Fibre Wonder

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DAR | LAB

DIGITAL ARCHITECTURE ROBOTICS

MSc Digital Architecture and Robotic Construction

Course Director: Federico Rossi

This book documents the work developed for the taught module adaptive systems and structures part of the course MSc Digital Architecture and Robotic Construction at the London South Bank University, School of Built Environment and Architecture, Division of Architecture.
It follows the chronological structure of course where initially students start to investigate the evolution and variations of biological forms in natural systems where form, structure and material act upon one another creating complex hierarchies.
In support of the material behavior module, students will start to develop computational design skills which are essential to recreate three-dimensional experiment or just develop small simple geometry components which can be assembled together or self-organized in complex structures.
During the second semester, students will start to embed in their innovative design processes the constrains and inputs of manufacturing and constructibility using robotics, CNC fabrication, 3D printing and extensive material experiments.
The course is structured so that students are introduced to theoretical concepts through lectures on history and theory and technology to support their individual interest in advanced robotic construction.
Most of the work is developed using the Digital Architecture and Robotic Lab – DARLAB – and the Digital Fabrication Facilities part of the Division of Architecture where students can have a seamless integration between design and digital manufacturing creating the perfect teaching/working environment.

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MSc Course Director
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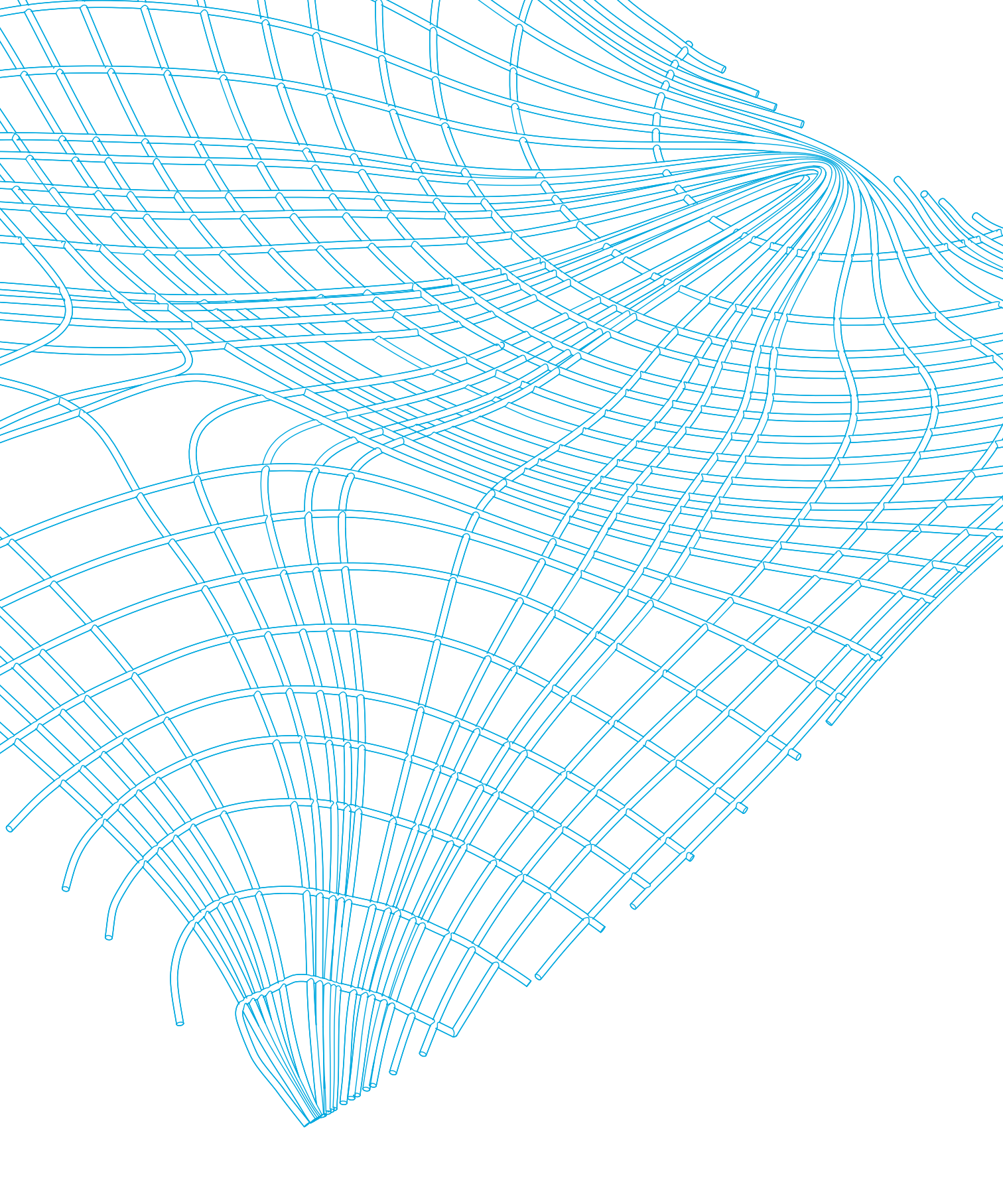
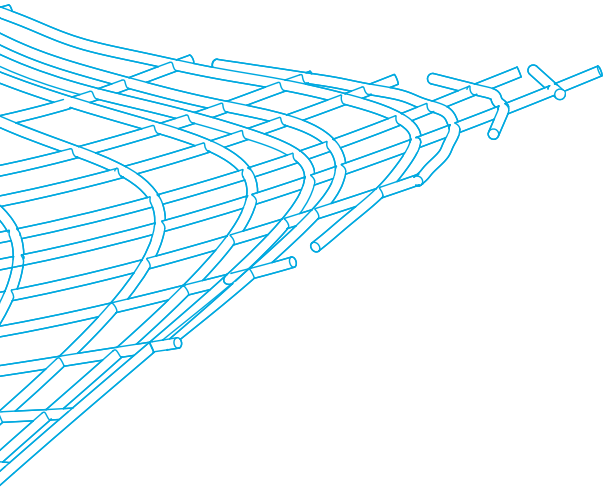
Robotics: Eng. Giuseppe D'Urzo, CEO of **QDRobotics**
Software: Thibault Schwartz, CEO of **HAL Robotics**





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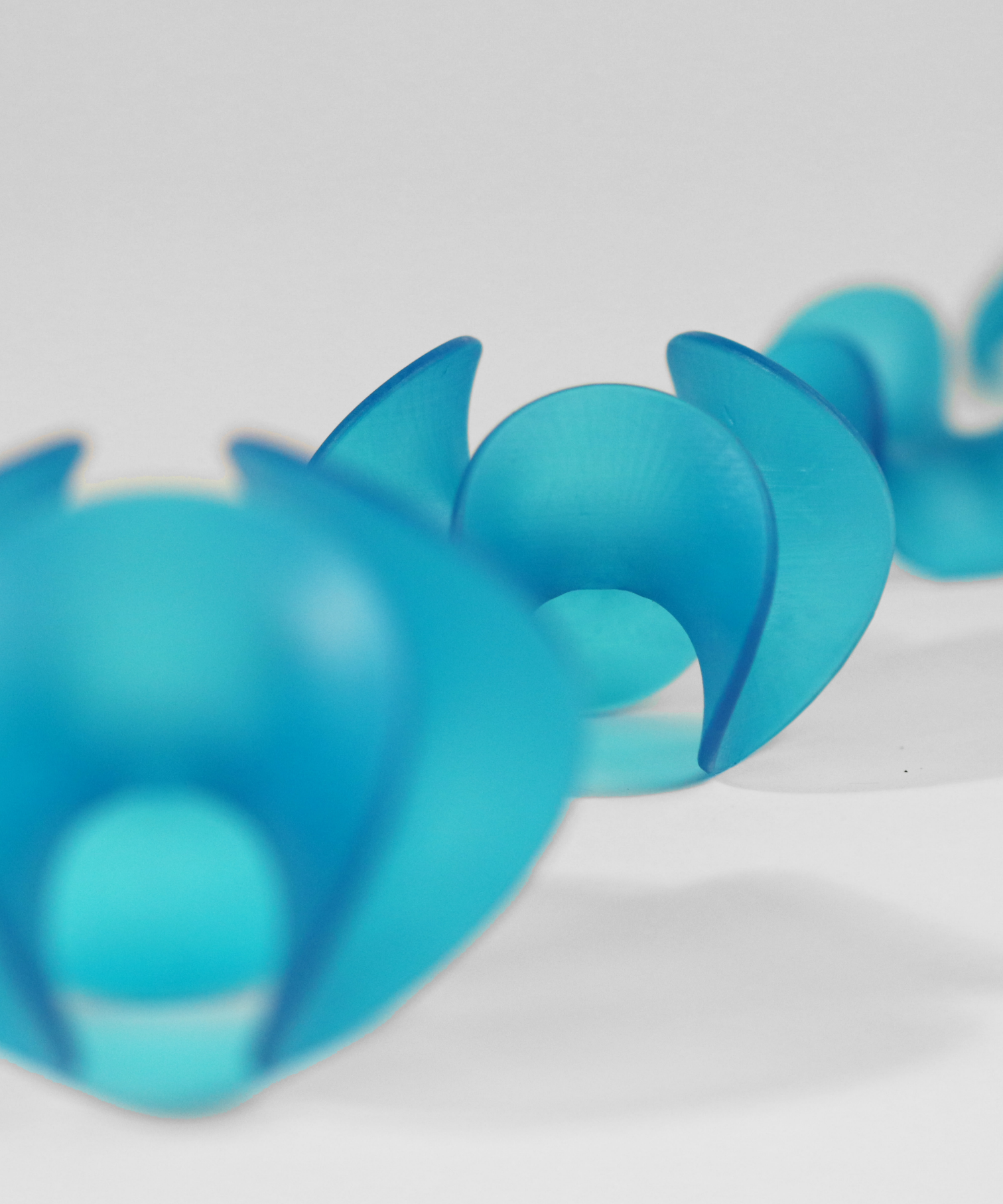
INTRO

#Objectives #Framework #Natural System #Optimization



Objectives

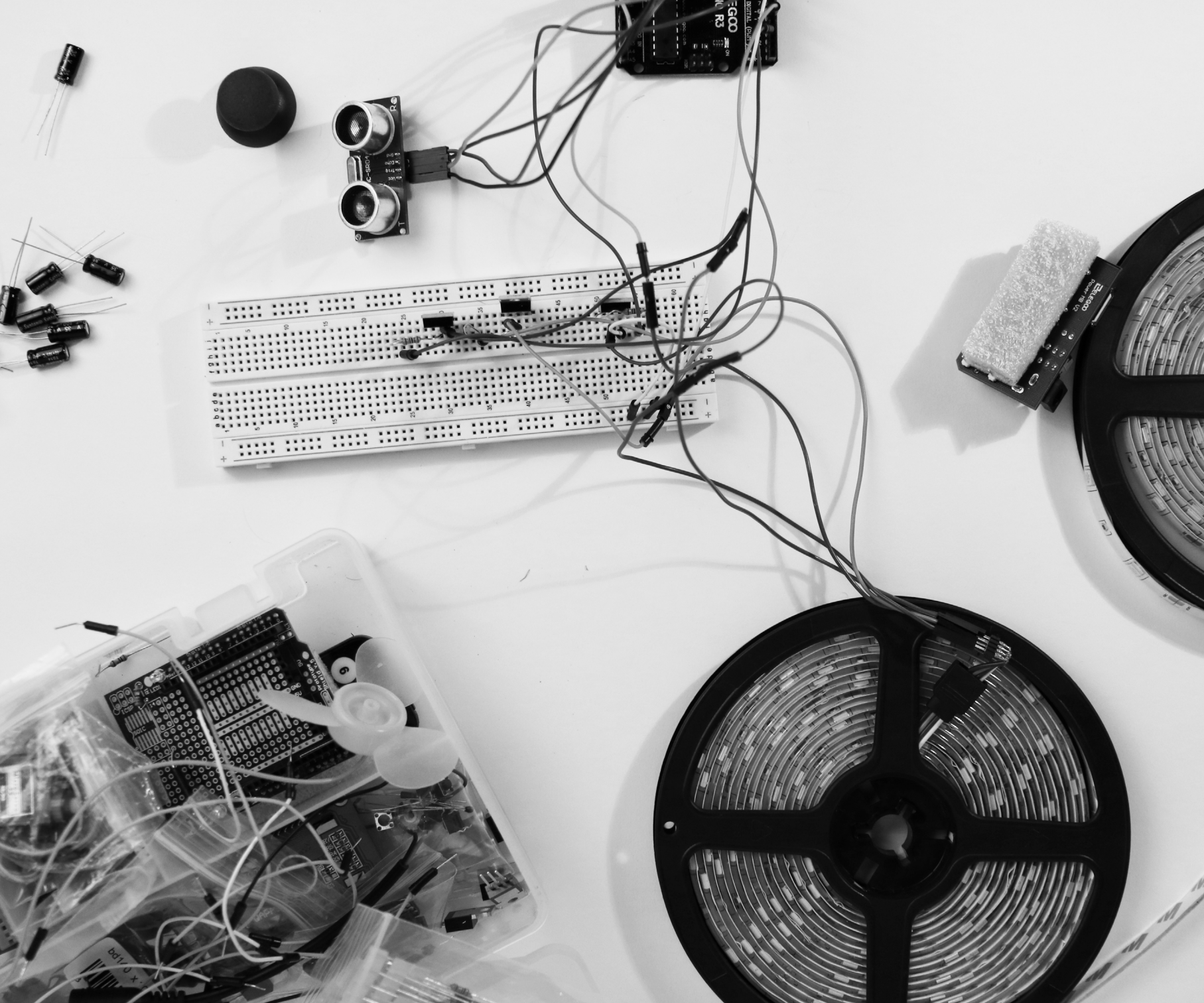
The main focus of this module is the design development and fabrication of a contemporary architectural research into spatial outcome which can be constructed on the university campus.

The students and teaching team will integrate on all phases of project development, from computational design, planning application, structural design through to digital fabrication and final assembly. The design process ideally will be based on both biological and structural principles that have been developed from the investigation of plant and geometry studies in the previous modules of previous semester.

Specific and careful attention will be based on physics, geometry, and finally the computational methods to understand both material behavior and its spatial outcomes on a given architectural condition. By looking at Robotic fabrication within its specific constraints and particulars such as hardware, software and finally the simulation, we will aim to apply all our early material behavior and computational research into architectural application which could be demonstrated on larger scale to explore and demonstrate spatial and technical concerns for future use.

The final project will be documented on a specific printed format. Students will prepare a booklet starting from the design process until fabrication. Many fabrication and computational errors or experiments will be recorded to demonstrate scientific approach produced on universal standards.


ART 73
PART 7
PART 82





CONTEXT

- LOCATION
- TOPOLOGY
- CONTEXT

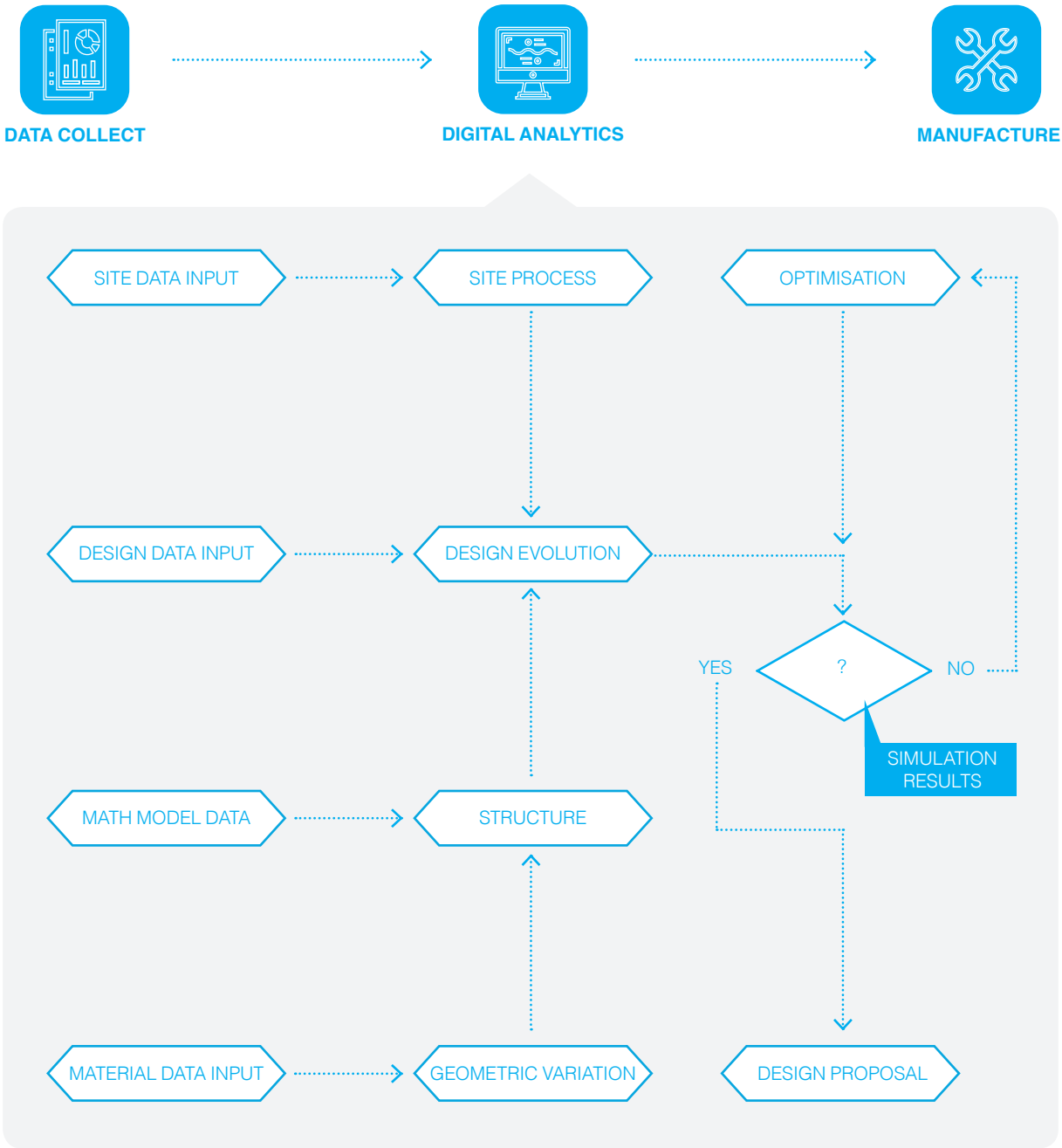
COMPOSITION

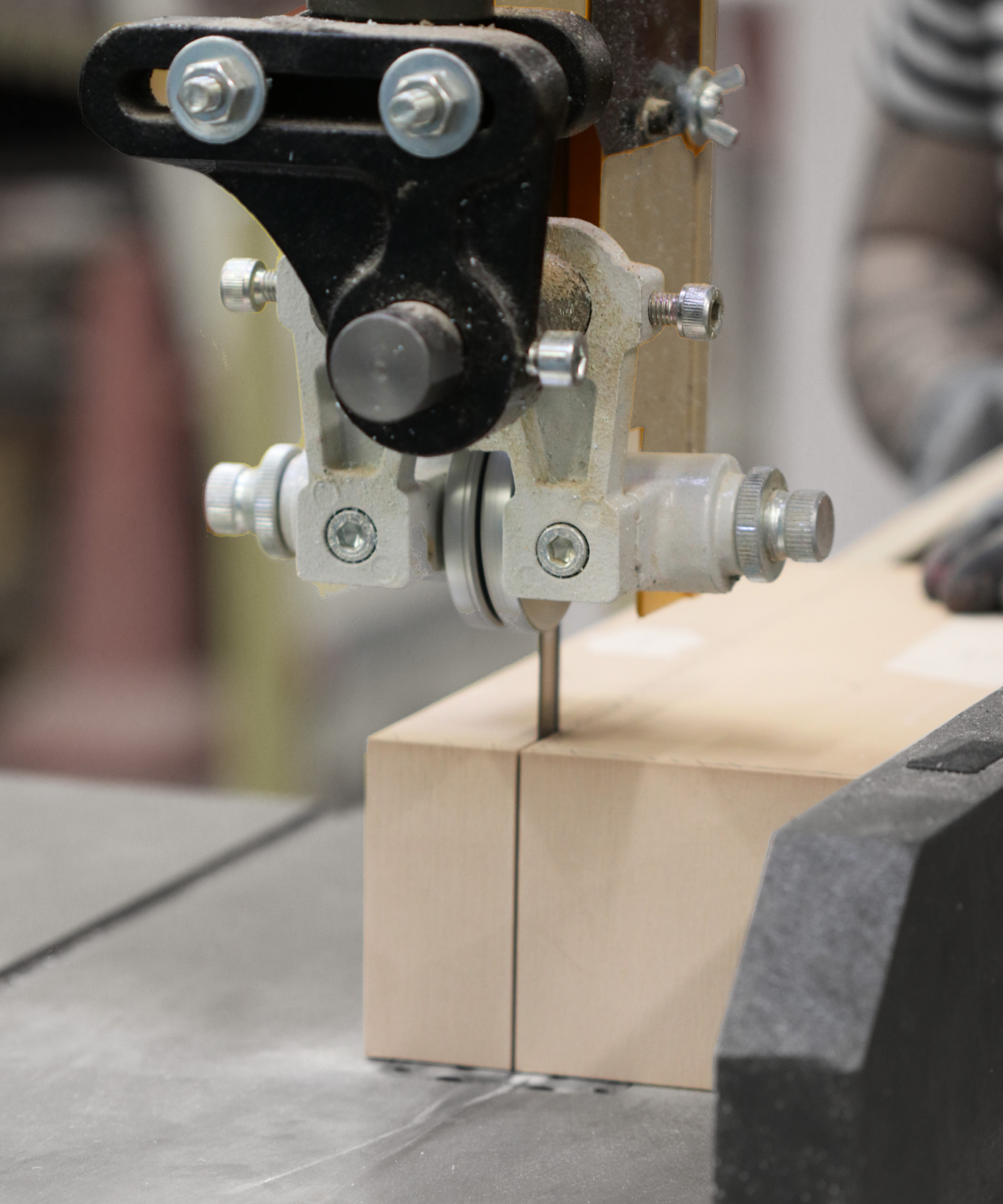
- STRUCTURE
- SKIN

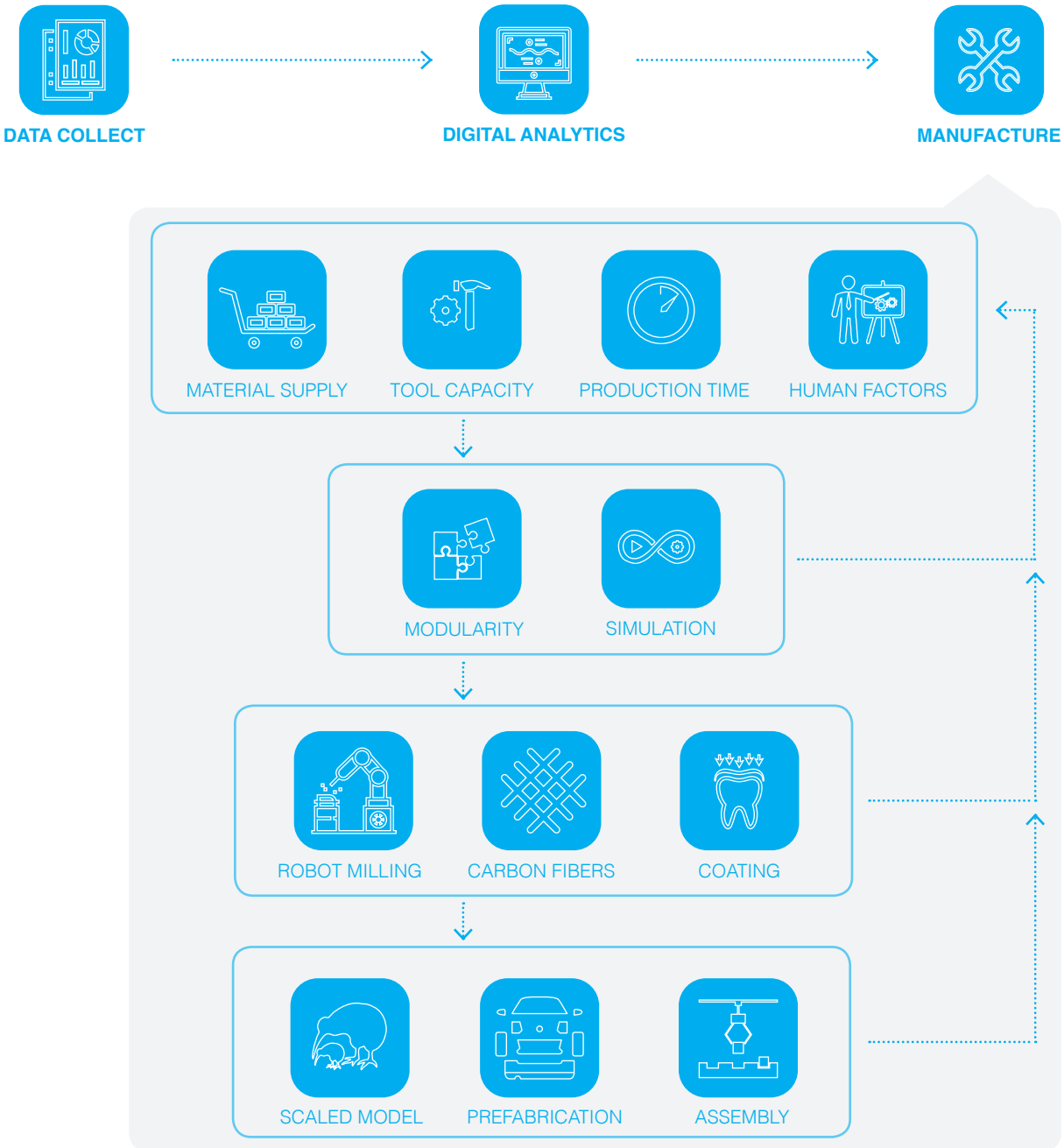
PERFORMANCE

- FUNCTION
- SPATIAL RESTRICTION
- CIRCULATION
- OCCUPATION


KUKA


DATA COLLECT
DIGITAL ANALYTICS
MANUFACTURE
SITE DATA INPUT
SITE PROCESS
OPTIMISATION
DESIGN DATA INPUT
DESIGN EVOLUTION
YES
?
NO
SIMULATION RESULTS
MATH MODEL DATA
STRUCTURE
MATERIAL DATA INPUT
GEOMETRIC VARIATION
DESIGN PROPOSAL



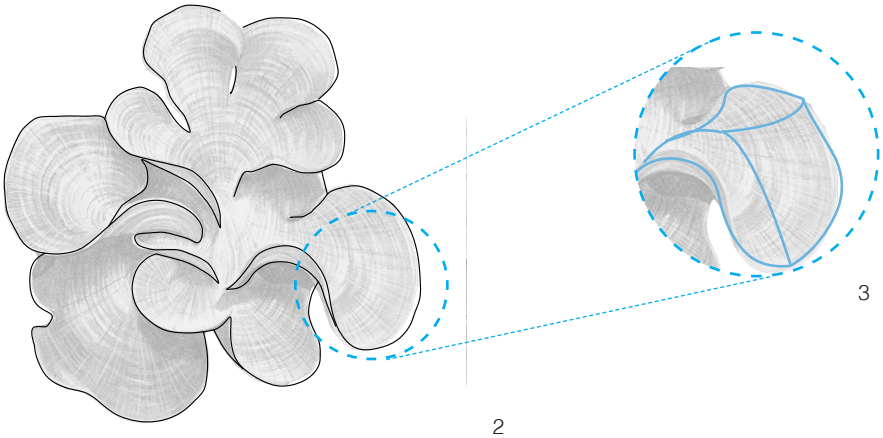

DATA COLLECT
DIGITAL ANALYTICS
MANUFACTURE
MATERIAL SUPPLY
TOOL CAPACITY
PRODUCTION TIME
HUMAN FACTORS
MODULARITY
SIMULATION
ROBOT MILLING
CARBON FIBERS
COATING
SCALED MODEL
PREFABRICATION
ASSEMBLY

Natural System

Information
Name: Padina Pavonica ‘Peacock’s Tail Algae’
Kingdom: Protista
Phyla: Heterokontophyta
Class: Phaeophyceae
Order: Dictyotales
Family: Dictyoptaceae
Genus: Padina
Species: P. pavonica(Linnaeus) Thiv
Location: North-east Atlantic European coast, South Atlantic, Indian and Pacific Oceans, and the Mediterranean.
Home: south coast of England and south coast of Ireland.
Habitat: pools on rocky shores of soft substrate, shallow infra-littoral.
Environment: clay, silt or sandy sediments.
Symmetry: Multiple rotations on a central point.

Features
Concave - almost funnel-shaped frond.
Frond thin with irregular lobed margin.
Upper surface has a thin layer of slime.
Lower surface banded with zones of brown and green.
Concentric lines of small fine hairs on lower surface
Dimensions: 22cm high X 37 cm wide.
Saddle surface blades size:12 cm, varying of size and symmetry.
Symmetry: Multiple rotations on a central point.



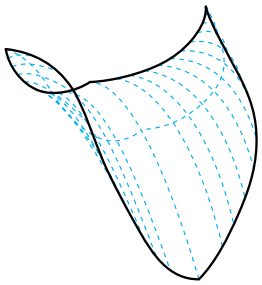


3

2



1



4

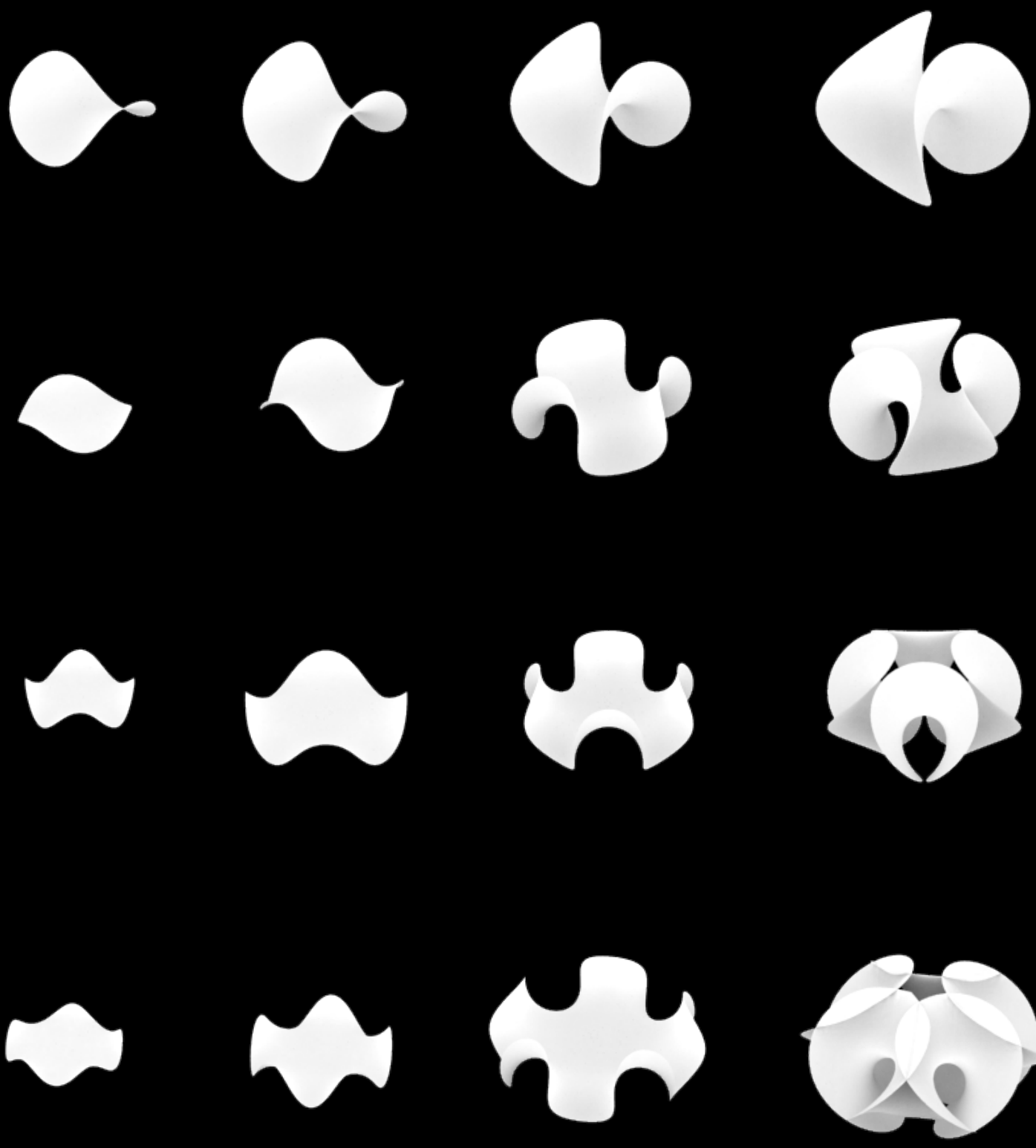


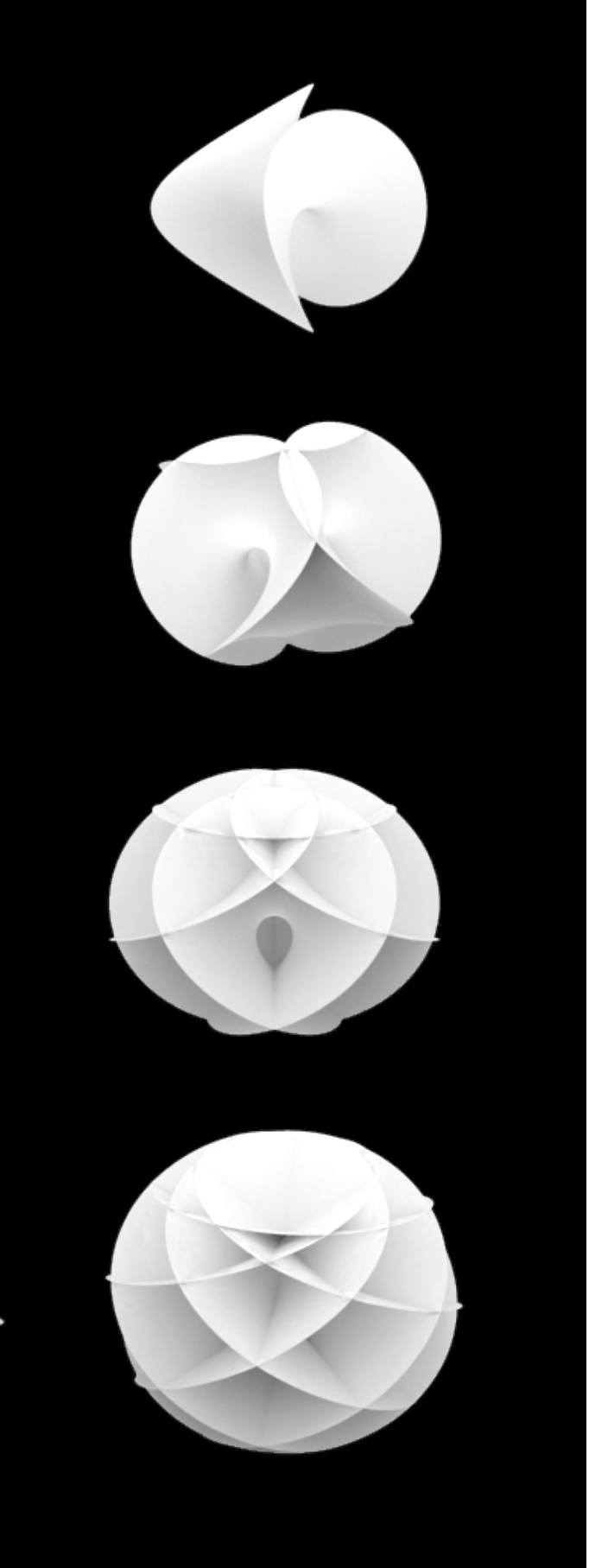
1
Drawing depiction of the peacock tail algae in its habitat.

2
Proportion study of the algae plant with its sizes.

3
Geometry study of a single piece of folding leaf of the algae plant

4
Geometry analysis of the concave shape of the leaf.





Left

Exponential evolution of the geometry to mimic the growth pattern of the peacock tail algae.

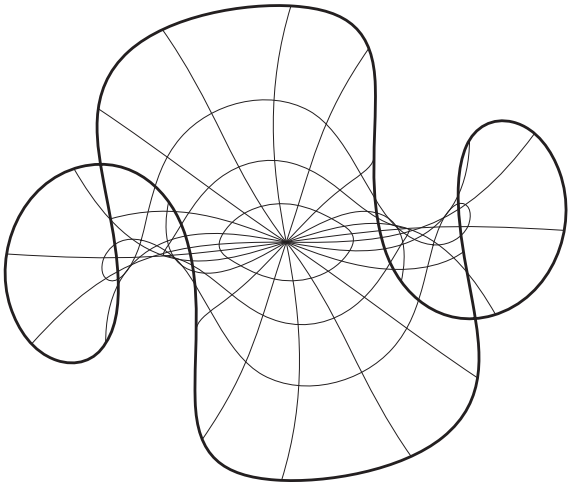
Geometry Development

Minimal surface is a surface that locally minimizes its area. It can be produced by dipping wire frame in soap water to create bubbles. The surface has the advantages of optimizing maximum strength with minimal amount of materials. In soap bubbles, this was achieved due to the surface tension excreted by molecules inside the liquid solution.

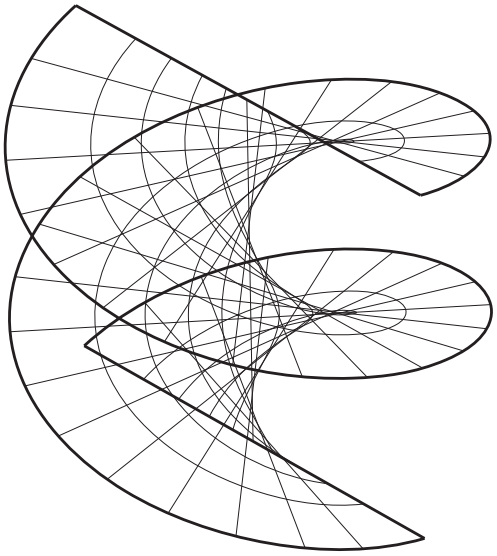
The math concept of minimal surface theory has rapidly evolved recently. Many examples are constructed and altered. Minimal area property makes this surface suitable for application in architecture. The surface minimizes surface tensions and Frei Otto brought this studies up to construction with tensile structures.
To certain extend It could be argued that this type of architecture is an application of big data as the it is impossible to achieve without complex data collection and analysis. There are many different types of Minimal surfaces with different characteristics.

The project will focus on Enneper surface due to its symmetrical characteristic and similarity to Hyperbolic Paraboloid which was explored in a previous project.

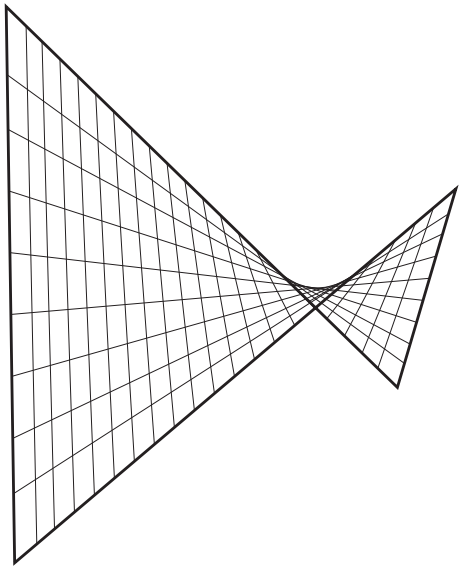
Mathematic formula is used to mimic the growth pattern of the peacock tail algae by generating input value exponentially. As the value increases, the reconstructed geometry will become more complex and larger in size.



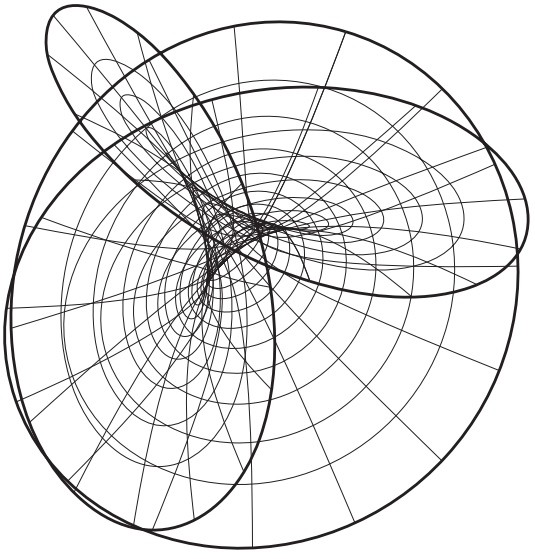
Enneper Surface



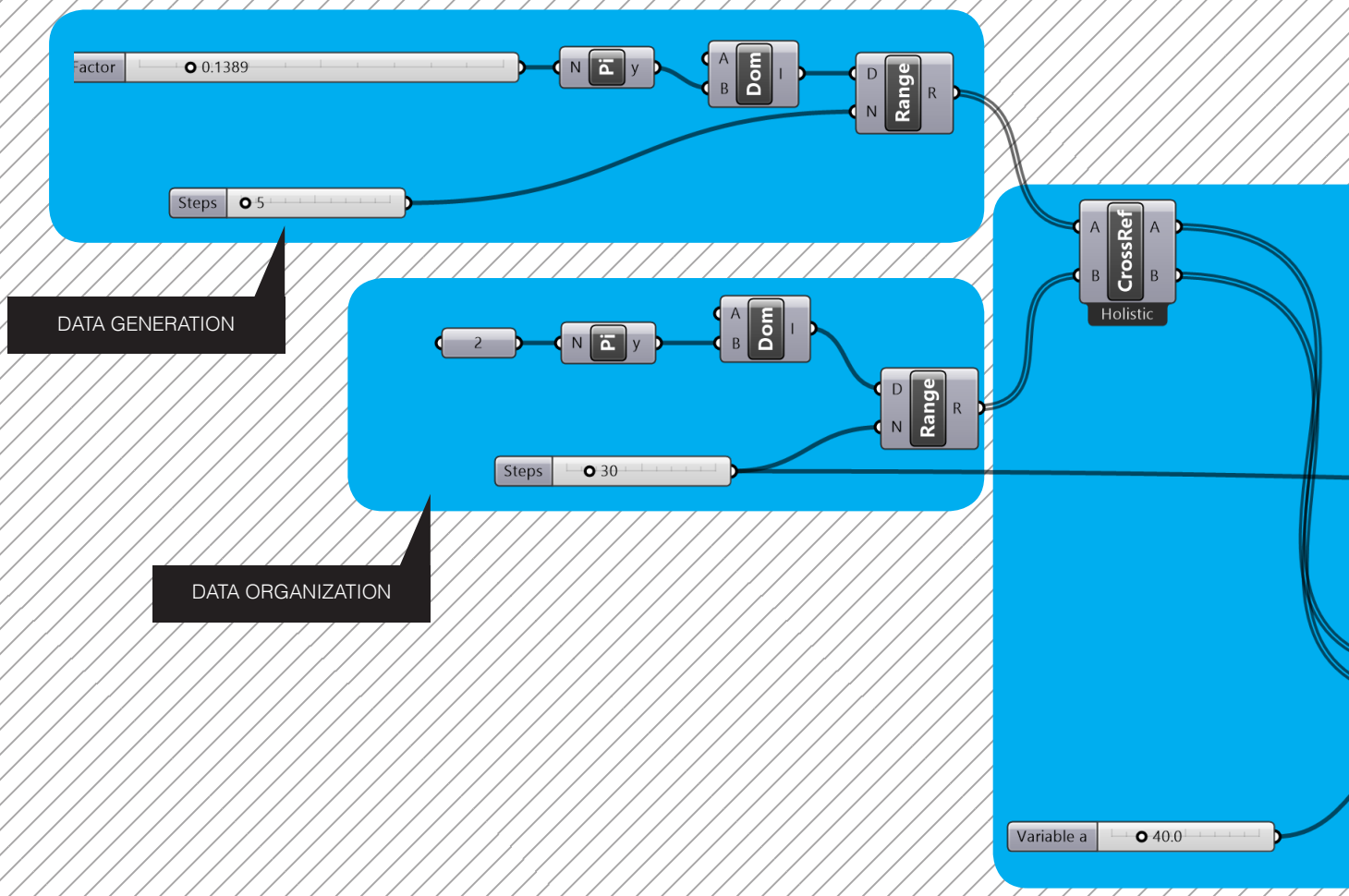
Helicoid Catenoid



Hyperbolic Paraboloid



Henneberg


Factor
0.1389
N
Pi
y
A
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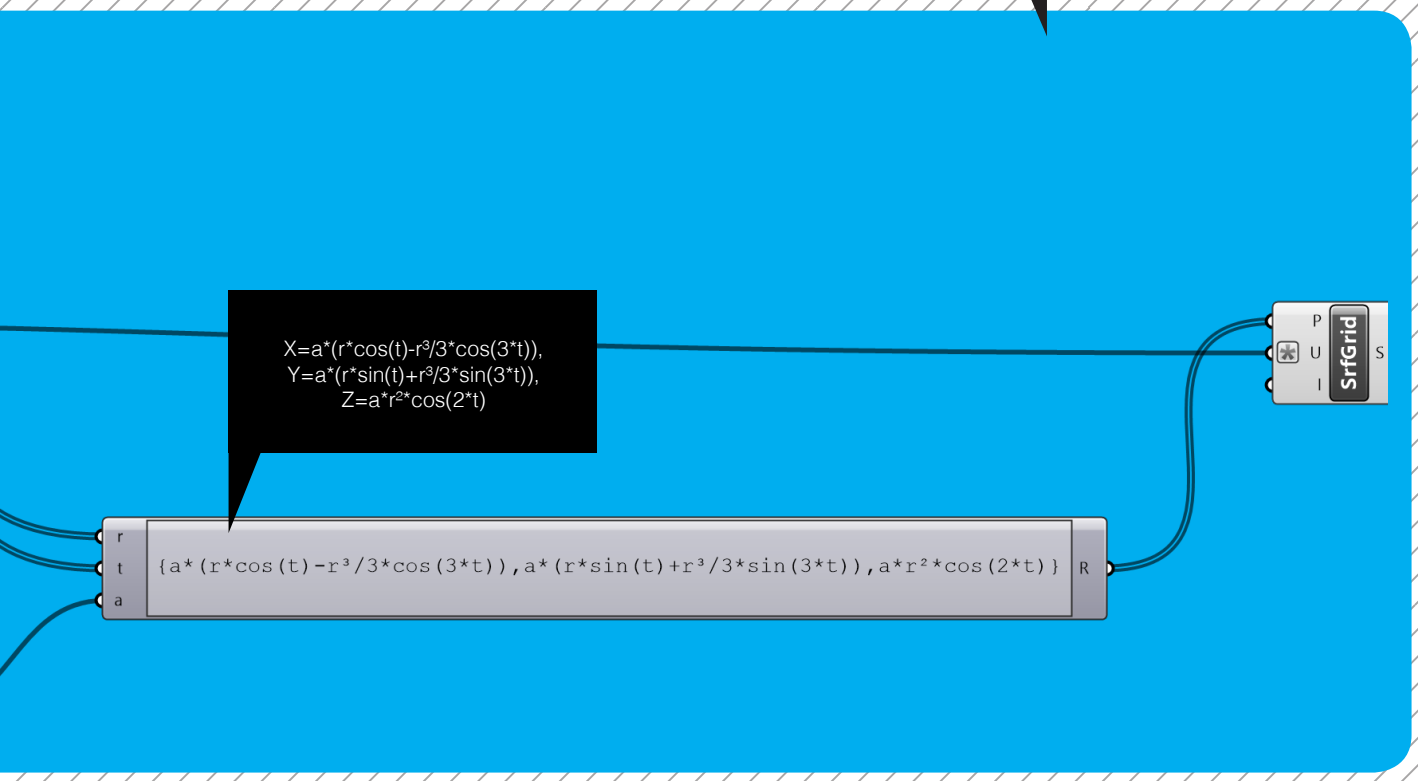
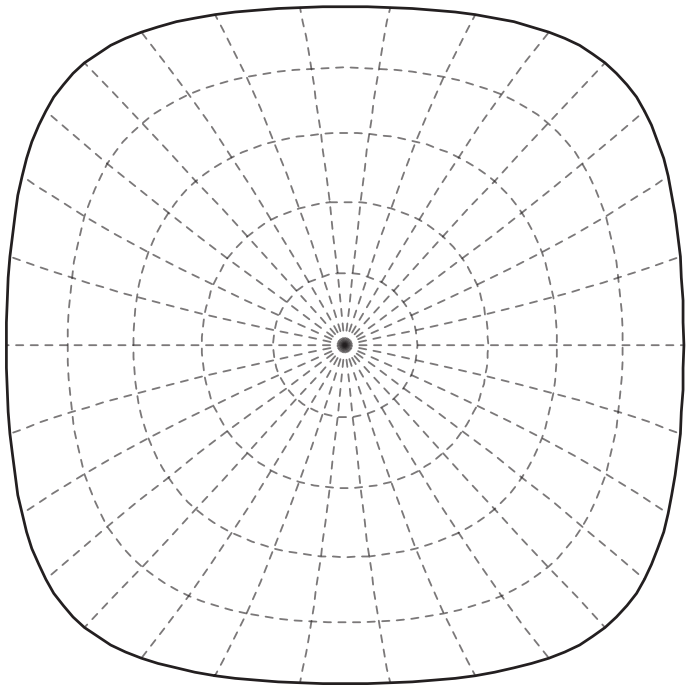
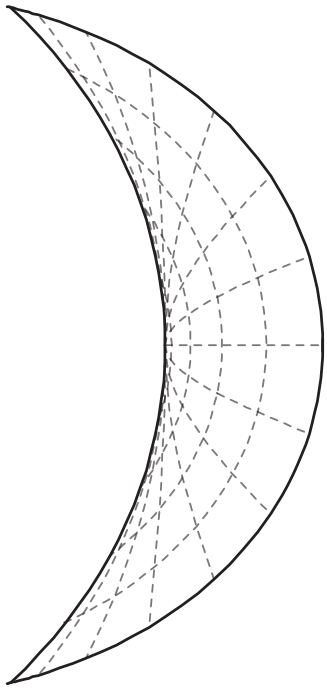
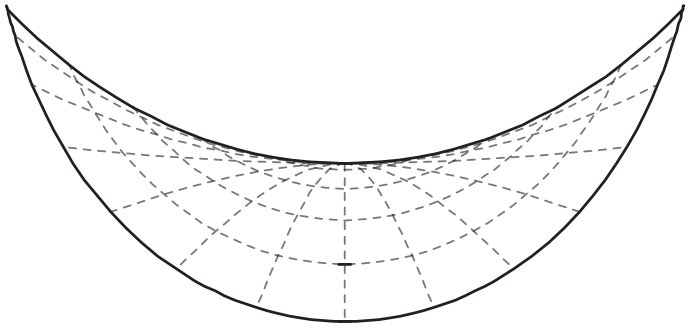
Dom
I
D
N
Range
R
Steps
5
DATA GENERATION
2
N
Pi
y
A
B
Dom
I
D
N
Range
R
Steps
30
DATA ORGANIZATION
A
B
CrossRef
A
B
Holistic
Variable a
40.0

GEOMETRY FORMATION









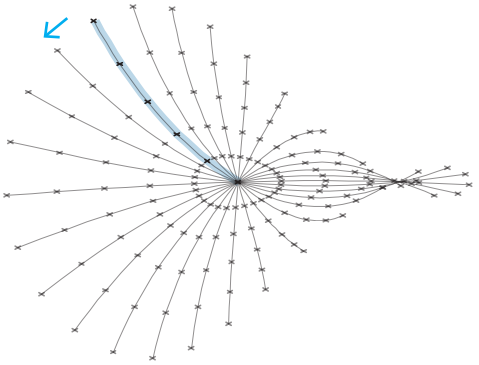
Surface Formation

Wire-frame top view, side view and front view of the generative Enneper surface.

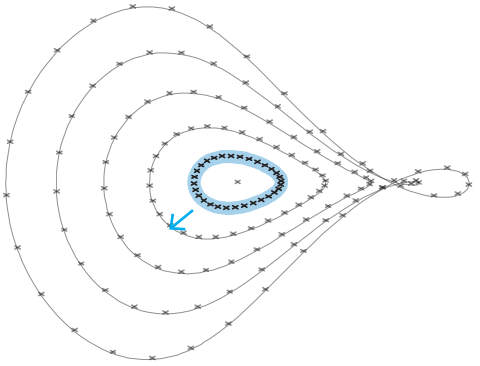
1
Generate 186 points organized into 30 columns with 5 points each.

2
Establish 5 rows of points accordingly.

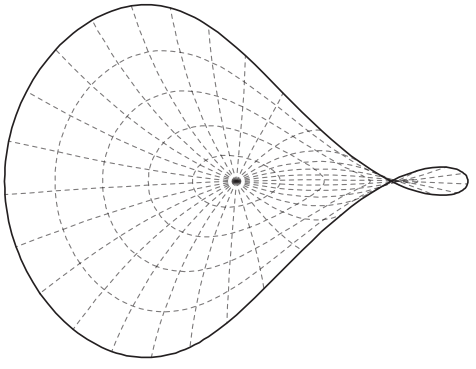
3
Loft point clusters into a surface.



1



2



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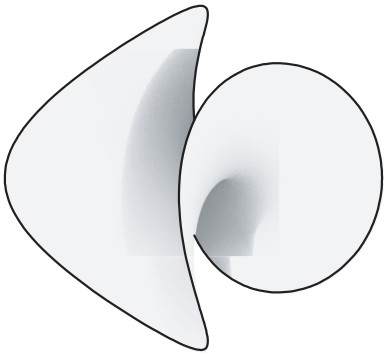
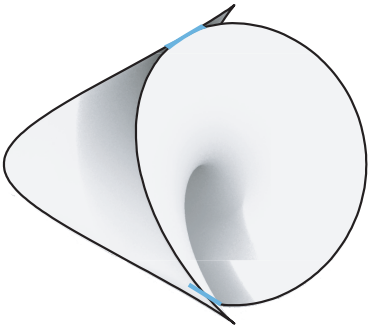


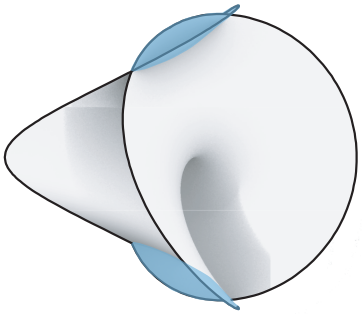
1

Scenario 1	Normal
A1	0.4
State	Self stand
Area/mm^2	27,068



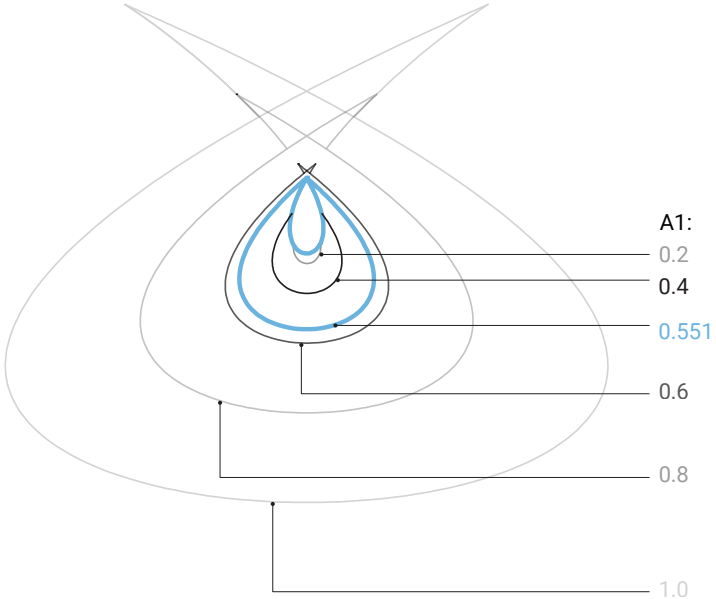
2

Scenario 2	Transit
A1	0.5513
State	Self-touch
Area/mm^2	105,521



3

Scenario 3	Intersect
A1	0.5513
State	Self-intersect
Area/mm^2	156,453



4

Surface deformation

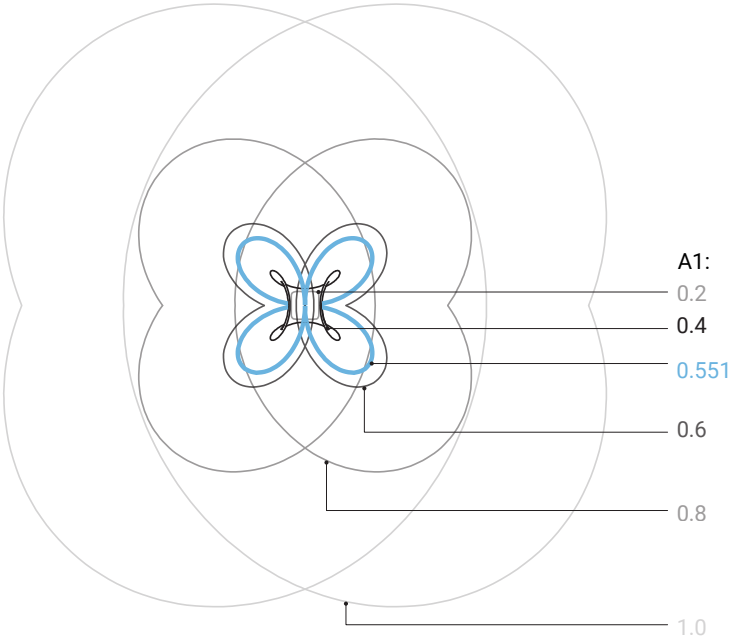
1
Surface self stand

2
Surface self touch

3
Surface self intersect.

4
Size chart front

5
Size chart top



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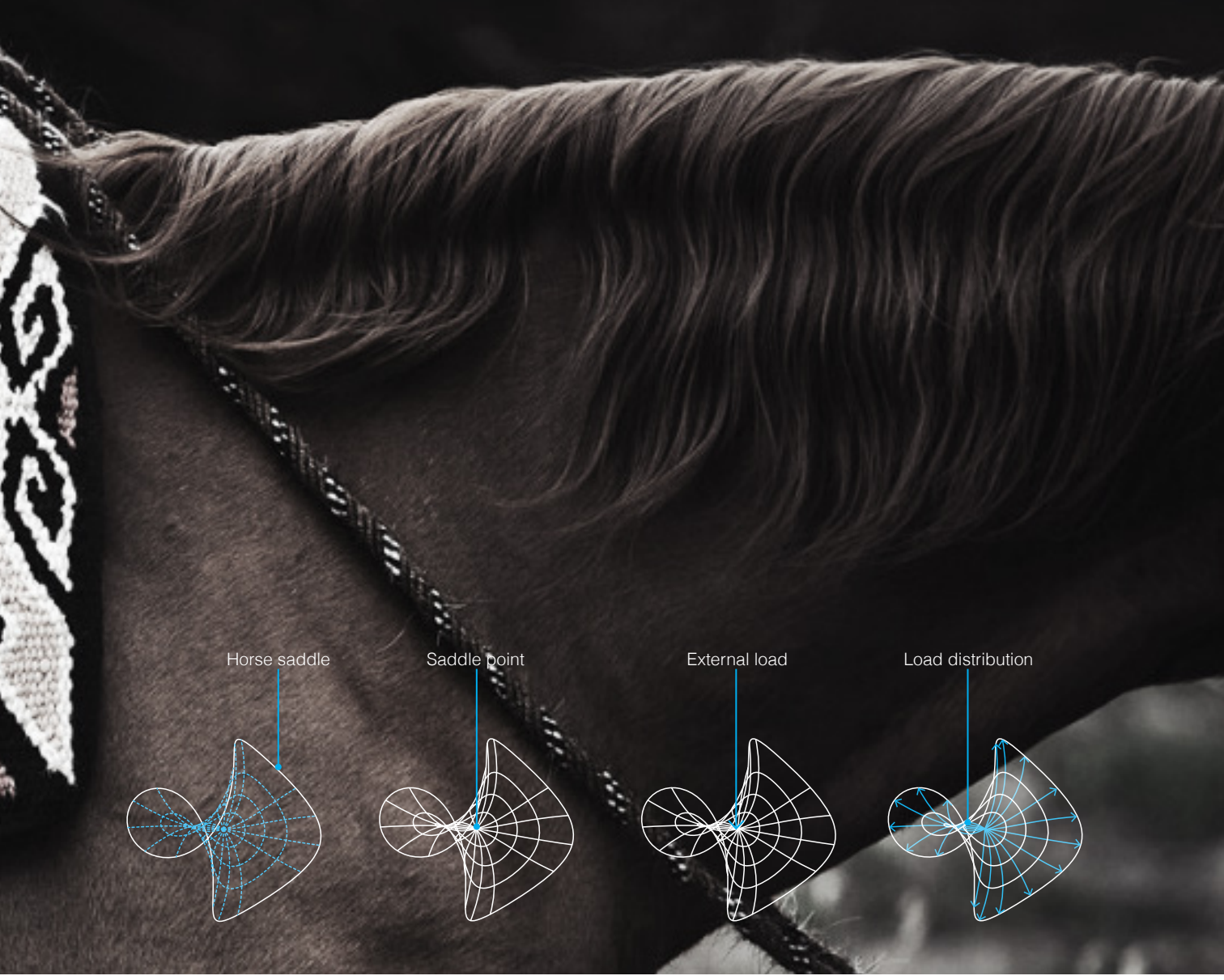


Real Life Example

Horse Saddle is a real life example of the Enneper surface application.

Diagrams

The saddle point in enneper is a point on a curve surface that goes completely flat. It is located in the center of the geometry where all the slope line meets. As the slope conducts the load that distributed evenly through out the entire surface, giving the saddle with optimized strength.


Seam stitches
Pulling fabrics
1
2
Pre stressed ball
1
2

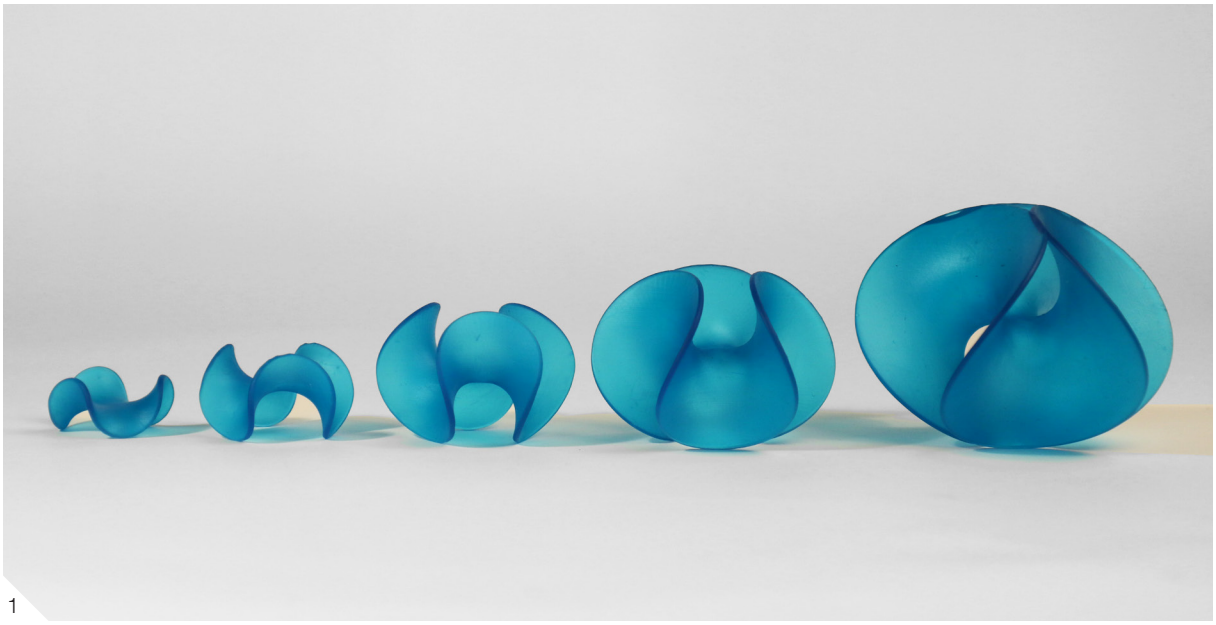


Real life example

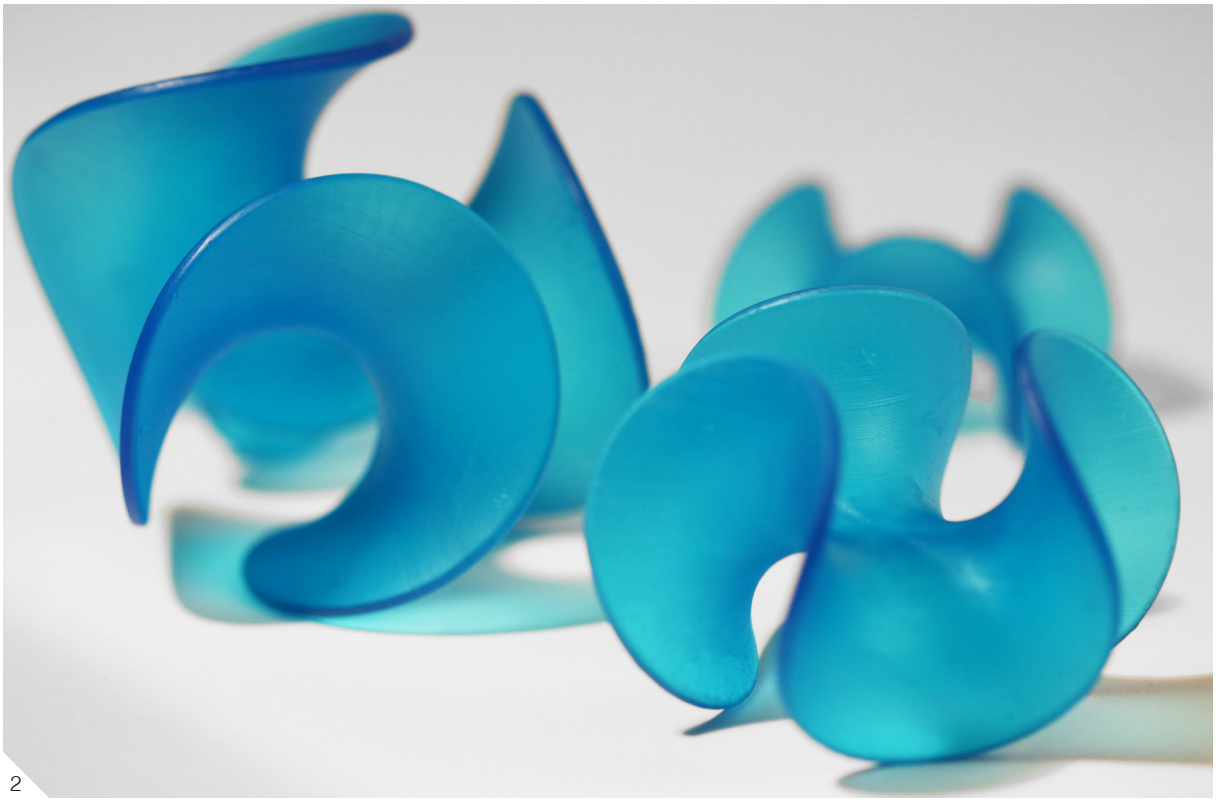
Tennis ball is another real life application of Enneper surface. The stitches on the ball Follows the outline of an Enneper surface.

Diagram

The ball is made of two flat pieces (1 and 2) of peanut shaped materials, which are stretched to form the spherical shape. Therefore the ball is in a per-stressed tension state with optimized strength.



1



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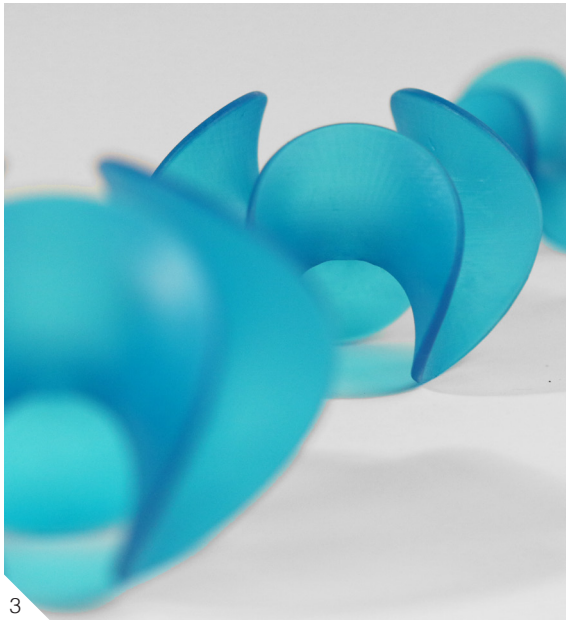


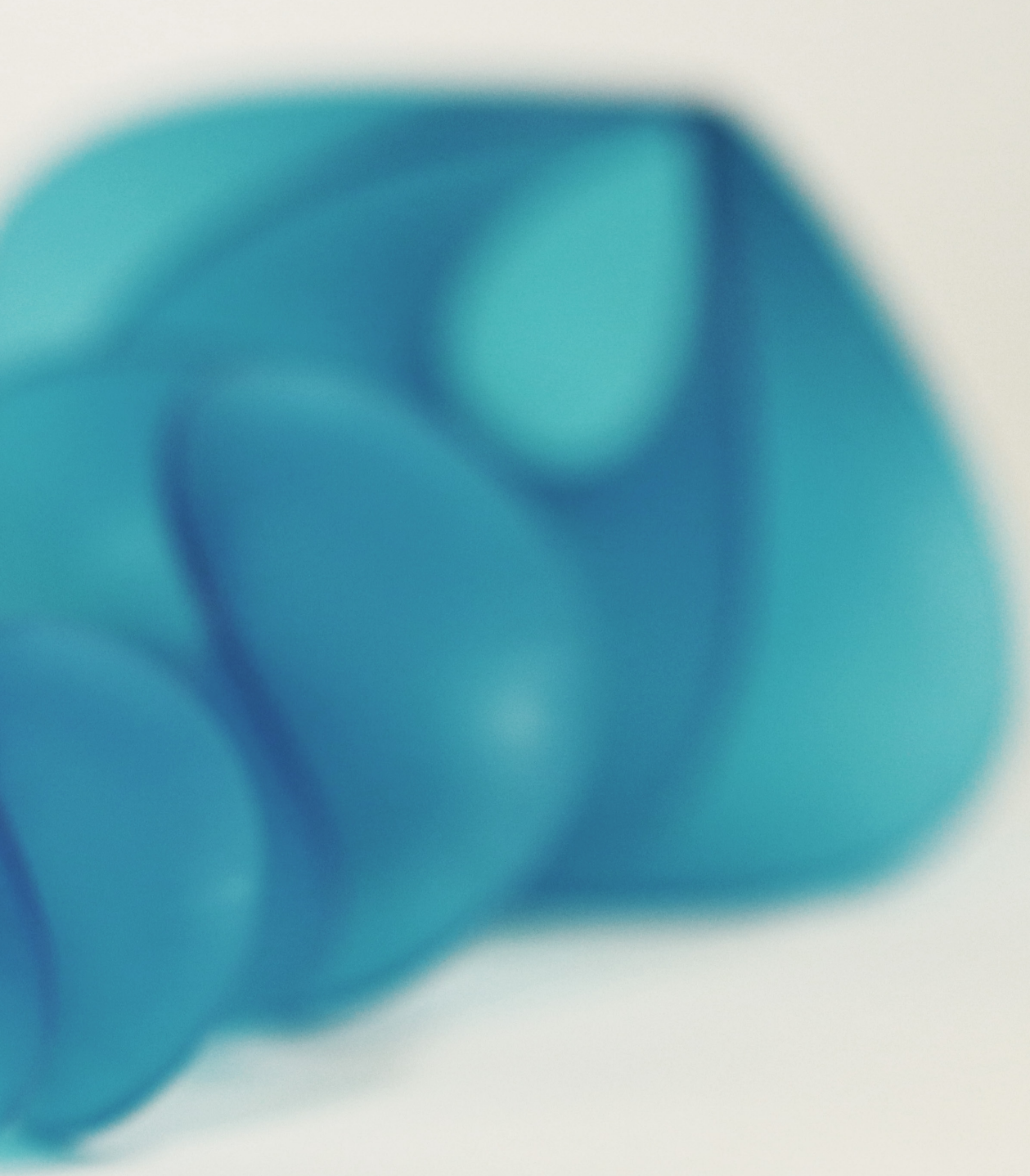
3



4

1-4
SLA 3D printed models from generative algorithm developed from Enneper surface.





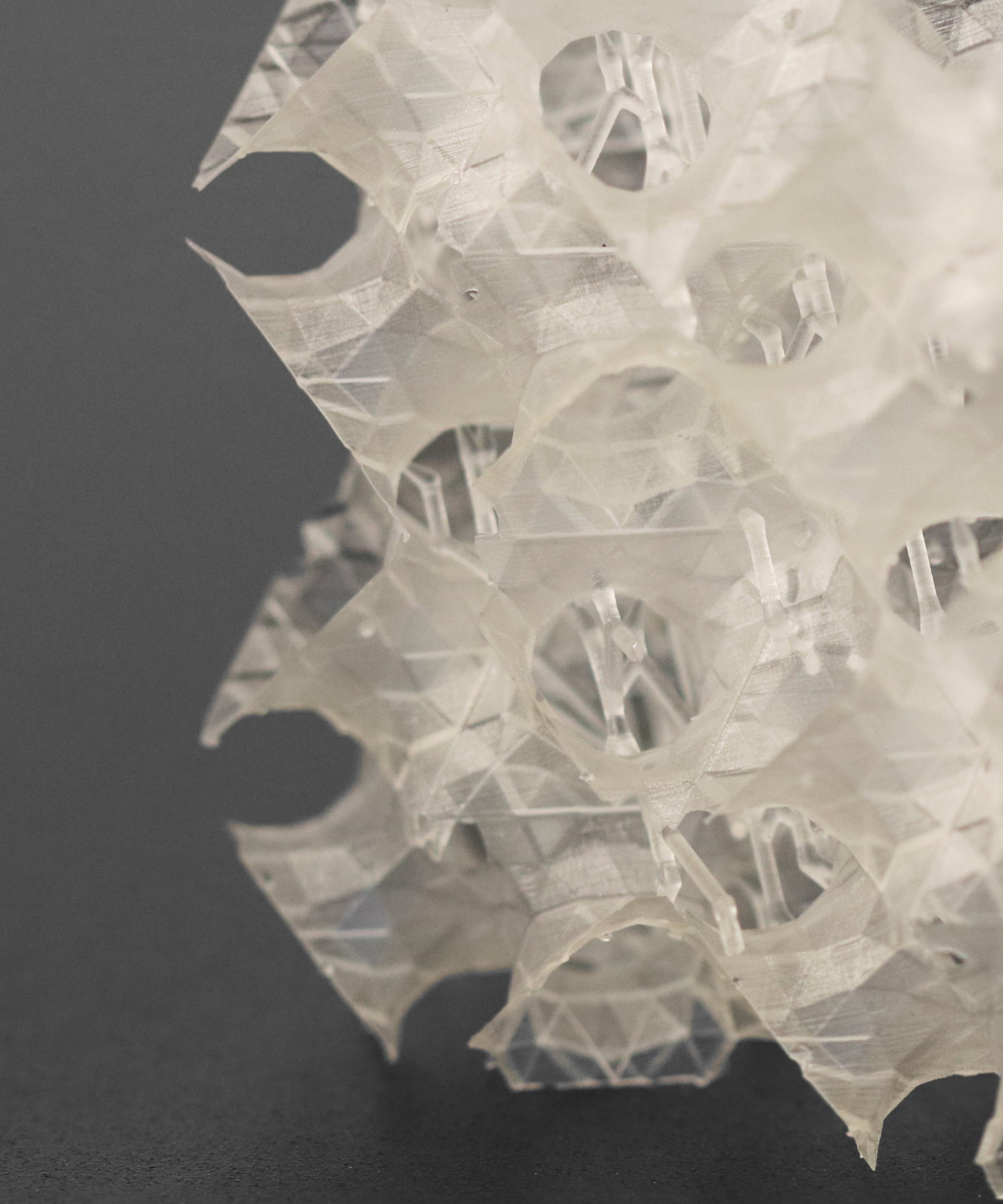
Optimization Theory

The optimization algorithm is developed on the basis of principle stress/strain theory.

Principal stress lines are numerical integration of principal stress directions over a structural body. Designers are interested in principal stress lines because they provide a visualization of the natural force flow of an applied load on the system, which shows the lines of desirable material continuity for a given design domain.
Rotating the element, the state of stress will remain unchanged, but the stress components will correspond to the transformed orientation.

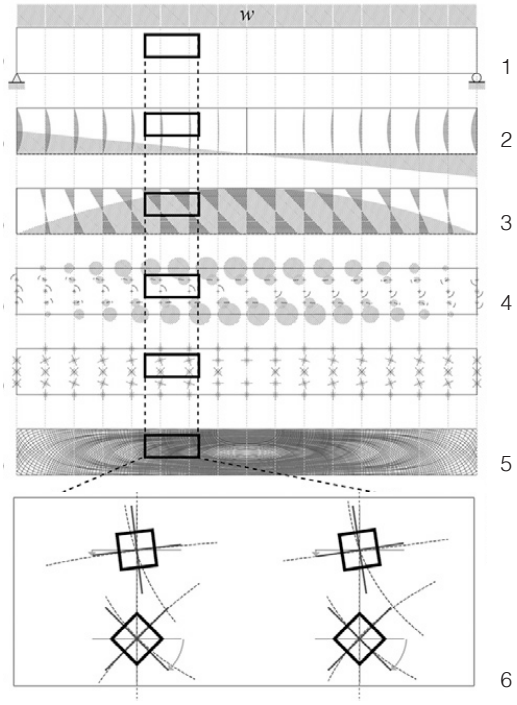
Principal stress directions are the normal stress components corresponding to the element orientation in which the shear stress is zero and normal stresses are maximum. Having determined the principal stress directions for various points across a structural body, these vectors are projected, or integrated, as lines that form the principal stress lines.
Principal stress lines will indicate trajectories of internal forces and, therefore, idealized paths of material continuity, naturally encode the optimal topology for any structure for a given set of boundary conditions.

Karamba, an algorithmic program is used to conduct this study. The program is a big data analytics engine which will calculate mass amount of data in the physical load with preset parameters. The findings and application of Karamba will be used for this project.





1 2 3



Top

Figure 1 to 3 as method evolution
1. Michell Cantilever
2. Ground structure
3. stress-line optimization

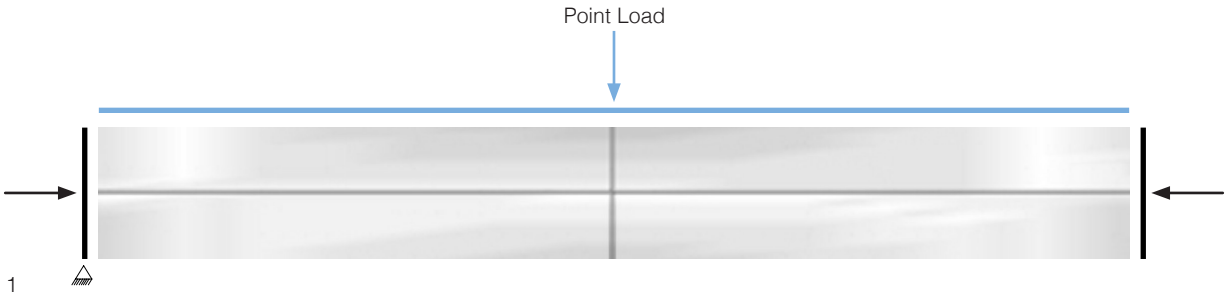
Left

1. Shear stress
2. Bending stress iii: Mohr circle
4. Reoriented stress direction
5. Principal stress
6. Plane reorientation

Next Page Top

1 and 2; set up vs result

Next Page Bottom
1 to 5 angle of deviation percentage



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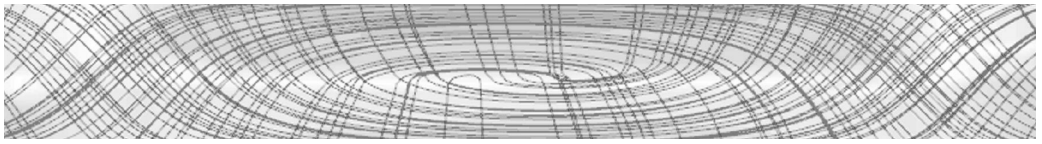

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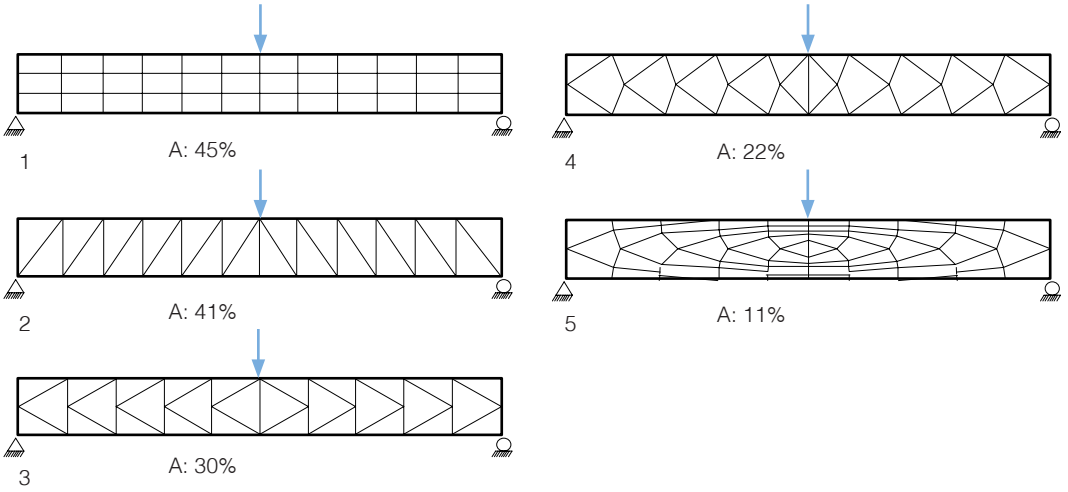
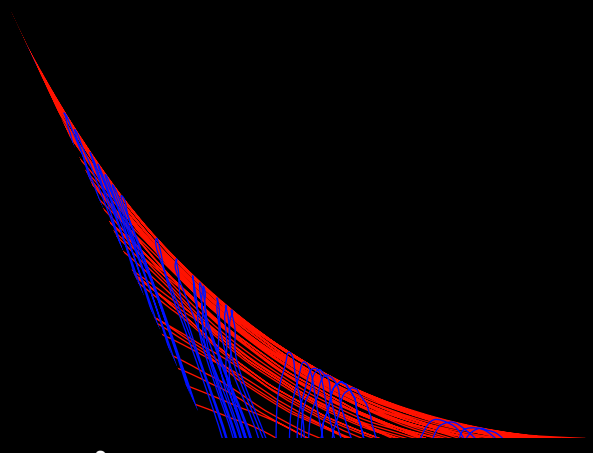


NATURAL SYSTEM → MATERIAL STUDY → DIGITAL ANALYTICS →



1



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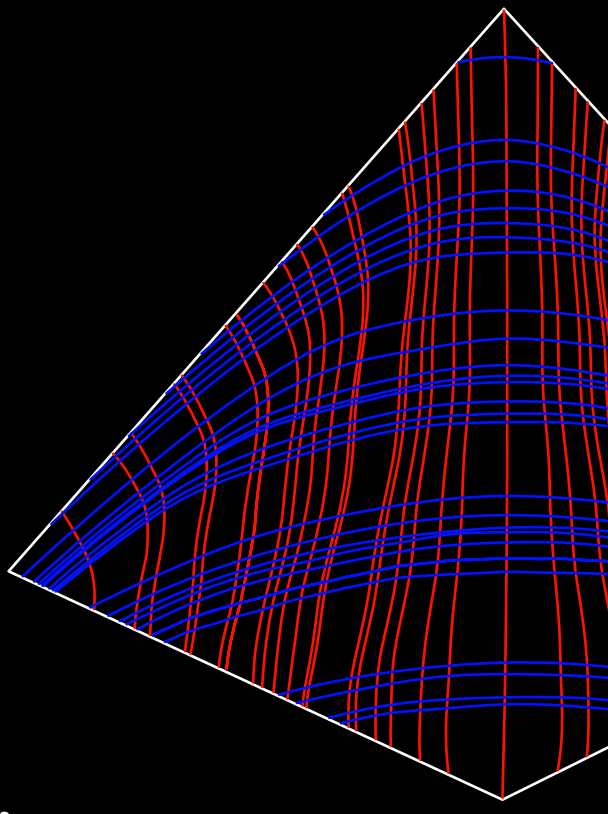

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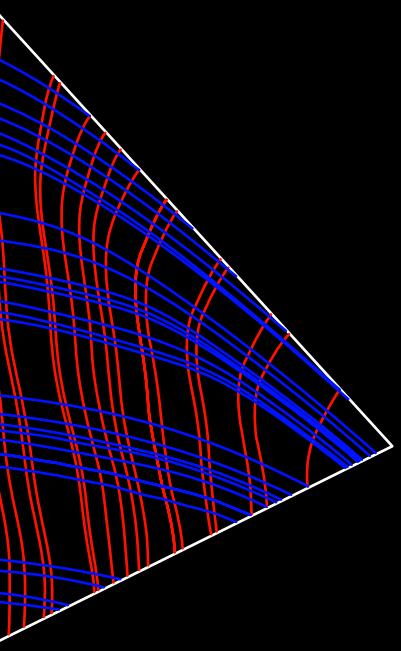


Diagram Top Left

Logic process from prerequisite project. Natural system take inspiration from plant analysis

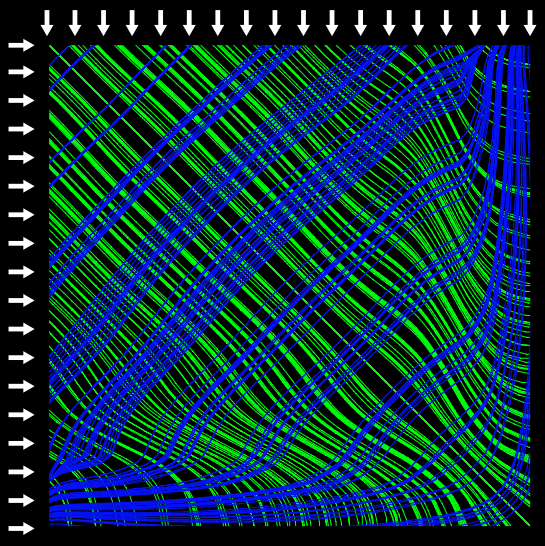
Material study exploration and development take inspiration from scientific analysis.

1. Study of physical model.

2. Side view of digital model reconstruction with help of Karamba algorithms. Blue and red lines indicate two stress directions.

3. Front view of digital model reconstruction with help of Karamba algorithms. Blue and red lines indicate two stress directions.

NATURAL SYSTEM → MATERIAL STUDY → DIGITAL ANALYTICS →



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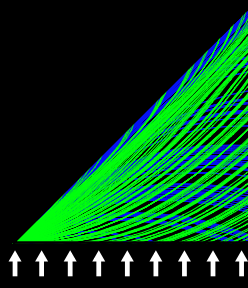

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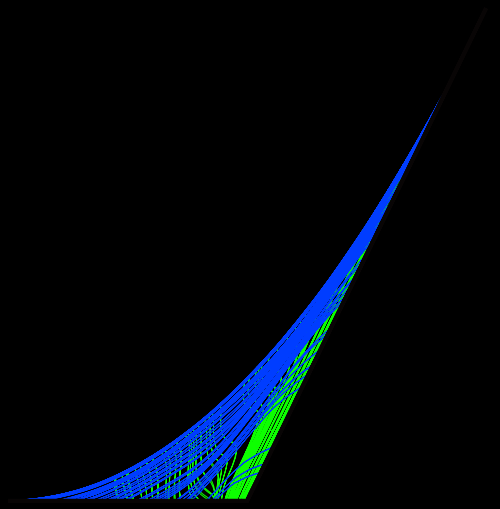

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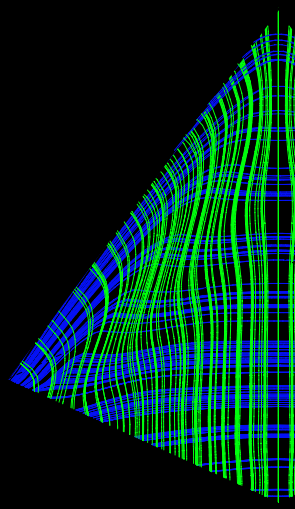

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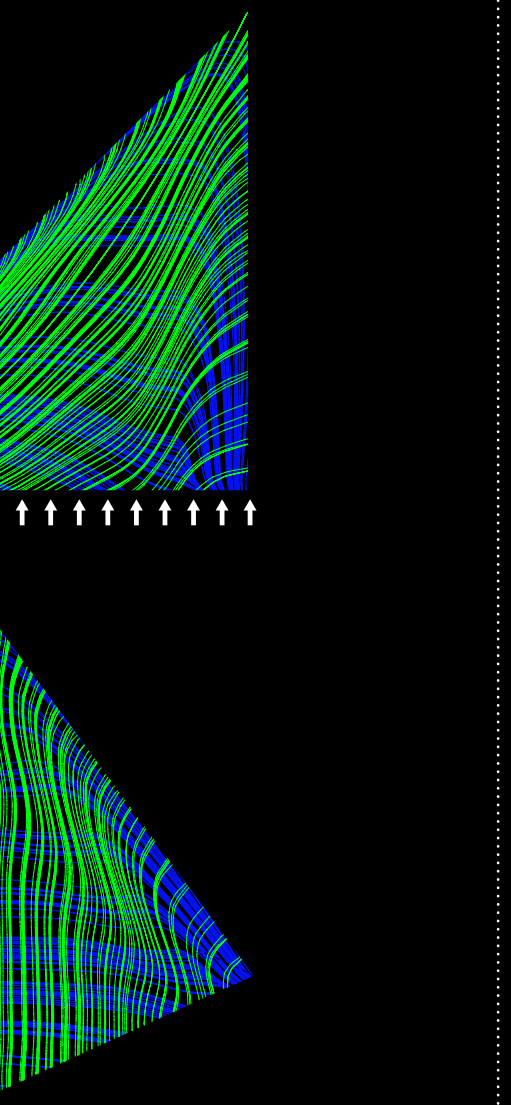


Diagram Top Left

Logic process from pre-requisite project.

Karamba stress analysis with known forces to recreate condition of the physical model.

1. Plan view of blue and green lines indicate two stress directions of load distribution.

2. 45° view of blue and green lines indicate two stress directions of load distribution.

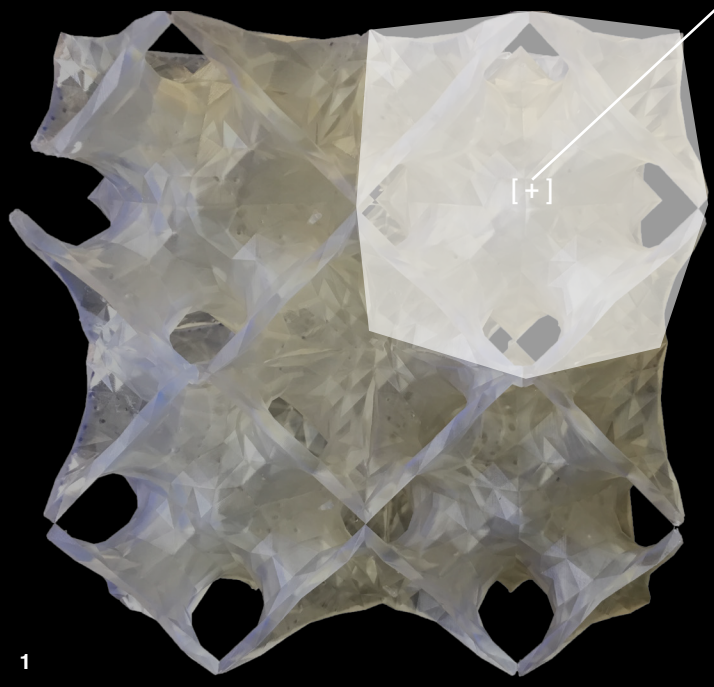
3. Side view of blue and green lines indicate two stress directions of load distribution.

4. Isometric view of blue and green lines indicate two stress directions of load distribution.

NATURAL SYSTEM

MATERIAL STUDY

DIGITAL ANALYTICS



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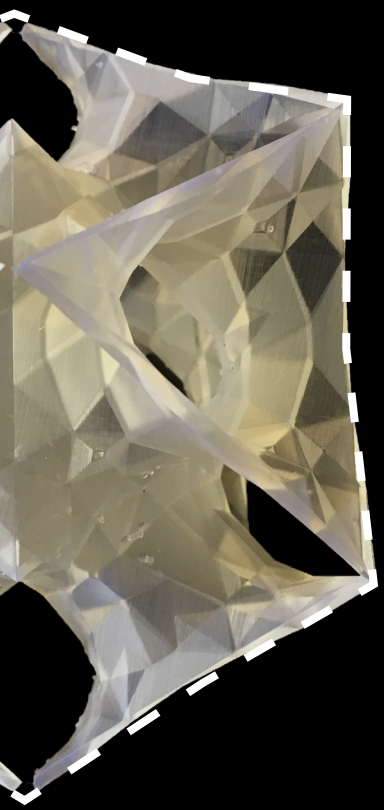


Diagram Top Left

Logic process from pre-requisite project. The process is still on going and this is the work in progress result.

Prototypes were developed to explore architectural and application of the result.

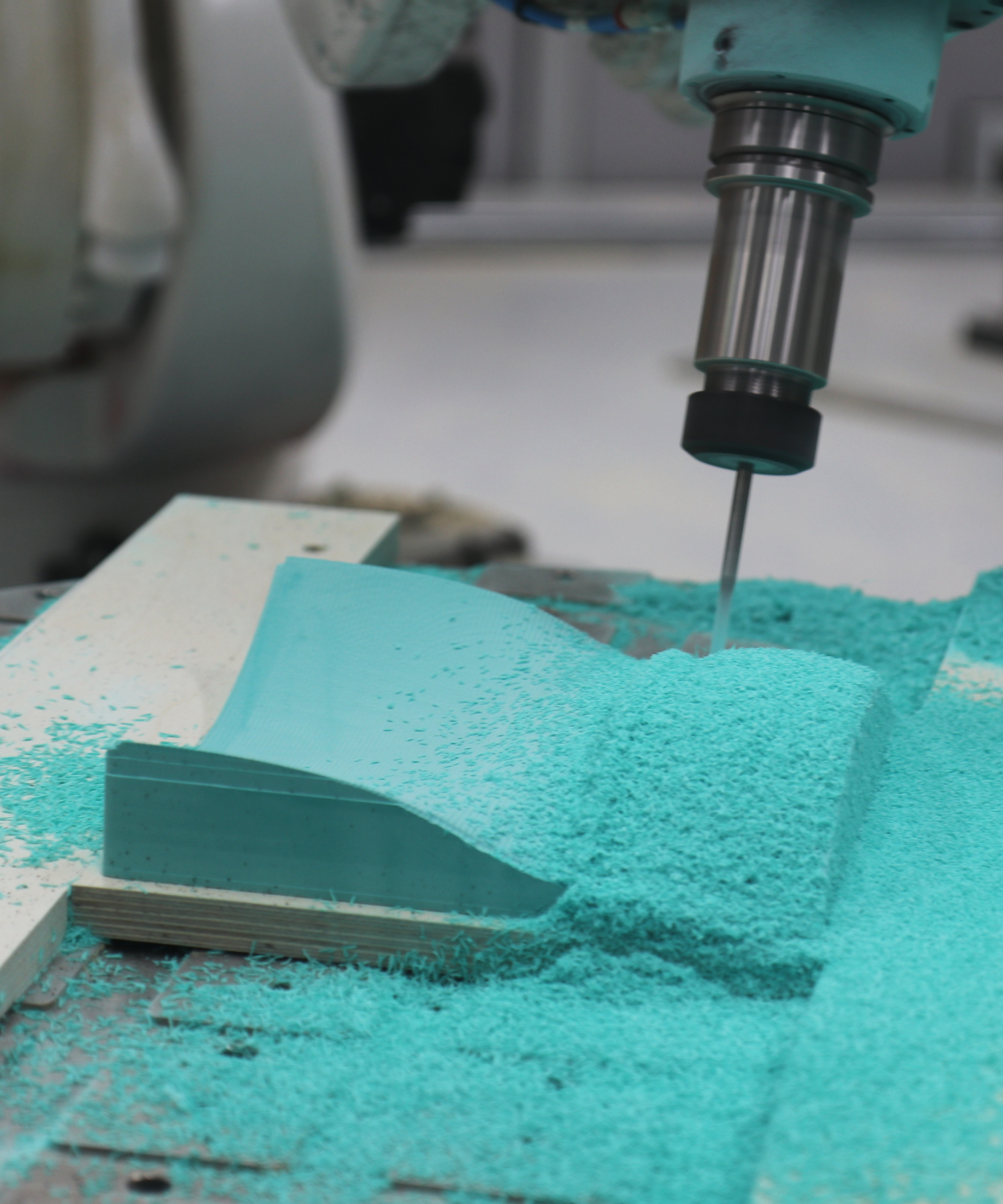
1. SLA 3D printed model of the prototype. The prototype combines a series generated result geometry.

2. SLA 3D printed prototype of one standard unit of the geometric component. This model has a larger scale.



MATERIAL

#Material Research #Material Behavior #Composite construction



Carbon Fiber

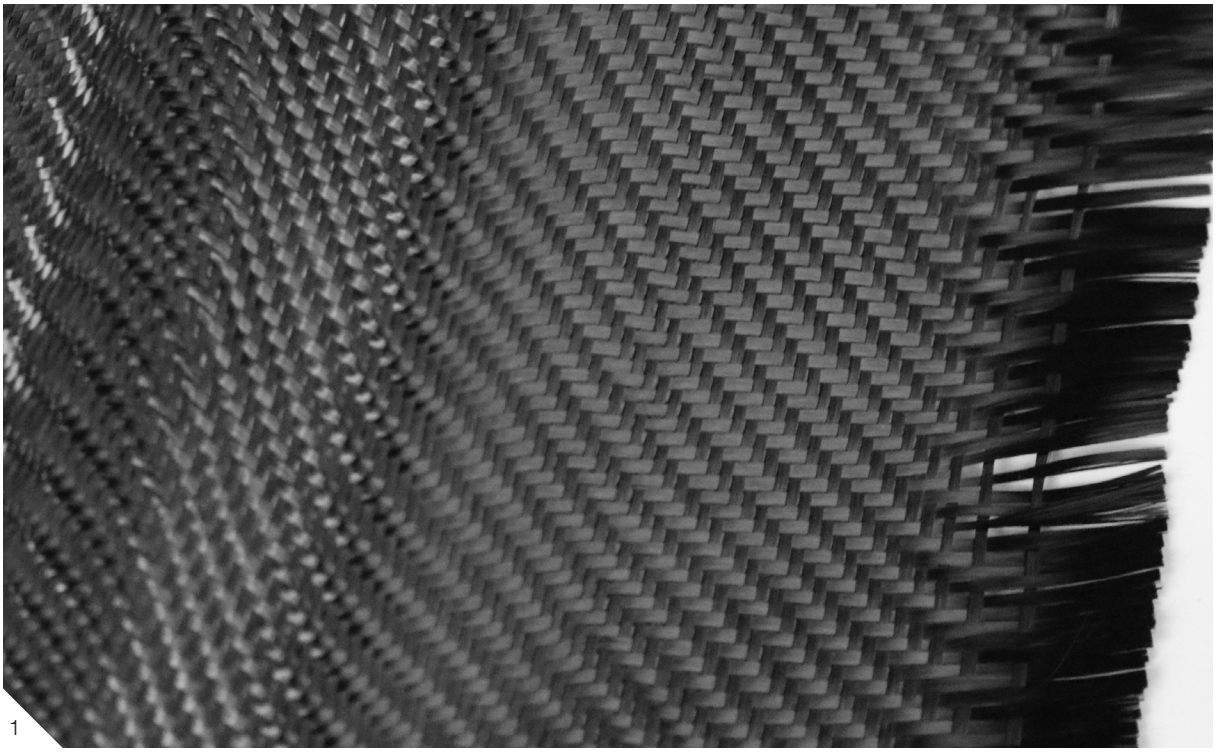
Carbon fibers (alternatively CF, graphite fiber or graphite fiber) are fibers about 5–10 micrometers in diameter and composed mostly of carbon atoms. Carbon fibers have several advantages including high stiffness, high tensile strength, low weight, high chemical resistance, high temperature tolerance and low thermal expansion. These properties have made carbon fiber very popular in aerospace, civil engineering, military, and motor-sports, along with other competition sports. However, they are relatively expensive when compared with similar fibers, such as glass fibers or plastic fibers.

To explore the potential in architecture and construction, the research will look at conventional fibers and sheets. To compare with traditional material such as wood and steel, carbon fiber has higher strength and ye retained lighter weight.

The research will also explore the use of digital design and robotic fabrication in conjunction with material research. The intention is to use the composite material in a smart way to reach an optimized outcome where the structural property is maximum and yet the cost and amount of material is at minimum.

Karamba Analytic program is used to carry out optimization study which will develop a suitable strategy that is unique for carbon fiber material.





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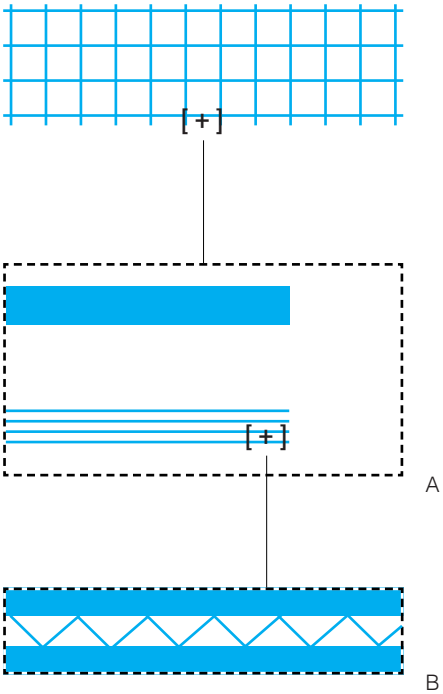
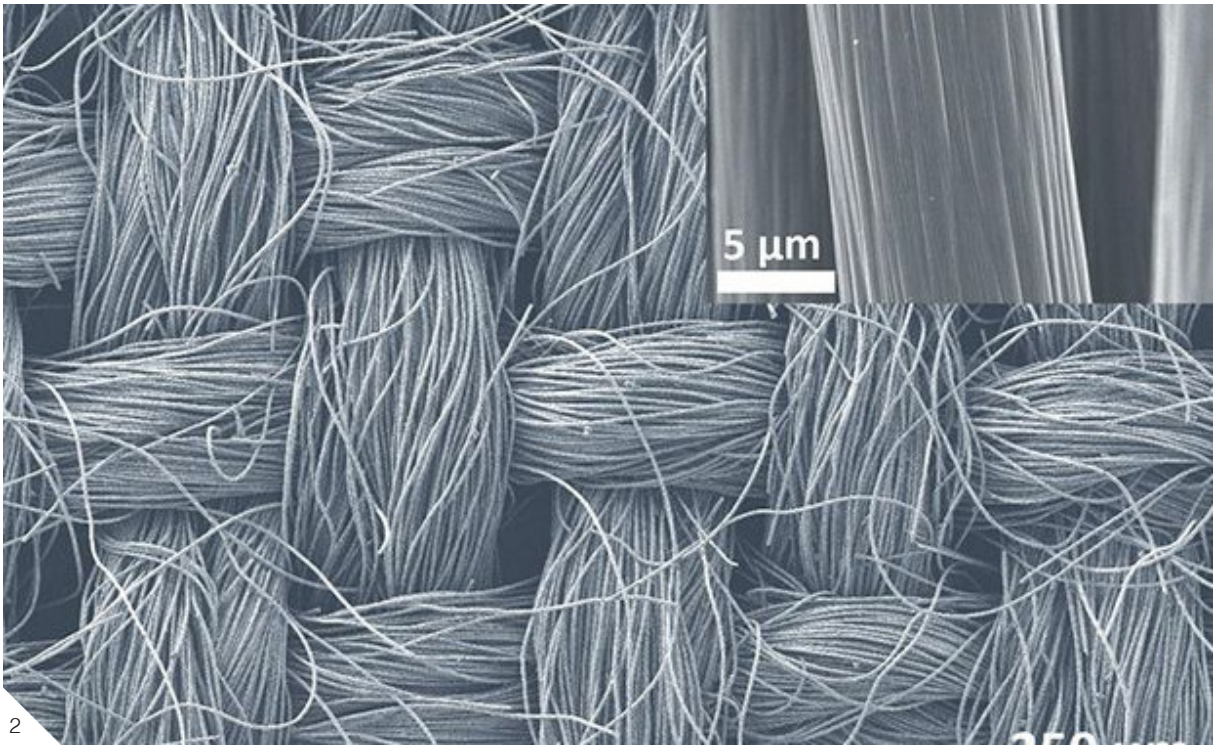


1
A sheet of carbon fiber commonly used industrially. a sheet consists of thousands of strands weaved together

2
a Microscopic view of the carbon fiber sheets.

3
a Microscopic view of a strand of carbon fiber at its end.
A
A strand of carbon fiber consists of many individual carbon fiber.

B
Between each individual fiber, it is commonly bonded together with small amount of chemical glue such as epoxy resin.



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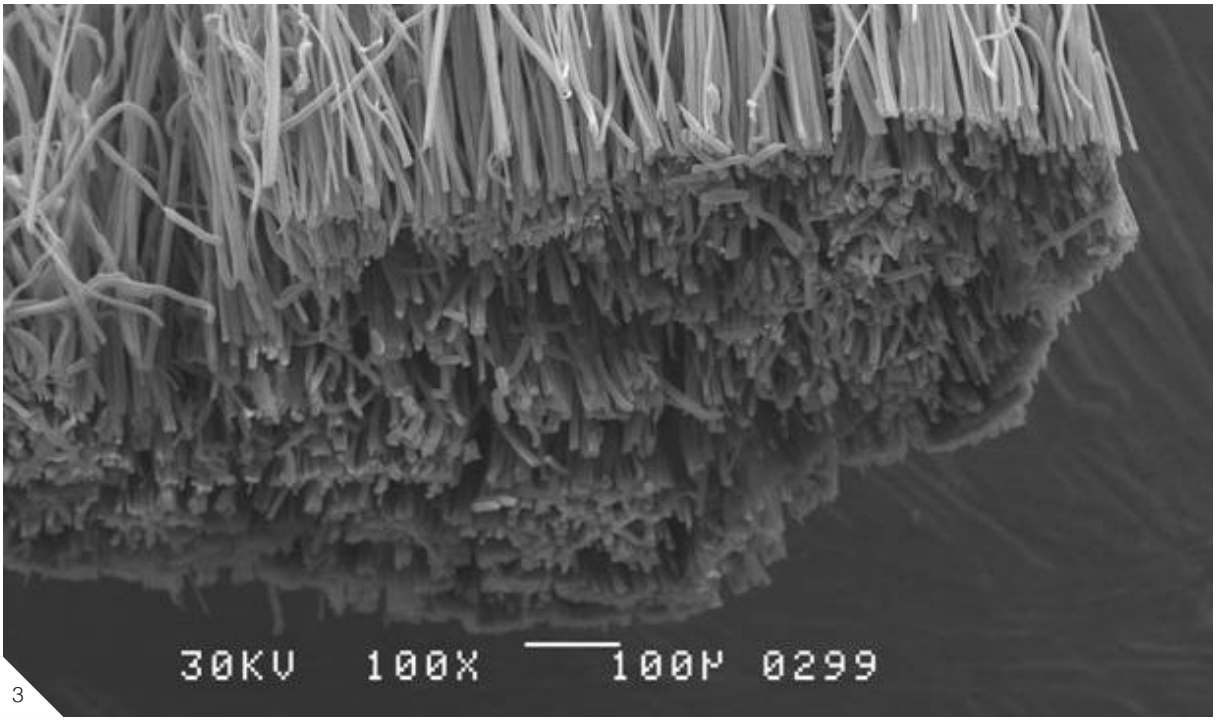

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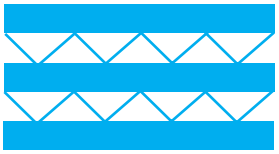

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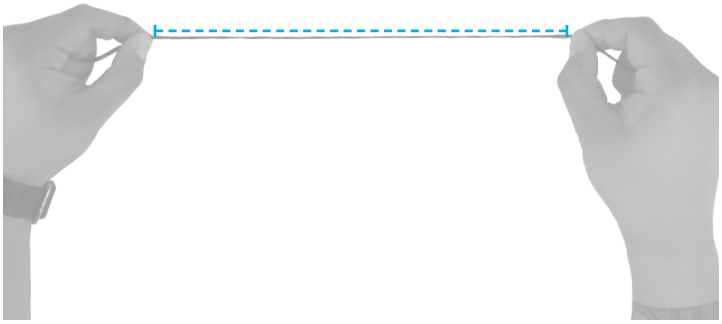

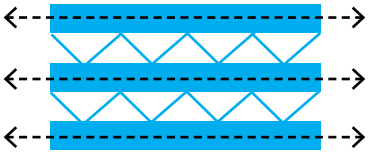

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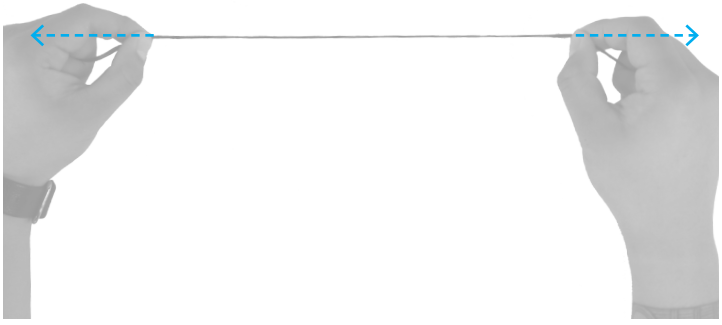

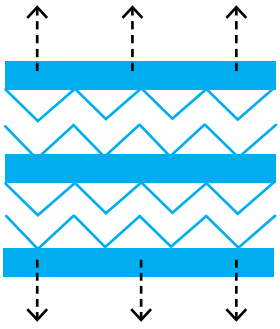

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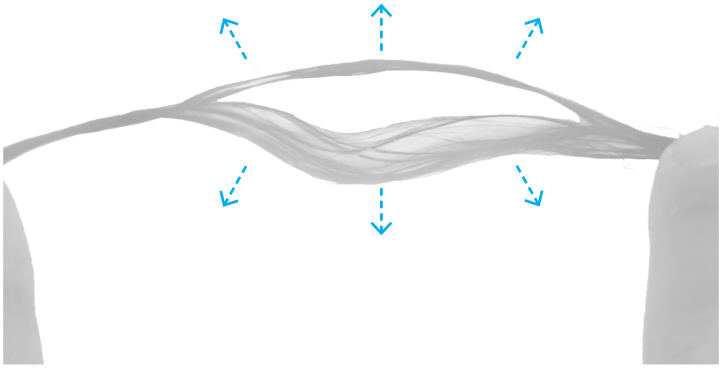
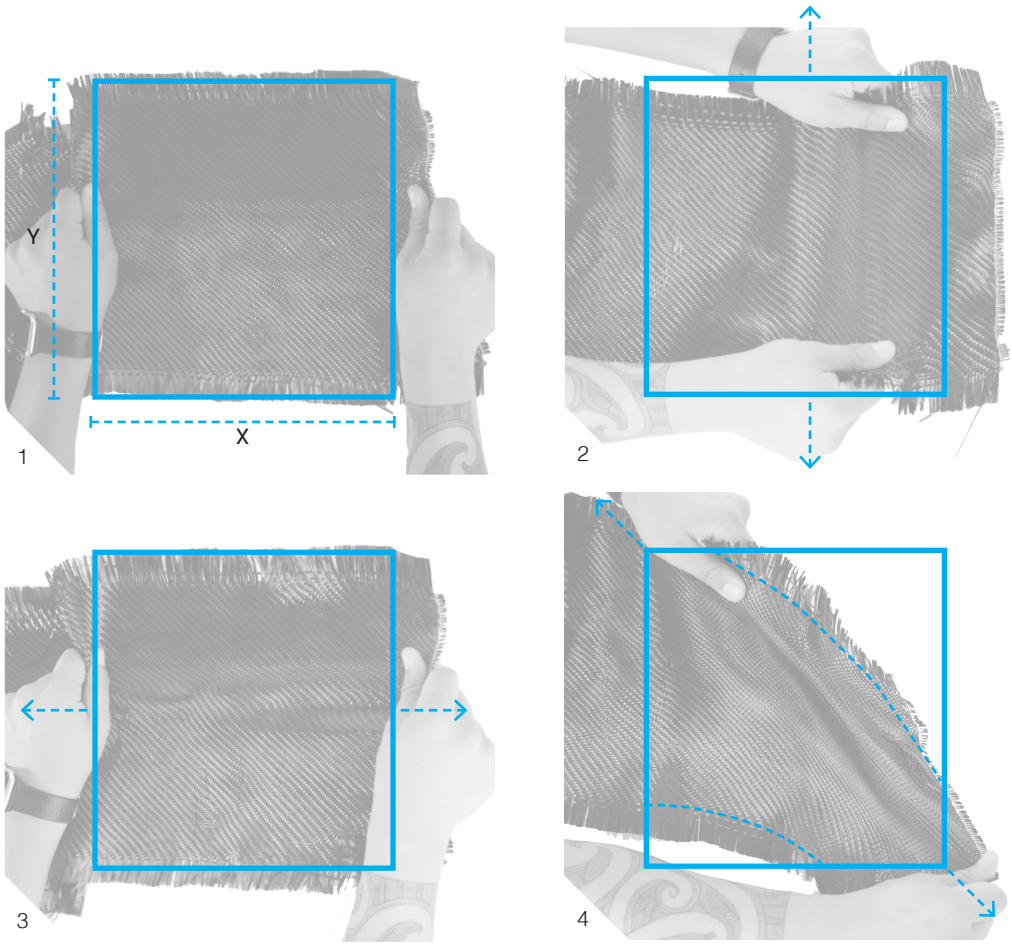




1
One Strand of carbon fiber consists a branch of single fibers bonded with glue.

2
The fiber strand shows strength when under strain along the direction of fibers.

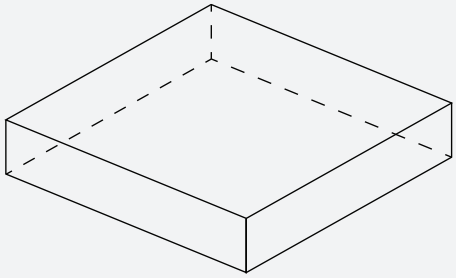
3
The strand falls apart when forces were placed perpendicular of the direction of fibers due to weak strength of the glue .

Carbon Fiber Structure

1. To overcome the weakness of carbon fiber, stands are weaved perpendicular to each other to form a sheet.
2. Carbon fiber sheet perform well when under strain along Y direction.
3. Carbon fiber sheet perform well when under strain along X direction.
5. When put under strain diagonally, the carbon fiber sheet performed poorly. The fiber perform well when forces act along direction of fiber.







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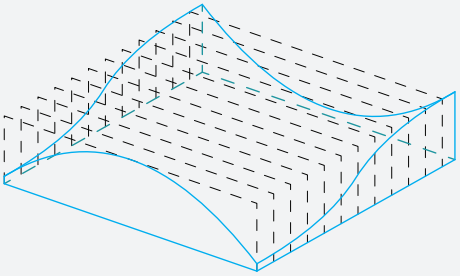

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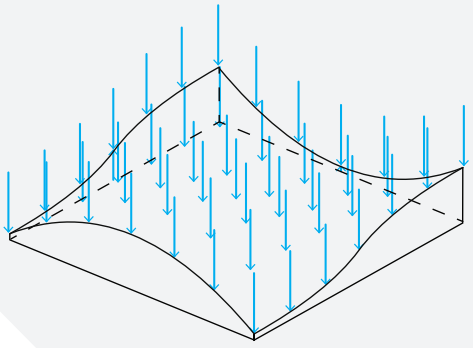
TESTING BLOCK → MILLING SURFACE

MILLING SURFACE → KARAMBA INPUT



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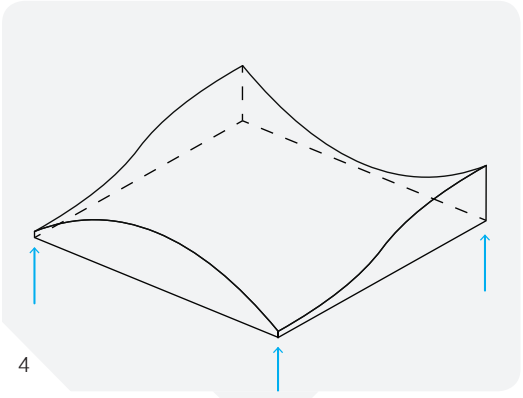

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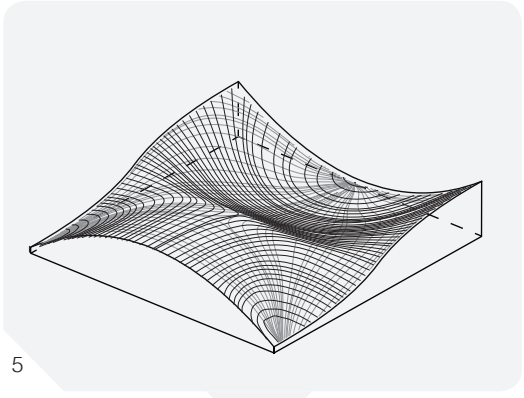


5

LOAD SUPPORT

KARAMBA OUTPUT

The Karamba algorithm will analyze a surface which will distribute load along the direction of stress lines. Hence, it is suitable for carbon fiber application given its load direction sensitive characteristics

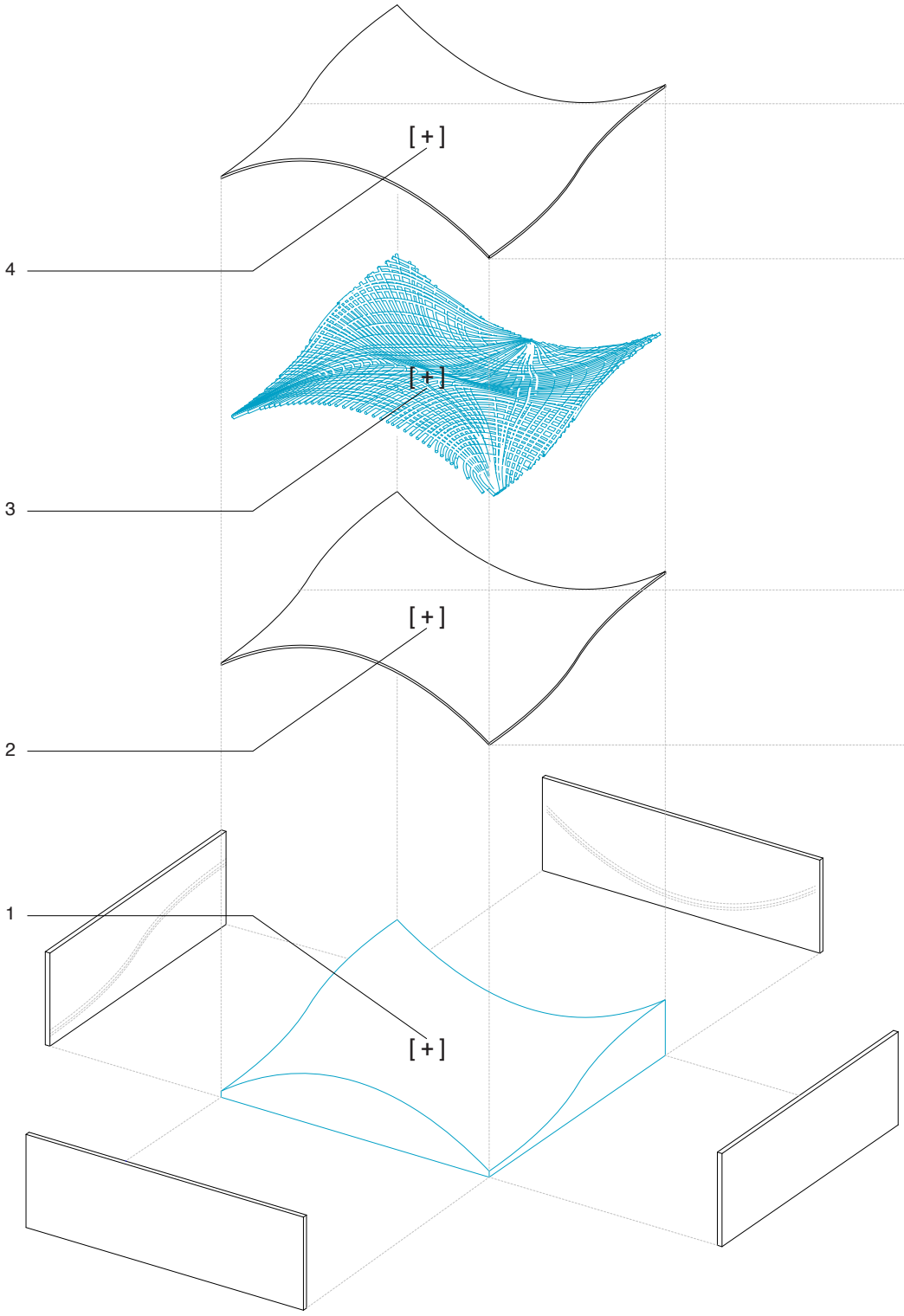
1
Input testing model of the block.

2
Milling process to acquire designated surface for testing

3
Karamba load input.

4
Karamba support input

5
Karamba stress line pattern output which will be followed by carbon fiber strands for optimal performance.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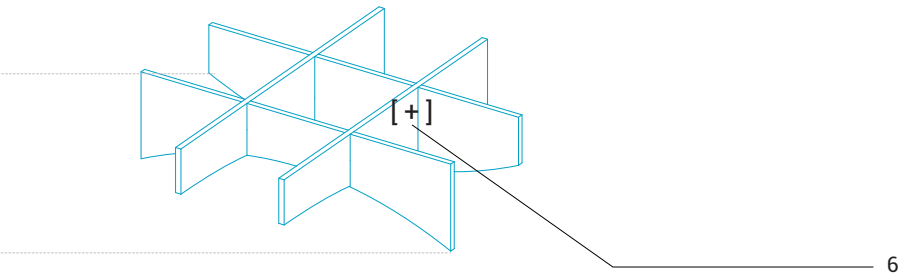
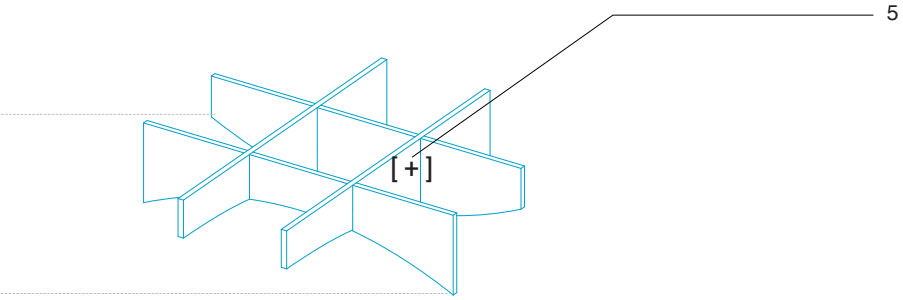




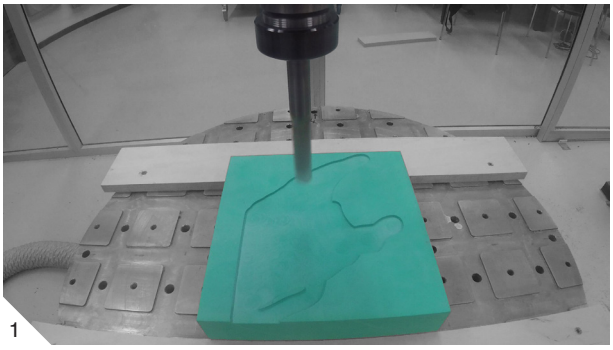
1
Base mould made of composite heat resisting material. Form work is added to close the mould.

2
First layer of resin applied and dried before laying carbon fiber. Resin is mixed with special bonding agent to increase viscosity.

3
Carbon fiber primed with resin is laid according to Karamaba output

4
top resin layer applied to finish of the panel.

5-6
jigs to check the geometry of bottom and top layer of resin to follow the curvature of the mould.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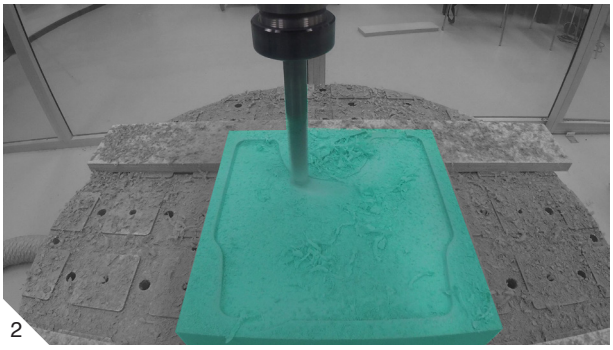
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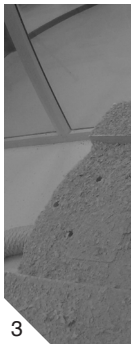
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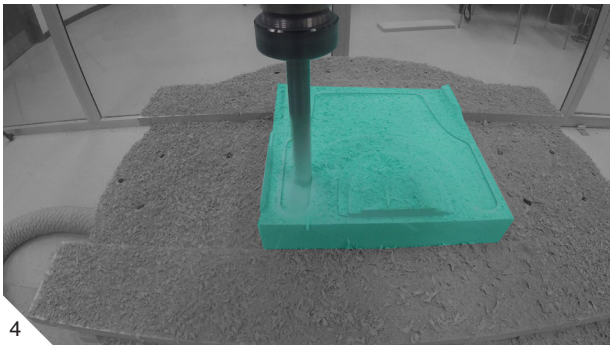
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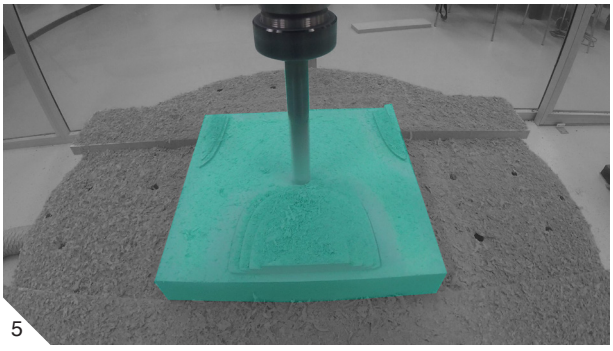
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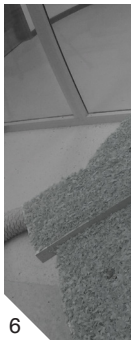
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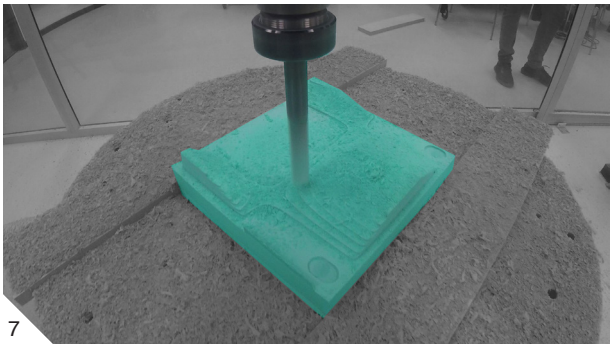
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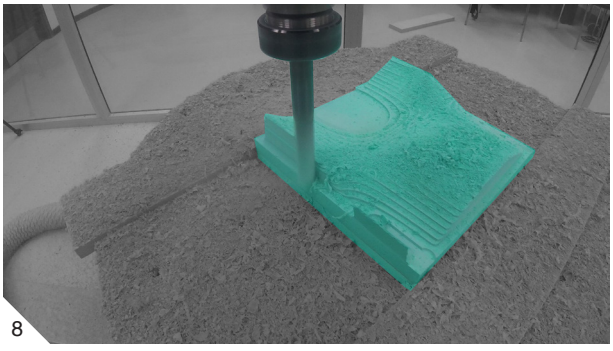
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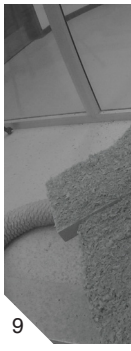
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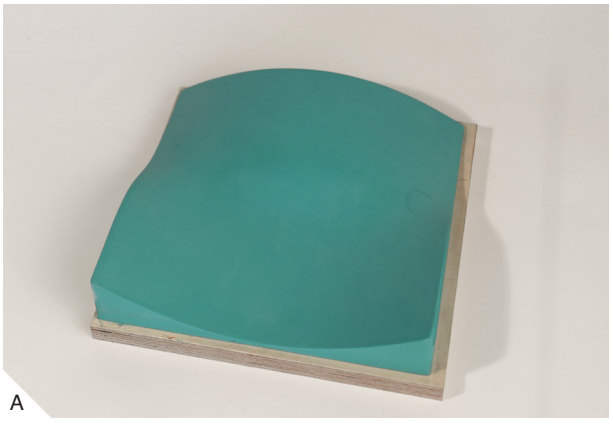
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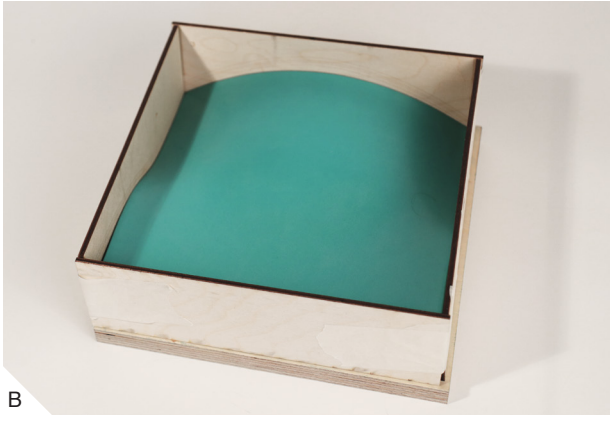
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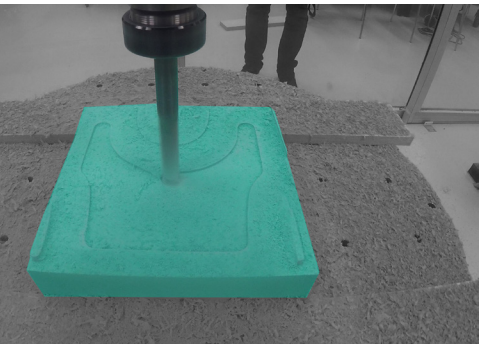
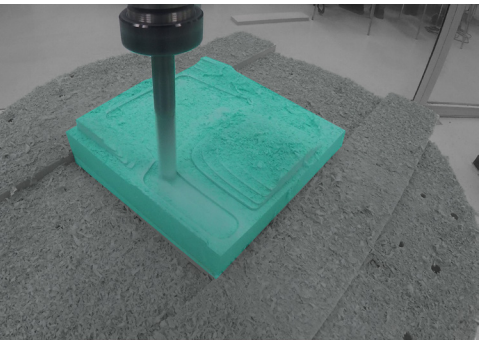
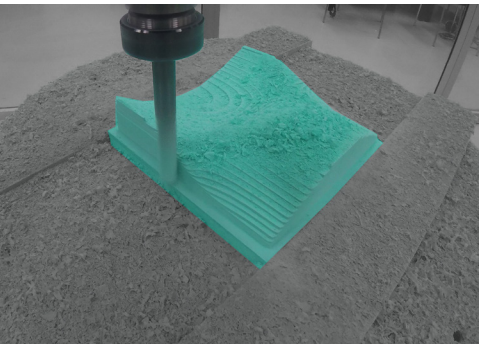
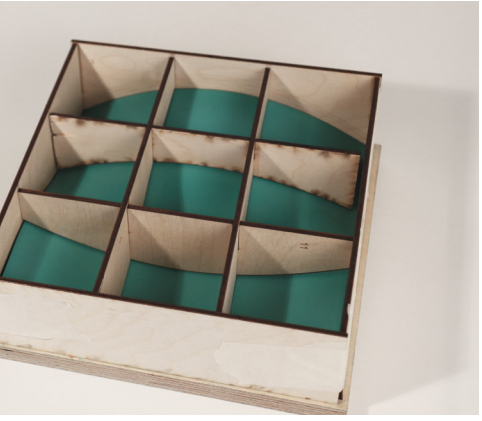






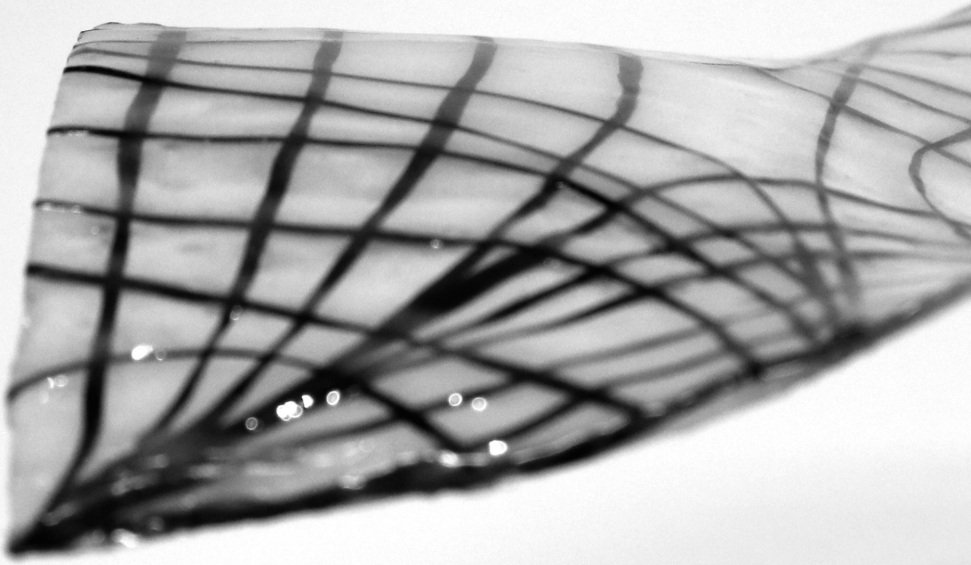


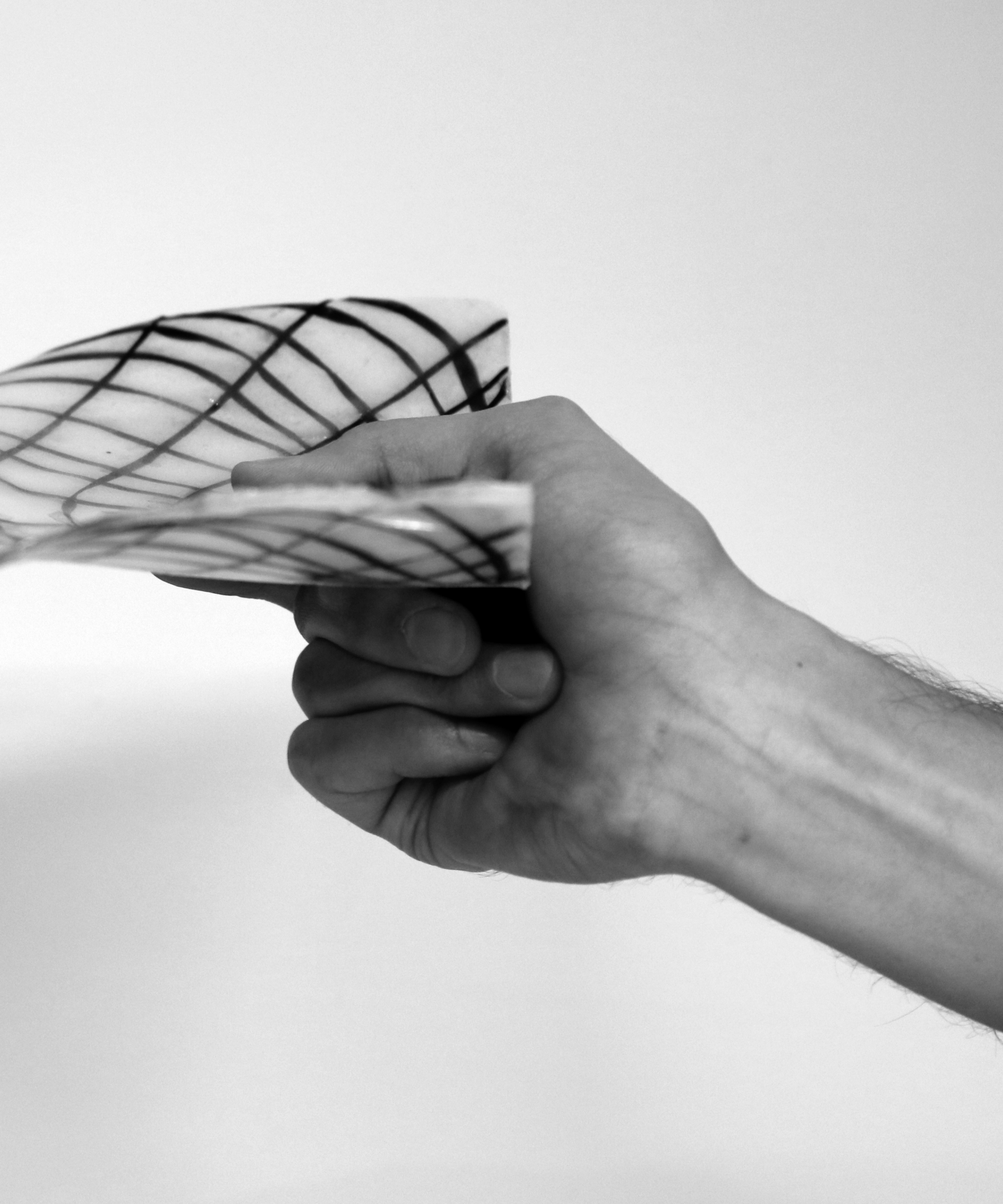
1-9
Robotic milling sequence
for producing the base mould.

A
Base mould with polished
finishing.

B
Additional parts to complete
the mould.

C
Special jig for checking the
curvature of the resin application



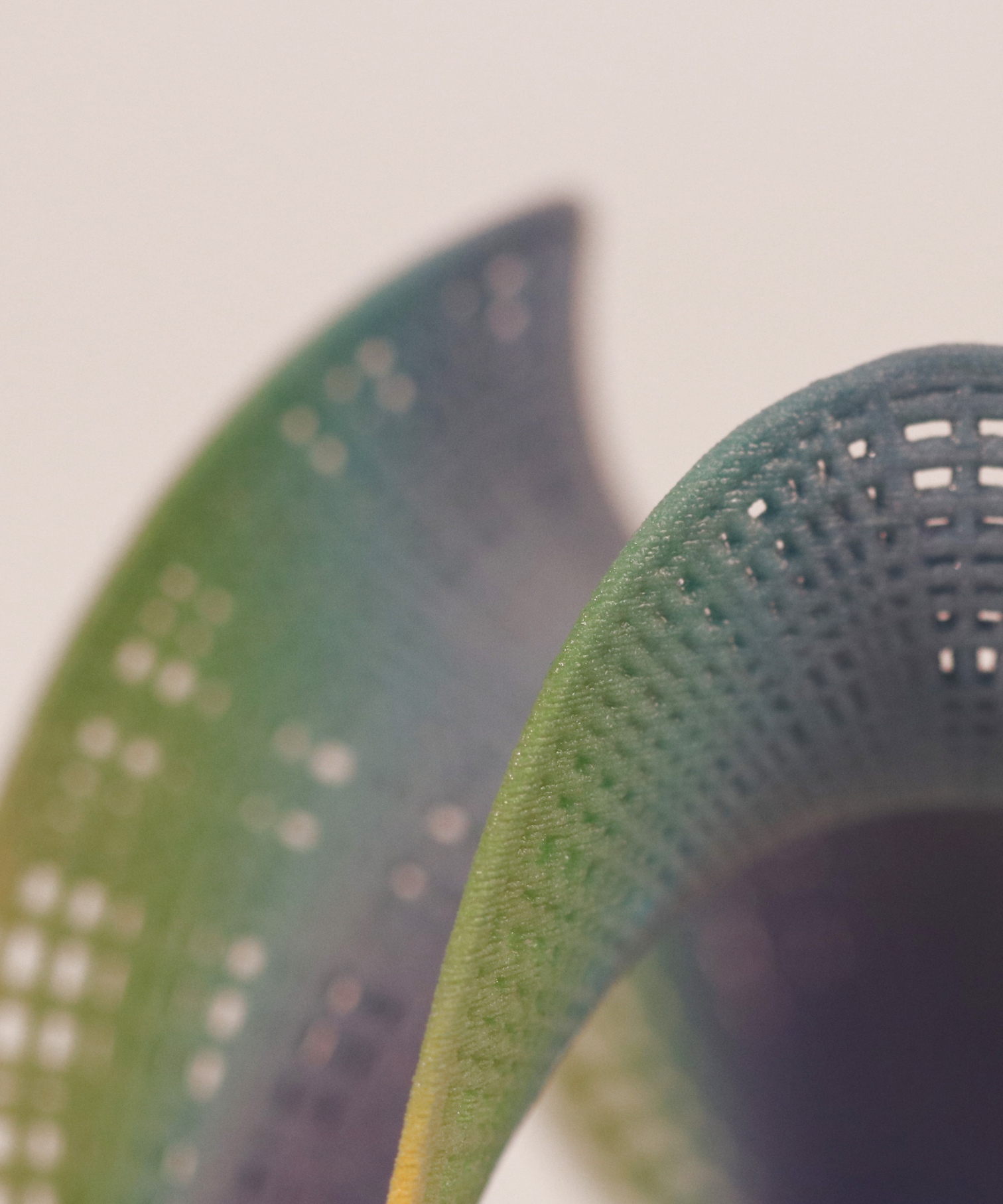


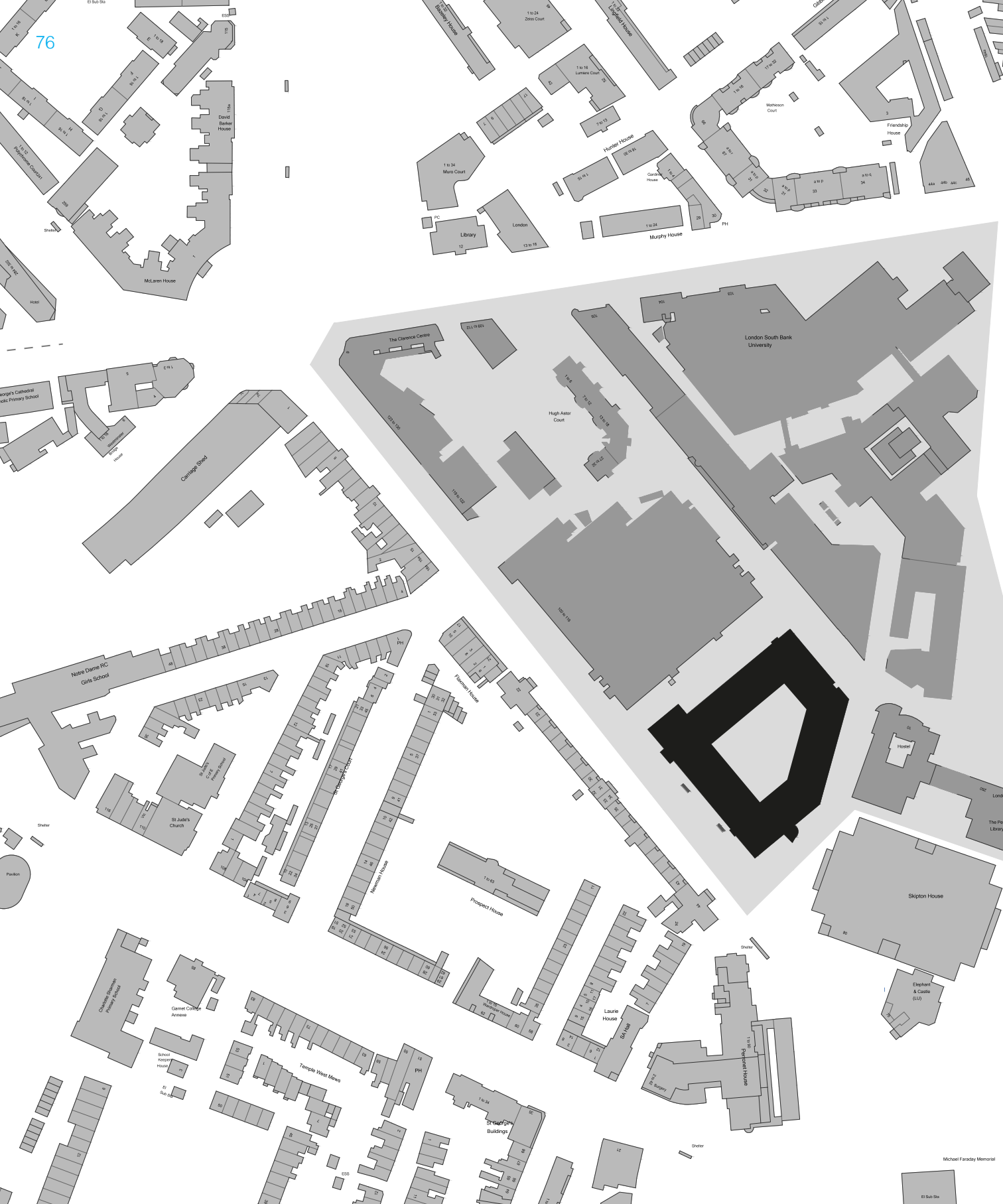



HSK F63

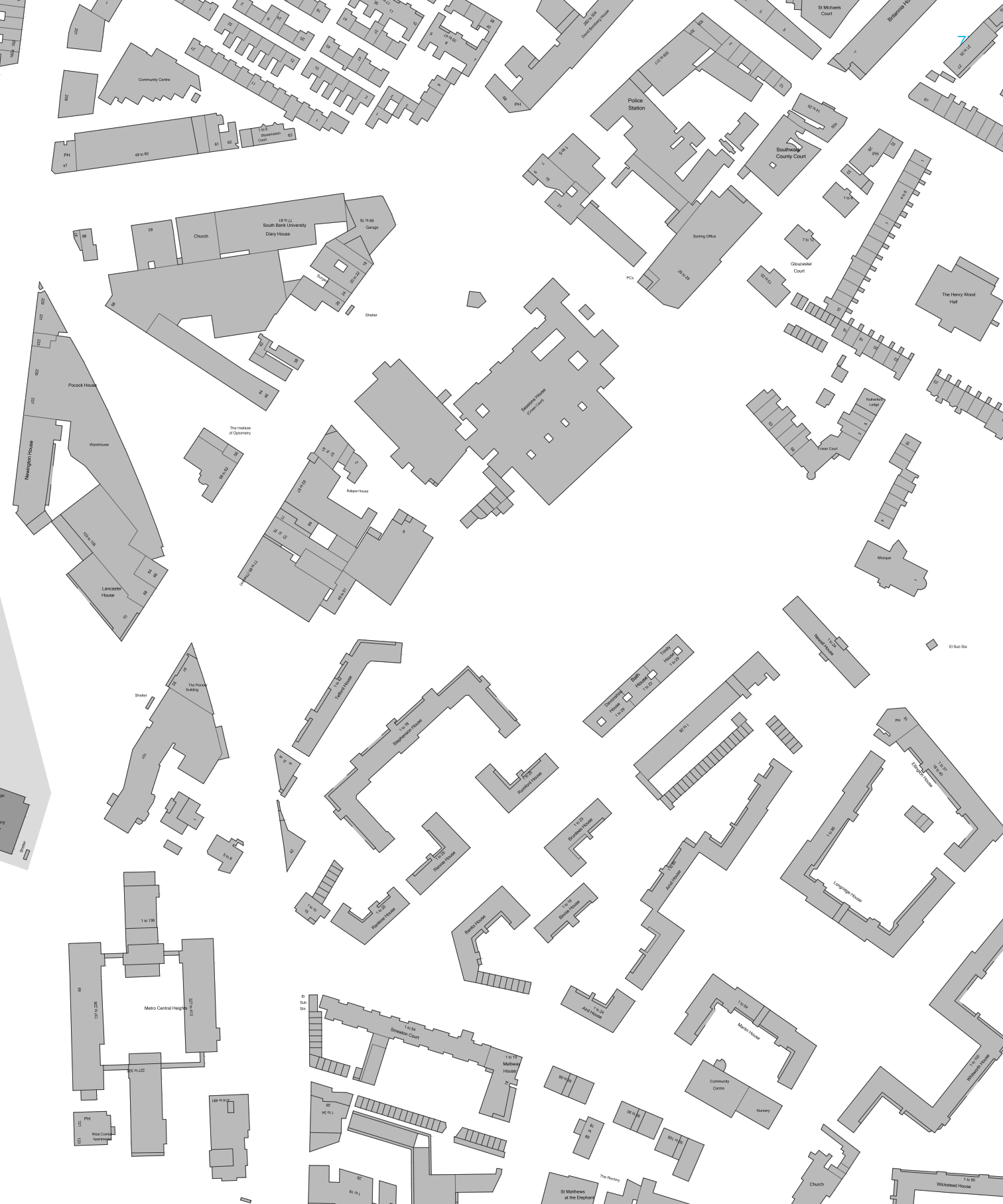
DESIGN

#Site Analysis #Design Method #Design Optimization #Structural Geometry

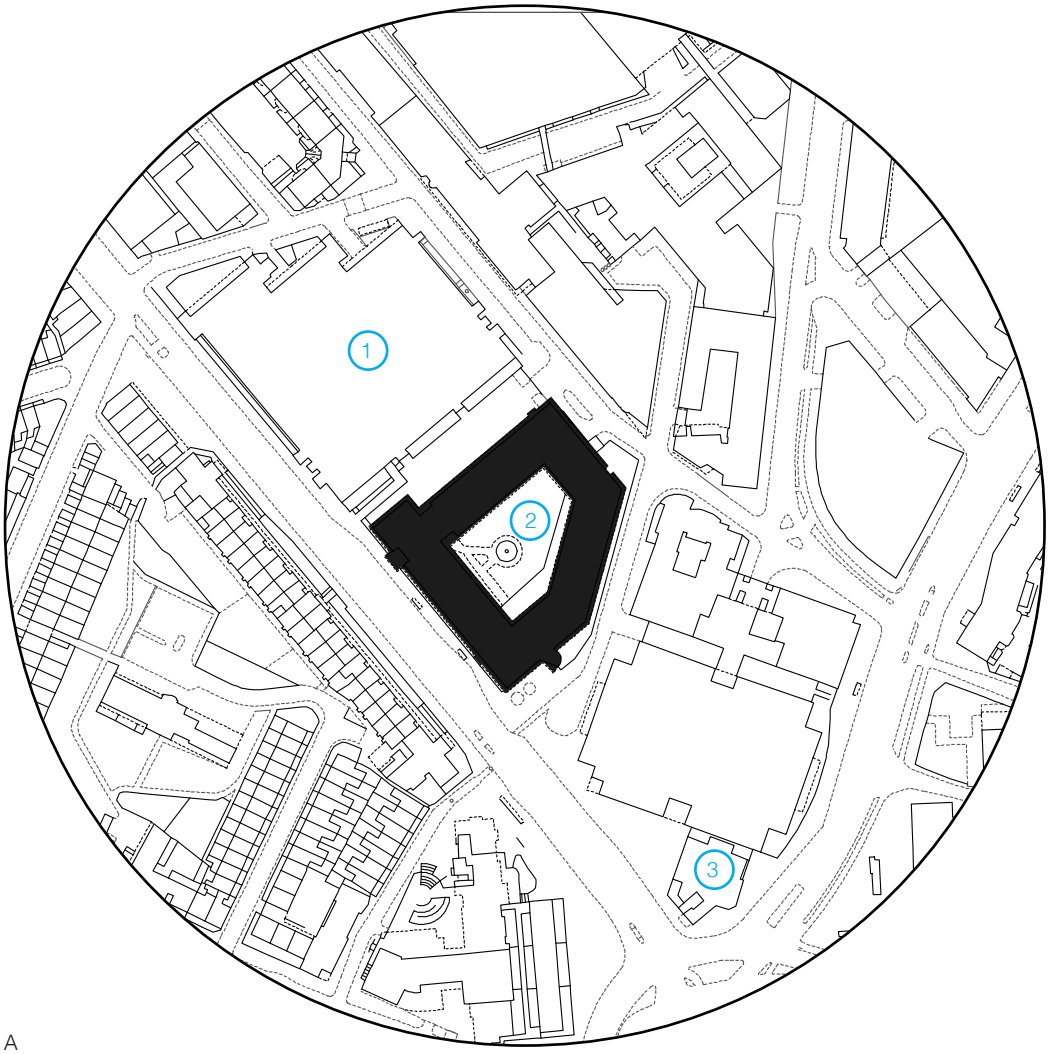




El Sub Sta
Bazeley House
1 to 24
Zeiss Court
Lingfield House
1 to 16
Lumens Court
Mathieson
Court
Friendship
House
David
Barker
House
Polychrome Court
Hunter House
1 to 34
Muro Court
Gardner
House
Library
London
Murphy House
PH
McLaren House
Hotel
The Clarence Centre
London South Bank
University
Hugh Astor
Court
Carriage Shed
Notre Dame RC
Girls School
Flaxman House
St Jude's
Church
Newman House
Prospect House
Hostel
Skipton House
Elephant
& Castle
(LU)
Laurie
House
SA Hall
Perronet House
Garnet College
Annexe
Temple West Mews
St George's
Buildings
Michael Faraday Memorial
El Sub Sta



Community Centre
PH
49 to 60
1 to 5 Stevenson Court
Church
South Bank University
Diary House
Garage
Shelter
Pocock House
Warehouse
Newington House
Lancaster House
The Institute of Optometry
Balppa House
Sequoia House (Crown Court)
Police Station
Southwark County Court
Sorting Office
PCs
Gloucester Court
The Henry Wood Hall
Rutherford Lodge
Fraser Court
Mosque
Newall House
El Sub Sta
Tinsley House
Bath House
Devonshire House
Telford House
Stephenson House
Rumford House
Brunlees House
Rennie House
Rankine House
Banks House
Binnie House
Arrol House
Aird House
Ellington House
Longridge House
Martin House
Community Centre
Nursery
Metro Central Heights
Smeaton Court
Mellway House
St Matthews at the Elephant
The Rectory
Church
Wickstead House
Whitworth House



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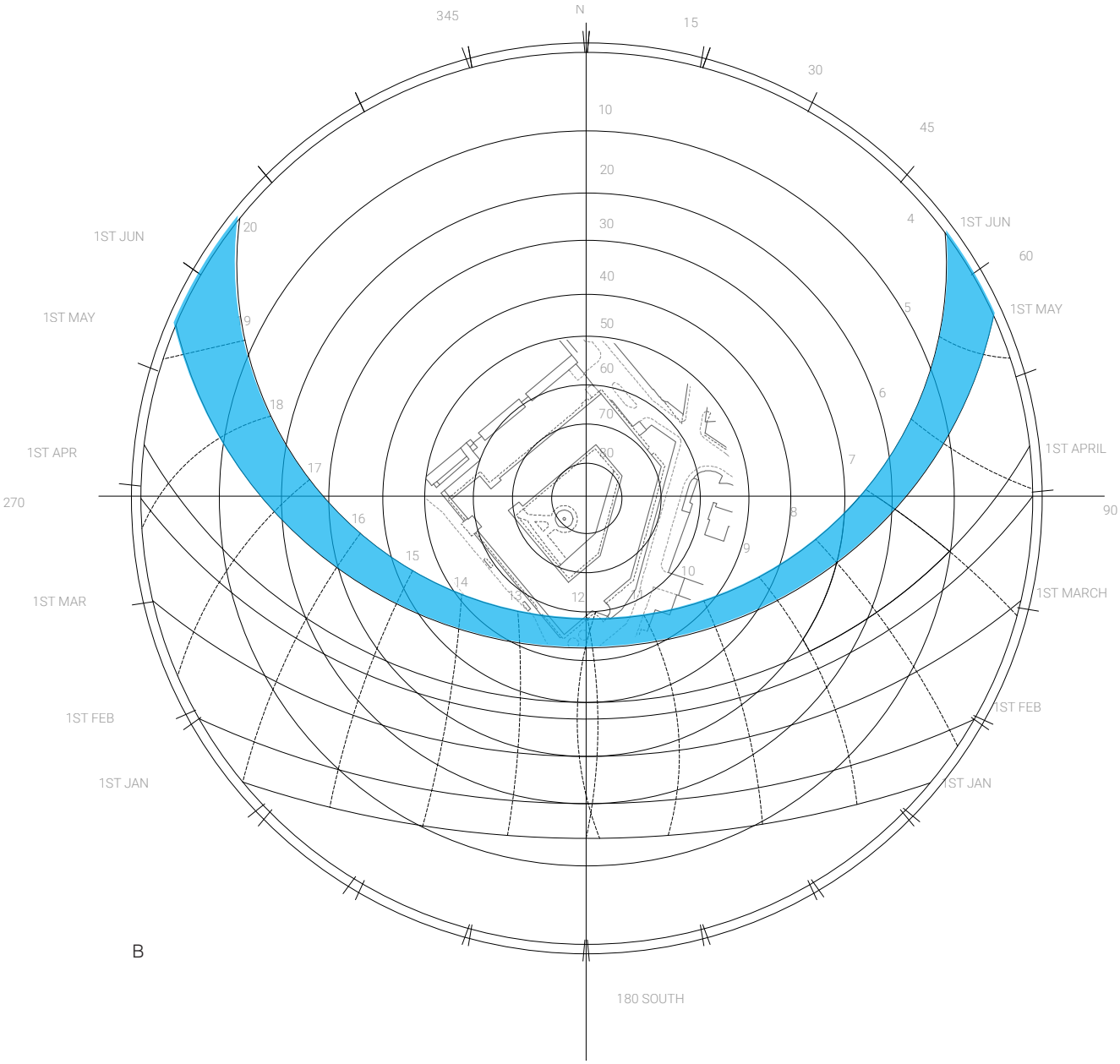
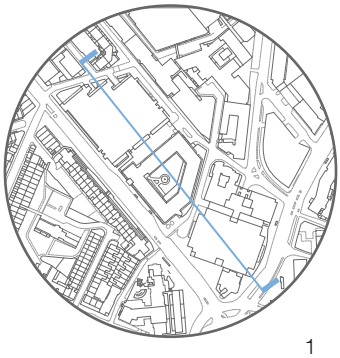


B

A
Site plan of University campus and surrounding.
1. Main University campuses.
2. Proposed site of open courtyard.
3. Elephant and Castle tube station.

B
Solar chart of proposed site for the exhibition. The gray area on the solar chart represents the sun path during the time of the proposed exhibition.



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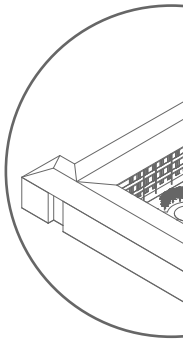

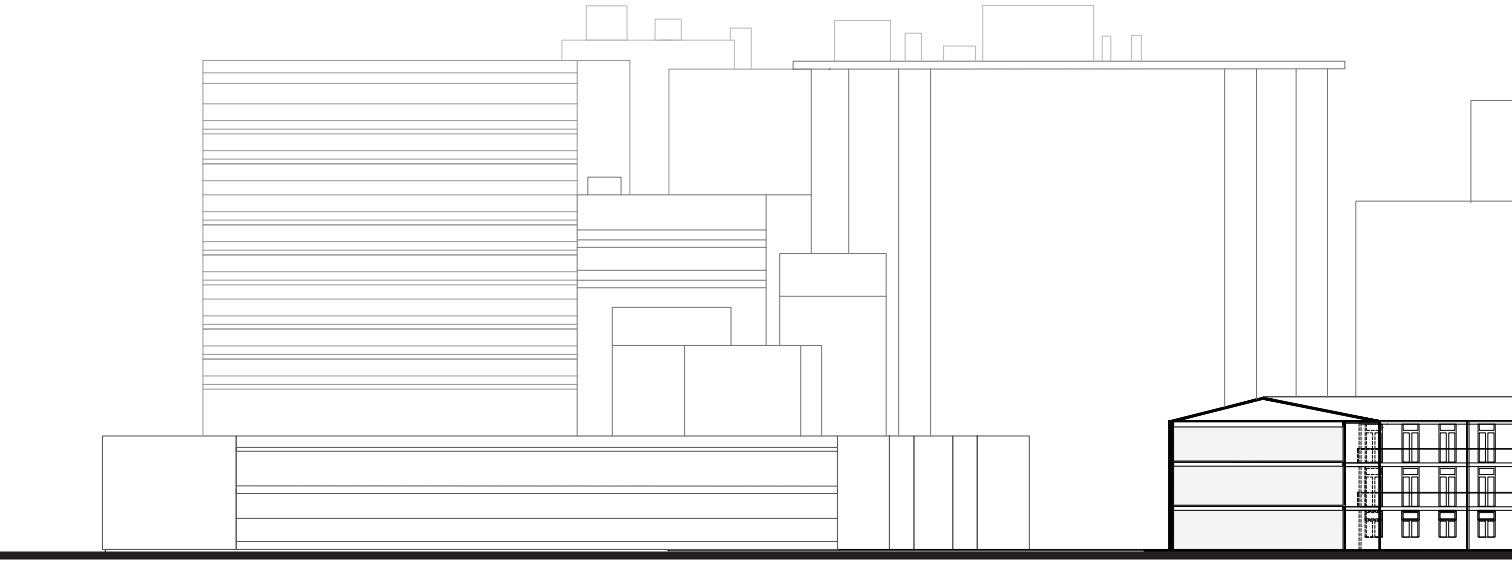

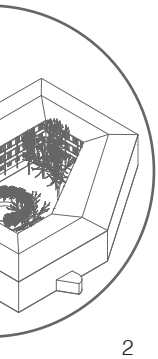

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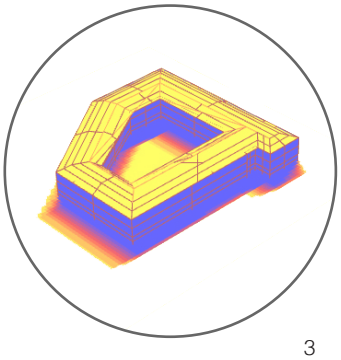

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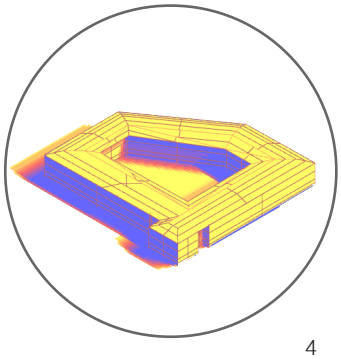

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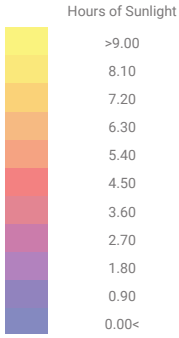

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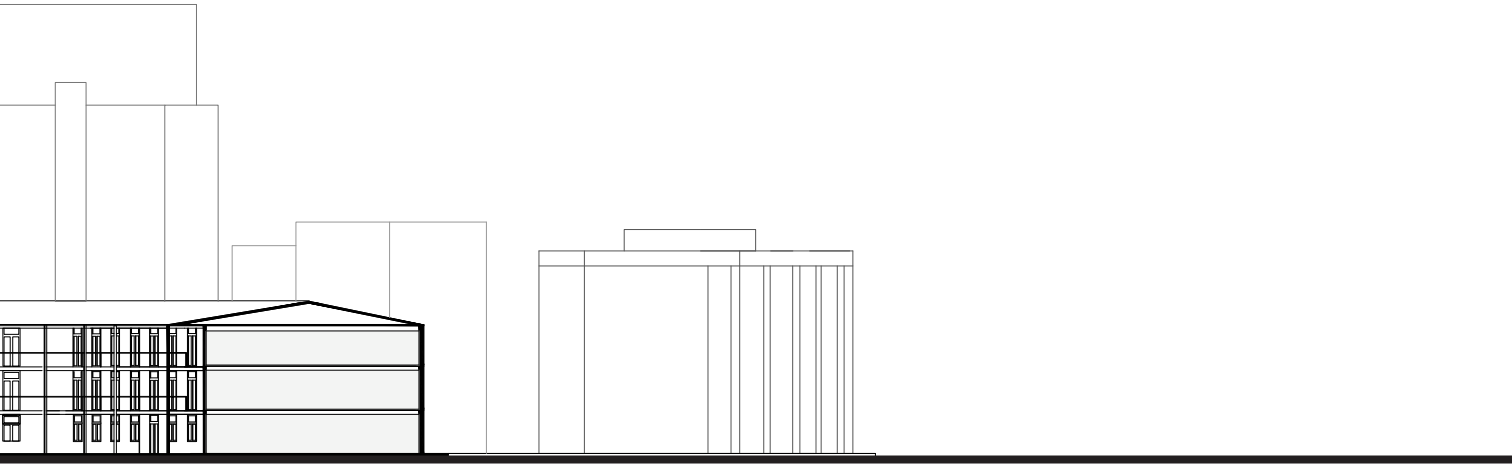


6

1
Site plan and location of the section.

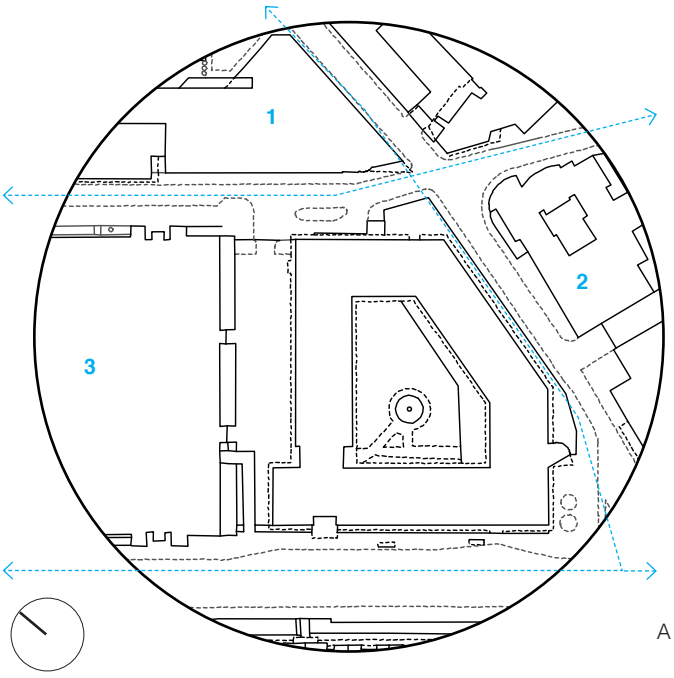
2
Axonometric drawing of the proposed Technopark site.

3
North East site view, Ladybug sunlight analysis showing exposure of sun radiation.

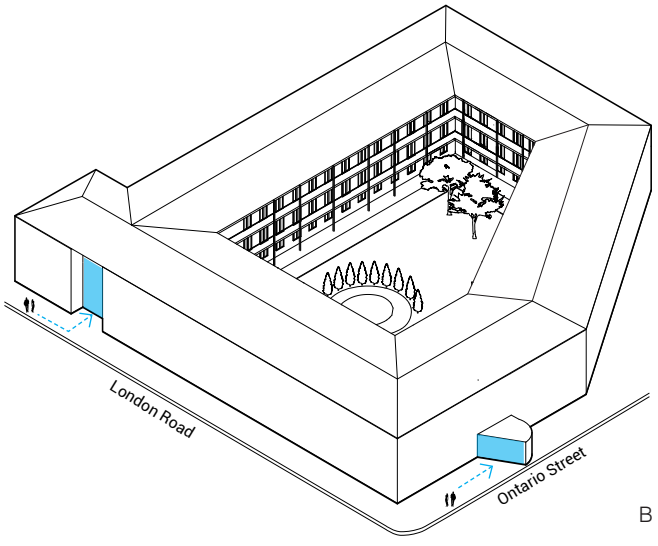
4
North West site view, Ladybug sunlight analysis showing exposure of sun radiation.

5
Solar chart of ladybug showing radiation exposure level.

6
Main section of the site and immediate surrounding.



A



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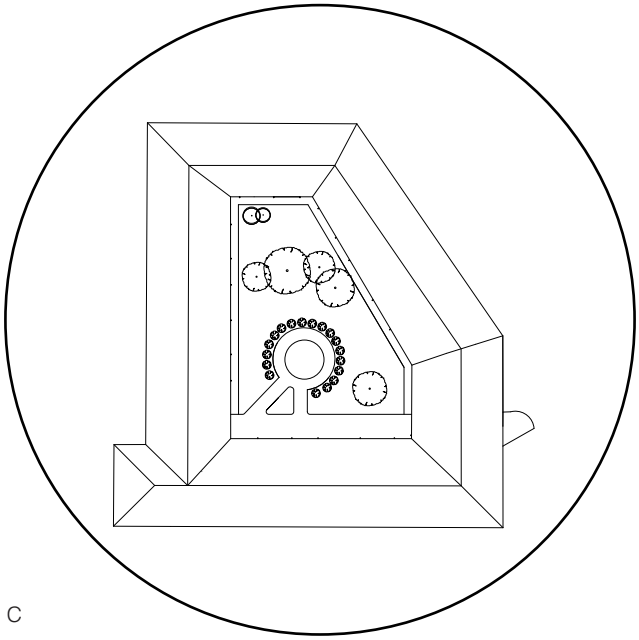
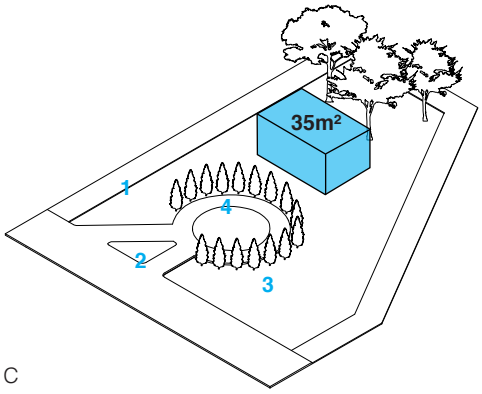


C



C

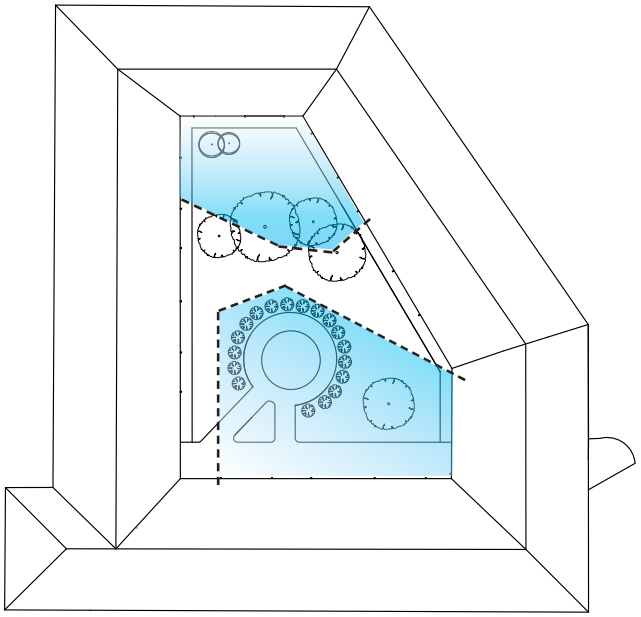
1. Gravels
2. Paved path
3. Grass
4. Pond

A
Site plan with street access of university.
1. Keyworth Centre
2. Perry Library
3. Sports Centre

B
Gate access to the site

C
Courtyard site plan

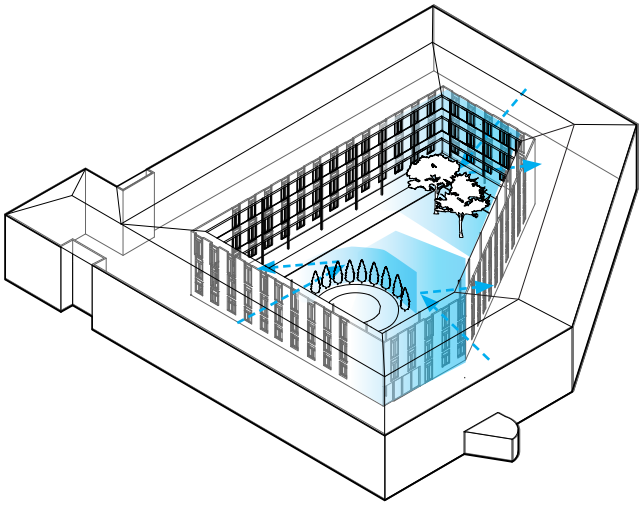
D
Courtyard condition



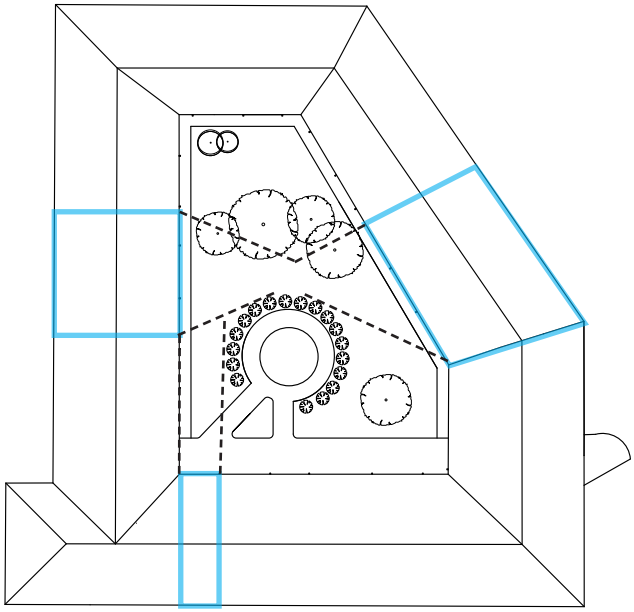
Tree lines

Visual blind zone

A



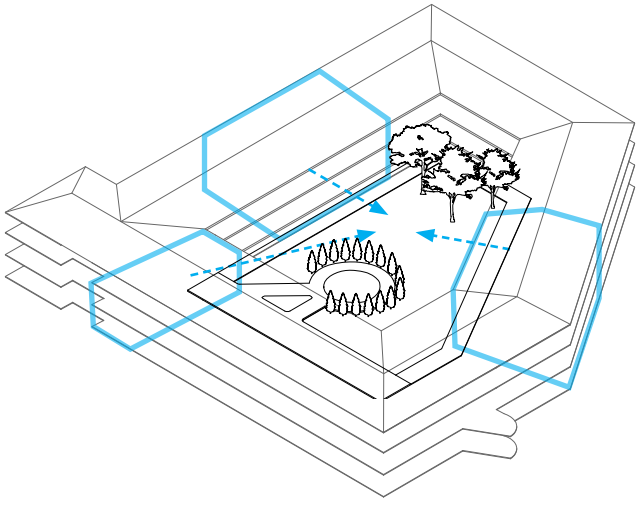
B



Viewing limits

Visible zones

C



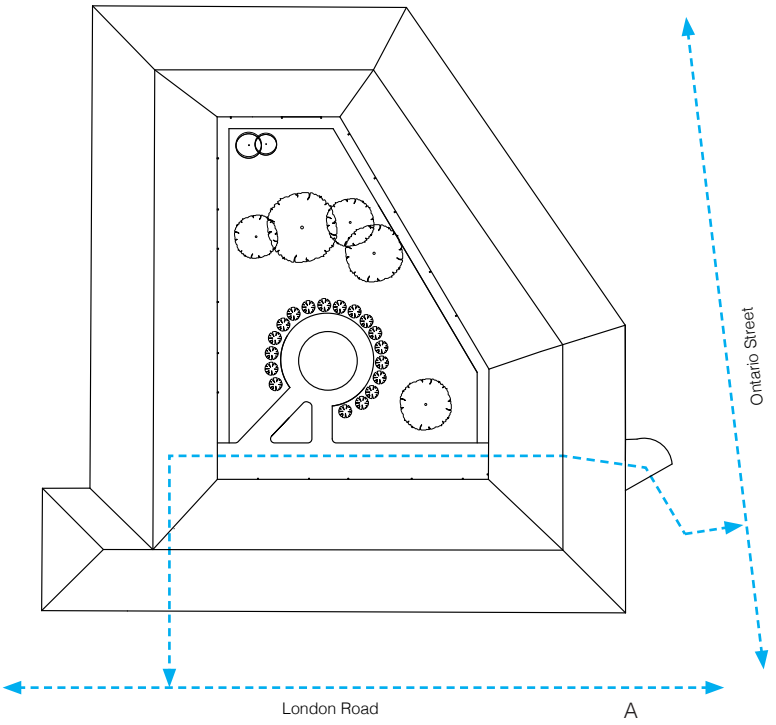
D

A
Tree lines blocks views from the building.

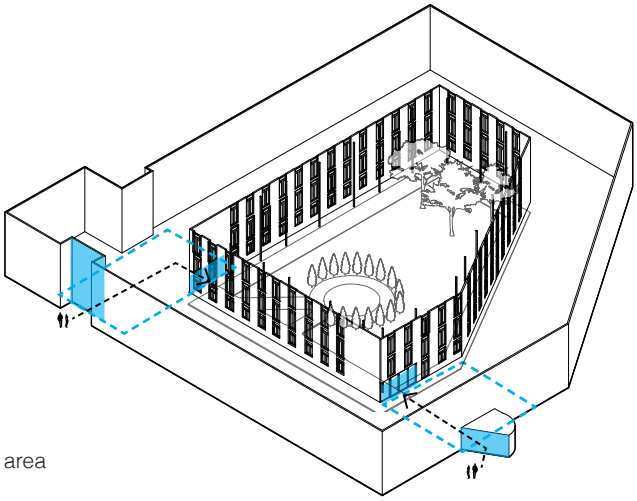
B
Parts of the building with blocked view

C
Viable viewing angle to the courtyard.

D
Parts of building with retained view



A



B

Public accessible area

Door entry

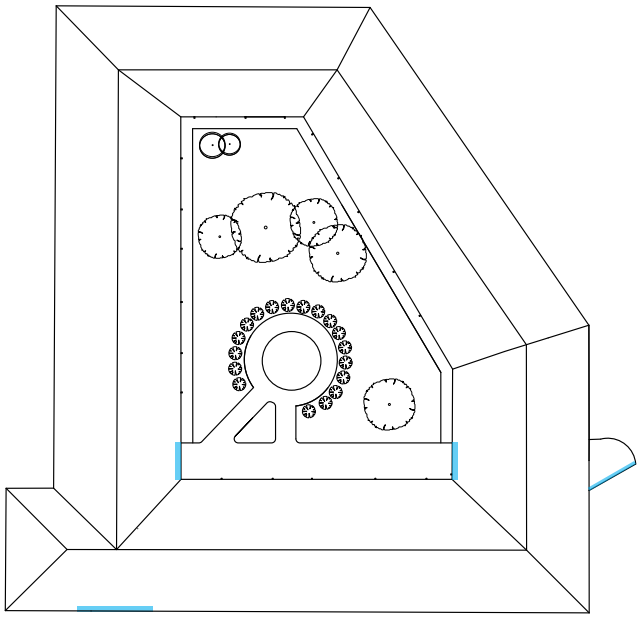
Access route

A
Site access plan.

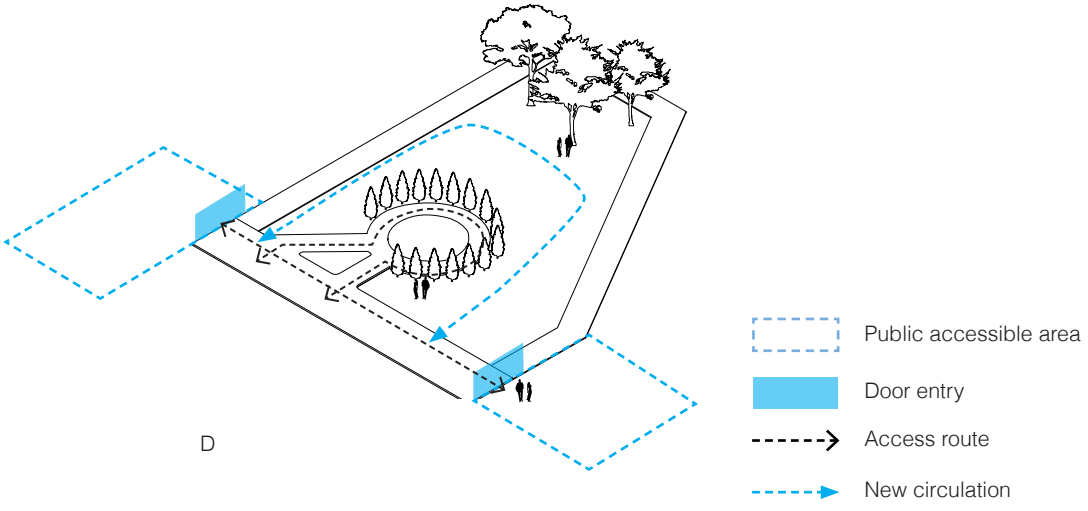
B
Public entrance to site. Dimension of the pavilion will be affected.

C
Proposed pavilion site highlighted

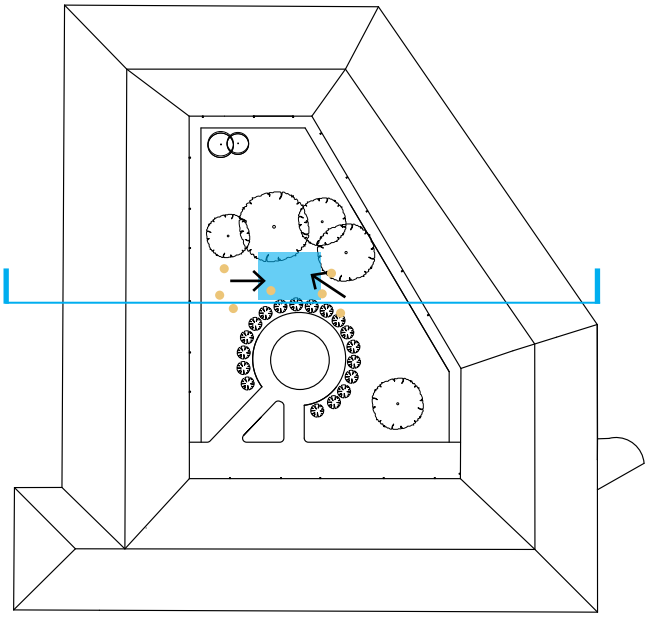
D
The pavilion space will bring life to inner city green space.



C


Public accessible area
Door entry
Access route
New circulation

D

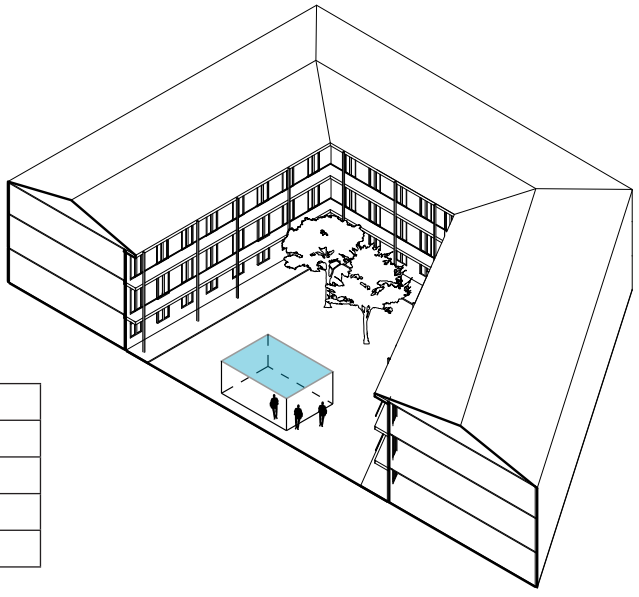


Pavilion footprint

Entry path

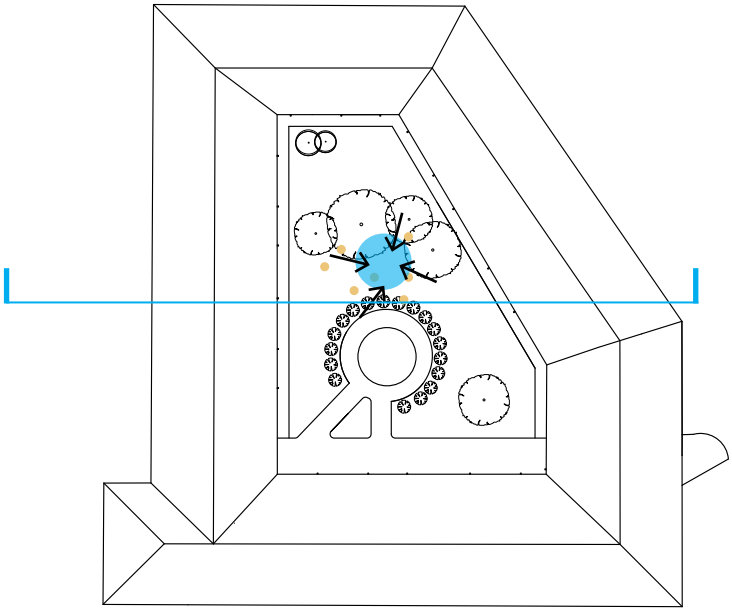
Human occupation

A



B

Type 1	Rectangular
Footprint	35sqm
Entry	2
Height	3m
Dimension	5x7m

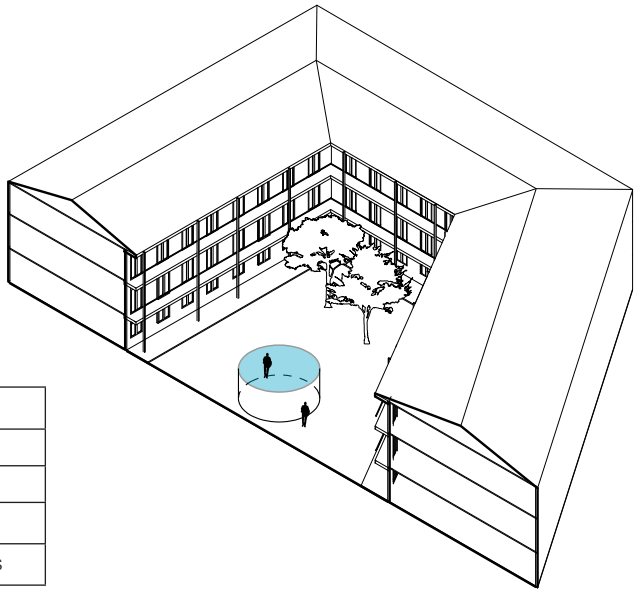


Pavilion footprint

Entry path

Human occupation

C



D

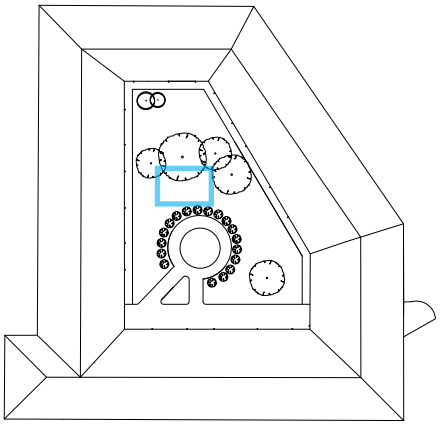
Type 2	Circular
Footprint	35sqm
Entry	3
Height	3m
Dimension	3.34m radius

A
Type 1 occupation.

B
Type1section people gathered on two end hindered access and blocked view.

C
Type 2 occupation

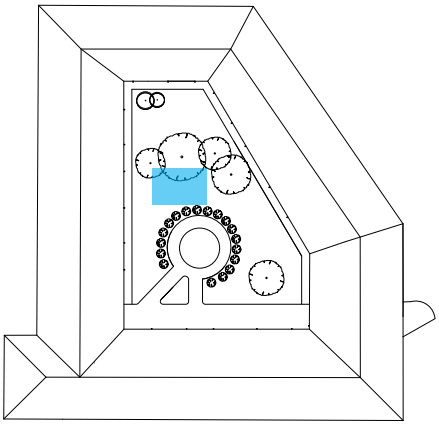
D
Type 2 section is chosen due to improved occupation, access and view.



A



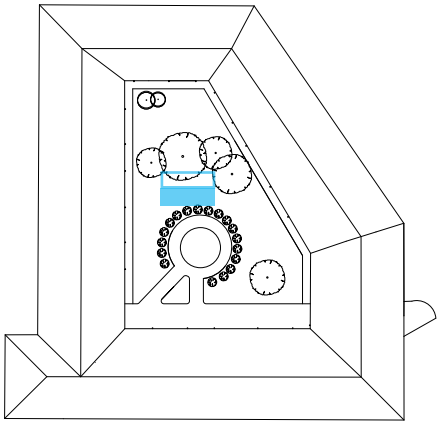
1



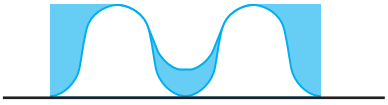
B



1



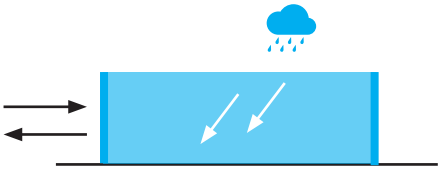
C



1



2



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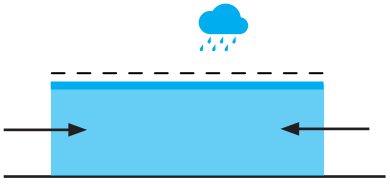
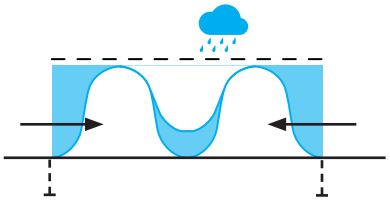


2



3



2

A

1. Envelope function pavilion.
2. Pro: Stable ground connection
3. Con: no rain protection. Restricts access and views.

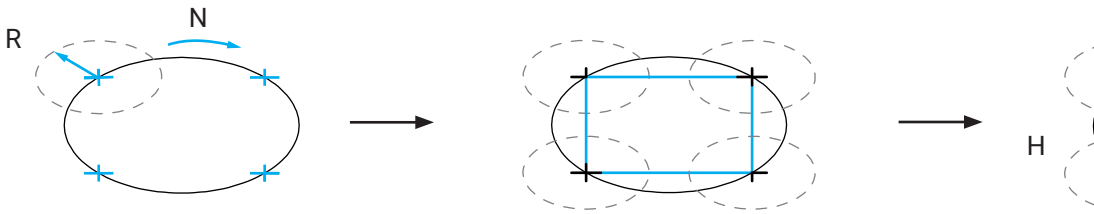
C

Shelter function pavilion.
1. Pro: rain and weather protection.
Unimpeded access and views.
2. Cons: requires flimsy support for the roof structure.

C

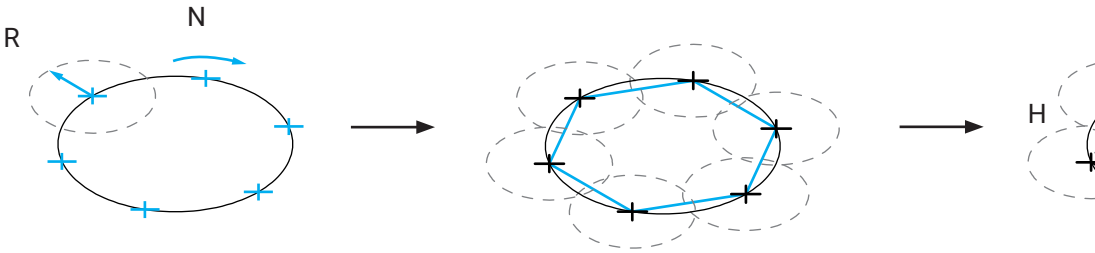
Hybrid function pavilion.
1.
Pro: rain and weather protection.
Unimpeded access and views.
Stable ground connection. This type is chosen for maximum performance.

Option 1	Params
R	2.2m
N	4
H	3m



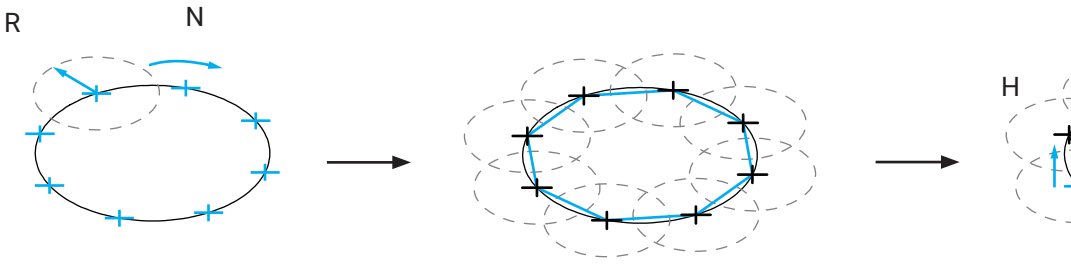
A

Option 2	Params
R	2.2m
N	6
H	3m

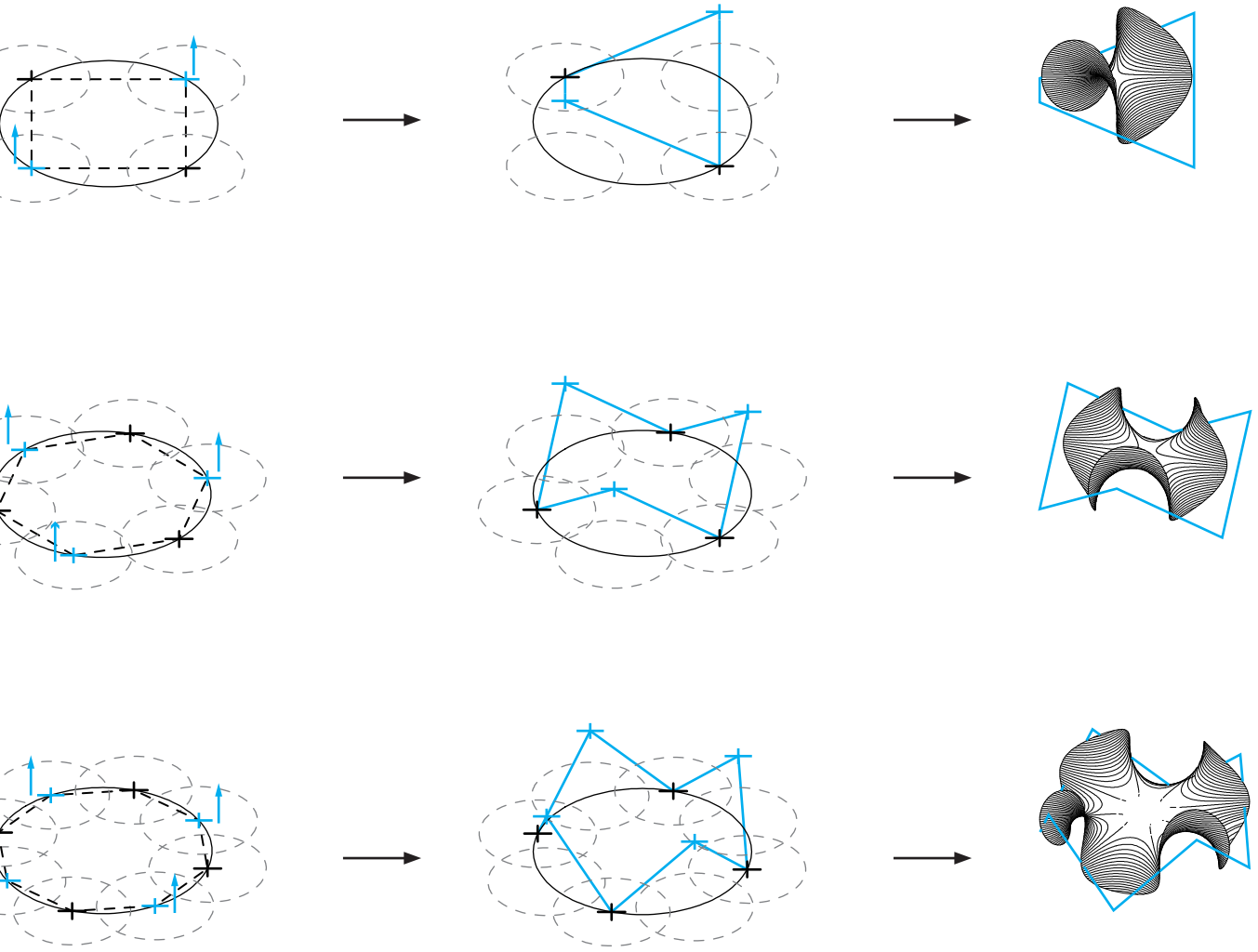


B

Option 3	Params
R	2.2m
N	8
H	3m



D

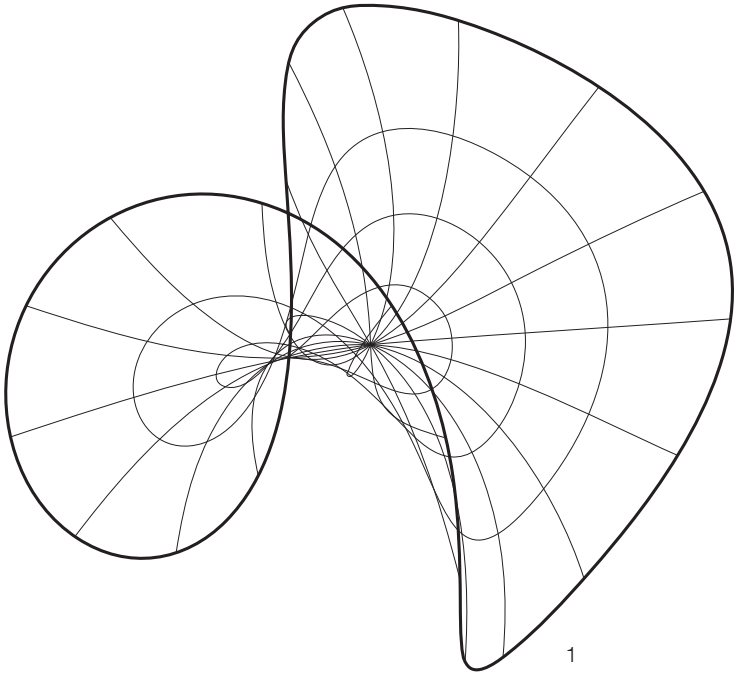


A-C
R: radius of support H: elevated height N: Number of anchor points in pairs, even number of points are needed.

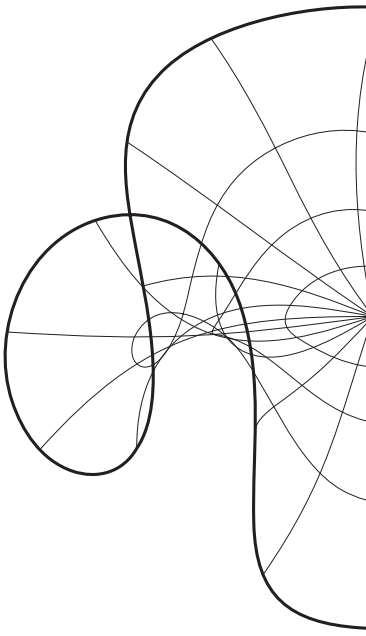
A
Option 1 is small tall, footprint area limited, with limited access.

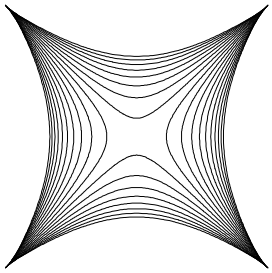
B
Option 2 in comparison has moderate height, footprint area and moderate access.

C
Option 3 has moderate height, large footprint area high access entrances.



1

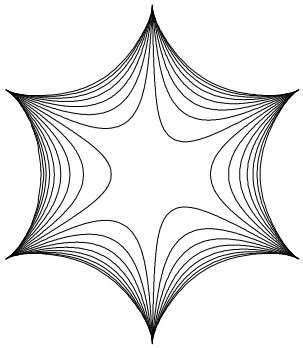




2

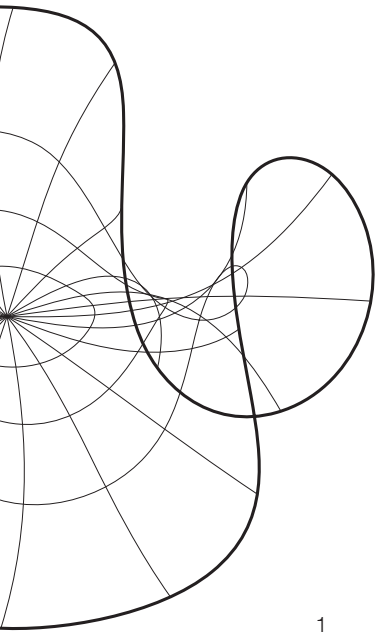
Scenario 1	type1
sym	2
low point	2
high point	2

3



2

A



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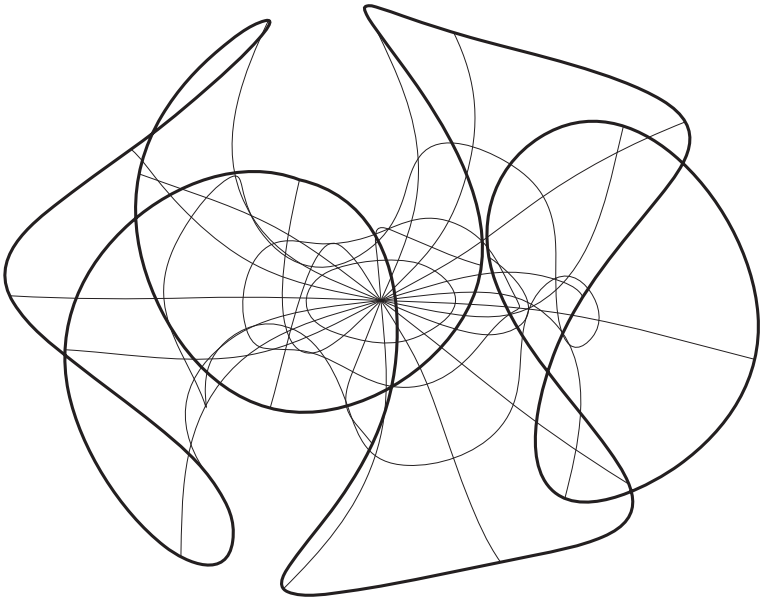
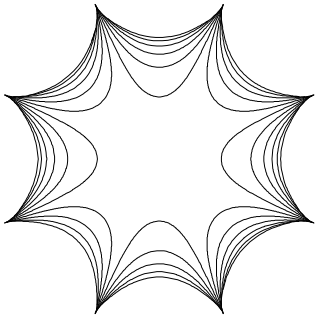


1

Scenario 2	type2
sym	3
low point	3
high point	3

3

B



2

Scenario 3	type3
sym	4
low point	4
high point	4

3

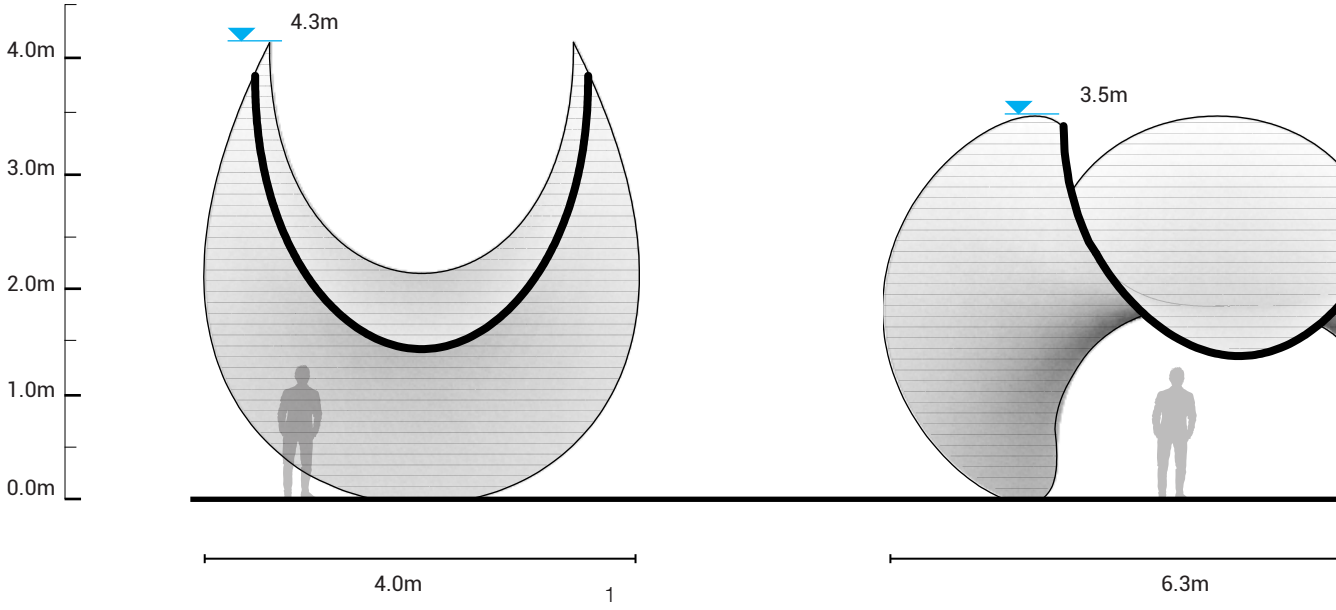
C

A-C
By adding the variable sym(symmetry factor) to the formula, different types of Enneper surface are generated. The sym factor controls the number of symmetry presented in the geometry.

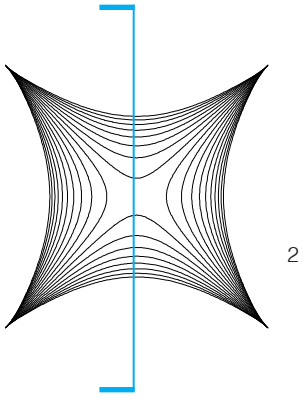
A
Enneper type 1
1. Type1 3d view
2. Type1 plan view
3. Type1 parameters

B
Enneper type 2
1. Type2 3d view
2. Type2 plan view
3. Type2 parameters

C
Enneper type 3
1. Type3 3d view
2. Type3 plan view
3. Type3 parameters



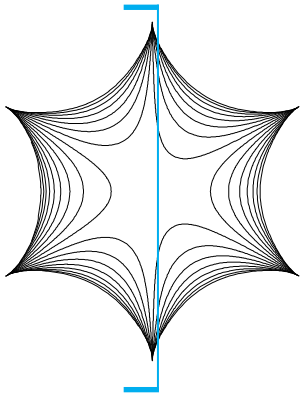
1



2

Option 1	Params
Footprint	25sqm
Entry no.	2
Height	4.3m

3

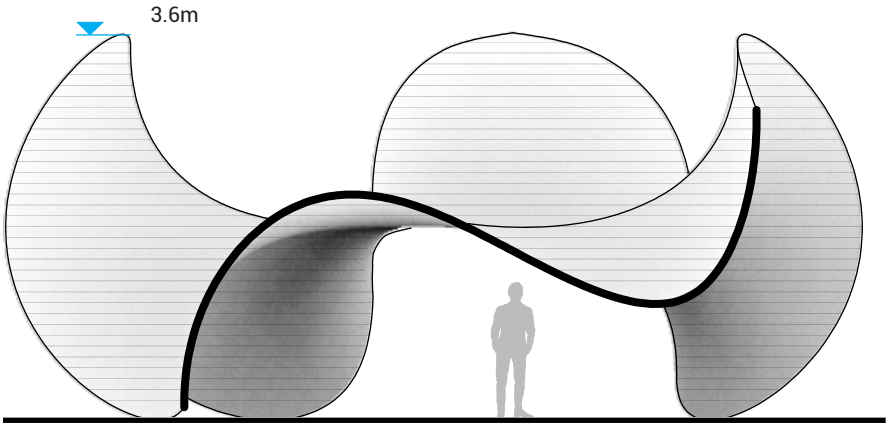


2

A



1



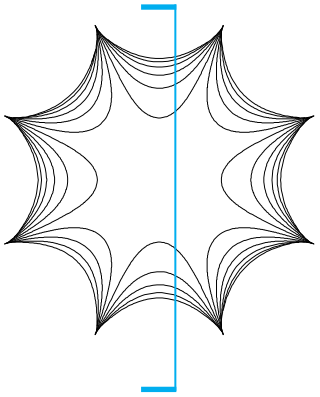
7.9m

1

Option 2	Params
Footprint	35sqm
Entry no.	3
Height	3.5m

3

B



2

Option 3	Params
Footprint	52sqm
Entry no.	4
Height	3.6m

3

C

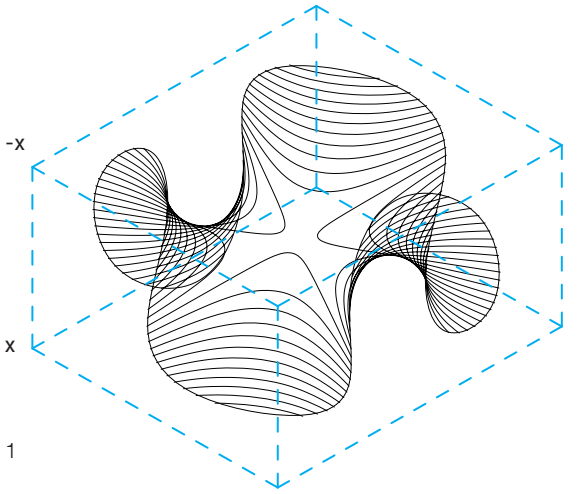
A-C
1. section
2. plan
3. parameter

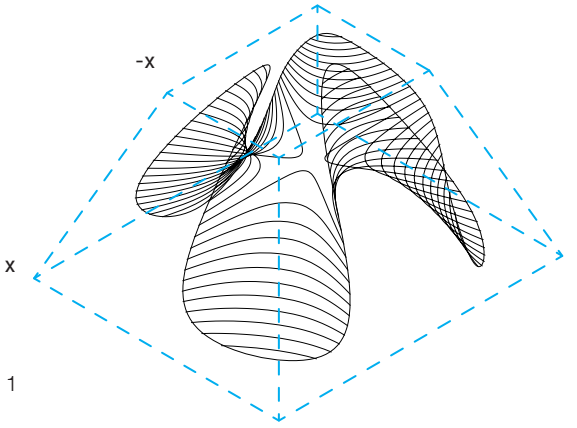
A
Option 1 is too tall, footprint area limited, less stability.

B
Option 2 has moderate height, footprint area and good number of access entry.

C
Option 3 has moderate height, but its footprint area too large and too many access entry.

Option 2 is chosen due to good access point, moderate height and foot print.


-x
x
1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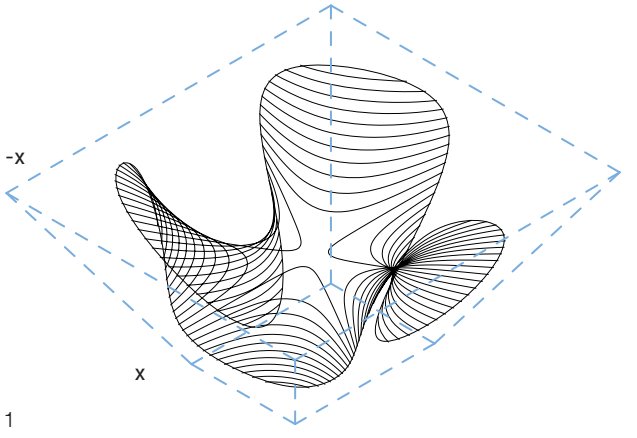
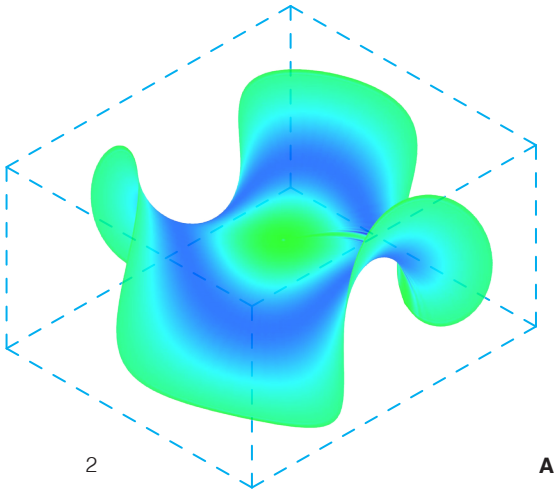
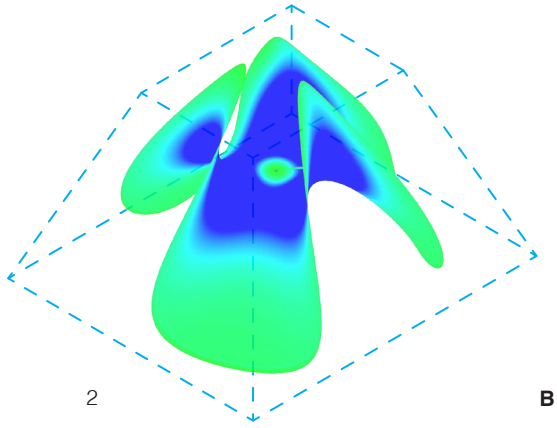

-x
x
1



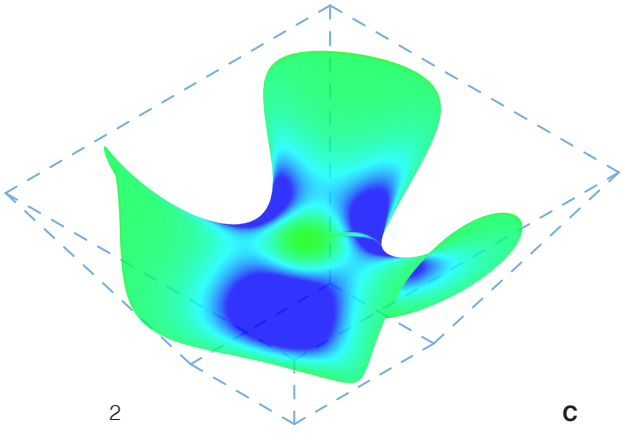
2

A



2

B



2

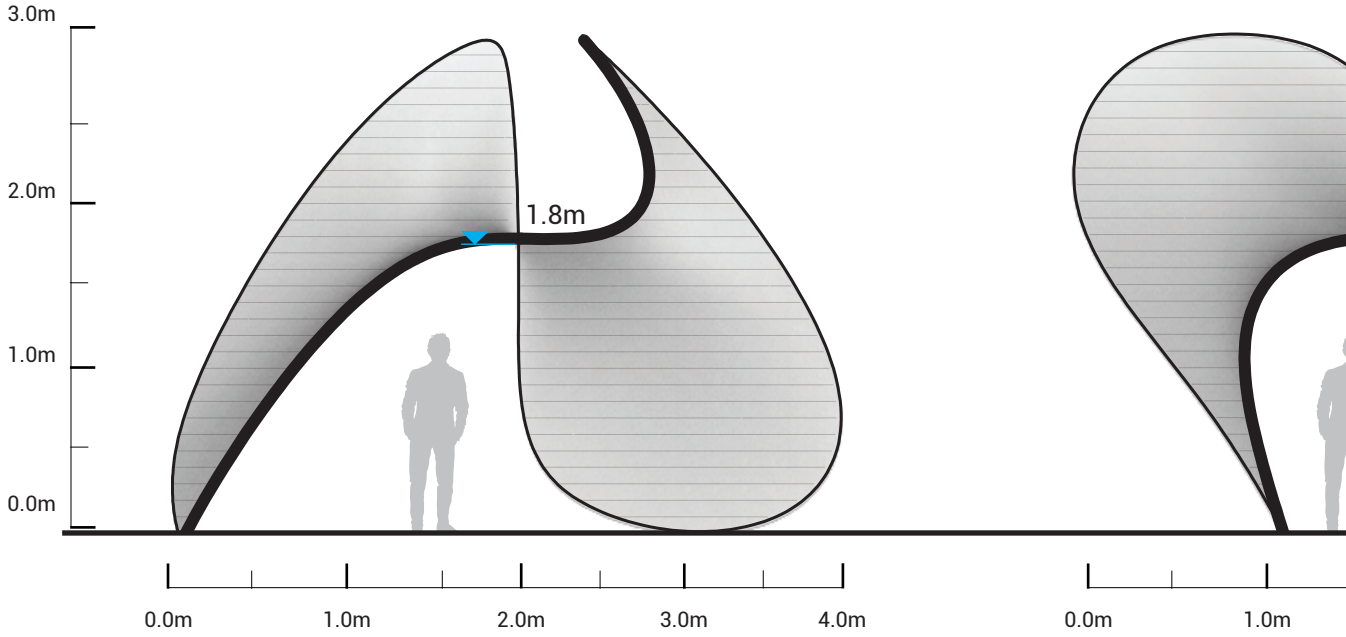
C

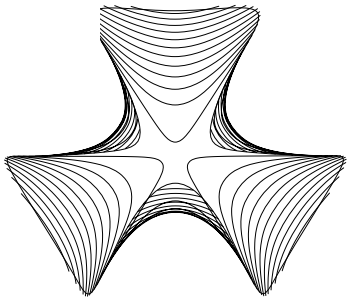
A-C
Bounding box manipulation to adjust height for site requirement.
2. curvature blue is max green is min

A
1. x=0, -x=0, area: 74m^2

B
1. x=2, -x=0, area:44m^2

C
1. x=-2, -x=1, area: 66m



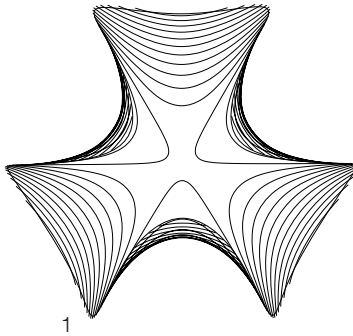


1

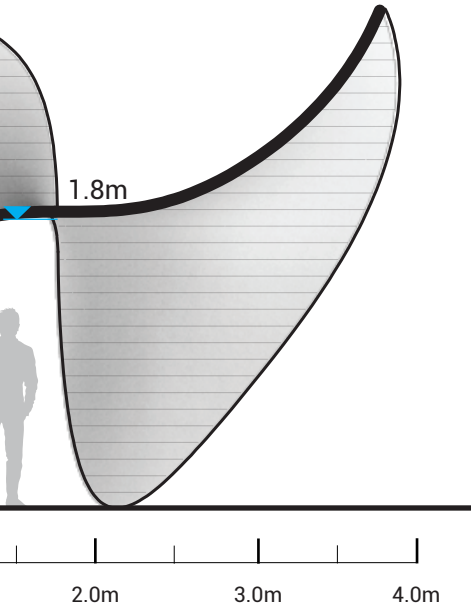
Option 1	Params
Footprint	6.9m²
Type	Tapered
Surface Area	18.9m²

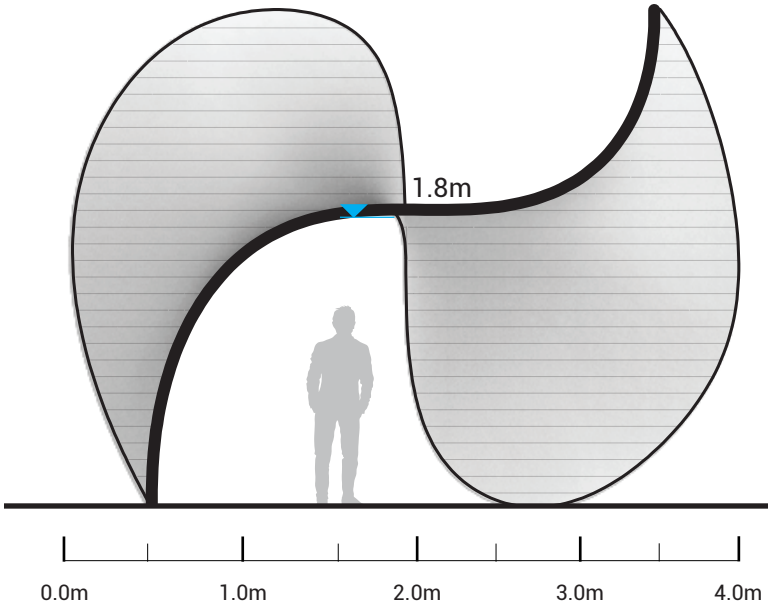
2

B



1

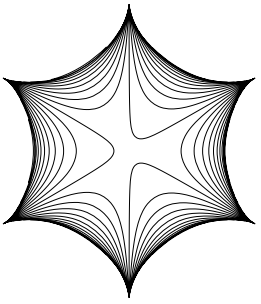




a

Option 2	Params
Footprint	7.2m²
Type	Expended
Surface Area	20m²

2 **C**



1

Option 3	Params
Footprint	7.9m²
Type	Standard
Surface Area	22.3m²

2 **D**

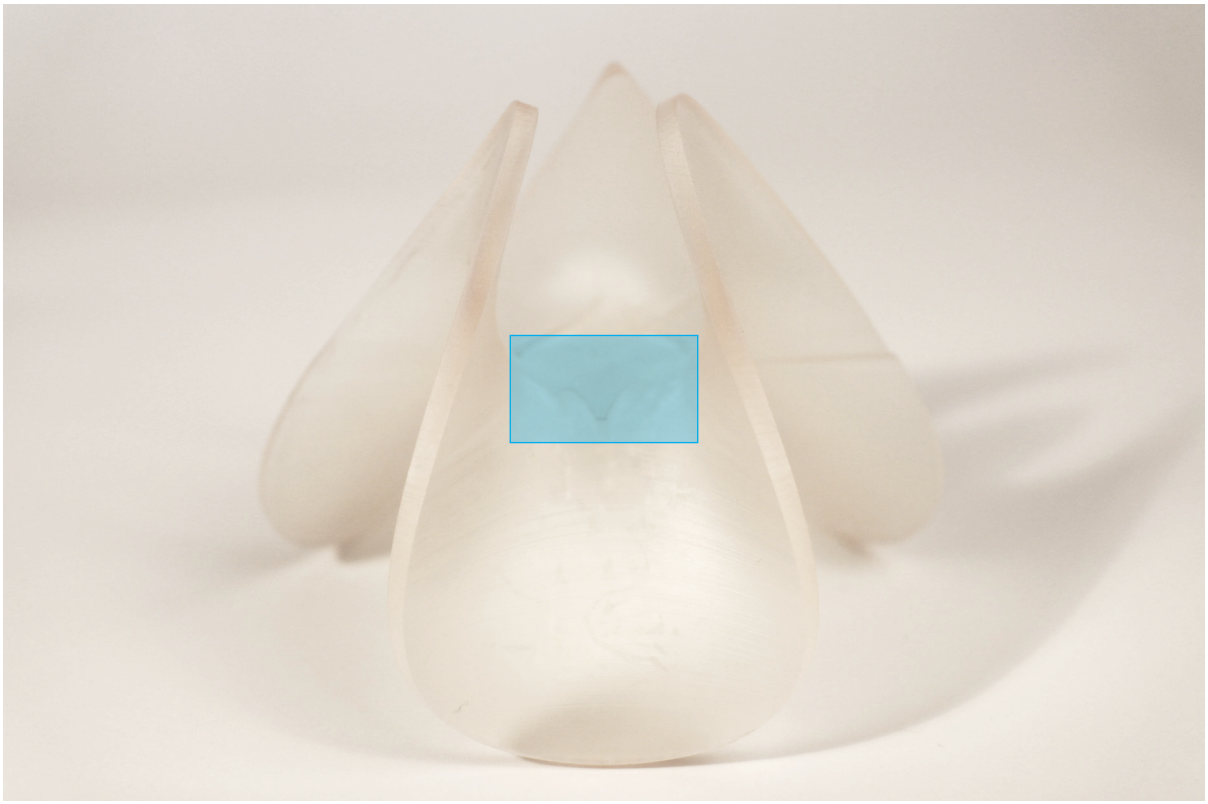
A
Sections of 3 options

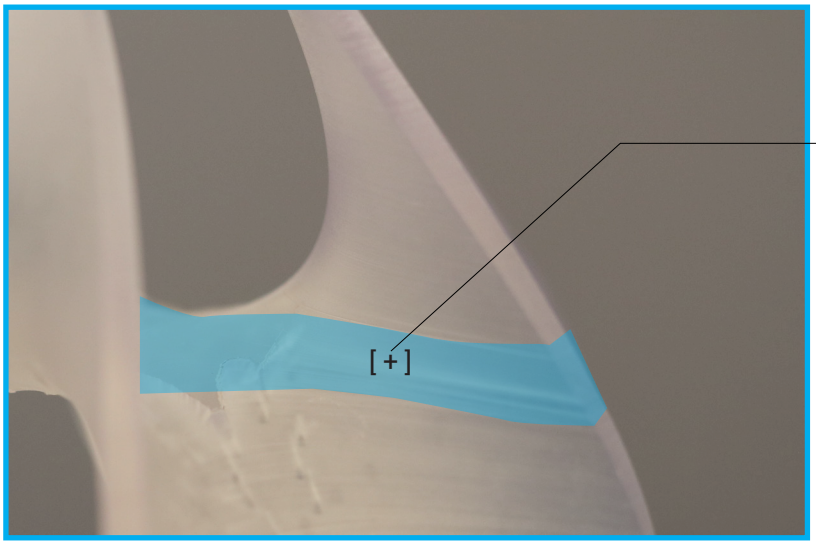
B
Top view and Parameter for option 1. Has smallest surface area.

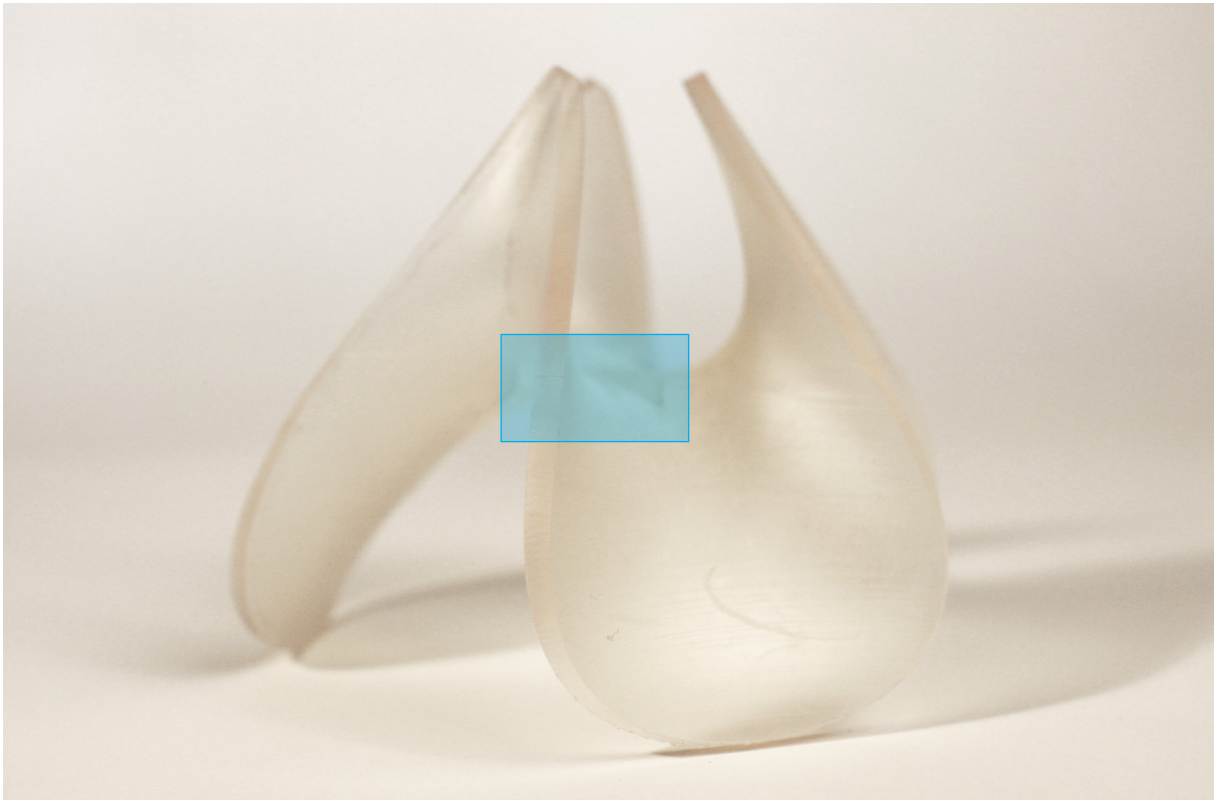
C
Top view and Parameter for option 2. Has medium surface area.

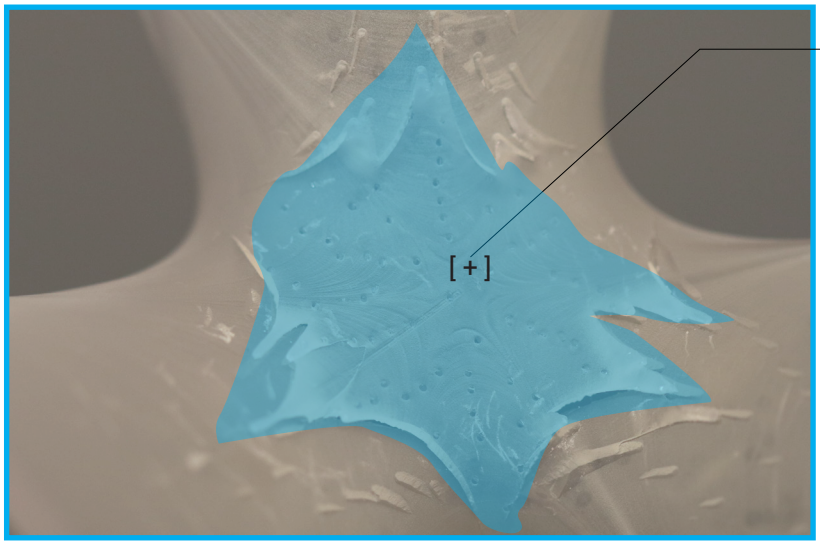
D
Top view and Parameter for option 3. Has large surface area.

Decision: option 1 is chosen due to smallest surface area due to budget and manufacturing concerns.



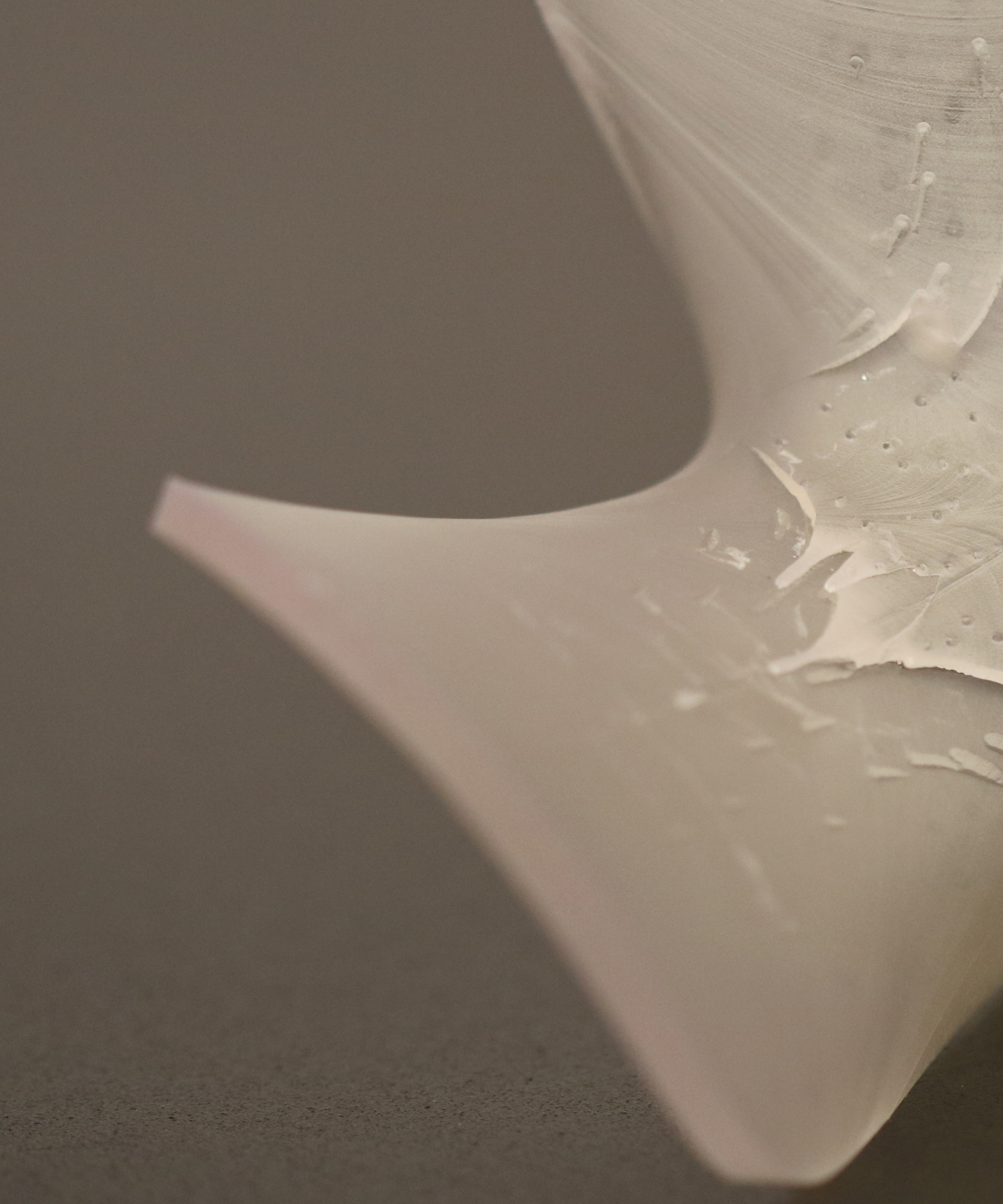

1
[+]

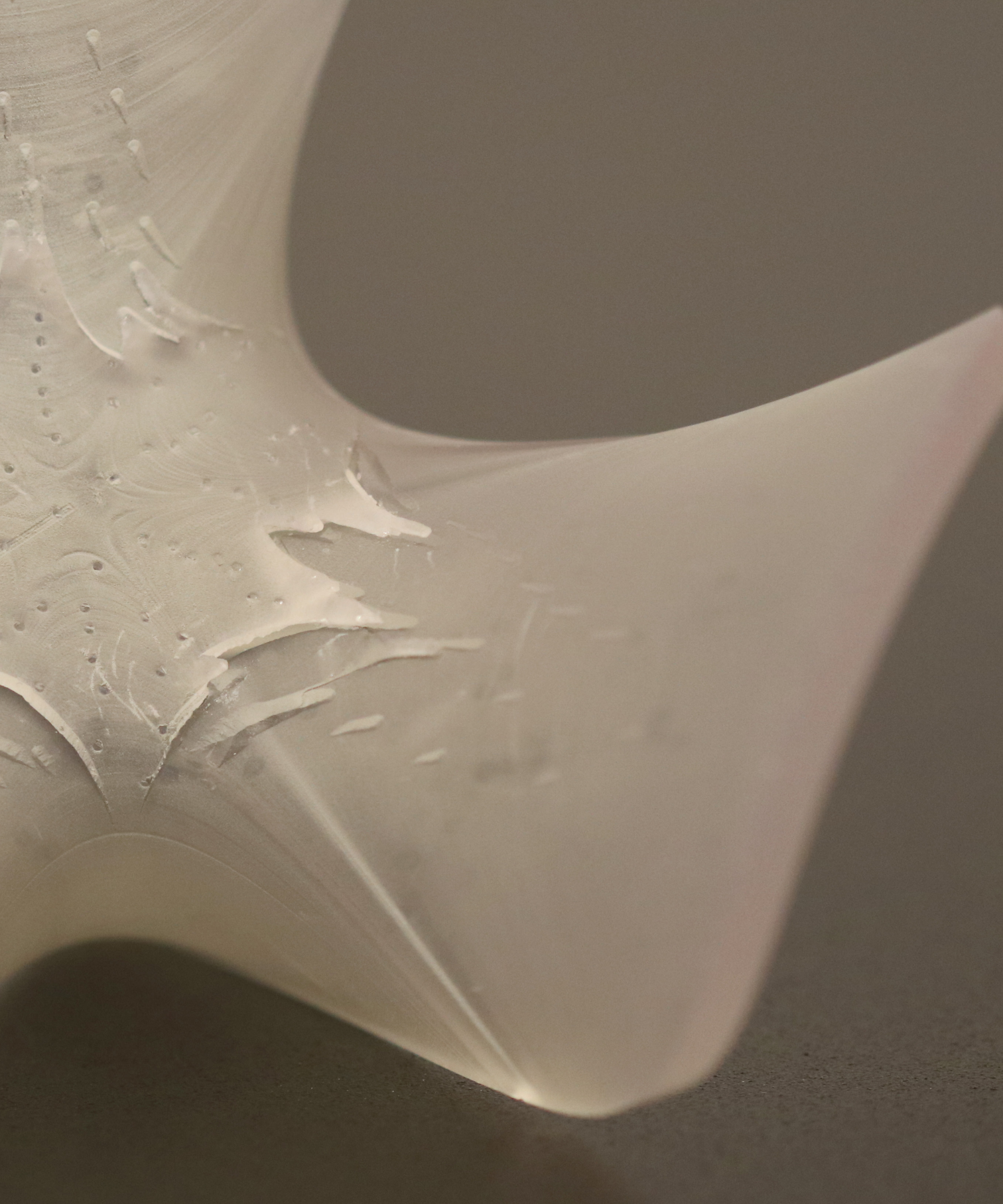


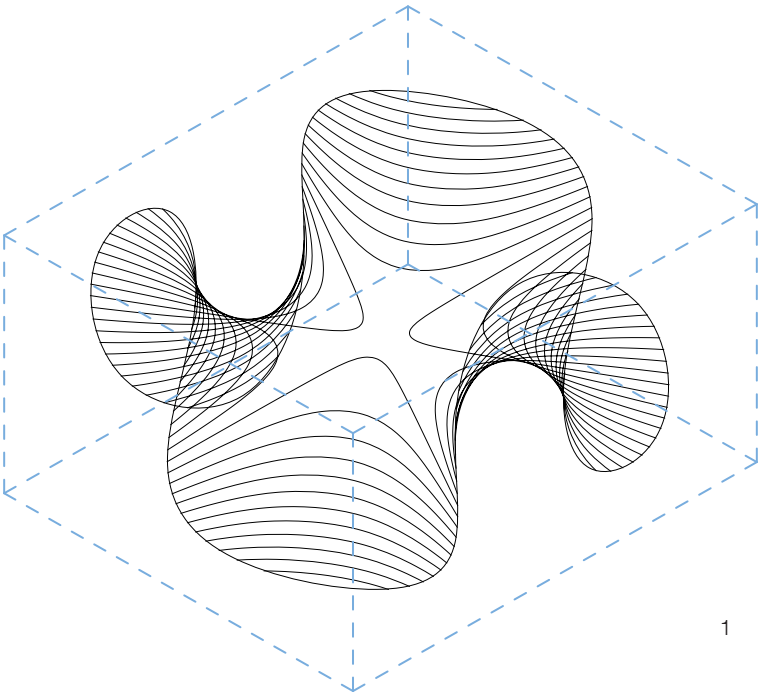


1
Offset edge occurred when approaching to the center of the model. This was caused by uneven distribution of surface tension when the resin is solidifying.

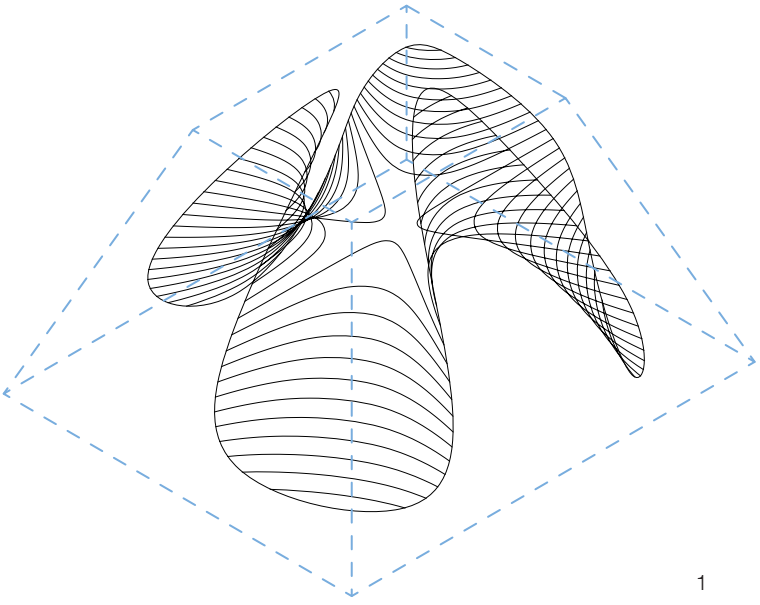
2
Bottom view: cracks are distributed unevenly, caused by uneven form of the model.



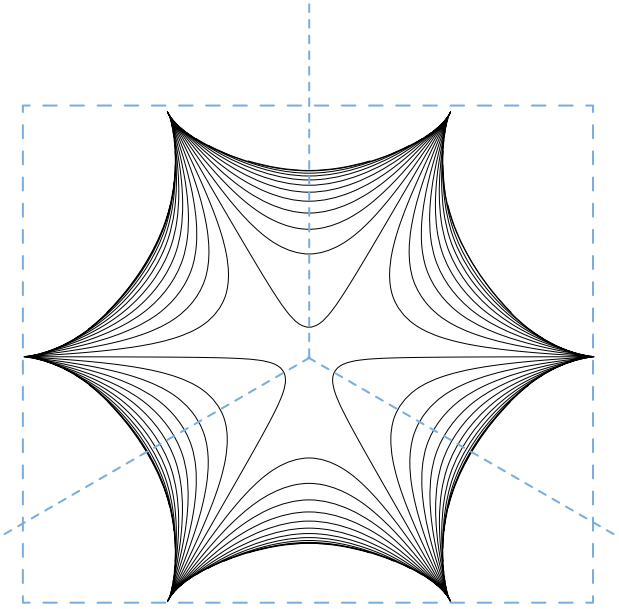




A 1



B 1



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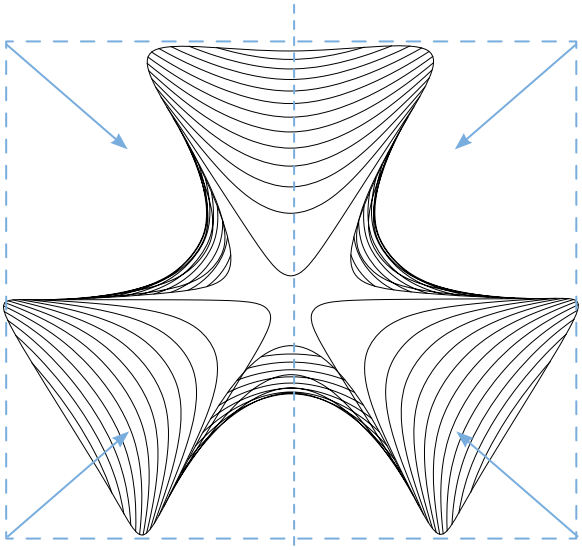
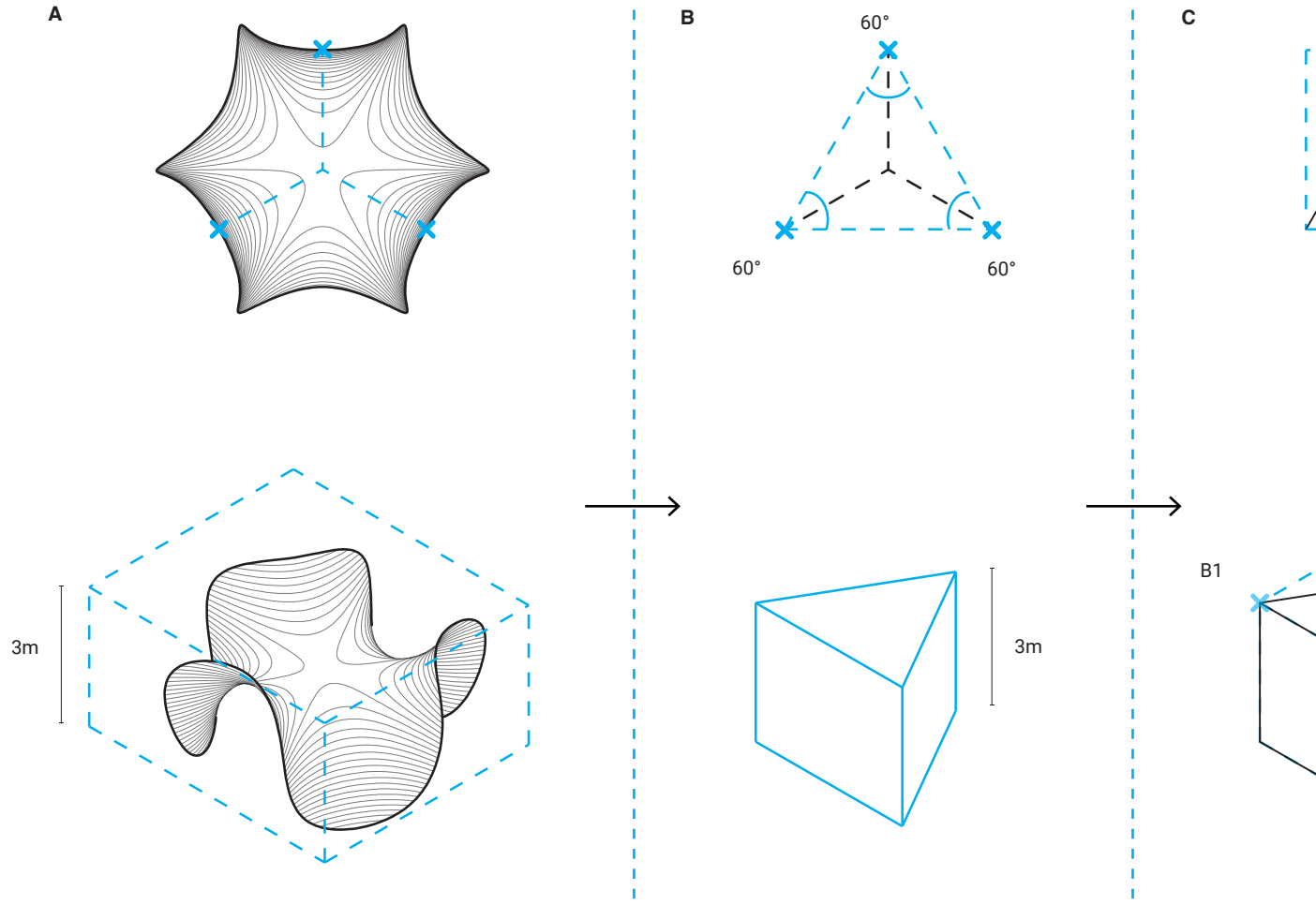


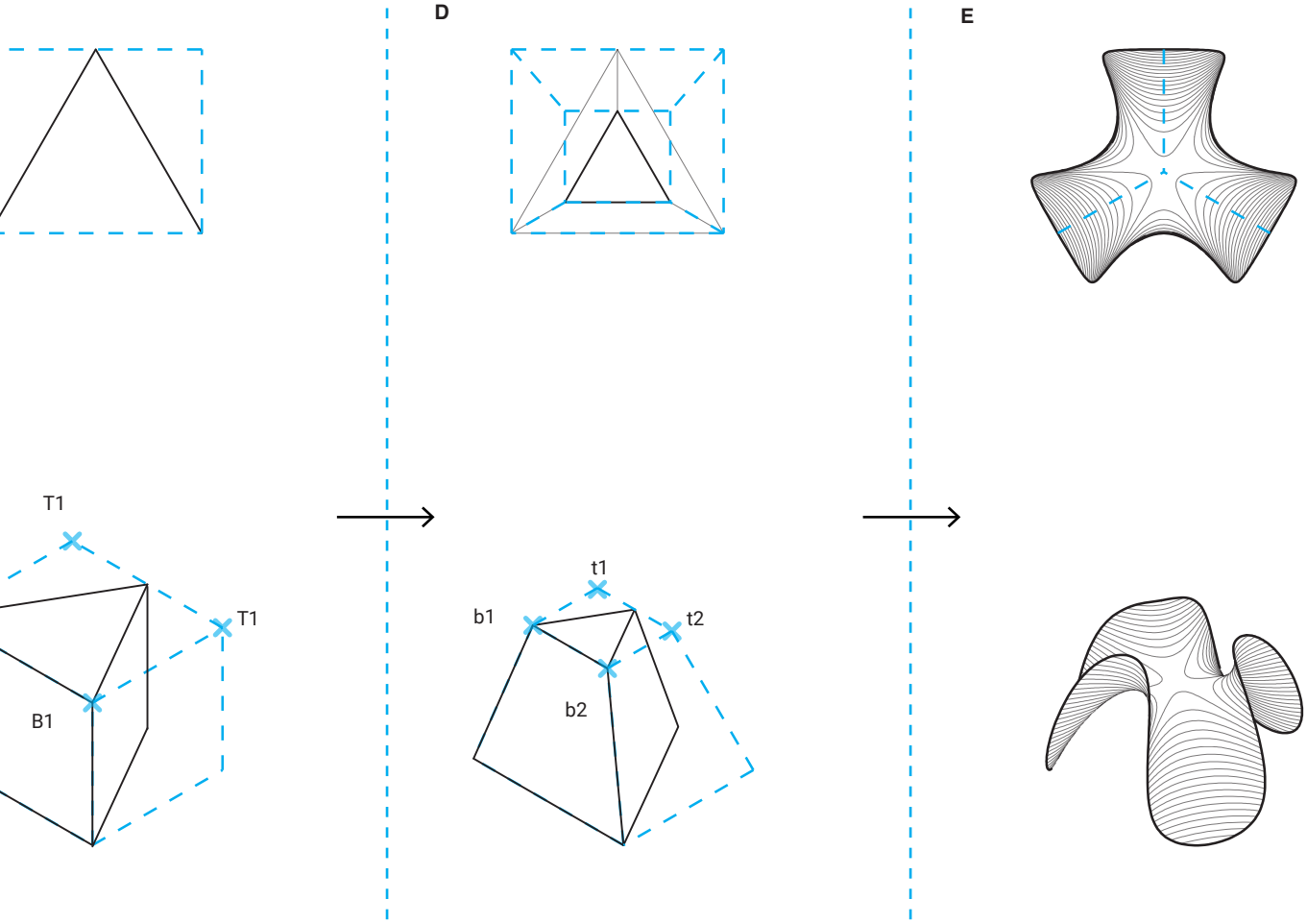
2

A
Original symmetry lines divide geometry into 3 identical wedges. The surface tension is evenly distributed.
1. Bounding box manipulation follows quad symmetry.
2. Enneper surface follows 120 degree triangular symmetry.

B
Modified geometry is distorted. The surface can no longer be rebuild by 3 equal parts.
1. Bounding box broke symmetry in the Enneper surface.

2.The distortion caused 3d printed model to crack due to unevenness.
Hence, bounding box need to be adjusted.


A
B
C
60°
60°
60°
3m
3m
B1



A
Extract total height from bounding box. Extract 3 axis

B
Construct equal side triangles from axis as reference.

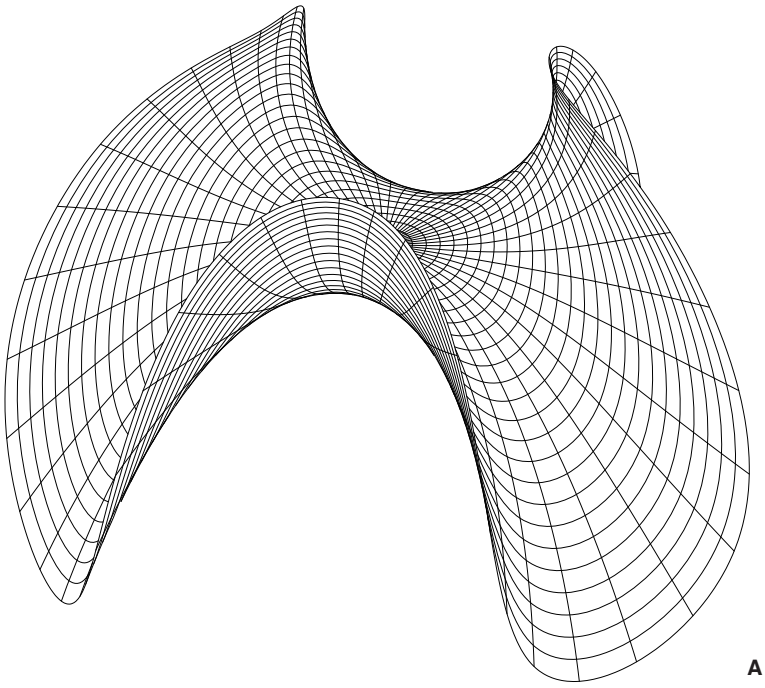
C
Known Coordinates from bounding box for triangular geometry below:

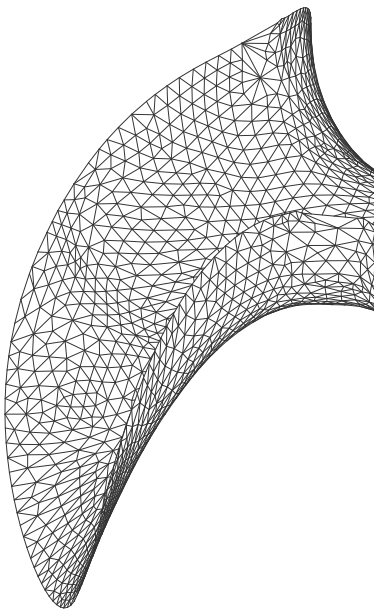
B1(x1, y1) B2(x2, y1) T1(x1, y2) T2(x2, y2)

D
Triangulate new coordinates following triangular symmetry according to trigonometry as below:
Value C is the changing factor

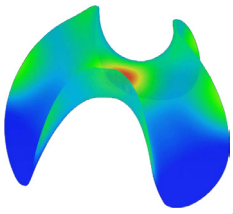
b1(x1+C, y1+(C*tan30))
b2(x2-C, y1+(C*tan30))
t1(x1+C, y2-{y2-y1-C*tan30°-[(x1+C)-(x2-C)]*tan30°})
t2(x2-C, y2-{y2-y1-C*tan30°-[(x1+C)-(x2-C)]*tan30°})

E
Apply new Bounding box to Enneper surface for final results

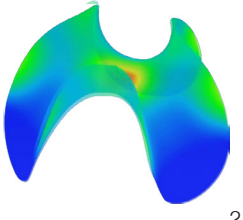




A



1



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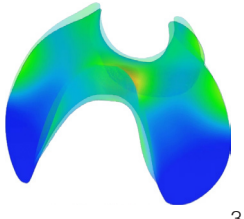

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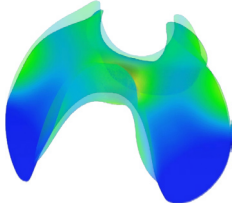

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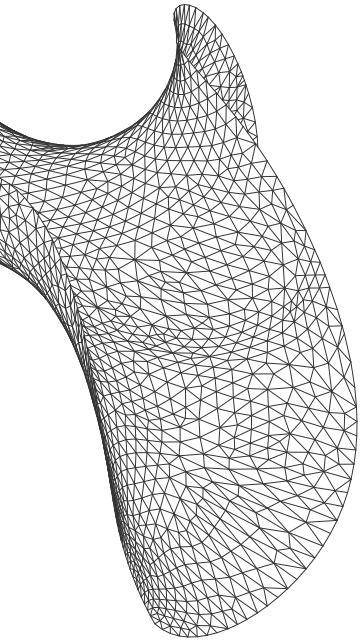
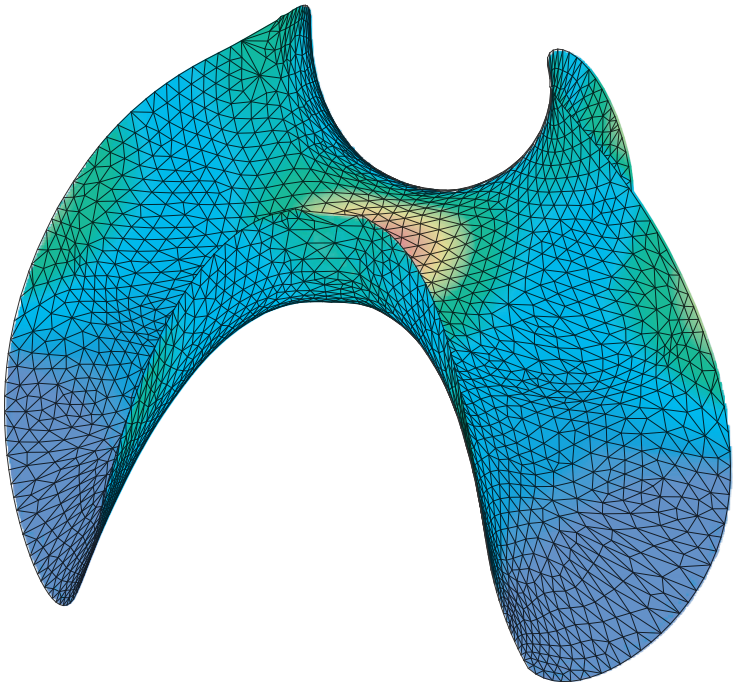


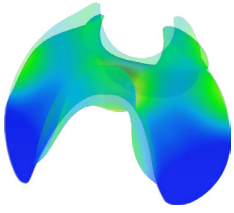
B



Min. deflection

Max. deflection

C



5

D

A
Final Nurb Surface with uv points converted to a mesh.

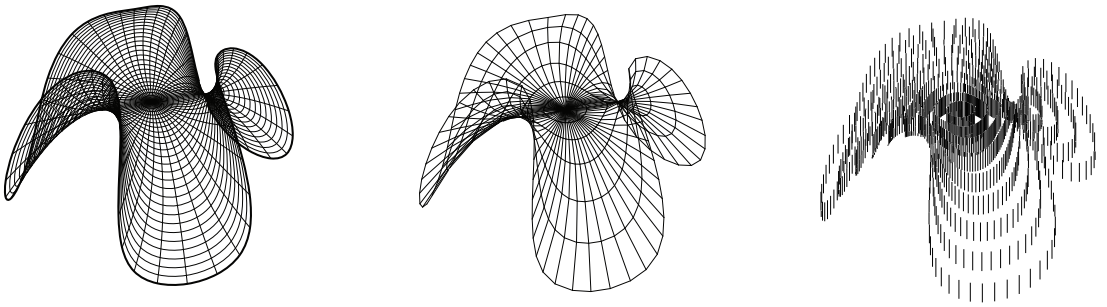
B
Mesh relaxation to re-build mesh and reduce interference from uv points.

C
Finite Element Analysis by Scan and Solve showing surface total displacement level.

D
i to v: Time line of potential moment of deflection under gravity load.

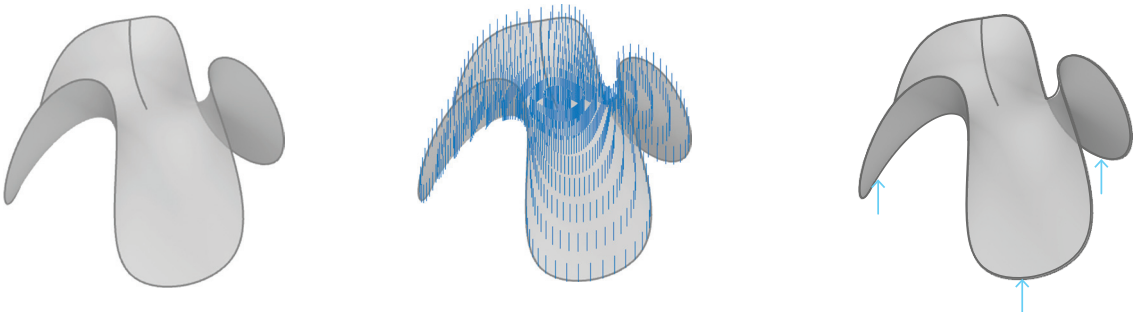
Scan and solve settings:
Material: glass fiber
Load: gravity load
Constraint: legs

Karamba is developed base on EFA.



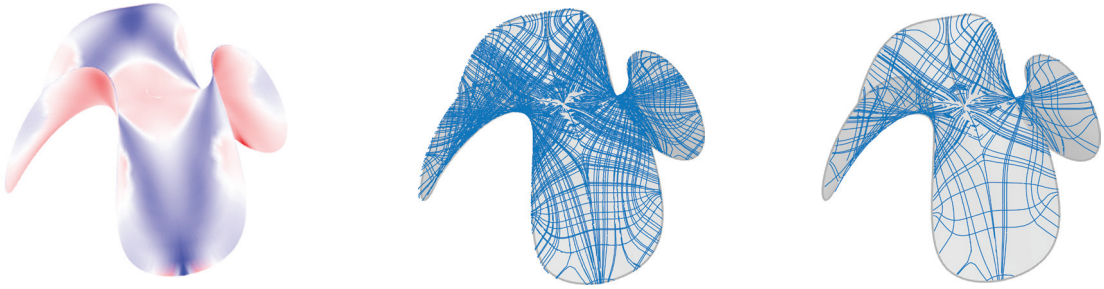
1 2 3

A



1 2 3

B



1 2 3

C

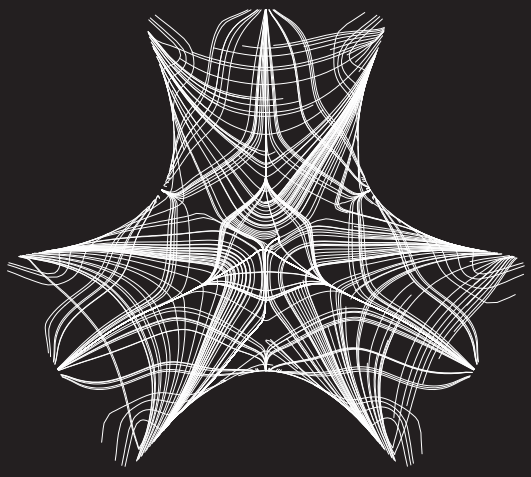
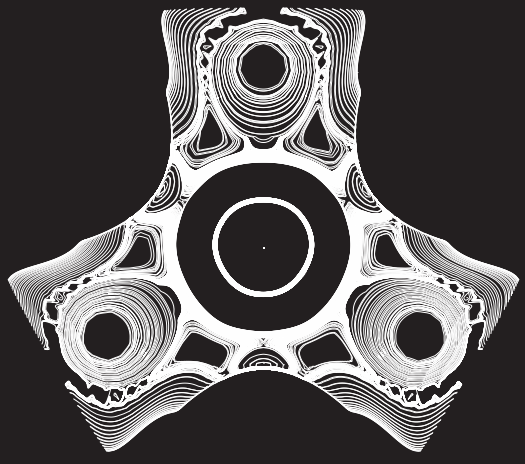
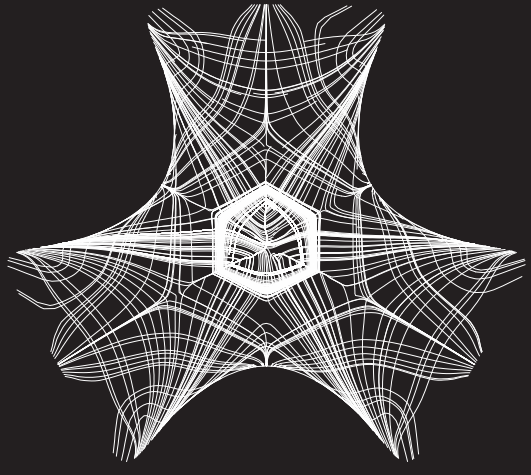
A-C
Karamba algorithm generation process.

A
Initiation
1. Parallel domain specification.
2. Initial surface meshing.
3. Seeding.

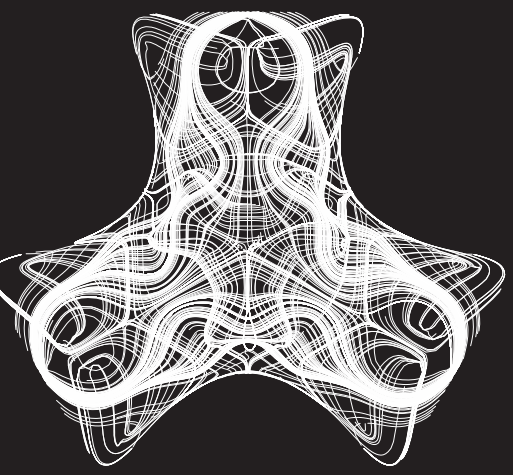
B
Generation
1. Defining the type of structure.
2. Stating the force location and the type of force.
3. Stating the support location and type of supports.

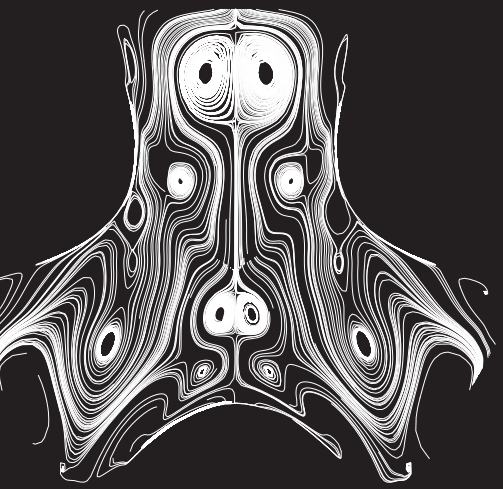
C
Processing
1. Structural analysis.
2. Interpolation and tracing.
3. Rationalizing.



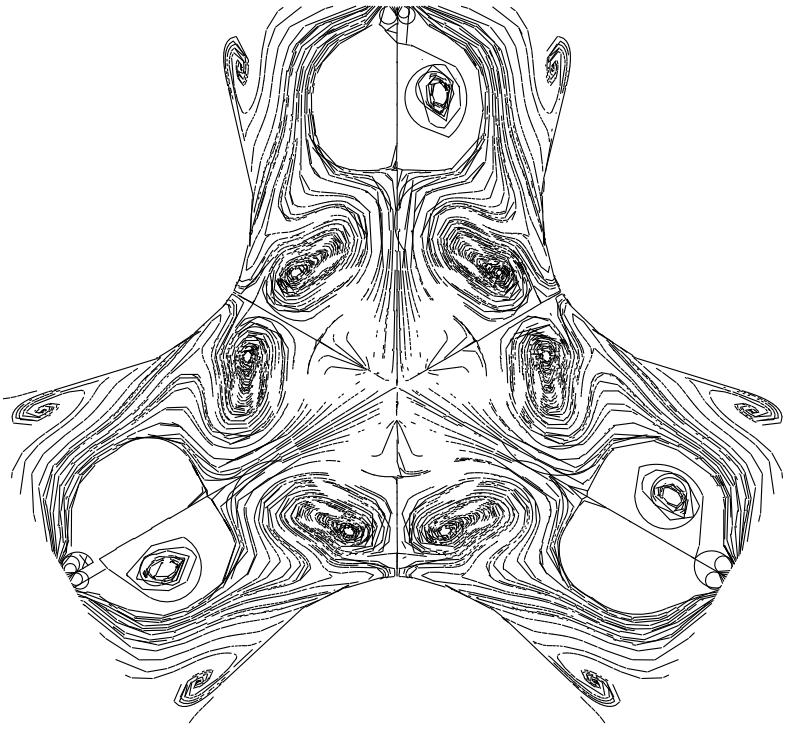




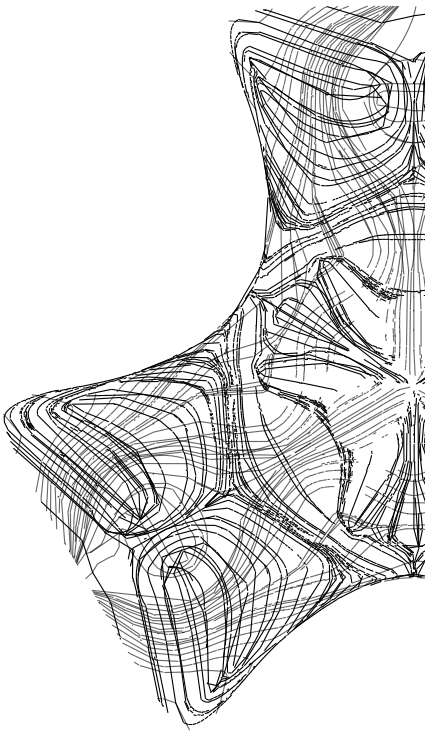
Stress Line Iteration

Karamba algorithm generation creates options for various outcome for different circumstances.

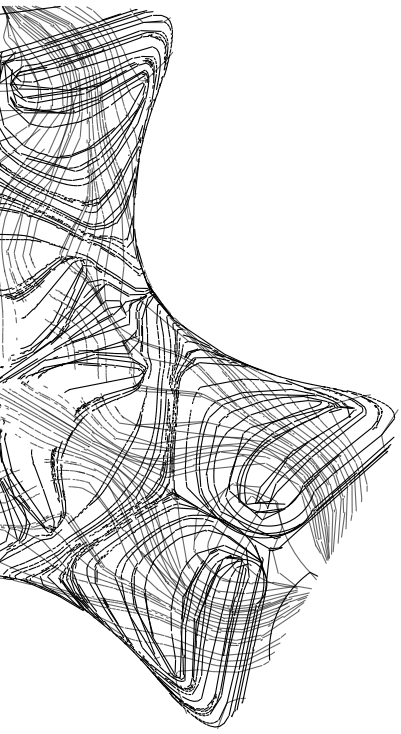


Setting	Force flow
Constraint	Ground support
Force	Gravity load

A

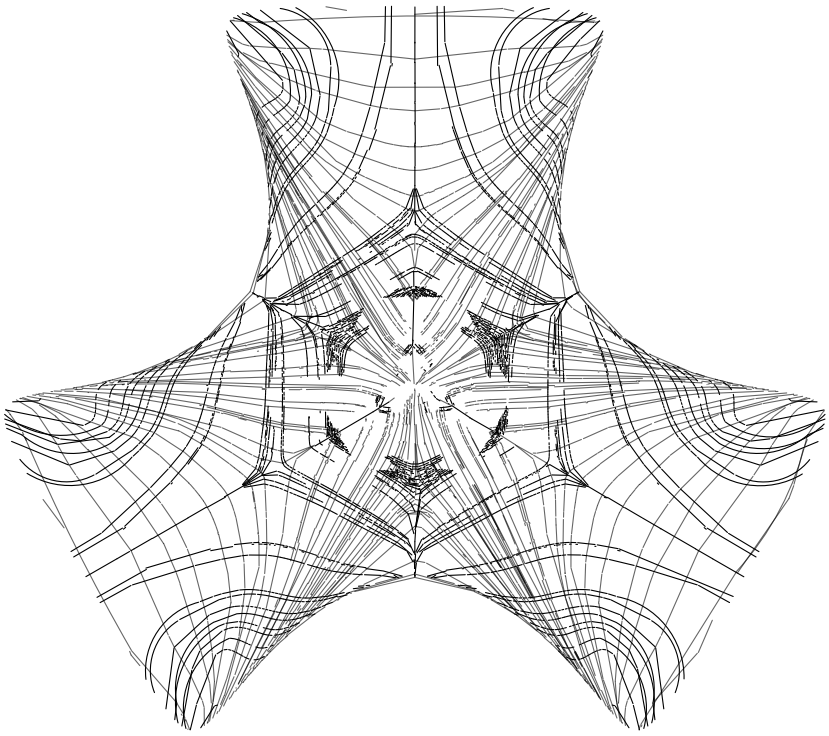


Setting
Constraint
Force



Principle stress
Ground support
Gravity load

B



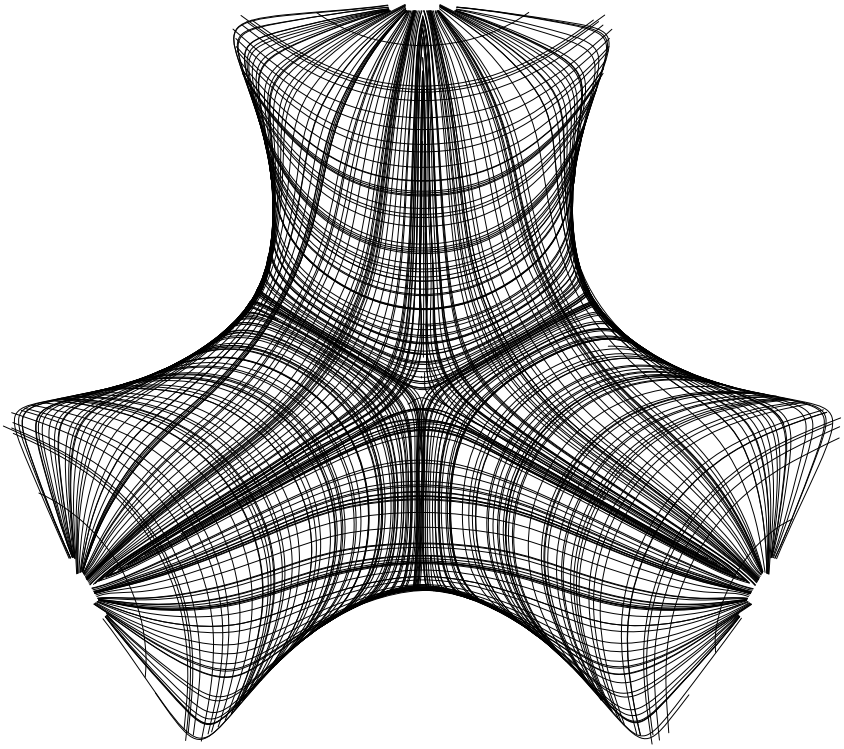
Setting	Principle Moment
Constraint	Ground support
Force	Gravity load

C

A
Inspired by fluid dynamics, force flow (FF) lines or load paths illustrate the load distribution in structures.

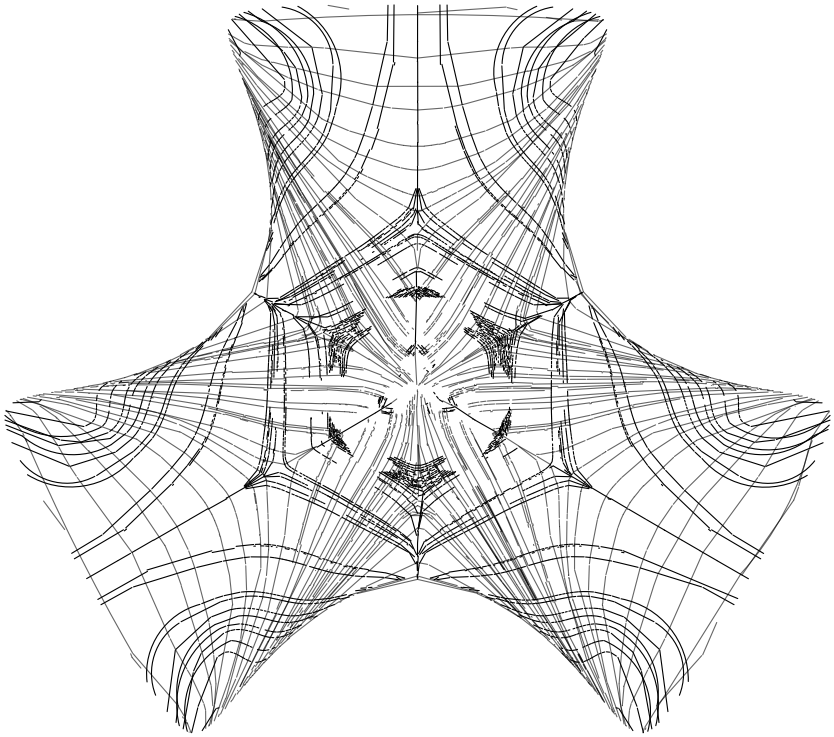
B
Principal stress (PS) lines are tangent to the principal stress directions. Principal and second principal stress lines intersect at 90degrees. In a cantilever they either run parallel or at right angle to the free boundaries.

C
Principle moment (PM) works like the Principal Stress Lines component Instead of principal stress lines it returns principal moment lines.



Programme	Millipede
Constraint	Ground support
Force	Gravity load

A



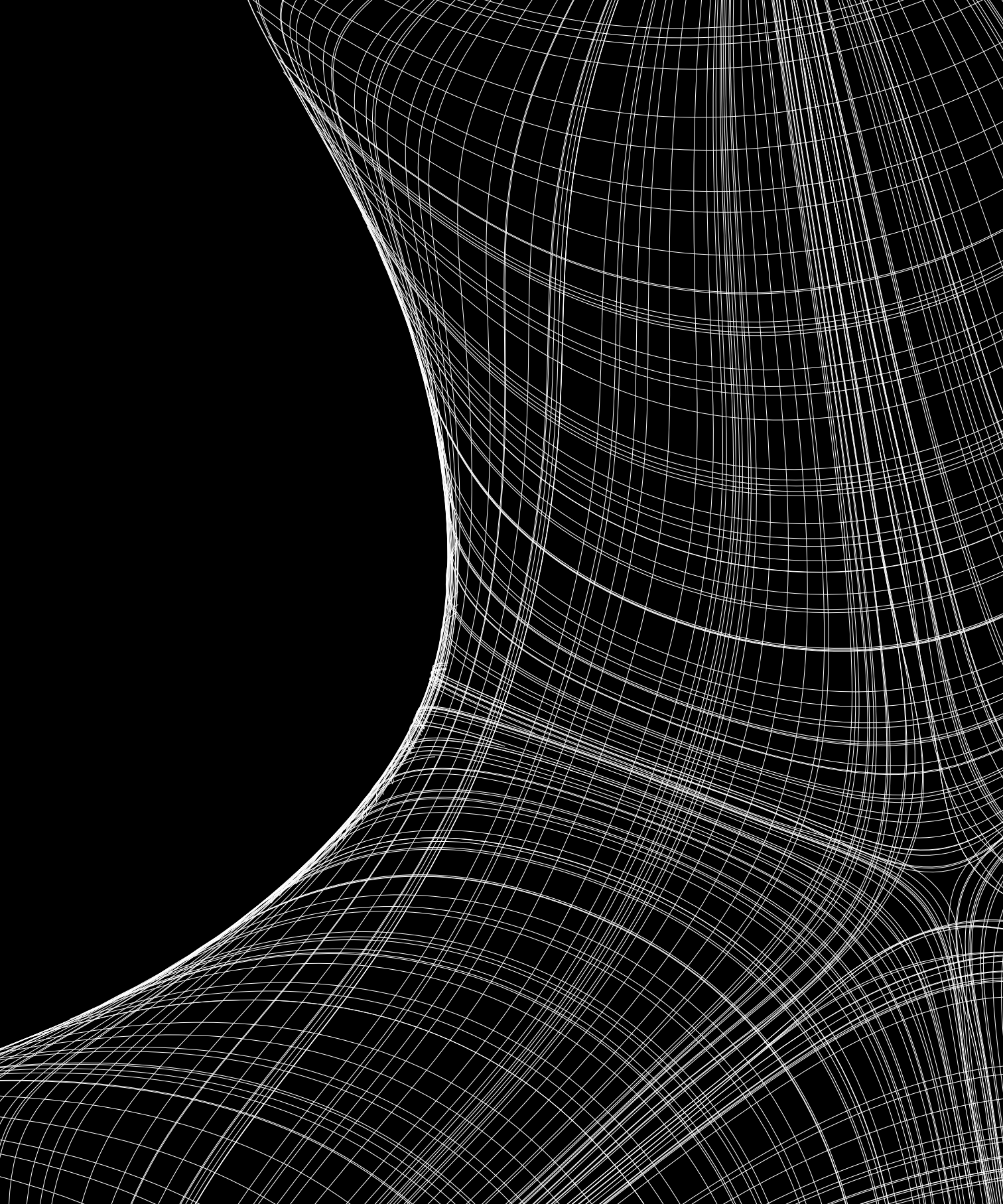
Programme	Karamba
Constraint	Ground support points
Force	Gravity load

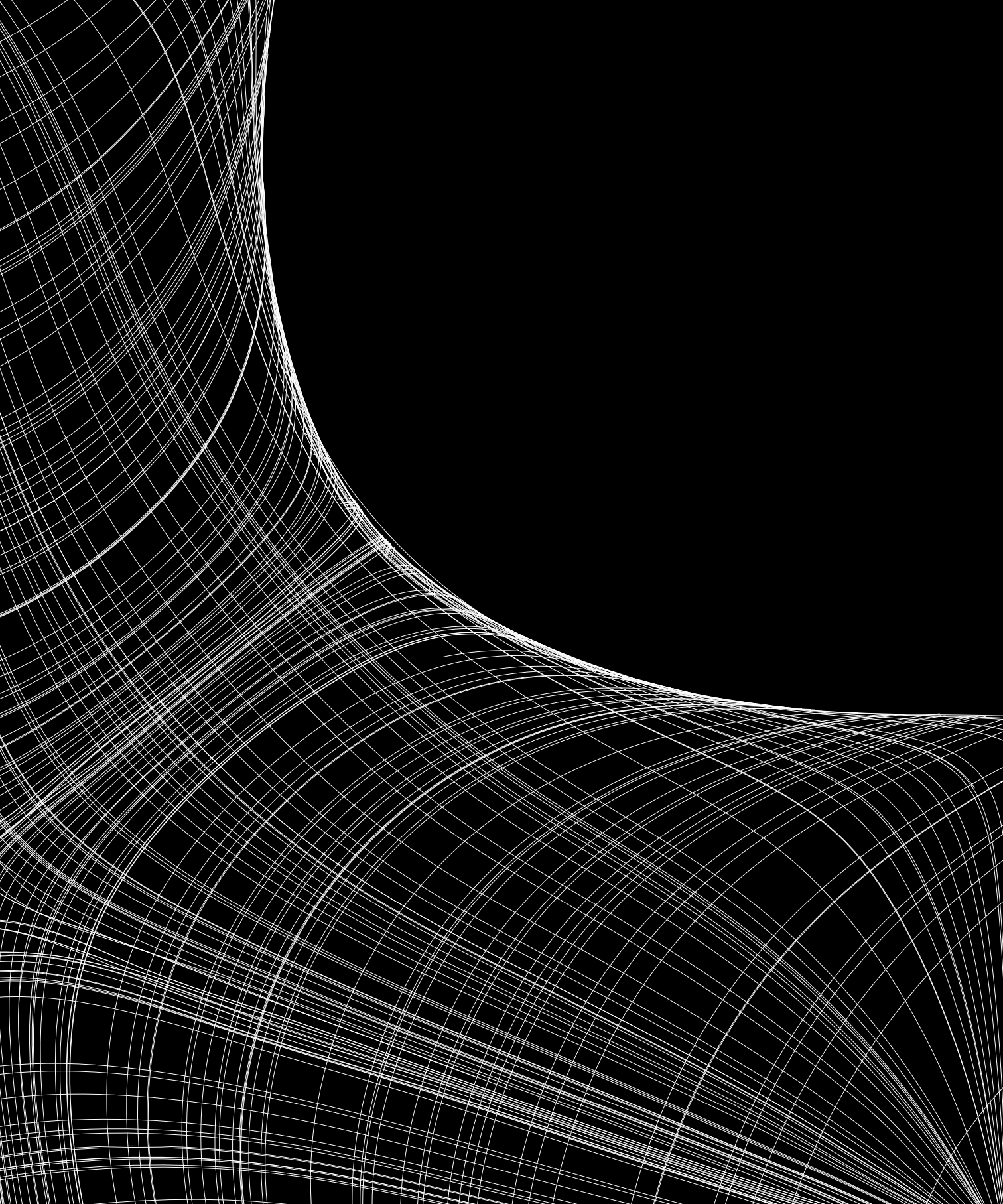
B

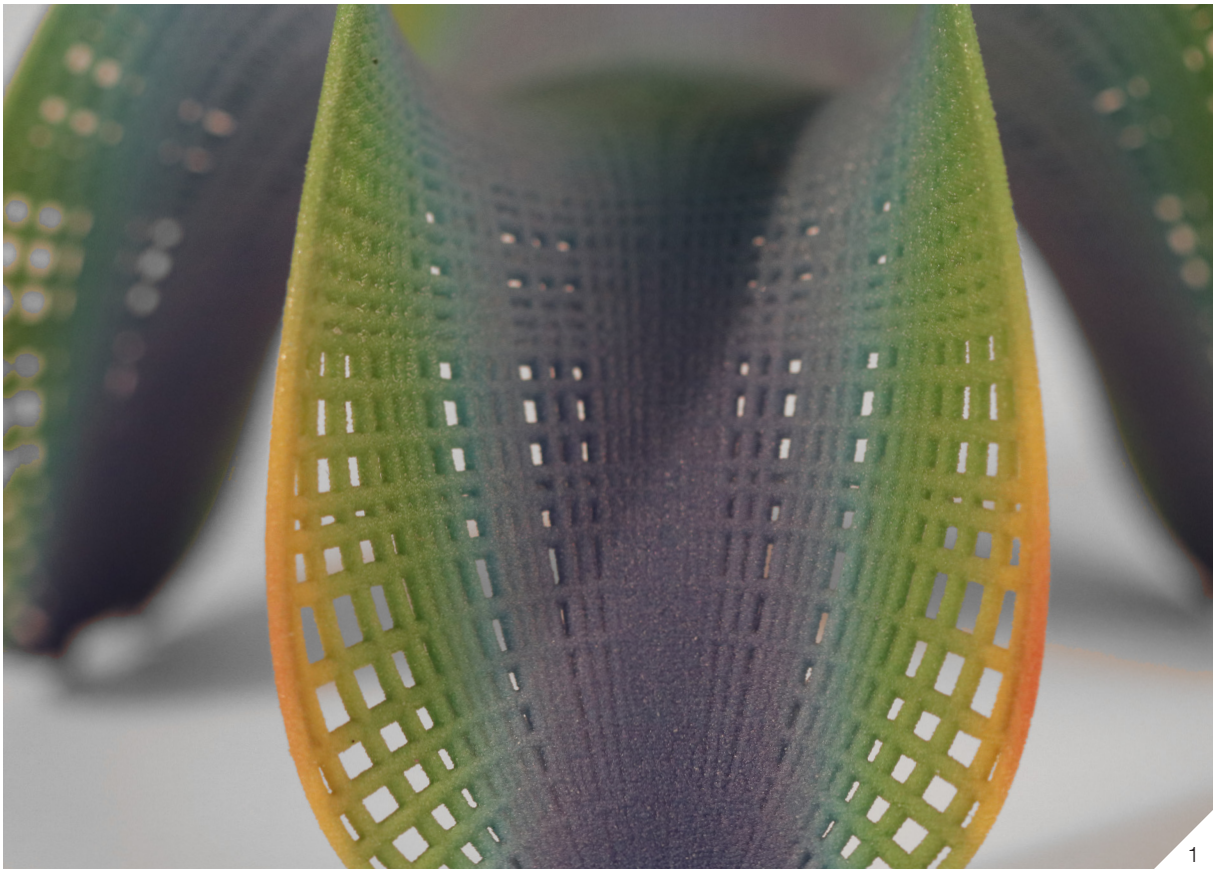
A
Millipedes software is similar to Karamba. The difference is that Millipedes requires input such as ground and testing geometry so the program can generate simulation based on ground intersection instead of manually assigning forces to the testing geometry.

B
Karamba generates result based on points assigned to the testing geometry. This method is considered to be questionable because the pavilion can't be in point contact with the ground.

Therefore, the output from Millipedes is chosen for further development.







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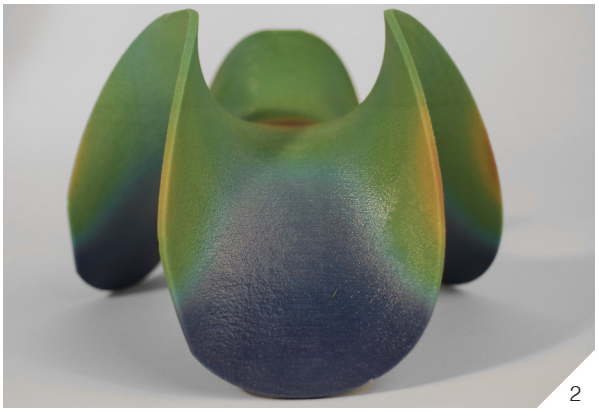

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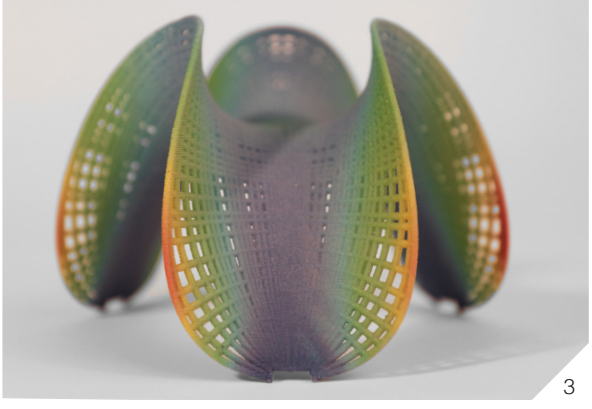

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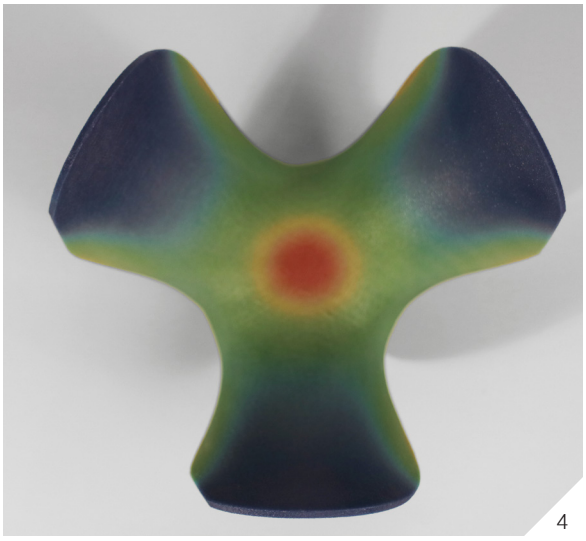

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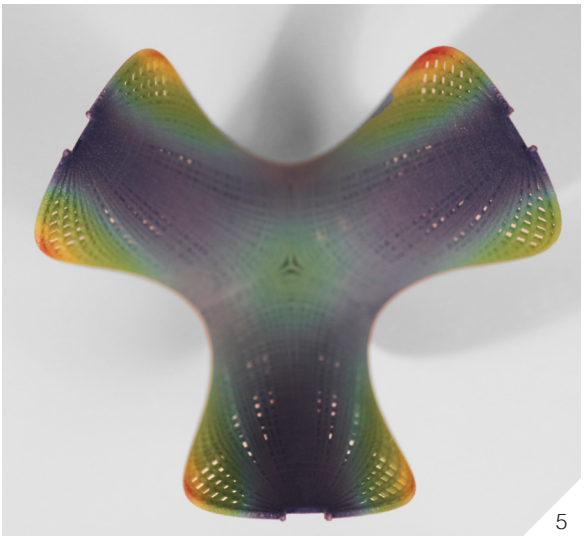

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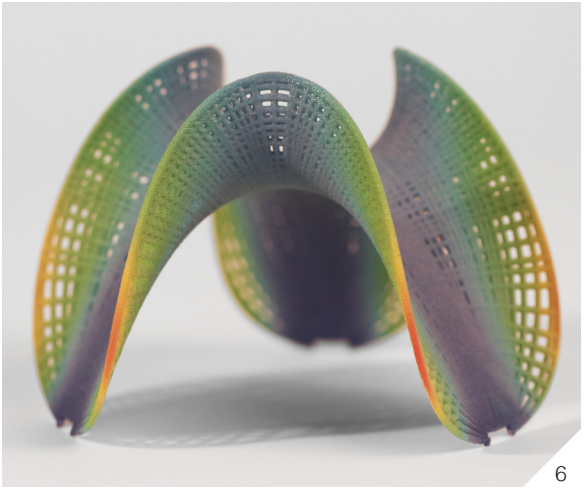

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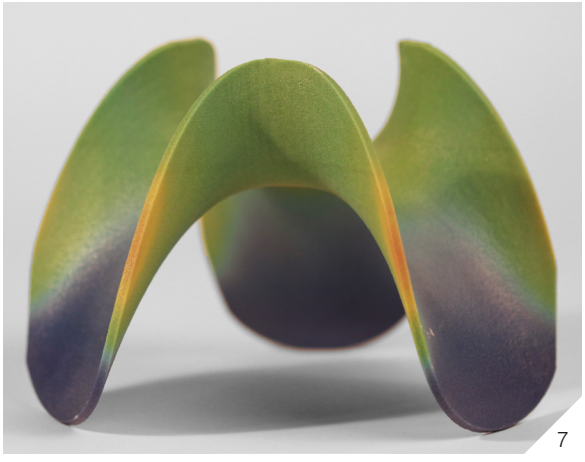


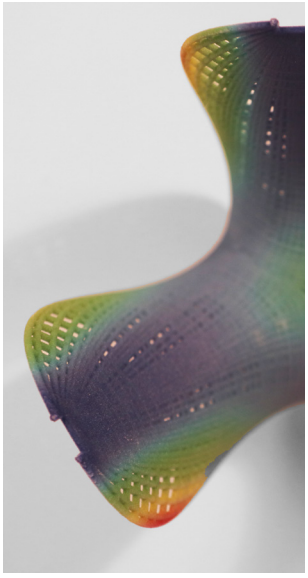
7

1
3D printed Surface remodeled with stress-line to optimize its strength

2-3
Comparison model showing before and after stress line optimization. Color gradient showing stress distribution,red is maximum and vice-versa.

4-5
Bottom view comparison model showing before and after stress line optimization.

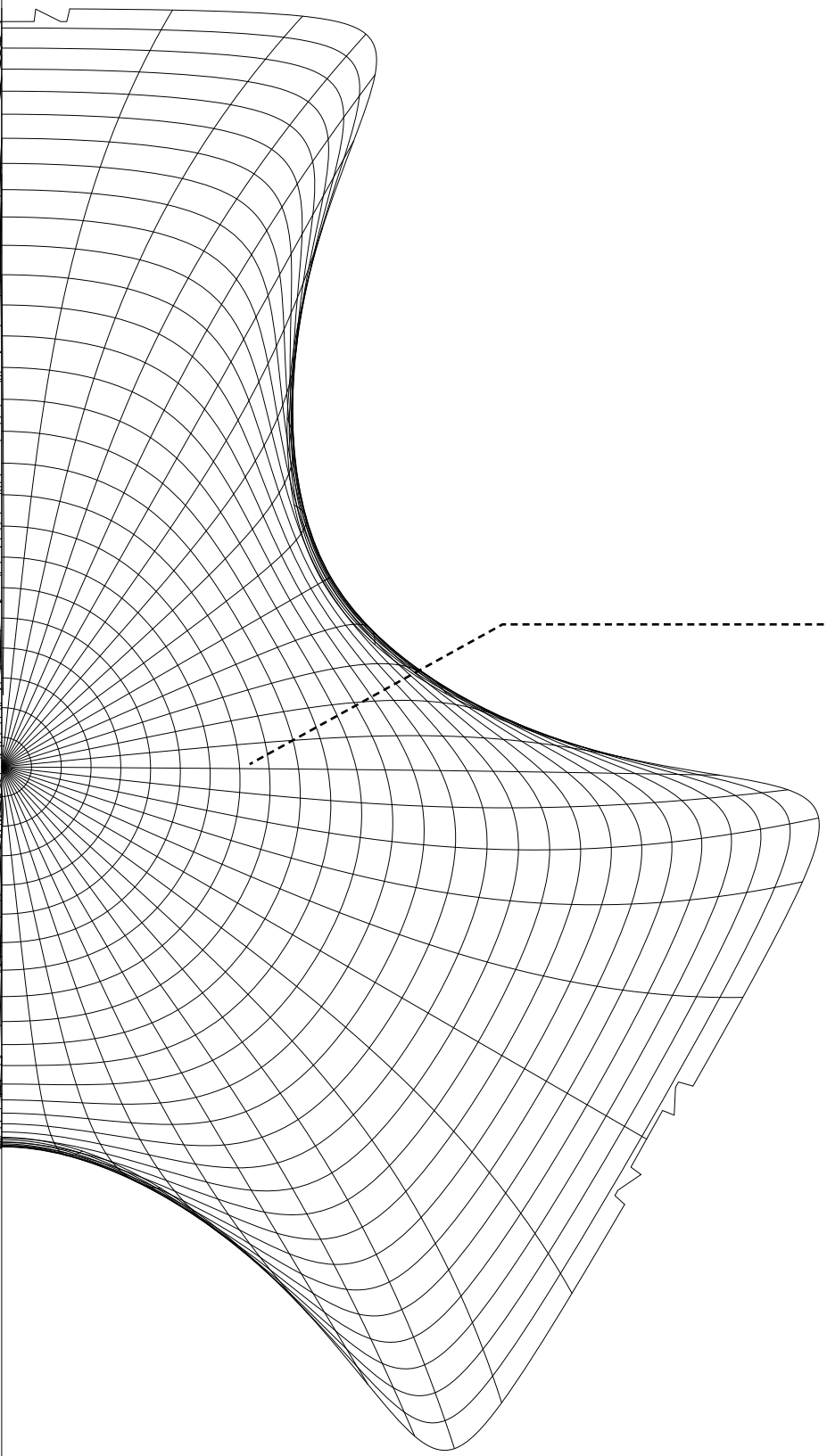
6-7
Side view comparison model showing before and after stress line optimization. Stress line surface has shown improvement via this testing method.

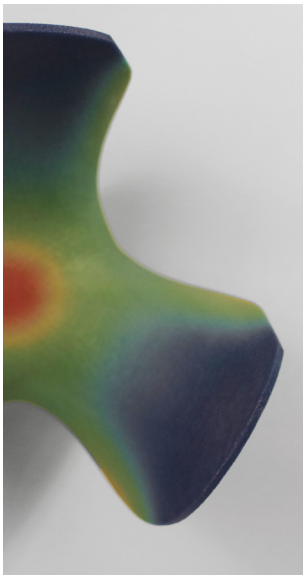


Carbon fiber + resin mix

Pro:
Weight reduction
Strength increases
Load distributed evenly
Overall increased performance

Con:
Price increases

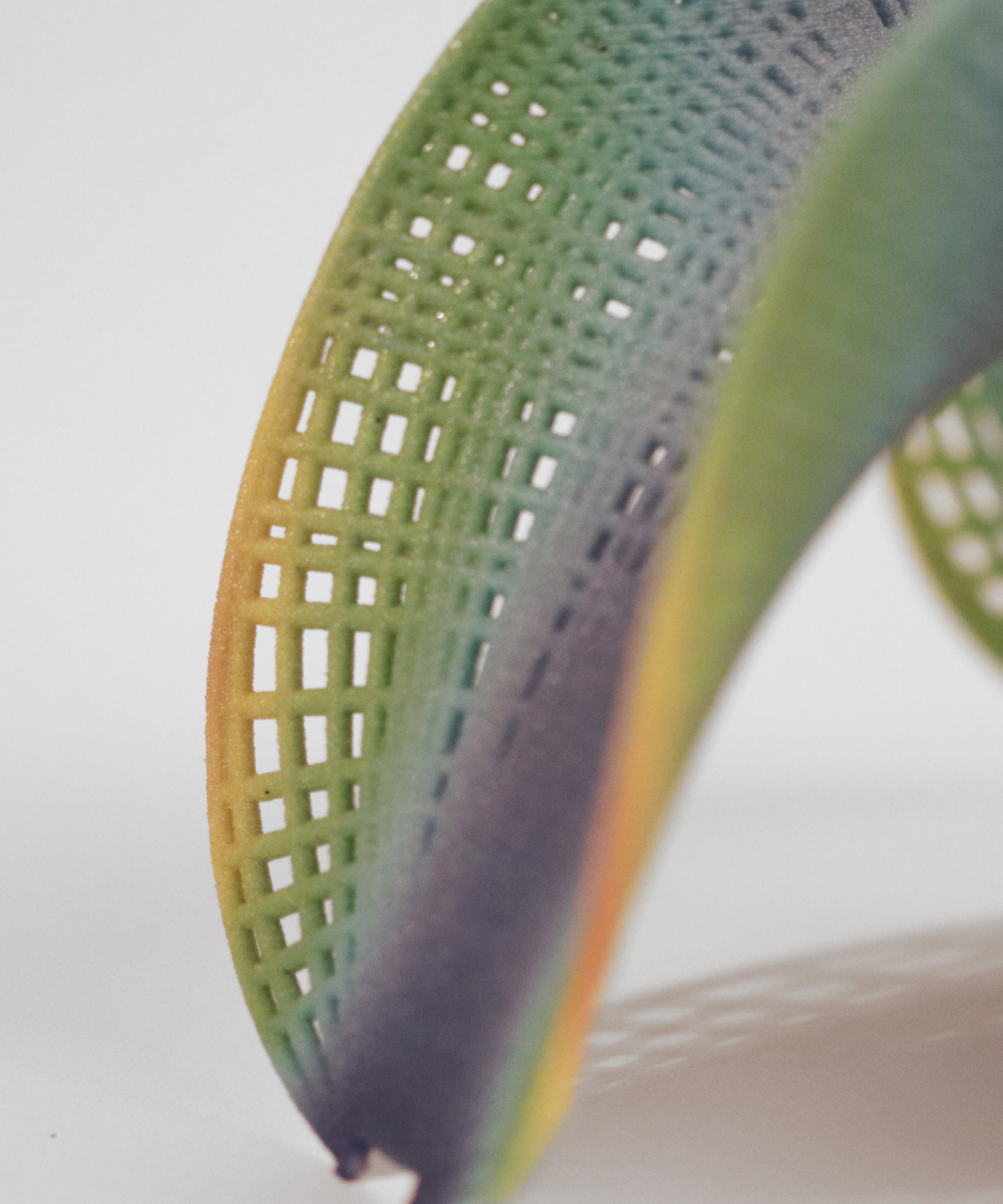


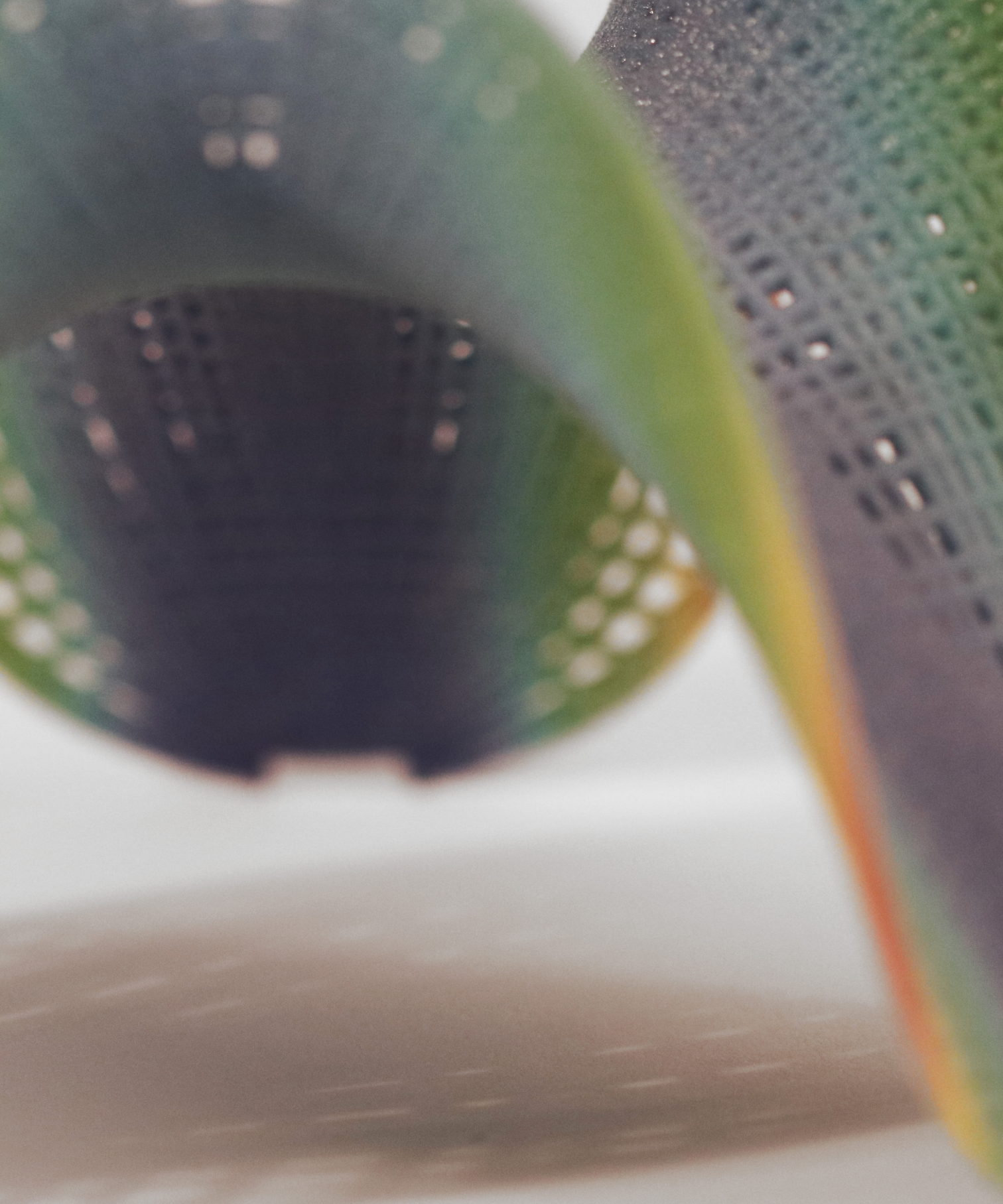


Generic reinforced concrete mix

Pro:
Mass and volumetric
Economical

Con:
Heavy weight
Inferior load distribution
Lower strength
Low strength to weight ratio

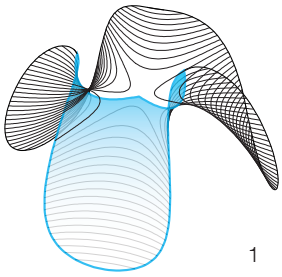




FAB RIC ATE

#Production Simulation #Rapid Prototyping #Scaled Modeling





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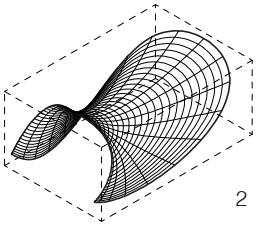

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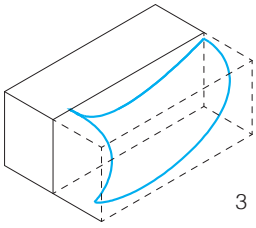

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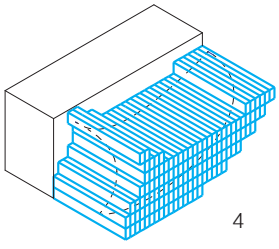

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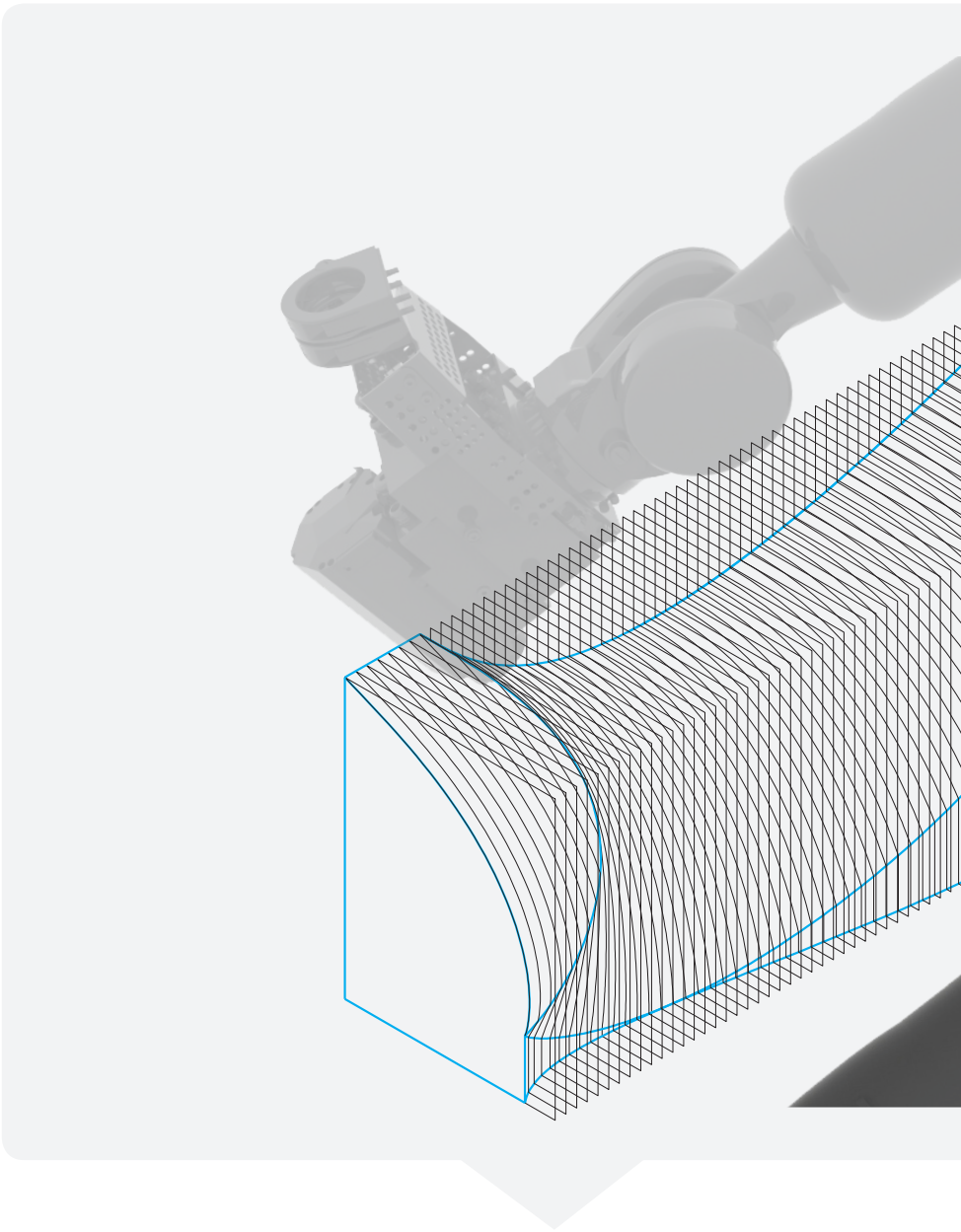

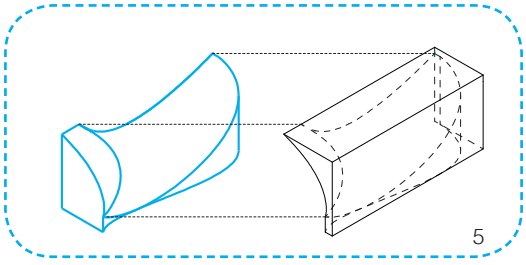

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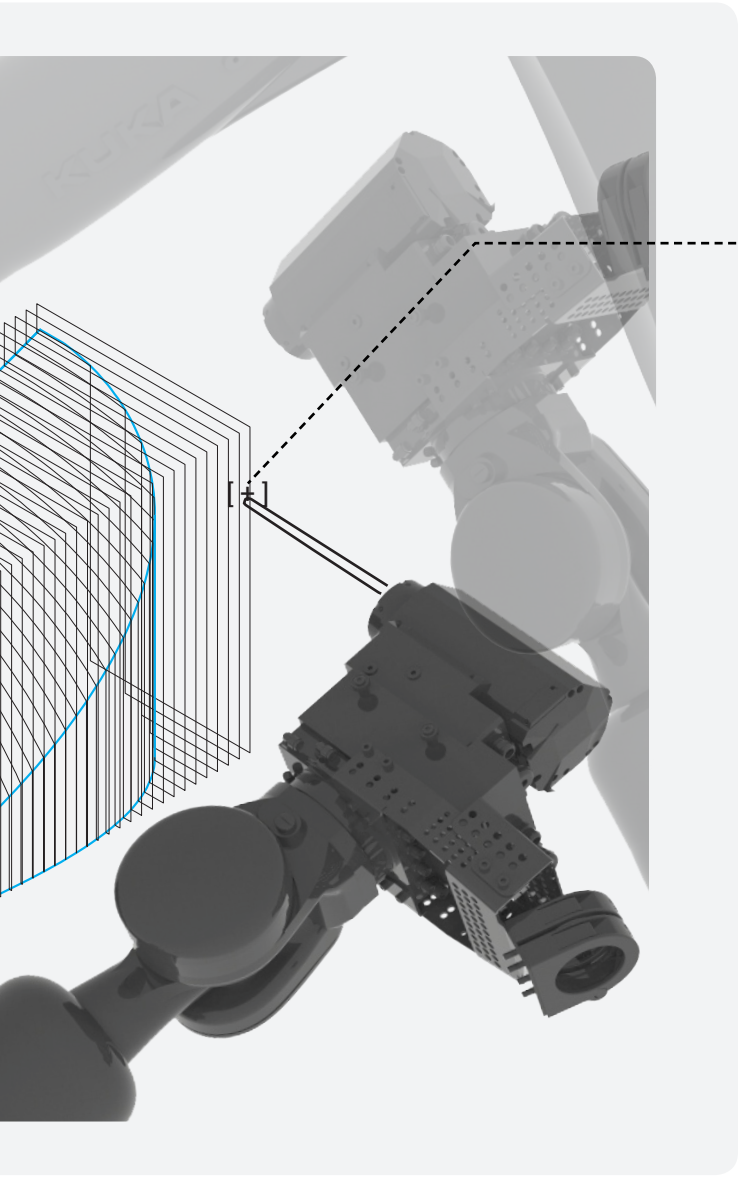
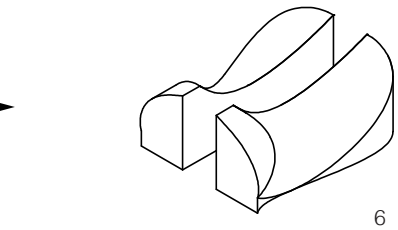






6

1
Extract one panel of the pavilion for mould production.

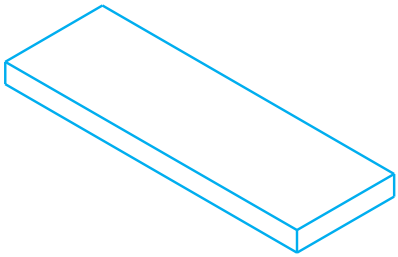
2
Split the panel and produce the mould in 2 halves.

3
Optimize the mould to save Sikablock® heat resisting material due to cost.

4
Repeat the process and produce two moulds with robotic milling

5
Robotic milling process.

6
Acquire two moulds.



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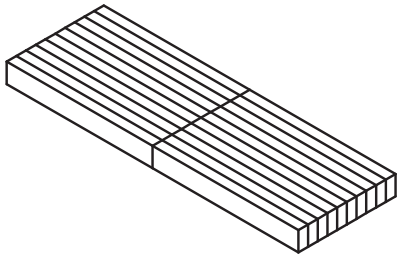

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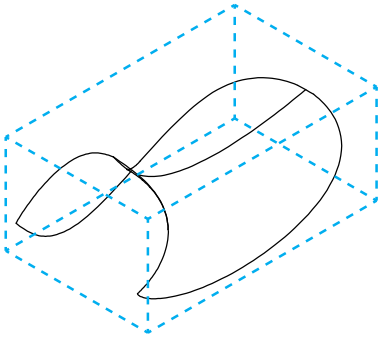

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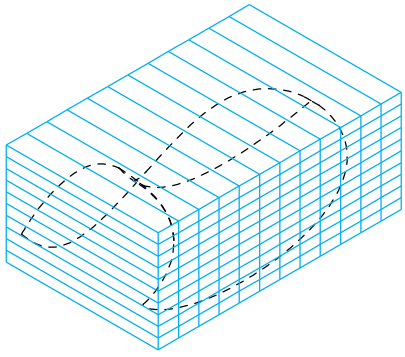

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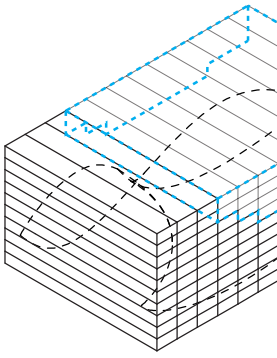

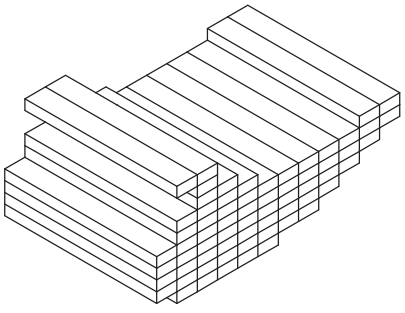

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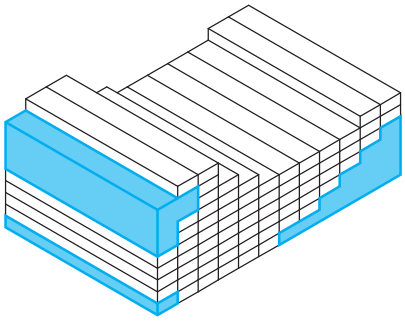
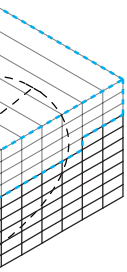


6

Material supply	Sikablock® M700
Number of sheets	4
Volume	150 cm3
Weight	150 kg
Characteristic	Heat & corrosive resistant

3 **A**



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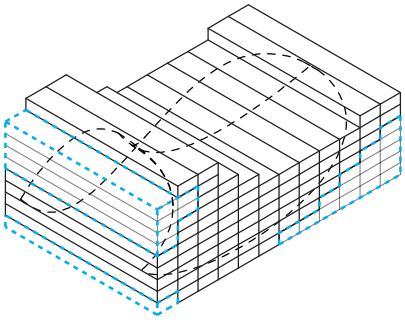

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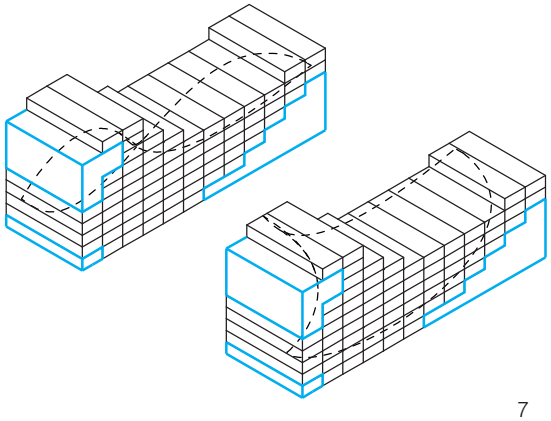


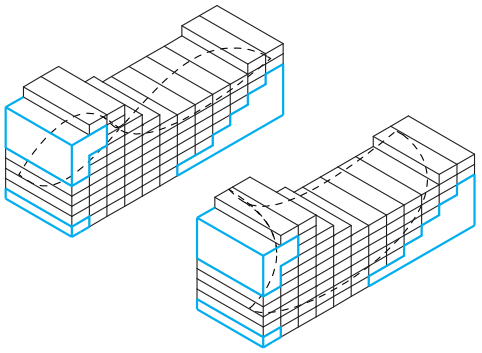
7 **B**

A
1. Dimension 1500x500x100mm
2. 20 blocks each with dimension 750x50x100mm
3. Material infos

B
1. Position the petal and establish bounding box
2. Populate bounding box with 750x50x100mm blocks

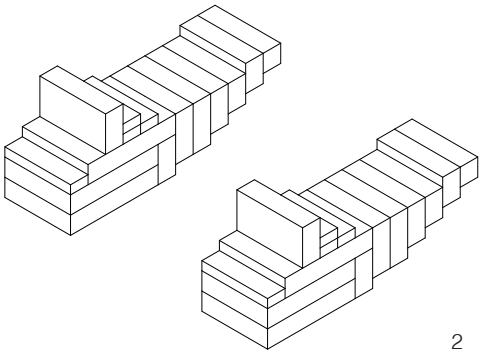
3. Remove top extra.
4. Remove bottom extra.
5. Finalized 65 blocks
6. Fill in jigs for support
7. Divide mould into two pieces

Number of pieces	65 blocks
Number of times to cut	64 cuts
Number of times to glue	32 times
Amount of glue available	2kg
Chances of error	High



1

Number of pieces	32 blocks
Number of times to cut	31 cuts
Number of times to glue	31 times
Amount of glue available	2kg
Chances of error	Low



2

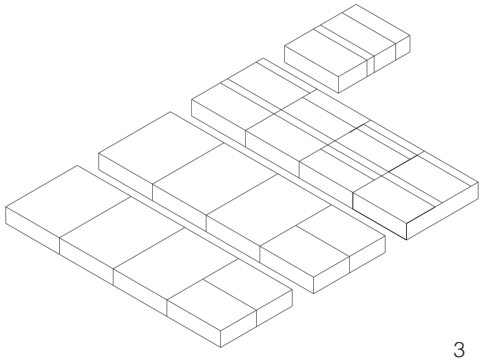
A

1. Optimization is needed before producing final mould.
2. Final mould configuration.
3. Final material billet for cutting takes 3 and a quarter sheets.

B

Optimization

1. Type1: 500x 375 x100mm
2. Type2: 375 x 250 x100mm
3. Type3: 375 x 200 x100mm
4. Type4: 375 x 100 x50mm
5. Type5: 375 x 150 x 100mm
6. Type6: 375 x 100 x 100mm



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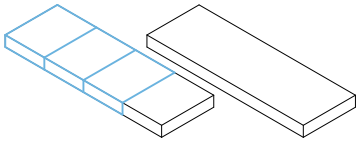

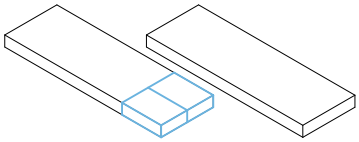

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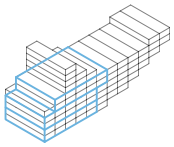

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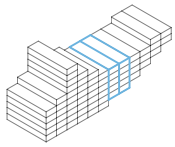

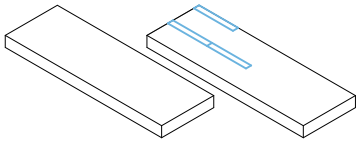

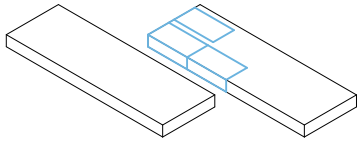

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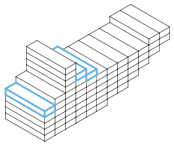

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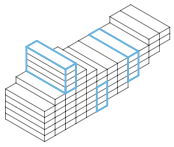

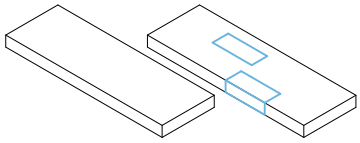

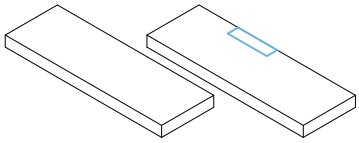

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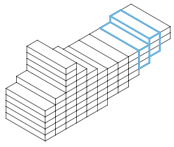

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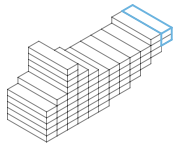

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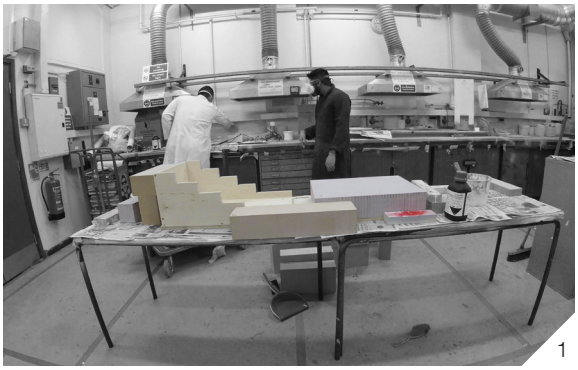
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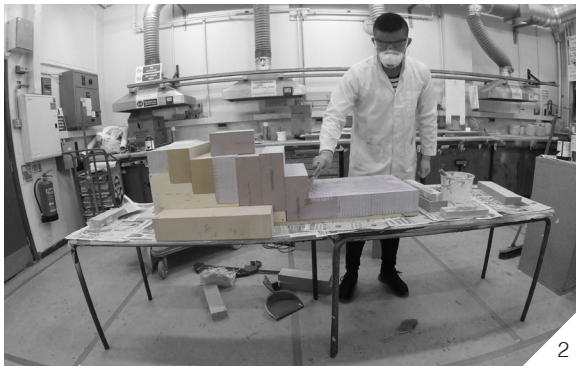
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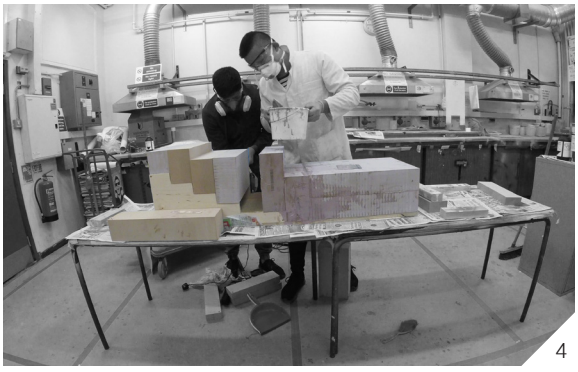
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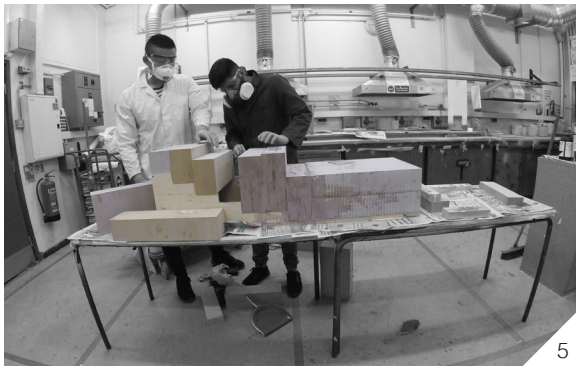
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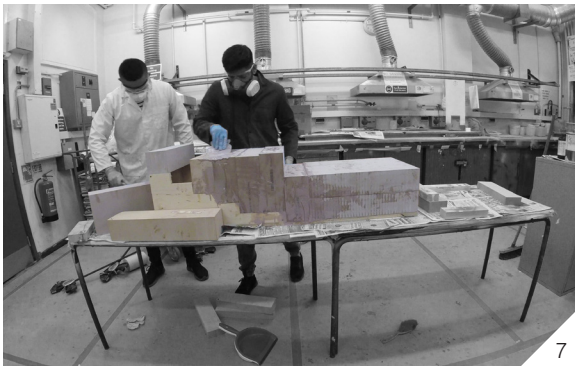
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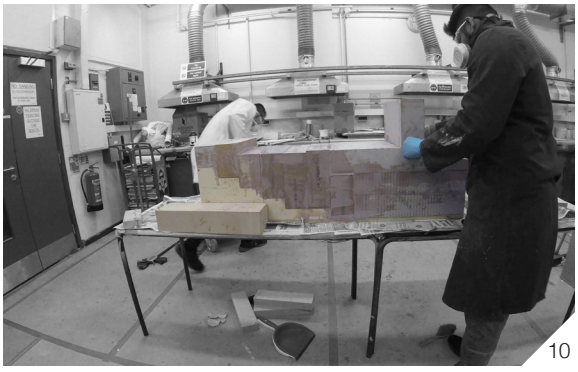
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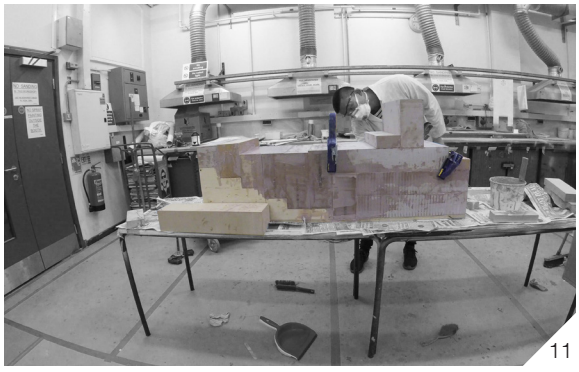
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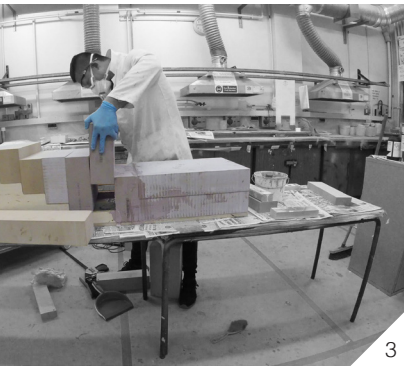
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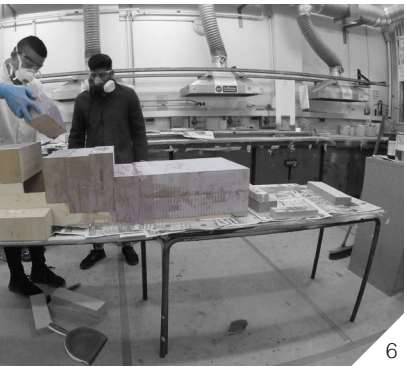
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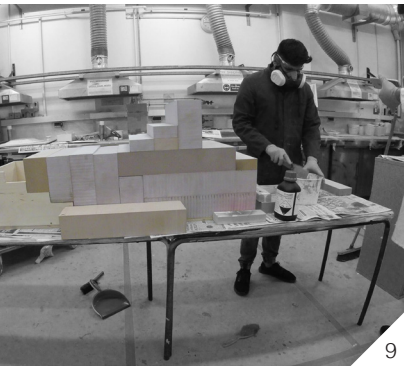
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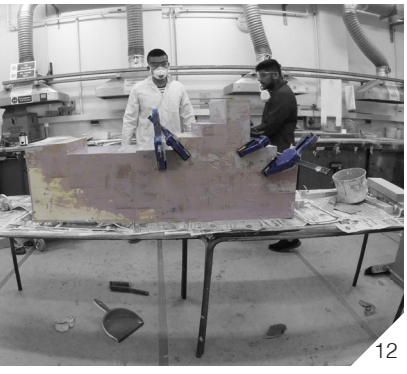
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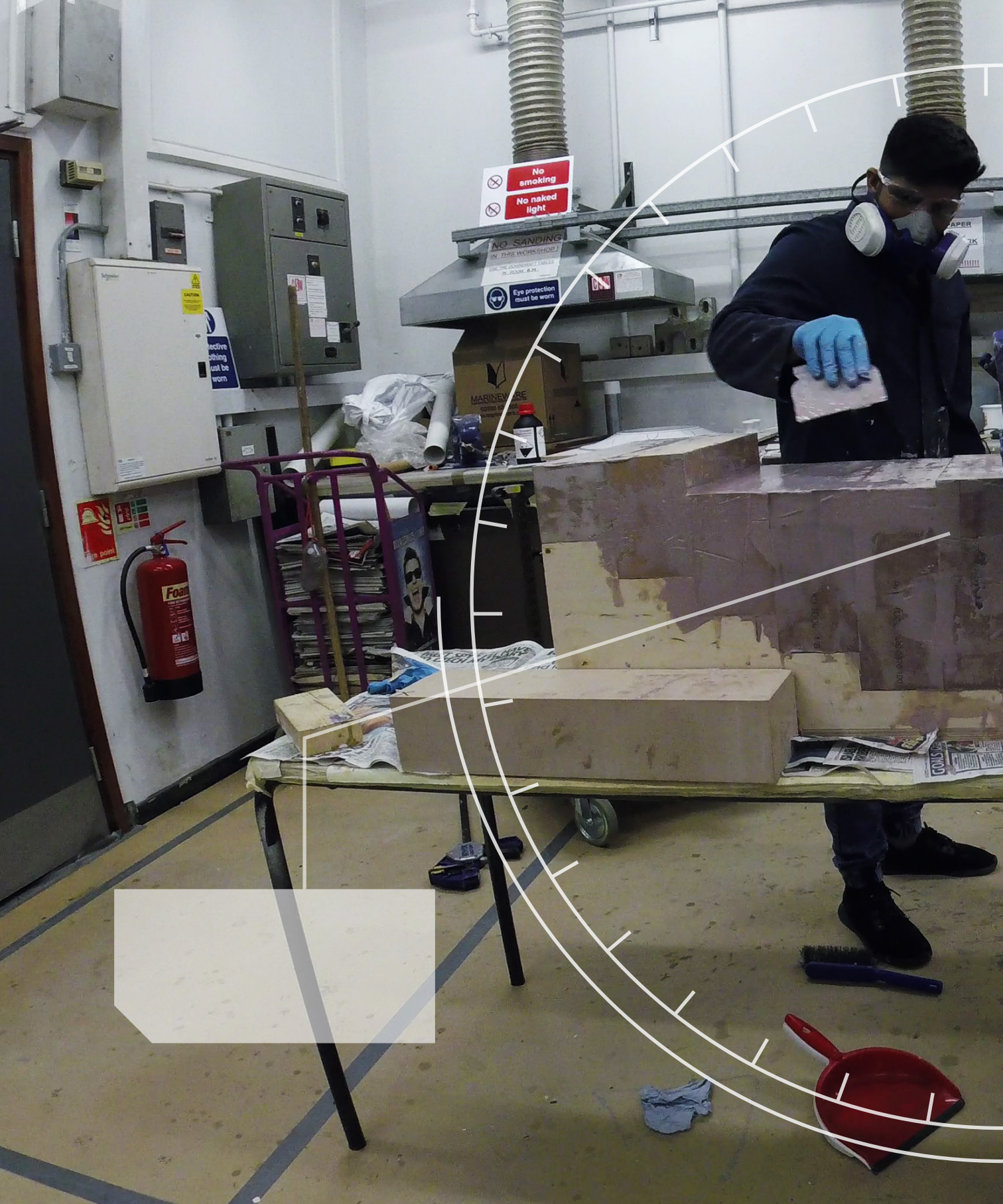
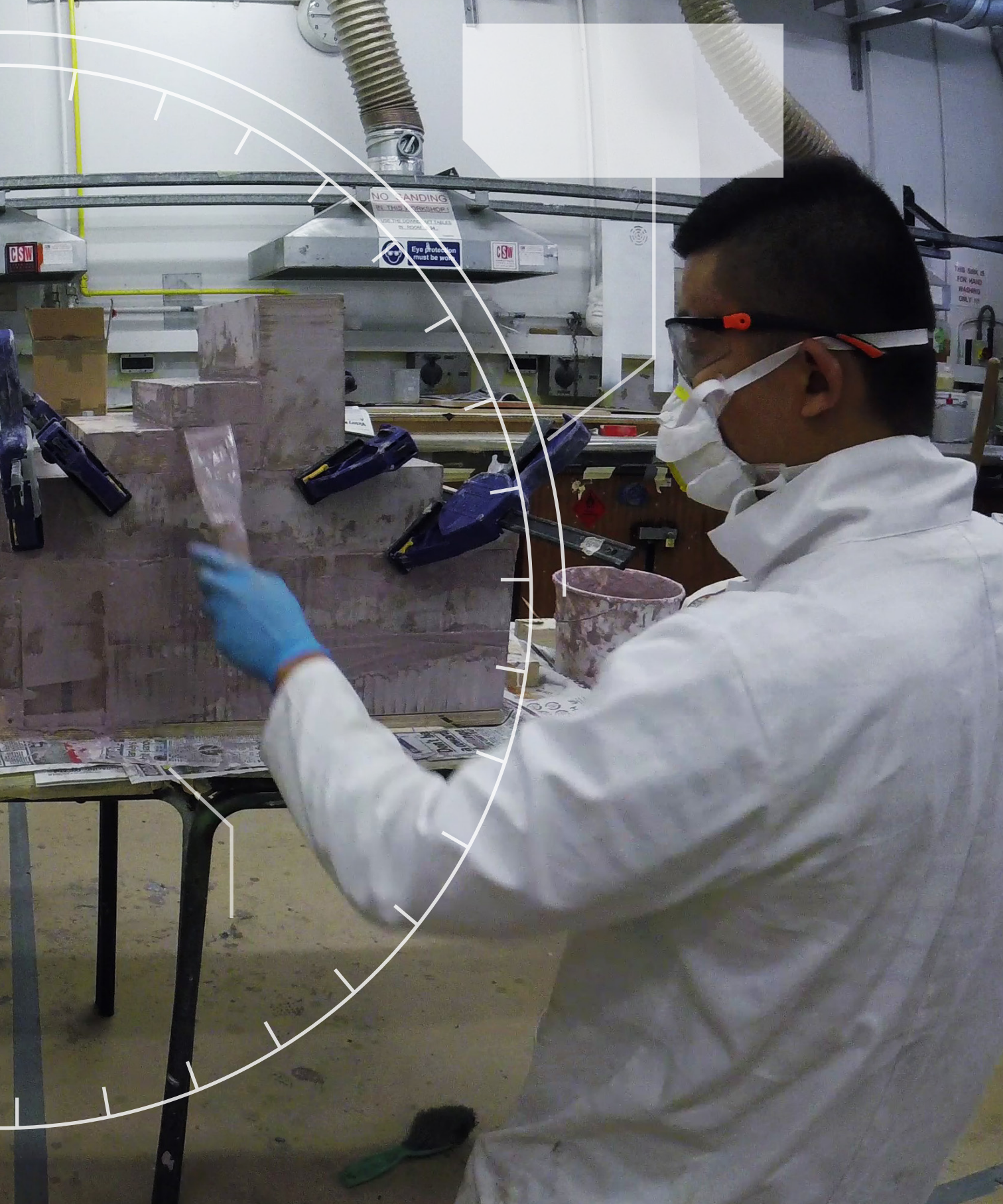
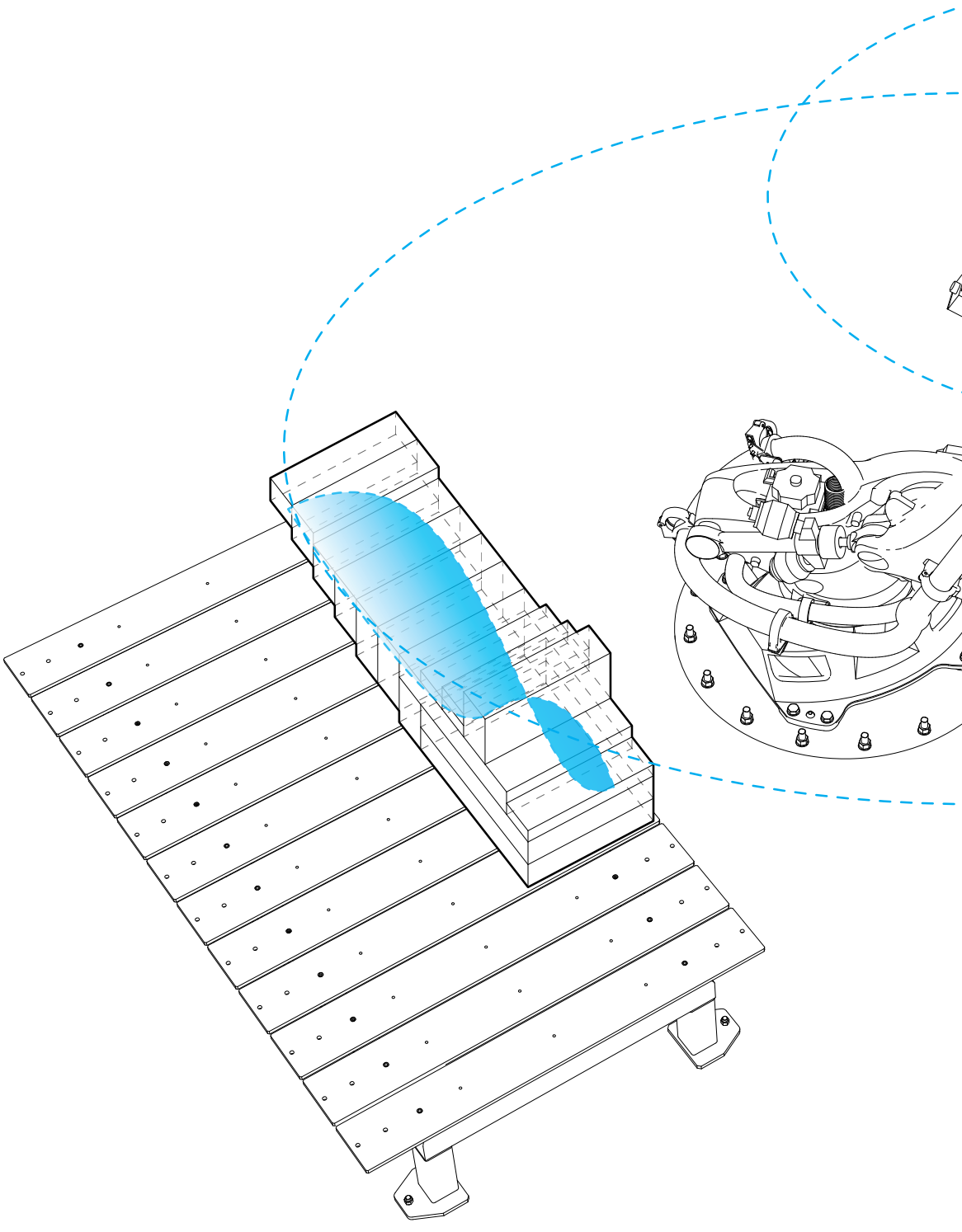
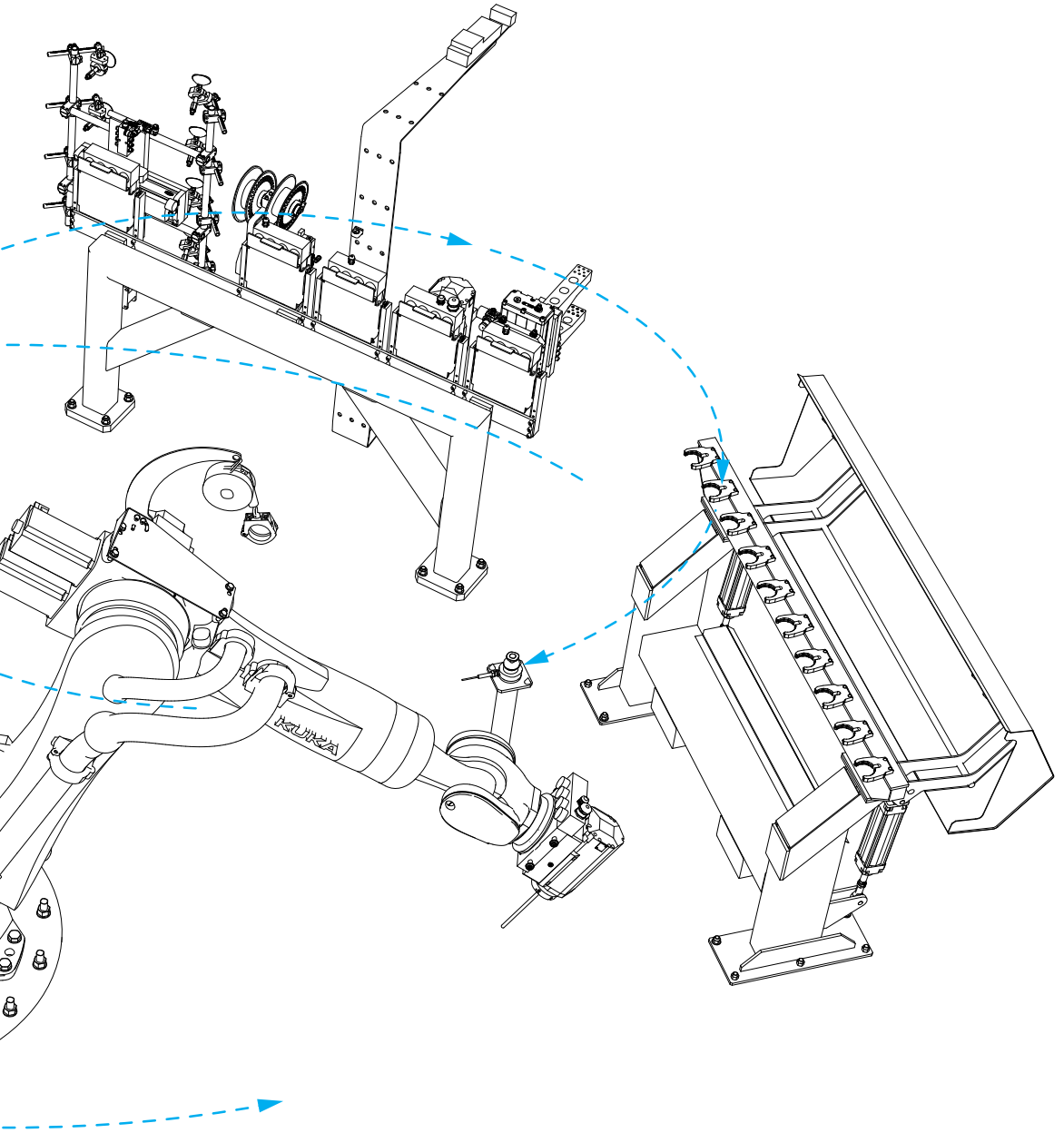
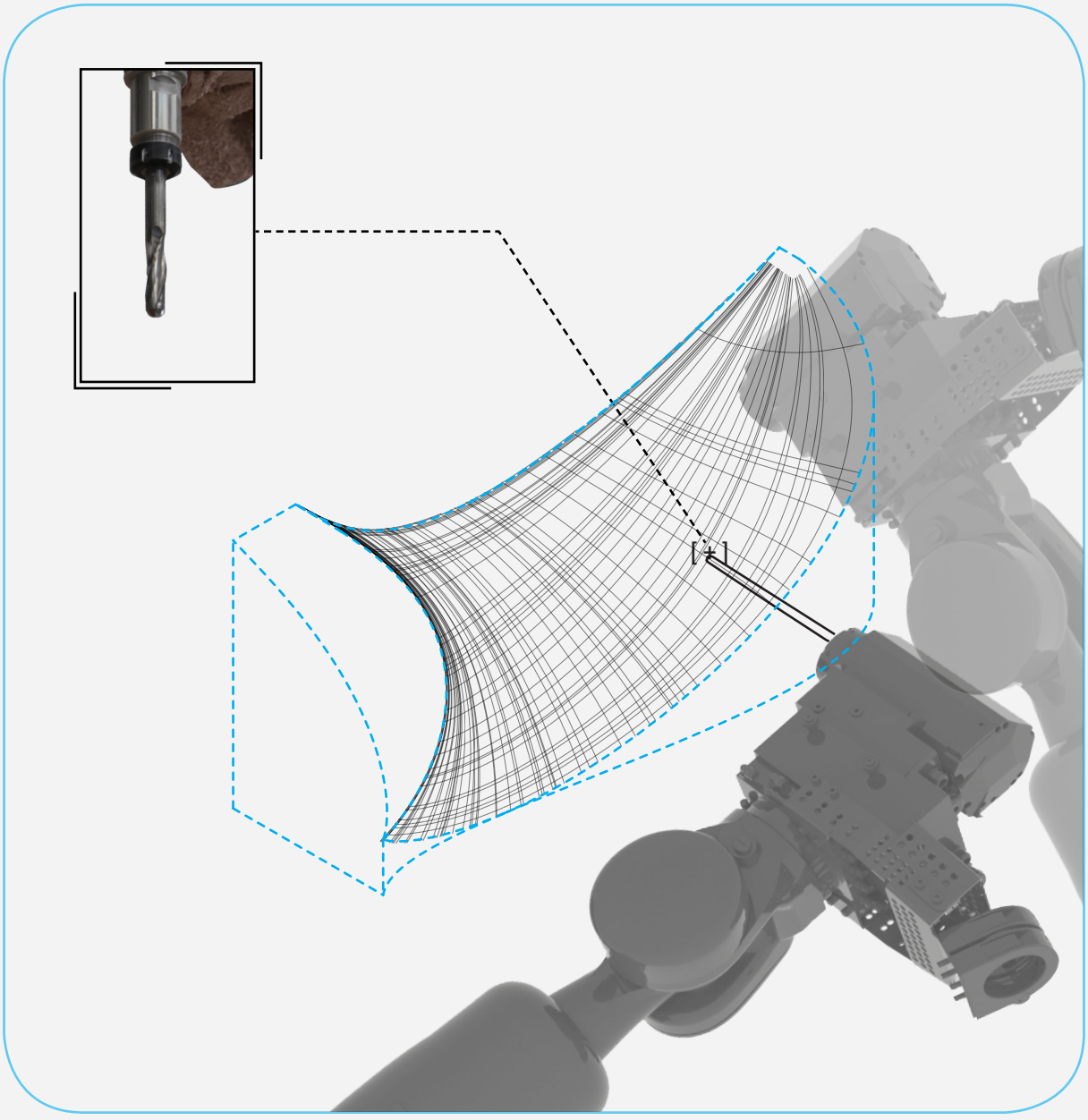
1-12
Block assembling sequence of the mould. Special resin binder is used to join the blocks. When dried, blocks and binders achieved uniformed structural and physical integrity due to their similar chemical composition.

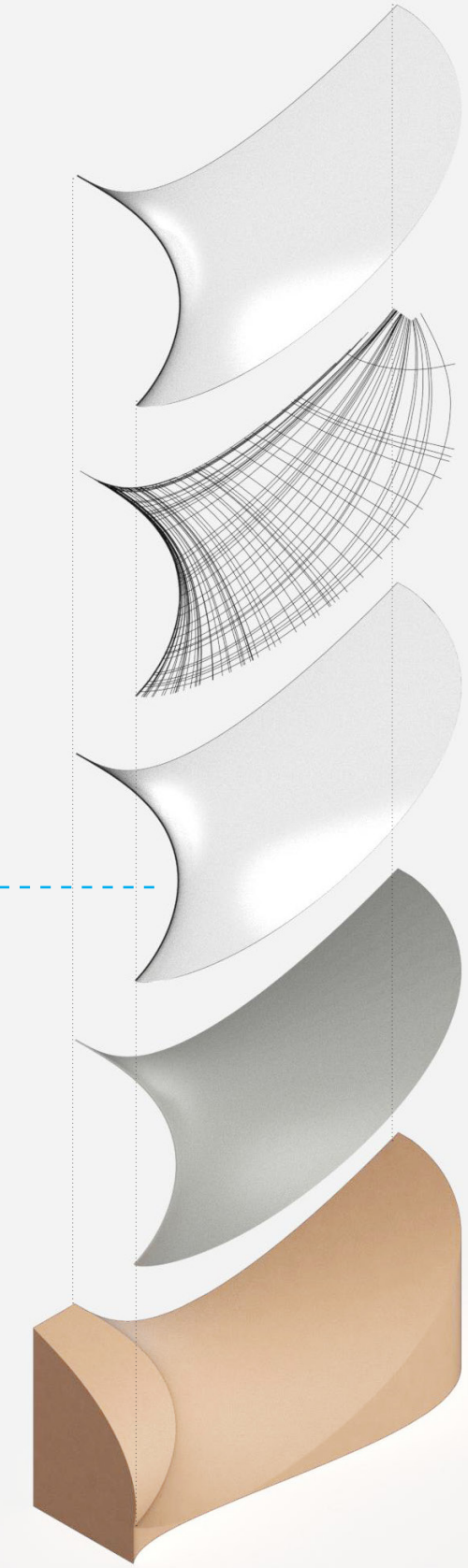

No smoking
No naked light
NO SANDING
IN THIS WORKSHOP
Eye protection must be worn


NO STANDING
CSW
CSW
Eye protection must be




KUKA





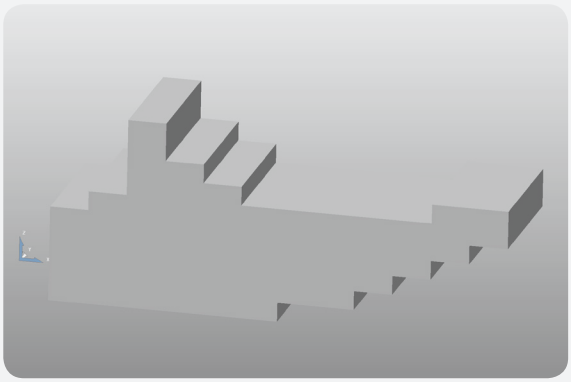
1.
Robotic milling to carve out patterns designed in 3d model.

2.
Apply special wax as releasing agent to the newly carved mould.

3.
Apply premixed resin over the waxed mould surface, wait for resin to dry. Then use robot to mill out pattern on top of the dried resin.

4.
Apply carbon fiber strips according to the pattern milling on the resin surface.

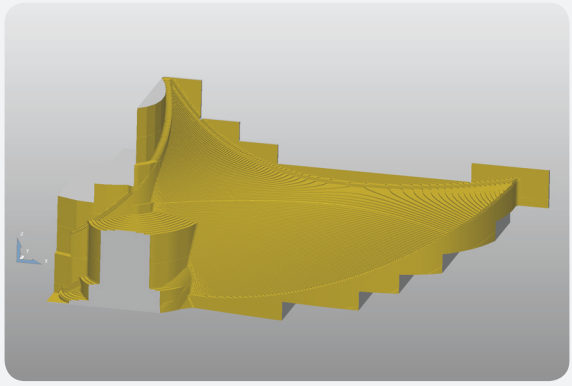
5.
Apply premixed resin on top of carbon fiber strips as well as the surface below. Wait for resin to dry before releasing from the mould.



1

INCEPTION

ROUGHING ONE



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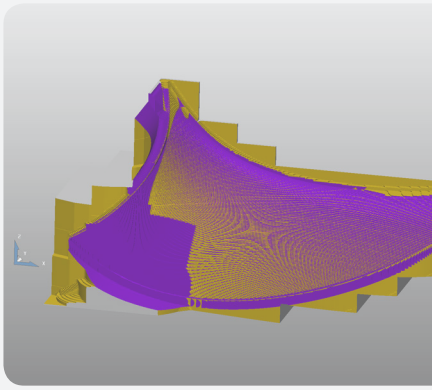
ROUGHING TWO



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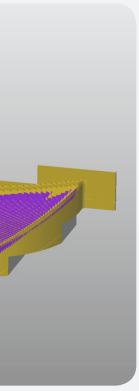
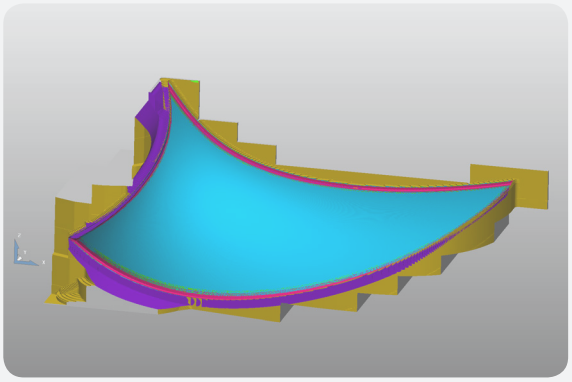


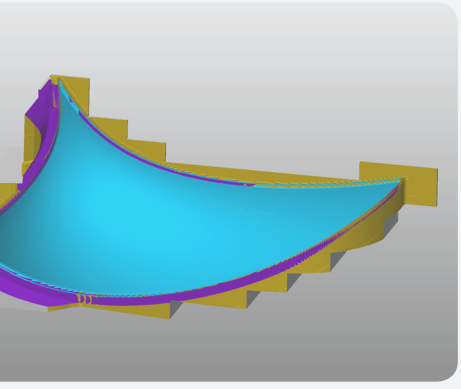


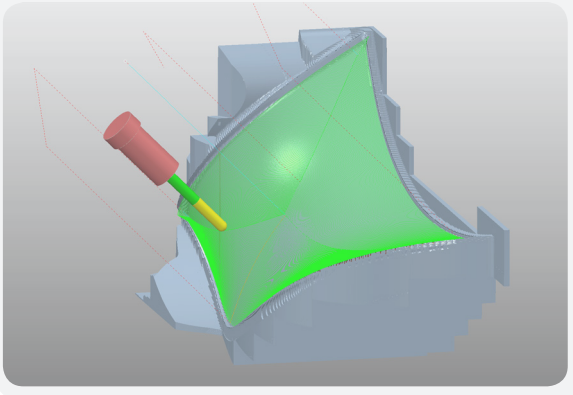
5

EDGE ROUGHING

EDGE REFINEMENT

SURFACE SMOOTHING





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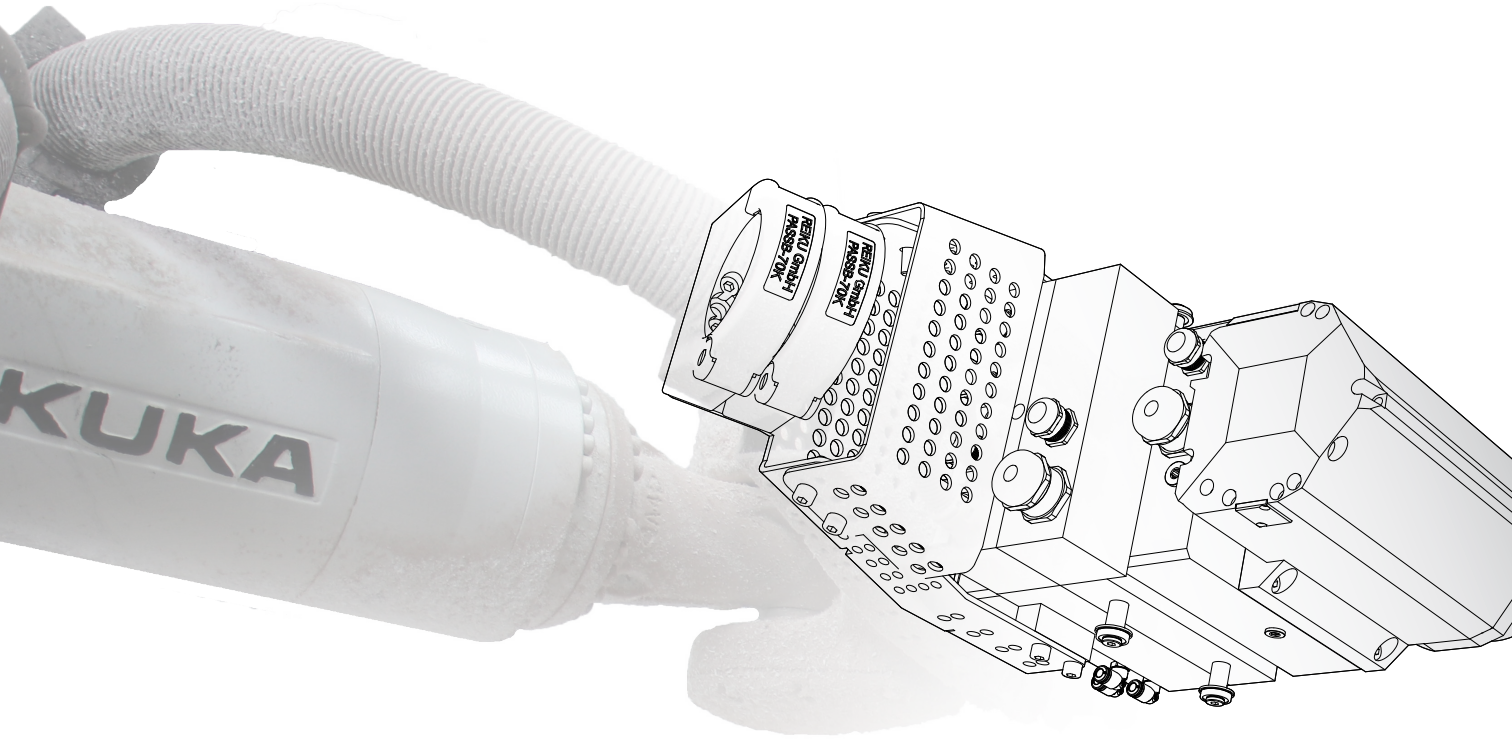



1



2

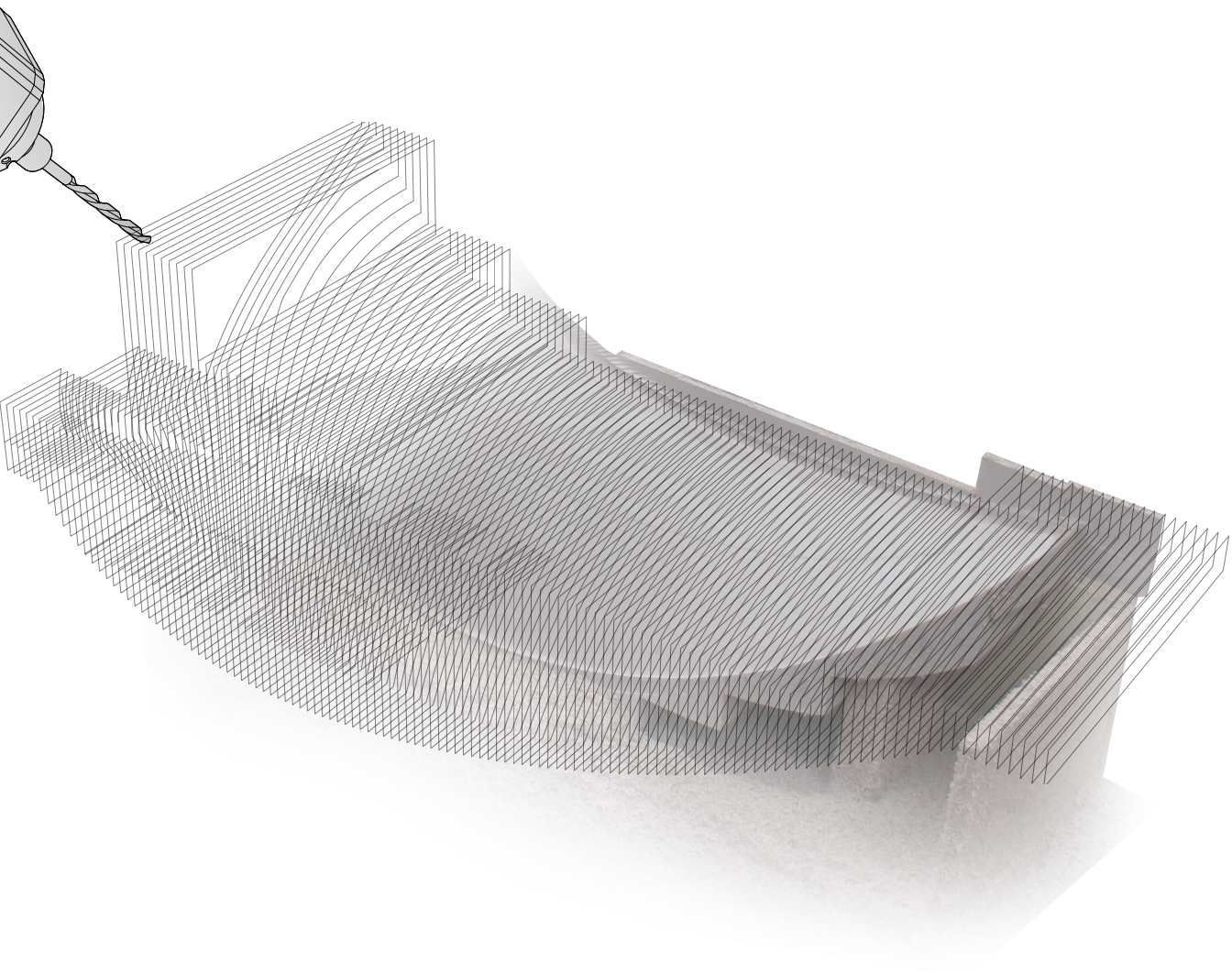

3

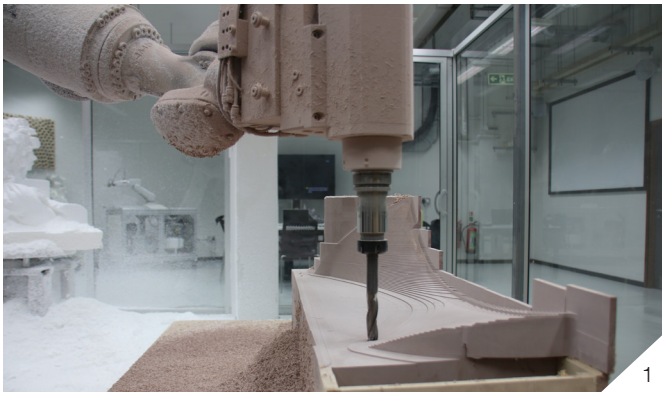

4


5


6

1 to 6
Automated preset sequence for tool measuring and tool changing sequence accordingly to various toolpaths from roughing to surface 3D finish.

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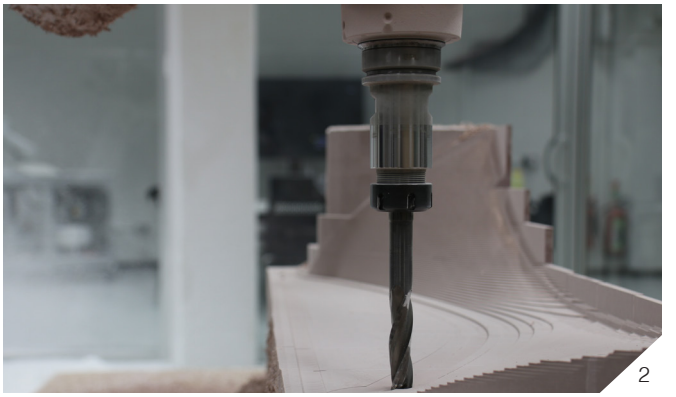
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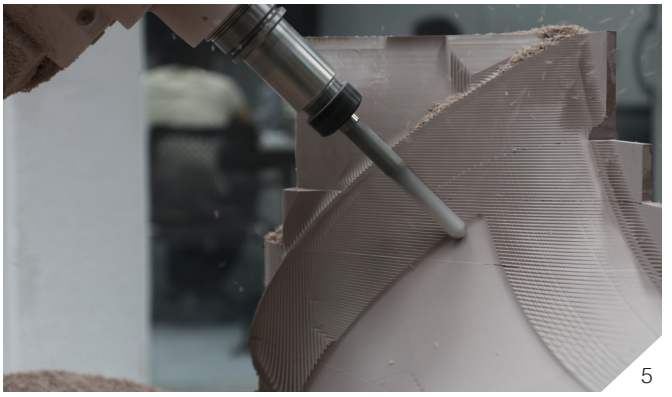
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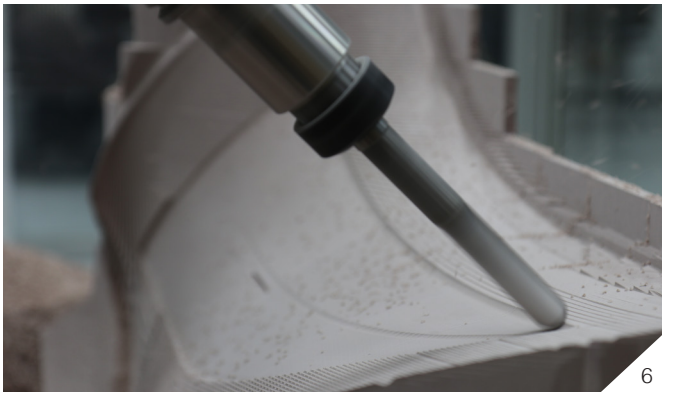
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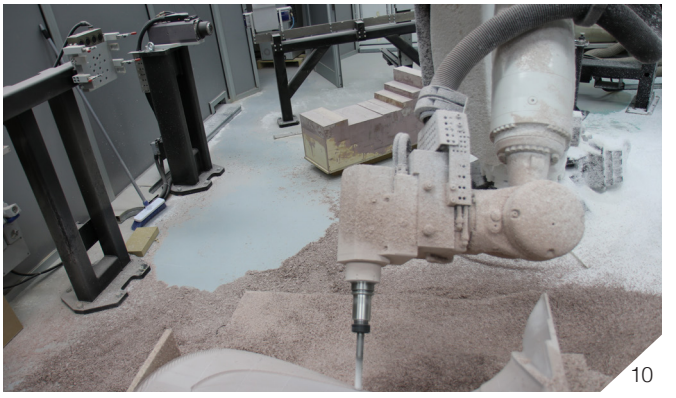
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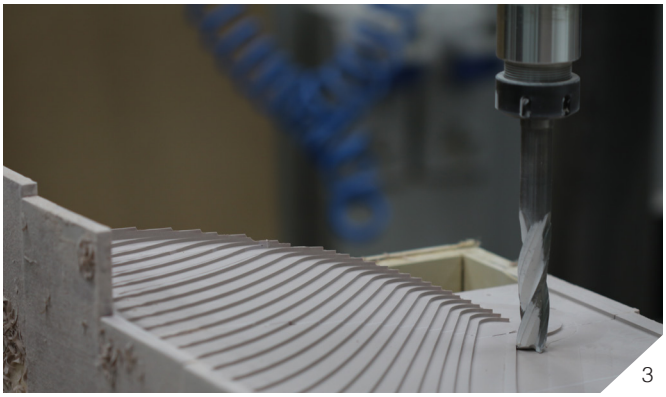
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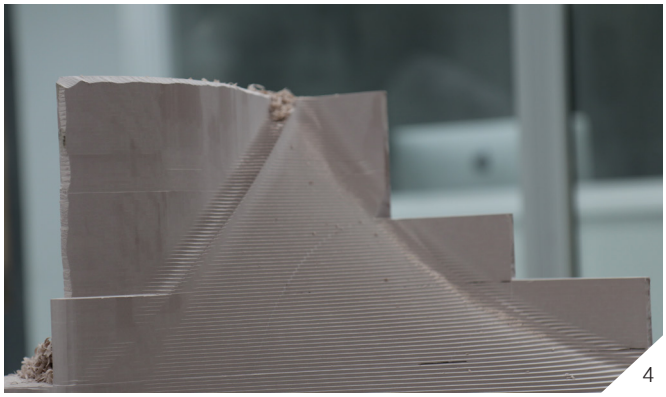

4


7

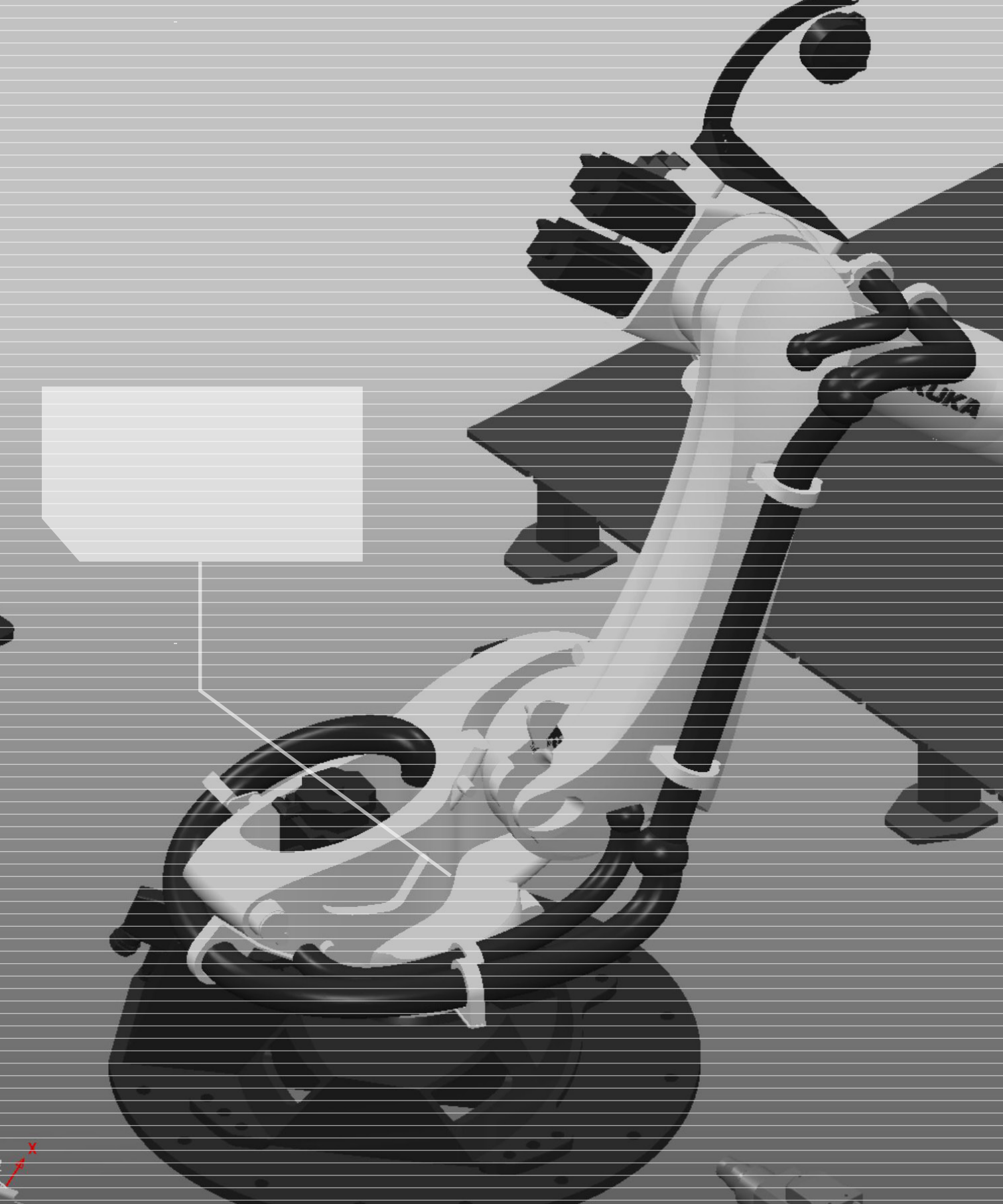

8

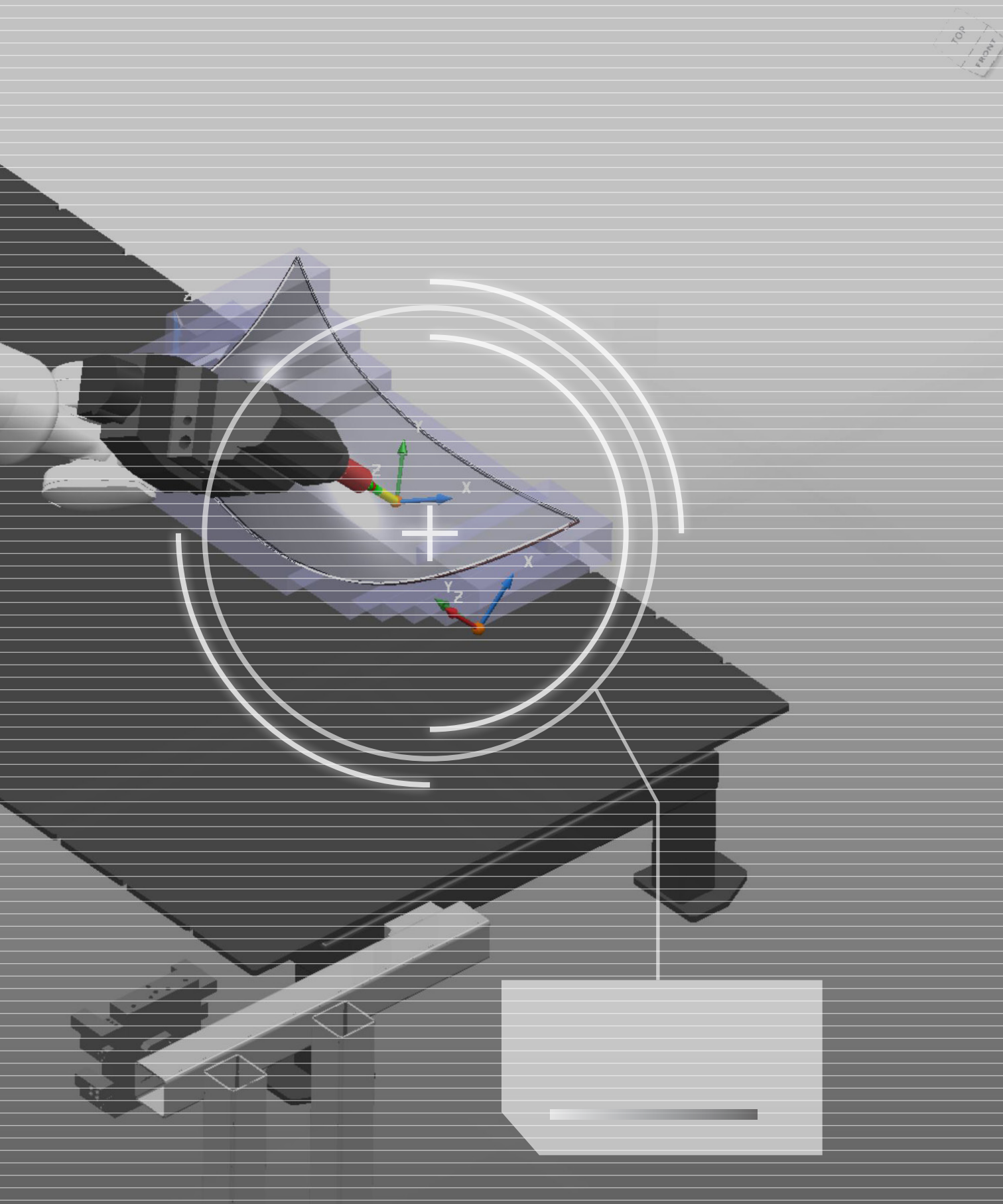

11



12

1 to 12
Block milling process through different stage of roughing and refinement. 5 axis robotic building gives it the ability to mill the surface while following curvature of designed surface via uv lines, achieving smooth finish.




TOP
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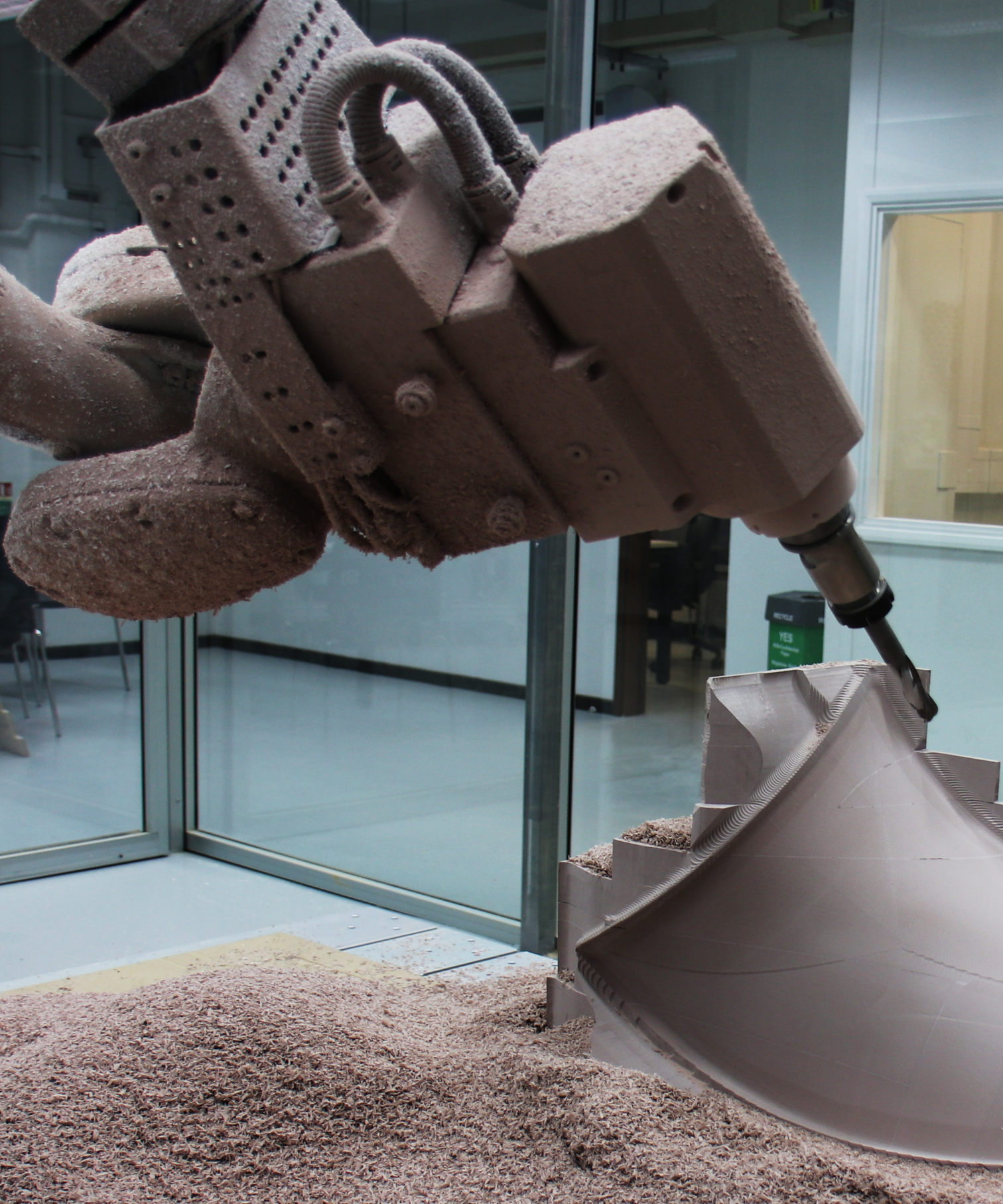
RECYCLE
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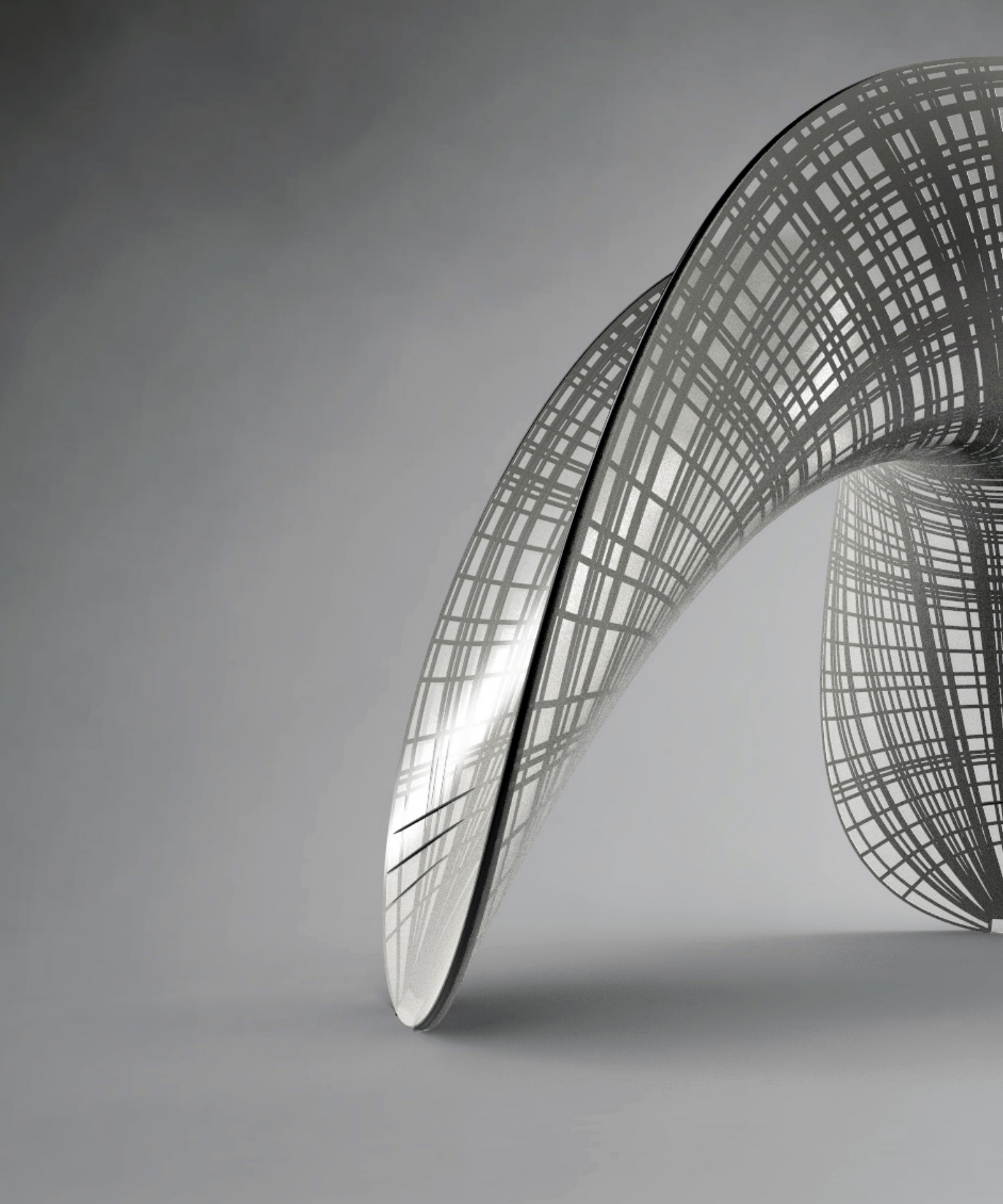







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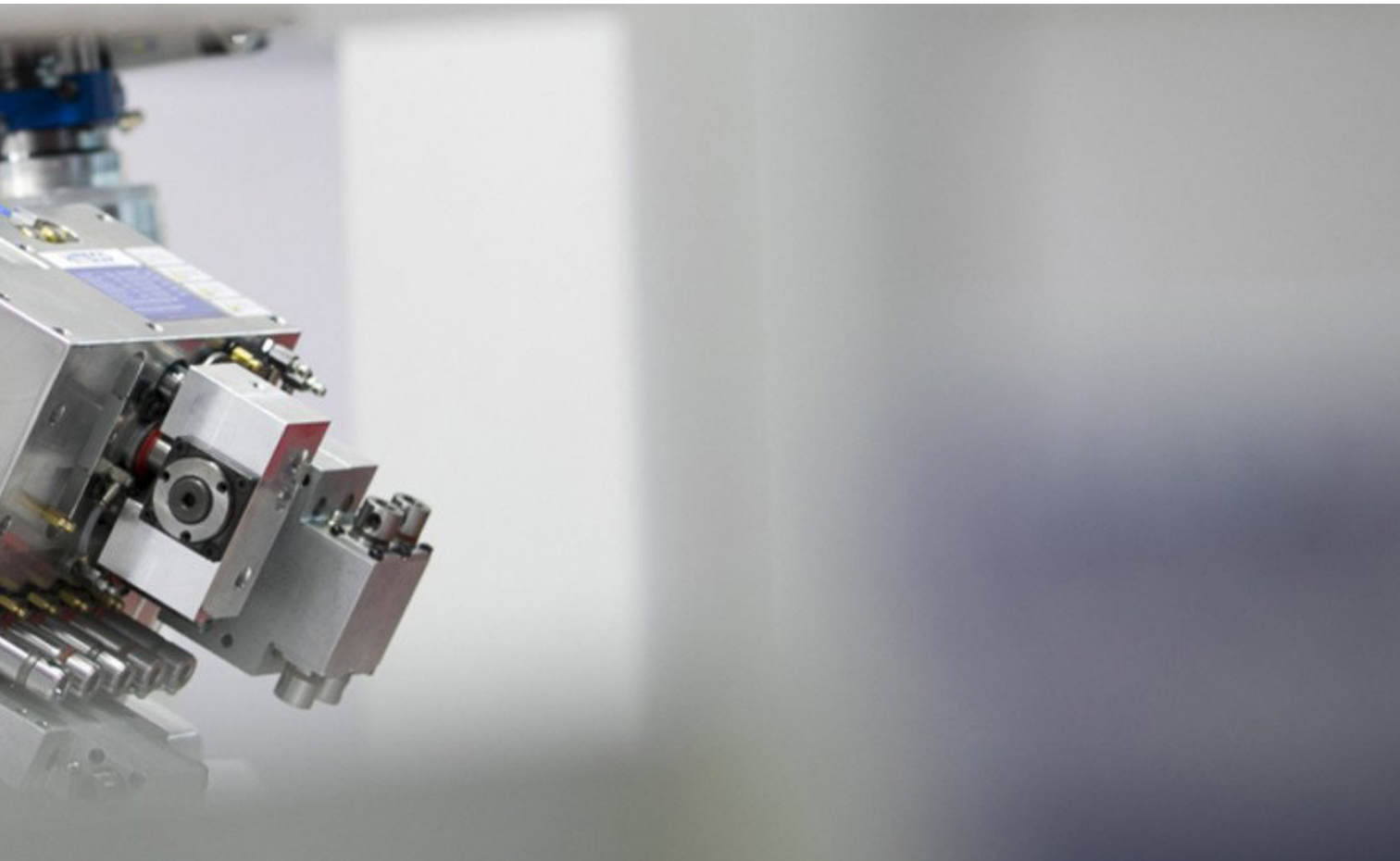


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