

Additive Manufactured Glass Connection

P5 Presentation

Willem Sebastiaan Koenen
4321596

First mentor: Ulrich Knaack
Second mentor: Christian Louter





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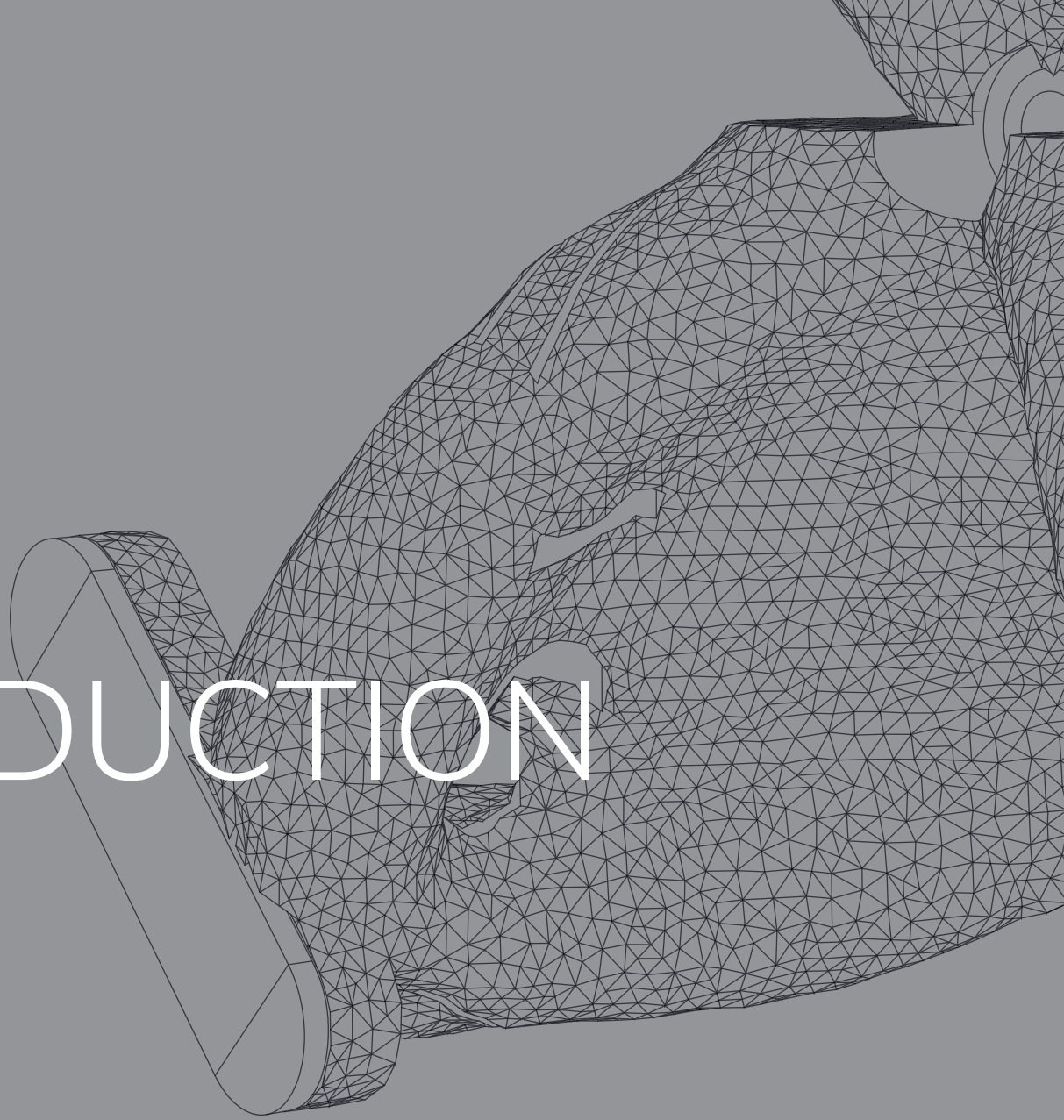
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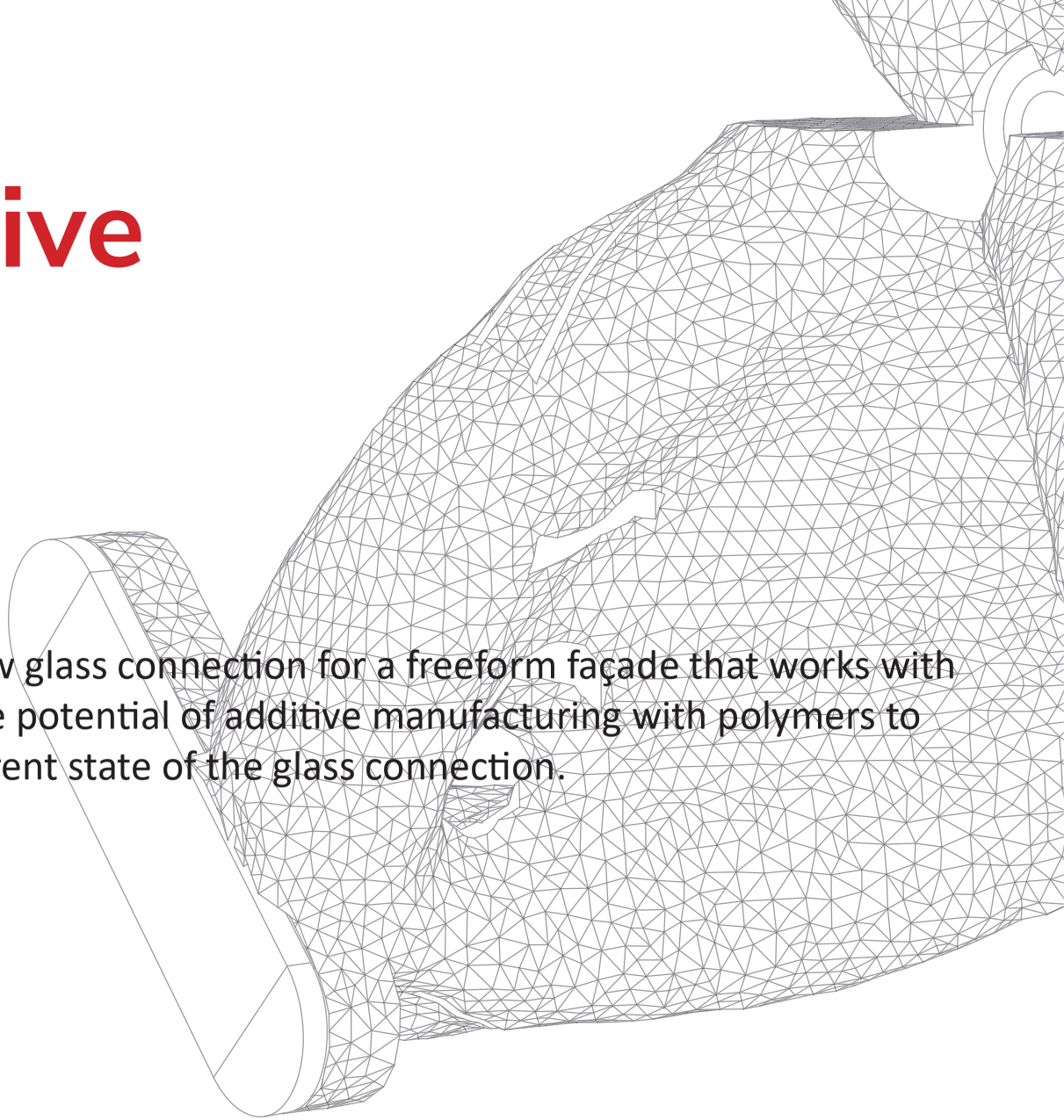
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INTRODUCTION



Introduction

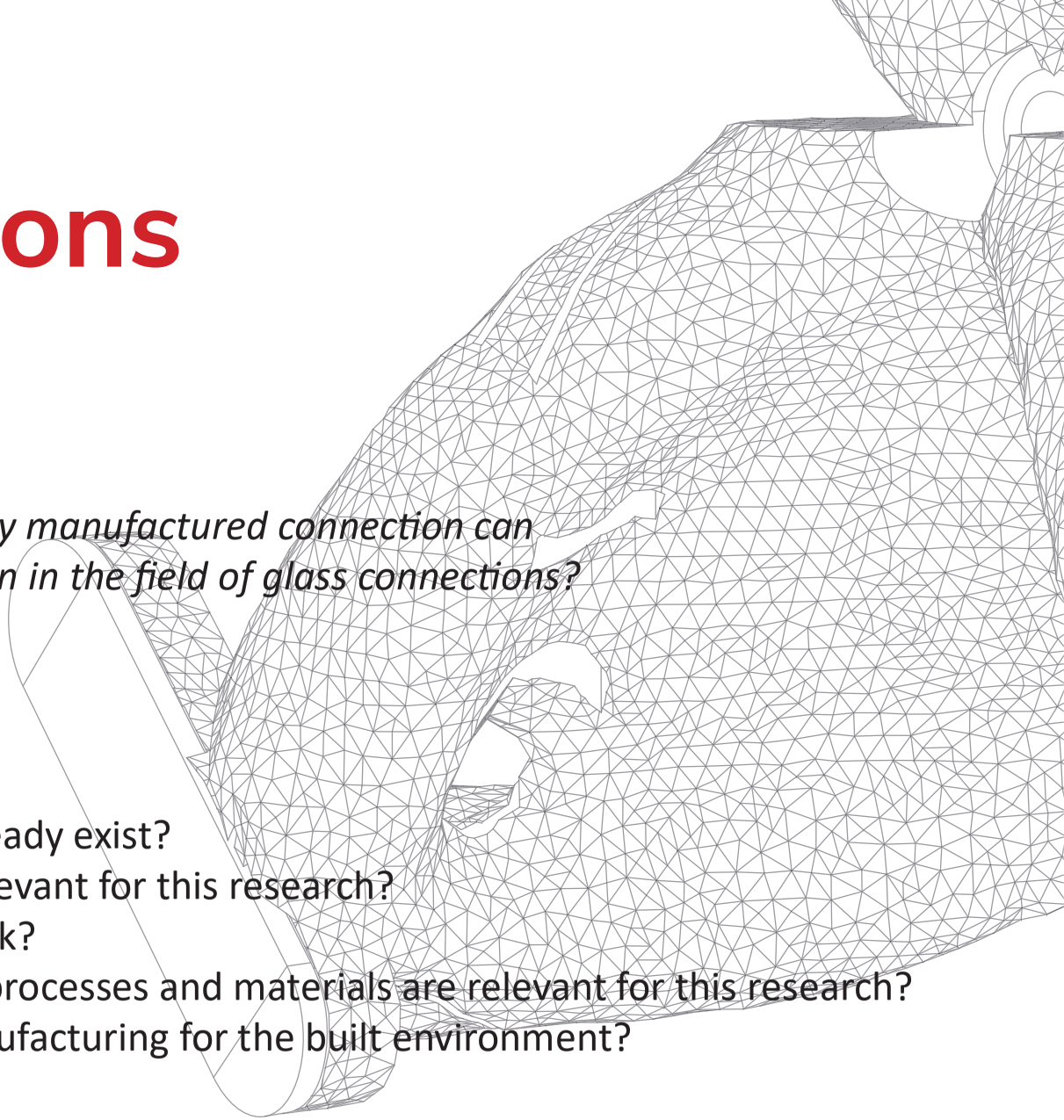
Research objective



The objective of this research is to design a new glass connection for a freeform façade that works with the glass. This should be done by utilizing the potential of additive manufacturing with polymers to further develop the current state of the glass connection.

Introduction

Research questions

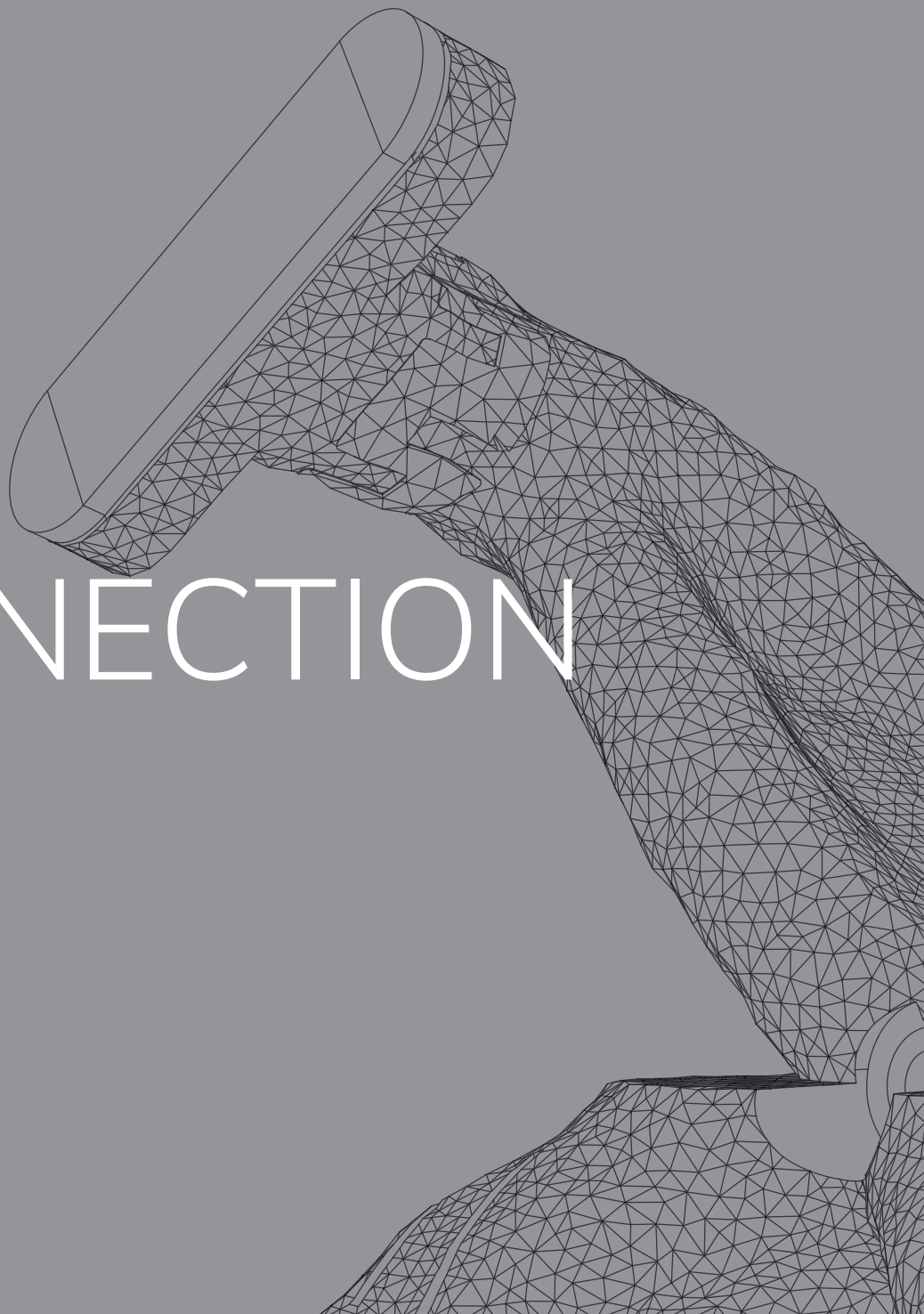


What kind of additively manufactured connection can be the next big innovation in the field of glass connections?

Sub questions:

- What kind of glass connections do already exist?
- What kind of glass connections are relevant for this research?
- How does additive manufacturing work?
- What kind of additive manufacturing processes and materials are relevant for this research?
- What are the benefits of additive manufacturing for the built environment?

GLASS CONNECTION



Glass connection

Time line

70 AD
Rebate glazing

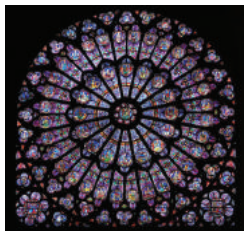
ca. 1400
Rebate with
glazingbead

1870
Pattent glazing

0 | 100 | 1400 | 1800 | 1900

100
Leaded glazing

Notre Dame
1163-1345



1810
T-profile

Chrystal Palce
1851



Glass connection

Time line

GM Technical Center, Waren
1949



1942
Post and
Beam facade

1963
Sealant glazing

1964
Suspended glazing
and patch fittings

1984
Planar glazing

1986
Spider glazing

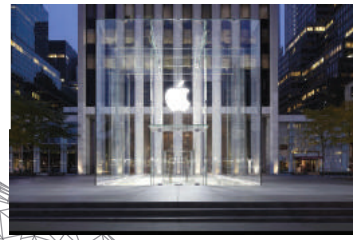
1993
Cable-Lattice
facades

1994
Laminated
Bridle joints

2000

2011
Laminated
Metal Inserts

Apple cube MKII
2011



2017

Glass connection

Spider

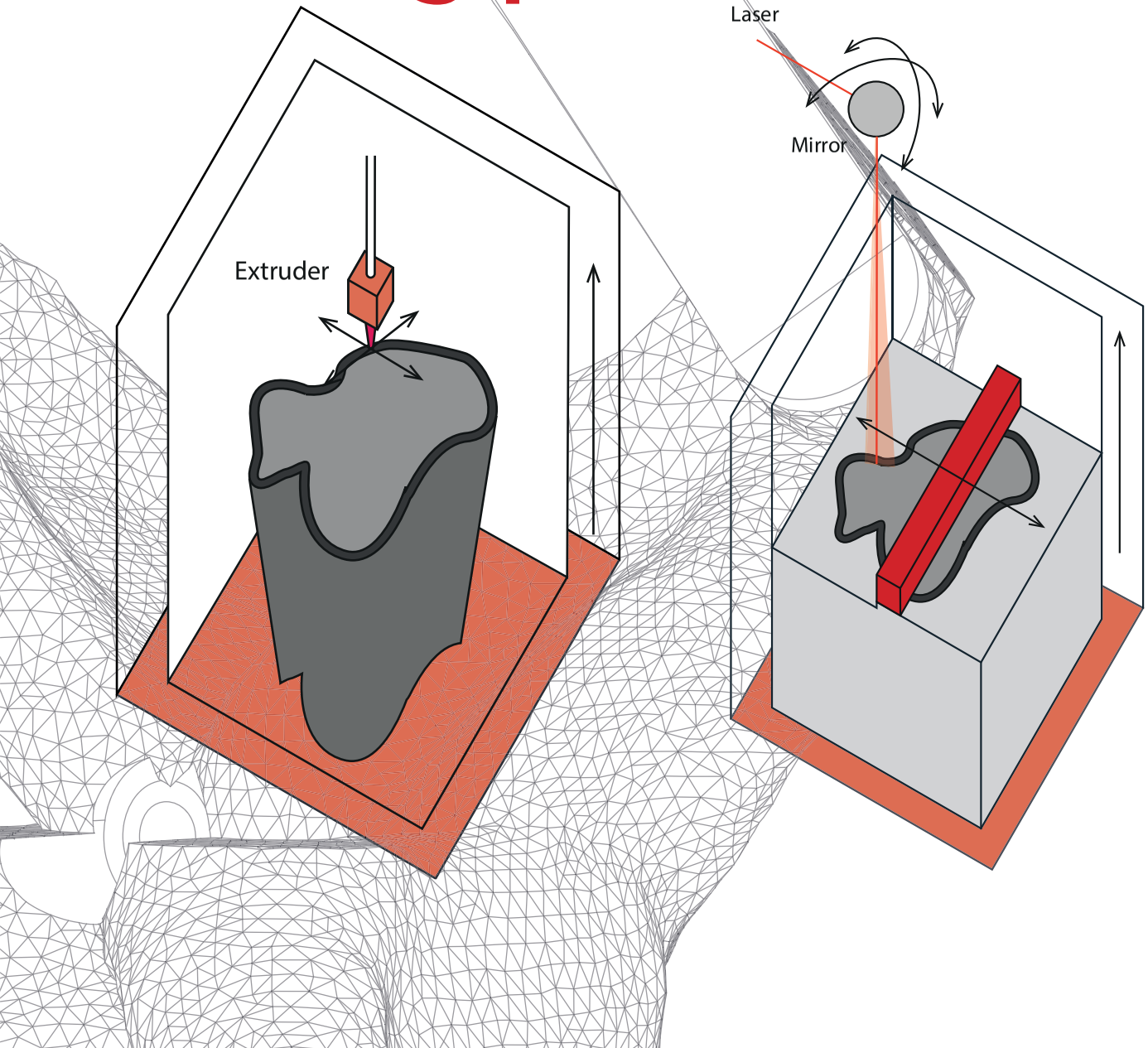


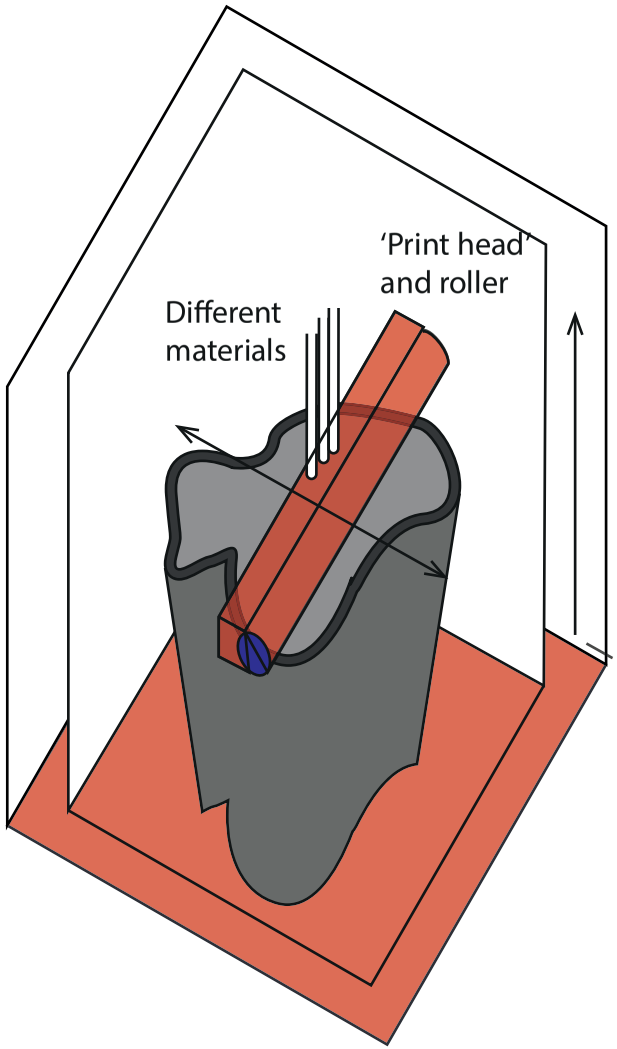


ADDITIVE MANUFACTURING

Additive manufacturing

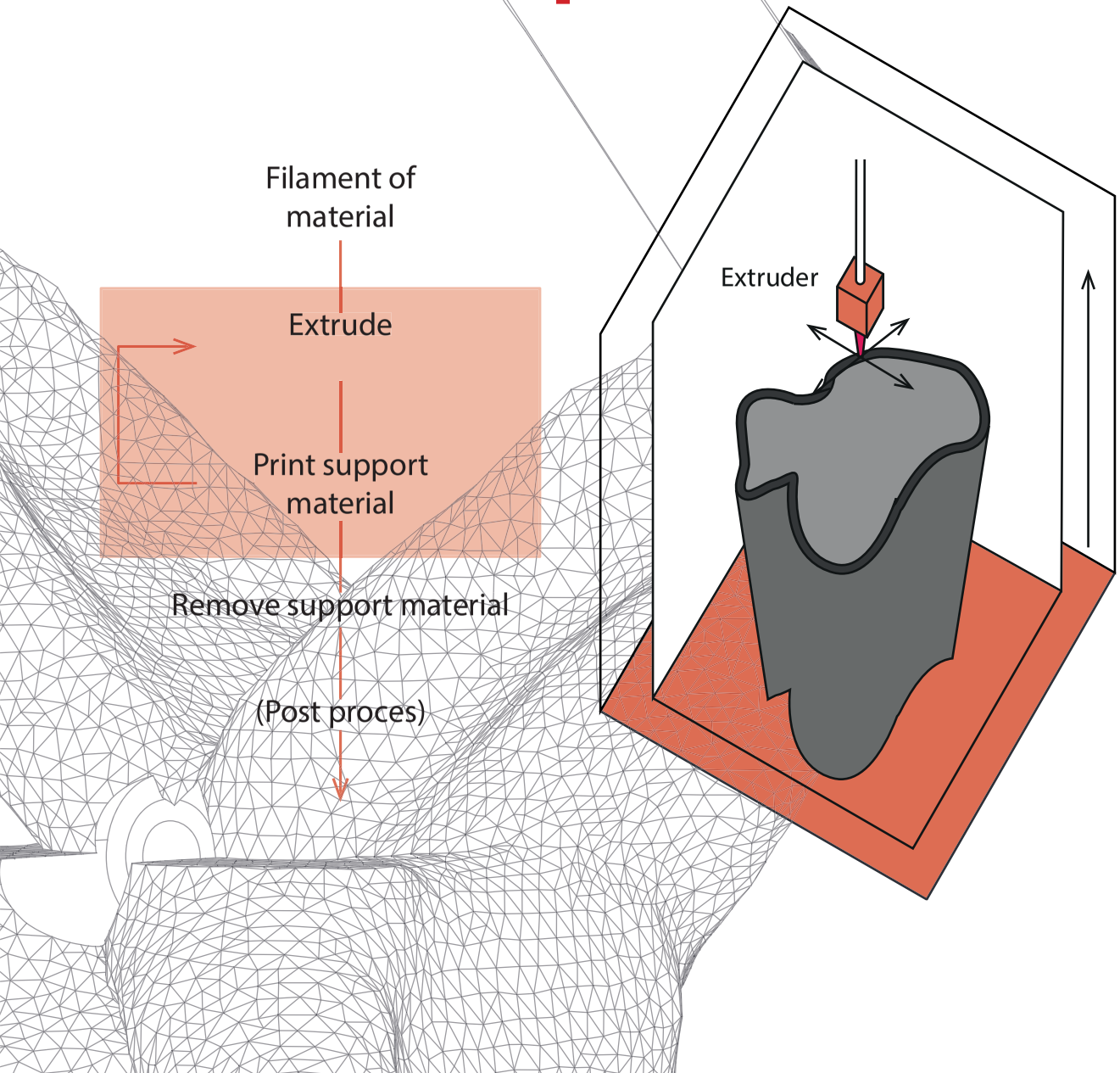
Printing processes

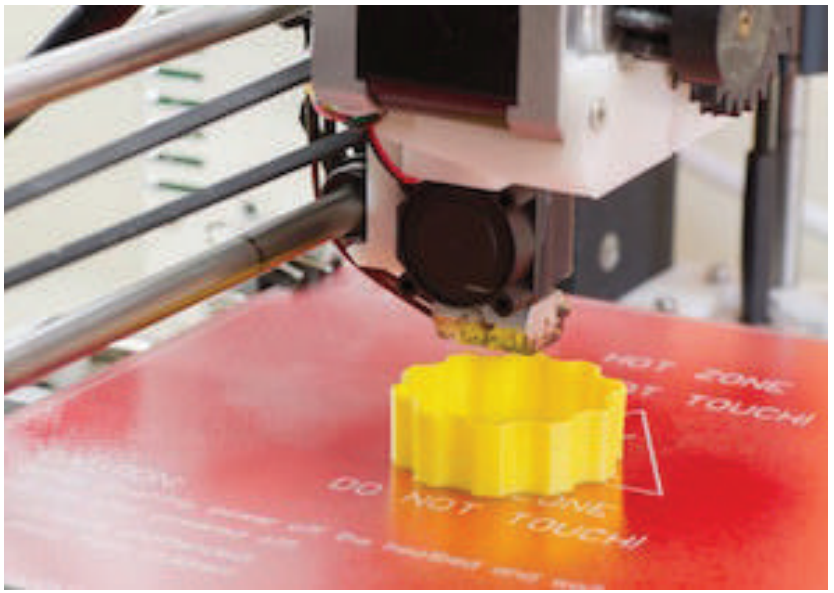




Additive manufacturing

Fused Deposition Modelling



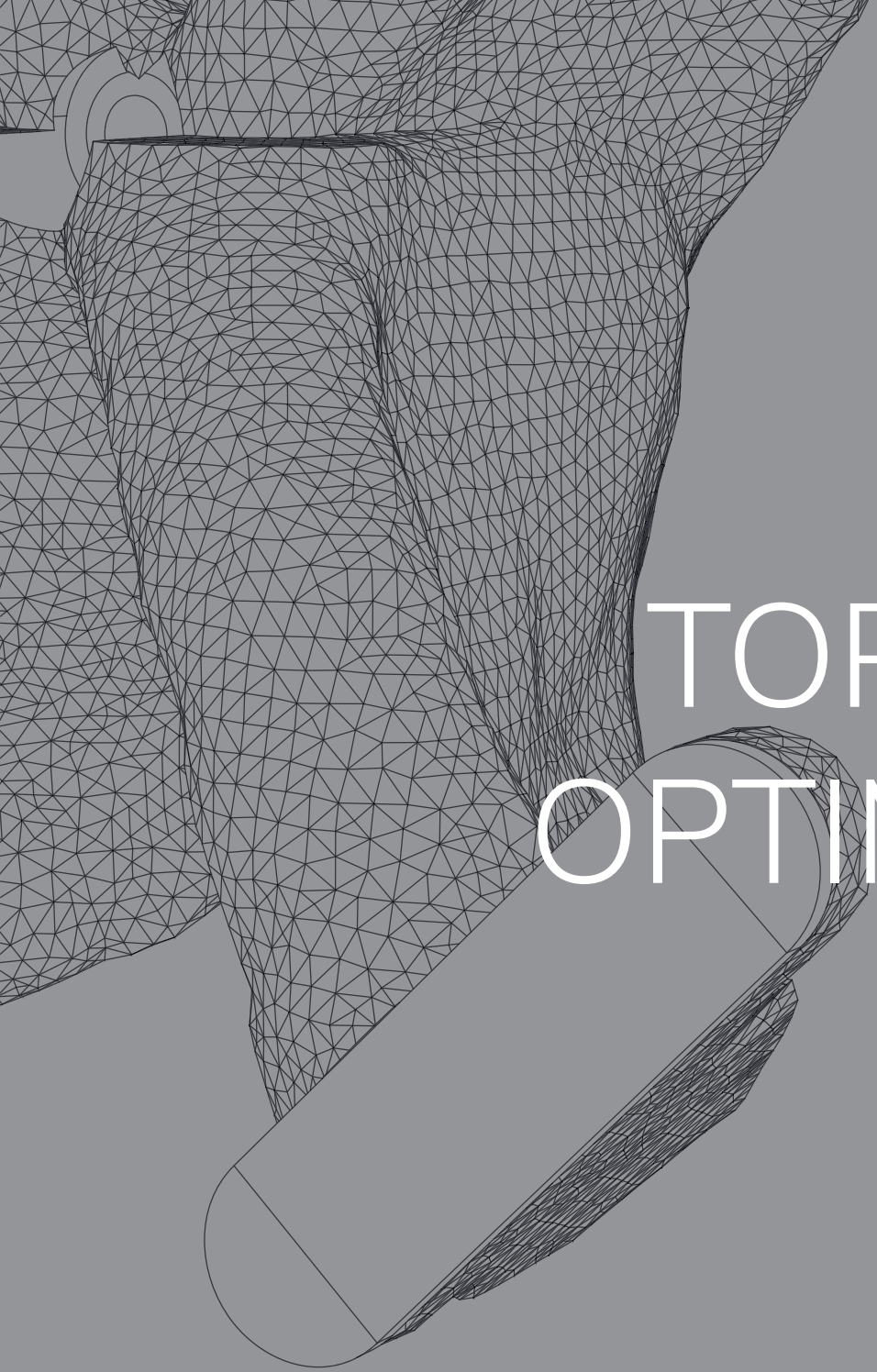


Additive manufacturing

Material



Density		1.35	g/cm3
Max tensile strenth		76	MPa
Elongation at break		7,5	%
Flexeural strength	X	6,2	GPa
	Y	6,2	GPa
	Z	4,1	GPa
Poison ratio	XY	0,33	%
	YZ	0,33	%
	XZ	0,33	%
Shear Modulus	XY	2,4	GPa
	YZ	1,6	GPa
	XZ	1,6	GPa

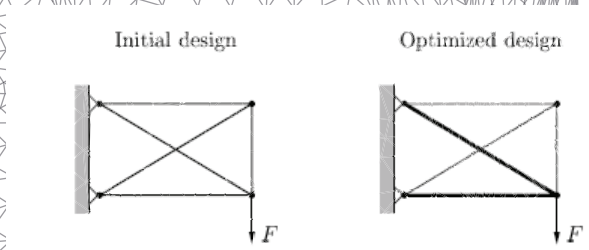


TOPOLOGY OPTIMIZATION

Topology optimization

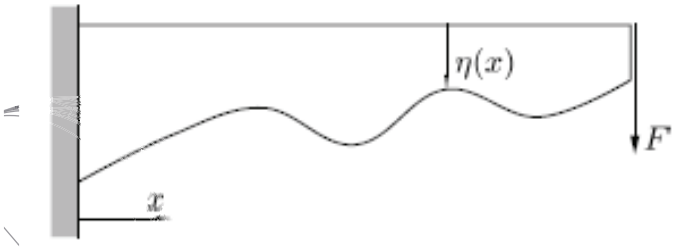
3 kinds of strategy's

Sizing optimization



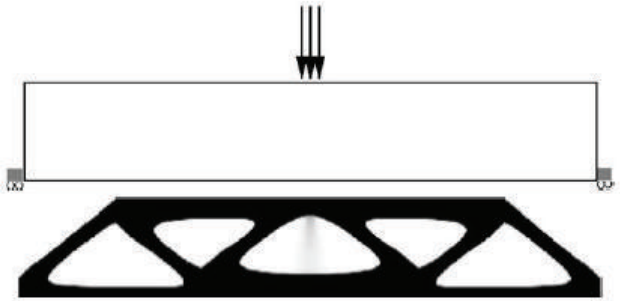
What dimension should the part have?

Shape optimization



What should the shape for the part be?

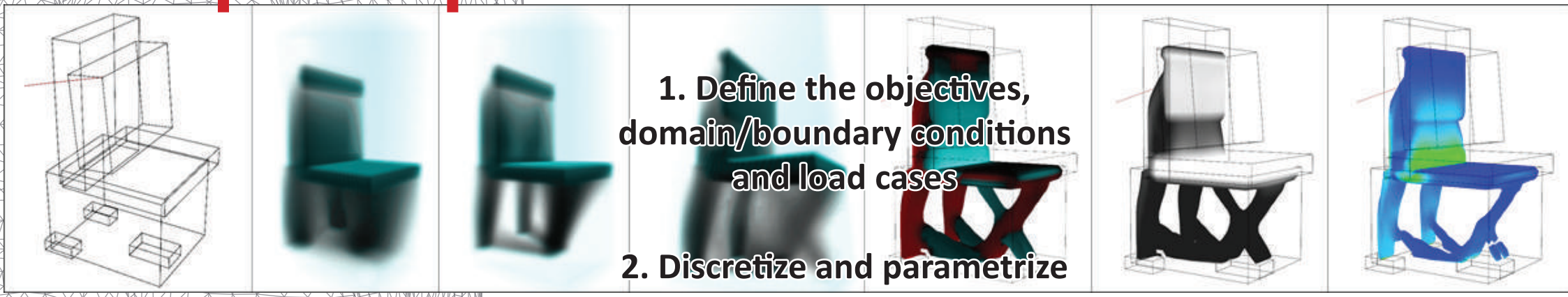
Topology optimization



Where to place the material?

Topology optimization

TO principles

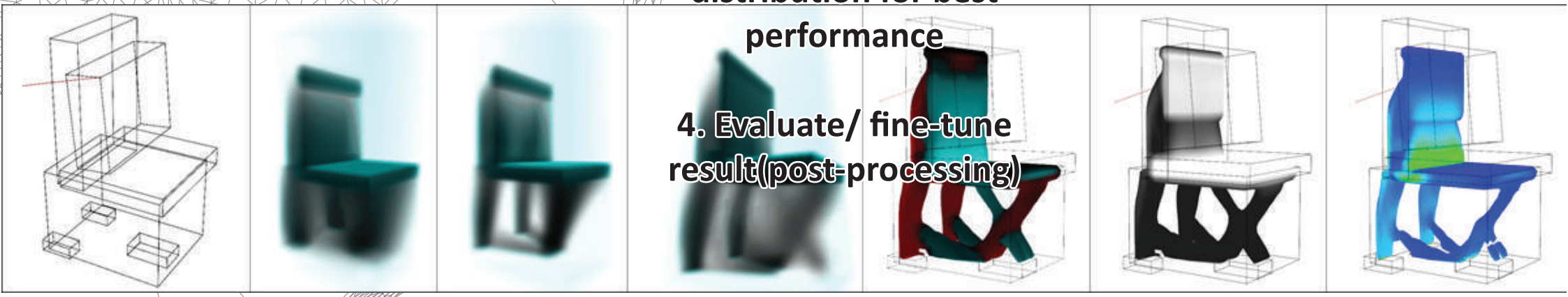


1. Define the objectives, domain/boundary conditions and load cases

2. Discretize and parametrize material distribution

3. Optimize material distribution for best performance

4. Evaluate/ fine-tune result(post-processing)



DESIGN



Design

Input for the design



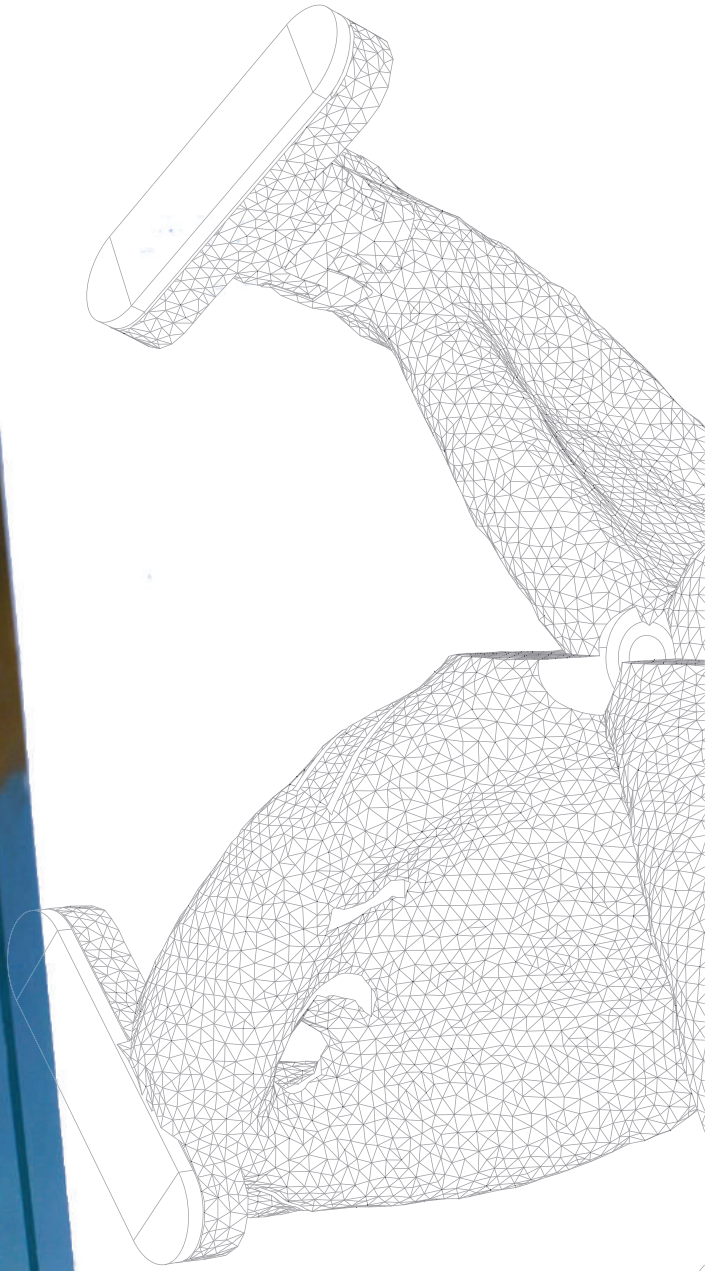
- 1 glass plate

-1500*1500mm glass plate

- 2*6mm glass

- 15 meters high

-Facing Southwest



Design
Loads

Dead load

2500*1.5*1.5*0.012

67.5kg = 70kg used value

<u>= 700 N</u>

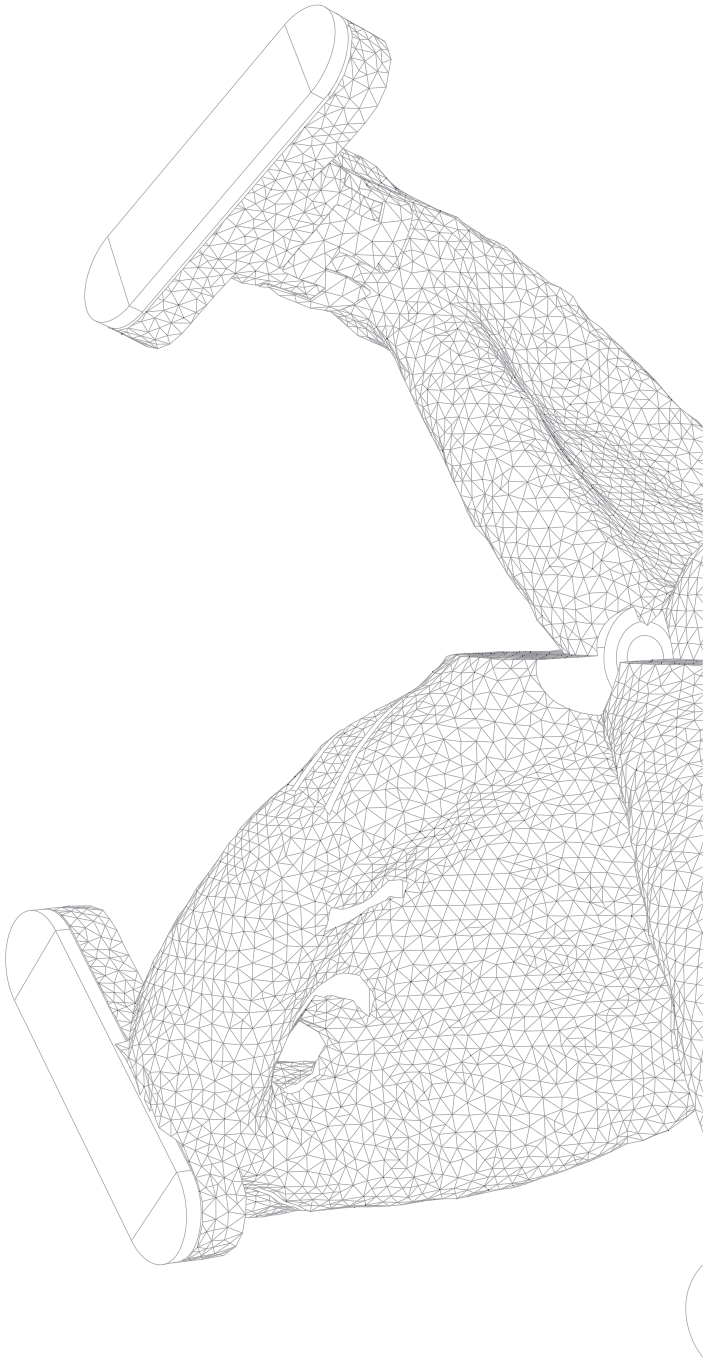
Wind load

Fw = CsCd*Cf*qp(ze)*Aref

= 1*1*549,28[N/$m^{2]}$* 2.25

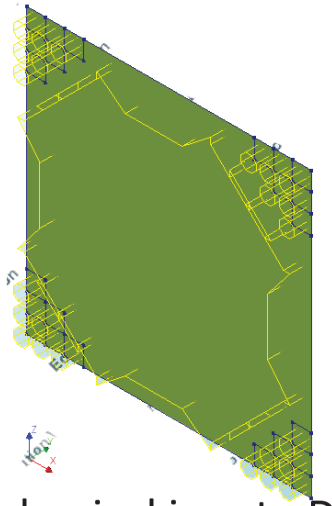
= 1.235,9 N

<u>= 1,2 kN</u>

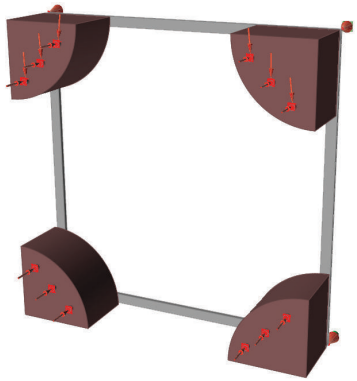


Design

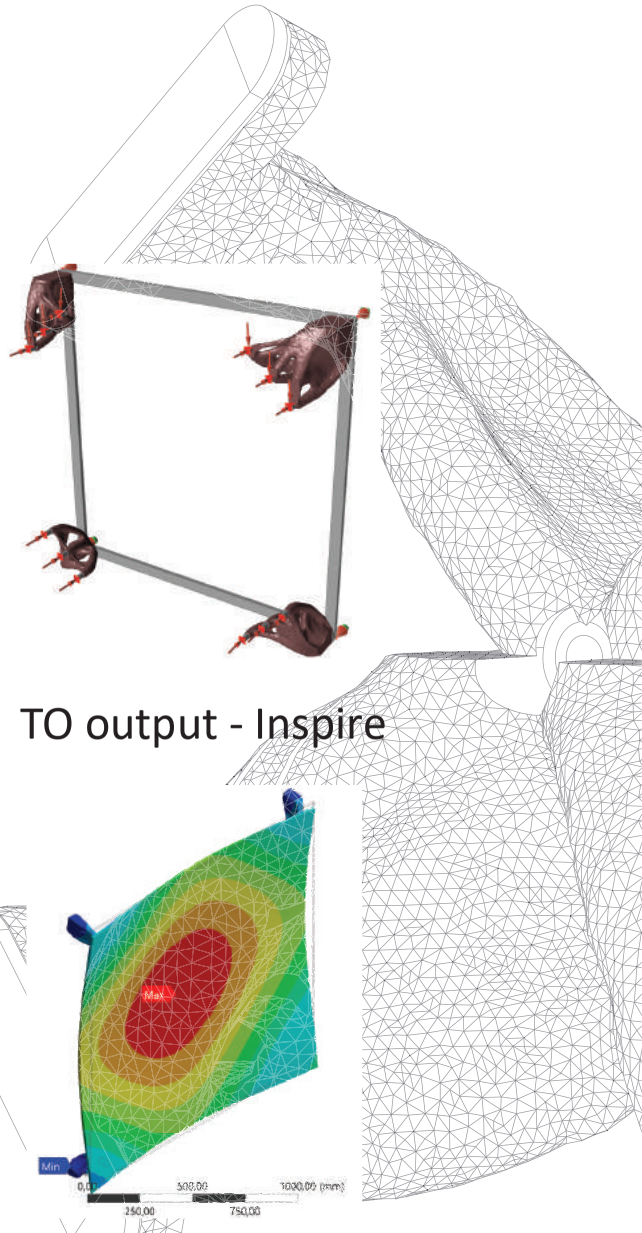
Process



Mechanical input - Diana



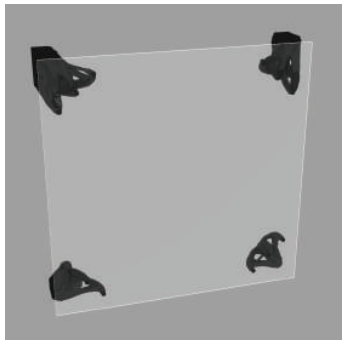
TO setup - Inspire



TO output - Inspire



Adapting the mesh - meshmixer

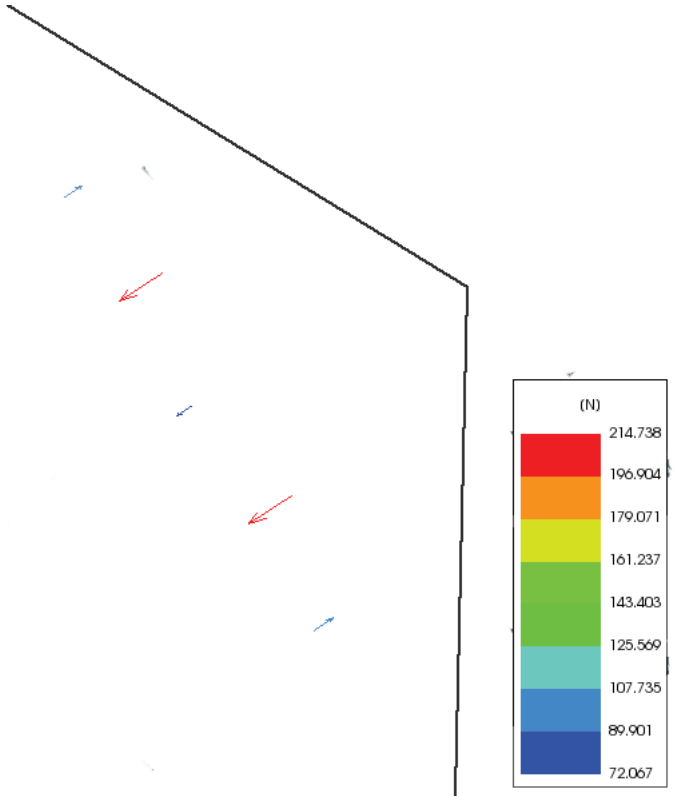


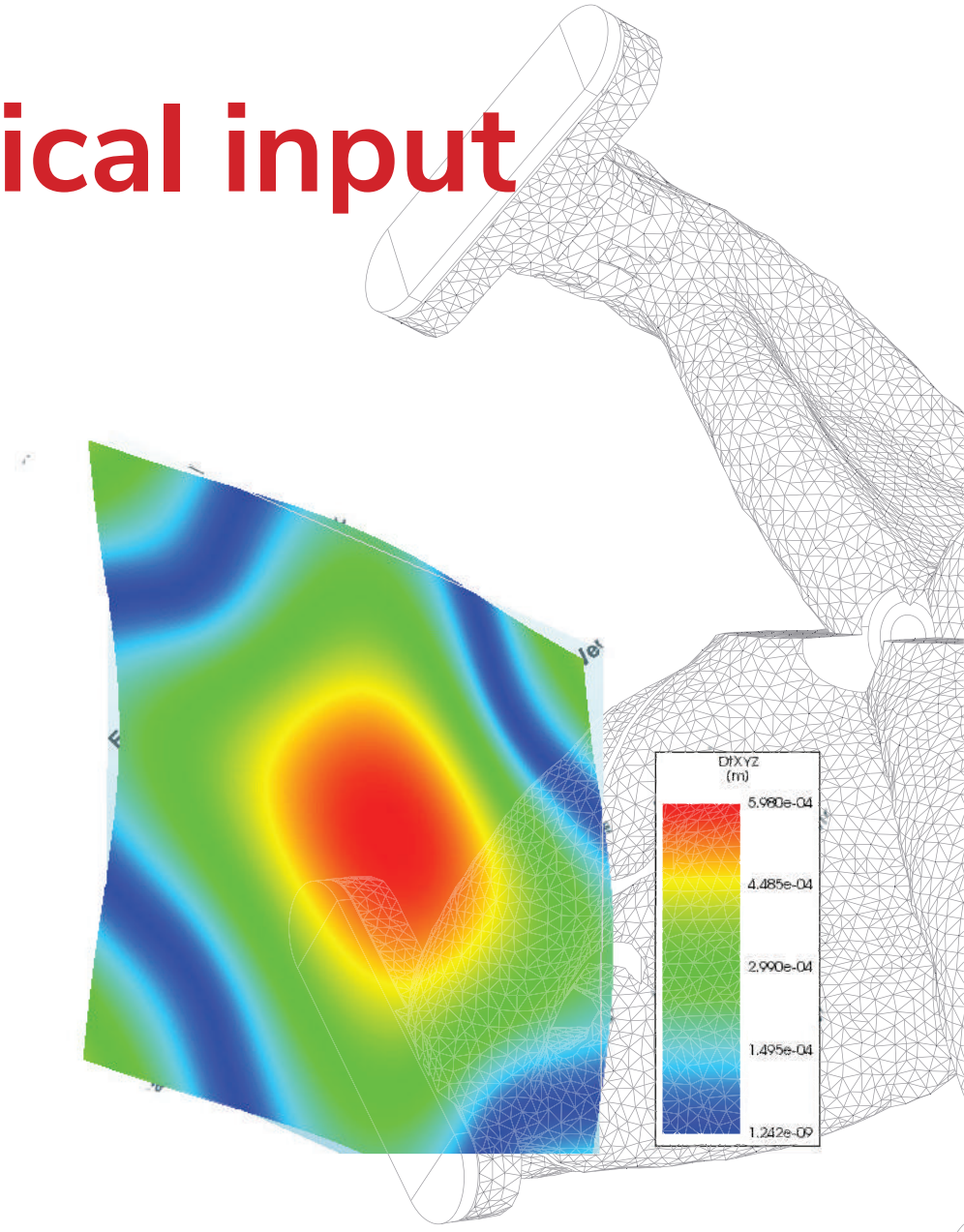
Adapting the connctions - Rhino

Calculating the system - Ansys

Design

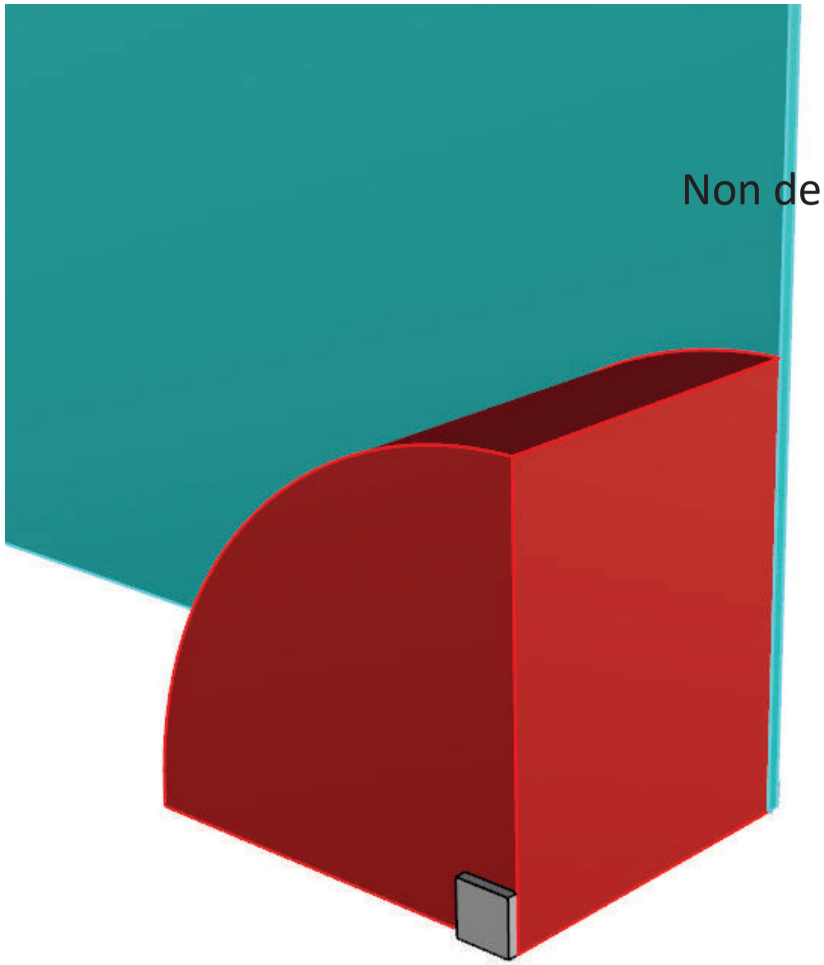
Generating mechanical input





Design

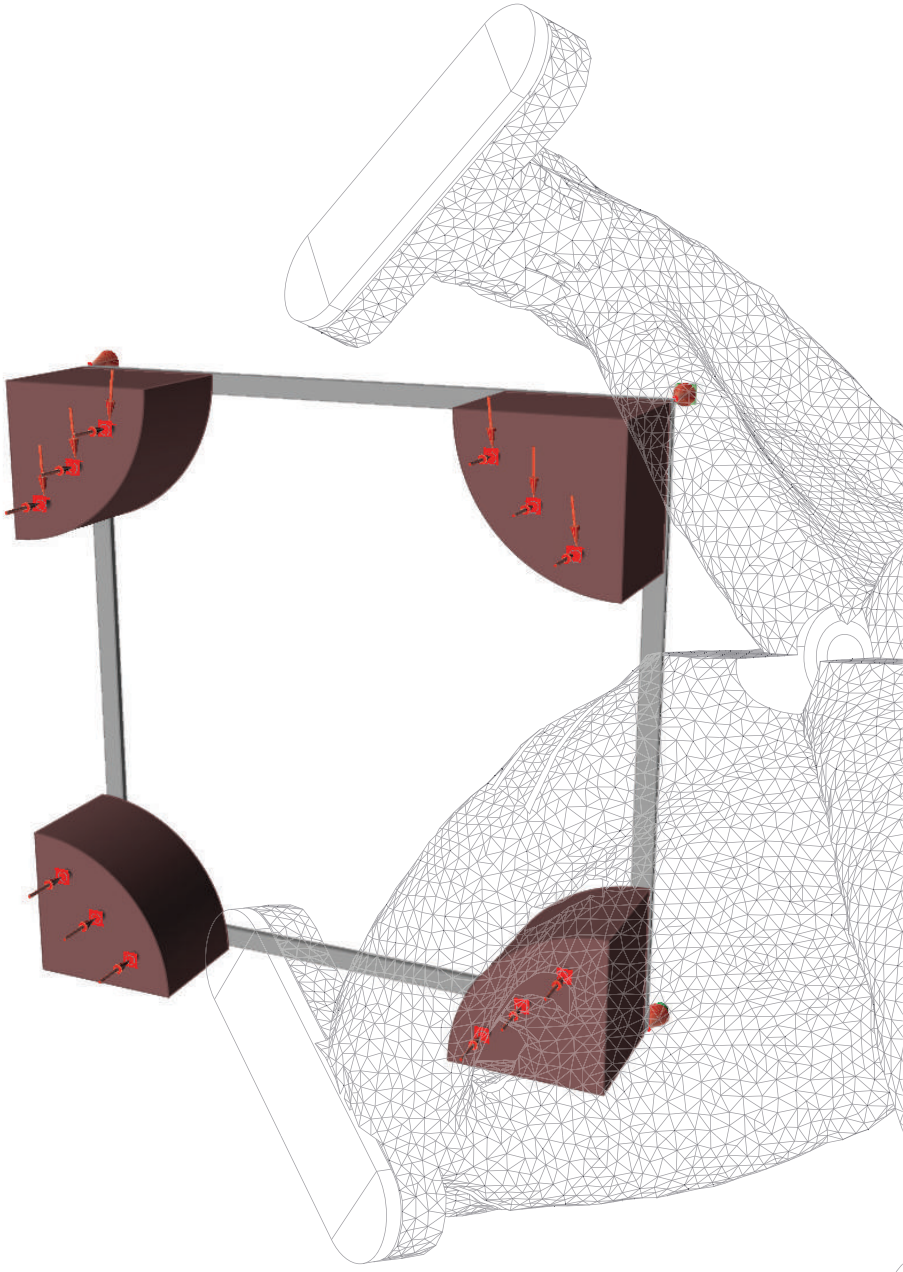
TO Setup



Non design space - glass

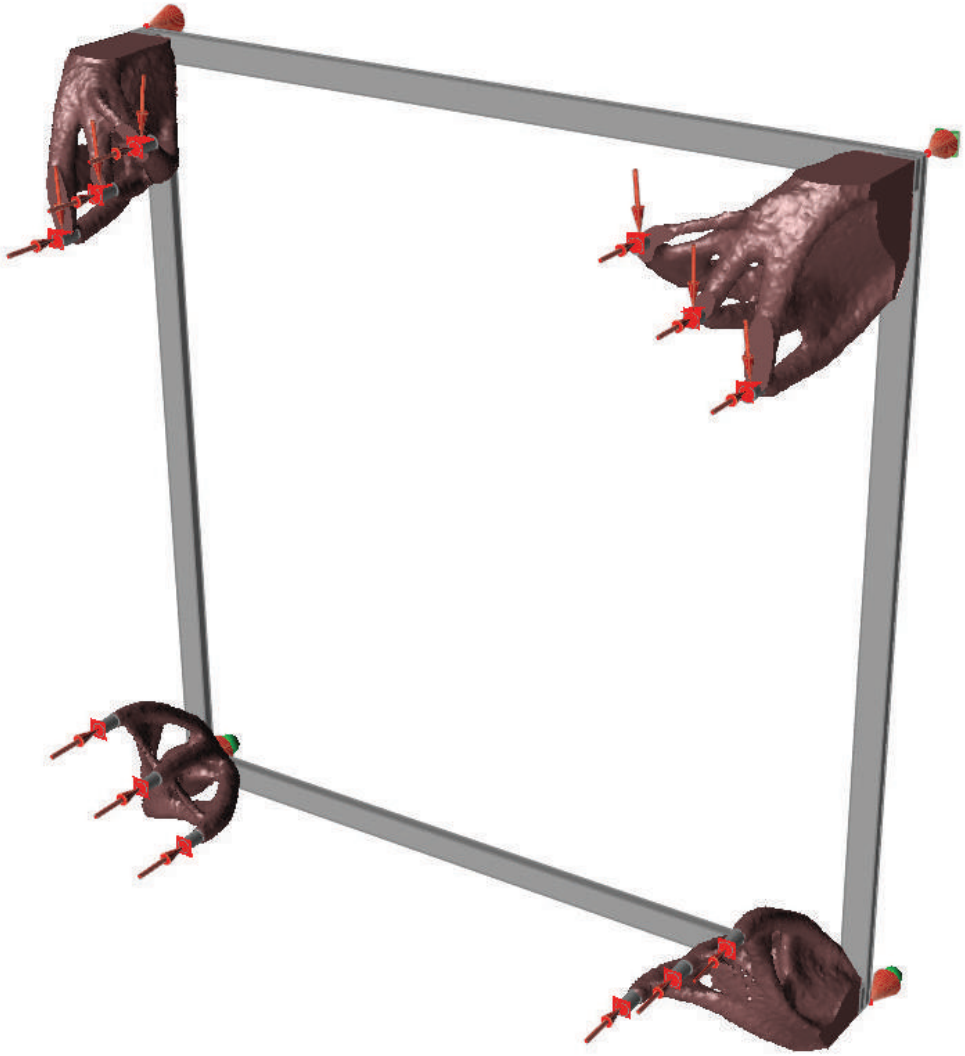
Design space

Non design space -W connection



Design

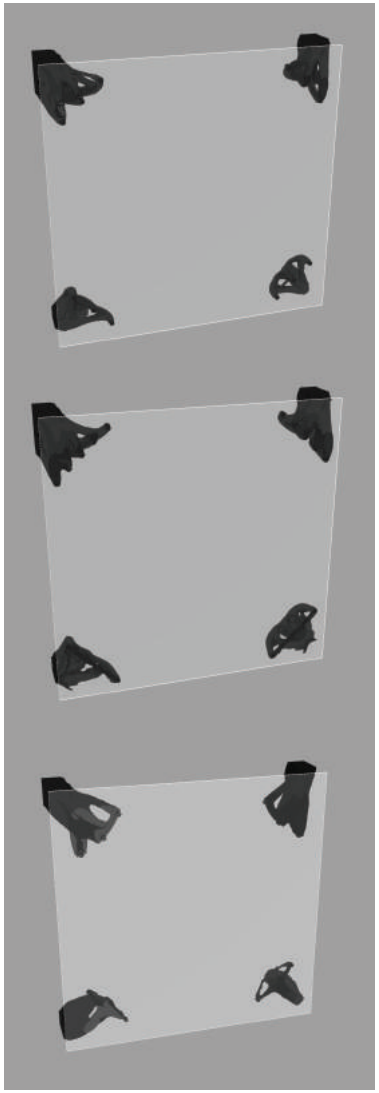
TO Output

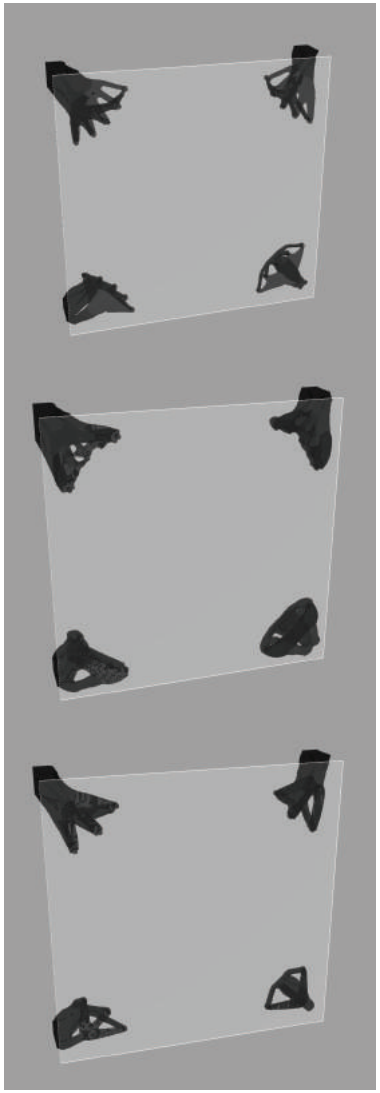


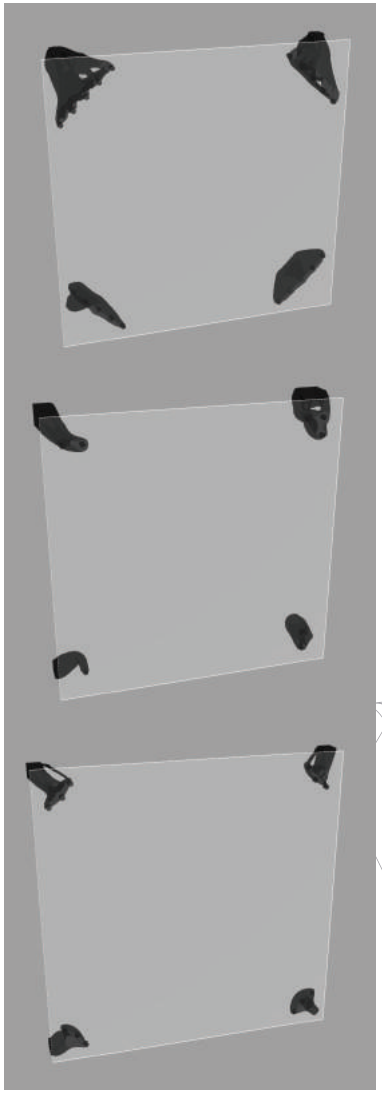


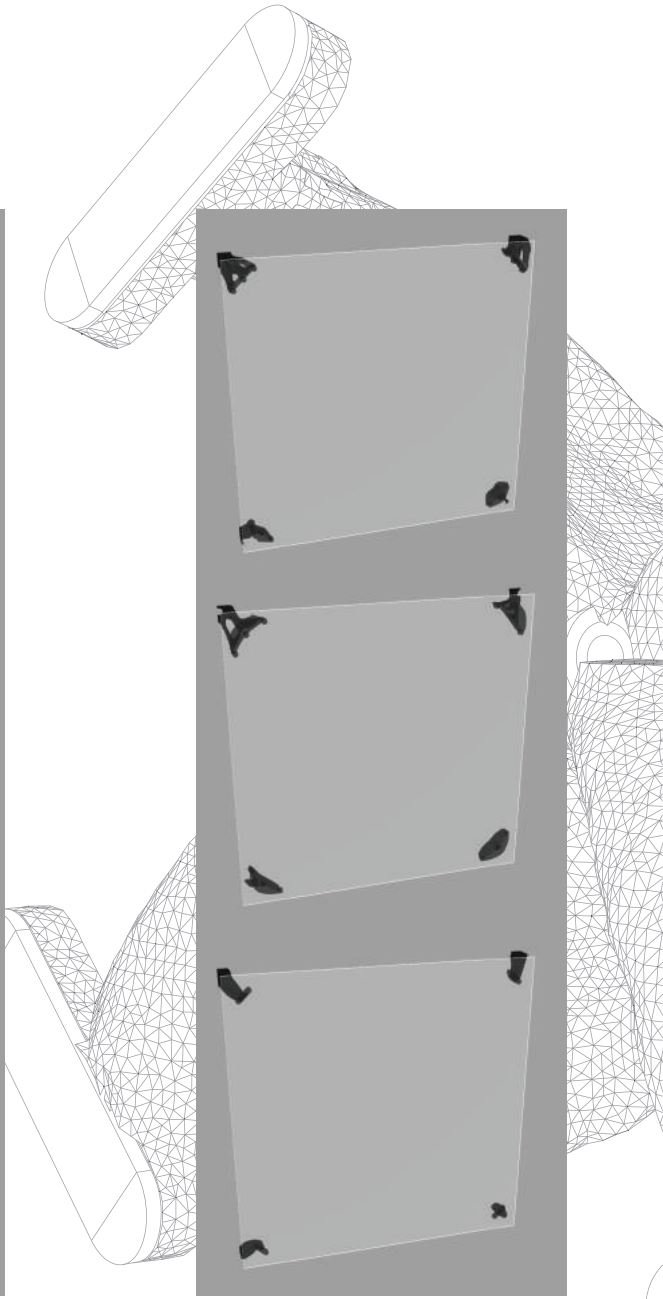
Design

TO designs



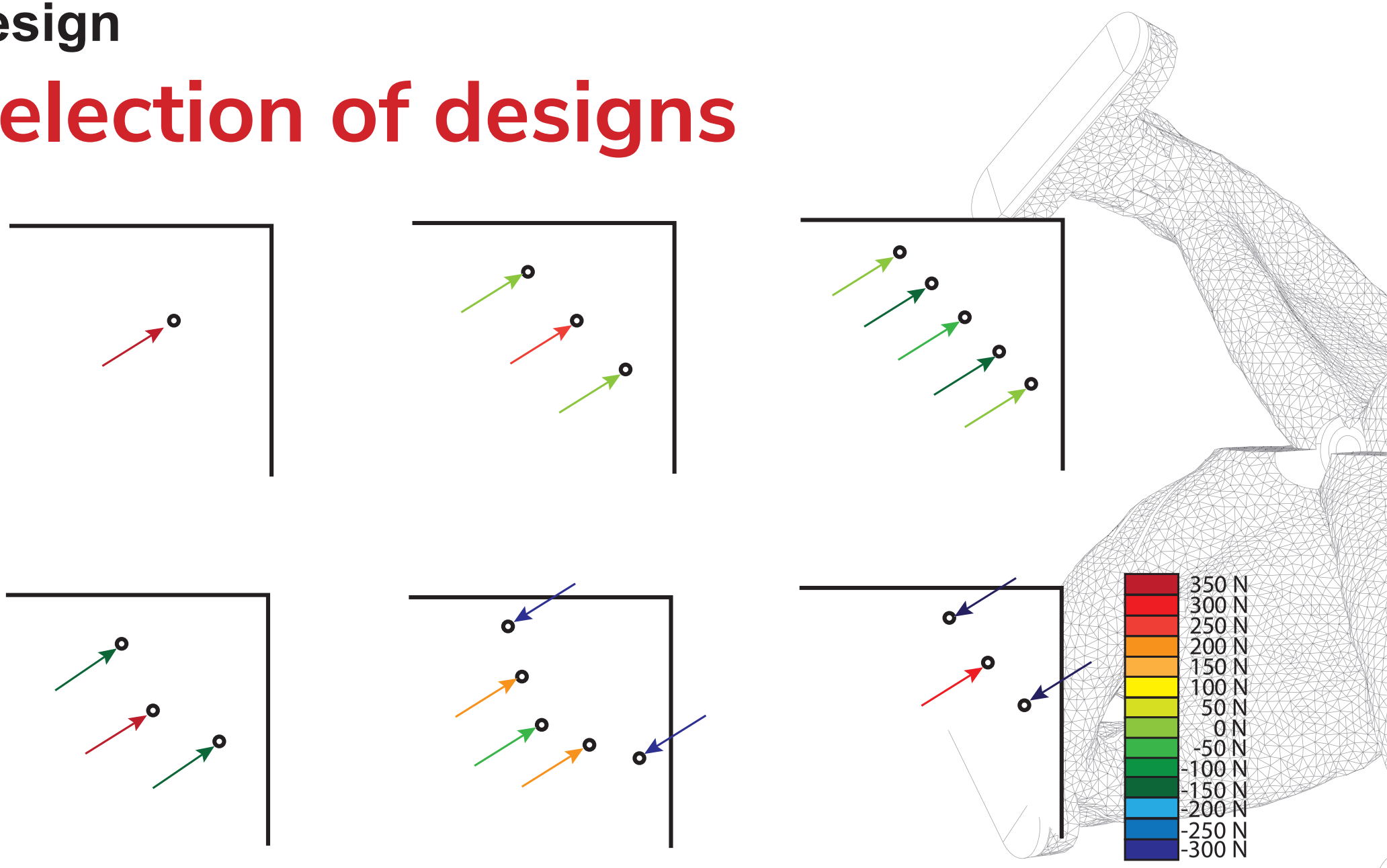






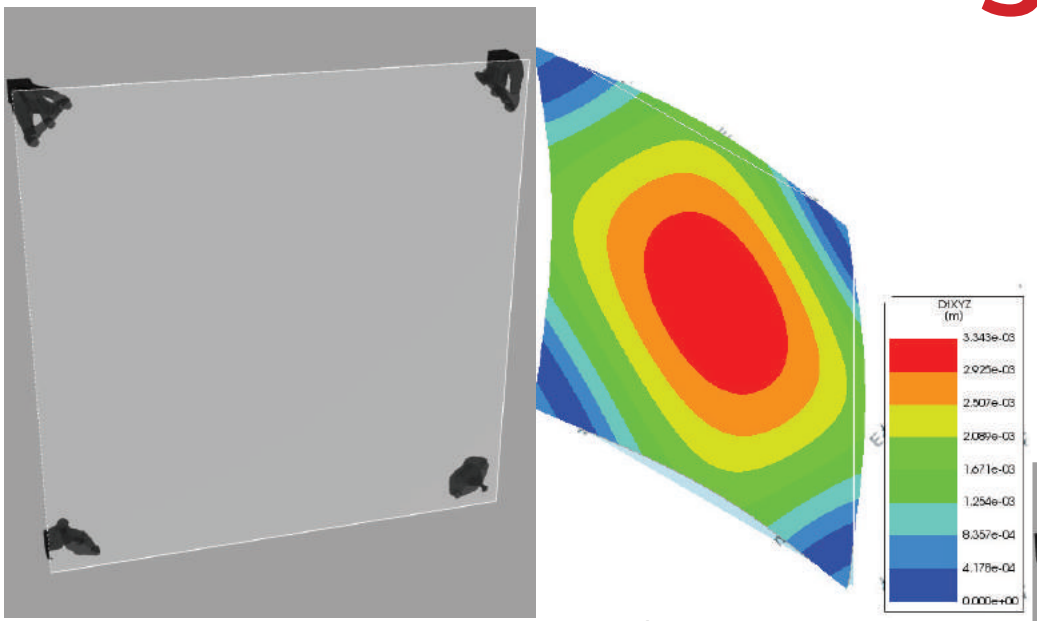
Design

Selection of designs

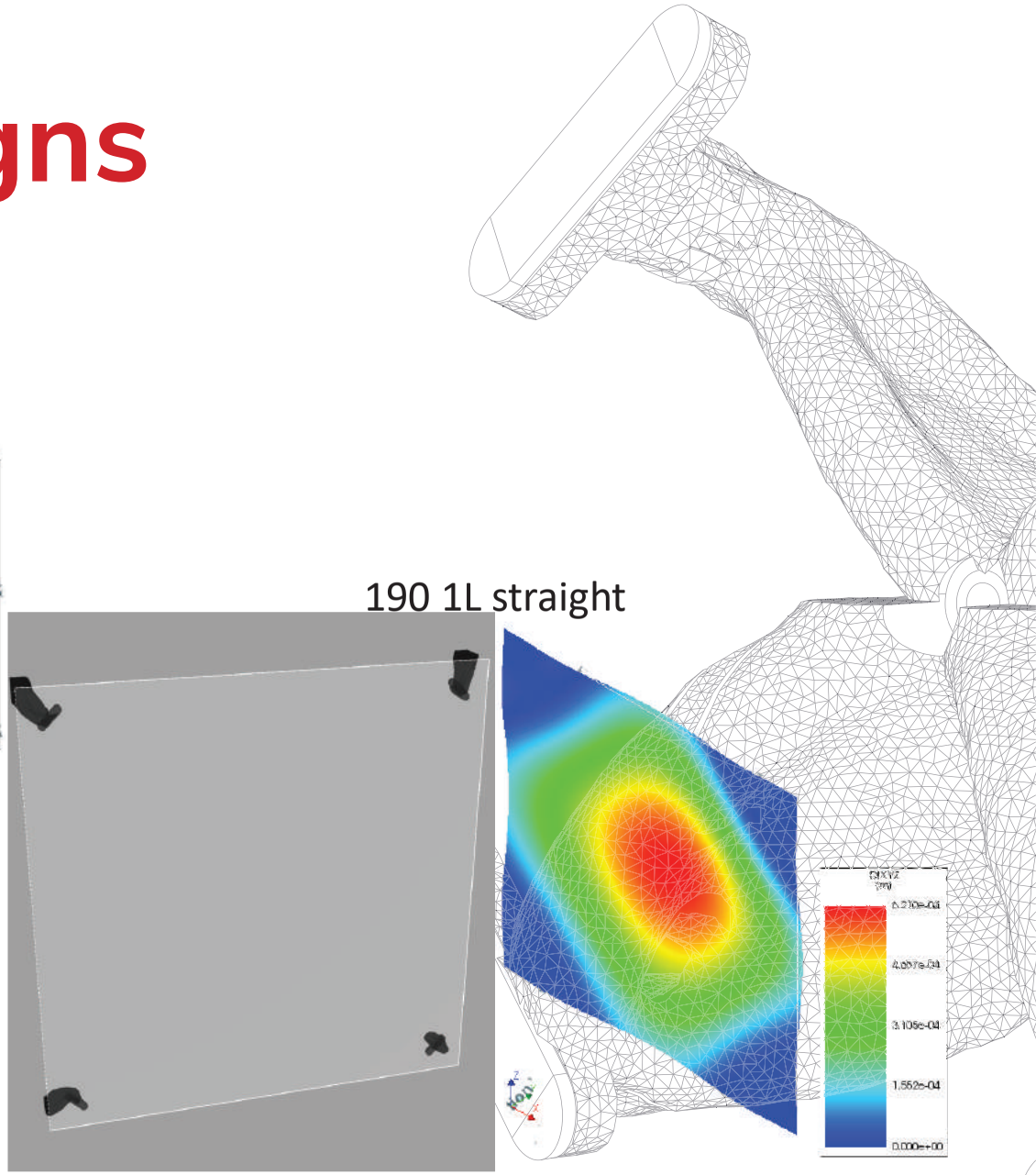


Design

Selection of designs



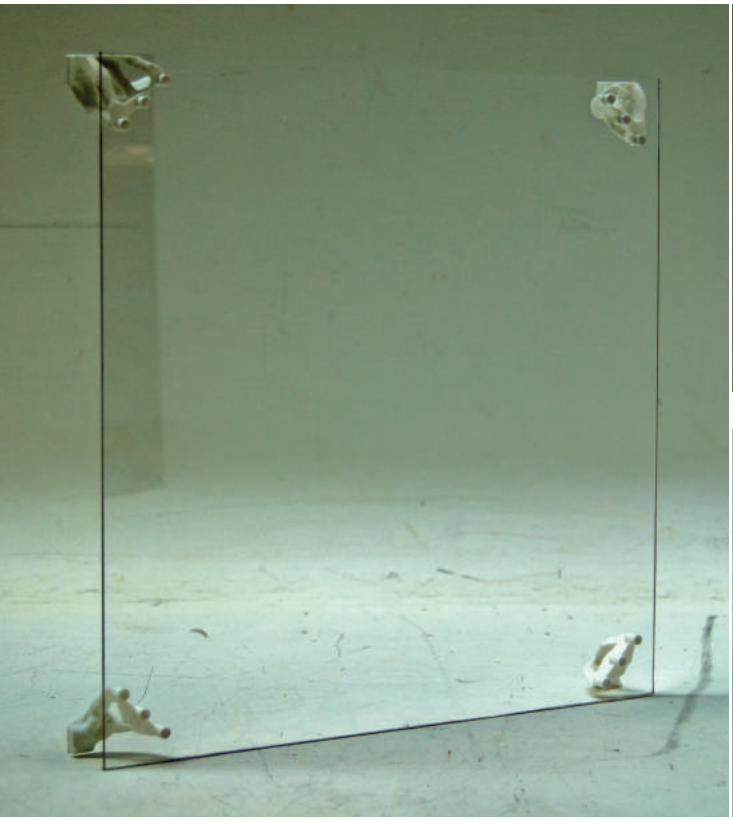
190 3P straight

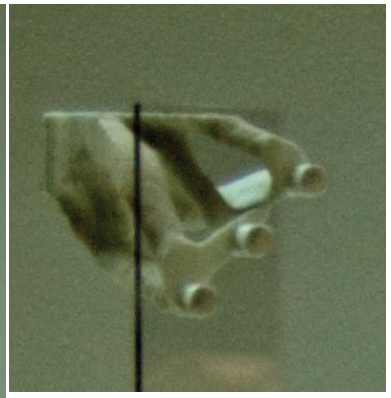


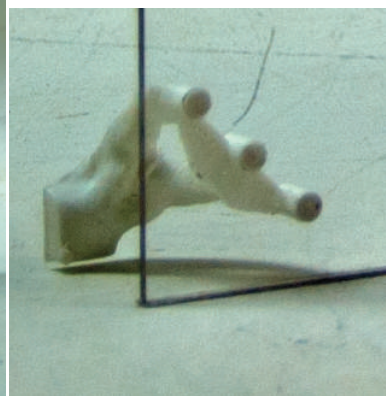
190 1L straight

Design

Prototyping

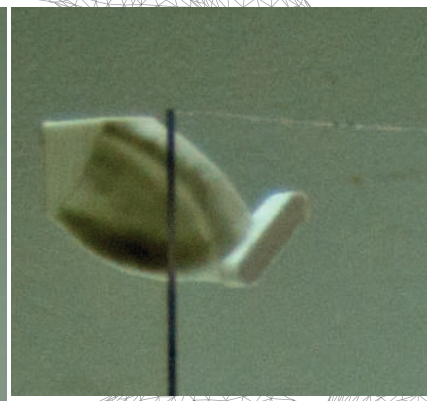


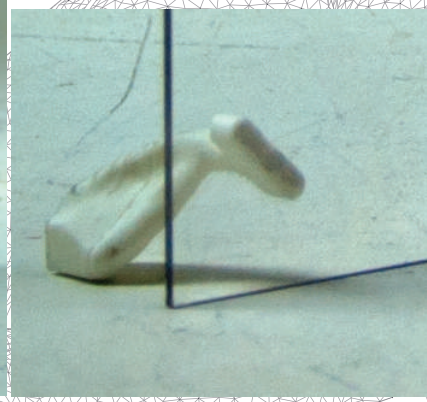




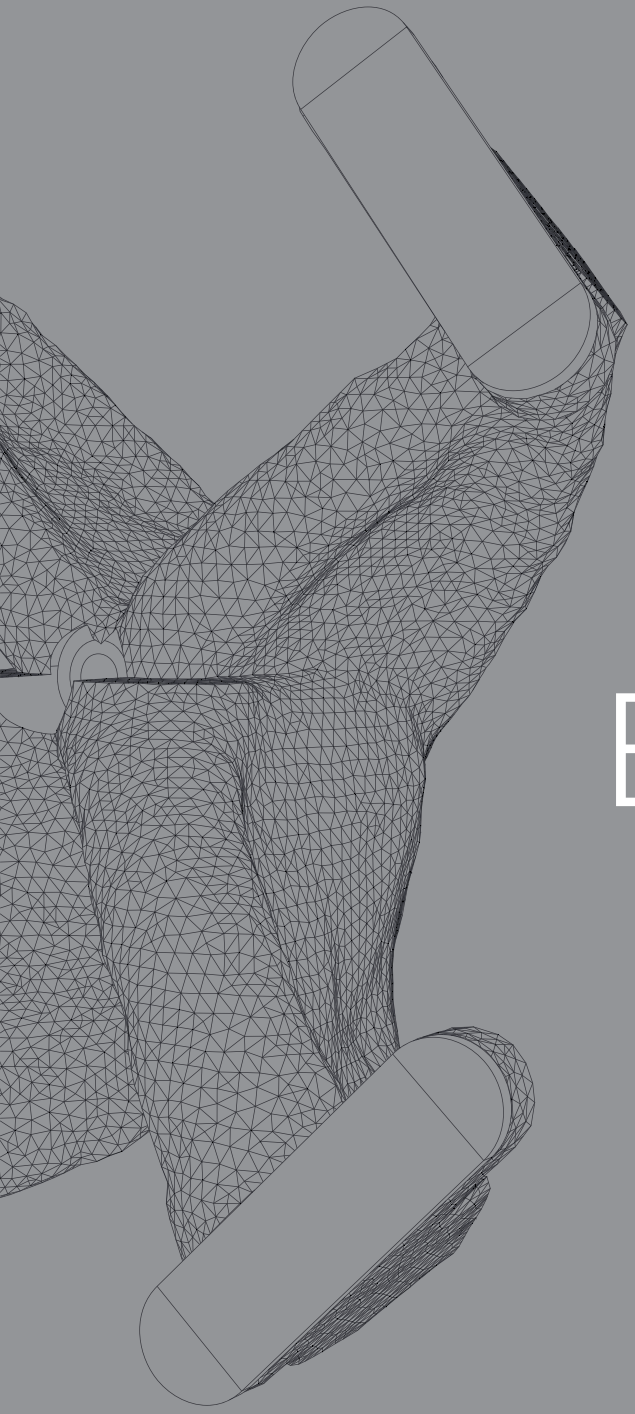
190 3P straight







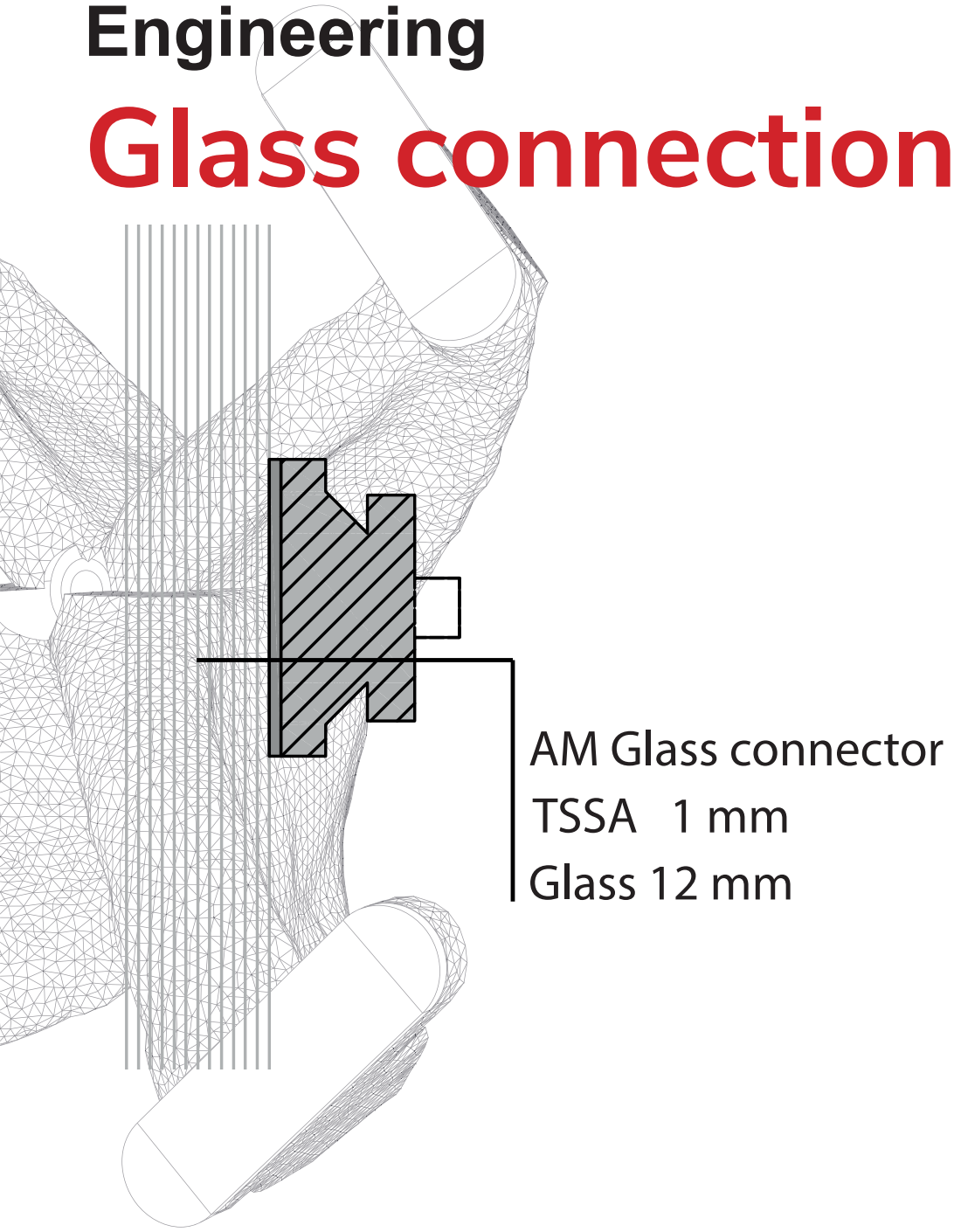
190 1L straight



ENGINEERING

Engineering

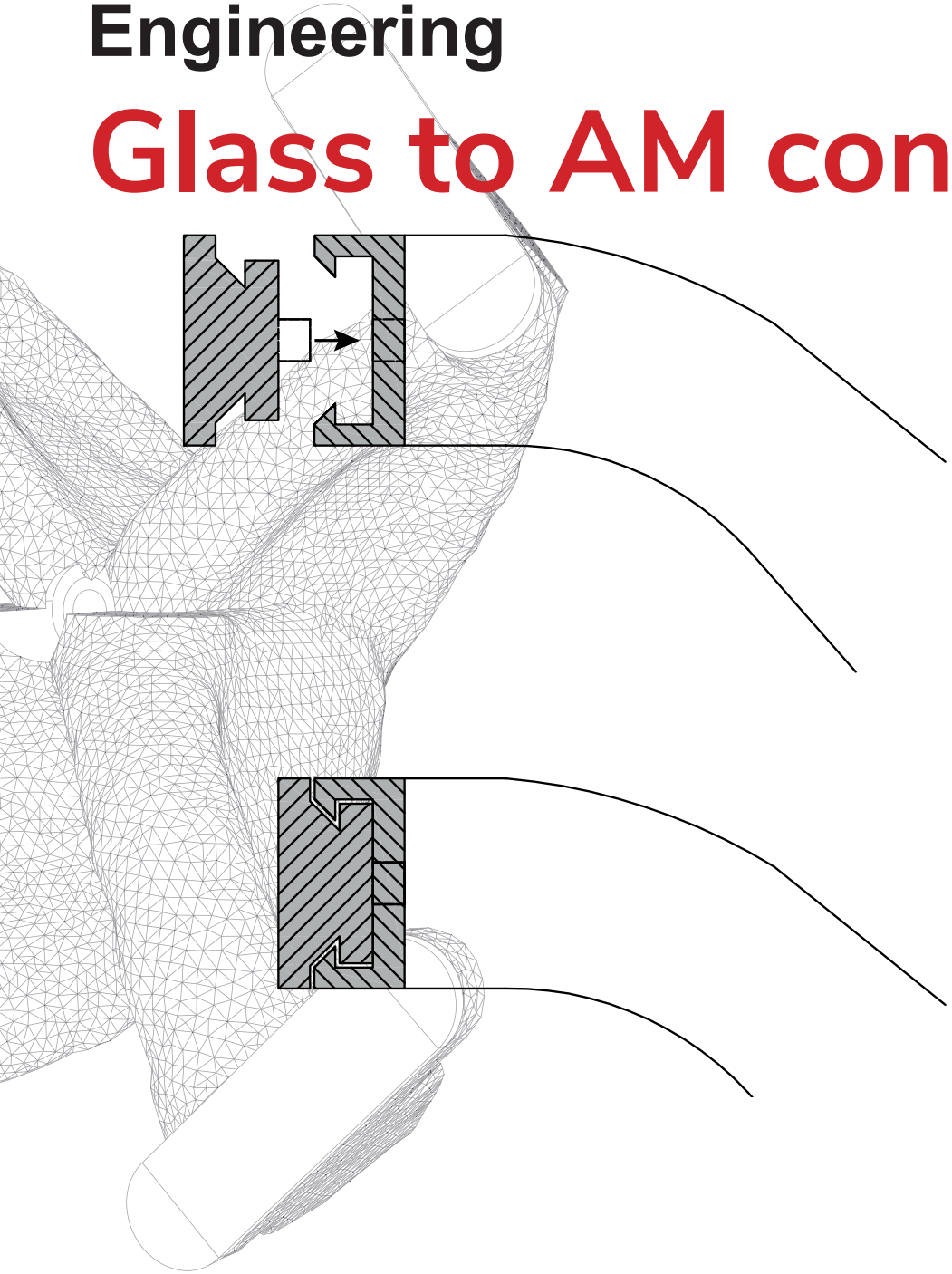
Glass connection

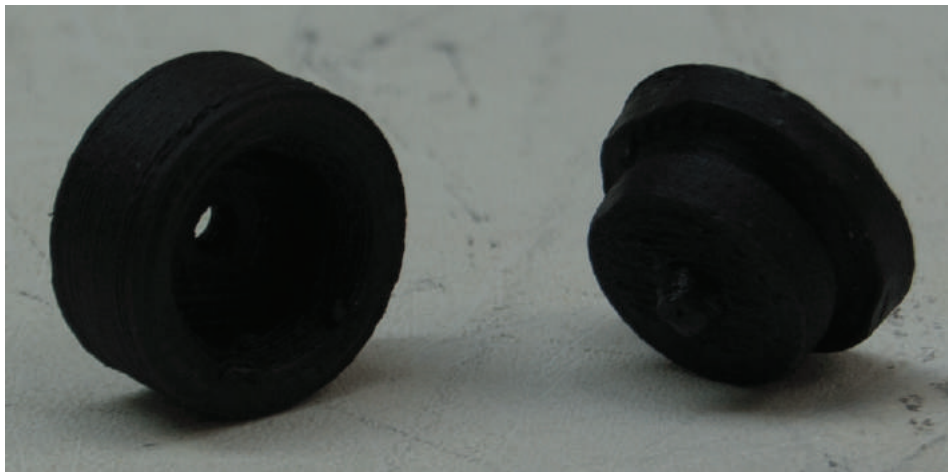


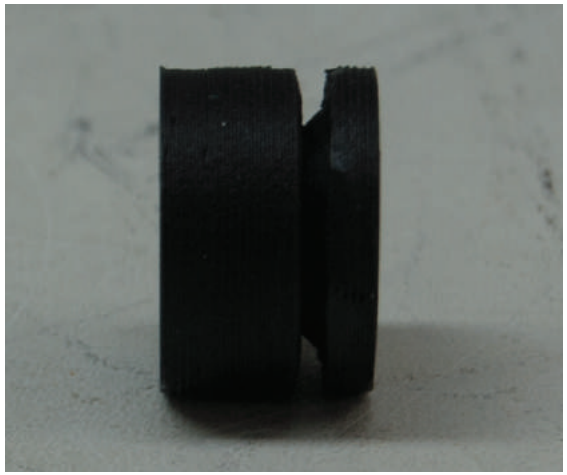


Engineering

Glass to AM connection

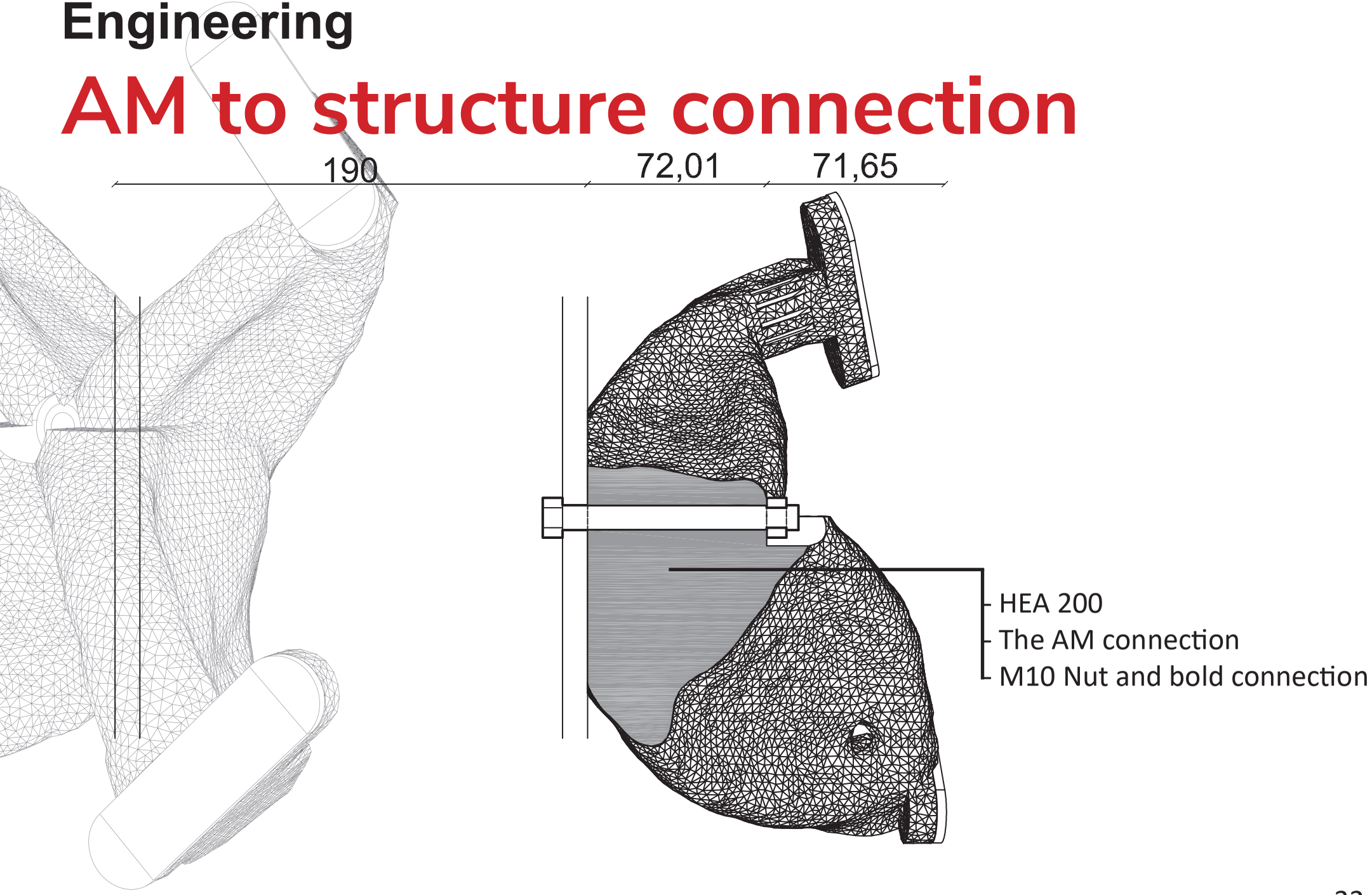






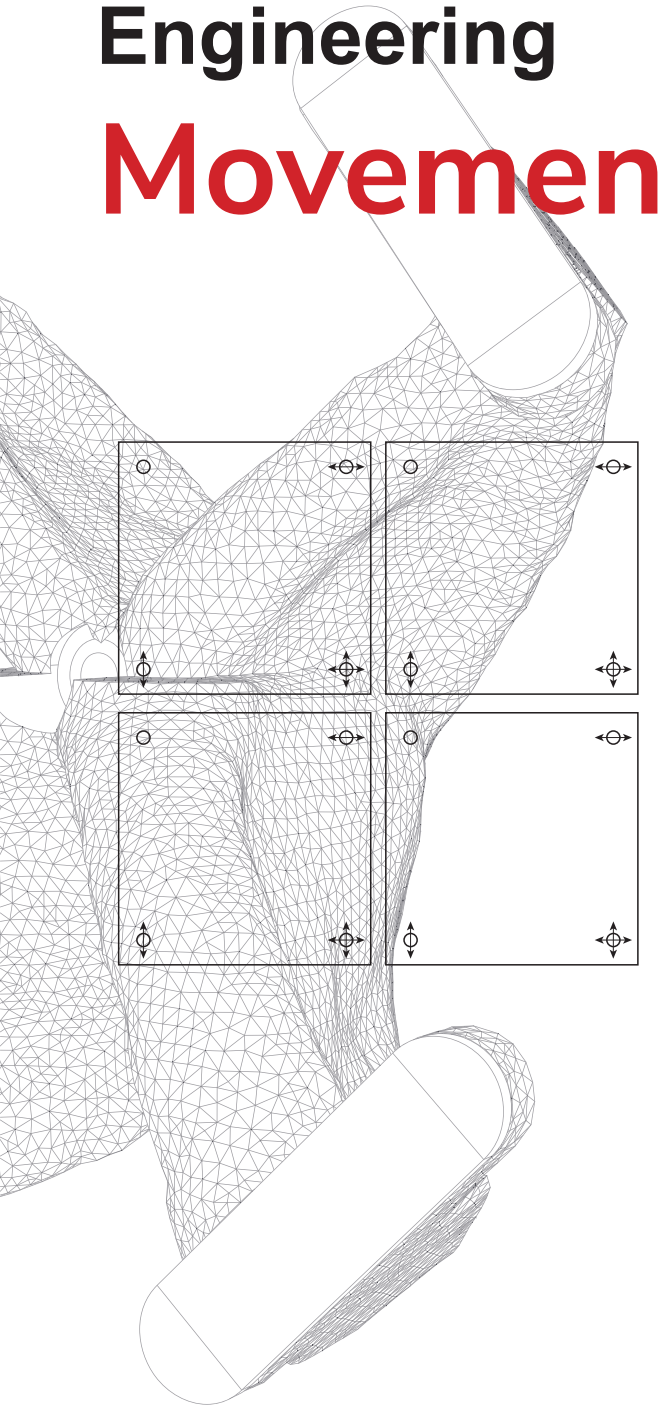
Engineering

AM to structure connection



Engineering

Movement of the glass

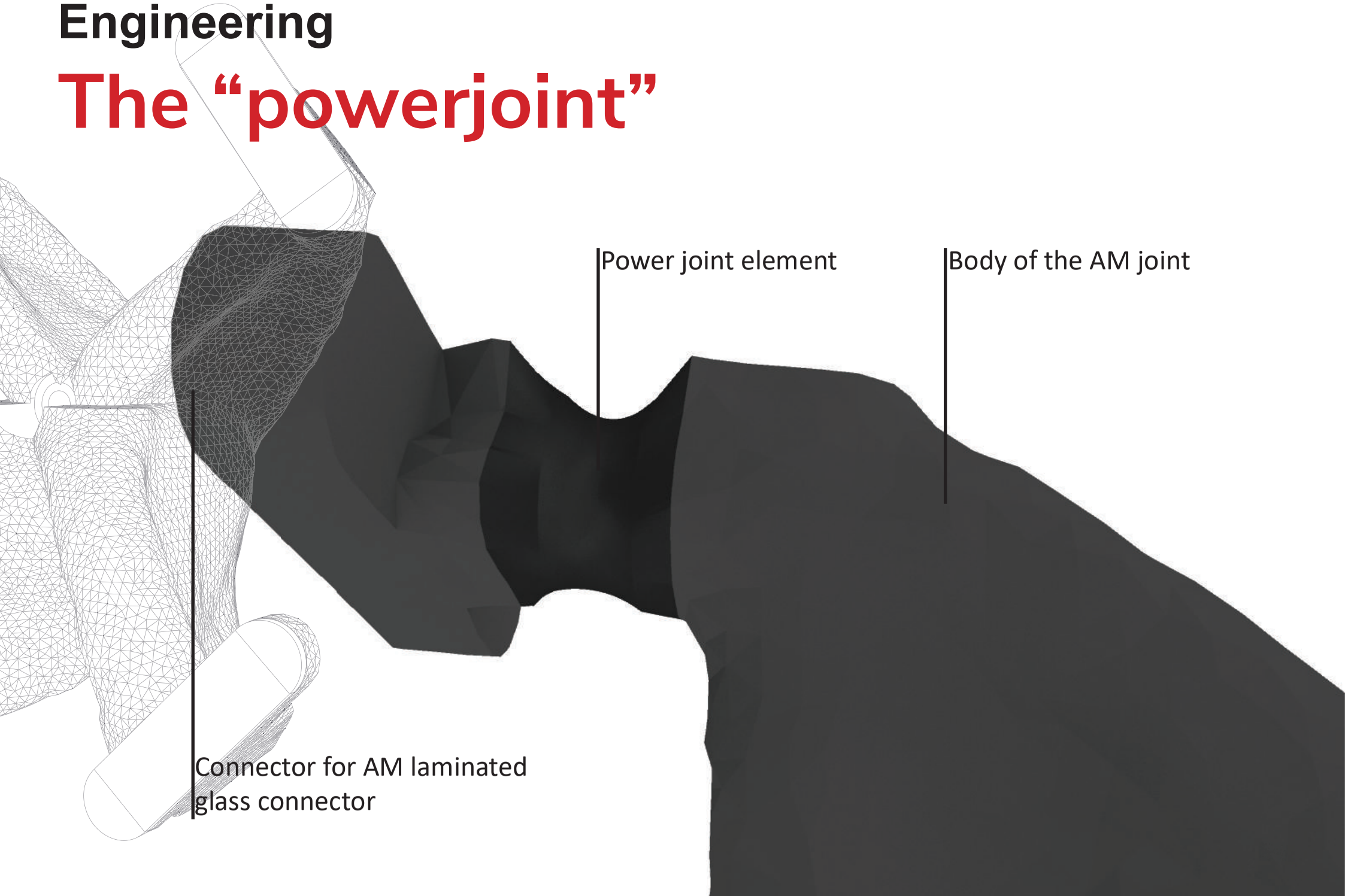






Engineering

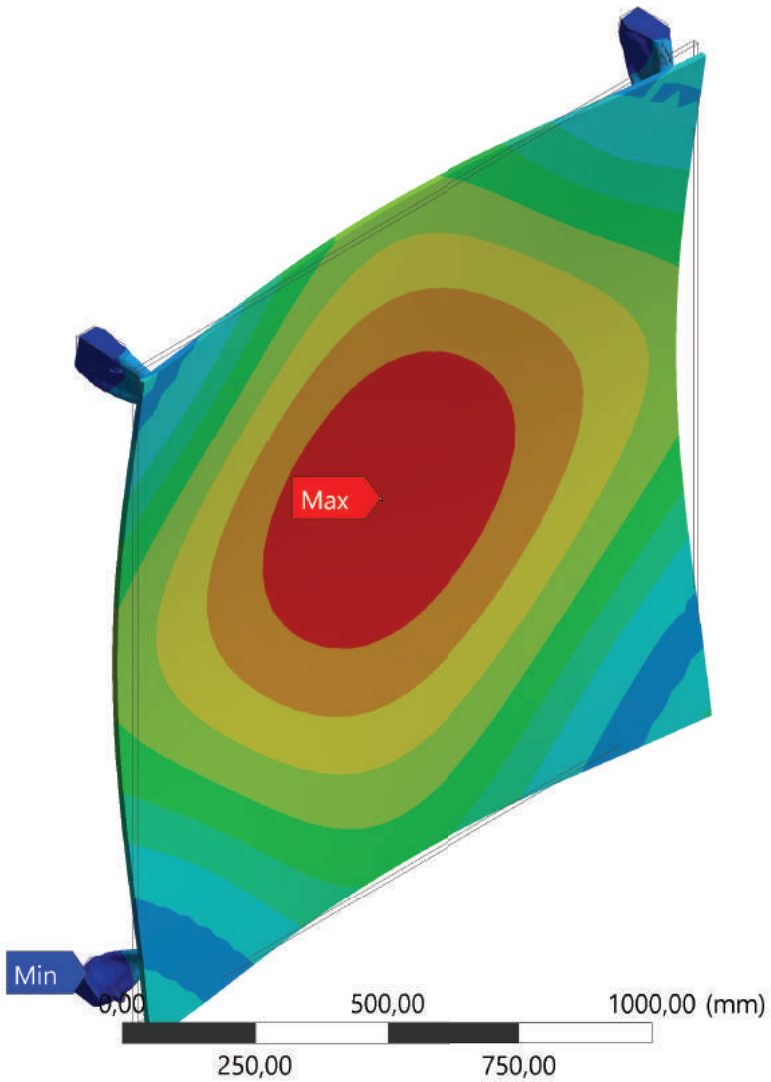
The “powerjoint”



Engineering

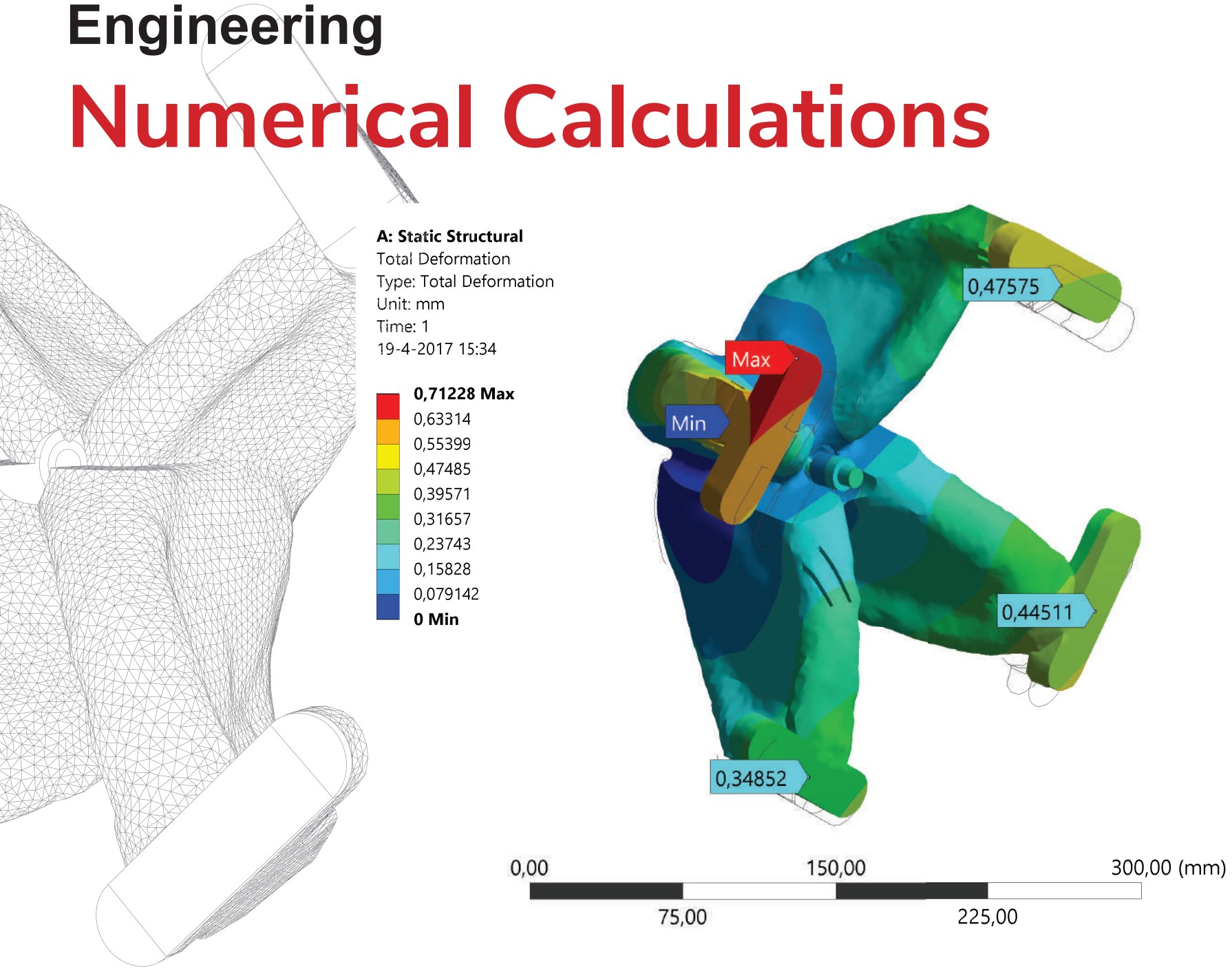
Numerical Calculations

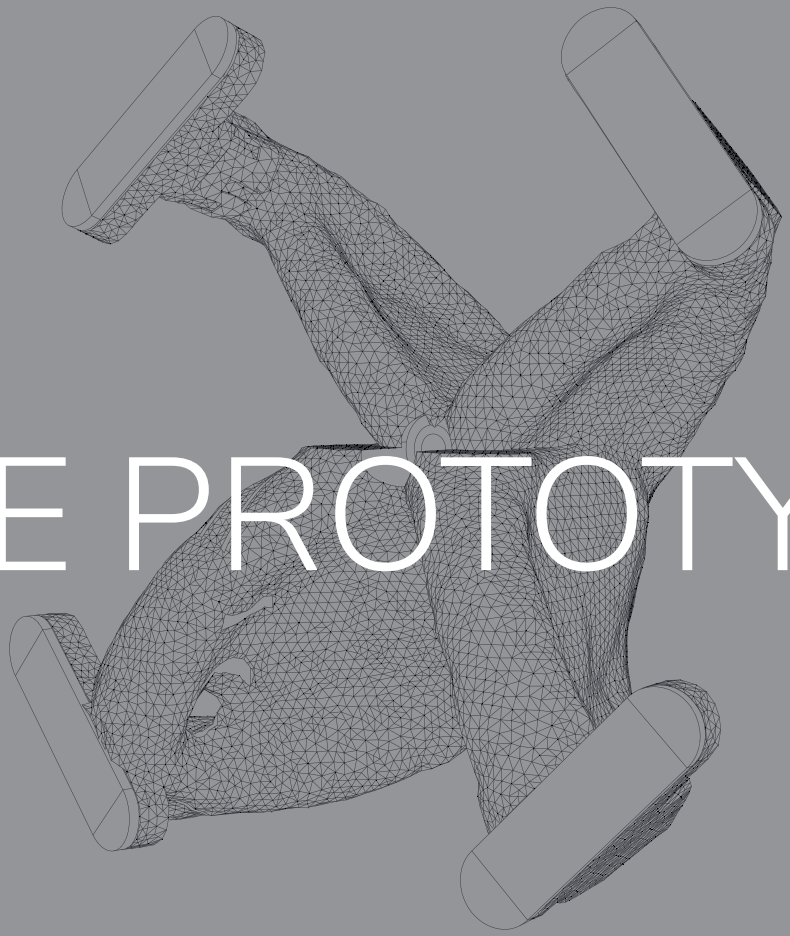
Density		1.35	g/cm3
Max tensile strenth		76	MPa
Elongation at break		7,5	%
Flexural strength	X	110	MPa
	Y	110	MPa
	Z	73	MPa
Flexural modulus	X	6,2	GPa
	Y	6,2	GPa
	Z	4,1	GPa
Poison ratio	XY	0,33	%
	YZ	0,33	%
	XZ	0,33	%
Shear Modulus	XY	1,6	GPa
	YZ	1,6	GPa
	XZ	2,4	GPa



Engineering

Numerical Calculations

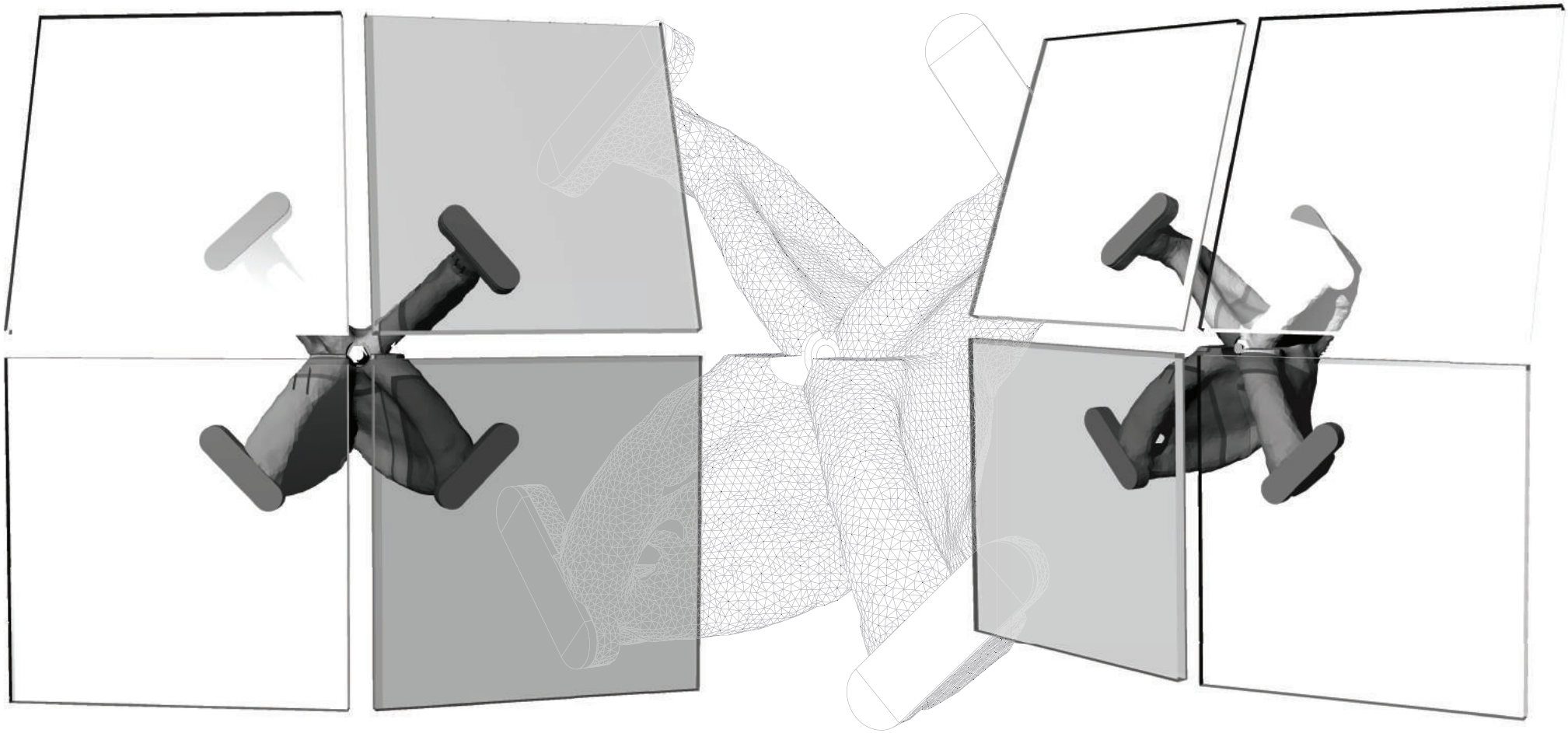




THE PROTOTYPE

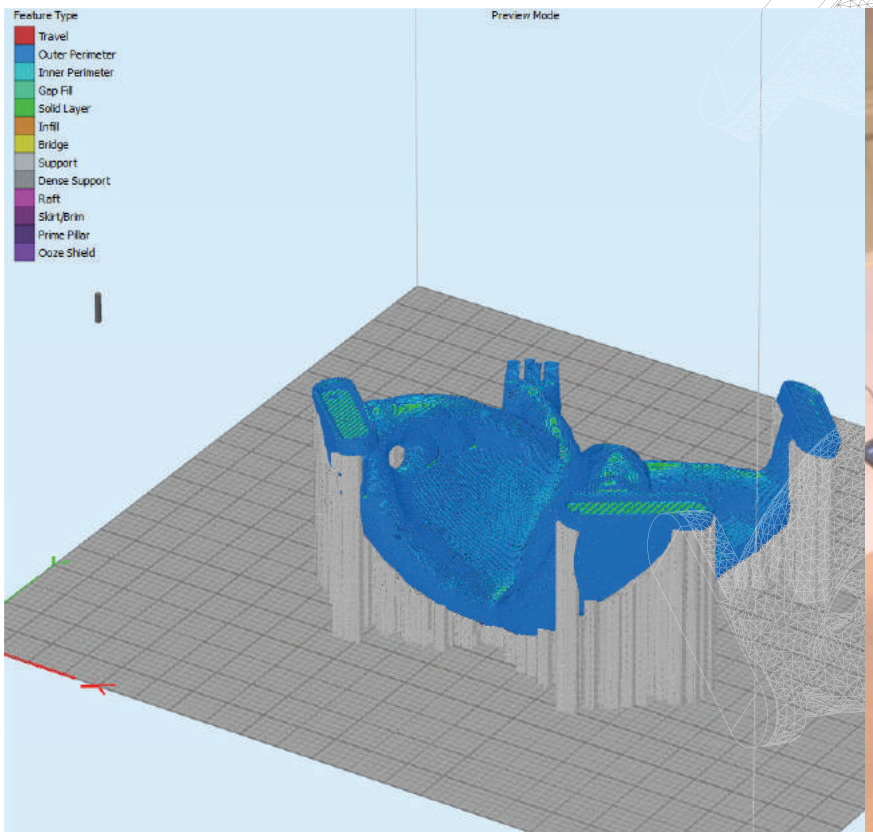
The prototype

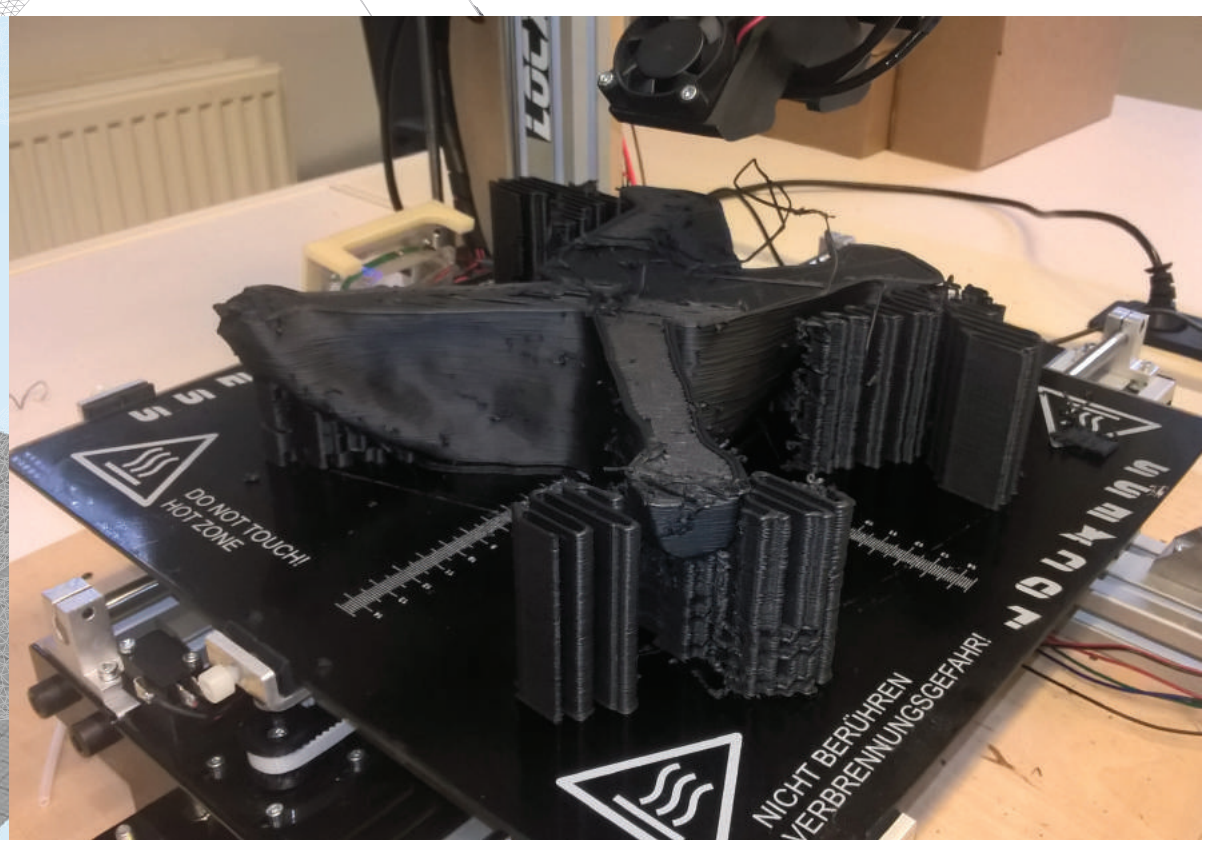
Renders



The prototype

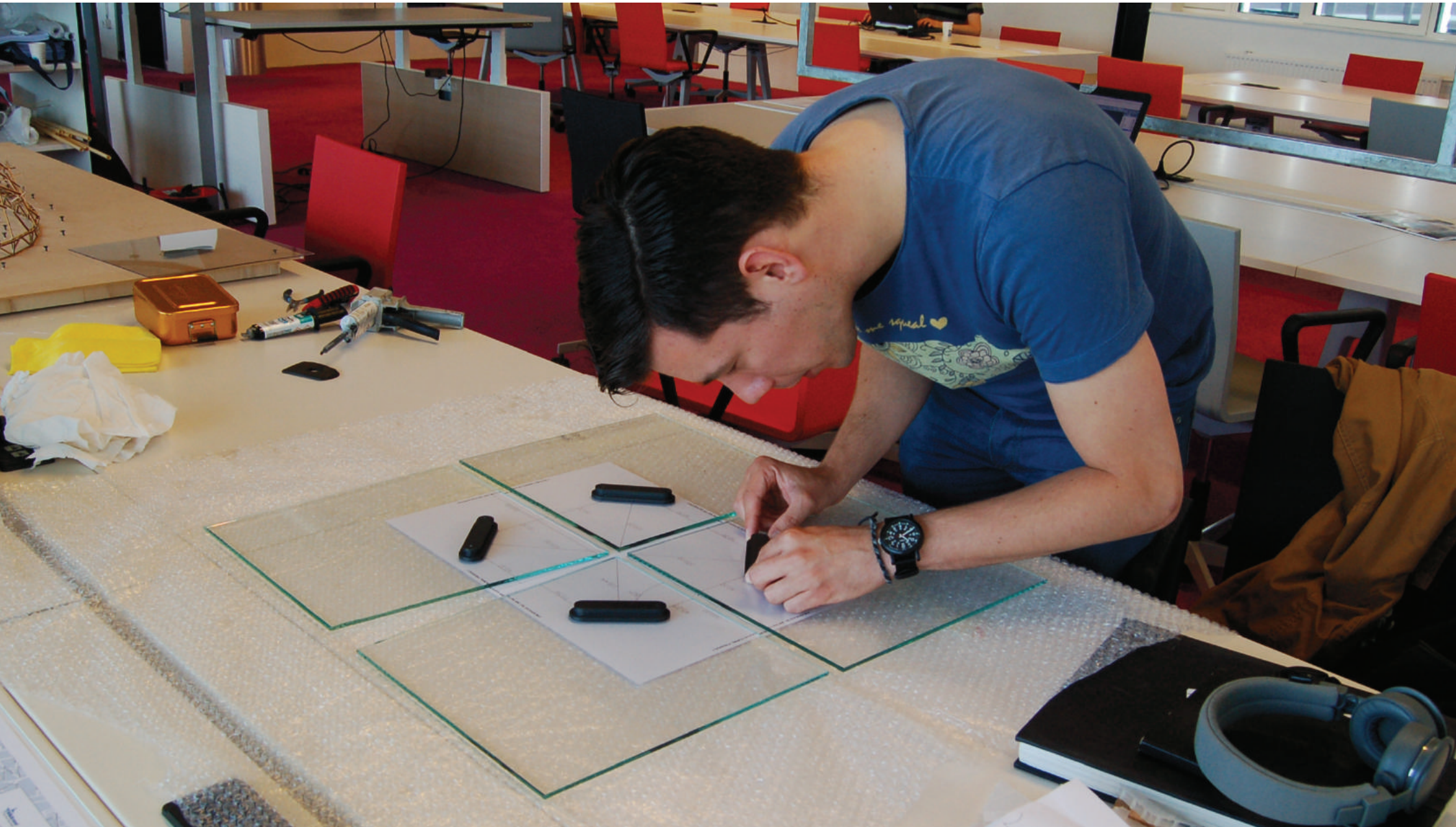
Production





The prototype

Production



The prototype

Production



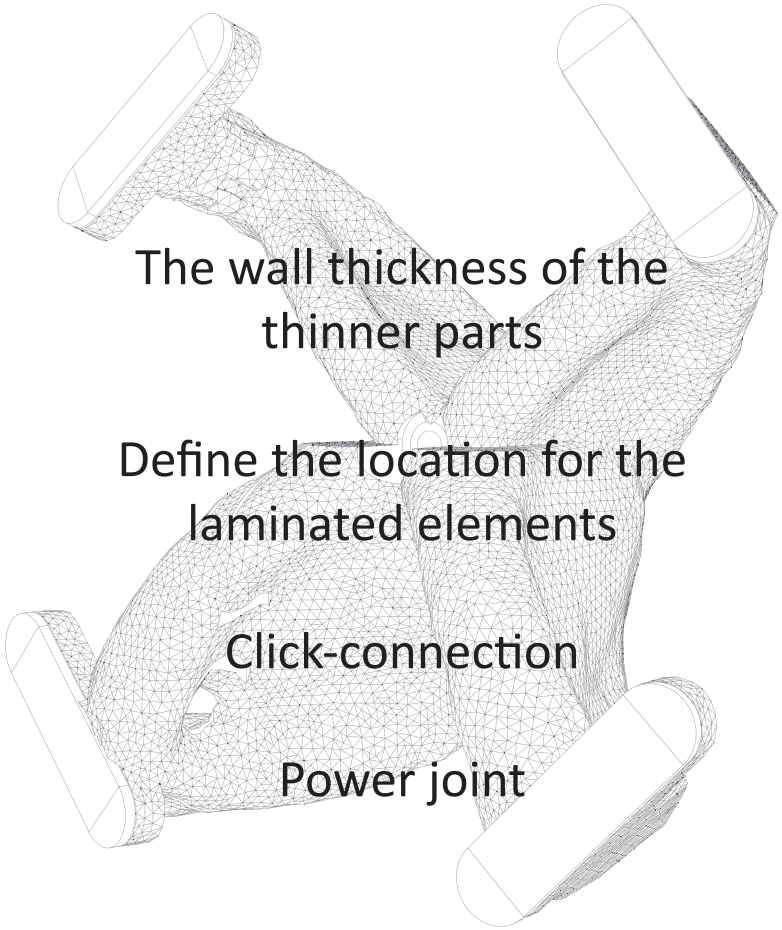
The prototype

Production



The prototype

Points of improvement

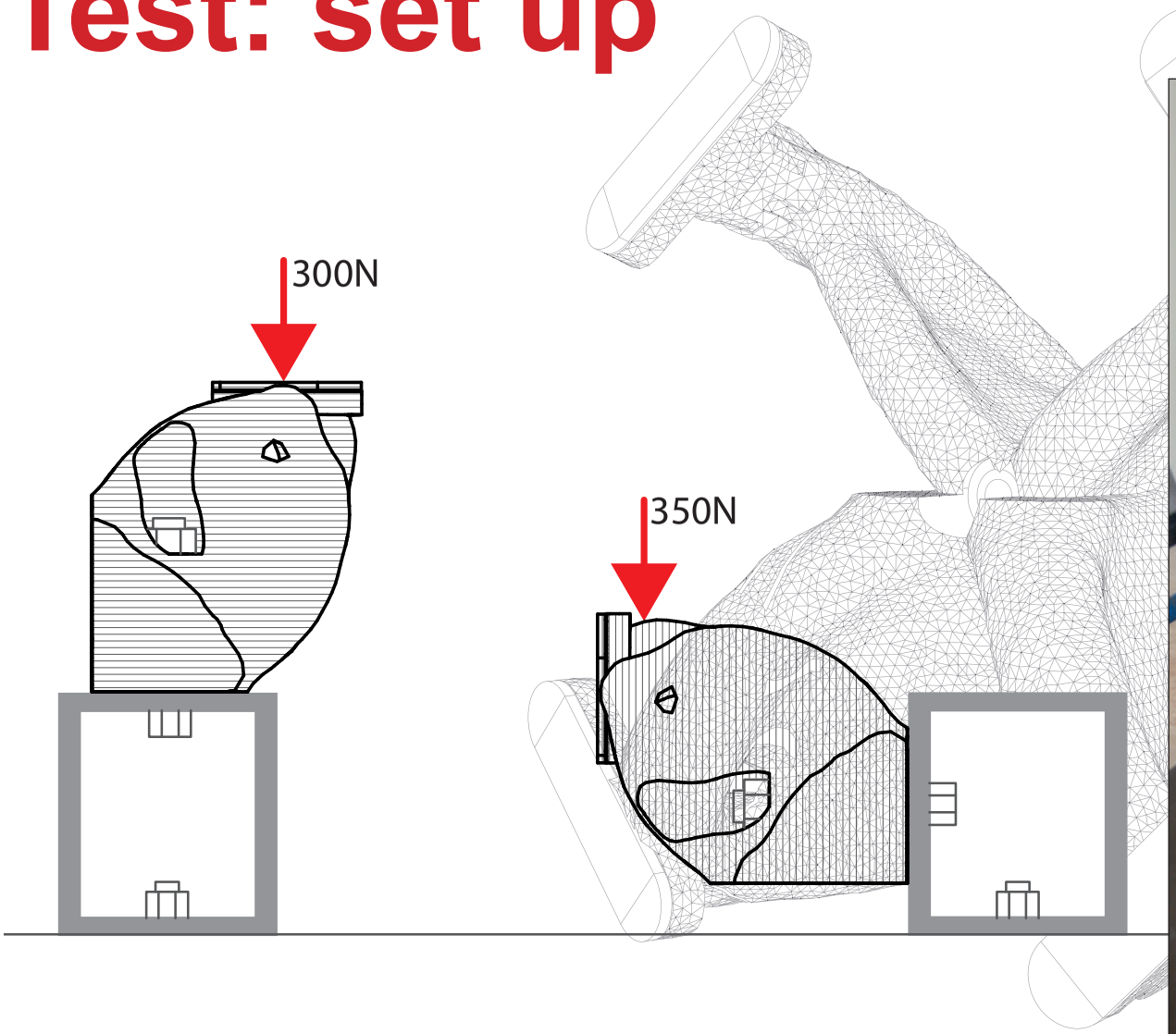




VALIDATION

Validation

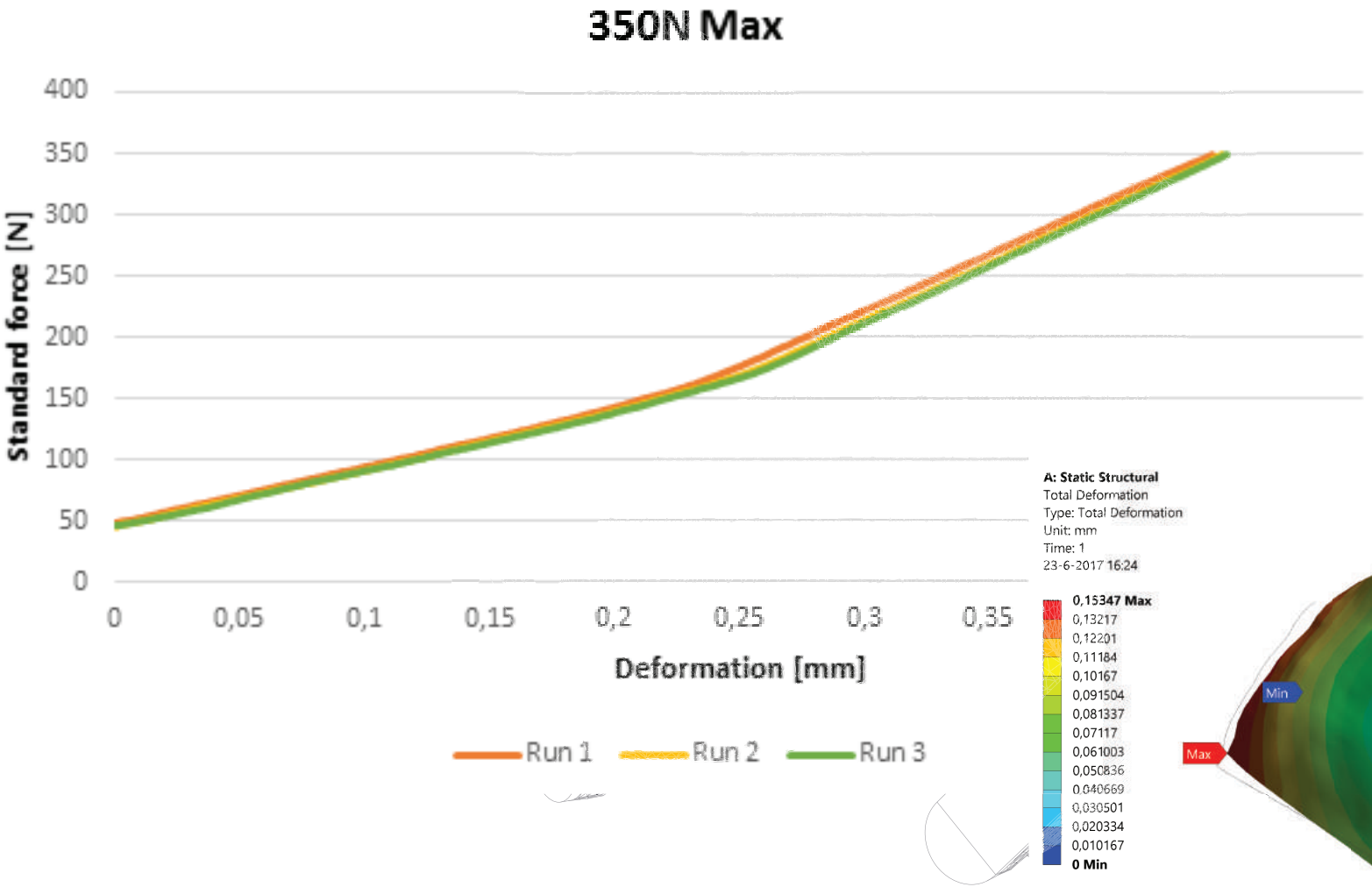
Test: set up

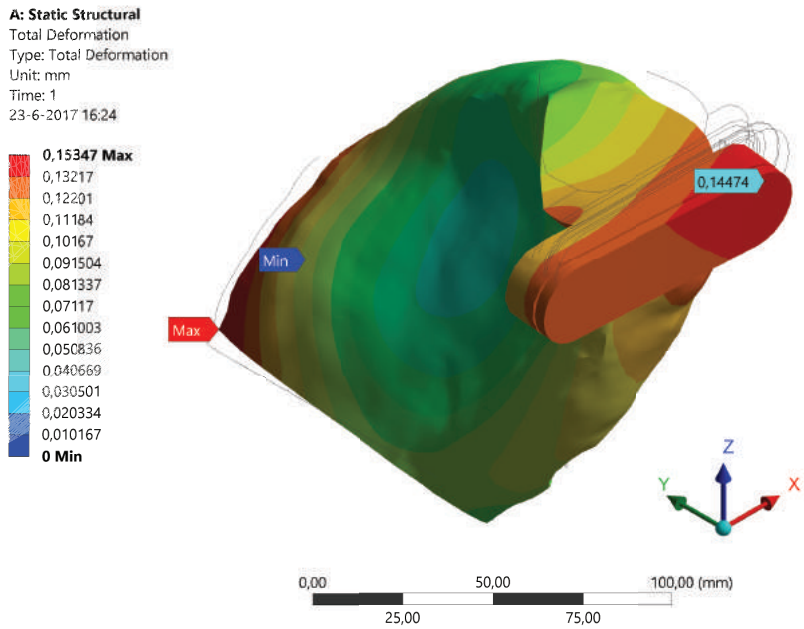




Validation

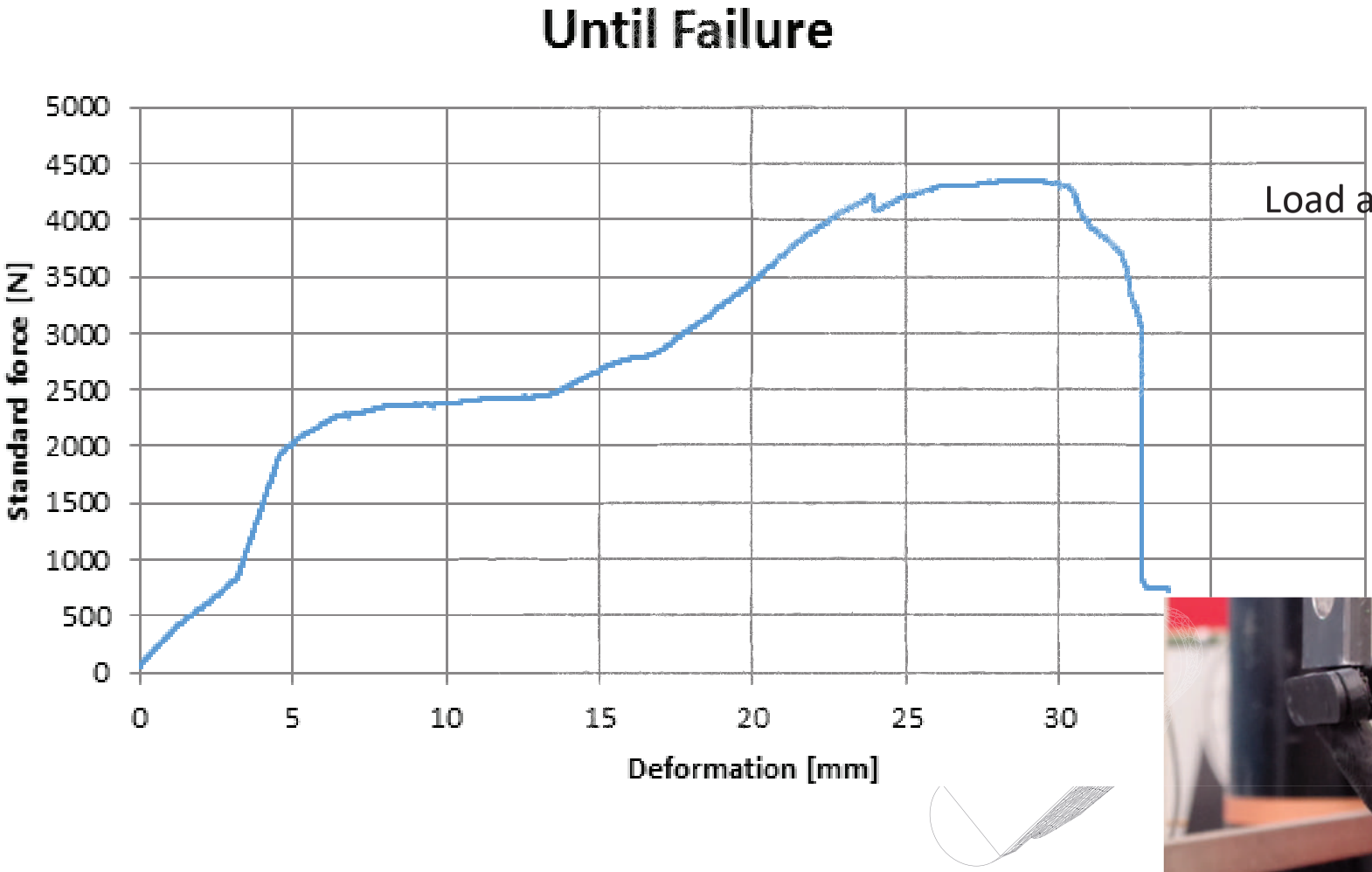
Test: Y - direction Stifness





Validation

Test: Y - direction Stifness

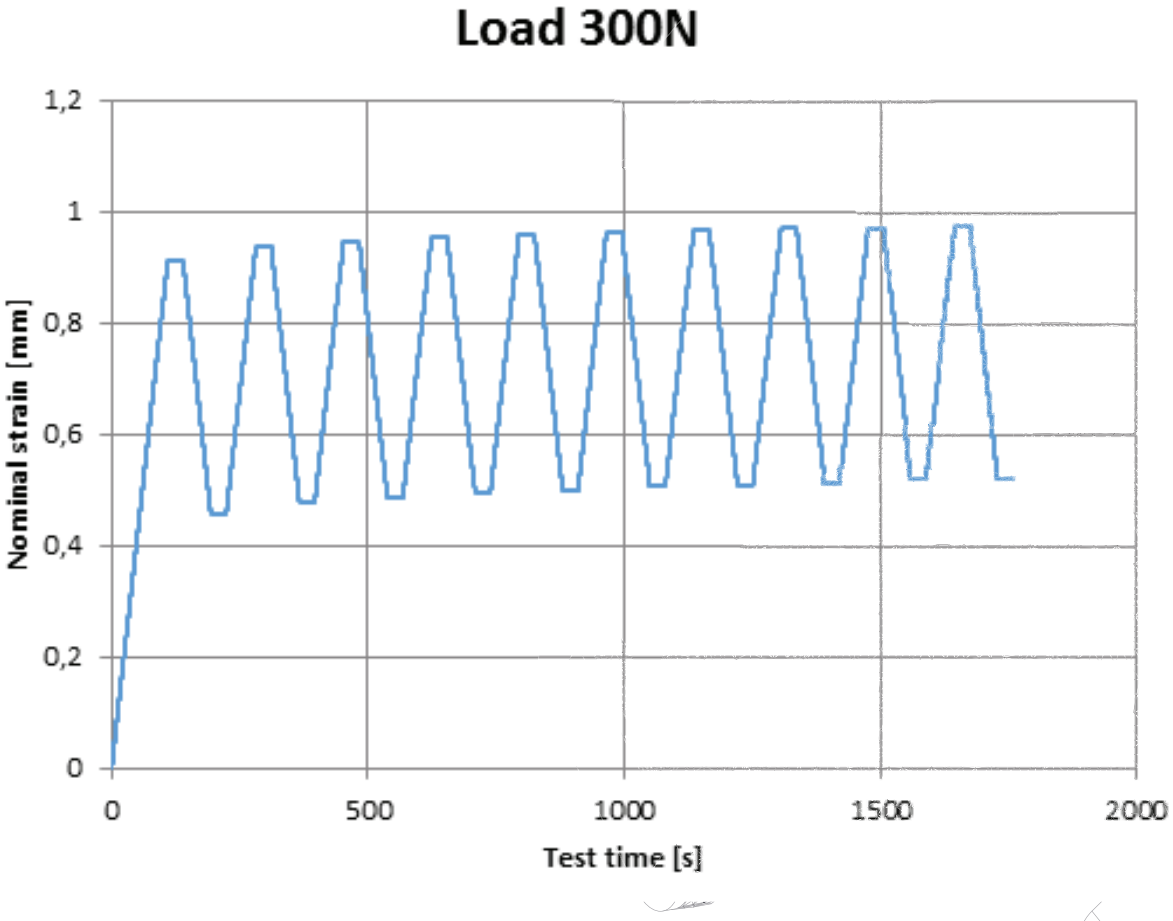


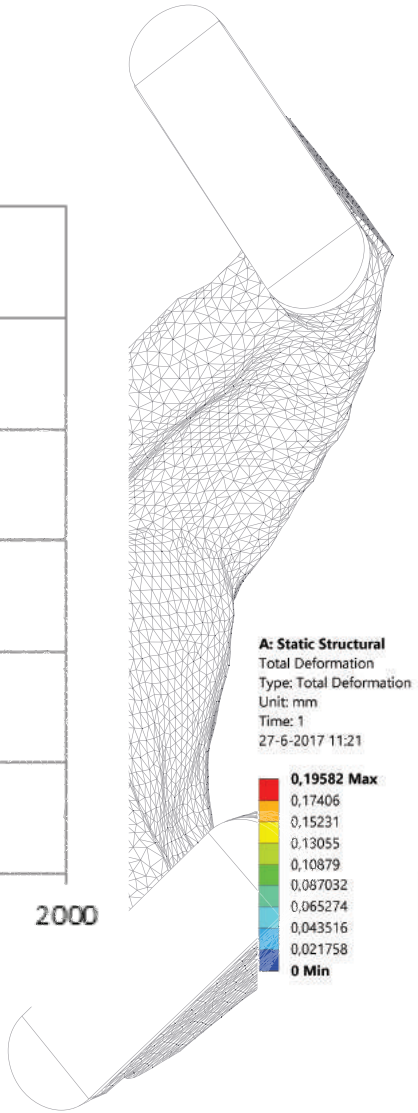
Load at failure 4309N

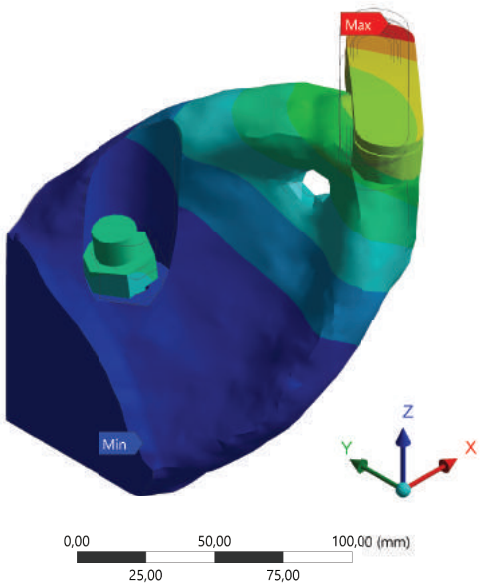


Validation

Test Z - direction

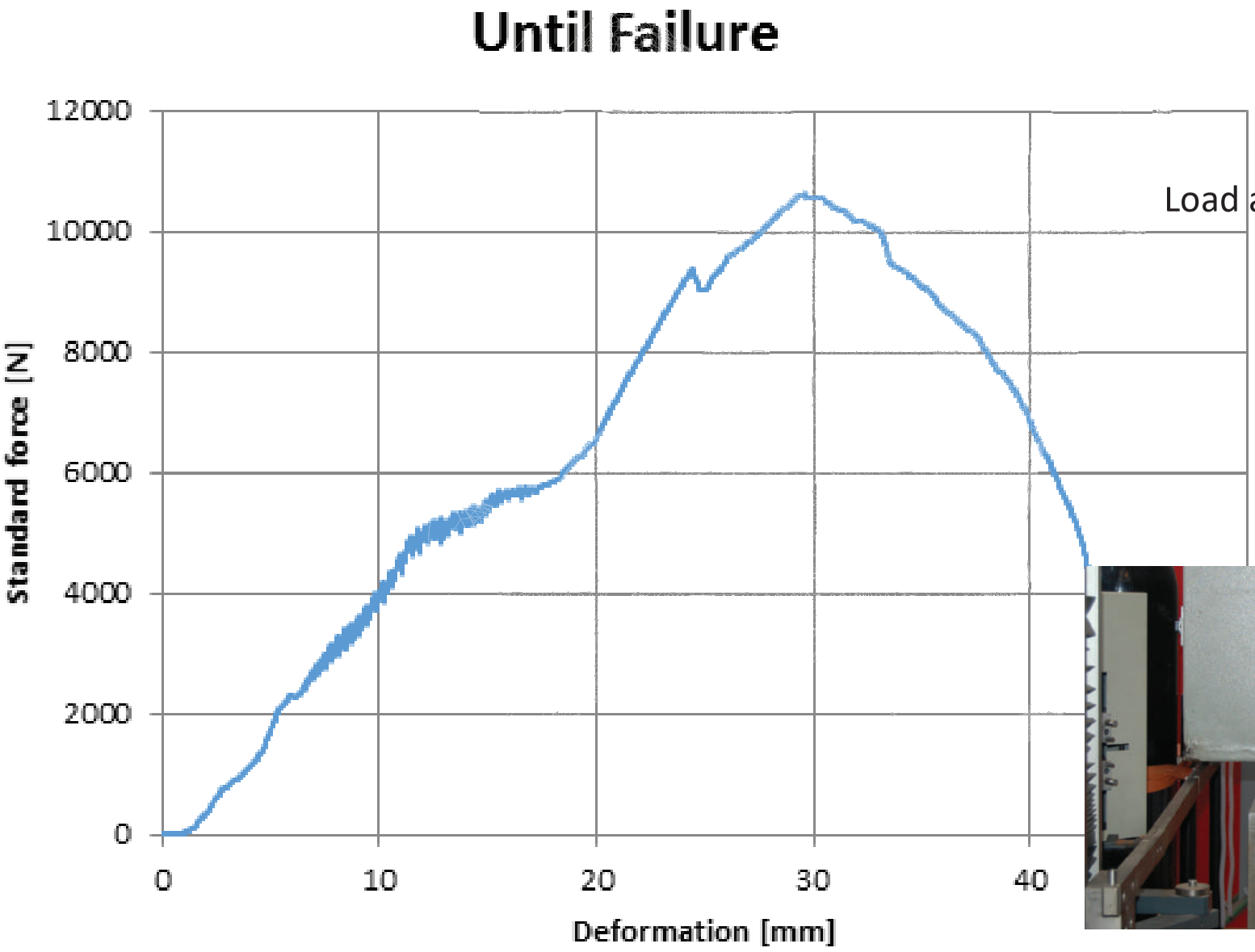




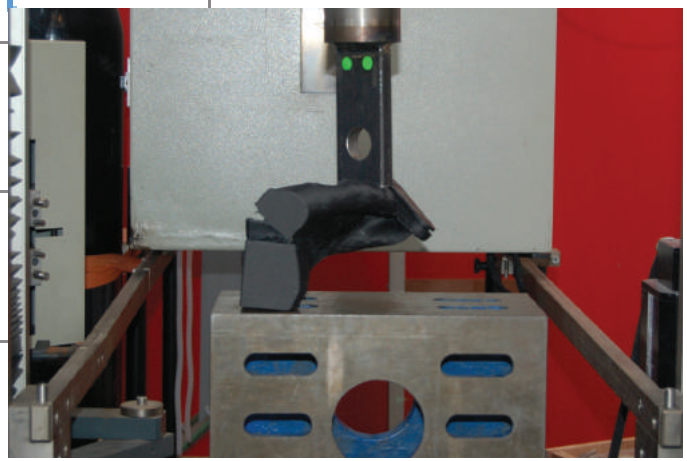


Validation

Test Z - direction

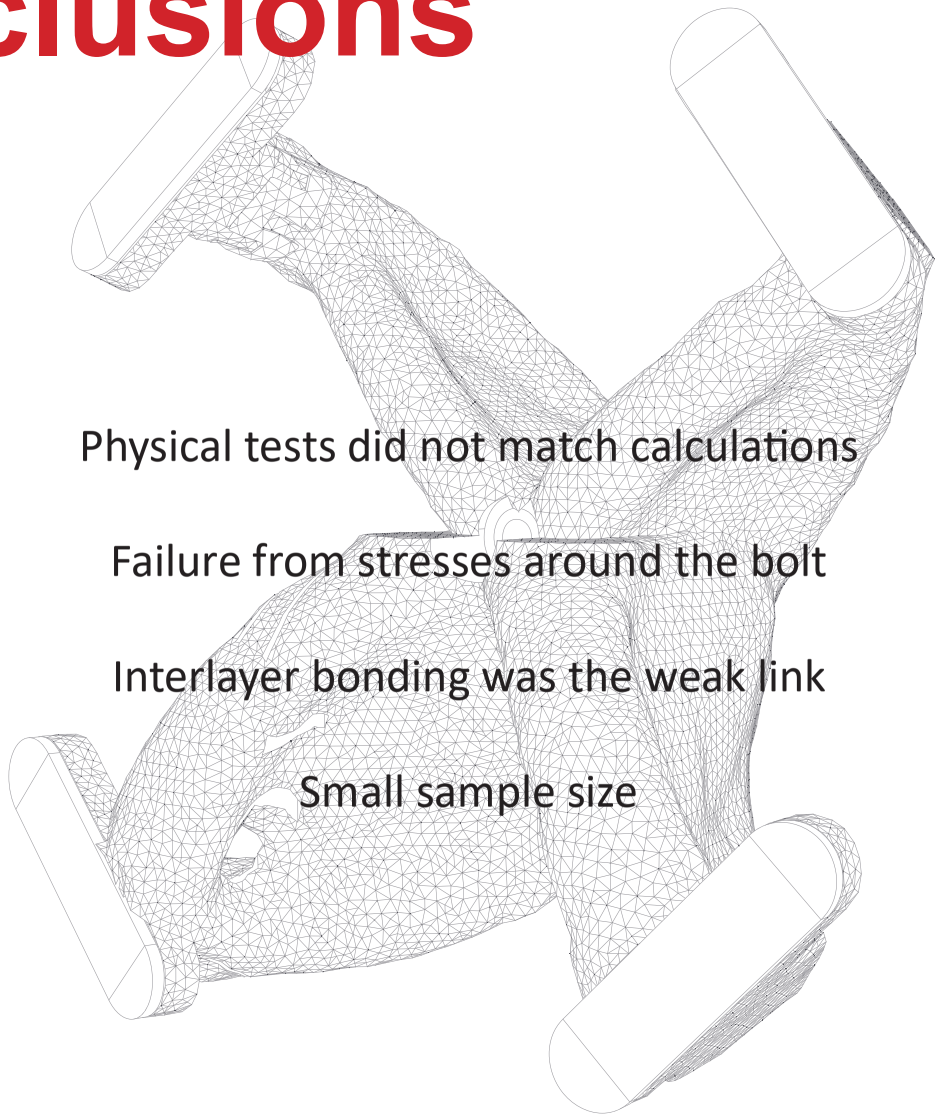


Load at failure 10624N



Validation

Test conclusions



Physical tests did not match calculations

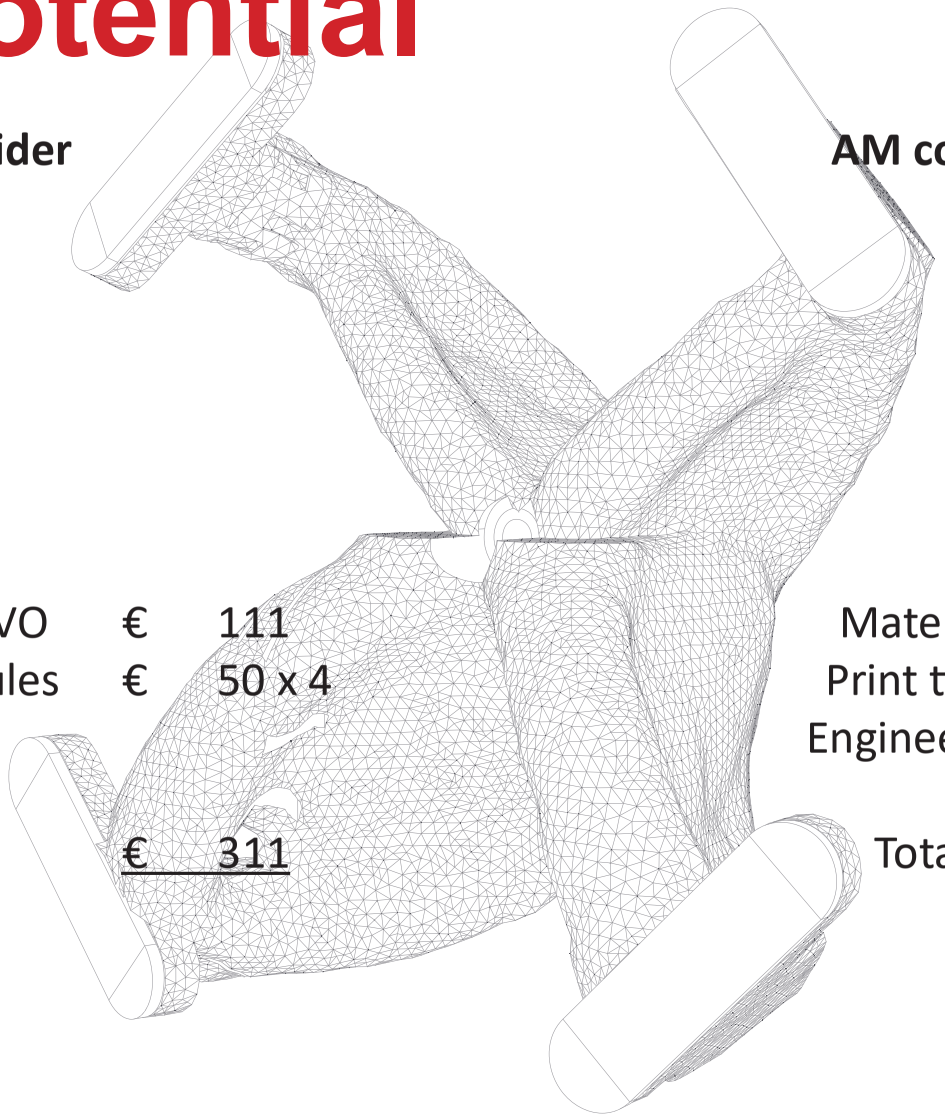
Failure from stresses around the bolt

Interlayer bonding was the weak link

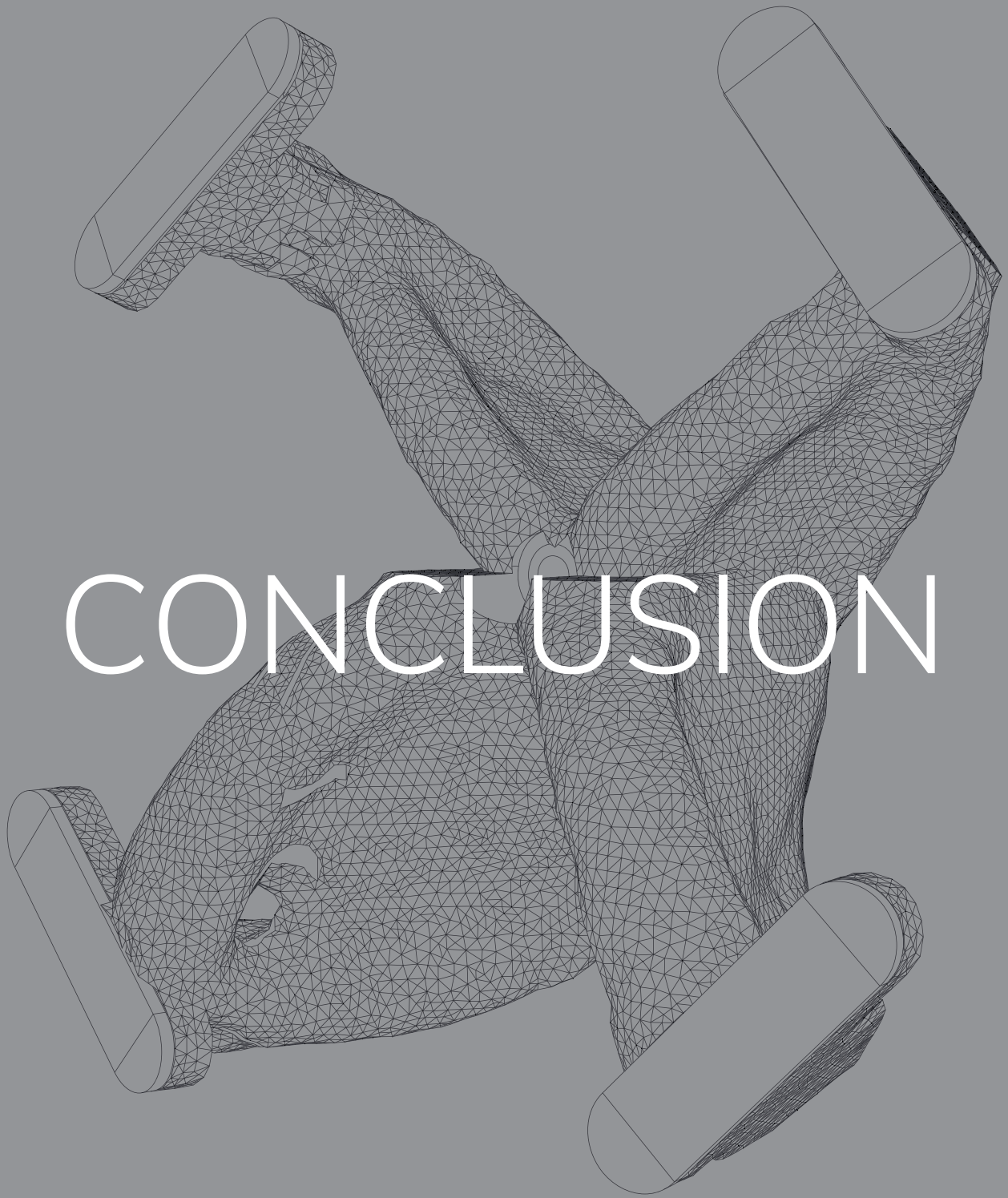
Small sample size

Validation

Market potential



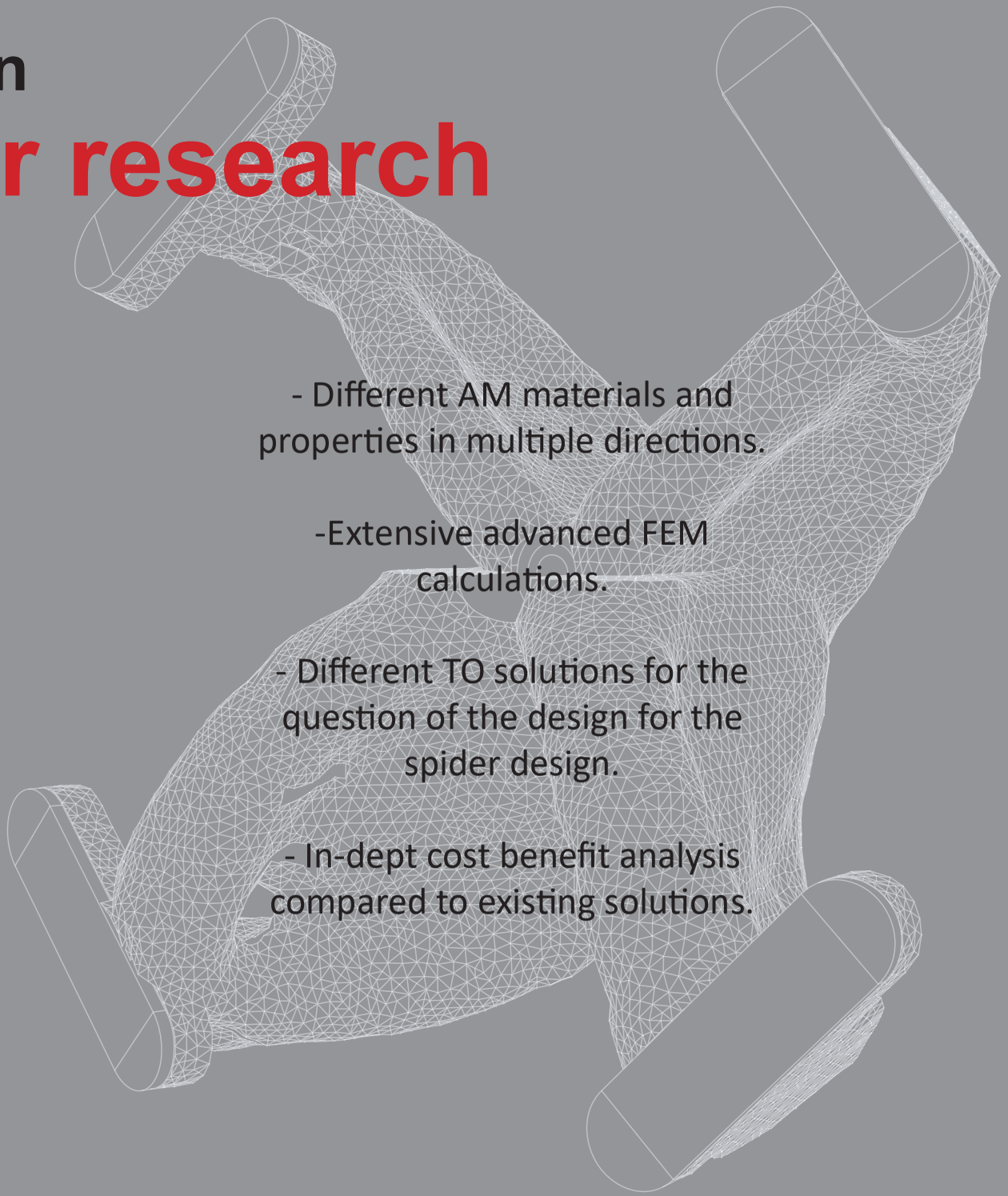
Steel spider			AM connection		
SADEV S 3001 EVO	€	111	Material	€	81,1 +13,5
R1006 TSSA Rotules	€	50 x 4	Print time	€	24
			Engineering	€	100*3
Total	€	311	Total	€	418,60



CONCLUSION

Conclusion

Further research



- Different AM materials and properties in multiple directions.

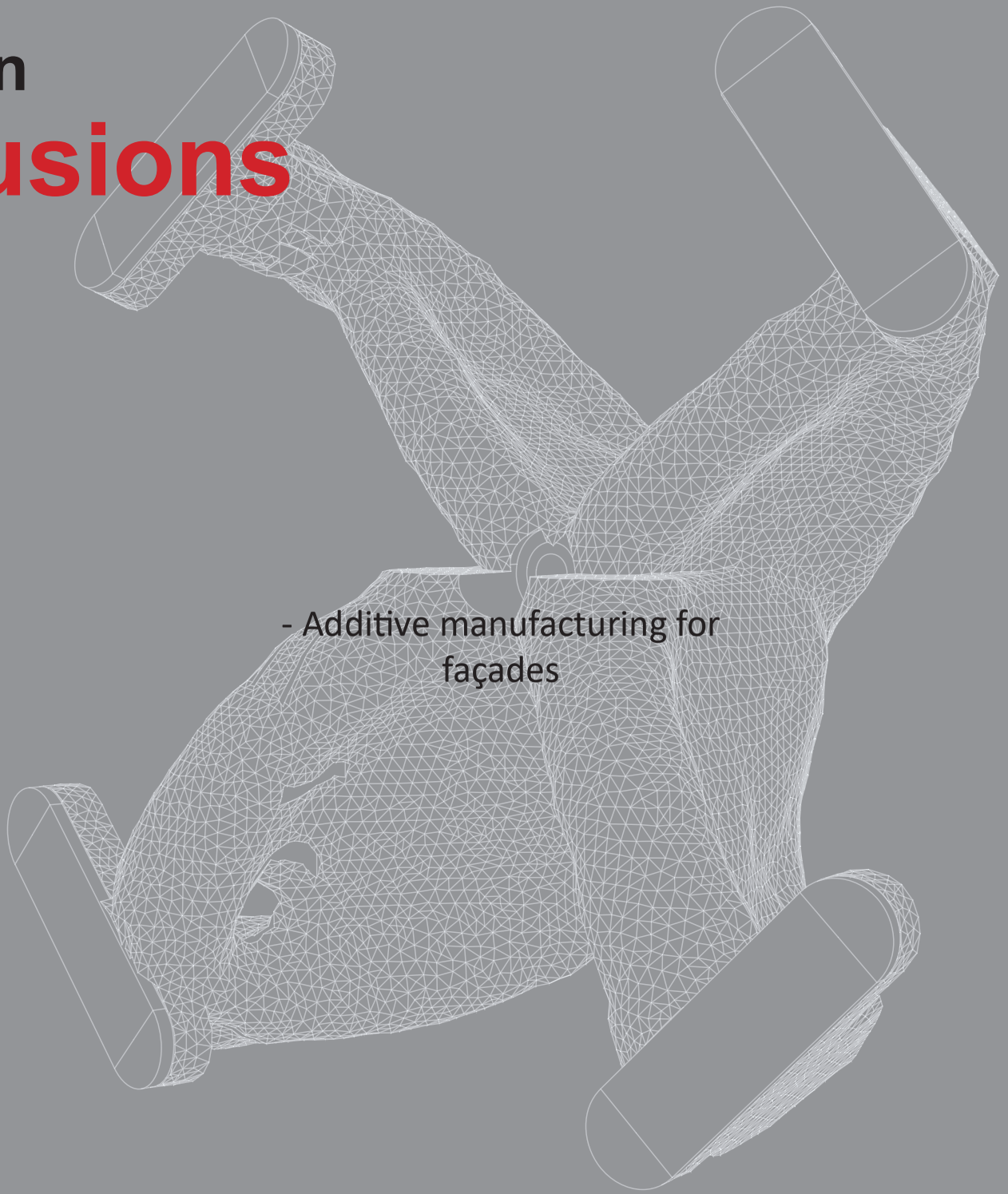
-Extensive advanced FEM calculations.

- Different TO solutions for the question of the design for the spider design.

- In-dept cost benefit analysis compared to existing solutions.

Conclusion

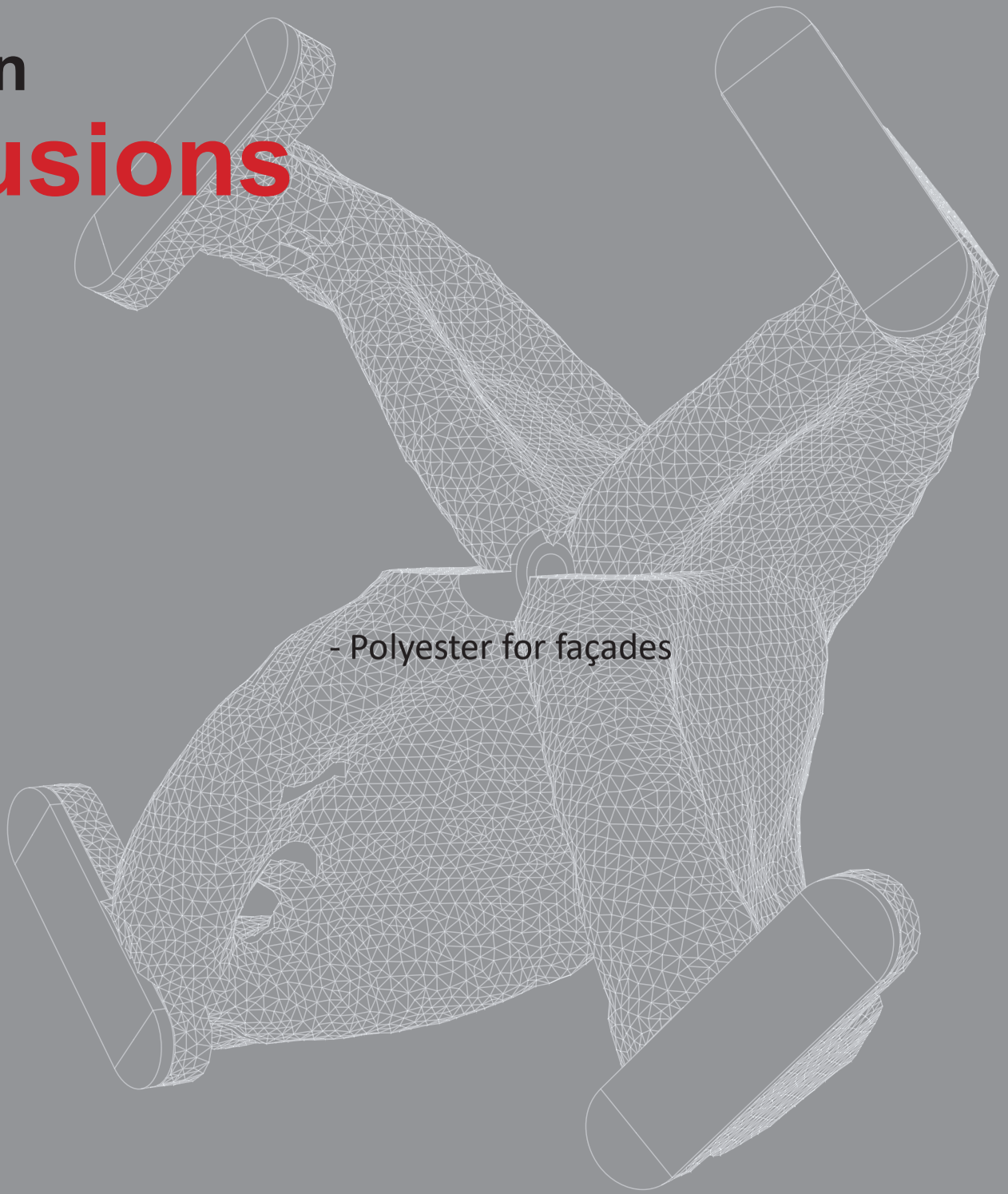
Conclusions



- Additive manufacturing for façades

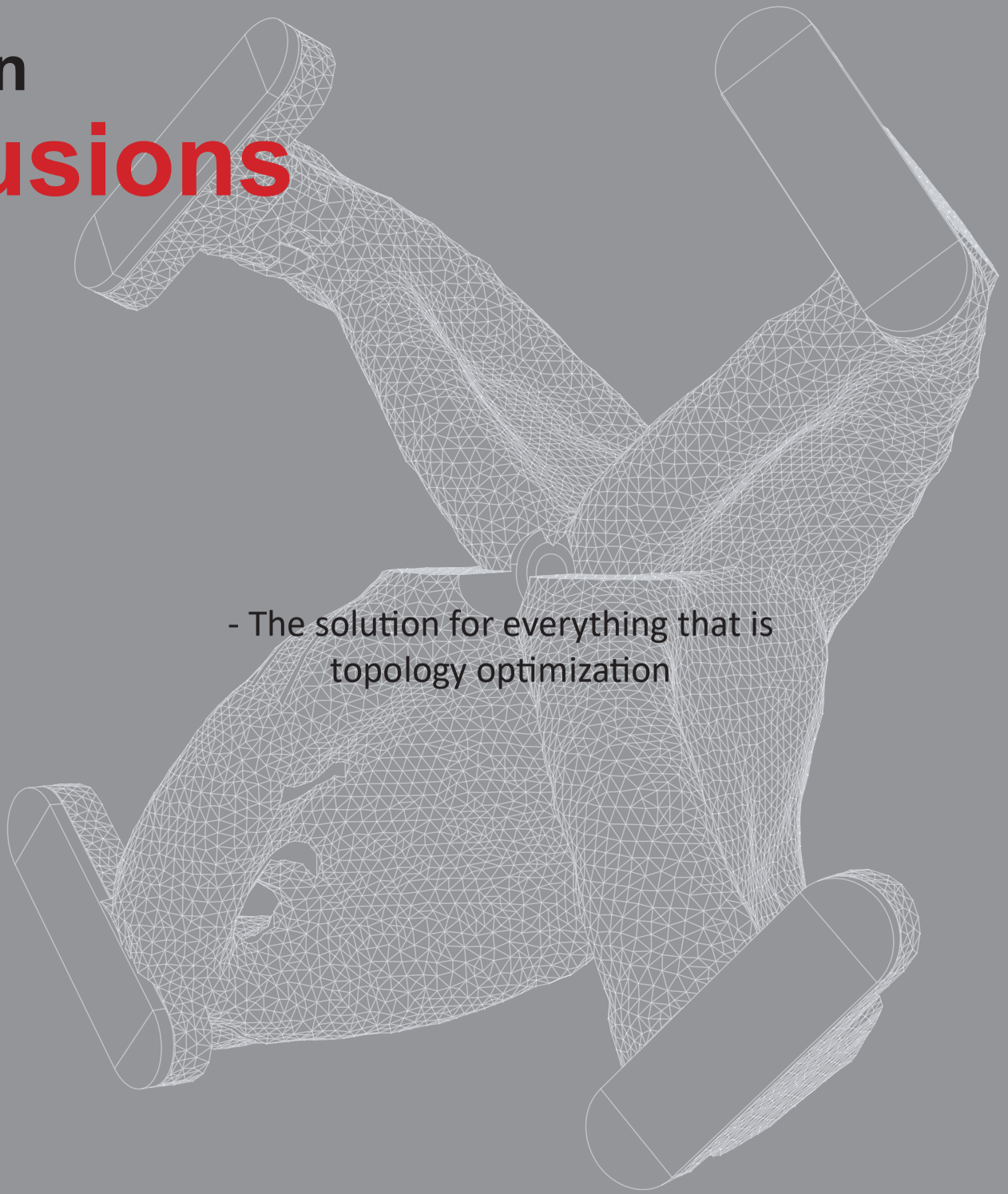
Conclusion

Conclusions

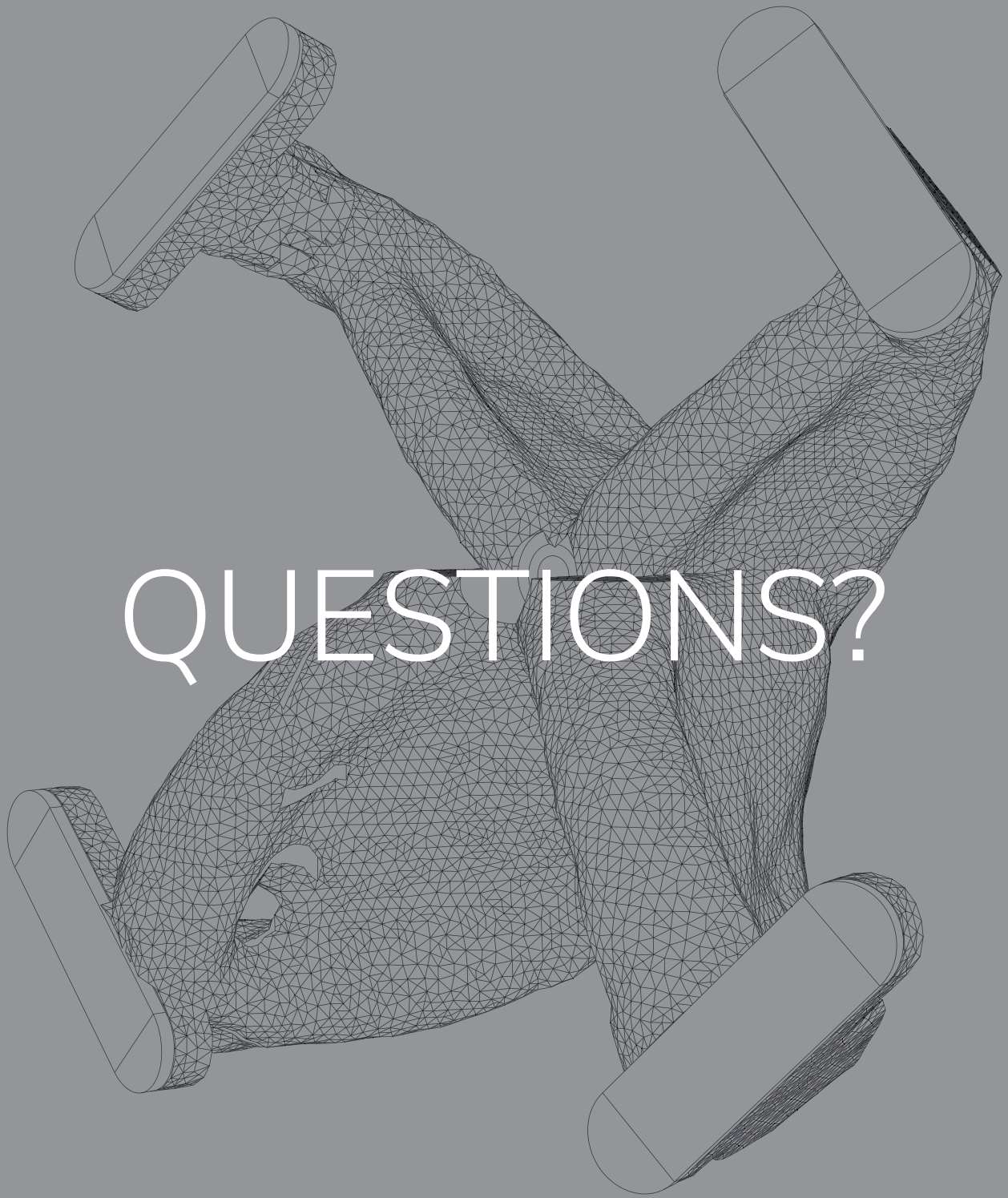


- Polyester for façades

Conclusions



- The solution for everything that is topology optimization


QUESTIONS?