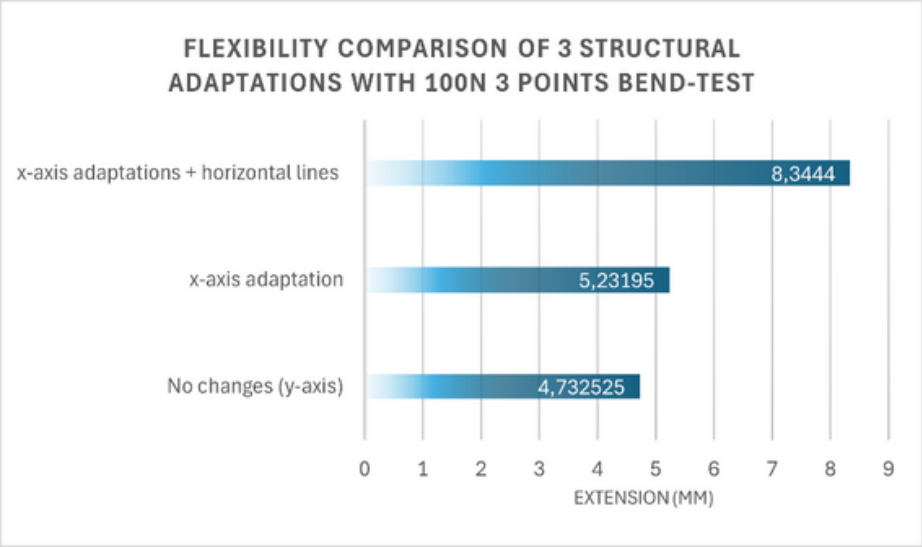


Figure 43, Bar chart comparing flexibility among samples and axes.



For Sample 6's X-axis flexibility, the average deformation was 7.93 mm with removed rows on top and 9.00 mm with removed rows on the bottom.
This suggests that removing lines from the outer side relative to the flexing direction enhances flexibility.

Figure 44, Horizontal bar chart comparing the 3 structural adaptations in sample 4 to 6

2.5.2 Dynamic impact test

Dynamic impact absorption was assessed at Rev'it's testing facilities using the Energy Transmission Test, a machine used for CE certification of motorcycle armor (Figure 45a). This test measures the force transmitted through armor on the body during an impact. Structural samples were placed on a rounded anvil (Figure 45b), and a 5 kg flat weight (Figure 45c) was dropped from a height of approximately 100 cm, simulating an impact energy of at least 50 joules.

To see the test in action klick here or go to Appendix 5.1.

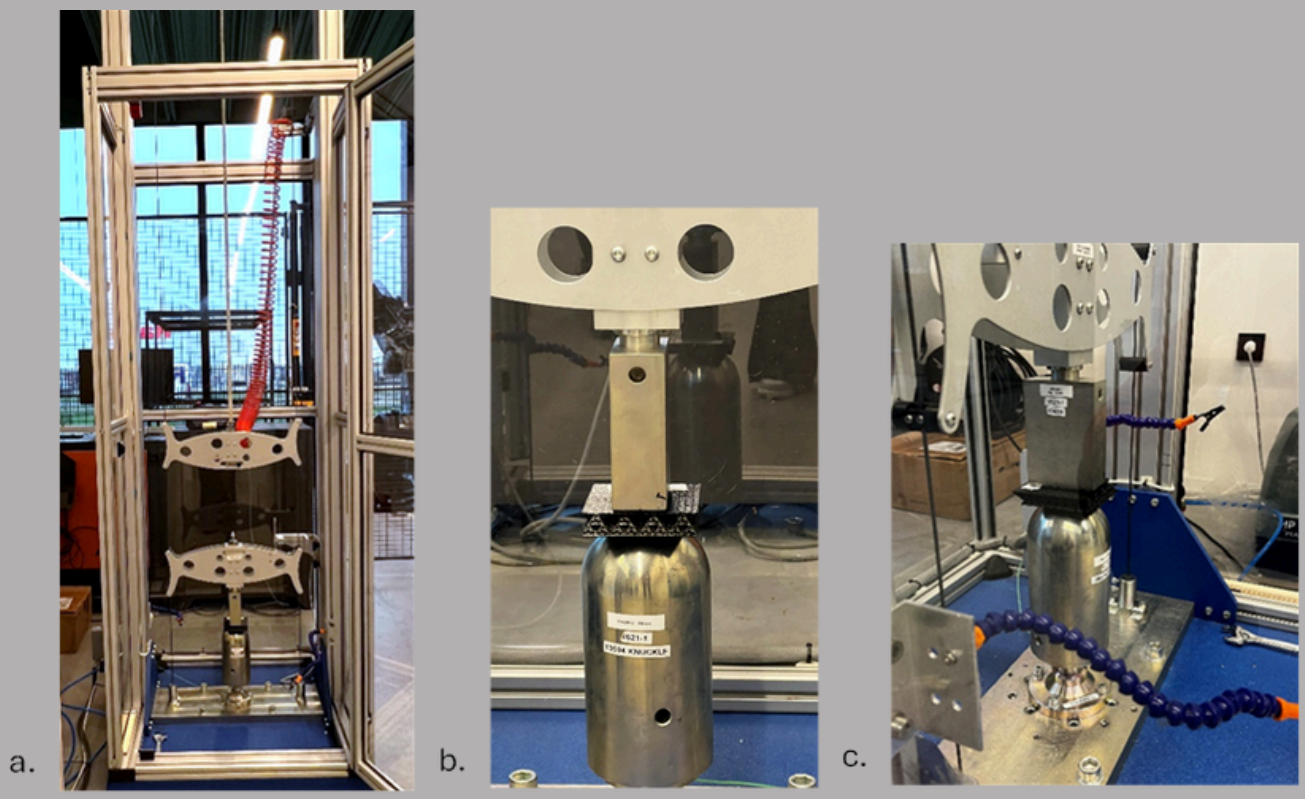


Figure 45, Energy transmission testing machine at Rev'it from various angles with sample 1 placed inside

Sample 6 was not tested as it shares the same structure as Sample 4, while Sample 3 was excluded due to being too soft, risking damage to the machine. Sample 1 and Sample 4 underwent two impacts each, while Sample 5 and Sample 6 included only one impact each Sample 5 due to its size and Sample 6 due to a permanent dent caused by its first impact (Figure 46).

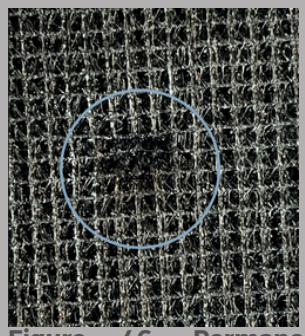


Figure 46, Permanent impact dent in sample 2

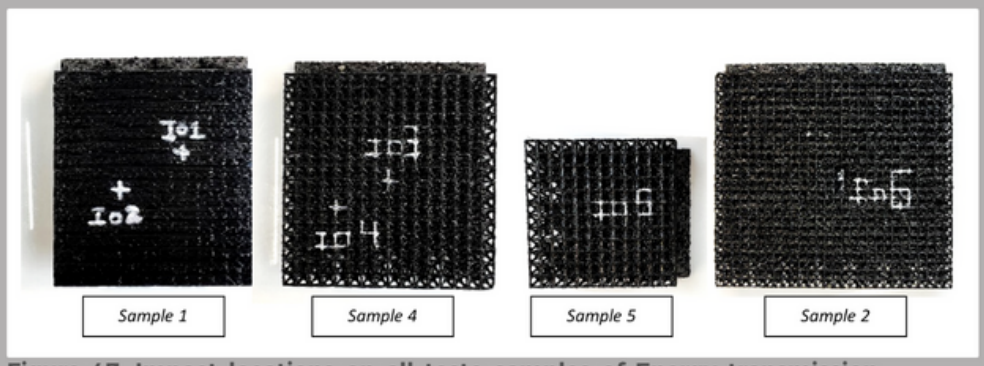
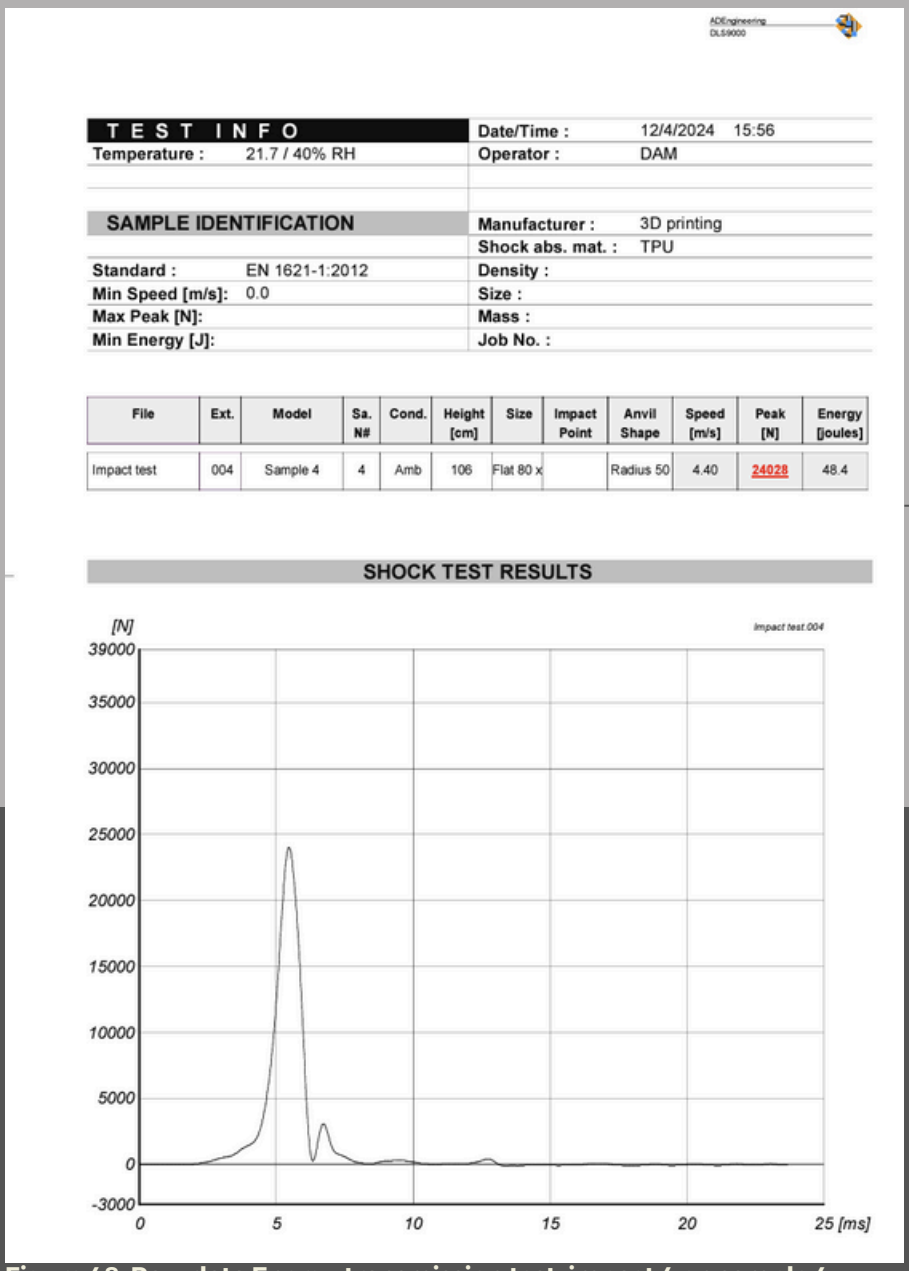


Figure 47, Impact locations on all teste samples of Energy transmission tests including their test numbers.



TEST INFO

Temperature :	21.7 / 40% RH	Date/Time :	12/4/2024 15:56
		Operator :	DAM
SAMPLE IDENTIFICATION		Manufacturer :	3D printing
		Shock abs. mat. :	TPU
Standard :	EN 1621-1:2012	Density :	
Min Speed [m/s]:	0.0	Size :	
Max Peak [N]:		Mass :	
Min Energy [J]:		Job No. :	

File	Ext.	Model	Sa. N#	Cond.	Height [cm]	Size	Impact Point	Anvil Shape	Speed [m/s]	Peak [N]	Energy [joules]
Impact test	004	Sample 4	4	Amb	106	Flat 80 x		Radius 50	4.40	24028	48.4

SHOCK TEST RESULTS

Figure 48, Raw data Energy transmission test, impact 4 on sample 4.

Results:
Impact locations on the structures are marked in Figure 47. The raw data output from the machine is shown in Figure 48, with the full datasheet available in Appendix 5.2.
This data includes a line graph of force (N) transmitted by each sample over time (ms) and additional details such as maximum force (N), sample name, drop height (cm), applied energy (J), and testing conditions (ambient).

The raw data was grouped and overlapped in Adobe Illustrator, with each sample assigned a distinct color, accommodating various types of color blindness (Figure 49). The graphs for Sample 4 and Sample 1 show consistent impact-absorbing qualities. Comparing this with the impact locations on Sample 4 (Figures 49 and 50), it is evident that X-axis impact location does not affect absorption, as both impacts yielded similar results.

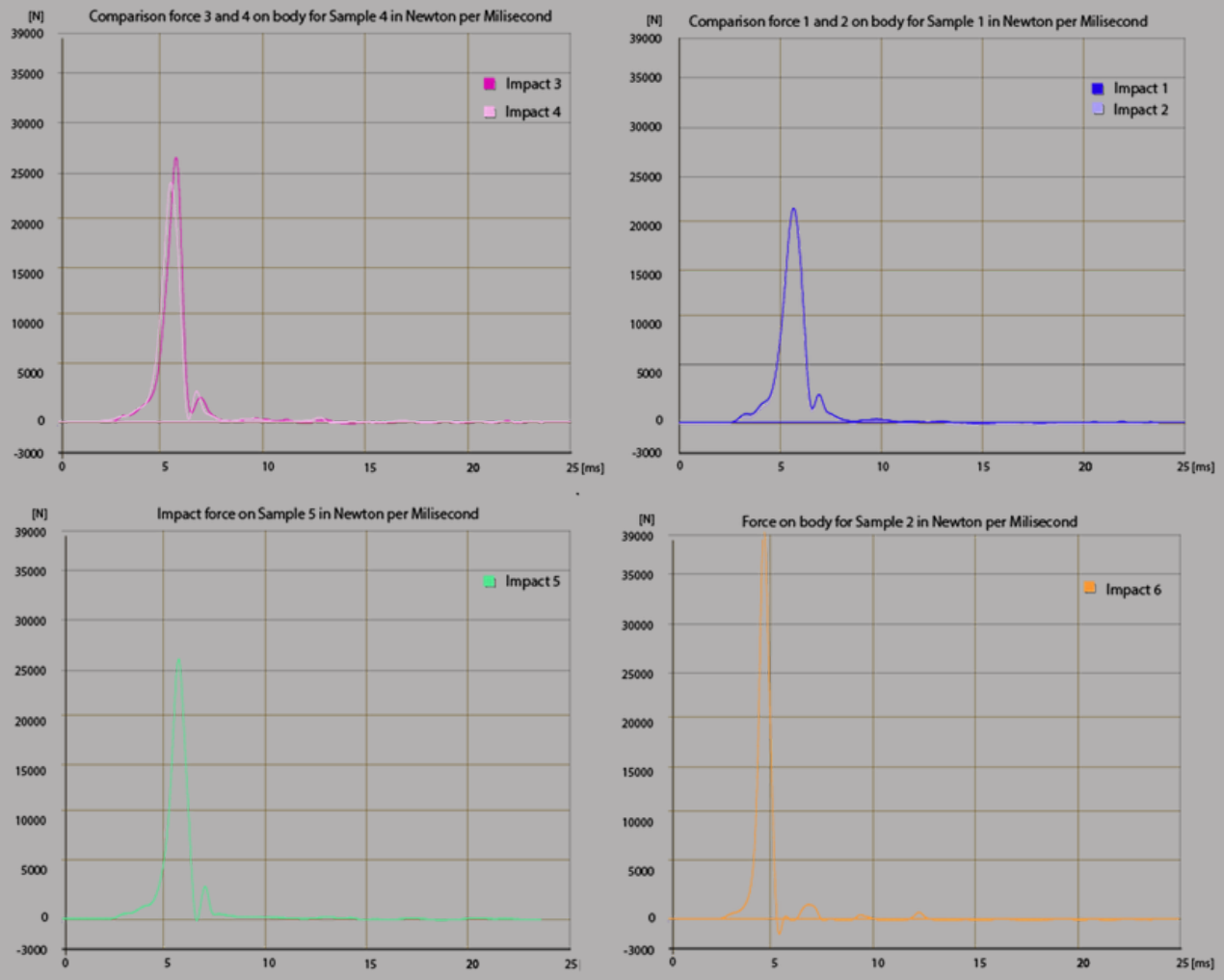


Figure 49, Coloured graphs of dynamic impact testing, grouped by Sample type

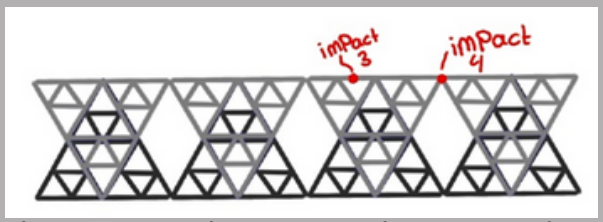


Figure 50, X-axis sketch of impact locations sample 4

To compare samples, all graphs were combined into one chart (Figure 51). This shows that Sample 2 is unsuitable for impact protection, while Samples 1, 4, and 5 achieve Level 1 CE certification. Notably, Sample 4 (with horizontal rows removed) shows minimal difference in performance compared to Sample 5, indicating that removing these rows has little to no impact on the structure's ability to absorb impacts.

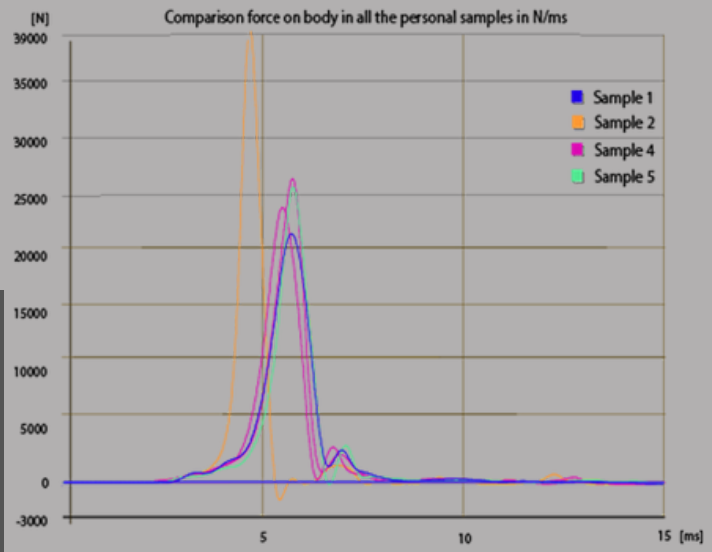


Figure 51, graph impact testing of all personal samples

2.5.3 Result comparison

A comparison of the impact absorption and three-point bend test results for Samples 1, 4, and 5 reveals key insights. While Sample 1 achieves the best impact absorption, its lack of flexibility makes it unsuitable for motorcycle armor. Samples 4 and 5 show similar impact absorption, but Sample 4 offers superior flexibility, demonstrating that removing the bottom X-axis rows improves flexibility without compromising impact absorption. Based on these results, Sample 4 is selected as the most suitable structure.

2.5.4 Benchmarking

Sample 4 was compared to two existing Rev'it motorcycle armor types: a Level 1 protector (Figure 52) and a Level 2 protector (Figure 53) using the same impact testing setup.

Sample 4 matches the impact absorption of Rev'it's Level 1 protector (Figure 54) but is more flexible and significantly lighter at 31 grams compared to the Level 1 protector's 129 grams and the Level 2 protector's 159 grams. Rev'it's Level 2 protector, however, demonstrates superior impact absorption. While Sample 4 will increase to 76 grams when morphed to armor form, it still remains lighter than both protectors. Rev'it's Level 1 protector is thinner, but Sample 4 provides a better balance of flexibility, weight, and impact absorption.

Figure 52, Rev'it Level 1 shoulder protector

Figure 53, Rev'it Level 2 shoulder protector

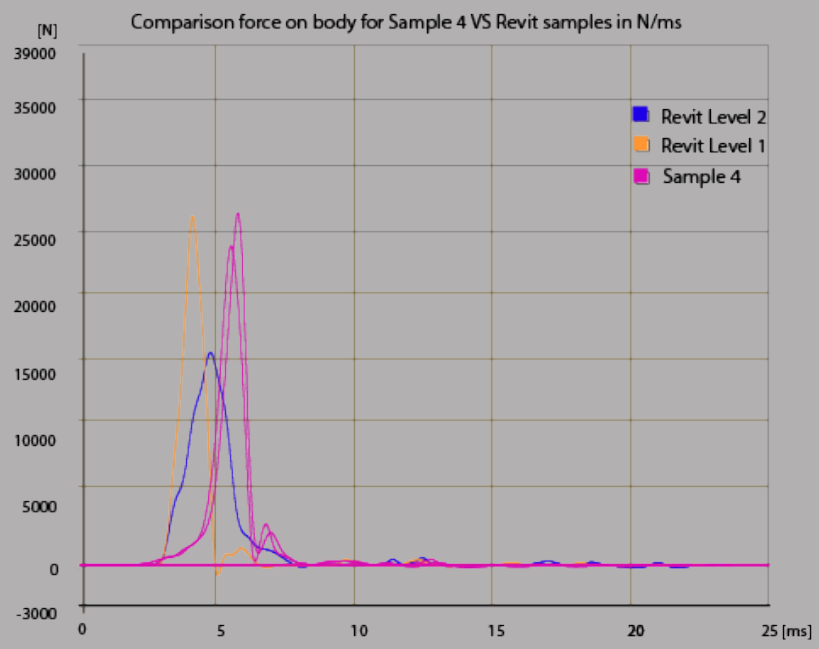
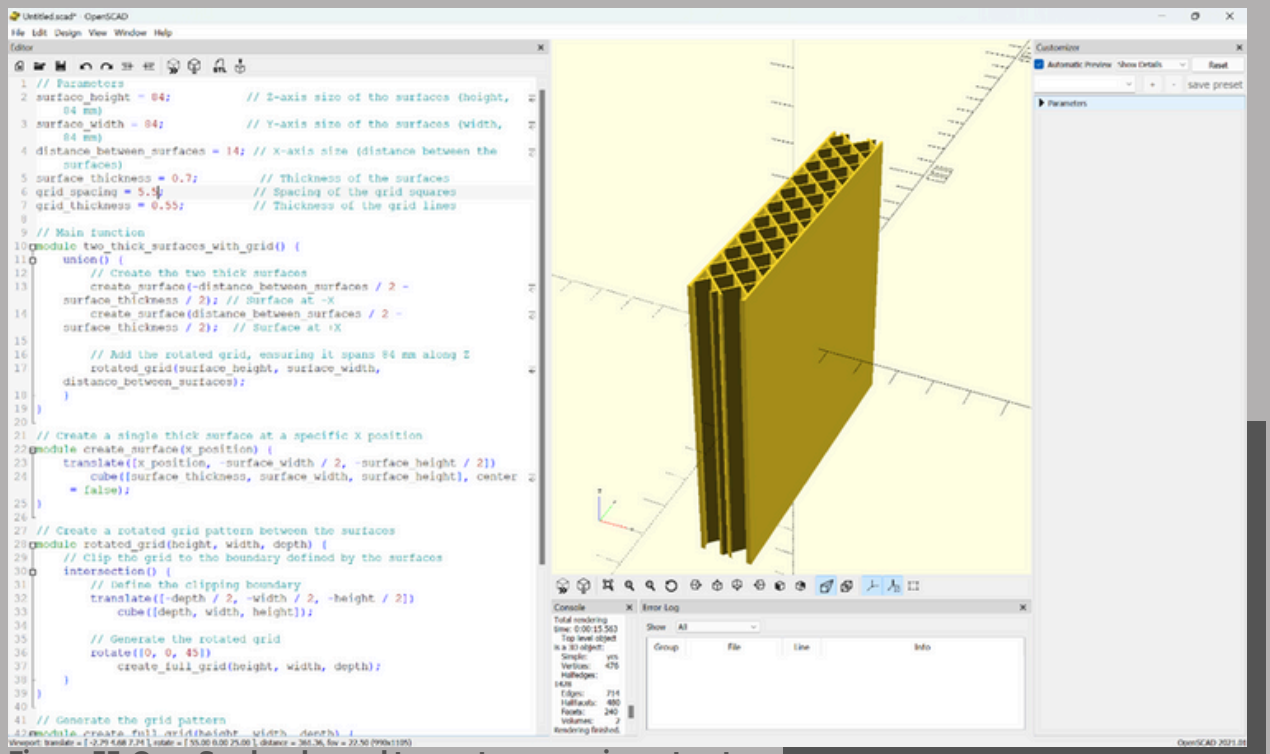


Figure 54, Dynamic impact comparison between Revit level 1 and 2 armor and Sample 4

To further investigate impact absorption and flexibility, Sample 1 was compared to a custom grid structure created in OpenScad (Figure 55). Sample 1 was selected for this comparison for its flat surfaces, which are easily replicable in other structures. OpenScad was chosen for its ability to precisely adapt dimensions, top and bottom thickness, line thickness, and weight (grid spacing) to match Sample 1. By using variables in its C++-code, structural parameters can be adjusted independently without affecting other components. Both samples' weights were compared and printed at a 30-degree angle using Ultimaker Cura 5.9 (UltiMaker Cura 5.9 - UltiMaker, n.d.).



```
// Parameters
surface_height = 84;          // Z-axis size of the surfaces (height, 84 mm)
surface_width = 84;           // Y-axis size of the surfaces (width, 84 mm)
distance_between_surfaces = 14; // X-axis size (distance between the surfaces)
surface_thickness = 0.7;      // Thickness of the surfaces
grid_spacing = 5.5;           // Spacing of the grid squares
grid_thickness = 0.55;        // Thickness of the grid lines

// Main function
module two_thick_surfaces_with_grid() {
    union() {
        // Create the two thick surfaces
        create_surface(-distance_between_surfaces / 2 -
    surface_thickness / 2); // Surface at -X
        create_surface(distance_between_surfaces / 2 -
    surface_thickness / 2);  // Surface at +X

        // Add the rotated grid, ensuring it spans 84 mm along Z
        rotated_grid(surface_height, surface_width,
    distance_between_surfaces);
    }
}

// Create a single thick surface at a specific X position
module create_surface(x_position) {
    translate([x_position, -surface_width / 2, -surface_height / 2])
        cube([surface_thickness, surface_width, surface_height], center
     = false);
}

// Create a rotated grid pattern between the surfaces
module rotated_grid(height, width, depth) {
    // Clip the grid to the boundary defined by the surfaces
    intersection() {
        // Define the clipping boundary
        translate([-depth / 2, -width / 2, -height / 2])
            cube([depth, width, height]);

        // Generate the rotated grid
        rotate([0, 0, 45])
            create_full_grid(height, width, depth);
    }
}

// Generate the grid pattern
module create_full_grid(height, width, depth) {
```

Figure 55, OpenScad code used to create comparison structure

Both samples were tested under a hydraulic press together, to ensure equal force was applied across their entire area. The grid structure compressed from 14 mm to 10 mm, while Sample 1 maintained its original 14 mm height. Switching the samples' positions confirmed Sample 1's superior structural integrity under pressure.

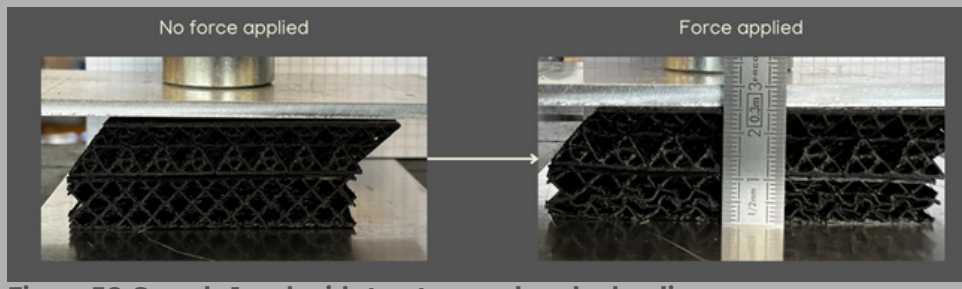


Figure 56, Sample 1 and grid structure under a hydraulic press

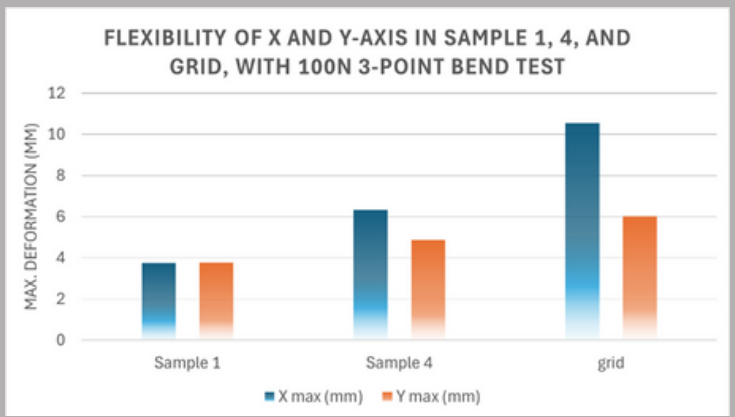


Figure 57, 3-point bend test bar graph comparing sample 1, 4 and the grid sample

Flexibility comparisons of Sample 1, 4, and the grid structure (Figure 57) shows that the Sierpinski structure does not show superior flexibility based on numerical data. However, visual analysis (Figure 58) reveals the grid sample crumples at the force application point, failing to bend uniformly like the Sierpinski structure. This crumpling compromises even force distribution and skews flexibility data. In contrast, the Sierpinski structure's even bending ensures predictable and reliable performance, making it more suitable for motorcycle armor.

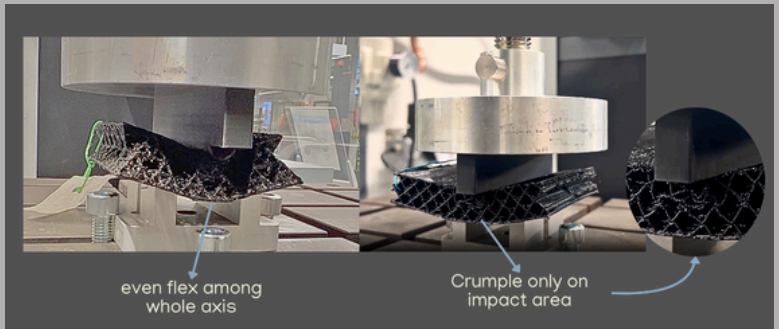
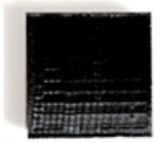
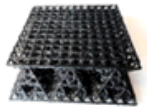
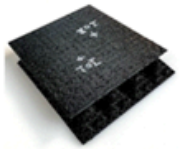
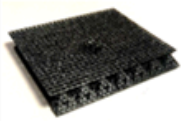
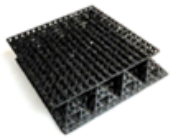
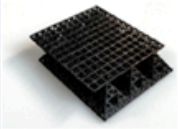
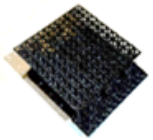
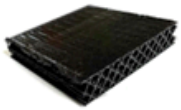
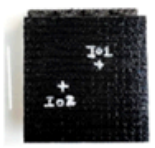


Figure 58, Visual comparison Sample 4 and grid Sample in 3-point bend test.

	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Revit Lvl 1	Revit Lvl 2	Compare structure
Z-axis							 *	 **	
X-axis							 *	 **	
Y-axis									
Three quarter view							 *	 **	
Sample size	90x90x14 mm	90x90x10 mm	90x90x14 mm	90x90x14 mm	70x70x14 mm	70x70x14 mm	±220x140 mm *	± 220x140 mm *	90x90x14 mm
pyramid size	15x15x14 mm	10x10x10 mm	15x15x14 mm	15x15x14 mm	15x15x14 mm	15x15x14 mm			
line thickness (radius)	0.55 mm	0.35 mm	0.45 mm	0.55 mm	0.55 mm	0.55 mm			0.55 mm
Top/bottom surface	solid	Squared	squared	lines	squared	lines	Hexagon	Squared	Solid
material	TPU 95A	TPU 95A	TPU 95A	TPU 95A	TPU 95A	TPU 95A	Unknown	Unknown	TPU 95A
Weight	38 g	25 g	25g	31	17 g	17 g	129 g	159 g	38g
max. impact	21.7 kN	39.7 kN	Too soft	24.0 kN	25.8kN	= sample 4	26.3 kN	15.9 kN	
bendability X-axis	3.74 mm	8.34 mm	16.38 mm	6.33 mm	5.23 mm	8.47 mm			10.54 mm
bendability Y-axis	3.77 mm	9.01 mm	17.06 mm	4.86 mm	4.54 mm	4.93 mm			6.02 mm
Deformation under press									
Impact zone									

* Martin, R. (2021, November 14). Rev'It Seesmart Armor Review (Knee/Elbow/Hip/Shoulder). Motorcycle gear hub. https://www.mcgearhub.com/motorcycle-armor/revit-seesmart-armor-review-knee-elbow-hip-shoulder/

** xlmoto. (n.d.). xlmoto. Xlmoto. https://www.xlmoto.nl/product/schouderbescherming-revit-seeflex-type-b-rv11_pid-FPG0430300-UNI?nosto=is-pdp-brand-cross-sale

Figure 59, table sample properties including test results and benchmark samples (Martin Roy, 2021), (Schouderbescherming Rev'It! SEEFLEX Type B RV13 Laagsteprijsgarantie | XLMOTO, n.d.)

The outcomes of all tests were added tot the Sample properties table (Figure 59).

ITERATION 3

After selecting the optimal structure, the focus shifted to its implementation in motorcycle armor, emphasizing fitment, aesthetics, and user interactions.

3.1 Form Creation

An existing piece of shoulder armor was analyzed and measured (Figure 61) to guide the development of a new form. Using Rhino 8's SubD modeling tools, a shoulder armor form was created by modeling half the surface and mirroring it. The design featured uneven thickness, measuring 14 mm at the center and tapering toward the edges. A PLA prototype was 3D-printed to assess real-life fitment, which confirmed a good fit (Figure 62).

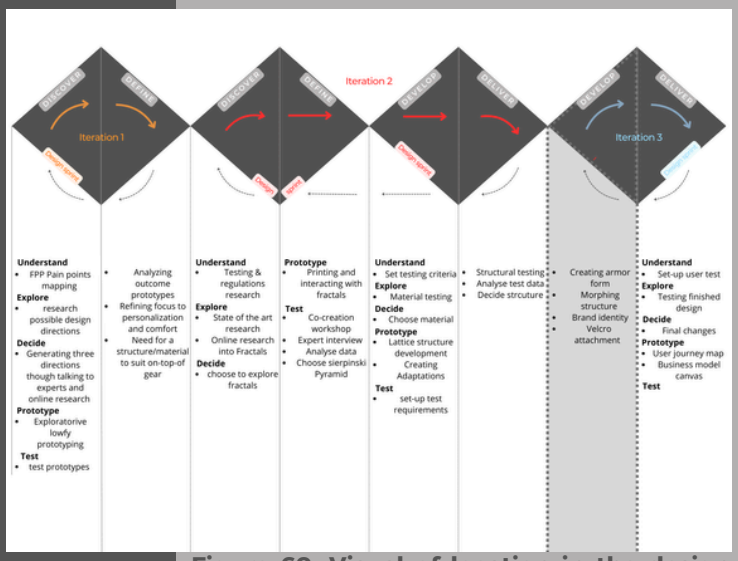


Figure 60, Visual of location in the design process 7

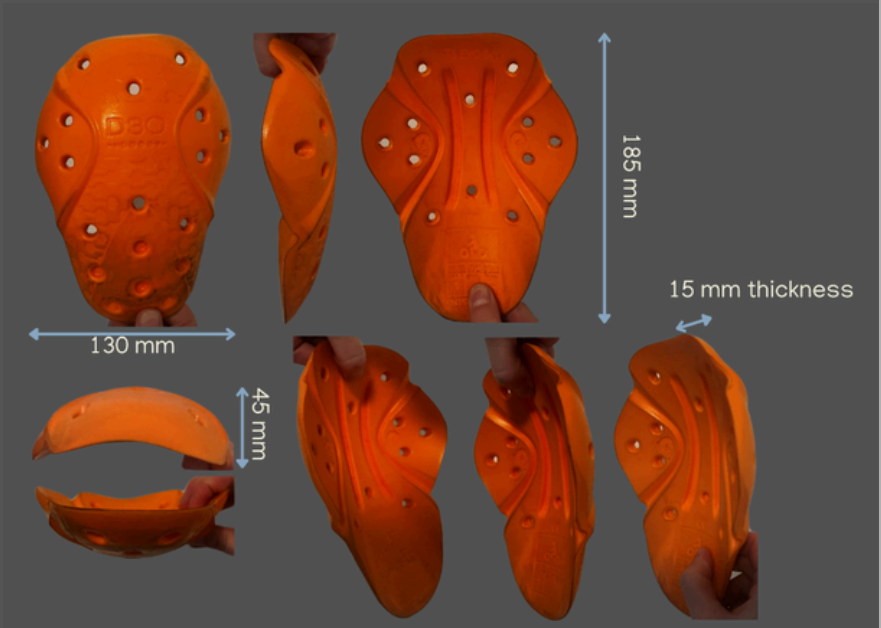


Figure 61, Armor measurements taken from an icon D3O® T5 Evo Pro shoulder protector (Icon D3O® T5 Evo Pro Schouderbeschermers - Beste Prijzen ▷ FC-Moto, n.d.).

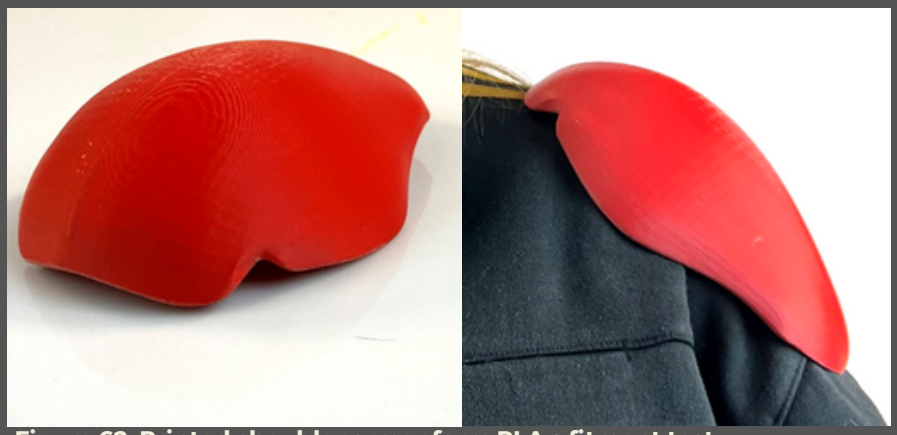


Figure 62, Printed shoulder armor form PLA + fitment test

3.2 Morphing the Structure

To create the intended armor, the Sample 4 structure was integrated with the armor form. Multiple iterations were explored (Appendix 1) to achieve the desired result. Which is created using various steps with rhino 8, grasshopper and blender (Figure 63).

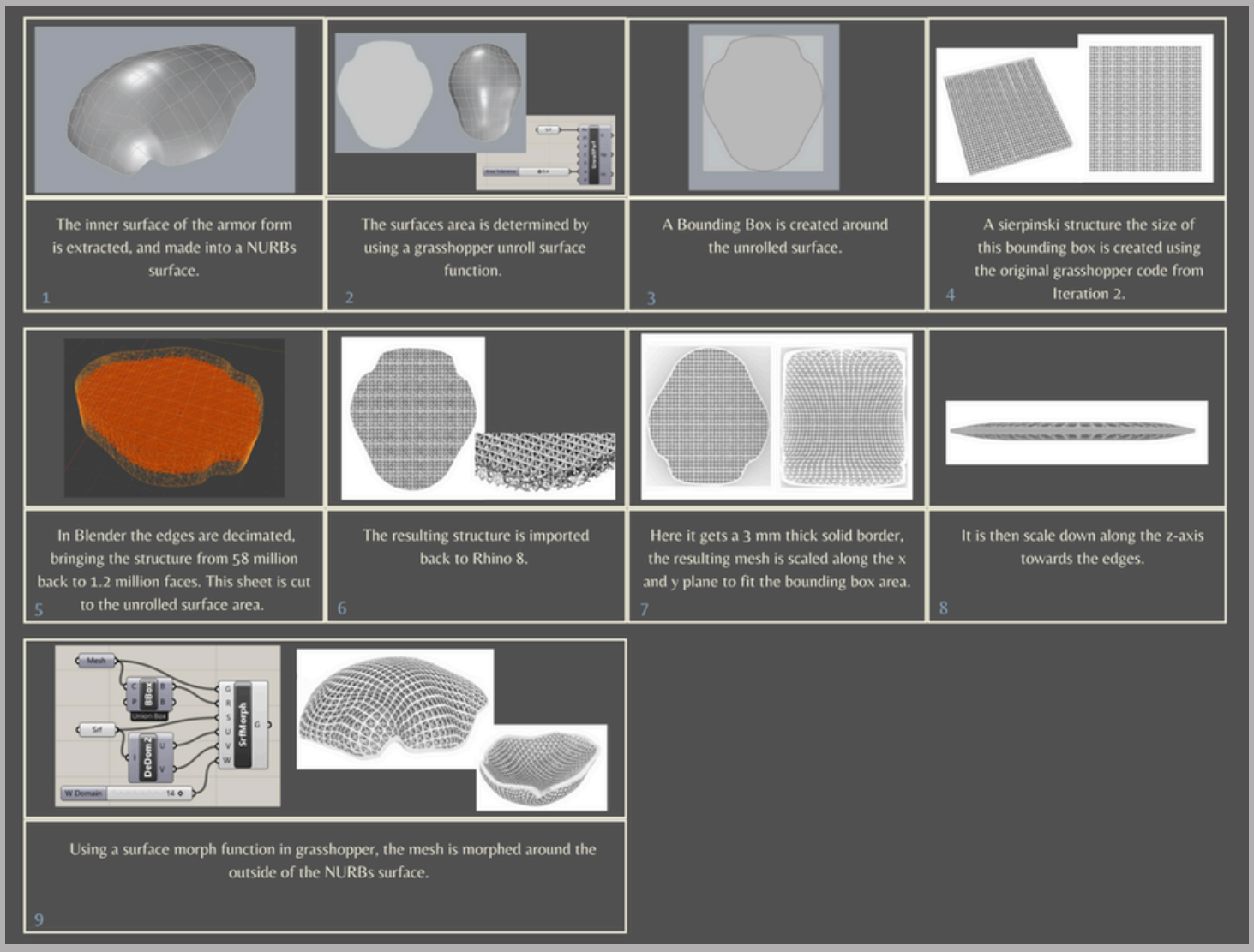


Figure 63, visualization of the steps taken for structural morphing.

The final morphed design is 3D-printed at the same 30-degree angle as the samples (Figure 64).
Following printing, the vertical rows on the inner layer are removed based on the 3-point bend test results (Figure 65).

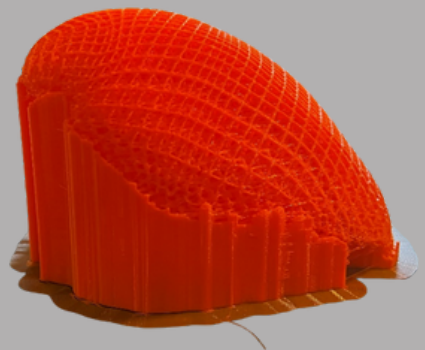


Figure 64, Printed armor on 30 degree angle

Figure 65, Inside of armor after vertical rows are removed

3.3 Brand identity

Brand identity is a vital element in motorcycle apparel, where aesthetics play a key role (Amorim, expert interview). The armor's brand identity includes a logo, name, and colorway that reflect its mathematical origins and protective qualities.

The chosen name, Aeg-X, combines "Aegis" (Greek for "shield" or "protection") with "-X," symbolizing the armor's mathematical design and its reference to operators and variables.

Logo development (Figure 66) drew inspiration from the Sierpinski structure, exploring geometric shapes, including insect-like forms found within the structure. The final selection came down to a fox and a bat-like form derived from the geometry of the Sierpinski pyramid. Both have strong geometric qualities that align with the brand's identity, but the Bat was chosen for its better aesthetic.

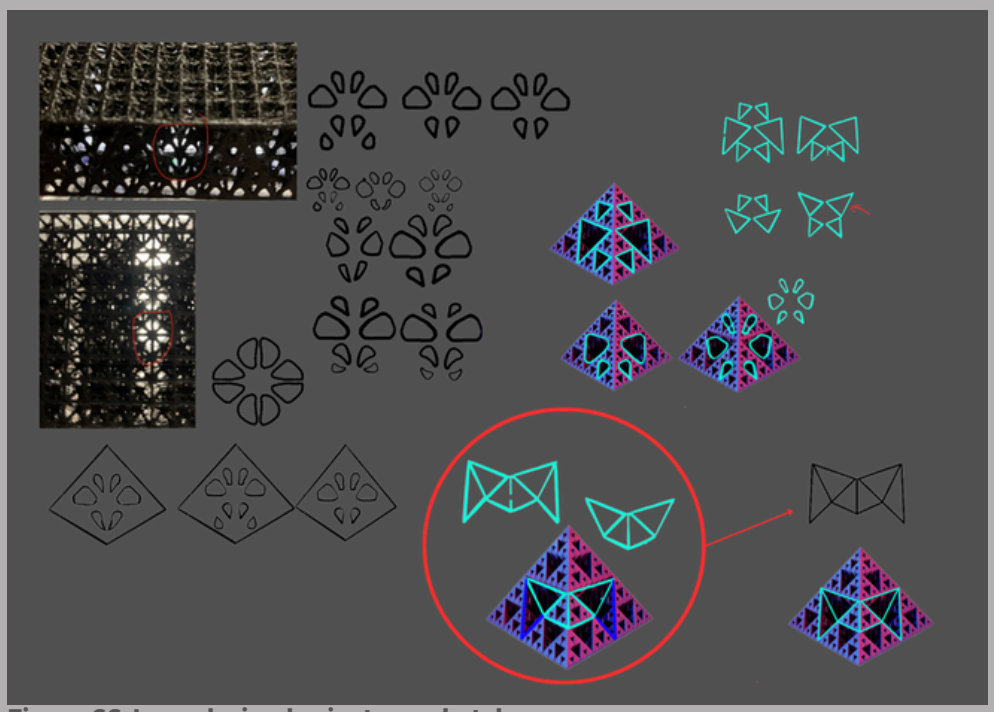


Figure 66, Logo design brainstorm sketches.

The brand's primary colors are orange and dark grey. Orange symbolizes, commonly seen in traffic cones and safety vests, while also offering a bold, striking aesthetic highlighting its aesthetic impact. Dark grey complements the orange, ensuring a balanced and professional appearance.
Various logo color variations were explored (Figure 67), with the final design featuring an orange-highlighted pyramid (Figure 68). This emphasizes the pyramid's central role in the structure while maintaining a clean, simplistic look.

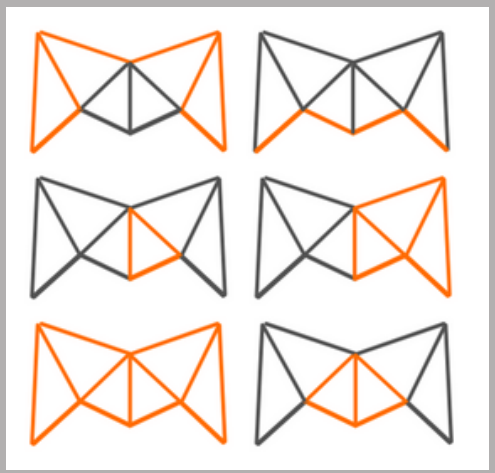


Figure 67, Logo colorway exploration

Figure 68, Final logo design, including the Name

The logo is added to the armor in Rhino 8 by placing a mesh of the logo with slightly extruded edges onto the pre-morphed structure (Figure 69). The surface morph is reapplied to integrate the logo into the design, resulting in a slightly extruded logo printed at the center of the armor's surface (Figures 70 to 72).

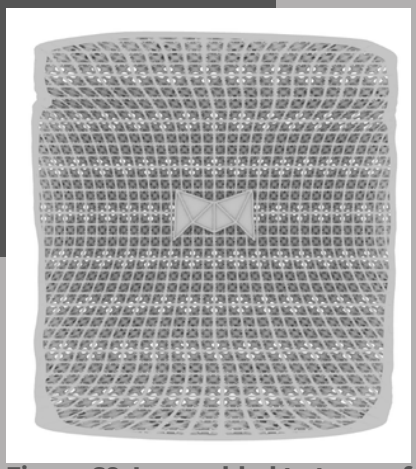


Figure 69, Logo added to top surface pre-morphed structure

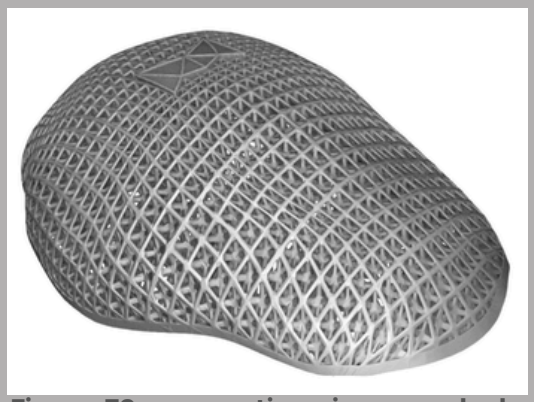


Figure 70, perspective view morphed armor with logo render

Figure 71, Printed black armor, with include Logo (front and back)

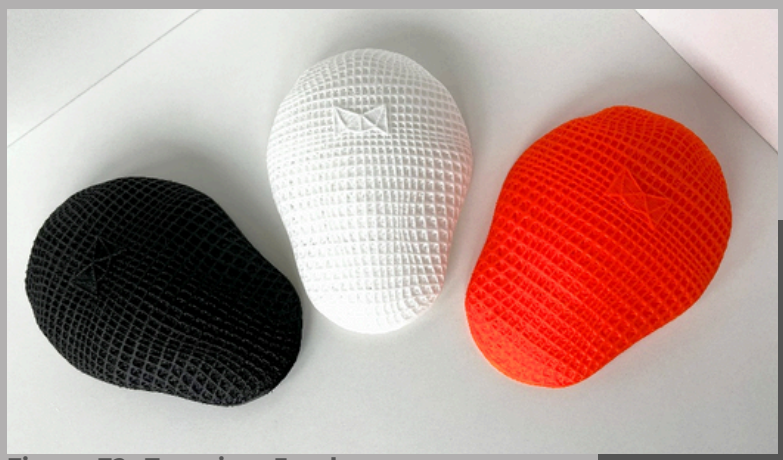


Figure 72, Top view 3 colours armor printed with Logo

Figure 73, Velcro attached to bottom of armor.

3.4 Attachment system

The attachment system for the armor prioritizes ease of use and secure modularity, a key criterion identified during the workshop.

Velcro was selected as the primary method for attaching the armor to the exterior of motorcycle gear (Figure 73). Its effectiveness is well-established in similar applications, such as knee and elbow sliders in motorcycle racing, where Velcro securely holds components in place even during ground contact (Figure 74) (Gilbert Michael, 2019; DemoneRosso, 2021).

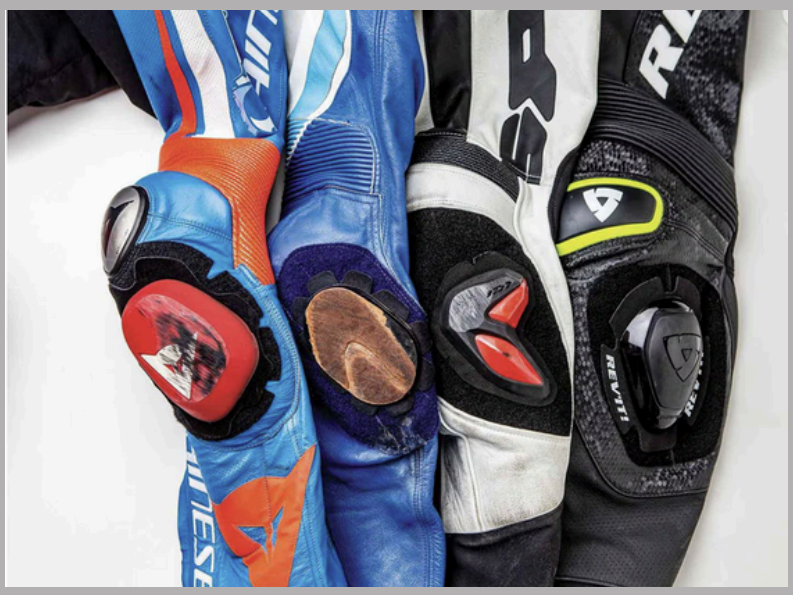


Figure 74, various knee sliders with Velcro attachments. (Gilbert Michael, 2019)

While Velcro is highly secure and easy to remove, making it ideal for modularity, workshop participants expressed concerns about its perceived lack of safety (Appendix 2.3). To address this, a slot attachment system was explored (Figure 75), where the armor is inserted into a dedicated slot from the inside, remaining visible on the outside. However, this system requires removing the jacket, suit, or pants to switch pieces, as the pieces need to be accessed from the inside, limiting ease of use and modularity compared to Velcro.

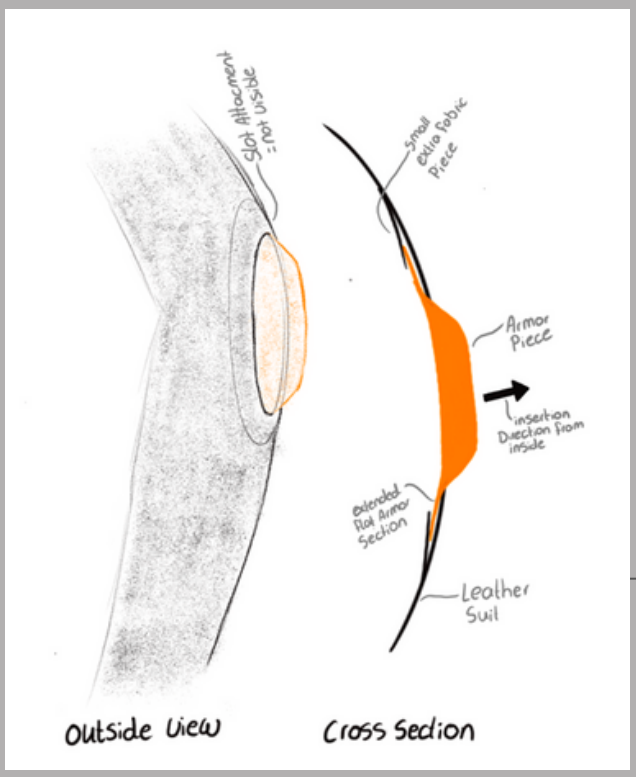


Figure 75, Sketch slot attachment system explained.

For users preferring traditional placement, the armor can be worn underneath a motorcycle jacket by purchasing a smaller size for proper fit. Velcro can be attached to the armor in two ways: sewn onto the structure using gaps in the lattice or directly integrated during 3D printing by printing onto Velcro fabric (Figure 76), as demonstrated in similar projects (Eutionnat-Diffo et al., 2020; Gorlachova & Mahltig, 2021; Kočevar, 2023; Singh et al., 2021).
To enhance modularity, fabric pieces with Velcro bottoms can be included with jackets or suits. These pieces cover the exposed Velcro when the armor is removed, maintaining a polished appearance for regular use.

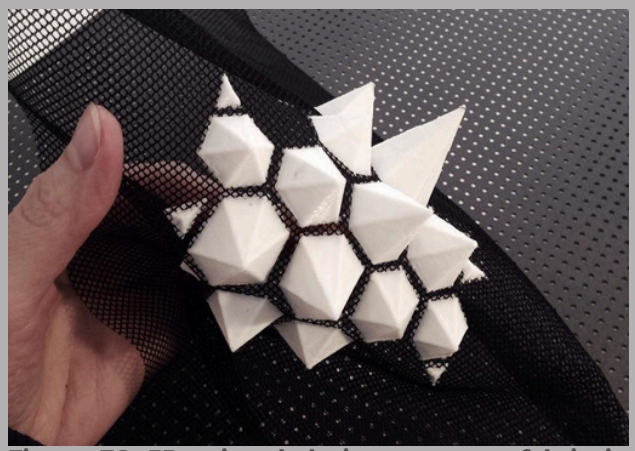


Figure 76, 3D printed design on wove fabric in project by Geetech (2018)

3.5 Real world Alignment:

To gather feedback on Aeg-X, two motorcycle drivers participated in a wear trial and interview (Appendix 7). Their responses informed the creation of a user persona, Thomas, and a corresponding user journey map (Figure 78). A second persona, Amber, was based on the designer's first-person perspective, with its own user journey map (Figure 79).

These maps outline five elements: stages, customer actions, thoughts, feelings, and opportunities. Insights emphasize the importance of marketing in communicating Aeg-X's versatility, highlighting features like comfort, customization, and modularity. Wheres the product itself excels at showcasing its aetheticc.

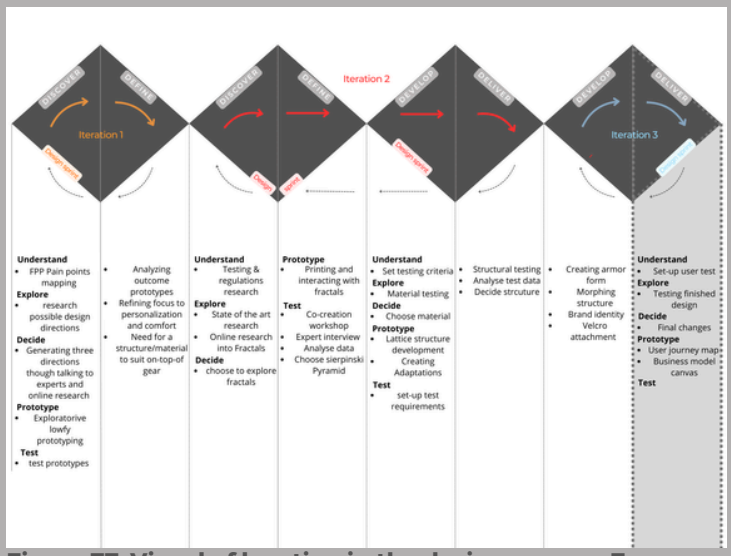


Figure 77, Visual of location in the design process 7

The maps also identify areas for improvement, such as achieving Level 2 safety standards and offering widened customization options to minimize the aesthetic impact of on-top armor. Overall, the user journey maps demonstrate how Aeg-X's modular and customizable design meets diverse user needs, including comfort, affordability, multifunctionality, and aesthetic variety.

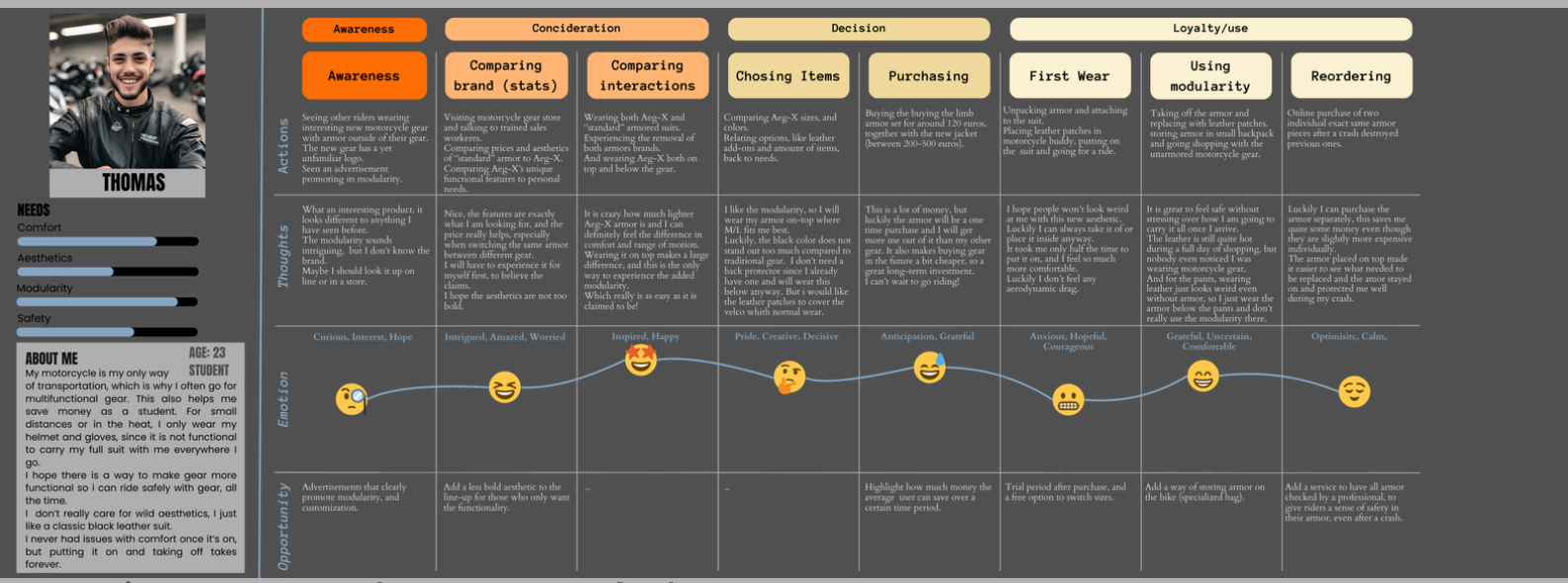


Figure 78, Persona and User Journey map for Thomas.

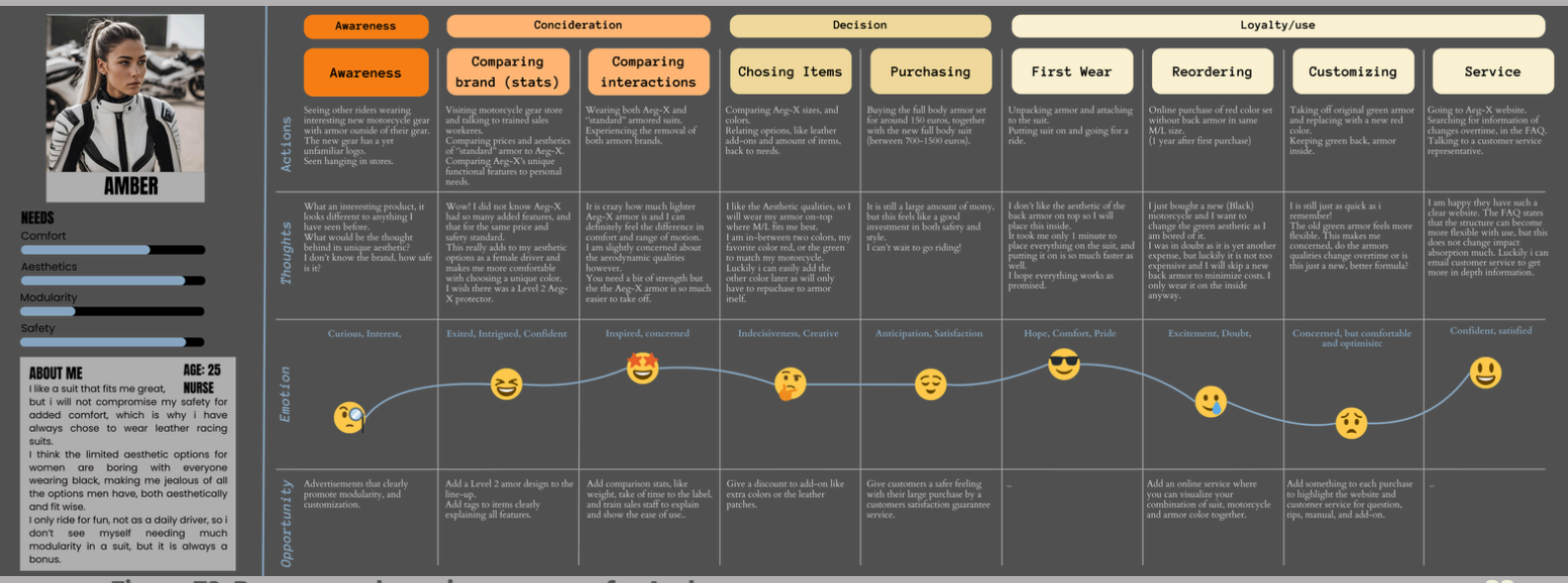


Figure 79, Persona and user journey map for Amber.

As the final step in the design process, a Business Model Canvas (BMC) was developed to evaluate Aeg-X's market potential (Figure 80). This analysis built on insights from user feedback and journey maps, offering a clearer understanding of the product's value, target audience, and supporting strategies.

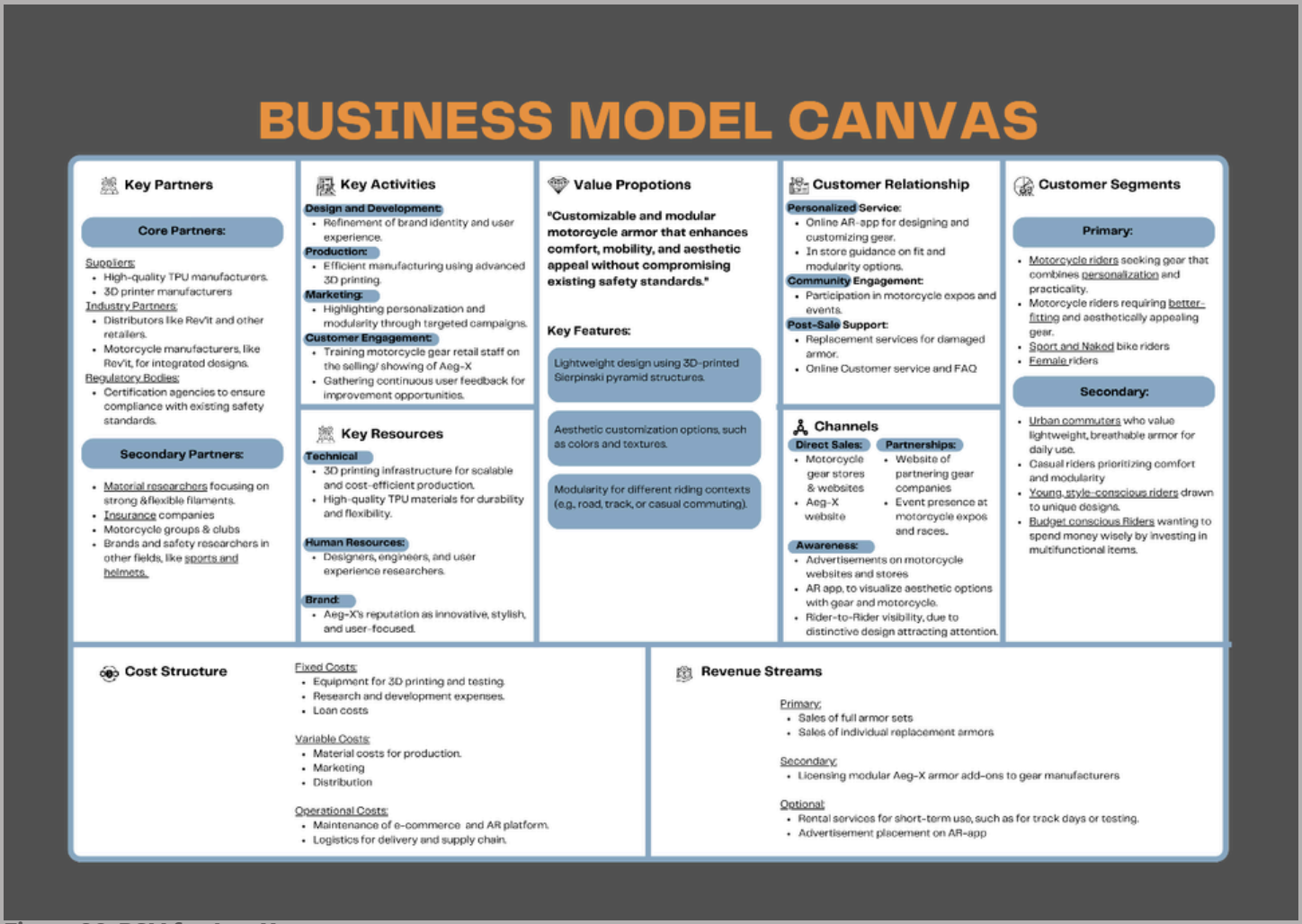


Figure 80, BSM for Aeg-X

A key insight was the role of rider-to-rider visibility as a natural marketing tool. Aeg-X's striking design attracts attention on the road, sparking curiosity and conversation within the motorcycle community, reducing reliance on traditional marketing strategies.

The BMC also highlighted Aeg-X's diverse customer segments, including sport and naked bike riders, female motorcyclists, urban commuters, and budget- or style-conscious riders. This diversity underscores its broad appeal and ability to address varied user needs.

Additionally, key partnerships beyond suppliers and distributors were identified as essential for strengthening community ties, increasing visibility, and fostering innovation.

In summary, the BMC expanded on earlier findings, offering a framework to assess Aeg-X's market potential and identify pathways for future growth.

DISCUSSION

The goal of this project was to address the lack of comfort, personalization, and modularity in motorcycle gear while maintaining high safety standards. This was achieved through the development of a custom Sierpinski fractal-based structural design, assessed on dynamic impact and flexibility, with validation from user and expert feedback. The results demonstrate that the structure effectively balances flexibility and impact absorption while highlighting market demand for modular and functional safety gear.
A key feature of the design is the Velcro-based modular attachment system, which proved practical and reliable. It supports personalization and modularity by enabling easy adjustments without compromising safety, addressing its initial concerns about its. The seamlessintegration of this attachment mechanism reinforces the adaptability of the overall design.showcasing its potential to enhance user experience. Future research could explore alternative attachment methods, such as sewing Velcro into the structure or integrating it during 3D printing, to assess their scalability and effectiveness.

The Velcro attachment complements the Sierpinski fractal structure, whose testing results confirm its ability to provide effective impact absorption and flexibility in motorcycle armor. Dynamic impact testing showed that the structure meets Level 1 CE safety standards, demonstrating its potential for real-world use. And proving that lightweight and modular designs can offers safety without sacrificing comfort, underscoring the value of combining user-driven insights with innovative structural approaches.Offering a promising directionfor future gear innovations.

Beyond meeting practical requirements, this project expands the application of fractals from quasi-static to dynamic impact scenarios using a new structure. This innovation opens new opportunities for safety-focused industries by demonstrating the untapped potential of fractal-inspired designs in high-impact scenarios.

While promising, the findings highlight areas for further investigation. The small user group of seven participants indicates market demand but is insufficient to quantify the its scale. Future studies should expand the scope by testing diverse user groups, alternative materials, long-term durability, and aerodynamic properties to confirm these findings under diverse conditions. Also, examining how structural morphing and the Velcro attachment affect the structure's properties.

Manufacturing scalability also requires exploration; while FDM printing sufficed for prototyping, alternative (printing) methods may be needed for mass production.
Additionally, while the on-topplacement of the armor is expected to comply with abrasion resistance standards due to the protective leatherunderneath, further testingand research is needed to confirm this.

Addressing these areas can refine the design, furthering its real-world applications and achieving Level 2 impact absorption Collaboration with regulatory bodies and manufacturers will be essential to overcoming challenges and transitioning the concept into a market-ready product .The findings, not only highlight the potential of fractal-based designs in motorcycle gear but also suggest broaderapplications in fieldslike sports and military safety equipment. Opening doors to user-focused advancements in protective technology across multiple industries.

The non-linear Double Diamond with integrated design sprints methodology was instrumental in managing the project's wide scope. Starting with the double diamond on its own, this provided a clear framework for addressing the broader design goals but proved to be chaoticin the smaller explorations of this multidisciplinary project. Design sprints were integrated to ensure the individual deep dives remained structured and productive. Together, they supported iterative refinement of individual components while maintaining alignment with the overarching project objectives.
The workbook documentation (Appendix 1) greatly enhanced this process, enabling insights gained from one exploration to be easilyintegrated into others.
The approach and documentation facilitated the technicaldevelopment and ensuredthe final design stayed user-centered and cohesive.

CONCLUSION

This project addressed the lack of comfort, personalization, and modularity in motorcycle gear while maintaining high safety standards. By integrating a new fractal-based Sierpinski structure with a modular Velcro attachment system, the design demonstrates that safety and user-centric features can coexist in motorcycle gear. Dynamic impact and flexibility testing evaluated the critical structural properties of impact absorption and comfort, validated through user and expert feedback to ensure alignment with real-world market demands. This combined approach allowed for a comprehensive validation of safety and usability.

Fractal geometries were chosen for their energy dissipation potential and lightweight nature. The project was undertaken with promising expectations but without concrete benchmarks, given the lack of precedent dynamic impact testing. Results confirmed the feasibility of fractals and revealed unexpected benefits of modular, on-top placement, enhancing personalization and modularity, expanding its user appeal.

The non-linear Double Diamond process with integrated design sprints was instrumental in maintaining structure throughout the project. While the Double Diamond and workbook documentation ensured a broad multidisciplinary approach to the overall design, the design sprints provided focus and organization to individual explorations.

Practitioners should explore modular, customizable designs to address diverse user needs. Future research should assess alternative fractal geometries, materials, and real-world applications, alongside scalable manufacturing techniques and compliance with abrasion resistance regulations as a more comprehensive evaluation.
This project contributes by introducing a novel structure and property, challenging conventional safety design approaches with user-driven insights and modularity, while also confirming the market potential for more user-friendly and adaptable motorcycle armor. Its implications extend beyond motorcycle gear to fields like military and sports equipment.
By addressing the growing need for user-focused safety solutions, this project marks an important step forward in the development of innovative protective technologies. Underscoring the importance of balancing user needs, technological advancements, and safety requirements, paving the way for future advancements in customizable, lightweight, and effective safety gear

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Finally, I am grateful to the workshop participants for their time and valuable user insights that significantly contributed to the development of this project.

Ai was used as a way of inspiration on the devision of certain

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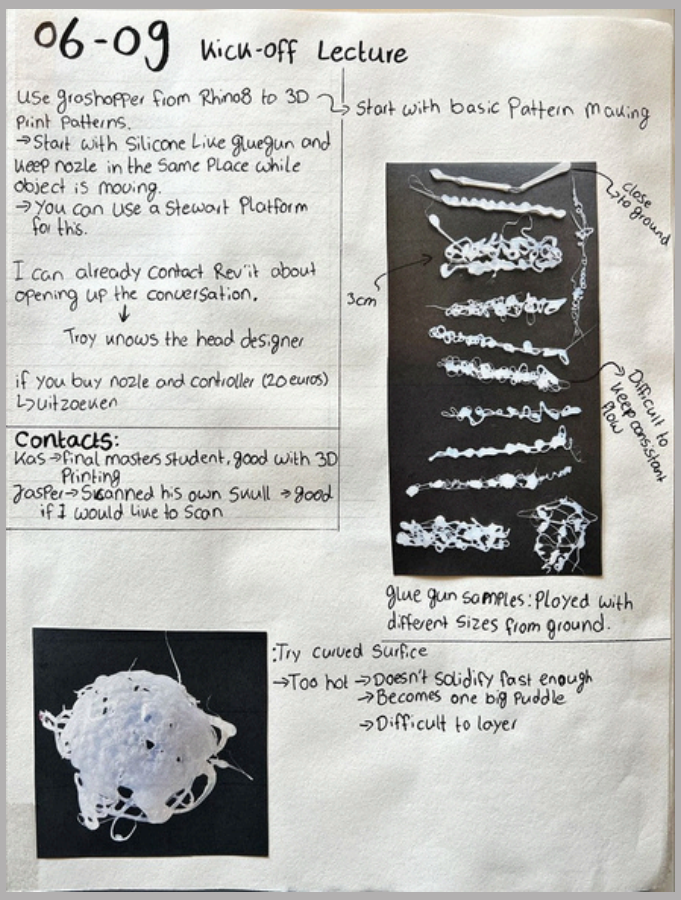
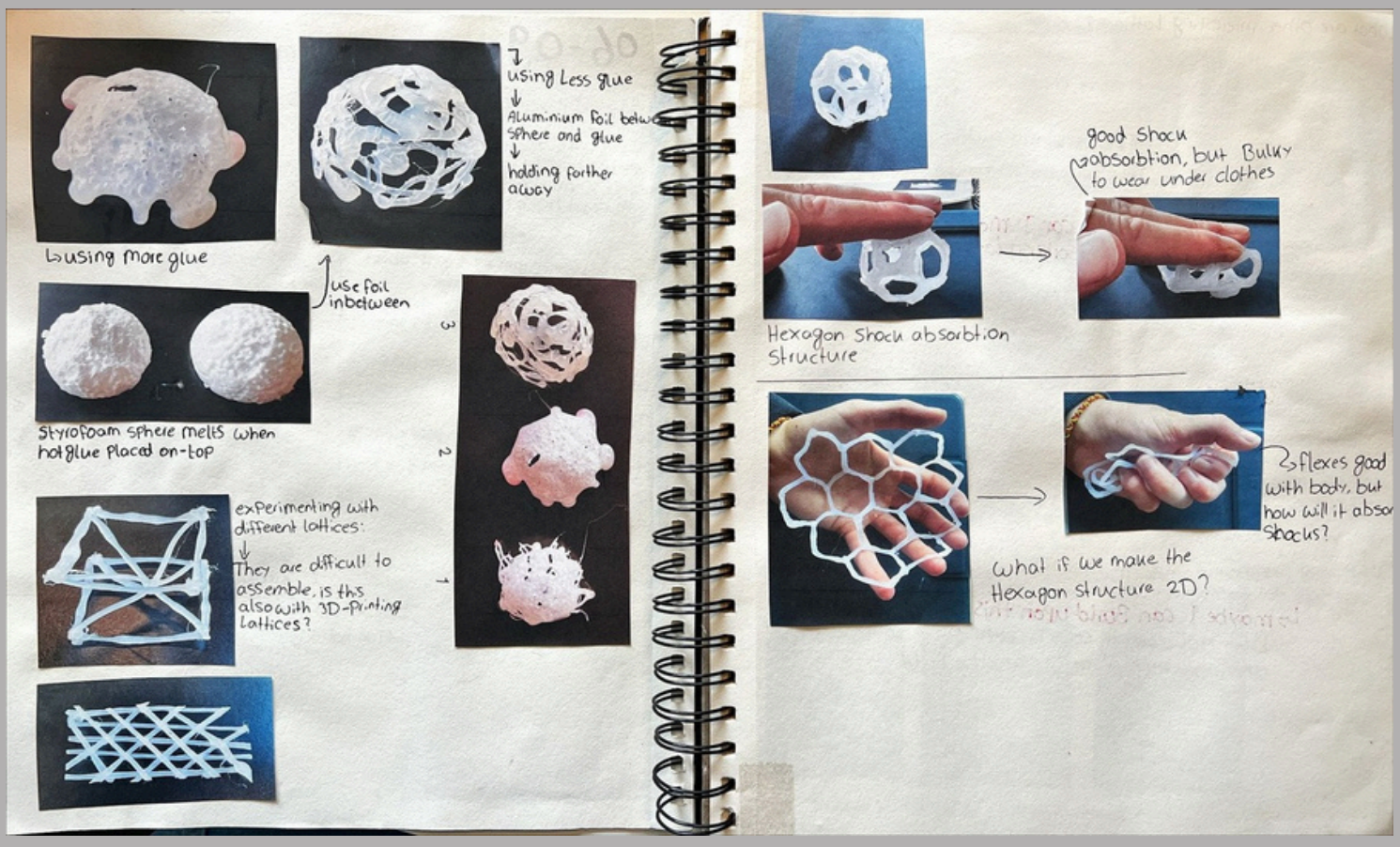
APPENDICES

Appendix 1

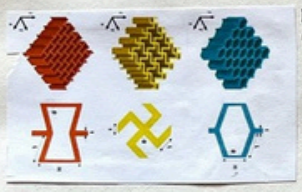




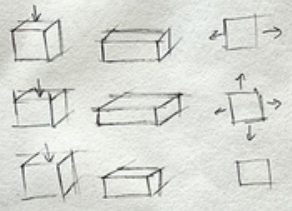
What are other interesting lattices?

↳ There's allread quite a lot of Research into lattices 3D Printed.

How can I make 3D-Printed shock absorbing lattices, innovative??



Different structures act different to Pressure.



A Paper using this concept for ultra Personalised Shoe soles Already exists.

"Exploring Mechanical meta-Material Structures through Personalised Shoe sole design."

↳ maybe I can Build upon this Paper?
But how/what can I contribute so its not just an implementation in another field

First experimentation with 3D Printing.

↳ Creality ender 3 v3 SE

Creating filament test swatches, to get to know the slicer settings and material qualities.

↳ TPU = Difficult to Print, has a lot of stringing

↳ Higher retraction + glue on Printbed helps create better swatch

Attempting a Simple lattice Structure

↳ too squishy

↳ lot of stringing (even with high retraction)

Trying to create coiling with the 3D Printer.

(Still very inconsistend)

Height nozzle at +1.8mm

→ → → → → → → → increasing Flow

4mm³/s 9mm/s 15mm³/s

How do they do it in the Paper:

"From dribbling Honey to Non-Planar 3D-Printing; coiling becomes craft."

Exploring Existing Helmet Structures

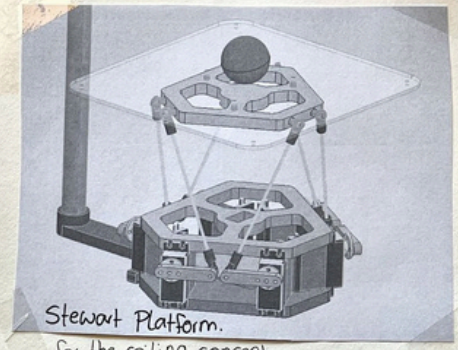
↳ ABS shell (Hard but flexible)
also in carbon and fyberglass

↳ Styrofoam
(Dries out & loses shock abortion)
Thick, but cheap and light.

↳ fabric comfort liner
(To combat hard styrofoam, and create perfect fit.)

feedBack Marina:
- Dive deeper into existing regulations/Rules/tests about the gear
- are there Papers on why all brand do it the way they do now?
- Loe is very good on finding patterns
- She is more interested in the protectors than the helmets
- I have a good Reasoning for choosing lattices

feedBack Oscar & Tijs:
- Look into combining lattices (for structure) and coiling (for shock & comfort)
- make an item a mono-material, so you remove the current layering
- Right now, start with state-of-the-art Research, what is already out there
- Materialize (Leuven), Look at website & we can visit if i want (Bicycle Seat / shoe Sole)
- fullcontrol code, helps take control of 3D-Printer, for Printing lattices



Stewart Platform.

for the coiling concept
↓
if you want to Print a 3D object
↓
object itself should rotate underneath the nozzle

otherwise you experience "Draping"

(To move the object, a Stewart Platform can be used.)

"Draping" (Nozzle moves)

"even coating" (object moves)

More an mechanical engineering Project??

Materialize (Leuven)

fullcontrolcode

How can you know/test that it works?
→ safety wise

Why "coiling" (FH) Why not "metamaterial?"

Have you identified any clear advantages to using Additive manufacturing (3D printing) versus injection moulding for example?

WHAT IF IT IS NOT PLASTIC?

What sets this research apart from Product already out there? (not only physical)

Can this lead towards ondemand personalized products?

What aspect is in need of innovation?

Is it more breakable 3D printed than what is on the market now?

Have you considered reaching out to a more specific target group — like a club for motor-cross?

Consider taking a step back and not to not compare current gear. Ask yourself the question "If motorcycle gear did not exist, yet how would I make it? Prevent body's

Combine the two, is this possible?

Different materials or looking into other types of 3D - printing

auxetic structures on the other table could be useful for you

Mono Materic?

Changes After an accident?

Personalized ???

WHAT BENEFIT BEYOND INNOVATION CAN 3D PRINTING OFFER?

Is the innovation in terms of increasing strength or flexibility or durability or safety?

Are there already companies doing this? +

How are you planning to test the safety? +1

here you considered combining protection with personalization? how can this gear be adjustable?

- based the analysis of an existing product.
- what values does this new concept offer to the user?

3D Reasons To 3D print:
- Local → ONDEMAND
- PERSONALIZED
- COMPLEXE STRUCTURES (AUXETICS ETC.
+ MANY MORE
but HOW CAN YOU EXPLORE EACH CASE?

Innovation in motorcycle protective gear through new 3D printing techniques. The current two main focuses are coiling (sample 1), and shock absorbing lattices (sample 2-3).

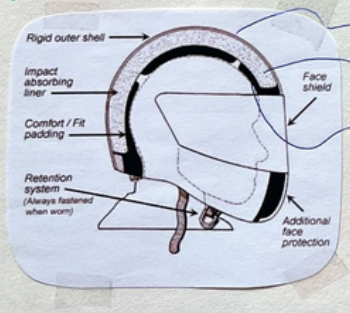
For motorcycle drivers and for a motorcycle gear company "Rev'it".

Feedback:
What tips/inspiration do you have to make either of these options both innovative and feasible enough to interest a real world company.

Reflection (20-09)
-main decisions and where from now.

State of Art.

The current market:



Resists Penetration & Abrasion

Disperses & Absorbs shock

Comfort & securing fit

ODS (omni directional suspension) by 6D
- 2 Styrofoam layers
- suspension between layers
  - on impact → suspension breaks
    Reduces linear & angular force
  - after crash rebuildable

Layer 1
Layer 2
Suspension

Flex by Bell
- 3 layers replace 1 foam layer.
- each layer = for different impact
- slit inbetween layers for rotation.
- → MIPS also lets inner lining Rotate.
  → Reducing angular force.

ARMOR
"Armor dispenses the Impact energy over its whole Area, therefor reducing energy transmitted to the body." by D30 (Armor brand)
- to dispense energy → stiff
- for comfort → flexible

Curren Armor types:
- foam → PU-Foam (Polyurethane)
- non-newtonian foam → D30
- Structures (stiff) → carbon elastomer/Polyamide/Polypropyleen
- Structures (soft/foam) → expanded nitrile Rubber/~~EVA~~ TPE /

The various structures on the market currently

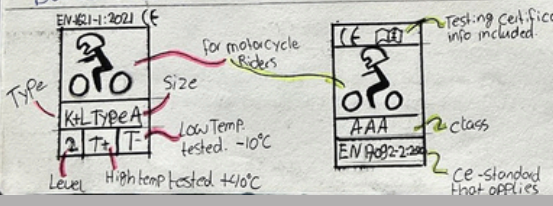
- Lots of hexagons
- Circles/diamond
- 3 Point Stars

↳ most shapes are build from triangles/Rounded triangles

- Waving only seen in back Protectors.

How 3D Printing is used:

Dainese uses it to do in-house Prototyping instead of outsourcing it.



Testing & Standards:

Cenelec, CEN, ETSi ⇒ the 3 European Standardization organisations
⇒ officially recognized by the EU and EFTA.

The dutch governing body for the regulations = NEN

The Standards can be devided into Two types: Armor & Gear

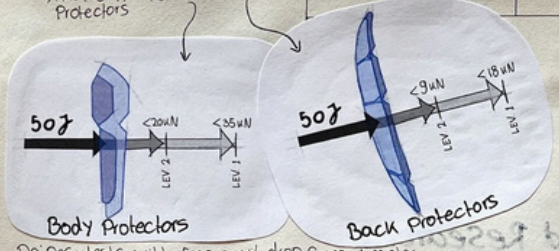
Armor:

each Protector has their own Standards.

if it complies ⇒ CE certified.

There are Two Levels:
↳ that differ for body & Back Protectors

Type	Symbol	Regulation	
Boots		EN 13634	2017
Gloves	KP	EN 13594	2014
elbow/knee/hip/shoulder	E/K/H/S/L	EN 1621-1	2021
Back	PBCB/LB	EN 1621-2	2014
chest	DC/C	EN 1621-3	2018
Airbags		EN 1621-4	2013



Dainese tests with 5kG anvil drop from 1 meter.

Gear:

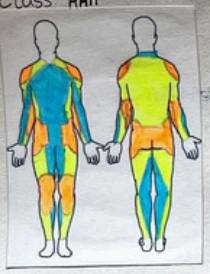
↳ The amount of Protection = indicated by its "class".

Class	Level of Protection
Abrasion & impact Protection — Class AAA	(prEN 17092-2:2017) Is the highest level of protection with which to take on the highest level of risk. Garments classified as such offer maximum protection, but are also heavier and less comfortable to use.
Class AA	(prEN 17092-3:2017) Is the second highest level of protection with which to take on the wide range of risks that motorcycle riding presents.
Class A	(prEN 17092-4:2017) Is the third highest level of protection. Protectiveness is less than the previous classes, but garments are lighter and more comfortable to wear on a daily basis.
only Abrasion — Class B	(prEN 17092-5:2017) Where the level of protection against abrasion is equivalent to Class A, but without the impact protectors. Garments in this class offer abrasion resistance in line with that of level A but are not equipped with protectors. Jeans without protection fall into this class for example.
only impact — Class C	(prEN 17092-6:2017) In the least protective class, we find so-called "protection containers" that resist impact but not abrasion (underwear with integrated impact protectors for example)

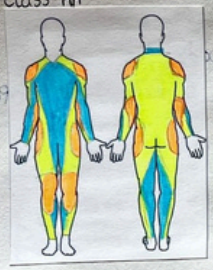
↳ CO = over clothing
EU = underclothing

for each class The Body = devided into 3 zones.

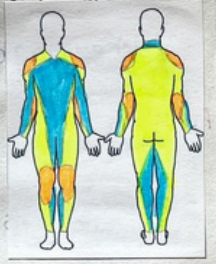
Class AAA



Class AA



Class A/B/CO



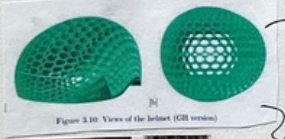
	Class AAA	Class AA	Class A/B/CO
zone: 3	45 kph	25 kph	25 kph
zone: 2	75 kph	45 kph	45 kph
zone: 1	120 kph	70 kph	70 kph

RISK CATEGORY ZONES	
Zone 1	The areas of motorcyclist's protective garments that have a high risk of damage e.g. impact, abrasion, and tearing. Must have impact protectors and needs to last 4 seconds on the abrasion test to meet Level 1 protection, and 7 seconds to meet Level 2.
Zone 2	The areas of motorcyclist's protective garments has a moderate risk of damage e.g. abrasion and tearing. Must have impact protectors and needs to last 4 seconds on the abrasion test to meet Level 1 protection, and 7 seconds to meet Level 2.
Zone 3	The areas of motorcyclist's protective garments has a low risk of damage e.g. tearing, which requires 1.8 seconds for Level 1 and 2 and 5 seconds for level 2 on the abrasion test

↳ each zone has its own Standards for Level 1 & 2

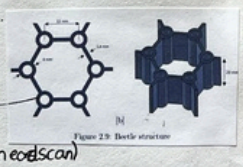
Related Research:

"3D Printing of a bycicle helmet with bioinspired structure and biomaterial: design, additive manufacturing, and FEM validation."

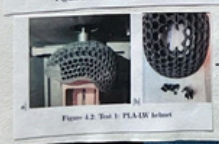


↳ 3D Printed PLA bycicle helmet.

Beetle structure



↳ Personalised (3D headscan)



↳ various tests
↳ Proved better than standard helmets for bycicles

"A wearable hydraulic shock absorber with efficient energy dissapation."

↳ wearable shock absorber "Soft Hydralic Shock"
made for American football

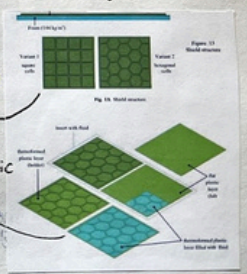
force = absorbed by fluid flowing through small orfices.

(100% absorbtion-rate, compared to 74%-90% in current design)

"Investigating foaming Materials in 3D Printing."

- 3D-Printed foaming PLA
  ↳ for motorcycle Helmets
- Replacing comfort lining & shock absorbing layer.

"The composite structure for Human body impact Protection."



Various impact Protectors
↳ for military/Police
↳ Sports
↳ motorcycles

Shear thickening/viscoelastic /High molecular weight

↳ uses non-newtonian fluids.

Auxetic Structures

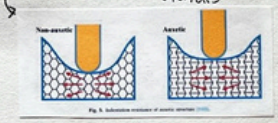
"Anti-Blast and Impact Performances of Auxetic Structures: A Review of Structures, materials, methods, and fabrications."

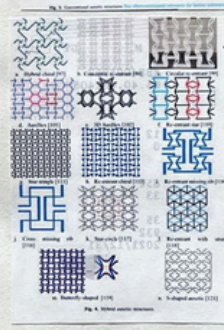
Auxetic Structures → negative Poissons Ratio

↳ Better energy absorbtion
↳ Better indentation Resistance
↳ improved mechanics

↳ various Auxetic Structures.

Densify under impact, like non-newtonian materials

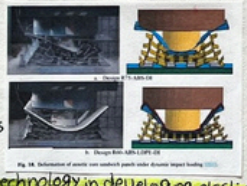




→ Hybrids → combining Auxetic Structures.
↓
improves Properties, like Better flex-stiff balance.

→ example:
↳ Re-entrant & chiral

(Already studied in:
Armor/helmets/Bumpers/seismic applications.)

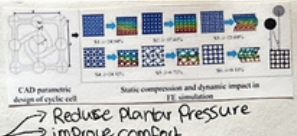


"utilizing 3D Printing technology in developing elastic auxetic materials for Protective gear."
They are: customizable, deformation resistant, flexible, lightweight, energy absorbing.

3D-Printed sport shoe midsoles: Enhancing comfort and performance through finite element Analysis of negative Poisson's Ratio Structures.

Exploring 3D-Printed NPR-Structures in sport-shoe midsoles.

↳ wear trials



↳ finite element analysis → Reduce plantar Pressure
→ improve comfort
→ Better energy dissapation

Taking a Step Back:

What if the Protector was on top of the gear?

Aesthetics? comfort? abrasion safety? knee sliders?

Two Prototypes ↓

Protector underneath

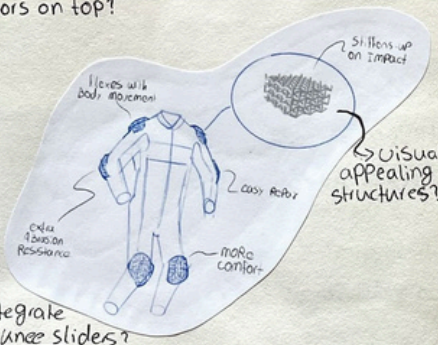
Protector on top

Findings:
- 5 People tested
- All found "Protector on top" more comfortabel
- comfort was influenced by two factors:
  1. movability/tightness
  2. Material against skin/softness
- most difference was felt in hand closed position
  ↳ = Position on motorcycle

movement wear trials

Aesthetics of Protectors on top?

- Badass/cool

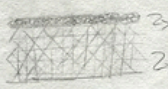


↳ visually appealing structures?

↳ integrate with knee sliders?

↳ impact below, Abrasion on top

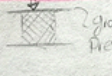
Visualizing the Struggle



↳ Abrasion Resistance
↳ impact absorber

Feedback:
- Auxetic Structures are already overdone?
- get inspired by nature
  ↳ tree Structures → look at how used in Architecture
  ↳ honey dripping → coiling

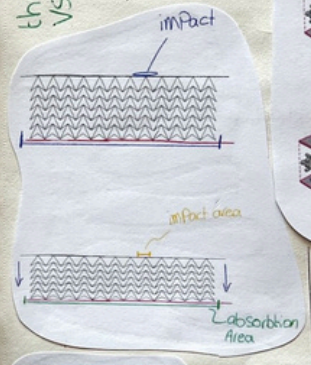
"A Bionic tree-liked fractal structure as energy absorber under axial loading."
- three like fractal structures are proven for "Quasi-static axial crushing" which = slow gradial crushing over its full area.

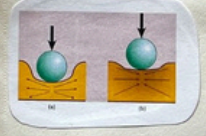


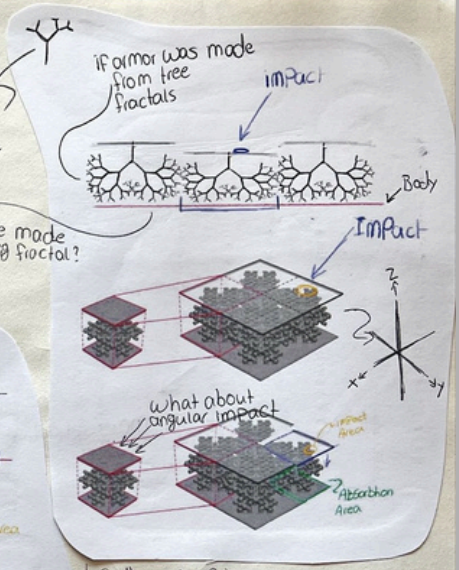
- this is not usefull for motorcycles
  ↳ for this you need "Dynamic impact tests".

"An additive manufactured fractal structure for impact absorbtion applications" → uses other fractal structure: (3D greek cross)
↳ But same Quasi-static axial crushing tests.

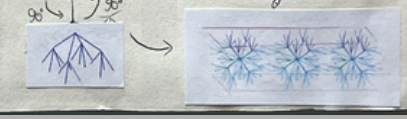
theorising About fractals VS Auxetics



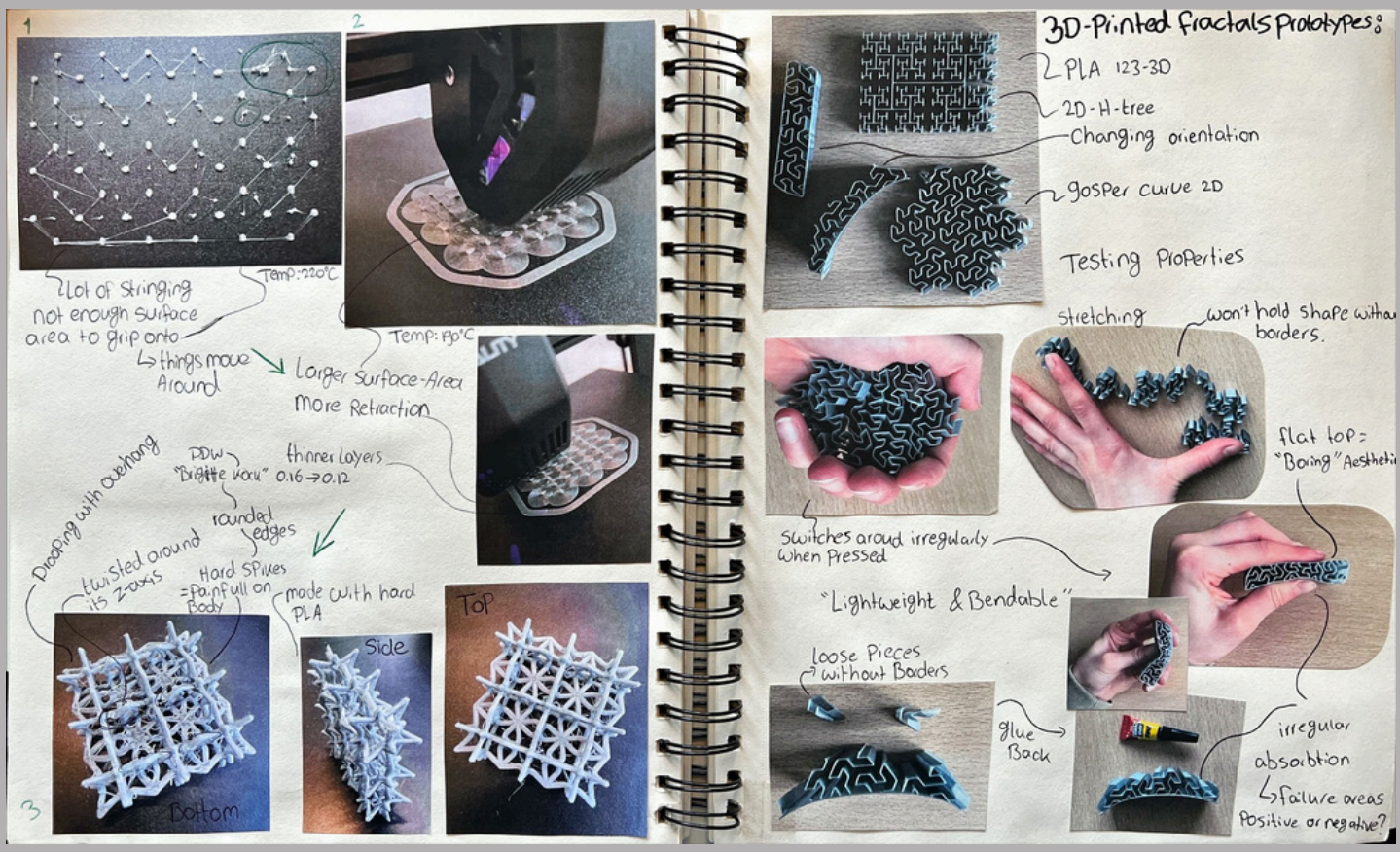


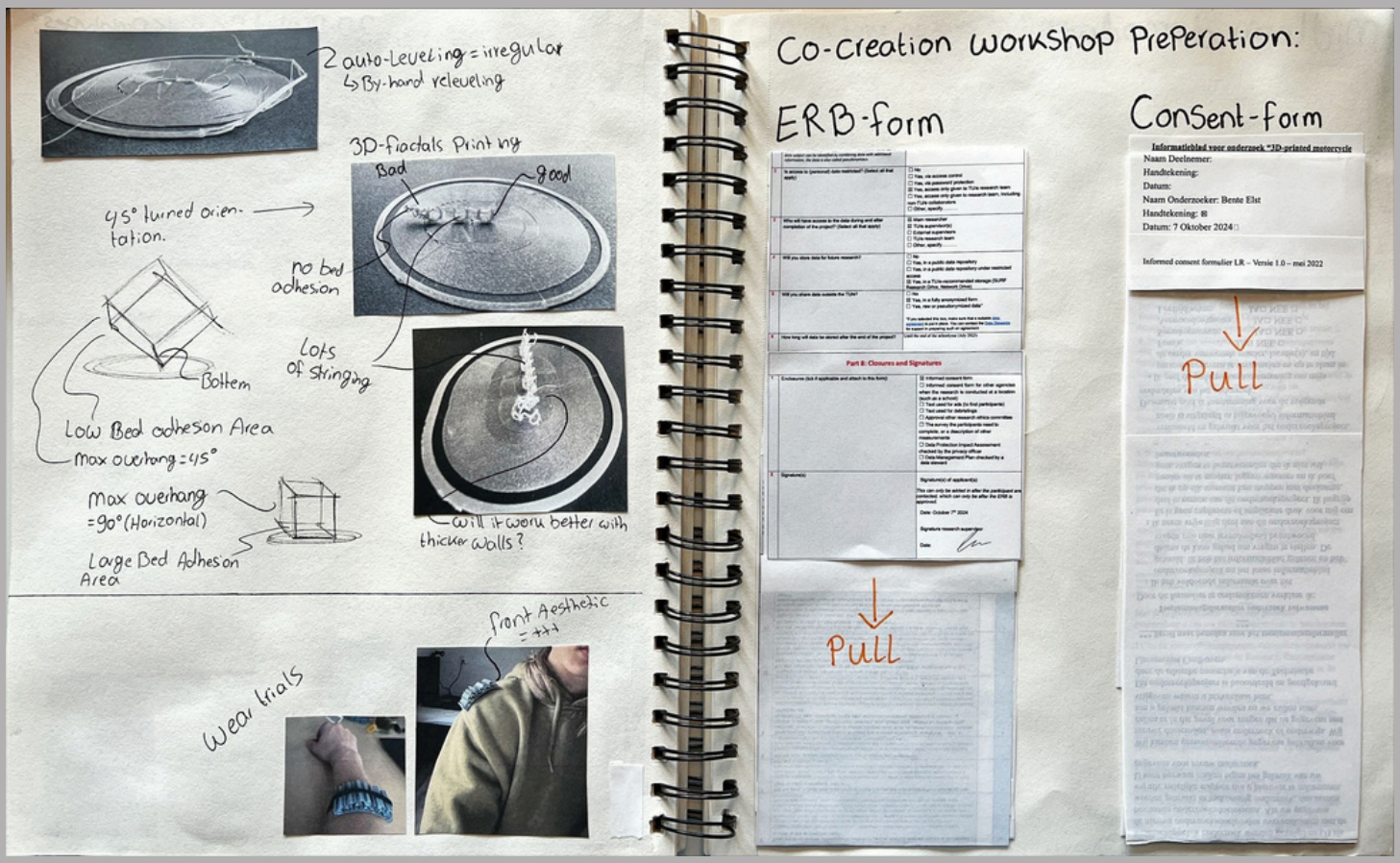


- feedback Laufels
  → interesting direction.
  → Lau will look into other papers that talk more about dynamic tests.
  → my hypothesis could be correct to him
  → ths focuses on dispensing impact, but fractals can also be used to absorb impact by crushing.
  ↳ fractal that also branches out on top surface and 4 way branching



→ DDW
Brigitte Kock


1
2
Temp: 220°C
Lot of Stringing
not enough surface area to grip onto
↳ things move Around
Temp: 190°C
Larger Surface-Area
More Retraction
thinner Layers
PDW "Brigitte Voxx" 0.16→0.12
rounded edges
Dropping with overhang
twisted around its Z-axis
Hard Spikes = Painfull on Body
made with hard PLA
Side
Top
Bottom
3
3D-Printed fractals Prototypes:
PLA 123-3D
2D-H-tree
Changing orientation
Gosper curve 2D
Testing Properties
stretching
won't hold shape without borders
flat top = "Boring" Aesthetic
switches around irregularly when Pressed
"Lightweight & Bendable"
Loose Pieces without Borders
glue Back
irregular absorbtion
↳ failure areas
positive or negative?


auto-Leveling = irregular
↳ By-hand releveling
3D-fractals Printing
Bad
good
45° turned orientation.
no bed adhesion
Lots of stringing
Bottem
Low Bed adhesion Area
Max overhang = 45°
Max overhang = 90° (Horizontal)
Large Bed Adhesion Area
will it work better with thicker walls?
Wear trials
front Aesthetic = +++
Co-creation Workshop Preperation:
ERB-form
Pull
Consent-form
Informatieblad voor onderzoek "3D-printed motorcycle
Naam Deelnemer:
Handtekening:
Datum:
Naam Onderzoeker: Bente Elst
Handtekening:
Datum: 7 Oktober 2024
Informed consent formulier LR – Versie 1.0 – mei 2022
Pull

Midterm demoday:

→ hot glue Prototypes

Aesthetic Prototype

Set-up

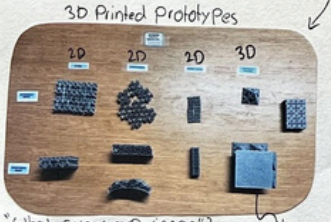
Poster

Workbook

Project explanation

Process diagram

3D Printed Prototypes



"What is your experience"?

heavy

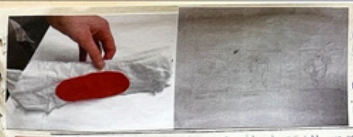
glove-wear trials

to experience the difference yourself!

Main take-aways midterm:

- opinion on Looks → +++++++ } ≠ to 1
  → -
- In Rev'It meeting → Show Prototypes Ask what he thinks which one is best for Impact / Aesthetics / weight / etc.
- Cars crumple zones work with failure areas that are meant to Break first → maybe this is implementable in Armor?
- Aesthetic personalization: Changing out Protectors as a way of Personalising one jacket/suit.
- See how much I am able to prove on its workings, then focus on th I can control, like Aesthetics, Aerodynamics, and market analysis
- See if ican use my unique Perspective as a female in the market (by Tic
- for the workshop → Provide the correct materials to create the correct structures (Fractal types) (by oscar)
- Contact miguel Bruns for knowledge on impact absorbing structures (by Loe Feiss)
- maybe make my own structures / Hybrids (by Loe Feiss)
- Process Poster helped especially with explaining future activities/steps

Co-Creation WORKSHOP



Aesthetics: 2 Part Racing suit to be worn over Racing suit
function: Cord attach to steering → if falling → cord snaps and full body Airbag deploys using Air capsules
inspo: Lifevests

Aesthetics: Harness with Plates on in-and outside of Ankle
function: Protects ankles while Riding with normal shoes
innovation: Protecting Ankles while not compromising on Ankle movability.
inspo: = a stuntdriver with normal shoes
↳ often hurts his ankles.

Aesthetics: Hoodie with two zippers on Backside hiding a flap up or avisible Back Protector
function: Modular hoodie to zip in a Back Protector to a normal hoodie when riding.
inspo: Drives a lot with hoodies, but misses some Protection now.

Aesthetics: Dragon skin/Scales in various colors and Patterns.
function: modular systems (clicking), each individual scale is Removable for Personalisation and only changing out damaged Parts.
inspo: own gear & Shopping experience

Aesthetics: normal knee sliders below, 1 mag and 1 bean
function: Both sliders have a magnet that Pushes away from eachother. when close together. to make Race-drivers more concious on their riding Posture.
inspo: coaches beginner drivers. and many beginner drivers often sit too straight & will it's difficult to make them concious of this.

Aesthetics: Speedhumps in various colors
function: Detachable Speedhump from suit top can slid into the back Protector inside the suit and the button with something like a button.
inspo: Recent switch to Racingsuit
↳ Discomfort when walking etc.
↳ looks weird.
innovation: modular Suit for Road & track

Aesthetics: Camouflaged zippers around knee-joint, or knee-Sliders on jeans.
function: Jeans with detachable kneesliders to allow safety riding in Jean through zippers.
inspo: own driving style in jeans.
wears now buckle on sliders but those tend to fall down when Riding

GroupDiscussion:

Biggest irritation in existing gear:

- Heavy: Suit is already heavy enough → Rev'it C-Smart = Lighter but they don't trust them
- ~~fitting~~ / underarm move around a lot
- Quickly growing out of clothes (Due to gym)
- Knee Protectors limit circulation in legs.

Does Ridingstyle influence this?
- yes, casual riders wear more comfortable clothes
- Jacket or Suit differ a lot

Would you reuse your armor after a crash?

Reuse	Knew	Reason
yes	no	currently doing it, They still look good."
yes	no	I don't believe they're not Safe
yes	no	It's expensive
yes	yes	I listen to the inspector at the track
yes	yes	Still using it now, maybe not with visible damage
yes	no	X
yes	yes	X

ordering based on importance for you:

Protection	Protection	Protection	Protection	comfort	comfort	aesthetics
comfort	comfort	comfort	Aesthetics	Protection	Protection	protection
Aesthetics	Aesthetics	Aesthetics	comfort	Aesthetics	Aesthetics	comfort
Personalisation	Personalizing	Personalizing	Personalizing	Personalizing	visualizing	Personalizing
visualizing	visualizing	visualizing	visualizing	visualizing	Personalizing	visualizing

↳ cognitive dissonance? ↳ Ranking doesn't line-up with behavior & Prototypes

Would you buy this concept if it was in stores & by Rev'it?

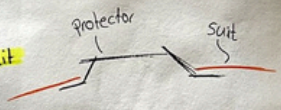
- Depends on the aesthetics → subtle
  - ↳ Like bionic vest
  - ↳ Shoulders not too broad.
- if it's safer than other options
- if changing the Protectors is very easy
- no, I don't like the aesthetics
- various sizes is a must

Acceptable Price:

Set of 4x2: 150,-
Buying seperate is a must → 30,- Set of 2
20,- Single

What would you change/add?

- only body without arms
- Velcro doesn't feel save, so maybe a slit
- camouflaging Armor with Suit
- flat suface on top, not structures



More realistic would be a hybrid → crumple + dispersing

Meeting Rev'it: (Davide)

3D Printing:
- Lines/wall instead of studs
- Davides Paper ↓ kirigamis

Issues with external Protectors:
- Regulation issues due to abrasion tests
- People often want a simple jacket for various situations

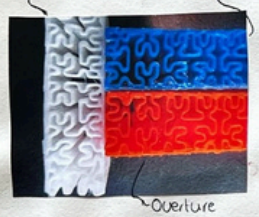
Previous techniques:
- multimaterial → Rev'it C-armor
- Current ones are cheaper/easier
- nothing = better than airbags

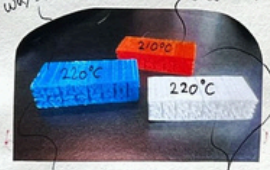
Can a crumple zone work:
- Theory yes → Doesn't always translate to testing
- Depends on base material

Other:
Comfort → you can make something very safe, but if people don't wear it.
I can test a their facilities. → But there are various Rules

Testing various fillaments

↳ TPU's 95A shoreness



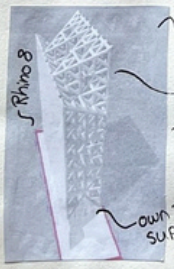


misforms when bending

Does the color also have influence?
↳ test on Orange VS Black overture TPU.

Testing Properties

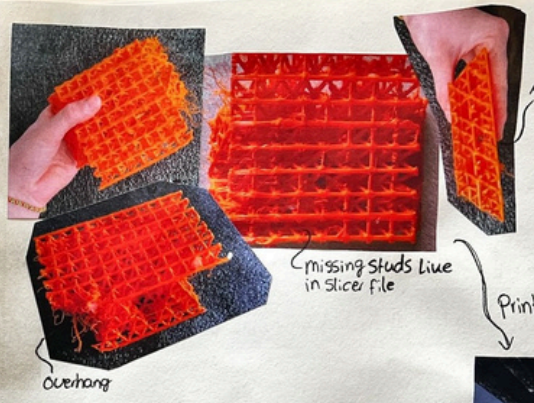
First Proto with correct structure & fillament



3D model structure

- made from existing Scrpinsu. model mesh frame
  - ↳ only to test Properties & Printability
- Creating structure by Repeating & Rotating Pyramid
- Playing with orientation
  - ↳ this is only one without Horizontal overhangs. @ max 45°

Slicer file
Random overhangs ↳ Blue parts
maybe this goes away with fire Printing



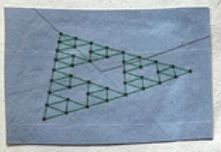
Print issues

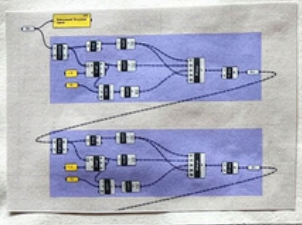
clogged nozzle?
↓
Replaced

what else could it be?

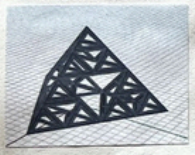
cleaning Hot-end 4 Has

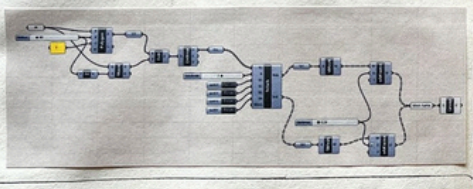
iteration 1
flat SierPinski model from Lines



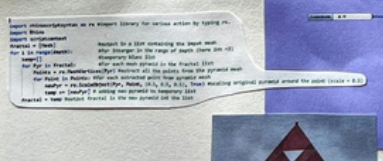


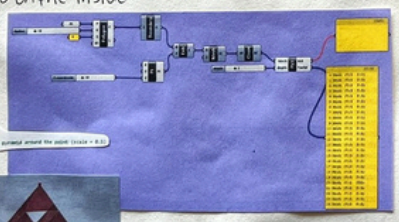
iteration 2
3D SierPinski model, with thickness, but only with structure on the surfaces.



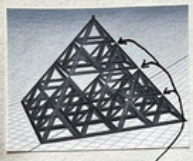


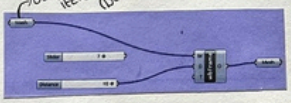
iteration 3
3D Pyramid with structure also on the inside
↳using python script





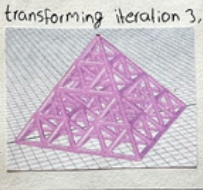
iteration 4
transforming iteration 3, to Lines with thickness

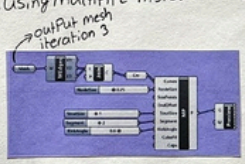




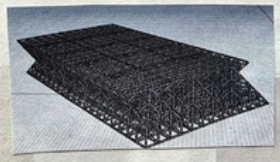
Iteration 5
weak Points → want 1 continuous thickness

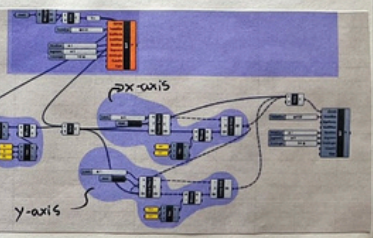
transforming iteration 3, using multiPipe instead of wbFrame (iteration 4).





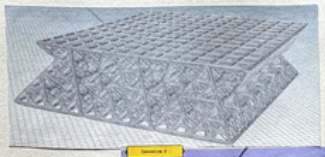
Iteration 6
Creating Pattern from iteration 5 Pyramid. using Anemone loop Function
↳ Moving + Rotating

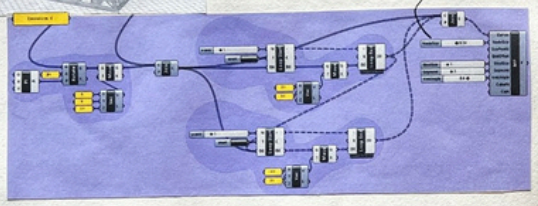




Rotating & moving the base Pyramid to have flat surface on both sides

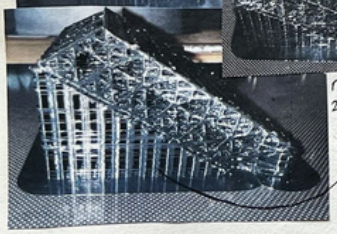
iteration 7:
changing thickness & repetition of iteration 6 for better Printability & Properties





Printing

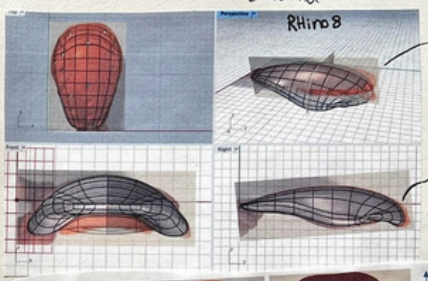
Printing on an angle so there are no horizontal overhangs
↳ improving Printability



nozzle: 0.4mm
222° Degrees

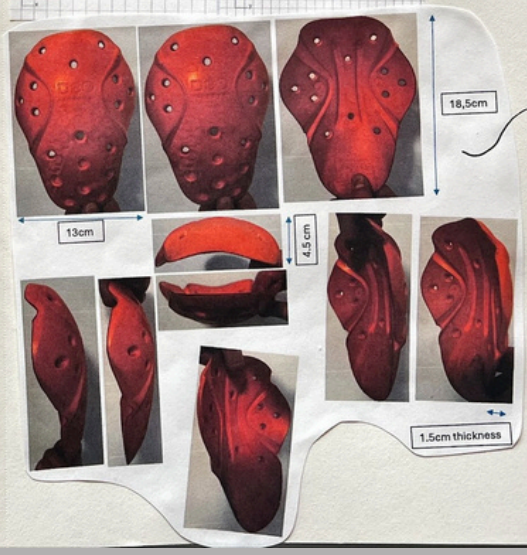
Supports below, but not inside Structure.

iteration 8:
not yet finished: ⇒ Create model for curvature of the Armor to later model SierPinski structure around



Schoulder model SubD in Progress

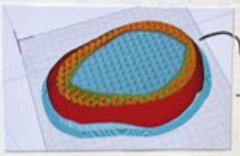
Based on 3 Perspective Pictures & a Protector.



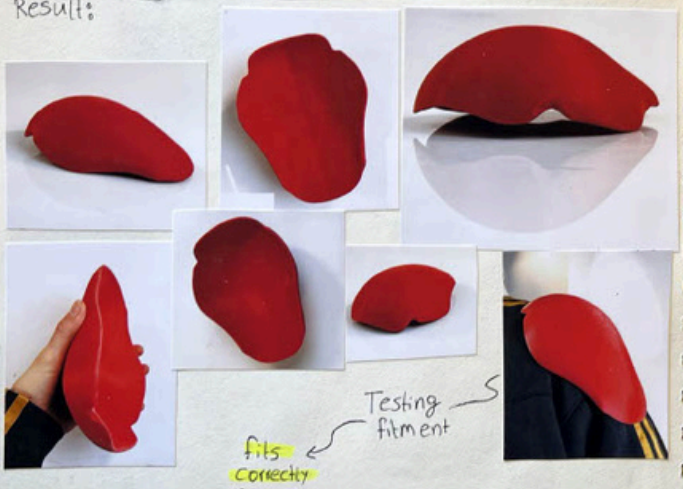
measurements

Printing Morphed Schoulder Armor

Supports



Result:



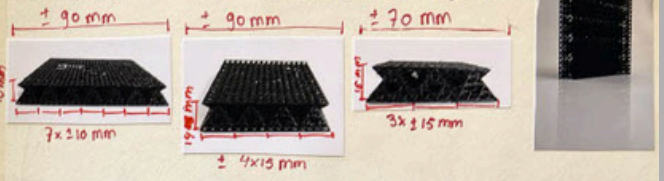
Testing fitment

fits correctly

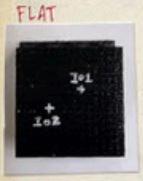
Next Step = in sierpinski structure

Iteration 9:

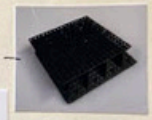
- Create sample variations of SierPinski structure in iteration 7
  - -Line thickness
  - -Pyramide Size
  - -top & Bottom Pattern → Hypothesis. Next Page ↷

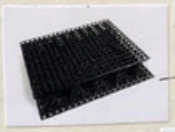


FLAT

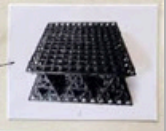


Line thickness?

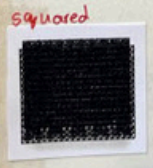


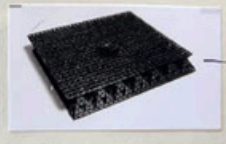


LINES



squared

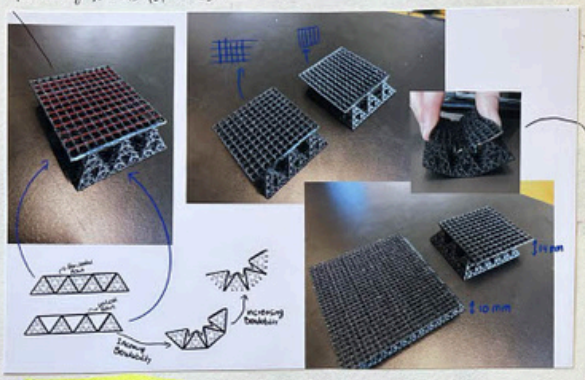




Why the difference?

Hypothesis for increasing Bendability along one axis while keeping impact absorbtion.

- Skipping every second Pyramid on X-axis
- Removing x-axis top Lines



- Should Be tested on both impact and flexibility
  - ↳ pg:
  - ↳ pg:

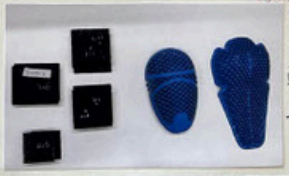
Gathering al Samples + Properties in a table:

↳ Living Document

Impact testing

Too soft for impact testing machine

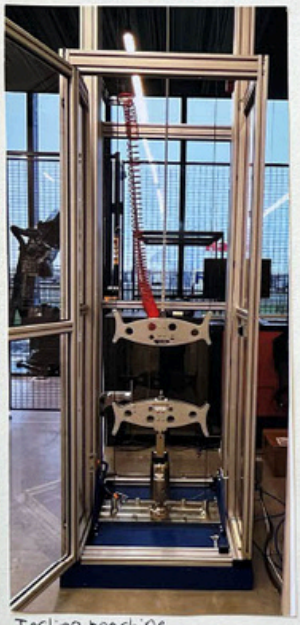
Same Structure as Sample 4, So no need for impact tests



4 samples & 2 existing Protectors from Revit

impact tests ↷

Dynamic impact testing at Revit:



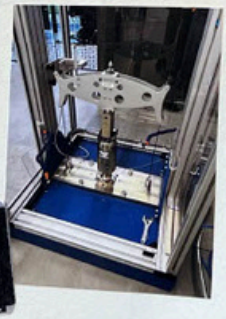
Testing machine

Rounded Bottom simulating a body part

Radius 50 mm

Flat anvil 2.98 kg

Sample to test



Impact locations + number

How the test works:

Drop Height = 106 cm

Initial impact

Bounces back up due to elastic Potential energy

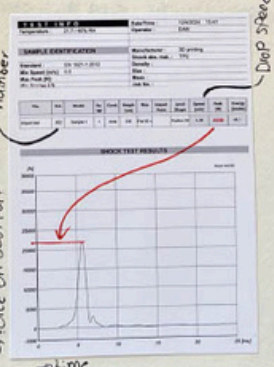
Second impact

Height of Anvil

106 cm

0 cm

RAW Data gathered (2 examples of the 12)



Impact number

Drop speed (m/s)

Force on body part

Time

Max force on body part

Which Sample

Second impact

Weighing Samples + Revit Armor

Revit Level 2

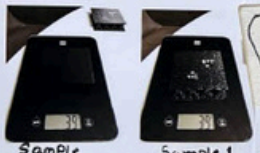
Revit Level 1

Sample 1

Sample 4

Sample 5

Sample 2



Sample

Sample 1

For comparing Structures

L>Pg:

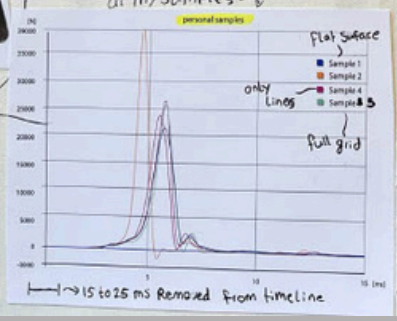
Sample 1, 4, and 6 almost the same.

Removing x-axis grid lines doesn't impact the impact

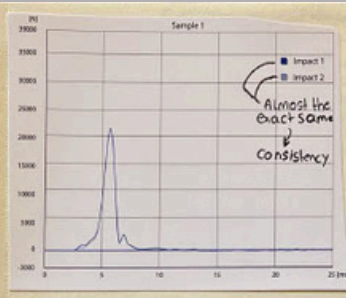
Data Analysis impact tests:

- overlapping graphs using illustrator

of my samples

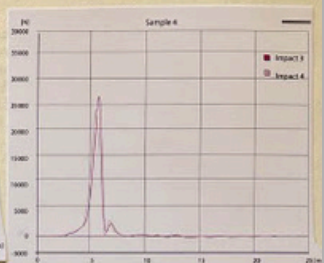


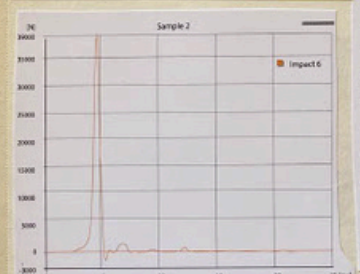
15 to 25 ms Removed from timeline

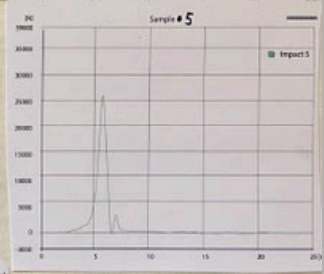


Almost the exact same

Consistency



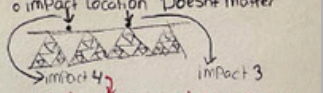




~Sample 4 = Revit Level 1

- using correct color Palette for color-blindness

- impact location Doesn't matter



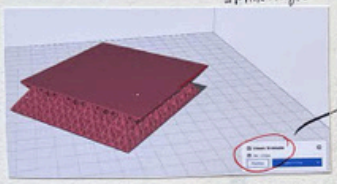
inbetween Pyramids results even better

is it the Structure or the material with these qualities?

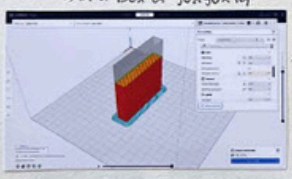
↓

Compare to another structure → Same:
- material → TPU 95A
- weight → 38g
- Surface area → 90x90 mm
- Line thickness → 0.55 mm
- Print Angle → 30°

→ 84x84 mm

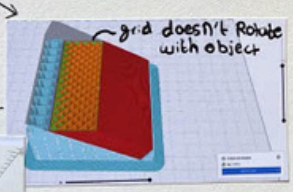


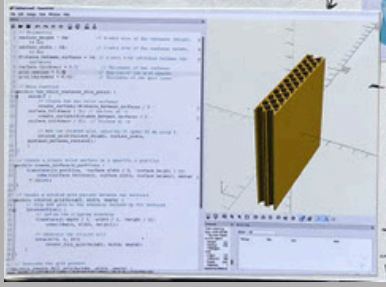
Version 1: → Structure to compare = squared grid
↳ create using cura infill generator → set correct line thickness
↳ in a box of 90x90x14



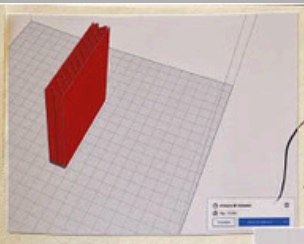
→ change infill density until it is 38g

30°



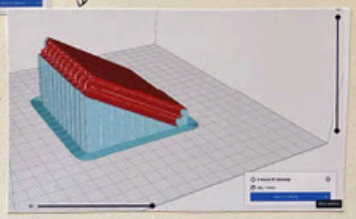


- coding my own structure in openScad.
  ↳ code makes it easy to change grid spacing / thickness and other parameters.
- C++ language
  - first tried a Bar and Removing 4 surfaces but that did not work

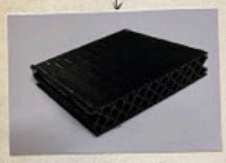


Make sure structure hits 38g (without supports)

30°



Print ←



confirming weight

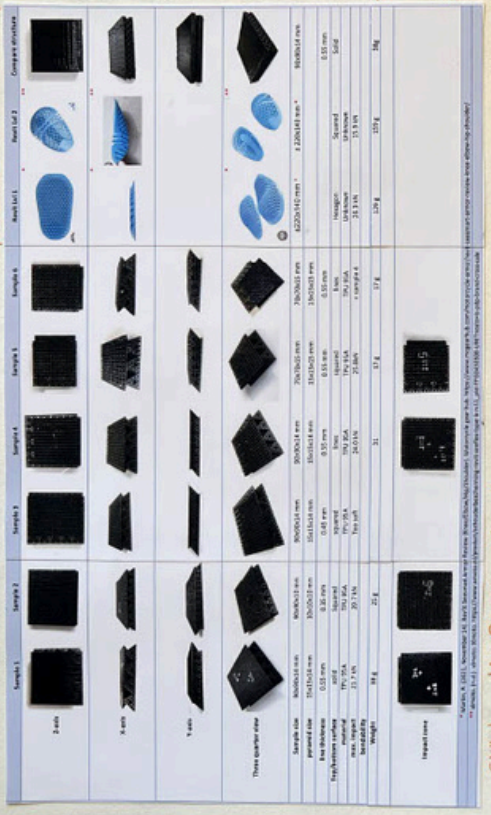
(35 -37g) (34 -36g)

eventhough they both fluctuate slightly the two structures are about the same weight.

→ Pressure deformation testing, using a UTM-machine (Universal Testing Machine)

added Samples

Weight Properties



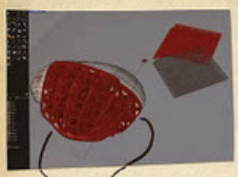
Updated Properties table:

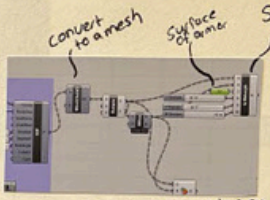
- Still to add → Pressure deformation → flexability → 3 Points Bend test

Morphing Structure to Shoulder armor

↳ from Sample 4

Iteration 10:

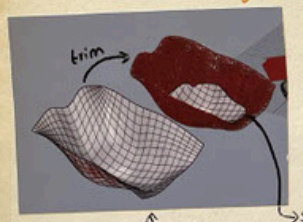


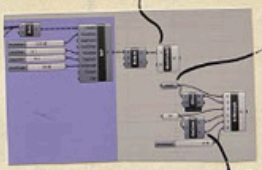


Surface used to create armor = mirrored → so a Poly surface
↳ morph function only takes a surface, so half

Sizing of grid = way too big (Scaled up)

new Surface using "Patch"



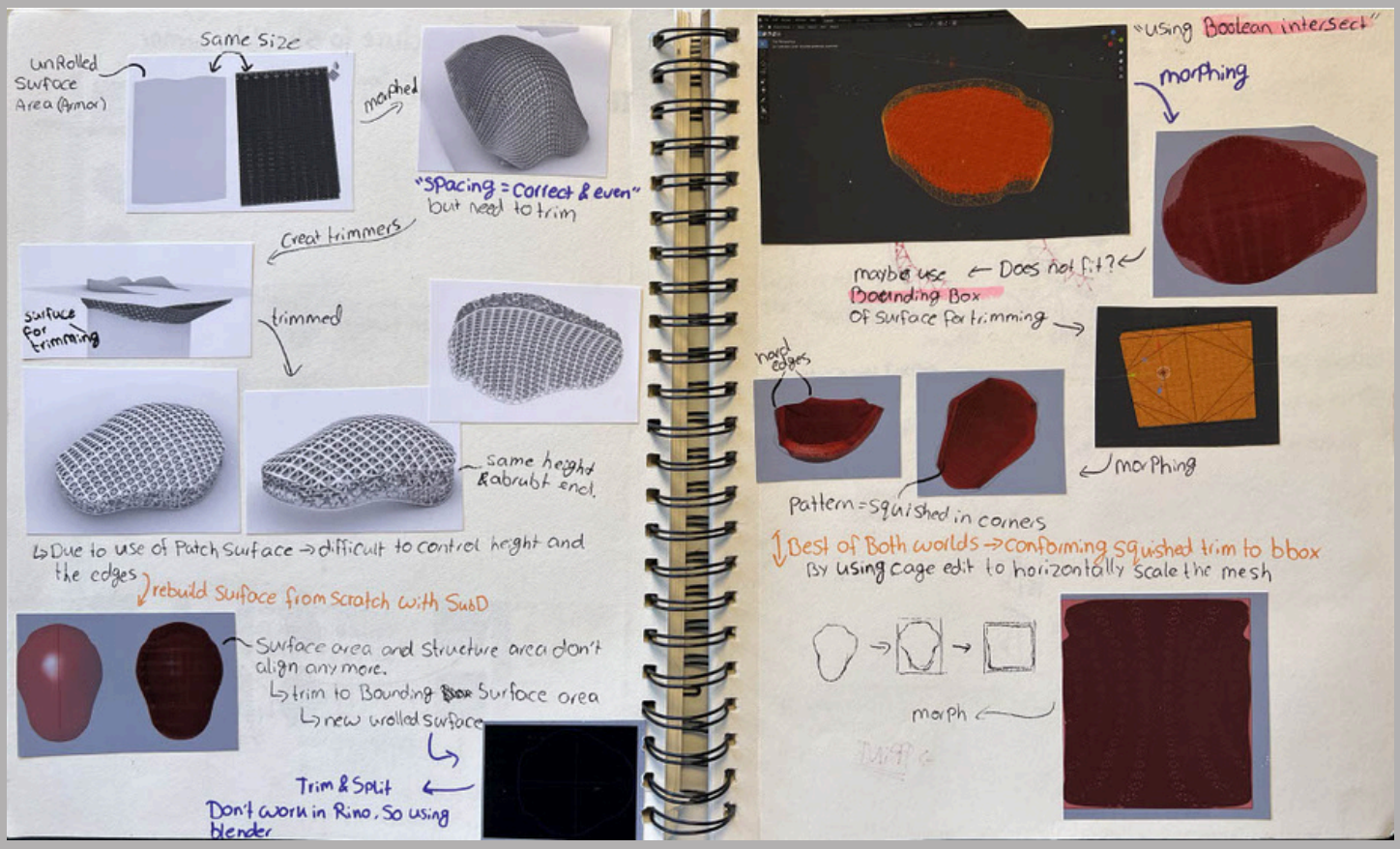


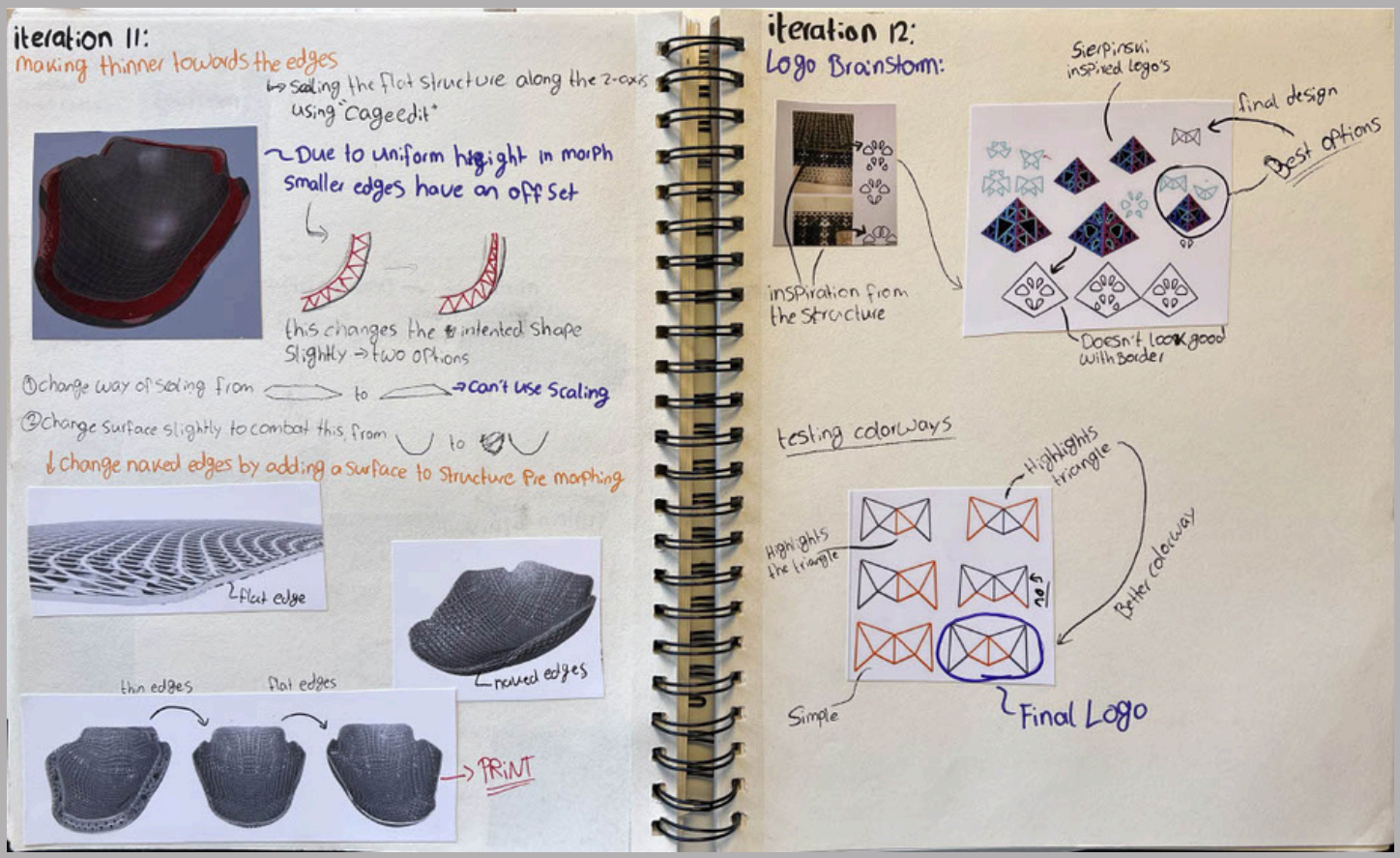
→ morph doesn't take trimmed Patch but Patch before trim

Deconstructed Surface domain as input, so it's Scaled correctly

↳ this causes stretching of the structure.

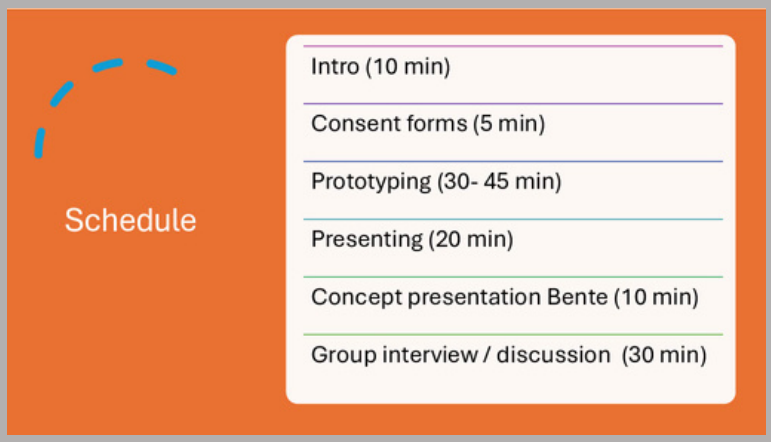
give structure same surface area as armor by unrolling the Patch's Surface →

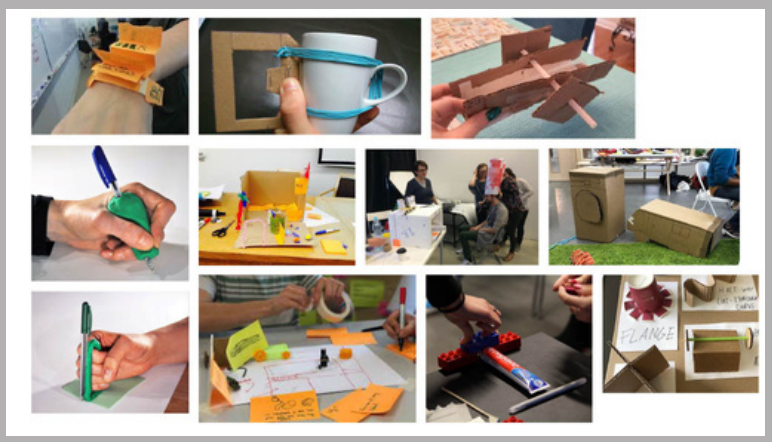

Same Size
UnRolled Surface Area (Armor)
morphed
"Spacing = correct & even" but need to trim
Creat trimmers
surface for trimming
trimmed
same height & abrubt end.
↳Due to use of Patch Surface → difficult to control height and the edges
rebuild Surface from scratch with SubD
Surface area and Structure area don't align anymore.
↳trim to Bounding Box Surface area
↳new unrolled surface
Trim & Split
Don't work in Rino, So using blender
"using Boolean intersect"
morphing
maybe use Bounding Box of Surface for trimming
← Does not fit?
naked edges
morphing
Pattern = squished in corners
↕Best of Both worlds → conforming squished trim to bbox
By using cage edit to horizontally scale the mesh
morph

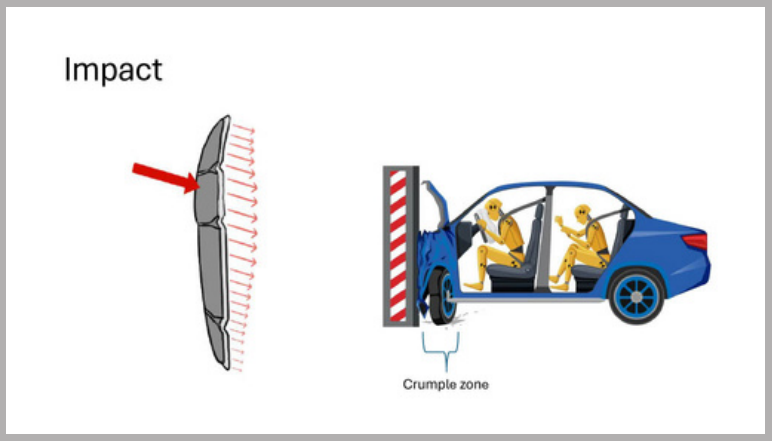

iteration 11:
making thinner towards the edges
↳ scaling the flat structure along the z-axis using "cageedit"
Due to uniform height in morph smaller edges have an off set
this changes the intented shape slightly → two options
①change way of scaling from to → can't use Scaling
②change surface slightly to combat this, from to
↓change naked edges by adding a surface to Structure Pre morphing
flat edge
rouned edges
thin edges
flat edges
PRINT
iteration 12:
Logo Brainstorm:
Sierpinski inspired logo's
final design
Best options
inspiration from the structure
Doesn't look good with Border
testing colorways
Highlights triangle
Highlights the triangle
Better colorway
Simple
Final Logo

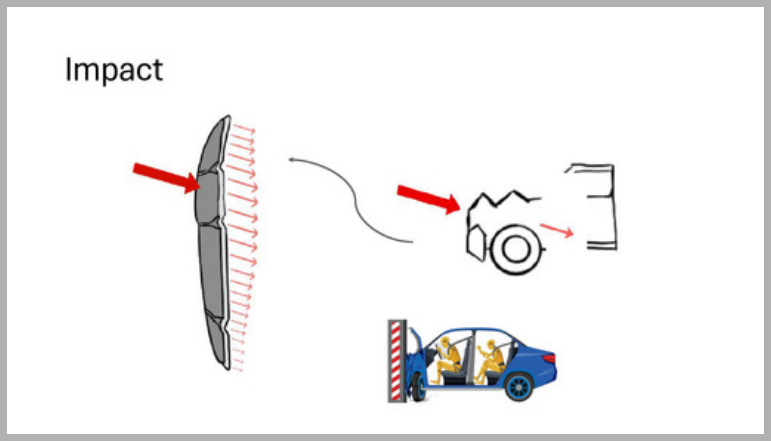
Appendix 2 Workshop

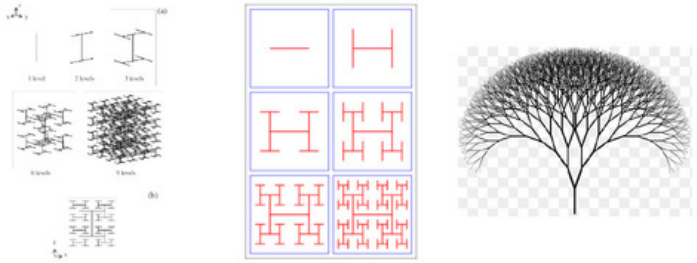
Appendix 2.1 Workshop presentation



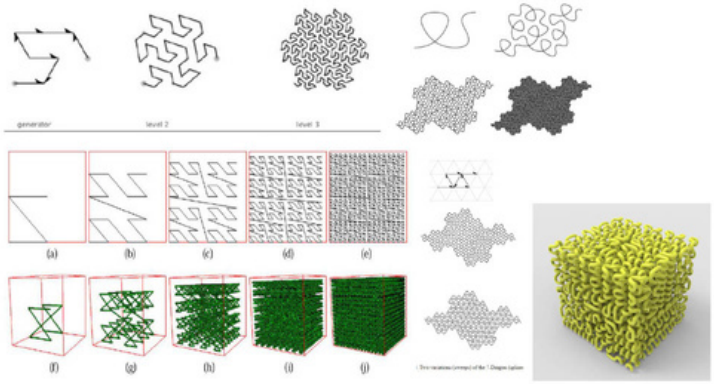


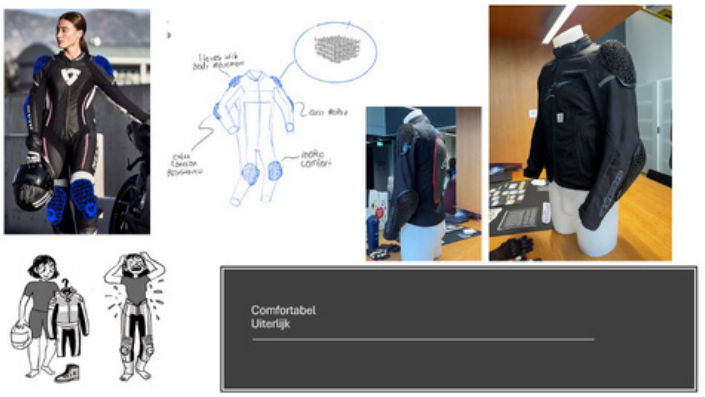




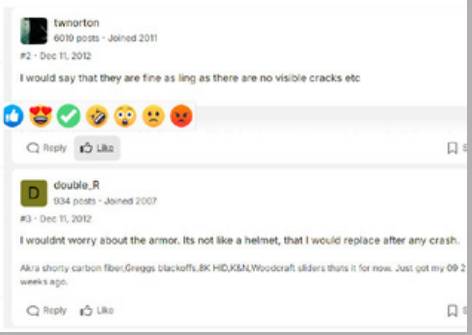


Fractals





One-Time-Use
Personalisatie



Wat zijn je grootste zorgen of irritaties over bestaande impact armor?

En welke Armor/Gear is dat?

Hebben jou rijsteil en/of de omstandigheden waarin je rijd hier iets mee te maken?

Zou jij je huidige armor hergebruiken na een crash?

En wist je dat dit vervangen moet worden ook zonder zichtbare schade?

Op welke volgorde zou jij de 5 aspecten van dit concept rangschikken?

Gebaseerd op belangrijkheid voor jou.

Uiterlijk

Comfort

Personalisatie

One-time-use

Protectie

Wat zou een acceptabele prijs zijn voor dit product?

Voor een set met Schouder, Ellenboog, Knie, en Heup Protectoren.

Zou jij dit concept kopen als het in een winkel zou liggen?

Waarom wel?

Zo niet, wat houdt je momenteel tegen?

Wat zou jij veranderen / toevoegen aan het huidige Concept ?

En waarom?

Appendix 2.2 Workshop consent form

Instructiepagina

Research consent form LR

Het doen van wetenschappelijk onderzoek is een publieke taak die de TU/e heeft op basis van de wet. Het verwerken van persoonsgegevens bij onderzoek valt daarom onder de wettelijke grondslag: publieke taak van de TU/e. In jouw project worden geen bijzondere categorieën van persoonsgegevens gebruikt (zie FAQ).

Dit toestemmingsformulier is voor onderzoek waarin reguliere persoonsgegevens worden gebruikt (zie FAQ). Als er bijzondere categorieën persoonsgegevens, waaronder bijvoorbeeld gezondheidsgegevens, binnen jouw onderzoek worden gebruikt, dan heb je een ander formulier nodig.

Gebruik van deze template
Volg dit template zo nauwkeurig mogelijk. Breng zo min mogelijk wijzigingen aan in de kernboodschap van het document. Maar pas de formulering, daar waar nodig aan voor jouw (potentiële) onderzoekspopulatie.

In de zijbalk staan invul-instructies. Verwijder deze opmerkingen uit het definitieve document. De geel gearceerde blokken geven aan bij welke onderdelen informatie moet worden toegevoegd, aangepast of geaccepteerd – afhankelijk van de relevantie binnen jouw onderzoeksproject.

Op basis van de informatie die aan (potentiële) deelnemers wordt verstrekt, worden zij in staat gesteld om een geïnformeerde beslissing te nemen over hun deelname aan jouw onderzoeksproject.

Informatie in delen
Het is belangrijk dat deelnemers alle relevante informatie ontvangen, maar dat hoeft niet allemaal in één keer. Denk bijvoorbeeld aan verschillende informatiemomenten, zoals:

- Flyers;
- Meer informatie op de website;
- Debriefings.

Integreren in websurvey etc.
Het is mogelijk dit formulier te integreren in een online websurvey. Zorg in dat geval dat dit formulier aan het begin van de survey wordt ingesloten op dezelfde pagina als de survey en gebruik geen weblink die leidt naar een aparte pagina. Zo voorkom je dat de deelnemers de informatie versnipperd moeten opzoeken.

Controle
Voltooi het formulier door gebruik te maken van track changes en deel deze vervolgens met de data steward van jouw faculteit ter review. Voor aanvullende ondersteuning en maatwerk kan eveneens contact opgenomen worden met de data steward.

Informatieblad voor onderzoek "3D-printed motorcycle impact Protectors"

1. Inleiding
De Technische Universiteit Eindhoven (TU/e) nodigt u uit om deel te nemen aan het onderzoek met als doel Het ontwerpen van een innovatieve impact protector voor motorrijders. De onderzoeksgegevens zullen gebruikt worden om het perspectief van de eindgebruiken in acht te nemen, gedurende het ontwerpproces. U ontvangt deze uitnodiging omdat U onderdeel uitmaakt van de einddoelgroep van dit product. U ontvangt voor deelname aan dit onderzoek geen Vergoeding.

Meedoen aan dit **onderzoeksproject is uw keuze. Uw deelname is volledig vrijwillig** en brengt geen lichamelijke, juridische of financiële risico's met zich mee. U bent niet verplicht vragen te beantwoorden die u niet wilt beantwoorden en u kunt zich te allen tijde uit het onderzoek terugtrekken, zonder dat u hiervoor een reden moet geven.
Niet deelnemen of stoppen met deelname na de start van het onderzoek, hebben geen nadelige gevolgen voor u.

De vragen die tijdens het onderzoek gesteld worden, stellen wij uitsluitend in het belang van het onderzoeksproject.

Voordat u besluit, kunt u de volgende informatie doorlezen. Zodat u weet waar het onderzoek over gaat, wat er van u verwacht wordt en hoe wij omgaan met uw persoonsgegevens. Na het doornemen van deze informatie, kunt u zich aanmelden op het bijgevoegde formulier.

Als u vragen heeft, dan kunt u deze aan ons stellen (contact gegevens staan hieronder). Ook kunt u de informatie uit dit informatieblad bespreken met mensen die u vertrouwt.

2. Wie zijn wij?
Dit onderzoeksproject wordt uitgevoerd door:

Bente Elst (Final Bachelor Student, Industrial Design) Technische Universiteit Eindhoven (TU/e) De Groene Loper 3 5612 AE Eindhoven	Verantwoordelijk voor uw persoonsgegevens binnen het onderzoek

In samenwerking met de volgende partij(en):

Rev'it Vorstengrafdonk 20 5342 LT Oss	[Heeft geen toegang tot persoonsgegevens]

Contactgegevens

Onderzoeker: Bente Elst	b.eslt@student.tue.nl
Privacy Operations	privacy@tue.nl
Functionaris Gegevensbescherming	dataprotectionofficer@tue.nl

3. Wat houdt deelname aan de studie in?
In het onderzoek gaan we uw persoonsgegevens op de volgende manier verzamelen:

- **2 keer op locatie** te komen voor 2 verschillende sessies
- De eerste keer op locatie is voor een **workshop** gezamenlijk met andere deelnemers (3 tot 8 deelnemers).
  - Tijdens deze workshop wordt u gevraagd om zelf een motor protector te maken van de materialen geleverd. Er kunnen foto's gemaakt worden tijdens deze workshop.

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  - Een korte presentatie over Uw creatie te geven (Max. 2 minuten). Uw presentatie kan opgenomen worden via een audio recording.
  - De onderzoekend student presenteert ook nog een impact protector design concept. U Krijgt een paar **vragen over Het gepresenteerde concept**, zoals Uw mening over het uiterlijk, of Hoe open U zelf staat om zo'n design te kopen. Er zal een audio-opnamen gemaakt worden, en uw antwoorden kunnen genoteerd worden.
- De tweede keer vind plaats later in het design Proces (Eind November).
  - U word gevraagd om één of meerdere Impact protector **Prototypes aan te passen**, Zowel staand als zittende op een geparkeerde motor. Er worden foto's gemaakt gedurende dit proces en opmerkingen of uitspraken kunnen genoteerd worden.
  - Na het passen krijgt u een **kort interview** over uw ervaring met de prototypes. Zoals Uw mentale en fysieke comfort level tijdens het dragen. Er zal een audio-opnamen gemaakt worden van dit interview, en ook kunnen er notities gemaakt worden van sommige uitspraken/antwoorden.

4. Welke persoonsgegevens verzamelen en verwerken wij van u?
Wij verzamelen de volgende persoonsgegevens die noodzakelijk zijn voor het doel van het onderzoek:

Categorie	Persoonsgegeven	Doeleinde	Bewaartermijn
Contactinformatie	*Email en Telefoonnummer*	*Met u communiceren over beschikbaarheid, data, en het beantwoorden van vragen, en zodat u uw privacyrechten kunt uitoefenen.*	*3 maanden na gegevensverzameling.*
Onderzoek-gerelateerde persoonsgegevens.	*Leeftijd, Sekse, Photos*	*Om te onderzoeken of dit beïnvloedende factoren kunnen zijn op comfort of esthetische ervaringen van het prototype. En om ervaringen visueel aan te duiden.*	*Tot Juli 2025 (+ - 9 Maanden)*
Alle categorieën hierboven genoemd	*Alle persoonsgegevens zoals hierboven genoemd*	*Opslag*	

Uw persoonsgegevens worden enkel bewaard voor de termijn zoals genoemd in de tabel hierboven. Het bewaren van uw gegevens helpt ons om aan onze wetenschappelijke verplichtingen te voldoen.

Na deze termijn worden uw persoonsgegevens verwijderd of geanonimiseerd, zodat deze niet meer aan u gelinkt kunnen worden. Tenzij u expliciet toestemming geeft voor het gebruiken van herkenbare gegevens over u (bijvoorbeeld als u wilt dat uw naam of uw quotes worden vermeld in publicaties).

5. Stopzetten deelname en uw rechten
Als u besluit uw deelname te stoppen, dan gebruiken wij uw persoonsgegevens vanaf dat moment niet meer in het onderzoek.

Indien u vragen of klachten heeft, of indien u uw deelname wilt stopzetten, dan kunt u contact opnemen met de Onderzoekend student, Bente Elst, via de contactgegevens zoals vermeld in sectie 2 hierboven.

Met zorgen of vragen over de omgang met persoonsgegevens kunt u een mail sturen naar de Functionaris Gegevensbescherming via de contactgegevens vermeld in sectie 2 hierboven. Ook kunt u een klacht indienen bij de Autoriteit Persoonsgegevens.

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U heeft het recht een verzoek tot inzage, wijziging, bezwaar, verwijdering of aanpassing van uw persoonsgegevens te doen. Dien uw verzoek in bij Bente Elst of team Privacy Operations via de contactgegevens zoals vermeld in de tabel in sectie 2.

6. Basis voor het verwerken van uw persoonsgegevens
Wij verwerken uw persoonsgegevens omdat het onderdeel is van onze publieke taak als Universiteit om wetenschappelijk onderzoek te doen, zoals is vermeld in artikel 1.3 van de Wet Hoger onderwijs en Wetenschappelijk onderzoek. Bij onderzoek houden wij ons aan de geldende gedragscode voor wetenschappelijke integriteit en de richtlijnen voor onderzoek.

7. Wie heeft toegang tot uw persoonsgegevens?
Alleen geautoriseerde medewerkers die betrokken zijn bij het onderzoek hebben toegang tot uw persoonsgegevens als dit nodig is voor hun taken. De geautoriseerde medewerkers behandelen uw persoonlijke gegevens vertrouwelijk.

Andere partijen/verwerkers die toegang hebben tot uw gegevens binnen het onderzoek staan hieronder vermeld:

Partij/verwerker	Waarom toegang?	Categorie gegevens	Verwerking binnen de Europese Economische Ruimte?
SURF Research Drive / Microsoft (Nederland)	Gegevensopslag		*Ja*
Rev'it Sport International B.V.	*Partner in design proces*	*Geanonimiseerd, en onder toezicht van onderzoekend student*	*Ja*

Met deze partijen heeft TU/e een passende overeenkomst om uw persoonsgegevens te beschermen.

TU/e, en samenwerkingspartner verwerken verwerkt uw persoonsgegevens binnen de Europese Economische Ruimte (EER) door uw gegevens op een server in de EER op te slaan.

Bovendien, heeft de TU/e en de samenwerkingspartners passende technische en organisatorische maatregelen getroffen om uw gegevens te beschermen. Deze maatregelen omvatten het gebruik van centraal beheerde en geverifieerde onderzoeks- en opslagtools.

8. Toekomstig onderzoek
Tijdens het onderzoeksproject kan blijken dat uw persoonsgegevens ook nuttig zijn voor nieuw, maatschappelijk relevant onderzoek. Wij hergebruiken uw gegevens in dat geval graag voor het nieuwe onderzoek. Dit gebeurt alleen als (1) de gegevens echt nodig zijn, (2) de erkende ethische normen voor wetenschappelijk onderzoek worden gevolgd en (3) als de nieuwe onderzoeksdoeleinden overeenkomen met de bestaande onderzoeksdoeleinden. Als uw gegevens worden gebruikt in toekomstig onderzoek, dan nemen wij alle redelijke stappen om u hierover te informeren. U kunt bezwaar maken tegen het gebruik van uw gegevens voor nieuw onderzoek.

Wij kunnen geanonimiseerde gegevens gebruiken voor nieuwe doeleinden, zoals onderzoek of onderwijs. Wij zullen er in dat geval voor zorgen dat de gegevens niet aan u gelinkt kunnen worden en we zullen niets vrijgeven waarin u herkenbaar bent.

Dit onderzoeksproject is beoordeeld en goedgekeurd door de ethische commissie van de Technische Universiteit Eindhoven.

Toestemmingsformulier LR – Versie 2.3 – Augustus 2024

TU/e EINDHOVEN UNIVERSITY OF TECHNOLOGY

*** Scroll naar beneden voor het toestemmingsformulier ***

Toestemmingsformulier onderzoek volwassene

Door dit formulier te ondertekenen verklaar ik:

1. Ik heb voldoende informatie over het onderzoeksproject uit het losse informatieblad gehaald. Ik heb het informatieblad gelezen en heb daarna de kans gehad om vragen te stellen. De vragen zijn naar tevredenheid beantwoord.
2. Ik neem vrijwillig deel aan dit onderzoeksproject. Er is geen expliciete of impliciete druk voor mij om deel te nemen aan dit onderzoeksproject. Ik begrijp dat ik op elk moment kan stoppen met deelname, zonder uit te moeten leggen waarom en ik hoef geen vragen te beantwoorden die ik niet wil beantwoorden.
3. Ik weet dat mijn persoonsgegevens worden verzameld en gebruikt voor het onderzoeksproject, zoals is uitgelegd in bijgevoegd informatieblad.

Daarnaast geef ik toestemming voor de volgende onderdelen van het onderzoek:

4. Ik geef de onderzoeker toestemming om mijn persoonsgegevens, waaronder bijvoorbeeld beeldopnames, audio-opnames, antwoorden of quotes die ik gaf tijdens het onderzoek, te gebruiken in publicaties en/of in presentaties – zonder daarbij mijn naam te vermelden.

JA ☐ NEE ☐

Naam Deelnemer:

Handtekening:

Datum:

Naam Onderzoeker: Bente Elst

Handtekening: ☒

Datum: October 7th 2024

TU/e EINDHOVEN UNIVERSITY OF TECHNOLOGY

Toestemmingsformulier onderzoek kind

Door dit formulier te ondertekenen verklaar ik:

1. Ik heb voldoende informatie over het onderzoeksproject uit het losse informatieblad gehaald. Ik heb het informatieblad gelezen en heb daarna de kans gehad om vragen te stellen. De vragen zijn naar tevredenheid beantwoord.
2. Mijn kind neemt vrijwillig deel aan dit onderzoeksproject. Er is geen expliciete of impliciete druk voor mij of mijn kind om deel te nemen aan dit onderzoeksproject. Ik begrijp dat mijn kind op elk moment kan stoppen met deelname, zonder uit te moeten leggen waarom. Mijn kind en ik hoeven ook geen vragen te beantwoorden die we niet willen beantwoorden.
3. Ik weet dat de persoonsgegevens van mijn kind worden verzameld en gebruikt voor het onderzoeksproject, zoals wordt uitgelegd in bijgevoegd informatieblad.

Daarnaast geef ik toestemming voor de volgende onderdelen van het onderzoek:

4. Ik geef de onderzoeker toestemming om de persoonsgegevens van mijn kind, waaronder bijvoorbeeld beeldopnames, audio-opnames, antwoorden of citaten die mijn kind gaf tijdens het onderzoek, te gebruiken in publicaties en/of in presentaties – zonder dat daarbij de naam van mijn kind wordt gepubliceerd.

JA ☐ NEE ☐

5. Ik geef toestemming om de echte naam van mijn kind te vermelden in de publicaties en/of presentaties bij de onder 5 bedoelde [beeldopnames, audio-opnames, antwoorden of citaten die mijn kind gaf tijdens het onderzoek].

JA ☐ NEE ☐

Naam kind dat aan het onderzoek deelneemt:	Ouder/voogd 1:	Ouder/voogd 2:	Naam onderzoeker:
	Handtekening:	Handtekening:	Handtekening:
Geboortedatum:	Datum:	Datum:	Datum:
[Handtekening:]			
[Datum:]			

Appendix 2.3 Workshop results

Presenting: 41.00 min - 55.51

1: full body Airbag suit (42.35)

- Aesthetics: none (full Racing suit) 2 Parts
- for on circuit
- wearing over motorcycle suit → attached to motorcycle steer with cord. → if fall of → you become a big balloon.
- to absorb impact shock
- Inspo: life rafts
- uses Air capsules

2: Dragon skin

function: Modular system (clicking?)
changing out only the damaged part after a fall + Personalising
Aesthetics: Dragon skin/scales
in Many colors & Patterns
inspo: own gear/shopping experience

3: hidden hoodie Protector (47.35)

function: flap on backside → Removable with zippers to place a Protector there
zip-up flap over Protector or without Protector to wear it as a normal hoodie after driving.
Aesthetics: two zippers on a hoodie or a visible Protector
inspo: Drives a lot with hoodies, but would like it to be safer

4: Removable speed-hump (49.10)

inspo: Recent switch to a race suit with speedhump
↳ experiencing Discomfort with walking etc.
↳ + looks weird (kwasimodo)
function: speedhump can detatch from the suit through a mechanism (the top can be slit into the back Protector inside the suit and the bottom can be detatch with something like a button.)
Aesthetics: speedhumps in various colors
· Attachment mechanism not visible
innovation: modular suit between Road & track

5: Ankle Protector (50.40)

function: Protects Ankles while still wearing normal shoes
a device you can easily Put on over your own shoes & Point with Plates on the inside and outside of your ankle.
innovation: Protecting the ankles, without compromising on ankle movability
inspo: = a stunt driver → often hurts his ankles when stunting, because he wears normal shoes to keep movability

6: Magnatic Sliders (51.55)

Aesthetics: normal knee & elbow Sliders, two different colors one from magnesium and one from titanium
function: the 2 different materials show are ~~able to~~ show you if your knee or elbow pushed harder.
· Both have a magnet that push away from eachother to move a race driver more concious about its posture. as a learning tool for beginning track drivers.
(helps feel if knee and elbow are close enough to eachother)
inspo: Many beginner track drivers sit to straight on the motorcycle moving it impossible to corner fast → = a coach for ew drivers
how do you make someone concious on what he she does on track?

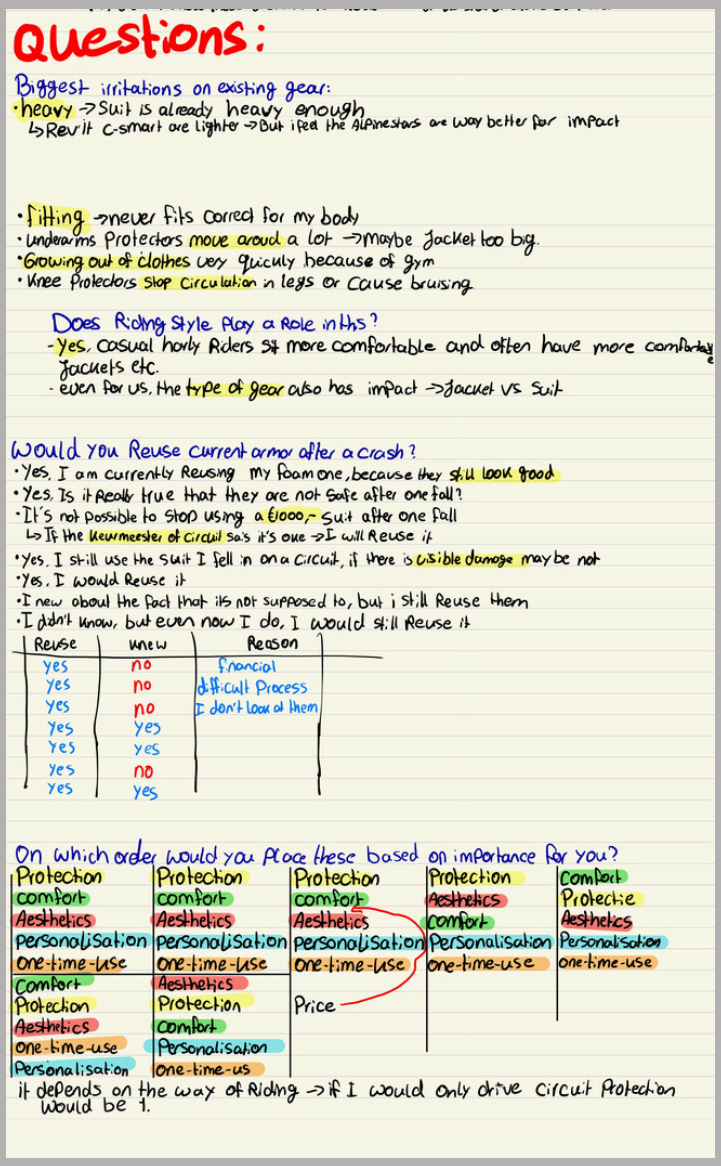
7: Detachable kneeslider jeans (54.50)

inspo: Likes to drive more ~~sporty~~ in jeans → wears buckle-on knee sliders over jeans to do so, but they tend to fall down while riding.
function: kneesliders that are detatchable from jeans with zippers to allow sporty driving in jeans
Aesthetics: Zippers allow to neatly secure sliders and tuck away when not attached

Concern → Doesn't it have to be very large to create a crumple zone?

my concept: (57:45 - 1:06:10)

I got the Question: But you already have these armor vest right?
↳ they did not know these weren't for Road use or as stand-alone clothes



Questions:

Biggest irritations on existing gear:
- heavy → Suit is already heavy enough
  ↳ Revit C-Smart are lighter → But i feel the Alpinestars are way better for impact
- fitting → never fits correct for my body
- underarms Protectors move around a lot → maybe jacket too big.
- Growing out of clothes very quicly because of gym
- knee Protectors stop circulation in legs or cause bruising

Does Riding Style Play a Role in this?
- yes, casual hordy Riders sit more comfortable and often have more comfortable jackets etc.
- even for us, the type of gear also has impact → jacket vs Suit

Would you Reuse current armor after a crash?
- Yes, I am currently Reusing my foam one, because they still look good
- Yes, Is it Really true that they are not safe after one fall?
- It's not possible to stop using a €1000,- Suit after one fall
  ↳ If the Keurmeester of Circuit sais it's save → I will Reuse it
- Yes, I still use the Suit I fell in on a Circuit, if there is visible damage may be not
- Yes, I would Reuse it
- I new about the fact that its not supposed to, but i still Reuse them
- I didn't know, but even now I do, I would still Reuse it

Reuse	knew	Reason
yes	no	financial
yes	no	difficult Process
yes	no	I don't look at them
yes	yes	
yes	yes	
yes	no	
yes	yes	

On which order would you Place these based on importance for you?

Protection	Protection	Protection	Protection	Comfort
comfort	comfort	comfort	Aesthetics	Protectie
Aesthetics	Aesthetics	Aesthetics	comfort	Aesthetics
personalisation	personalisation	personalisation	Personalisation	Personalisation
one-time-use	one-time-use	one-time-use	one-time-use	one-time-use
Comfort	Aesthetics			
Protection	Protection	Price		
Aesthetics	comfort			
one-time-use	Personalisation			
Personalisation	one-time-us			

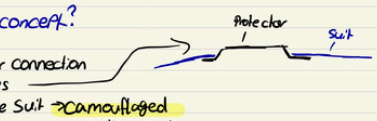
it depends on the way of Riding → if I would only drive Circuit Protection would be 1.

Would you buy this concept if it was in stores (it's Proven to work & sold by Rev'it)
- Depends on the Aesthetics → subtle, like the gear now → than 100% → I like the other aspects a lot
- I would buy it if it looks like a bionic vest type
- I wouldn't, → shoulders are too broad
- If it is more safe than other types, yes
- no, I just don't like the Aesthetics
- I would buy it, if the changing of Protectors is very easy and done at home
- I would wait for couple of months to see how it does → with Safety
  ↳ and to see if it starts making sound due to wind

What is an acceptable Price for this Product: Set of 4 Pairs?
- 150 euro. → +1111
- Buying seperate is a must. → 30,- / 20,-
- I would pay more if its actually better.

Would there be interest for personalised Armor?
no, with the flexibility & Placement that is kind of obsolete.
but, various sizes are a must → like 5 sizes

What would you change/add to this concept?
- full body, without Arms (Suit)
- Velcro doesn't feel safe to me, so other connection maybe slit into something on the sides
- that Protectors look the same as the Suit → Camouflaged
- Do something with the boots, they are more annoying than suits
- seperate compartments? → Doing something with light
- Personalising structures besides colors? no
- I like the flat surface on top, not structures.



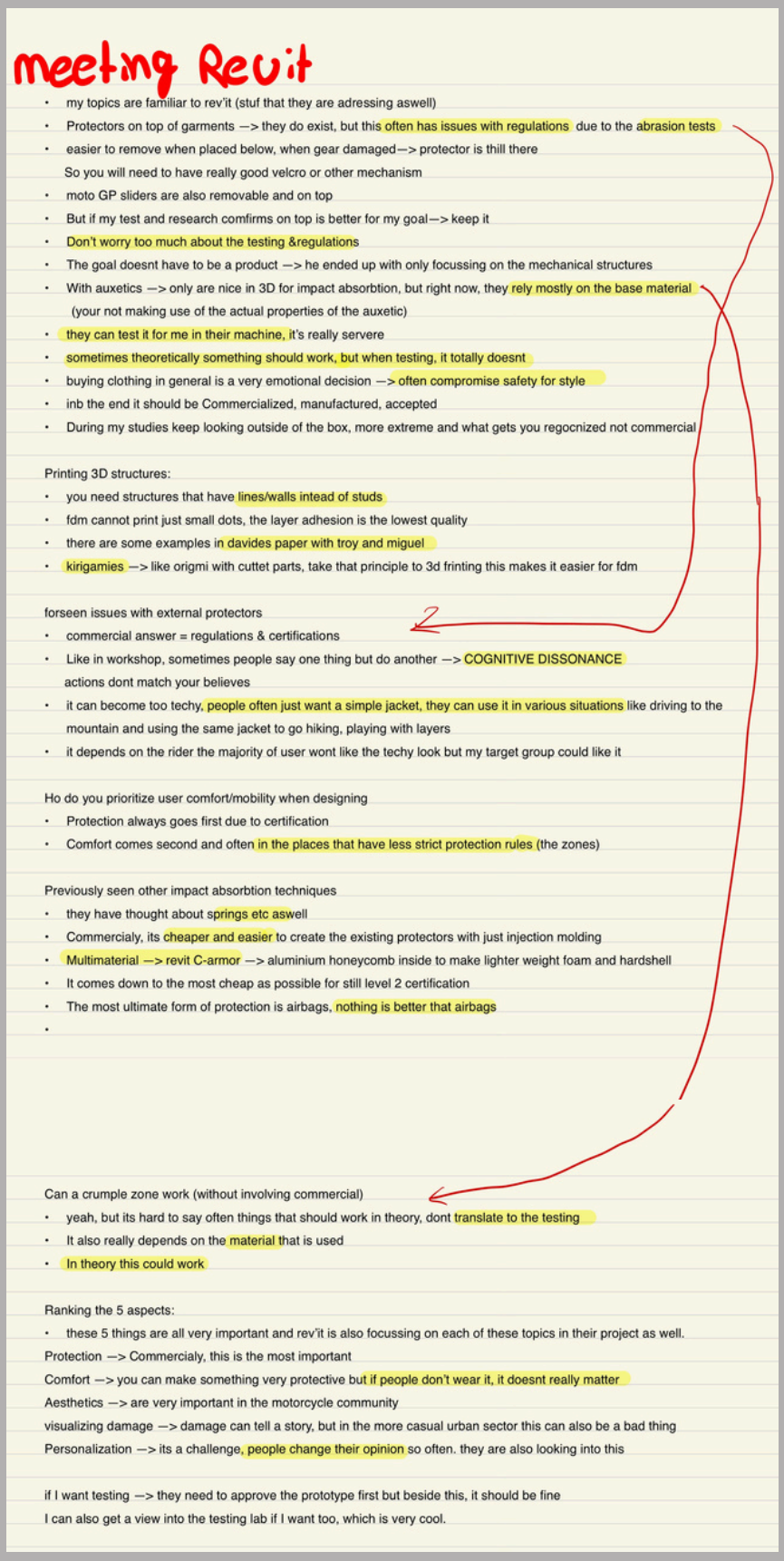
More Realistic would be a hybrid → crumple + dispersing.

Appendix 2.4 workshop audio recoding

https://tuenl-my.sharepoint.com/:u:/g/personal/b_elst_student_tue_nl/EWMdo8p3S_hGhsddvXOweY8BwhPUI4KTZIbe2JRxJqMW3w?e=AyBdex

Appendix 3 Expert interview

Appendix 3.1 Expert interview presentation



meeting Revit

- my topics are familiar to rev'it (stuf that they are adressing aswell)
- Protectors on top of garments —> they do exist, but this often has issues with regulations due to the abrasion tests
- easier to remove when placed below, when gear damaged—> protector is thill there
  So you will need to have really good velcro or other mechanism
- moto GP sliders are also removable and on top
- But if my test and research comfirms on top is better for my goal—> keep it
- Don't worry too much about the testing &regulations
- The goal doesnt have to be a product —> he ended up with only focussing on the mechanical structures
- With auxetics —> only are nice in 3D for impact absorbtion, but right now, they rely mostly on the base material
  (your not making use of the actual properties of the auxetic)
- they can test it for me in their machine, it's really servere
- sometimes theoretically something should work, but when testing, it totally doesnt
- buying clothing in general is a very emotional decision —> often compromise safety for style
- inb the end it should be Commercialized, manufactured, accepted
- During my studies keep looking outside of the box, more extreme and what gets you regocnized not commercial

Printing 3D structures:

- you need structures that have lines/walls intead of studs
- fdm cannot print just small dots, the layer adhesion is the lowest quality
- there are some examples in davides paper with troy and miguel
- kirigamies —> like origmi with cuttet parts, take that principle to 3d frinting this makes it easier for fdm

forseen issues with external protectors

- commercial answer = regulations & certifications
- Like in workshop, sometimes people say one thing but do another —> COGNITIVE DISSONANCE
  actions dont match your believes
- it can become too techy, people often just want a simple jacket, they can use it in various situations like driving to the mountain and using the same jacket to go hiking, playing with layers
- it depends on the rider the majority of user wont like the techy look but my target group could like it

Ho do you prioritize user comfort/mobility when designing

- Protection always goes first due to certification
- Comfort comes second and often in the places that have less strict protection rules (the zones)

Previously seen other impact absorbtion techniques

- they have thought about springs etc aswell
- Commercialy, its cheaper and easier to create the existing protectors with just injection molding
- Multimaterial —> revit C-armor —> aluminium honeycomb inside to make lighter weight foam and hardshell
- It comes down to the most cheap as possible for still level 2 certification
- The most ultimate form of protection is airbags, nothing is better that airbags
-

Can a crumple zone work (without involving commercial)

- yeah, but its hard to say often things that should work in theory, dont translate to the testing
- It also really depends on the material that is used
- In theory this could work

Ranking the 5 aspects:

- these 5 things are all very important and rev'it is also focussing on each of these topics in their project as well.

Protection —> Commercialy, this is the most important
Comfort —> you can make something very protective but if people don't wear it, it doesnt really matter
Aesthetics —> are very important in the motorcycle community
visualizing damage —> damage can tell a story, but in the more casual urban sector this can also be a bad thing
Personalization —> its a challenge, people change their opinion so often. they are also looking into this

if I want testing —> they need to approve the prototype first but beside this, it should be fine
I can also get a view into the testing lab if I want too, which is very cool.

Appendix 3.2 Expert interview audio recording

https://tuenl-my.sharepoint.com/:u:/g/personal/b_elst_student_tue_nl/EeERoovhZ3lKvxCjl4wteXUBCBMDmpbT2MJ9QrISWRhFPA?e=zUMoSz

Appendix 4 Three-point bend test

Appendix 4.1 Bend test video Sampl 6

https://youtu.be/wfahj7MYK5g

Appendix 4.2 Bend test video Comparison structure

https://youtu.be/iFwJIWemRWg

Appendix 4.3 Bend test results excel

Click here to view full Excel file

Sample 6 extentions

X bottom 1	X bottom 2	X top 1	X top 2	Y1	Y2
0,3707	1,0139	1,0477	0,68236	0,7311	0,24619
0,4952	1,0957	1,1461	0,75914	0,7954	0,29636
0,59947	1,1771	1,2456	0,83568	0,85977	0,34638
0,71423	1,2588	1,3441	0,91221	0,92453	0,39619
0,82886	1,3407	1,4432	0,98879	0,98888	0,44718
0,94334	1,4224	1,542	1,0651	1,0536	0,49762
1,0581	1,5041	1,6412	1,142	1,1178	0,5479
1,1729	1,5858	1,7402	1,2183	1,1825	0,59954
1,2873	1,6675	1,8392	1,2948	1,2469	0,64908
1,4019	1,7492	1,9382	1,3714	1,3113	0,69926
1,5165	1,8308	2,0372	1,448	1,3758	0,7503
1,6311	1,9125	2,1361	1,5245	1,4402	0,80104
1,7457	1,9941	2,2351	1,6011	1,5047	0,85132
1,8604	2,0758	2,334	1,6777	1,5691	0,90198
1,975	2,1574	2,4329	1,7542	1,6336	0,95282
2,0897	2,2391	2,5318	1,8308	1,6981	1,0031
2,2043	2,3208	2,6307	1,9074	1,7626	1,0536
2,3189	2,4024	2,7296	1,9839	1,8271	1,1043
2,4336	2,4841	2,8285	2,0605	1,8916	1,1547
2,5482	2,5657	2,9274	2,137	1,9561	1,2052
2,6629	2,6474	3,0263	2,2136	2,0205	1,2559
2,7775	2,7290	3,1252	2,2902	2,085	1,3067
2,8921	2,8107	3,2241	2,3667	2,1495	1,3573
3,0068	2,8924	3,323	2,4433	2,214	1,4079
3,1214	2,9740	3,4219	2,5199	2,2785	1,4585
3,236	3,0557	3,5208	2,5964	2,3429	1,5091
3,3507	3,1373	3,6197	2,673	2,4074	1,5597
3,4653	3,2190	3,7186	2,7496	2,4719	1,6102
3,58	3,3007	3,8175	2,8261	2,5364	1,6608
3,6946	3,3823	3,9164	2,9027	2,6009	1,7114
3,8092	3,4640	4,0153	2,9792	2,6653	1,762
3,9239	3,5456	4,1142	3,0558	2,7298	1,8126
4,0385	3,6273	4,2131	3,1324	2,7943	1,8632
4,1531	3,7089	4,312	3,2089	2,8588	1,9138
4,2678	3,7906	4,4109	3,2855	2,9233	1,9644
4,3824	3,8723	4,5098	3,3621	2,9877	2,015
4,4971	3,9539	4,6087	3,4386	3,0522	2,0655
4,6117	4,0356	4,7076	3,5152	3,1167	2,1161
4,7263	4,1172	4,8065	3,5917	3,1812	2,1667
4,841	4,1989	4,9054	3,6683	3,2457	2,2173
4,9556	4,2805	5,0043	3,7449	3,3102	2,2679
5,0702	4,3622	5,1032	3,8214	3,3746	2,3185
5,1849	4,4439	5,2021	3,898	3,4391	2,3691
5,2995	4,5255	5,301	3,9746	3,5036	2,4196
5,4142	4,6072	5,3999	4,0511	3,5681	2,4702
5,5288	4,6888	5,4988	4,1277	3,6326	2,5208
5,6434	4,7705	5,5977	4,2042	3,697	2,5714
5,7581	4,8521	5,6966	4,2808	3,7615	2,6219
5,8727	4,9338	5,7956	4,3574	3,826	2,6723
5,9874	5,0155	5,8945	4,4339	3,8905	2,7227
6,102	5,0971	5,9934	4,5105	3,955	2,7732
6,2166	5,1788	6,0923	4,5871	4,0194	2,8238
6,3313	5,2604	6,1912	4,6636	4,0839	2,8744
6,4459	5,3421	6,2901	4,7402	4,1484	2,925
6,5605	5,4238	6,389	4,8168	4,2129	2,9756
6,6752	5,5054	6,4879	4,8933	4,2774	3,0262
6,7898	5,5871	6,5868	4,9699	4,3418	3,0767
6,9045	5,6687	6,6857	5,0464	4,4063	3,1273
7,0191	5,7504	6,7846	5,123	4,4708	3,1779
7,1337	5,8320	6,8835	5,1996	4,5353	3,2285
7,2484	5,9137	6,9824	5,2761	4,5998	3,2791
7,363	5,9954	7,0813	5,3527	4,6643	3,3297
7,4776	6,0770	7,1802	5,4293	4,7287	3,3803
7,5923	6,1587	7,2791	5,5058	4,7932	3,4308
7,7069	6,2403	7,378	5,5824	4,8577	3,4814
7,8216	6,3220	7,4769	5,6589	4,9222	3,532
7,9362	6,4036	7,5758	5,7355	4,9867	3,5826
8,0508	6,4853	7,6747	5,8121	5,0511	3,6332
8,1655	6,5670	7,7736	5,8886	5,1156	3,6838
8,2801	6,6486	7,8725	5,9652	5,1801	3,7343
8,3947	6,7303	7,9714	6,0418	5,2446	3,7849
8,5094	6,8119	8,0703	6,1183	5,3091	3,8355
8,624	6,8936	8,1692	6,1949	5,3735	3,8861
8,7387	6,9752	8,2681	6,2715	5,438	3,9367
8,8533	7,0569	8,367	6,348	5,5025	3,9873
8,9679	7,1386	8,4659	6,4246	5,567	4,0378
9,0826	7,2202	8,5648	6,5011	5,6296	4,0884
9,1972	7,3019	8,6637	6,5777	5,6287	4,139
9,3119	7,3835	8,7626	6,6543		4,1896
9,4265		8,8615	6,7308		4,2293
9,5411		8,9604	6,8074		4,2258
9,6558		9,0593			
9,7704					
9,885					
9,9997					
10,114					
10,229					
10,344					
10,458					
10,573					
10,623					
Max	Max	Max	Max	Max	Max
10,623	7,3835	9,0593	6,8074	5,6296	4,2293

Sample 5 extentions

x1	x2	y1	y2
0,88	0,789	0,3437	0,6509
0,9458	0,8448	0,4032	0,6984
1,012	0,9005	0,4626	0,7459
1,0783	0,9568	0,5226	0,7939
1,1441	1,0123	0,5824	0,8414
1,2104	1,0683	0,6419	0,8889
1,2762	1,1247	0,7018	0,9368
1,3423	1,1805	0,7616	0,9846
1,4084	1,2364	0,8216	1,0323
1,4741	1,2923	0,8816	1,0797
1,5403	1,3482	0,9412	1,1277
1,6065	1,4042	1,0011	1,1754
1,6726	1,46	1,0611	1,2229
1,7386	1,5159	1,1206	1,2704
1,8047	1,5717	1,1806	1,3181
1,8707	1,6277	1,2403	1,3657
1,9368	1,6837	1,3	1,4133
2,0029	1,7397	1,3601	1,461
2,0689	1,7957	1,4201	1,5087
2,135	1,8517	1,48	1,5564
2,201	1,9077	1,5399	1,6041
2,2671	1,9637	1,5997	1,6518
2,3331	2,0197	1,6596	1,6995
2,3992	2,0757	1,7194	1,7472
2,4653	2,1317	1,7793	1,7949
2,5313	2,1877	1,8391	1,8426
2,5974	2,2438	1,8989	1,8903
2,6634	2,2998	1,9588	1,938
2,7295	2,3558	2,0186	1,9857
2,7956	2,4118	2,0785	2,0334
2,8616	2,4679	2,1383	2,0811
2,9277	2,5239	2,1982	2,1288
2,9937	2,5799	2,258	2,1765
3,0598	2,6358	2,3178	2,2242
3,1258	2,6917	2,3777	2,2719
3,1919	2,7477	2,4375	2,3196
3,258	2,8036	2,4974	2,3673
3,324	2,8596	2,5572	2,415
3,3901	2,9155	2,6171	2,4627
3,4561	2,9715	2,6769	2,5104
3,5222	3,0274	2,7367	2,5581
3,5882	3,0834	2,7966	2,6058
3,6543	3,1393	2,8564	2,6535
3,7204	3,1953	2,9163	2,7013
3,7864	3,2512	2,9761	2,749
3,8525	3,3072	3,036	2,7967
3,9185	3,3631	3,0958	2,8444
3,9846	3,4191	3,1556	2,8921
4,0506	3,475	3,2155	2,9398
4,1167	3,5309	3,2753	2,9875
4,1828	3,5869	3,3352	3,0352
4,2488	3,6428	3,395	3,0829
4,3149	3,6988	3,4549	3,1305
4,3809	3,7547	3,5147	3,1782
4,447	3,8107	3,5745	3,2259
4,5131	3,8666	3,6344	3,2735
4,5791	3,9226	3,6942	3,3212
4,6452	3,9785	3,7541	3,3688
4,7112	4,0345	3,8139	3,4165
4,7773	4,0904	3,8738	3,4642
4,8433	4,1464	3,9336	3,5118
4,9094	4,2023	3,9934	3,5595
4,9755	4,2582	4,0533	3,6072
5,0415	4,3142	4,1131	3,6548
5,1076	4,3701	4,173	3,7025
5,1736	4,4261	4,2328	3,7501
5,2397	4,482	4,2926	3,7978
5,3057	4,538	4,3525	3,8455
5,3718	4,5939	4,4123	3,8931
5,4379	4,6499	4,4722	3,9408
5,5039	4,7058	4,532	
5,57	4,7618	4,5919	
5,636		4,6517	
5,7021		4,7115	
		4,7714	
		4,8312	
		4,8911	
Max	Max	Max	Max
5,7021	4,7618	5,1304	3,9408

Sample 1 extensions

x1	x2	y1	y2
0,81	0,9094	0,8827	0,7641
0,8519	0,9528	0,9295	0,8058
0,8943	0,9967	0,9756	0,8476
0,9369	1,0407	1,0221	0,8895
0,9789	1,0847	1,069	0,9307
1,0205	1,1279	1,1155	0,9725
1,0632	1,172	1,1613	1,0142
1,1058	1,216	1,2062	1,0559
1,148	1,2596	1,2551	1,097
1,1902	1,3031	1,3013	1,1389
1,2324	1,3471	1,3475	1,1807
1,2746	1,3912	1,394	1,2225
1,3168	1,435	1,4406	1,2637
1,3591	1,4785	1,4872	1,305
1,4013	1,5224	1,5339	1,3467
1,4435	1,5663	1,5805	1,3885
1,4857	1,6101	1,6271	1,4302
1,5279	1,6539	1,6736	1,4718
1,5701	1,6977	1,7201	1,5135
1,6124	1,7415	1,7666	1,5552
1,6547	1,7854	1,8132	1,5968
1,697	1,8292	1,8597	1,6384
1,7393	1,873	1,9062	1,68
1,7817	1,9169	1,9528	1,7216
1,824	1,9607	1,9993	1,7632
1,8663	2,0045	2,0458	1,8048
1,9086	2,0484	2,0923	1,8464
1,9508	2,0922	2,1389	1,8881
1,9931	2,1361	2,1854	1,9297
2,0354	2,1799	2,2319	1,9713
2,0776	2,2237	2,2784	2,0129
2,1199	2,2676	2,325	2,0545
2,1622	2,3114	2,3715	2,0961
2,2044	2,3552	2,418	2,1377
2,2467	2,399	2,4645	2,1793
2,289	2,4428	2,5111	2,2209
2,3312	2,4866	2,5576	2,2625
2,3735	2,5304	2,6041	2,3041
2,4158	2,5743	2,6507	2,3457
2,4581	2,6181	2,6972	2,3873
2,5003	2,6619	2,7437	2,4289
2,5426	2,7057	2,7902	2,4706
2,5849	2,7495	2,8368	2,5122
2,6271	2,7933	2,8833	2,5538
2,6694	2,8372	2,9298	2,5954
2,7117	2,881	2,9764	2,637
2,7539	2,9248	3,0229	2,6786
2,7962	2,9686	3,0695	2,7202
2,8385	3,0124	3,116	2,7618
2,8807	3,0562	3,1626	2,8034
2,923	3,1	3,2091	2,845
2,9653	3,1439	3,2557	2,8866
3,0076	3,1877	3,3022	2,9282
3,0498	3,2315	3,3488	2,9698
3,0921	3,2753	3,3953	3,0114
3,1344	3,3191	3,4419	3,0531
3,1766	3,3629	3,4885	3,0947
3,2189	3,4068	3,535	3,1363
3,2612	3,4506	3,5816	3,1779
3,3034	3,4944	3,6281	3,2195
3,3457	3,5382	3,6747	3,2611
3,388		3,7212	3,3027
3,4303		3,7678	3,3443
3,4725		3,8144	3,3859
3,4964		3,8609	3,4275
3,4934		3,9075	3,4691
3,5388		3,954	3,5107
3,5859		3,9984	3,5523
3,6133			
3,6651			
3,7325			
3,7509			
3,7899			
3,8545			
3,8943			
3,9467			
Max	Max	Max	Max
3,9467	3,5382	3,9984	3,5523

Sample 2 extensions

x1	x2	y1	y2
0	0	0	0
0,1454	0,1372	0,1499	0,148
0,2908	0,2745	0,2998	0,2959
0,4362	0,4118	0,4496	0,4439
0,5817	0,549	0,5994	0,5918
0,7271	0,6863	0,7493	0,7398
0,8725	0,8236	0,8992	0,8878
1,0179	0,9609	1,049	1,0357
1,1634	1,0982	1,1989	1,1837
1,3088	1,2355	1,3488	1,3317
1,4542	1,3727	1,4987	1,4796
1,5996	1,51	1,6485	1,6276
1,7451	1,6473	1,7984	1,7756
1,8905	1,7846	1,9483	1,9235
2,0359	1,9219	2,0982	2,0715
2,1813	2,0592	2,248	2,2194
2,3268	2,1964	2,3979	2,3674
2,4722	2,3337	2,5478	2,5154
2,6176	2,471	2,6977	2,6633
2,763	2,6083	2,8475	2,8113
2,9085	2,7456	2,9974	2,9593
3,0539	2,8829	3,1473	3,1072
3,1993	3,0201	3,2972	3,2552
3,3448	3,1574	3,4471	3,4031
3,4902	3,2947	3,5969	3,5511
3,6356	3,432	3,7468	3,6991
3,781	3,5693	3,8967	3,847
3,9265	3,7066	4,0466	3,995
4,0719	3,8438	4,1964	4,143
4,2173	3,9811	4,3463	4,291
4,3627	4,1184	4,4962	4,4391
4,5082	4,2557	4,6461	4,5871
4,6536	4,393	4,7959	4,7351
4,799	4,5303	4,9458	4,883
4,9445	4,6675	5,0957	5,0306
5,0899	4,8048	5,2453	5,1786
5,2352	4,9421	5,3953	5,3266
5,3812	5,0794	5,5453	5,4746
5,5262	5,2166	5,6953	5,6226
5,6712	5,3546	5,8453	5,7706
5,8172	5,4926	5,9953	5,9186
5,9622	5,6296	6,1453	6,0666
6,1082	5,7666	6,2943	6,2146
6,2532	5,9036	6,4443	6,3626
6,3992	6,0416	6,5943	6,5106
6,5442	6,1786	6,7443	6,6586
6,6892	6,3156	6,8943	6,8066
6,8352	6,4536	7,0443	6,9546
6,9802	6,5906	7,1943	7,1026
7,1262	6,7276	7,3433	7,2506
7,2712	6,8646	7,4933	7,3986
7,4172	7,0026	7,6433	7,5466
7,5622	7,1396	7,7933	7,6946
7,7072	7,2766	7,9433	7,8426
7,8532	7,4146	8,0933	7,9906
7,9982	7,5516	8,2433	8,1386
8,1442	7,6886	8,3933	8,2866
8,2892	7,8256	8,5423	8,4346
8,4352	7,9636	8,6923	8,5826
8,5802		8,8423	8,7306
8,7252		8,9923	
		9,1423	
		9,2893	
Max	Max	Max	Max
8,7252	7,9636	9,2893	8,7306

Sample 4 extensions

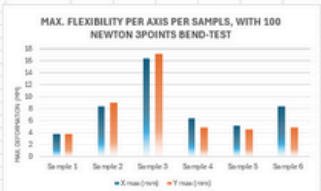
bottom	bottom	y1	y2
1,0737	0,45285	0,67	0,89
1,1381	0,53086	0,7295	0,9424
1,202	0,60877	0,7885	0,9951
1,266	0,68655	0,8479	1,0477
1,3303	0,76473	0,9074	1,1
1,3946	0,84294	0,9662	1,1528
1,4588	0,92107	1,0258	1,2054
1,523	0,99909	1,0855	1,2579
1,5873	1,0768	1,1443	1,3104
1,6515	1,1552	1,2041	1,3629
1,7157	1,2326	1,2634	1,4155
1,7798	1,3111	1,3223	1,4681
1,8439	1,3893	1,382	1,5207
1,908	1,4674	1,441	1,5733
1,9722	1,5454	1,5003	1,6259
2,0363	1,6234	1,5599	1,6784
2,1005	1,7014	1,6193	1,731
2,1646	1,7794	1,6787	1,7835
2,2288	1,8574	1,738	1,8361
2,2929	1,9354	1,7973	1,8886
2,3571	2,0135	1,8567	1,9411
2,4212	2,0916	1,916	1,9937
2,4854	2,1696	1,9754	2,0462
2,5495	2,2477	2,0347	2,0988
2,6136	2,3257	2,094	2,1513
2,6778	2,4038	2,1534	2,2038
2,7419	2,4818	2,2127	2,2564
2,8061	2,5599	2,272	2,3089
2,8702	2,638	2,3314	2,3615
2,9344	2,716	2,3907	2,414
2,9985	2,7941	2,4501	2,4666
3,0627	2,8721	2,5094	2,5191
3,1268	2,9502	2,5687	2,5716
3,191	3,0283	2,6281	2,6242
3,2551	3,1063	2,6874	2,6767
3,3193	3,1844	2,7468	2,7293
3,3834	3,2624	2,8061	2,7818
3,4476	3,3405	2,8654	2,8343
3,5117	3,4186	2,9248	2,8869
3,5759	3,4966	2,9841	2,9394
3,64	3,5747	3,0435	2,992
3,7042	3,6527	3,1028	3,0445
3,7683	3,7308	3,1621	3,0971
3,8324	3,8088	3,2215	3,1496
3,8966	3,8869	3,2808	3,2021
3,9607	3,965	3,3401	3,2547
4,0249	4,043	3,3995	3,3072
4,089	4,1211	3,4588	3,3598
4,1532	4,1991	3,5182	3,4123
4,2173	4,2772	3,5775	3,4648
4,2815	4,3553	3,6368	3,5174
4,3456	4,4333	3,6962	3,5699
4,4098	4,5114	3,7555	3,6225
4,4739	4,5894	3,8149	3,675
4,5381	4,6675	3,8742	3,7276
4,6022	4,7455	3,9335	3,7801
4,6664	4,8236	3,9929	3,8326
4,7305	4,9017	4,0522	3,8852
4,7947	4,9797	4,1116	3,9377
4,8588	5,0578	4,1709	3,9903
4,9229	5,1358	4,2302	4,0428
4,9871	5,2139	4,2896	4,0953
5,0512	5,292	4,3489	4,1479
5,1154	5,37	4,4083	4,2004
5,1795	5,4481	4,4676	4,253
5,2437	5,5261	4,527	4,3055
5,3078	5,6042	4,5863	4,358
5,372	5,6822	4,6456	4,4106
5,4361	5,7603	4,705	4,4631
5,5003	5,8384	4,7643	4,5157
5,5644	5,9164	4,8237	4,5548
5,627	5,9945	4,883	
	6,0725	4,9424	
	6,1506	5,0017	
	6,2287	5,061	
	6,3067	5,1204	
	6,3848	5,1715	
Max	Max	Max	Max
5,627	7,0255	5,1715	4,5548

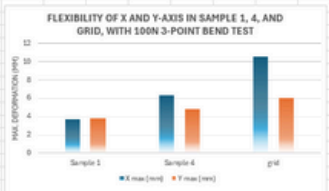
Sample 3 extensions

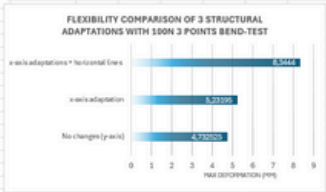
x1	x2	y1	y2
0,9701	0,8304	0,7177	0,762
1,1471	1,001	0,9066	0,934
1,3237	1,1723	1,0953	1,106
1,5008	1,3432	1,2837	1,2777
1,6778	1,514	1,4724	1,4499
1,8549	1,6849	1,6611	1,622
2,032	1,8559	1,8498	1,7941
2,2091	2,0269	2,0385	1,9662
2,386	2,1979	2,2272	2,1384
2,5629	2,369	2,4159	2,3105
2,7399	2,54	2,6046	2,4826
2,9168	2,711	2,7933	2,6547
3,0937	2,882	2,982	2,8268
3,2707	3,053	3,1709	2,9988
3,4476	3,224	3,3597	3,1708
3,6245	3,395	3,5483	3,3428
3,8014	3,566	3,7367	3,5148
3,9784	3,737	3,9253	3,6868
4,1553	3,909	4,1139	3,8588
4,3322	4,079	4,3026	4,0308
4,5092	4,2501	4,4913	4,2029
4,6861	4,4211	4,6799	4,3749
4,863	4,5921	4,8686	4,5469
5,04	4,7631	5,0572	4,7189
5,2169	4,9341	5,2459	4,8909
5,3938	5,1051	5,4346	5,0629
5,5708	5,2761	5,6232	5,2349
5,7477	5,4471	5,8119	5,407
5,9246	5,6181	6,0006	5,579
6,1016	5,7891	6,1892	5,751
6,2785	5,9601	6,3779	5,923
6,4554	6,1311	6,5666	6,095
6,6323	6,3021	6,7552	6,267
6,8093	6,4731	6,9439	6,439
6,9862	6,6441	7,1326	6,611
7,1631	6,8151	7,3212	6,7831
7,3401	6,9861	7,5099	6,9551
7,517	7,1571	7,6985	7,1271
7,6939	7,3281	7,8872	7,2991
7,8709	7,4991	8,0759	7,4711
8,0478	7,6701	8,2645	7,6431
8,2247	7,8412	8,4532	7,8151
8,4017	8,0122	8,6419	7,9871
8,5786	8,1832	8,8305	8,1592
8,7555	8,3542	9,0192	8,3312
8,9325	8,5252	9,2079	8,5032
9,1094	8,6962	9,3965	8,6752
9,2863	8,8672	9,5852	8,8472
9,4633	9,0382	9,7739	9,0192
9,6402	9,2092	9,9625	9,1912
9,8171	9,3802	10,151	9,3632
9,994	9,5512	10,34	9,5353
10,171	9,7222	10,529	9,7073
10,348	9,8932	10,717	9,8793
10,525	10,064	10,906	10,051
10,702	10,235	11,095	10,223
10,879	10,406	11,283	10,395
11,056	10,577	11,472	10,567
11,233	10,748	11,66	10,739
11,409	10,919	11,849	10,911
11,586	11,09	12,038	11,083
11,763	11,261	12,226	11,255
11,94	11,432	12,415	11,427
12,117	11,603	12,604	11,599
12,294	11,774	12,792	11,771
12,471	11,945	12,981	11,943
12,648	12,116	13,17	12,115
12,825	12,287	13,358	12,287
13,002	12,458	13,547	12,459
13,179	12,629	13,736	12,631
13,356	12,8	13,924	12,803
13,533	12,971	14,113	12,975
13,71	13,142	14,302	13,147
13,887	13,313	14,49	13,319
14,063	13,484	14,679	13,491
14,24	13,655	14,868	13,663
14,417	13,826	15,056	13,835
14,594	13,997	15,245	14,007
14,771	14,168	15,434	14,179
14,948	14,339	15,622	14,351
15,125	14,51	15,811	14,523
15,302	14,681	16	14,695
15,479	14,852	16,188	14,867
15,656	15,023	16,377	15,039
15,833	15,194	16,566	15,211
16,01	15,365	16,754	15,383
16,187	15,536	16,943	15,555
16,363	15,707	17,132	15,727
16,54	15,878	17,32	15,899
16,717	16,049	17,509	16,071
		17,698	16,243
		17,886	
Max	Max	Max	Max
16,717	16,049	17,886	16,243

Sample	X max [mm]	Y max [mm]
Sample 1	3,74245	3,77535
Sample 2	8,3444	9,00995
Sample 3	16,383	17,0645
Sample 4	6,32625	4,86315
Sample 5	5,23195	4,5356
Sample 6	8,4683	4,92945
grid	10,5475	6,0186

	extension in mm
No changes (y-axis)	4,732525
x-axis adaptation	5,23195
x-axis adaptations +	8,3444







Comparison sample			
X1	X2	Y1	Y2
0,21685	0,30903	0,0031704	0,060729
0,33295	0,41768	0,029763	0,13326
0,45018	0,52683	0,071147	0,2113
0,56748	0,63649	0,11762	0,29275
0,6852	0,74599	0,16724	0,3742
0,80291	0,85516	0,21847	0,45743
0,92044	0,96486	0,2707	0,53975
1,038	1,0745	0,32336	0,62261
1,1559	1,1836	0,37627	0,70491
1,2732	1,2934	0,42976	0,78832
1,3911	1,4026	0,48274	0,87078
1,5088	1,5123	0,53621	0,95383
1,6265	1,6219	0,58977	1,0363
1,7442	1,7315	0,64277	1,1193
1,8619	1,8411	0,69634	1,2018
1,9796	1,9507	0,74991	1,2846
2,0973	2,0602	0,80296	1,3673
2,215	2,1697	0,85652	1,4501
2,3327	2,2792	0,90991	1,5329
2,4504	2,3887	0,96307	1,6156
2,5681	2,4982	1,0166	1,6984
2,6858	2,6077	1,0702	1,7812
2,8035	2,7172	1,1233	1,8639
2,9212	2,8267	1,1769	1,9467
3,0389	2,9362	1,2305	2,0295
3,1566	3,0457	1,2835	2,1123
3,2742	3,1552	1,3369	2,195
3,3919	3,2648	1,3904	2,2778
3,5096	3,3743	1,4436	2,3606
3,6273	3,4838	1,497	2,4434
3,745	3,5933	1,5505	2,5261
3,8626	3,7028	1,6039	2,6089
3,9803	3,8123	1,6574	2,6917
4,098	3,9218	1,7108	2,7745
4,2157	4,0313	1,7642	2,8573
4,3334	4,1408	1,8176	2,94
4,451	4,2503	1,871	3,0228
4,5687	4,3598	1,9244	3,1056
4,6864	4,4693	1,9778	3,1884
4,8041	4,5789	2,0312	3,2711
4,9218	4,6884	2,0846	3,3539
5,0394	4,7979	2,138	3,4367
5,1571	4,9074	2,1914	3,5195
5,2748	5,0169	2,2448	3,6023
5,3925	5,1264	2,2982	3,685
5,5102	5,2359	2,3516	3,7678
5,6278	5,3454	2,405	3,8506
5,7455	5,4549	2,4584	3,9334
5,8632	5,5644	2,5118	4,0161
5,9809	5,6739	2,5652	4,0989
6,0986	5,7834	2,6186	4,1817
6,2163	5,893	2,672	4,2645
6,3339	6,0025	2,7254	4,3473
6,4516	6,112	2,7788	4,43
6,5693	6,2215	2,8322	4,5128
6,687	6,331	2,8856	4,5956
6,8047	6,4405	2,939	4,6784
6,9223	6,55	2,9924	4,7611
7,04	6,6595	3,0458	4,8439
7,1577	6,769	3,0992	4,9267
7,2754	6,8785	3,1526	5,0095
7,3931	6,988	3,206	5,0923
7,5107	7,0976	3,2594	5,175
7,6284	7,2071	3,3128	5,2578
7,7461	7,3166	3,3662	5,3406
7,8638	7,4261	3,4196	5,4234
7,9815	7,5356	3,473	5,5061
8,0991	7,6451	3,5264	5,5889
8,2168	7,7546	3,5798	5,6717
8,3345	7,8641	3,6332	5,7545
8,4522	7,9736	3,6866	5,8372
8,5699	8,0831	3,74	5,92
8,6875	8,1926	3,7934	6,0028
8,8052	8,3021	3,8468	6,0856
8,9229	8,4117	3,9002	6,1684
9,0406	8,5212	3,9536	6,2511
9,1583	8,6307	4,007	6,3339
9,2759	8,7402	4,0603	6,4167
9,3936	8,8497	4,1137	6,4995
9,5113	8,9592	4,1671	6,5822
9,629	9,0687	4,2205	6,665
9,7467	9,1782	4,2739	6,7478
9,8644	9,2877	4,3273	6,8305
9,982	9,3972	4,3807	6,9132
10,1	9,5067	4,4341	6,9959
10,217	9,6162	4,4875	7,0786
10,335	9,7258	4,5409	7,1614
10,453	9,8353		7,2441
10,57	9,9448		7,3268
10,688	10,054		7,4096
10,806			7,4923
10,923			
11,041			
max	max	max	max
11,041	10,054	4,5409	7,4923
à			
10,5475		6,0166	

Appendix 5 Dynamic impact test

Appendix 5.1 impact test video

https://youtu.be/es2bZ3tRkeg

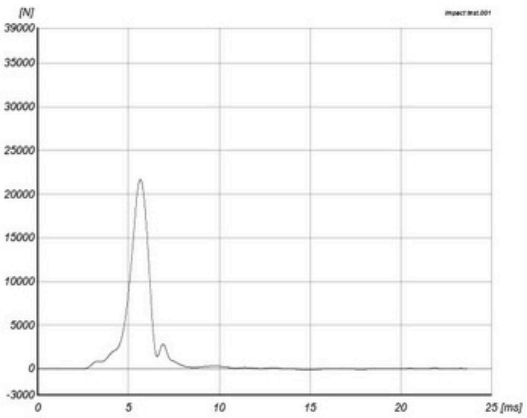
Appendix 5.2 impact test Raw data

Appendix 5.2 impact test Raw data

TEST INFO		Date/Time :	12/4/2024 15:44
Temperature :	21.7 / 40% RH	Operator :	DAM
SAMPLE IDENTIFICATION		Manufacturer :	3D printing
		Shock abs. mat. :	TPU
Standard :	EN 1621-1:2012	Density :	
Min Speed [m/s]:	0.0	Size :	
Max Peak [N]:		Mass :	
Min Energy [J]:		Job No. :	

File	Ext.	Model	Sa. N#	Cond.	Height [cm]	Size	Impact Point	Anvil Shape	Speed [m/s]	Peak [N]	Energy [joules]
Impact test	001	Sample 1	1	Amb	106	Flat 80 x		Radius 50	4.39	21675	48.1

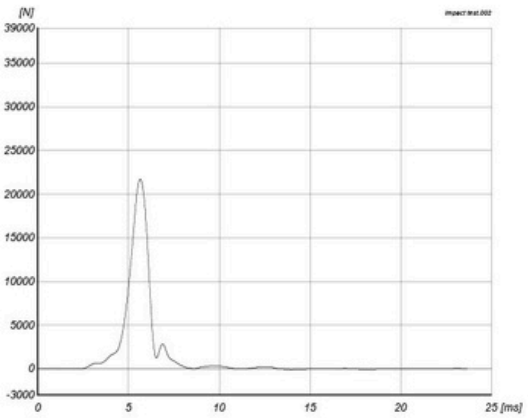
SHOCK TEST RESULTS



TEST INFO		Date/Time :	12/4/2024 15:47
Temperature :	21.7 / 40% RH	Operator :	DAM
SAMPLE IDENTIFICATION		Manufacturer :	3D printing
		Shock abs. mat. :	TPU
Standard :	EN 1621-1:2012	Density :	
Min Speed [m/s]:	0.0	Size :	
Max Peak [N]:		Mass :	
Min Energy [J]:		Job No. :	

File	Ext.	Model	Sa. N#	Cond.	Height [cm]	Size	Impact Point	Anvil Shape	Speed [m/s]	Peak [N]	Energy [joules]
Impact test	002	Sample 1	1	Amb	106	Flat 80 x		Radius 50	4.39	21700	48.1

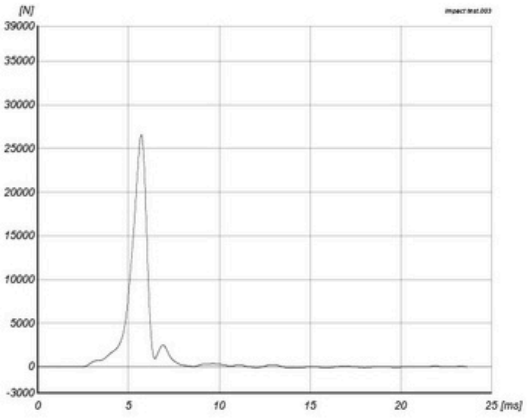
SHOCK TEST RESULTS



TEST INFO		Date/Time :	12/4/2024 15:53
Temperature :	21.7 / 40% RH	Operator :	DAM
SAMPLE IDENTIFICATION		Manufacturer :	3D printing
		Shock abs. mat. :	TPU
Standard :	EN 1621-1:2012	Density :	
Min Speed [m/s]:	0.0	Size :	
Max Peak [N]:		Mass :	
Min Energy [J]:		Job No. :	

File	Ext.	Model	Sa. N#	Cond.	Height [cm]	Size	Impact Point	Anvil Shape	Speed [m/s]	Peak [N]	Energy [joules]
Impact test	003	Sample 4	4	Amb	106	Flat 80 x		Radius 50	4.42	26559	48.8

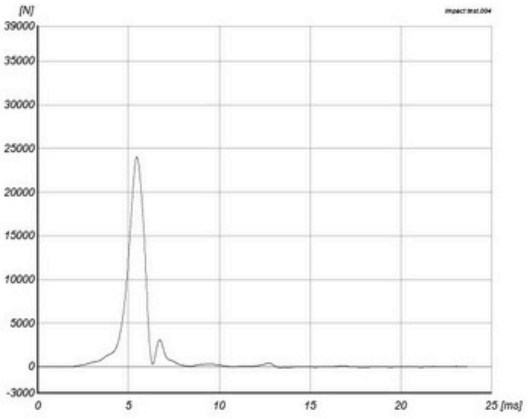
SHOCK TEST RESULTS



TEST INFO		Date/Time :	12/4/2024 15:56
Temperature :	21.7 / 40% RH	Operator :	DAM
SAMPLE IDENTIFICATION		Manufacturer :	3D printing
		Shock abs. mat. :	TPU
Standard :	EN 1621-1:2012	Density :	
Min Speed [m/s]:	0.0	Size :	
Max Peak [N]:		Mass :	
Min Energy [J]:		Job No. :	

File	Ext.	Model	Sa. N#	Cond.	Height [cm]	Size	Impact Point	Anvil Shape	Speed [m/s]	Peak [N]	Energy [joules]
Impact test	004	Sample 4	4	Amb	106	Flat 80 x		Radius 50	4.40	24028	48.4

SHOCK TEST RESULTS



TEST INFO

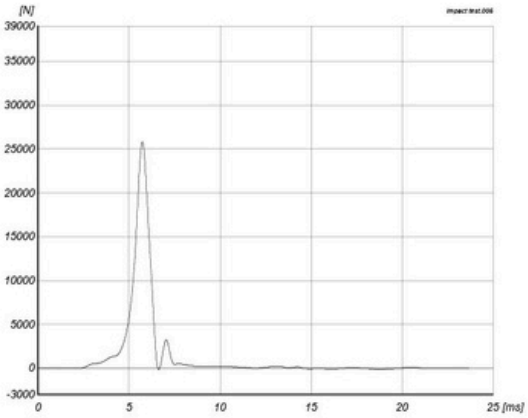
Temperature :	21.7 / 40% RH	Date/Time :	12/4/2024 15:59
		Operator :	DAM

SAMPLE IDENTIFICATION

		Manufacturer :	3D printing
		Shock abs. mat. :	TPU
Standard :	EN 1621-1:2012	Density :	
Min Speed [m/s]:	0.0	Size :	
Max Peak [N]:		Mass :	
Min Energy [J]:		Job No. :	

File	Ext.	Model	Sa. N#	Cond.	Height [cm]	Size	Impact Point	Anvil Shape	Speed [m/s]	Peak [N]	Energy [joules]
Impact test	005	Sample 6	6	Amb	106	Flat 80 x		Radius 50	4.39	25818	48.3

SHOCK TEST RESULTS



TEST INFO

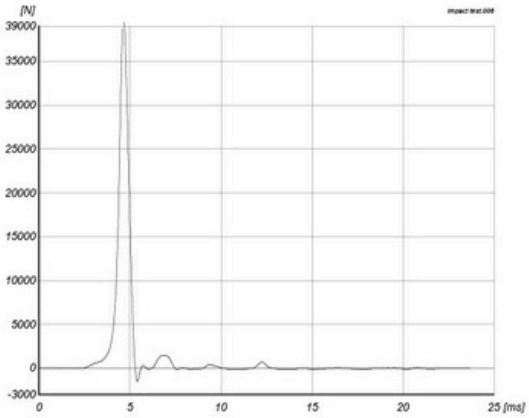
Temperature :	21.7 / 40% RH	Date/Time :	12/4/2024 16:04
		Operator :	DAM

SAMPLE IDENTIFICATION

		Manufacturer :	3D printing
		Shock abs. mat. :	TPU
Standard :	EN 1621-1:2012	Density :	
Min Speed [m/s]:	0.0	Size :	
Max Peak [N]:		Mass :	
Min Energy [J]:		Job No. :	

File	Ext.	Model	Sa. N#	Cond.	Height [cm]	Size	Impact Point	Anvil Shape	Speed [m/s]	Peak [N]	Energy [joules]
Impact test	006	Sample 6	6	Amb	106	Flat 80 x		Radius 50	4.40	39734	48.4

SHOCK TEST RESULTS



TEST INFO

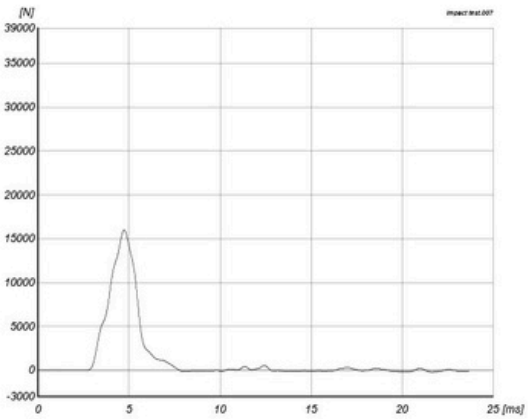
Temperature :	21.7 / 40% RH	Date/Time :	12/4/2024 16:13
		Operator :	DAM

SAMPLE IDENTIFICATION

		Manufacturer :	REV' IT!
		Shock abs. mat. :	
Standard :	EN 1621-1:2012	Density :	
Min Speed [m/s]:	0.0	Size :	
Max Peak [N]:		Mass :	
Min Energy [J]:		Job No. :	

File	Ext.	Model	Sa. N#	Cond.	Height [cm]	Size	Impact Point	Anvil Shape	Speed [m/s]	Peak [N]	Energy [joules]
Impact test	007	SEEFLEX		Amb	106	Flat 80 x		Radius 50	4.39	15979	48.3

SHOCK TEST RESULTS



TEST INFO

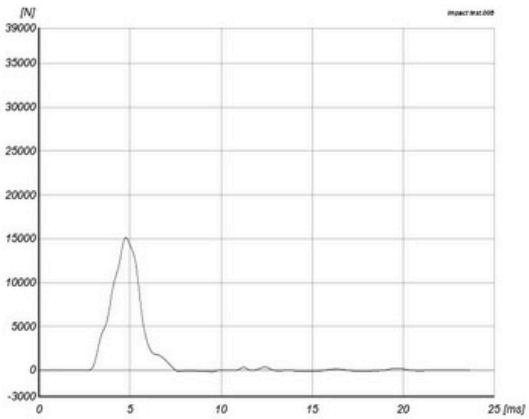
Temperature :	21.7 / 40% RH	Date/Time :	12/4/2024 16:14
		Operator :	DAM

SAMPLE IDENTIFICATION

		Manufacturer :	REV' IT!
		Shock abs. mat. :	
Standard :	EN 1621-1:2012	Density :	
Min Speed [m/s]:	0.0	Size :	
Max Peak [N]:		Mass :	
Min Energy [J]:		Job No. :	

File	Ext.	Model	Sa. N#	Cond.	Height [cm]	Size	Impact Point	Anvil Shape	Speed [m/s]	Peak [N]	Energy [joules]
Impact test	008	SEEFLEX		Amb	107	Flat 80 x	Zone B	Radius 50	4.39	15124	48.1

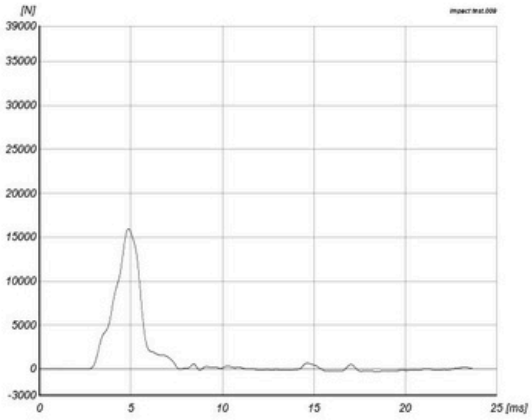
SHOCK TEST RESULTS



TEST INFO		Date/Time :	12/4/2024 16:14
Temperature :	21.7 / 40% RH	Operator :	DAM
SAMPLE IDENTIFICATION		Manufacturer :	REV' IT!
		Shock abs. mat. :	
Standard :	EN 1621-1:2012	Density :	
Min Speed [m/s]:	0.0	Size :	
Max Peak [N]:		Mass :	
Min Energy [J]:		Job No. :	

File	Ext.	Model	Sa. N#	Cond.	Height [cm]	Size	Impact Point	Anvil Shape	Speed [m/s]	Peak [N]	Energy [joules]
Impact test	009	SEEFLEX		Amb	107	Flat 80 x	Zone B	Radius 50	4.41	15965	48.6

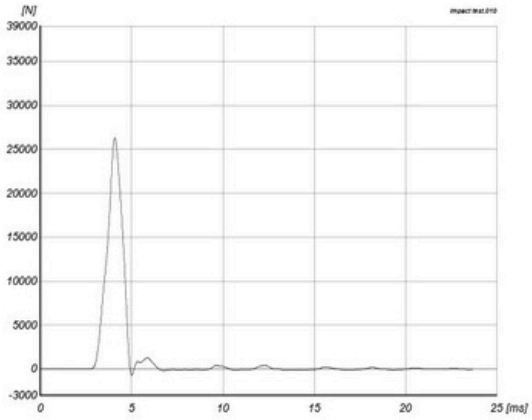
SHOCK TEST RESULTS



TEST INFO		Date/Time :	12/4/2024 16:19
Temperature :	21.7 / 40% RH	Operator :	DAM
SAMPLE IDENTIFICATION		Manufacturer :	REV' IT!
		Shock abs. mat. :	
Standard :	EN 1621-1:2012	Density :	
Min Speed [m/s]:	0.0	Size :	
Max Peak [N]:		Mass :	
Min Energy [J]:		Job No. :	

File	Ext.	Model	Sa. N#	Cond.	Height [cm]	Size	Impact Point	Anvil Shape	Speed [m/s]	Peak [N]	Energy [joules]
Impact test	010	SEESMART		Amb	106	Flat 80 x	Zone A	Radius 50	4.38	26298	47.9

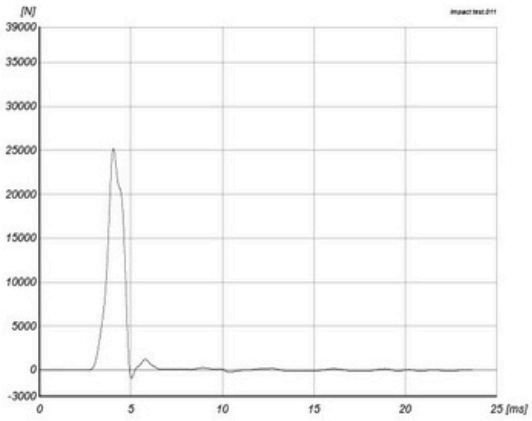
SHOCK TEST RESULTS



TEST INFO		Date/Time :	12/4/2024 16:20
Temperature :	21.7 / 40% RH	Operator :	DAM
SAMPLE IDENTIFICATION		Manufacturer :	REV' IT!
		Shock abs. mat. :	
Standard :	EN 1621-1:2012	Density :	
Min Speed [m/s]:	0.0	Size :	
Max Peak [N]:		Mass :	
Min Energy [J]:		Job No. :	

File	Ext.	Model	Sa. N#	Cond.	Height [cm]	Size	Impact Point	Anvil Shape	Speed [m/s]	Peak [N]	Energy [joules]
Impact test	011	SEESMART		Amb	106	Flat 80 x	Zone B	Radius 50	4.40	25152	48.4

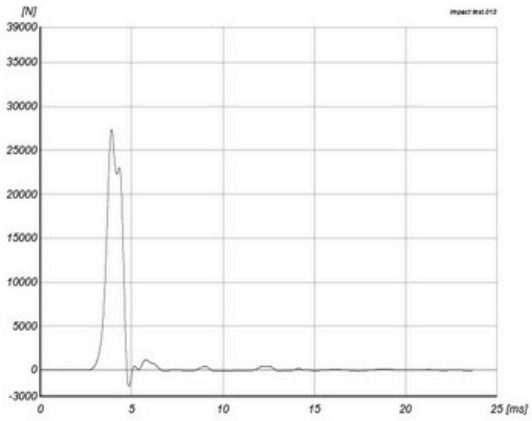
SHOCK TEST RESULTS



TEST INFO		Date/Time :	12/4/2024 16:20
Temperature :	21.7 / 40% RH	Operator :	DAM
SAMPLE IDENTIFICATION		Manufacturer :	REV' IT!
		Shock abs. mat. :	
Standard :	EN 1621-1:2012	Density :	
Min Speed [m/s]:	0.0	Size :	
Max Peak [N]:		Mass :	
Min Energy [J]:		Job No. :	

File	Ext.	Model	Sa. N#	Cond.	Height [cm]	Size	Impact Point	Anvil Shape	Speed [m/s]	Peak [N]	Energy [joules]
Impact test	012	SEESMART		Amb	106	Flat 80 x	Zone C	Radius 50	4.41	27373	48.6

SHOCK TEST RESULTS



Appendix 6 Final user wear trials transcriptions

Final user feedback (transcription) User 1.

'Ik merk niet dat het erop zit, maar dat komt omdat het erop zit.

Oké, oké. Hele goede vergelijking is het trouwens wel want heel flexibel materiaal wat eigenlijk gewoon dun hapje stof is met een klein beetje rubber eraan geplakt uit negentien honderd negentig ergens is net zo comfortabel als een harde project protector, projector in het scherm. Een harde protector van nu. En die harde protector ja, als je daarmee geslagen wordt of valt ja dan voel je dat niet. En met dat slappe flubige flutding uit negentien honderd negentig nou dat voel je dus wel.

Dat doet helemaal niks het is wel comfortabel maar beschermt niet dit is comfortabel en het beschermt wel. Dus ik zeg als vergelijking weet je wel vergeleken dat tien van de tip. Oké en het plaatsen bovenop merk je dan een groot verschil met als je het onderop plaatst? Ik denk dat je het bovenop en onderop kan dragen en dan allebei nog steeds even comfortabel. Het is lastig te merken met een leren pak.

Ik denk dat je als je een gewoon kleding meer stijl pak aan hebt, dat bovenop iets comfortabeler is. Maar aangezien allebei mogelijk is met deze applicatie denk ik dat je gewoon goed product te pakken hebt. Pakken. Eigenlijk voor een bedrijf standpunt ook naar rechts want dan heb je meteen geen reclame aangezien niemand het logo ziet. Verder ja design ik weet niet hoeveel de designer valt aan een protector aangezien het een vrij ja alles valt echt een beetje binnen dezelfde lijnen over het algemeen.

Maar het ziet er goed uit. Moet ik eerlijk toegeven, ziet er futuristisch uit. Dus ik denk dat er een hoop mensen zijn die bijvoorbeeld negen rijden of misschien een streetfider of wat dan ook die denken van weet je het is best gaaf, dit zou ik wel bovenop mijn kleding willen dragen. Zeker omdat ze het ook een andere kleurtje kan krijgen. Zou jij het bijvoorbeeld willen krijgen met een bovenkant die helemaal glad is in plaats van dit gaas.

Zou je dat mooier vinden? Of zou je zeggen van dit vind ik jij veel leuk? Het doel heeft juist wel iets wat. Ik denk, want ja heel machinaal zou je er denk ik wel qua aerodynamica iets profijt in hebben als het helemaal glad is. Ook op zijn kleine oppervlakte dus ja maar dat zou dan meer een reis applicatie zijn en ik denk niet dat heel veel mensen die echt een circuit opgaan dat helemaal glad willen.

Ja, ik denk dat ik het juist zoals het ruw is dat ik het juist ruw mooi zou vinden. Of misschien als het glad is mat in ieder geval niet glanzend. Want dan lijkt het net alsof je echt zo'n zo'n harde kunststof protaire ja, sluiers zeg maar geplaatst hebt. Alleen dan heel groot. Dat ziet er voor mij een beetje daar uit.

Ja, maar welk aspect zou je dan het meeste gebruiken daarvan? Het personaliseren van het uiterlijk Of het customization van rijden naar normaal dragen. Of het customization tussen rijden op straat versus track? Ik zou het meeste persoonlijk, zou voor mij meer uitgaan naar jij dat motor, naar gewoon normaal gebruik van fast jas, broek, wat dan ook. En kopen omdat het modulair is daartussen? Ja, maar ik denk wel dat dat meer in budgetvriendelijke applicaties zou zijn.

Ik merk dat als je meer het hogere segment dat daar sowieso al mensen dingen kopen die het hogere segment allemaal makkelijker kunnen veroorloven. En die vinden het vaak, ja die hebben meestal ook gewoon het geld om aparte kleding daarvoor te hebben. Ik denk dat dit dan ook meer handig is voor de mensen die eigenlijk wel heel graag motor willen rijden. Maar meer krap in kas zitten, dus ook een keer nieuwe motorkleding of nieuwe jas betalen waar dat moeilijker voor is. Ja.

Ik denk dat dit dan een betere uitkomst zou zijn voor veel gedoe vinden om aan te doen of om mee te slepen als ze ergens naartoe gaan. Dat voor hun dit een goed alternatief zou kunnen zijn. Ja, je kunt het vrij compact meenemen. Maar als je gewoon een klein doosje op een kopbergt tasje hebt. Gewoon in klein formaat tasje waar alles vier compact in kunnen.

Dan kun je dat kleine tasje overal mee naartoe nemen. Dan hoef je niet altijd twee claimstukken mee te nemen of bij je te hebben. Of ergens naartoe te lopen om net weer die andere jas tevoorschijn te toveren. Maar je zegt overal, ja dat kleine tasje kun je zo ergens neerleggen en dan zo omtoveren. Dus ja.

Oké, zeg maar wat zou jij zeggen dat het main selling punt is van deze armor? Deze vraag had je hem ook mogen stellen en dan eerst even na mogen laten denken. Oké Allebei, het zit comfortabeler of in ieder geval dat is afhankelijk van hoe je het gebruikt maar het kan comfortabeler zitten dus dat is gebruiksgemak. Het is lichter dus je zult het minder voelen in gewicht als je iets aan hebt En minder gewicht is over het algemeen ook meer vrijheid met bewegen. Wat ook weer leidt voor meer gebruikersgemak.

Je kunt het makkelijke switchen. Stel je wilt het eruit halen of ergens erop plakken of ergens eraf halen, is het makkelijker. Wederom gebruikers gemak dus ik denk over het algemeen gebruik gemak.

Final user feedback (transcription) User 2.
En de protector zelf denk dat het mooie eraan is dat je het dat je de grootte ook kan aanpassen. Dus niet iedereen heeft natuurlijk dezelfde maat. Dus ik denk dat je ook een stukje personal dat vind ik wel fijn. En ik vind de structuur vind ik ook wel gaaf aan de binnenkant. Ik weet alleen niet helemaal hoe of ik het zelf zou dragen met deze structuur aan de buitenkant.

Ik denk dat ik hem eerder of een glad zou hebben of een bijvoorbeeld En ik vind het ook wel een gaaf idee dat je dat je je als je het moment dat je bijvoorbeeld ergens bent dat je er makkelijk vanaf kan halen en op die manier dus gewoon een normale jas af. Is nou nog het uiterlijk of die onduidelijkheid als je net bereiden voor normale vragen de meningelling voor? Wat staat op één van die twee? Ik denk dat je van een motorjas om male jas op dat moment kan maken. Je zegt dan van modariteit tussen het rijden en normaal dragen is voor jou de main sign point.

In welke situaties zie je zelf hier gebruik van maken? Ik denk dat het grootste verkooppunt is dat Voor jou hè? Ja ja ja precies voor mij dat het moment dat ik dat ik zo'n protectctct is het is het nu al best wel stevig 10 opzichte van de protectoren die ik bijvoorbeeld nu in mijn jas heb zitten op mijn schouders en armen dus het geeft ook wel iets wat meer gevoel van veiligheid. En ik denk dat gewicht ook een heel groot gedeelte meespeelt maar ik denk dat vooral gewicht is in combinatie met het gevoel van veiligheid. Want ik denk dat dat vooral een burger meespeelt.

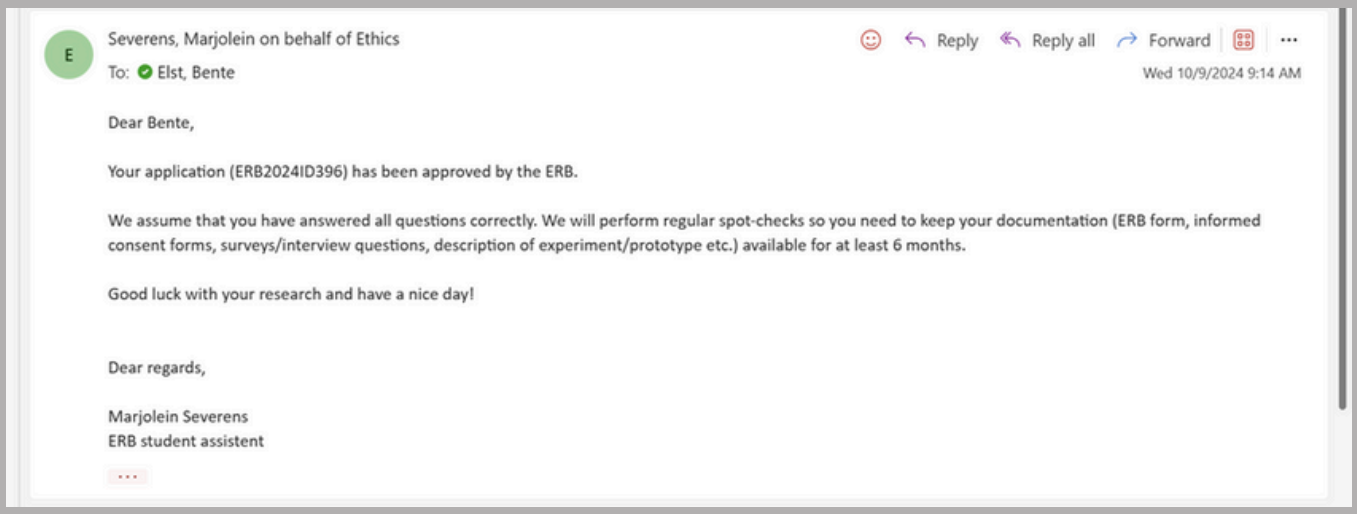
Er zit een mooie mooi logo bij, een koele naam dus het is ook wel makkelijk om daar zeg maar jezelf aan te verbinden Ja, ik denk dat dat wel was. Ik noem drie dingen als je meest selling point, is dat dan omdat die drie dingen samen werken op het totaalplaatje van alles wat samenwerkt wat voor jou de meest selling point is of is er echt één van die dingen die eruit springt? Nee, het is denk ik een combinatie van. En dan een combinatie van die drie? Ja.

Oké, hoe voelt het comfort level vergeleken met je eigen motor keer? En dat kan gewicht zijn, movability. En of je het wel of niet voelt zitten hoe strak het zit. Ja, gewicht is niet zozeer echt een ik voel niet echt een heel erg groot verschil. Wat ik wel heel erg merk is dat dat een groot verschil is tussen de arm die nu aan de binnenkant zit 10 opzichte van dat het nu aan de buitenkant zit.

Hoe aan de buitenkant zit is het ik vind het gewoon een heel stuk en comfortabel. Natuurlijk het is eigen smaak of je dat mooi vindt alleen het spel aan buitenkant heb je gewoon veel meer bewegingsvrijheid 10 opzichte dat het aan de binnenkant zit. Ook vind ik het fijner wel aanvoelen ik heb vaak dat mijn armen zit tegen je lichaam zelf aan dus dat voelt gewoon wat minder prettig en af en toe in voel je het drukken of iets en dat heb je als je aan de buitenkant hebt heb je dat toch een stuk minder. Oké, ik heb wel een doorvraag daarop. Je gaf aan dat je bijvoorbeeld misschien meer interesse zou hebben als het een solide bovenkant zou hebben.

Maakt het voor jou uit dat je daardoor geen ventilatie meer krijgt? De huidige factoren hebben ook niet vaak niet heel veel ventilatie. Dus het is natuurlijk wel fijn als je wel iets wel meer als je pakken ook iets wel meer kan ademen natuurlijk maar het is ja het kan natuurlijk ook een selling point zijn dat je een ander soort design kiest wat ook daarmee helpt natuurlijk. Waarmee helpt? Dus dat je dus dat het moment dat je een design kiest wat wat meer open is dat dat ik van de selling point is natuurlijk dat dat

Appendix 7 Signed ERB + email confirmation



Severens, Marjolein on behalf of Ethics

To: Elst, Bente

Reply | Reply all | Forward | ···

Wed 10/9/2024 9:14 AM

Dear Bente,

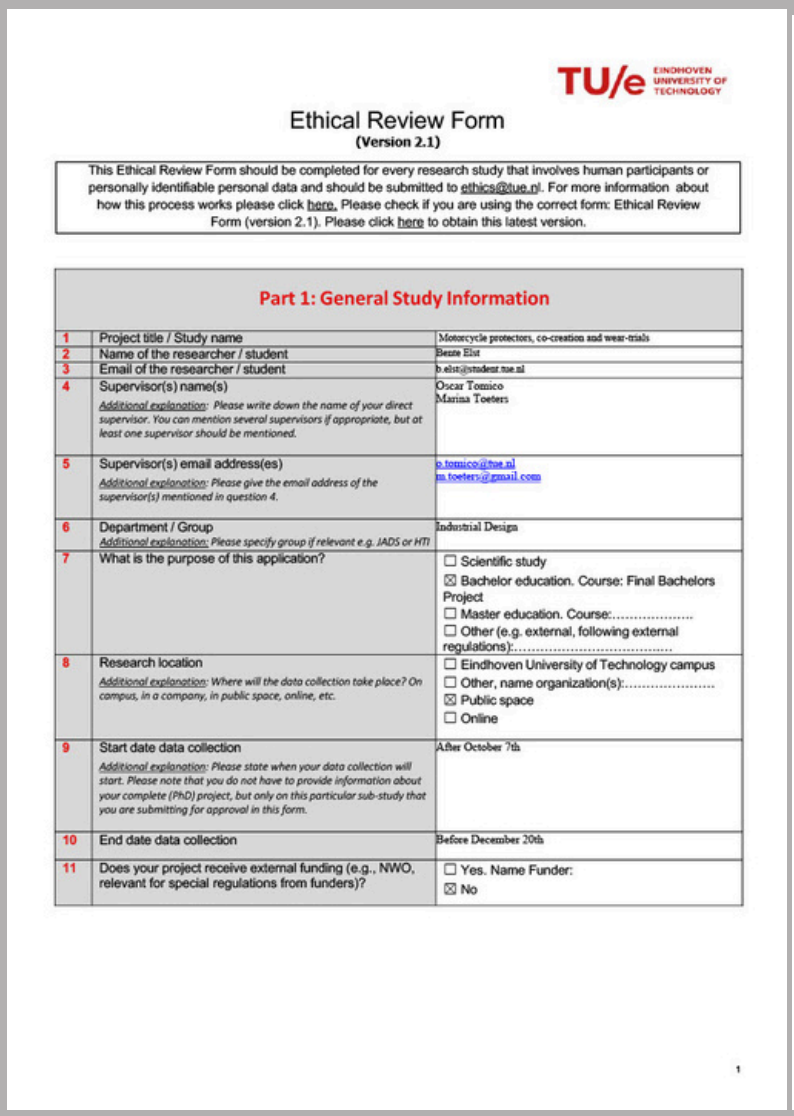
Your application (ERB2024ID396) has been approved by the ERB.

We assume that you have answered all questions correctly. We will perform regular spot-checks so you need to keep your documentation (ERB form, informed consent forms, surveys/interview questions, description of experiment/prototype etc.) available for at least 6 months.

Good luck with your research and have a nice day!

Dear regards,

Marjolein Severens
ERB student assistent



TU/e Eindhoven University of Technology

Ethical Review Form

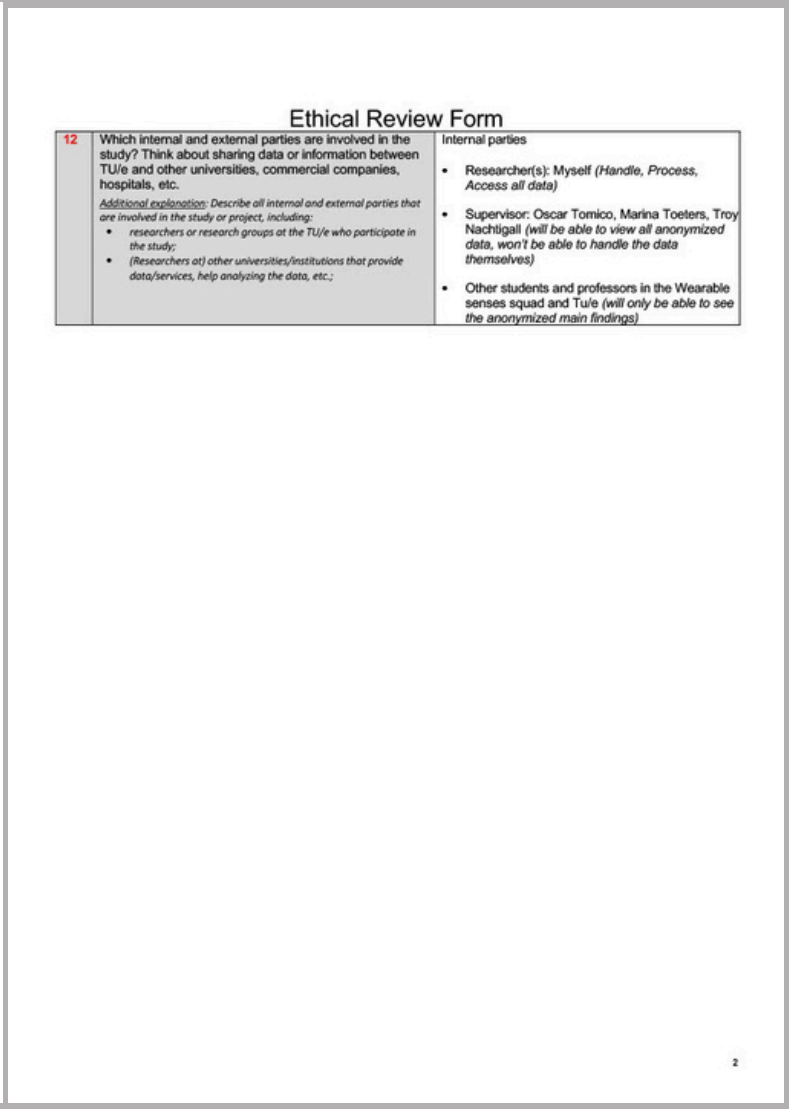
(Version 2.1)

This Ethical Review Form should be completed for every research study that involves human participants or personally identifiable personal data and should be submitted to ethics@tue.nl. For more information about how this process works please click here. Please check if you are using the correct form: Ethical Review Form (version 2.1). Please click here to obtain this latest version.

Part 1: General Study Information

1	Project title / Study name	Motorcycle protectors, co-creation and wear-trials
2	Name of the researcher / student	Bente Elst
3	Email of the researcher / student	b.elst@student.tue.nl
4	Supervisor(s) name(s) *Additional explanation: Please write down the name of your direct supervisor. You can mention several supervisors if appropriate, but at least one supervisor should be mentioned.*	Oscar Tomico Marina Toeters
5	Supervisor(s) email address(es) *Additional explanation: Please give the email address of the supervisor(s) mentioned in question 4.*	o.tomico@tue.nl m.toeters@gmail.com
6	Department / Group *Additional explanation: Please specify group if relevant e.g. JADS or HTI*	Industrial Design
7	What is the purpose of this application?	☐ Scientific study ☒ Bachelor education. Course: Final Bachelors Project ☐ Master education. Course:…… ☐ Other (e.g. external, following external regulations):……
8	Research location *Additional explanation: Where will the data collection take place? On campus, in a company, in public space, online, etc.*	☐ Eindhoven University of Technology campus ☐ Other, name organization(s):…… ☒ Public space ☐ Online
9	Start date data collection *Additional explanation: Please state when your data collection will start. Please note that you do not have to provide information about your complete (PhD) project, but only on this particular sub-study that you are submitting for approval in this form.*	After October 7th
10	End date data collection	Before December 20th
11	Does your project receive external funding (e.g., NWO, relevant for special regulations from funders)?	☐ Yes. Name Funder: ☒ No

1



Ethical Review Form

12	Which internal and external parties are involved in the study? Think about sharing data or information between TU/e and other universities, commercial companies, hospitals, etc. *Additional explanation: Describe all internal and external parties that are involved in the study or project, including:* • *researchers or research groups at the TU/e who participate in the study;* • *(Researchers at) other universities/institutions that provide data/services, help analyzing the data, etc.;*	Internal parties • Researcher(s): Myself *(Handle, Process, Access all data)* • Supervisor: Oscar Tomico, Marina Toeters, Troy Nachtigall *(will be able to view all anonymized data, won't be able to handle the data themselves)* • Other students and professors in the Wearable senses squad and Tu/e *(will only be able to see the anonymized main findings)*

2

	• *(commercial) partners, companies, government bodies, municipalities, consultancy firms, hospitals or care institutions that provide data (e.g., contact details of participants, data for further analysis).* *Indicate which role each party plays: who defines the means and purposes in the study, who will supply the data (external parties?), who will process/handle the data, who will be able to access the data during and after research (only researchers at TU/e or also others)?*	External parties A Motorcycle gear company. Either Rev'it, Macna, or Richa. *(Will only be able to see the anonymized, main findings. Won't be able to access this data themselves.)* • Others:
13	Have any special agreements already been made with an external party, such as a Non-Disclosure Agreement (NDA) or a data sharing agreement?	☐ Yes, namely: ☒ No
14	Has your proposal already been approved by an external Ethical Review Board or Medical Ethical Review Board? *Additional explanation: For example, when you are collaborating with another university and the project has been approved by their Ethical Review Board, or when you received a WMO-waiver from a Medical Ethical Review Board.*	☐ Yes ☒ No
15	If yes: Please provide the name, date of approval and contact details of the ERB. Please also include the registered number for your project approval. Additionally, please send in the Ethical Review Form upon which ethical approval was granted together with this form.	
16	If you process personal data that are likely to result in high privacy risks for participants, you need to perform a Data Protection Impact Assessment (DPIA). Have you done this for this or a very similar project? ***Please read the information below: a DPIA is not the same as a regular privacy impact assessment. More detailed questions on privacy will follow in the section below.*** *Additional explanation: A Data Protection Impact Assessment (DPIA) is a formal document that must be drafted under the guidelines of the General Data Protection Regulation (GDPR). Think of research with vulnerable people, high-risk medical research,* *The Dutch DPA (Autoriteit Persoonsgegevens) and our website provides more information about a DPIA.*	☒ Not applicable (no high privacy risks) ☐ Yes (the form is attached to the application) ☐ No
	Part 2: Medical study	
1	Does the study have a medical scientific research question or claim? *Additional explanation: Medical/scientific research is research which is carried out with the aim of finding answers to a question in the field of illness and health (etiology, pathogenesis, signs/symptoms, diagnosis, prevention, outcome or treatment of illness), by systematically collecting and analyzing data. The research is carried out with the intention of contributing to medical knowledge which can also be applied to populations outside of the direct research population. If your research contains questions about health and health related parameters (such as well-being, vitality, feelings of anxiety or stress) but your research question is not primarily medical, then you can answer 'no' to this question.*	☐ Yes* ☒ No *If yes or in doubt, please contact Susan Hommerson via s.m.hommerson@tue.nl

	Part 3: Use of (medical) devices in the study	
1	Does your research include a device? *Additional explanation: A device is a complete piece of physical hardware that is used to compute or support computer functions within a larger system. Devices can be divided into input-, output-, storage-, internet of things-, or mobile device.*	☐ Yes, not self-made ☐ Yes, self-made ☒ No
2	Please describe your device or link to an online description of the device	
3a	Will you use a device that is 'CE' certified for **unintended use** (meaning you will use existing CE certified devices for other things than they were originally intended for) or use a device that is not 'CE' certified? *Additional explanation: You can find more information about CE certification here*	☐ Yes ☒ No ☐ ☐
3b	If no: Please explain to what extent the device was assembled according to relevant standards and provide a risk assessment *Additional explanation: You can find more information about a risk assessment here*	I won't be using a device
3c	If yes: Do you use a device or software that has a medical purpose such as diagnosis, prevention, monitoring, prediction, prognosis, treatment or alleviation of disease or injury?	☐ Yes, my device or software currently has a medical purpose ☐ Yes, my device or software could have a medical purpose in the near future ☐ No ☐ I'm not sure
	Part 4: Information about the study	
1	What are your main research questions? *Additional explanation: You need to provide at least one clear research question.*	"How do motorcycle drivers respond to a piece of motorcycle armor above the motorcycle gear?" "What do motorcycle drivers see as the ideal impact armor for comfort and aesthetics (co-creation session)?" "How does my motorcycle impact protector design make motorcycle drivers feel in the area of mental and physical comfort, aesthetics, and Mental and physical safety, During wear-trials?"
2a	Please check the box that indicates the relevant study population *Additional explanation: Please select which persons are eligible for your study.*	☐ Students ☐ General healthy population ☒ General population with specific feature, Specifically, Motorcycle driver that wear leather sporty motorcycle gear. ☐ Patients, specifically ..... ☐ Other, specifically .....
2b	Age category of participants	☐ Younger than 12 years of age ☐ Older than 11 and younger than 16 years of age ☒ 16 years or older

3	Description of the research method (select all that applies)	☒ (Semi-structured) interviews ☐ Surveys

	Additional explanation: Please specify your research method. Note that you need to provide information about the research method in an additional file that you attach to the ERB form. E.g., for interviews you provide the interview questions, for surveys you provide the survey questions, etc.	☒ Group workshops/roundtable discussios ☐ Diary studies ☒ Behavioral observations ☐ Building sensor data ☐ Wearable device (e.g. Fitbit watch, on-skin sensors) ☐ User testing ☐ Pilot study ☐ GPS tracking/location data ☐ Living Lab ☐ Other, namely .....
4	Description of the measurements and/or stimuli/treatments *Additional explanation: Think about your outcome measures and the variables you will be collecting and describe them in a way such that another person understands what the participant will experience. For example: Participants will perform task A and see pictures from database B, and we measure validated Scale 1.*	The research is divided into two different parts. Part 1: Participants will be asked to join a co-creation workshop. In a group participants get the task to each make a quick prototype of their ideal motorcycle armor, using the various materials provided. Before they start making, a couple of examples will be shown and mentioned to stimulate inspiration. Than the prototypes will be discussed with the group, the participants will give a quick explanation of their intended features (if they want to). After the workshop The current design idea of the student doing the research will be presented. The participants will be asked for their opinions about this design. Part 2: Later on the design process, participant will be asked to come back once more. They will be asked to wear the current design prototype, both while standing and while sitting on a parked motorcycle. The participant will be asked various questions on its feel, aesthetics, and other features.
5	Describe and justify the number of participants you need for this study. Also justify the number of observations you need, taking into account the risks and benefits. *Additional explanation: Think about if you need 3 or 30 participants for example, and why? Do they need to provide their input once, or several times, and why? If relevant, specify the duration of the study per participant and the compensation that is needed for the study.*	It is a qualitative study, so anywhere between 5 and 20 participants will be needed. The number of observations will be two, One to assist in the exploratory phase, and one to provide feedback on the end-design.
6	Explain why your research is societally important. What benefits and harm to society may result from the study? *Additional explanation: What benefit will the results of your study have to society in general?*	My research will help provide more comfortable motorcycle protector design that do not compromise in safety. This research is most crucial in providing input from the end-user, to ensure maximal gain for this group.
7	Describe the way participants will be recruited *Additional explanation: How will you recruit participants for your study? For example, by using flyers, personal network, panels, etc.*	☐ Survey link posted online, e.g., social media platforms ☐ On campus flyers ☒ Personal network ☐ Via a company, namely ..... ☐ Via a hospital, namely ..... ☐ Via an organization ..... ☐ By a Consortium Partner, namely ..... ☐ Other, namely .....

TU/e EINDHOVEN UNIVERSITY OF TECHNOLOGY

Ethical Review Form

8	Provide a brief statement of the risks you expect for the participants or others involved in the study and explain. Also take into consideration any personal data you may gather and associated privacy issues. *Additional explanation: Risks for the participants can be anything from risk of data breach to risk of safety or well-being (think about stress, extreme emotions, visual or auditory discomfort). Describe these possible risks and describe the way these risks are mitigated.*	During the workshop and wear-trials, Photos will be taken. Which aren't anonymized, which can cause privacy issues (Photos will only be taken from those who consent). All other user related data will be anonymized immediately. No further risks are envisioned.

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Ethical Review Form

Part 5: Self-assessment checklist

	Note: answers in the blue boxes indicate that your research is eligible for fast-track approval	Yes	No
1a	Does the study involve human material? (e.g., surgery waste material derived from non-commercial organizations such as hospitals)		x
1b	Will blood or other (bio)samples be obtained from participants? (e.g., hair, sweat, urine or other bodily fluids or secretions, also external imaging of the body)		x
2	Will the participants give their consent – on a voluntary basis – either digitally or on paper? Or have they given consent in the past for the purpose of education or for re-use in line with the current research question?	x	
3	Are the participants, outside the context of the research, in a dependent or subordinate position to the investigator? Additional explanation: Think about doing research on your own students or on your own employees. When there is a dependency or power imbalance between you and the research participants, you need to answer 'yes' to this question.		x
4	Does the study involve participants who are particularly vulnerable or unable to give informed consent? (e.g., children (<16 years of age), people with learning difficulties, patients, people receiving counselling, people living in care or nursing homes, people recruited through self-help groups)		x
5	Will participating in the research be burdensome? (e.g., requiring participants to wear a device 24/7 for several weeks, to fill in questionnaires for hours, to travel long distances to a research location, to be interviewed multiple times)?		x
6	May the research procedure cause harm or discomfort to the participant in any way? (e.g., causing pain or more than mild discomfort, stress, anxiety or by administering drinks, foods, drugs, or showing explicit visual material)		x
7	Will financial inducement (other than reasonable expenses and compensation for time) be offered to participants? Additional explanation: For an explanation of what is considered a reasonable compensation, see the topic participant fees from the HTI group		x
8a	Will it be necessary for participants to take part in the study without their knowledge and consent at the time? (e.g., covert observation of people)		x
8b	If yes: Will you be observing people without their knowledge in public space? (e.g. on the street, at a bus-stop)		
9	Will the study involve actively deceiving the participants? (e.g., will participants be deliberately falsely informed, will information be withheld from them, or will they be misled in such a way that they are likely to object or show unease when debriefed about the study)		x
10	Will participants be asked to discuss or report sexual experiences, religion, alcohol or drug use, suicidal thoughts, or other topics that are highly personal or intimate? Additional explanation: Think about your research population. For some participants, particular topics can be considered sensitive or intimate, whereas the same topics will not be perceived as such by other participants.		x
11	Elaborate on all boxes answered outside of the blue boxes in part 5. Describe how you safeguard any potential risk for the research participant.		

TU/e EINDHOVEN UNIVERSITY OF TECHNOLOGY

Ethical Review Form

Part 6: Self-assessment on privacy

The following questions (1-11) concern privacy issues, as laid down in the General Data Protection Regulation (GDPR). The Data Stewards and – if necessary – privacy team of TU/e will assess these questions. In some cases, more information is required to assess the privacy risks. If this is the case, you will be notified that the Data Stewards team will contact you.

The GDPR defines 'personal data' as any information relating to an identified or identifiable natural person ('data subject'). Personal data also includes data that indirectly reveals something about a natural person. Personal data can lead to the physical, physiological, genetic, mental, economic, cultural or social identity of a natural person. There are two main categories of personal data: regular personal data and special category personal data.

If you are not sure whether some of these questions below should be answered with a Yes or No, please contact a Data Steward first through rdmsupport@tue.nl.

	Note: answers in the blue boxes indicate that your research is eligible for fast-track approval	Yes	No
1	Will the study involve discussion/collection/processing of **regular** personal data, or will you collect and (temporarily) store video or voice recordings for the purpose of conducting interviews? *Additional explanation: For example, name, address, phone number, email address, IP address, gender, age, video or interview recordings? If you are not sure whether your data contains personal data, please contact the Data Stewards Team (rdmsupport@tue.nl).*	x	
1A	If yes: Please describe which regular personal data you will collect in this study?	Age, Gender, Photos	
2	Will the study involve discussion/collection/processing of **special category** personal data or other **sensitive data**? *Additional explanation: Examples of special category personal data are race, religion, health information, political views, genetic or biometric data for the unique identification of a person, sexual preference, etc. Health information concerns personal data of the physical or mental health of persons, including the provision of health care. Examples of other sensitive data is information such as communication data, financial records or credit scores, camera surveillance data, location/GPS data, internet-of-things data, employee monitoring, observing or influencing behaviour, criminal records, data of vulnerable persons (children, people with disabilities, refugees), BSN number etc. Please be aware that the use of special category personal data in research requires extra security measurements in order to safeguard the privacy of data subjects and to comply with the GDPR. Processing of this special category data is prohibited, except for specific purposes and under certain circumstances. If you need to process special category data, please consult the data stewards at rdmsupport@tue.nl.*		x
2A	If yes: Please describe which special-category personal data and/or sensitive data you will collect in this study?		

If you answered yes to either question 1 or 2, please answer the questions below. If you answered no to both questions, you can skip this part and continue onto part 7. Also, if an answer to any of the following questions is 'yes', please contact a Data Steward at rdmsupport@tue.nl

		Yes	No
3	Will your project involve the processing of personal data on a **large scale**? *Additional explanation: In general, any processing that involves more than 10.000 data subjects should be considered "large scale". However, if the data of approximately 1000 persons (or more) are involved, the data processing may still be considered large scale. In that case, besides the number of persons involved in the study, one should also assess (i) the amount of data collected from these persons taking into account the type/risk level of the personal data, (ii) the duration of the data processing, (iii) the geographic scope or extent of the processing. For example, if you would collect and process data across several European countries with 10+ socio-economic data items of 1200 individual persons for several years in a row, that is likely "large-scale processing". Other examples of a large-scale processing activity are:* • *Monitoring driving behavior of road users on Dutch highways* • *Collecting data of Covid patients* • *A hospital that processes patient data as part of its usual operations*		x

TU/e EINDHOVEN UNIVERSITY OF TECHNOLOGY

Ethical Review Form

	• *A transport company that processes travel information of people who travel by public transport in a certain city. For example, by tracking them through travel maps.*		
4	Does this processing activity involve the use of new or innovative technologies? *Examples of a new technology: combining fingerprints and facial recognition for physical access control, the use of bodycams in public spaces, the use of new technical methods in conducting research such as AI. This question also refers to new technologies that have not been deployed by TU/e so far.*		x
5	Does your study involve systematic (c.q. automated) monitoring of persons? *Additional explanation: Consider data processing activities that have the purpose of observing, monitoring or controlling individuals, for example in circumstances where the individuals are not aware by whom their personal data is collected and how it is used. Examples of such activities are using camera systems to monitor driving behavior on highways, monitoring email inactivity or employee phone use, certain applications of machine learning and artificial intelligence.*		x
6	Does the study involve collaborations (with third parties) in which data are shared or exchanged in order to link or combine data? *Additional explanation: This may often apply in a collaboration between the university and a commercial party, contract research, etc. It is important to assess this for all data in the entire project, not just your own data. An important consideration in this situation is whether the person whose data is involved could have expected that data from these different databases or sources of information were to be combined. For example, it is less likely for data subjects to expect that databases from different parties will be combined and the results are used for different purposes than one could reasonably expect; this may apply for example in a collaboration between the university and a commercial party.*		x
7	Will the study include data processing activities that prevent data subjects from exercising their rights or using a service or contract? *Additional explanation: Examples include processing operations carried out in public places that people cannot avoid (train station, airport, shopping mall, public university premises, etc.) or processing operations whose purpose is to allow or not allow data subjects to use a service or enter into a contract (examples: by refusing to pay a benefit, not being able to apply for a loan, etc.).*		x
8	Will the study process personal data to score, rank or profile persons? *Additional explanation: Examples: monitoring (highway) roads to give road users a "score" based on their detected driving behavior, a bank assessing its customers based on their creditworthiness, or an organization building behavioral and marketing profiles based on use of their website or navigating their website.*		x
9	Does your data processing include activities that involves composing "**blacklists**" – and, in particular, in relation to sensitive or special category data, such as communication data, financial records or credit scores, genetic data, biometric data, health data, camera surveillance data, location/GPS data, internet-of-things data, employee monitoring, observing or influencing behaviour, etc. *Additional explanation: This situation will not be a common occurrence in research, but you may indirectly be involved in this. In general, this typically concerns processing operations involving personal data relating to criminal convictions and offences, data relating to unlawful acts, data concerning unlawful or annoying behaviour or data concerning bad payment behaviour by companies or individuals are processed and shared with third parties (blacklists or warning lists, as used, for example, by insurers, hospitality companies shopping companies, telecom providers as well as blacklists relating to unlawful behavior of employees, for example in the healthcare sector or by employment agencies, etc.).*		x
10	Will personal data be transferred or shared outside the EU/EEA? EU data protection rules apply to the European Economic Area (EEA), which includes all EU countries and non-EU countries Iceland, Liechtenstein and Norway. *Additional explanation: The GDPR has drafted additional requirements for transfers data outside of the EU/EEA. Typically, additional safeguards must be implemented to protect the personal data of residents in the European Union. For example, if you collaborate with an American, Indian or Chinese university or other third party outside the EU/EEA, you must first check whether this is allowed and under which conditions this is allowed. Another typical example is storage of data on American providers of cloud (storage) services. Please contact the data stewards first to discuss this.*		x
11	Will any raw or anonymized personal data or any other sensitive data or research results from the project possibly be transferred to a high-risk country*? ***High risk countries**: China, Russia, Iran, Turkey, and North Korea.* *If personal data or other potentially sensitive data is exchanged with one of these countries, or if part of the data processing takes place in one of these countries: **an advice from the Data Protection Officer, the kennisveiligheidsteam (Knowledge Security team), and the CISO (Chief Information Security Officer) is ALWAYS required.***		x

TU/e EINDHOVEN UNIVERSITY OF TECHNOLOGY

Ethical Review Form

Part 7a: Processing of research data

1	Is consent your legal basis for processing the personal data in your study? *Additional explanation: What is a legal basis? One of main principles in the GDPR is to ensure that personal data is processed lawfully, fairly, and transparently. To comply with this principle, the processing of personal data also requires that you have a valid legal basis for the personal data processing activity.* *In research projects, the legal basis is often but not always consent. However, it is possible that it is not clear or not possible to establish whether to use consent as a legal basis.* *Some examples where consent may not be applicable as legal basis are covert research, data collection in public spaces, secondary data analysis of existing data, data that are transferred to you by a third party, consent is not possible or would require disproportionate effort, etc. In that case, please indicate which legal basis you think that applies or (preferably) contact a data steward first.*	☒ Yes and it will be obtained via …… An informed consent template* is attached to this application. ☐ No, I will use another legal basis to process the data. Namely, …….. * You can download a suitable template **here**.
2	Where will the data come from?	☐ Data obtained from another party (secondary data use) ☒ New data collected only by my research team ☐ New data collected together with collaborators
3	Which of the following tools will you use to process personal data?	**Surveys** ☐ Qualtrics ☐ Limesurvey ☐ MS Forms ☐ Other, namely …….. **Interview/workshop recordings** ☒ Voice/video recorder ☒ Phone in a flight mode ☐ MS Teams ☐ Other, namely …….. **Transcription** ☐ Manual transcription ☒ Microsoft Office software (e.g. Word, Teams) ☐ Other, namely …….. **Statistical analysis** ☐ SPSS ☐ R ☐ Other, namely …….. **Other tools**, specifically……..
4	Where will the data and in particular the personal data be stored during and after completion of the study? If you have already uploaded your Data Management Plan, you can refer to your Data Management Plan.	☒ SURF drive ☐ Onedrive ☒ Research Drive ☐ Network Drive

TU/e EINDHOVEN UNIVERSITY OF TECHNOLOGY

Ethical Review Form

	Additional explanation: University supported-storage facilities are SURFdrive, SURF Research Drive, Ceph, departmental drives (this includes BE Project Drive), and the TU/e instance of Microsoft OneDrive. For most personal data, the use of SURF Research Drive, departmental drives (including BE Project Drive) and SURFdrive is required.	☐ Research Manager ☐ Other, namely ……

Part 7b: Safety and security measures

1	Will you pseudonymize/anonymize the data? *Additional explanation:* *Anonymization: remove all direct identifiers (name, address, telephone number etc.) but also indirect identifiers (age, place of birth, occupation, salary) that, linked with other information, can lead to a person's identification. Anonymization to the point that a data subject is no longer identifiable means that the anonymized data is not considered to be personal data anymore.* *Pseudonymization: replacing the unique identifier of a data subject with an artificial pseudonym. This means that identification is still possible with the identification key. The identification key needs to be stored securely and separately from the pseudonymized data. If the data subject can be identified by combining data with additional information, the data is also called pseudonymous.*	☒ Yes ☐ No If yes, describe how:
2	Is access to (personal) data restricted? (Select all that apply)	☐ No ☐ Yes, via access control ☐ Yes, via password protection ☒ Yes, access only given to TU/e research team ☐ Yes, access only given to research team, including non-TU/e collaborators ☐ Other, specify……
3	Who will have access to the data during and after completion of the project? (Select all that apply)	☒ Main researcher ☒ TU/e supervisor(s) ☐ External supervisors ☐ TU/e research team ☐ Other, specify……
4	Will you store data for future research?	☐ No ☐ Yes, in a public data repository ☐ Yes, in a public data repository under restricted access ☒ Yes, in a TU/e-recommended storage (SURF Research Drive, Network Drive)
5	Will you share data outside the TU/e?	☐ No ☒ Yes, in a fully anonymized form ☐ Yes, raw or pseudonymized data* *If you selected this box, make sure that a suitable data agreement is put in place. You can contact the Data Stewards for support in preparing such an agreement
6	How long will data be stored after the end of the project?	Until the end of the schoolyear (July 2025)

TU/e EINDHOVEN UNIVERSITY OF TECHNOLOGY

Ethical Review Form

Part 8: Closures and Signatures

1	Enclosures (tick if applicable and attach to this form):	☒ Informed consent form ☐ Informed consent form for other agencies when the research is conducted at a location (such as a school) ☐ Text used for ads (to find participants) ☐ Text used for debriefings ☐ Approval other research ethics committee ☐ The survey the participants need to complete, or a description of other measurements ☐ Data Protection Impact Assessment checked by the privacy officer ☐ Data Management Plan checked by a data steward
2	Signature(s)	Signature(s) of applicant(s) *This can only be added in after the participant are contacted, which can only be after the ERB is approved.* Date: October 7th 2024 Signature research supervisor Date: October 8th 2024 Oscar Tomico