CUBIC

NOVEL BIOBASED MATERIALS TO IMPROVE CIRCULARITY

Thermoforming of Biobased Thermoplastics

Hans Knudsen- COMFIL

Circular Bio-based Europe Joint Undertaking

Bio-based Industries Consortium

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Comfil® From chips to Part

- Outline
  - Comfil
  - Thermoforming of Biobased thermoplastics

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COMFIL®
Thermoplastic Composites

Comfil®

(Comfil®, Hybrid yarns, SR-Polymers yarn, thermoplastic composit materials and Bio4M®)

Comfil® From chips to Part

- COMFIL® is an innovation and production company, who develops for and supply materials to the thermoplastic fibre composite industry
- Started in 1991 within Trevira Neckelmann in Silkeborg (Belonged to Hoechst)
- MBO 1/10-2001
- Research, development and administration in Gjern, Denmark
- Production in Romania

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Comfil® today (incl. Comfil® Ro)

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Comfil® from chips to part

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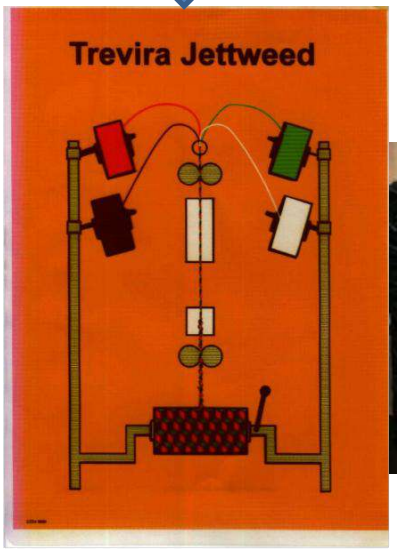

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Reinforcement fibres

- HT-PET (High tenacity polyester) Sr-PET
- Glass
- Aramid
- Carbon
- Basalt
- Other HT fibres

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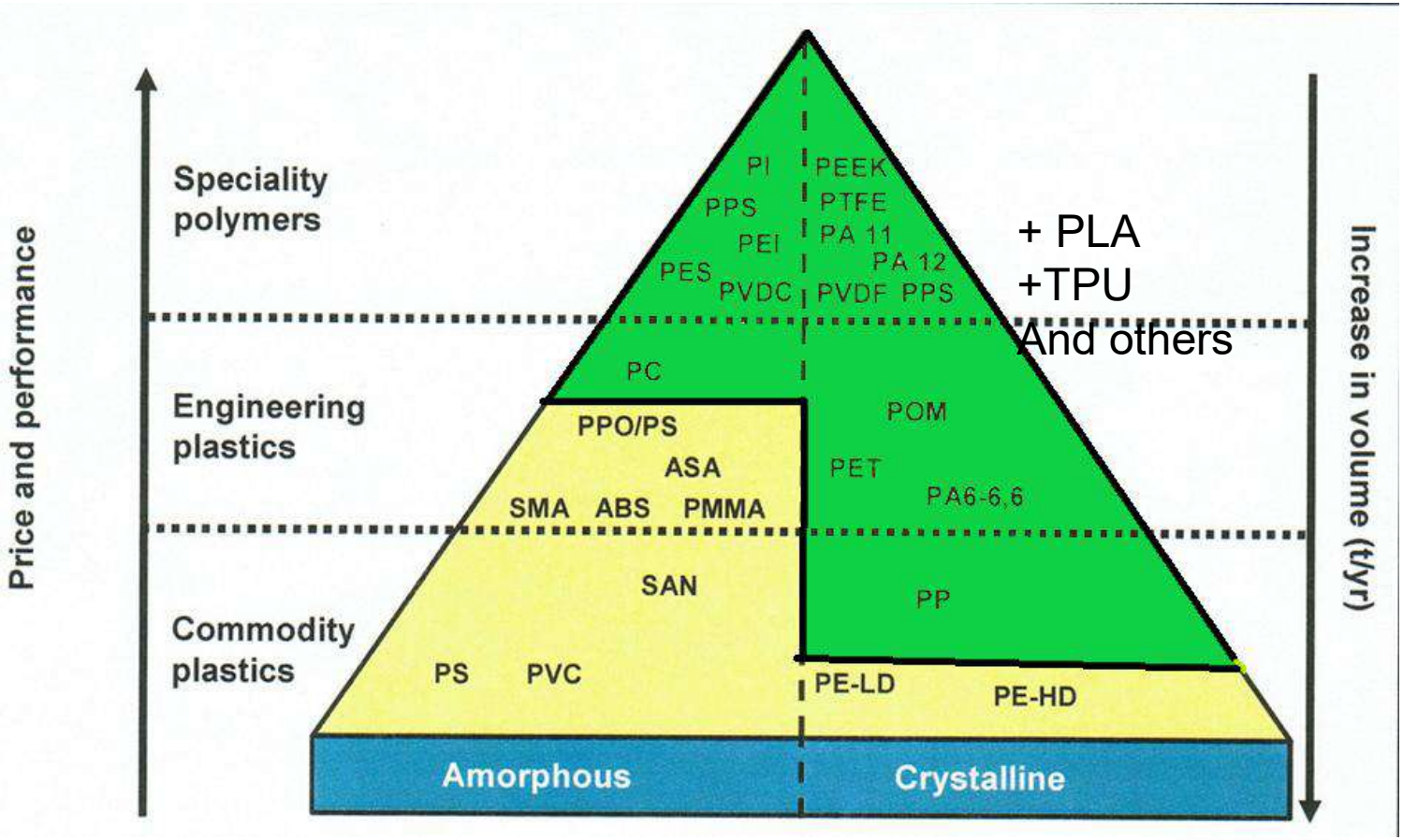
Thermoplastic overview



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SR-PET

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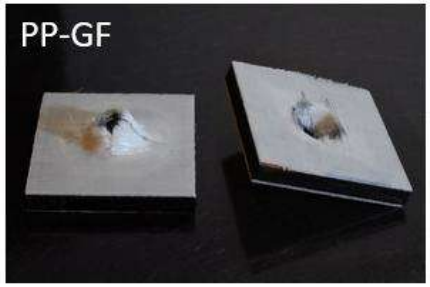
- SR-PET sandwich is a **MONO** material made 100% of PET.
- This sandwich can also be formed
- The sandwich has very good impact properties>120J



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COMPOSITE SANDWICH (multiple options)

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SR-PET and sandwich can also be overmoulded

Contact:
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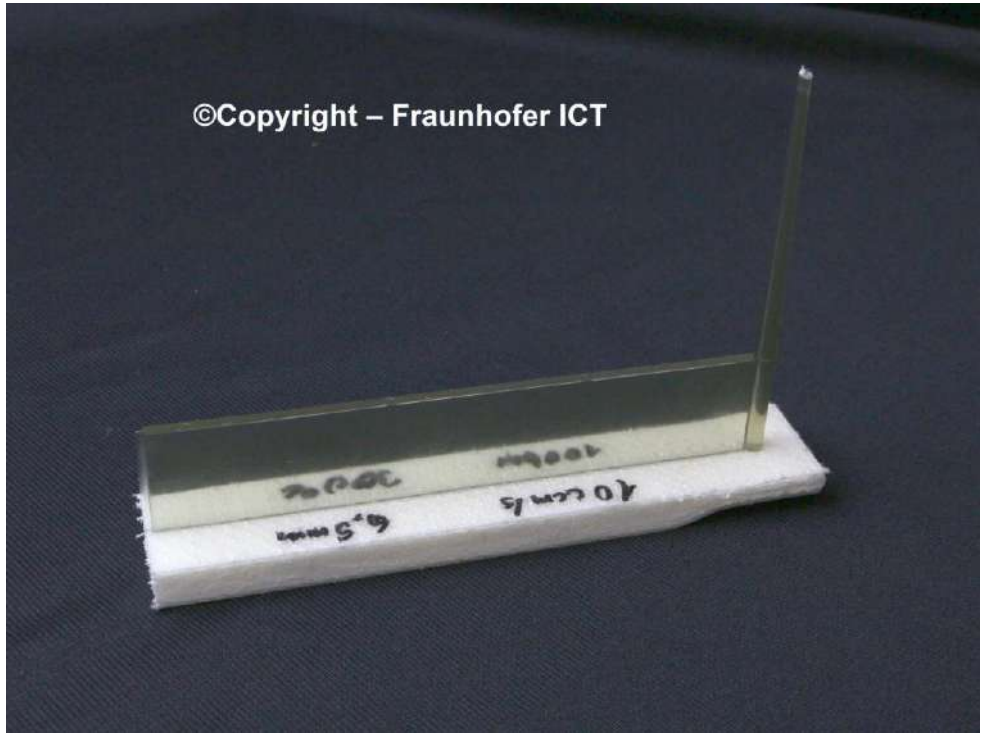

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SR-PET and sandwich can also be overmoulded with foils in PET

Examples of PET foils moulded direct on PET composites.
Keeping the material 100% PET.
=>
Easy to recycle

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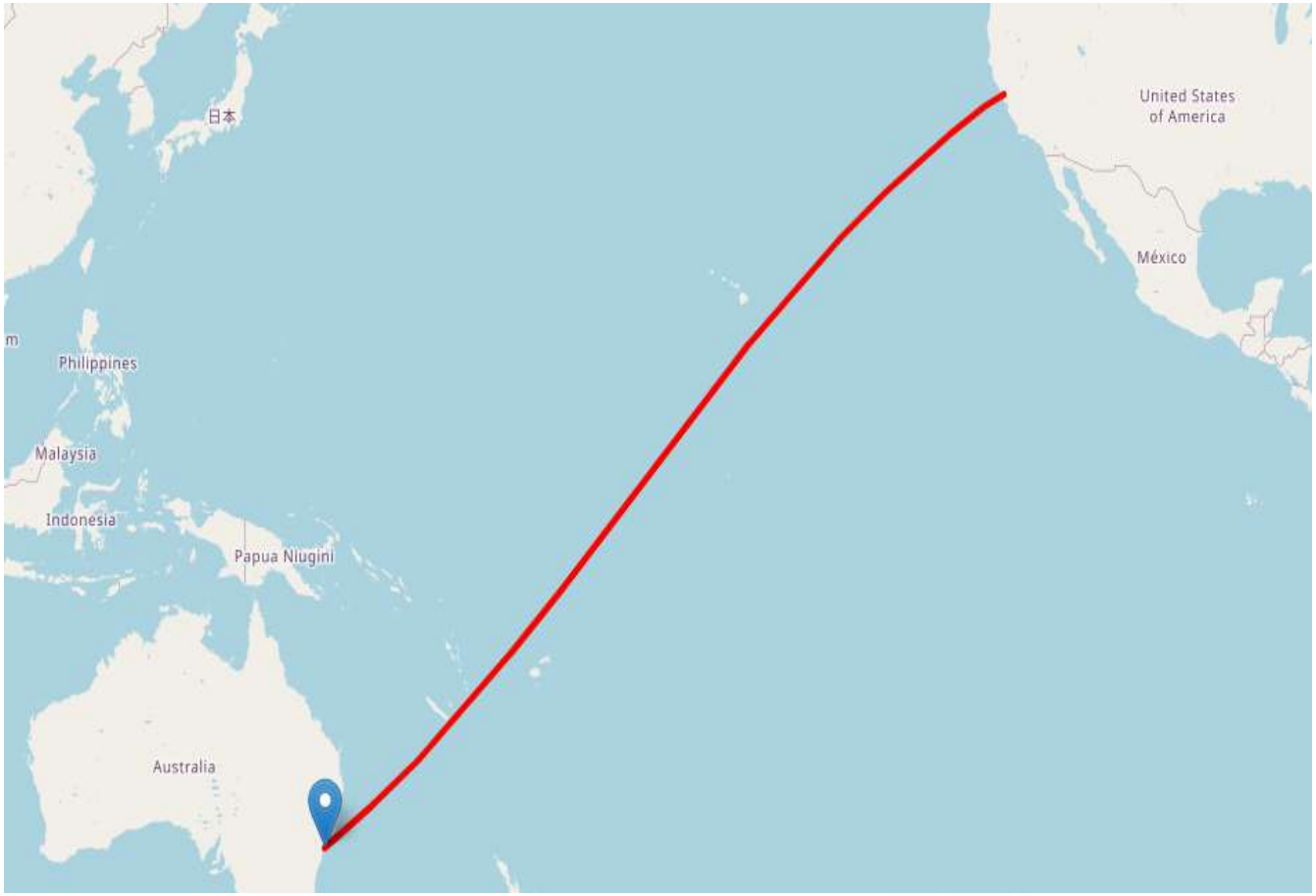
Construction made of SR-PET sandwich

- **Plastiki**

- A catamaran made from SR-PET Sandwich and SR-PET and 12.500 PET-bottles

- Year: 2010
- Time: 4 Monate



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Construction made of SR-PET sandwich

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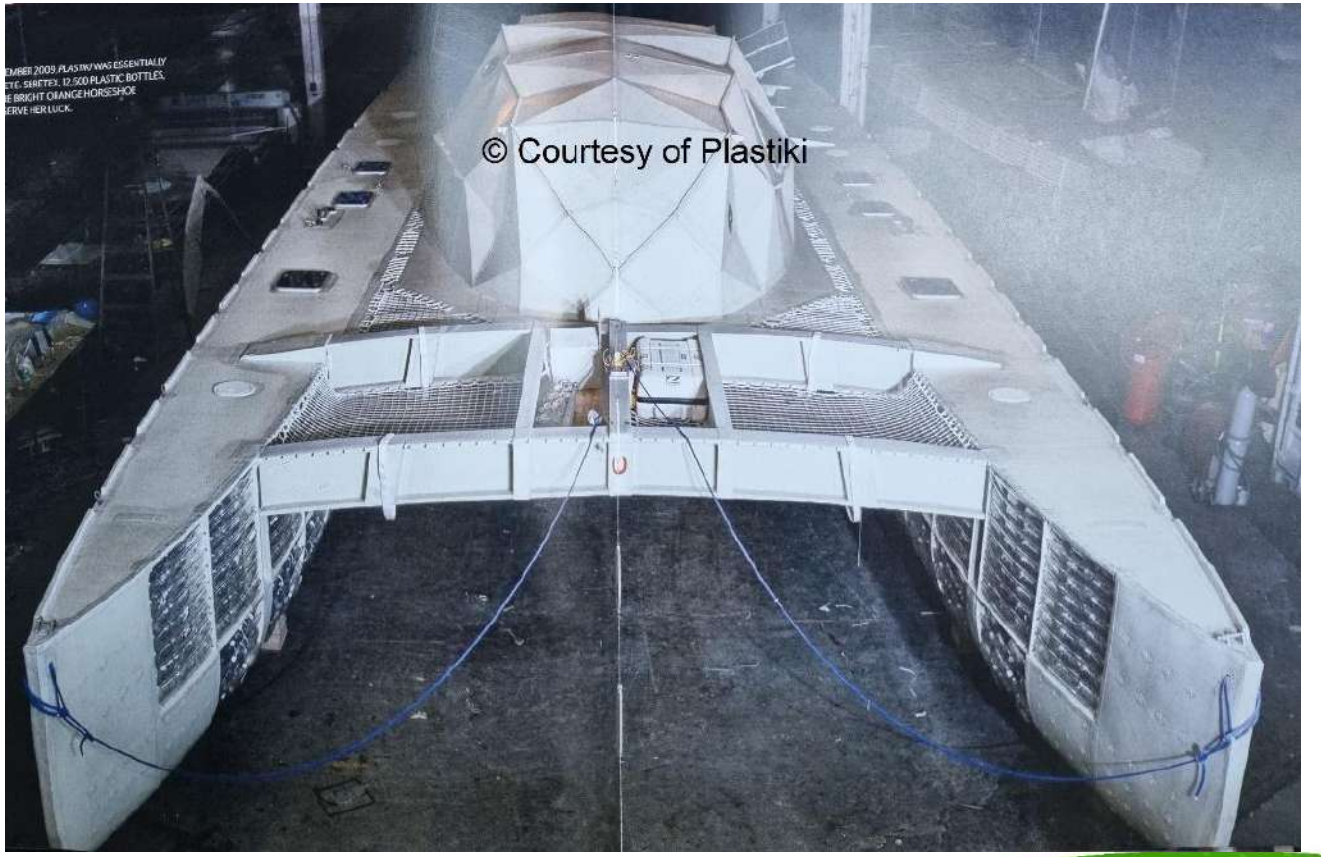
Size:

Length: 18m
Width: 7,2m
Weight: 12 tonnes

Fully made of SR-PET material and PET bottles



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SR-PET sandwich

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Outline

- Darcy's law
- Manufacturing processes
  - Vacuum consolidation
  - Press consolidation
- Consolidated part.

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Darcy's law

- The purpose is to melt the matrix and force it to wet out the filaments in the reinforcement fibres
- Use Darcy's law as a guide line. This is one way of writing it

$$T = \frac{c * \eta * x^2}{P}$$

- T = time
- C = constant for the system
- $\eta = permability\ of\ the\ system\ at\ temperature$
- X = average flow distance for the polymer (low with commingled yarns)
- P= pressure

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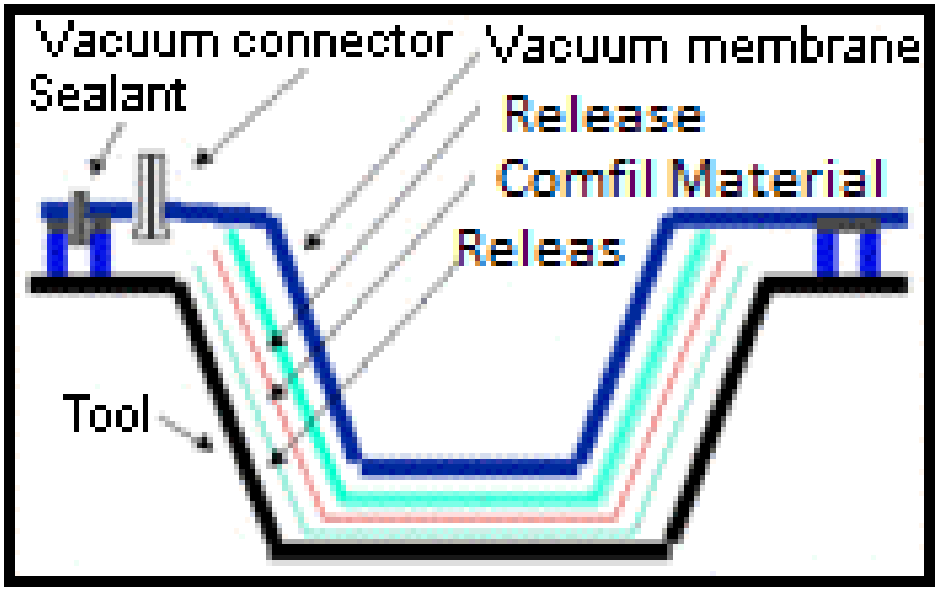
Vacuum consolidation

- Also called vacuum bag consolidation.
- Vacuum consolidation is a “simple”, flexible and “easy” process to consolidate a composite part in.
- Works with vacuum only and heat



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Vacuum consolidation

- Like baking a cake
- Recipe with layup of materials
- Time at temperature(s)
- Temperature measurements
  - Outer layers
  - In the middle of the laminate, very important (until correlation with system temperature is established)
- Drying.

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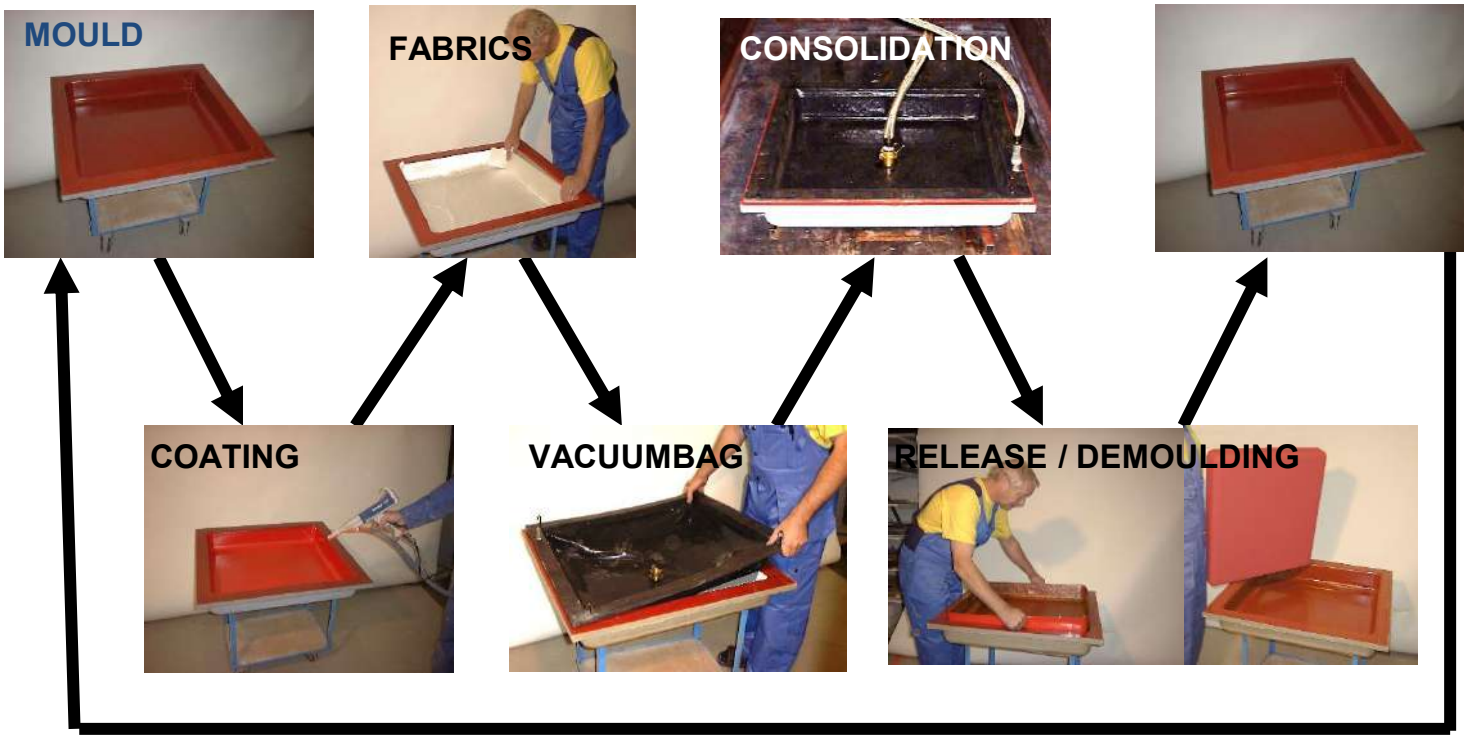
Process Overview



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Vacuum consolidation Recipe example

Konsolideret plade fra VVV2

Plade nr: Demo-1 | Dato: 24-03-2026 | Ansvarlig: XXX | Kunde:

Plade dimensioner: længde (cm): 76 | bredde (cm): 76

Stof nr.	beskrivelse	Stof Type	Produktnr.	arealvægt g/m2	forstærkningsfiber	F vægt %:	F densitet g/cm3	Matrix	M vægt%	M densitet g/cm3	Stof densitet g/cm3	Lag tykkelse mm	antal lag	Tykkelse mm	Vinkel grader
1				600	LCP	54	1,4	PA6	46	1,14	1,27	0,47	2	0,95	0
2				1004	GLAS	71,4	2,48	PA6	28,6	1,14	1,86	0,54	36	19,47	0
3				600	LCP	54	1,4	PA6	46	1,14	1,27	0,47	2	0,95	90
4				1000	ML1-20	100	1		0	1,14	1,00	1,00	1	1,00	
5				35325		100	8		0	1	8,00	4,50	1	4,50	

Total tykkelse: 26,87 mm

Total kvadratmeter vægt: 74,9 kg/m2

Oplægnings beskrivelse:

Stof rækkefølge (start fra bunden): 5+2*2+(1+3)*2+2*34

release folie bund		plade bund		mellem plade		plade top		release folie top		Vakuum dug
Tæt teflon væv		Stål med T+P teflon		nej		Stål med T+P teflon		Tæt teflon væv		Teflon 100 µm

Kørsel:

1. Olie temp C	1. plade temp C	1. Tid: min
160	140	150

2. Olie temp C	2. Plade temp C	2. Tid min
290	290	90

3. Olie temp C	3. plade temp C	3. tid min
227	227	90

Vakuum %
Fuld

4. Olie temp C	4. plade temp C	4. Tid: min
15	60	0

5. Olie temp C	5. plade temp C	5. Tid: min

5. Olie temp C	5. plade temp C	5. Tid: min

Bemærkninger:

Plade udskæres til 76*76 cm

Det er vigtigt at midt temperaturen når samme temperatur som top og bundplade!!!
inden temperatur 4 sættes i gang.

Lufttryk:

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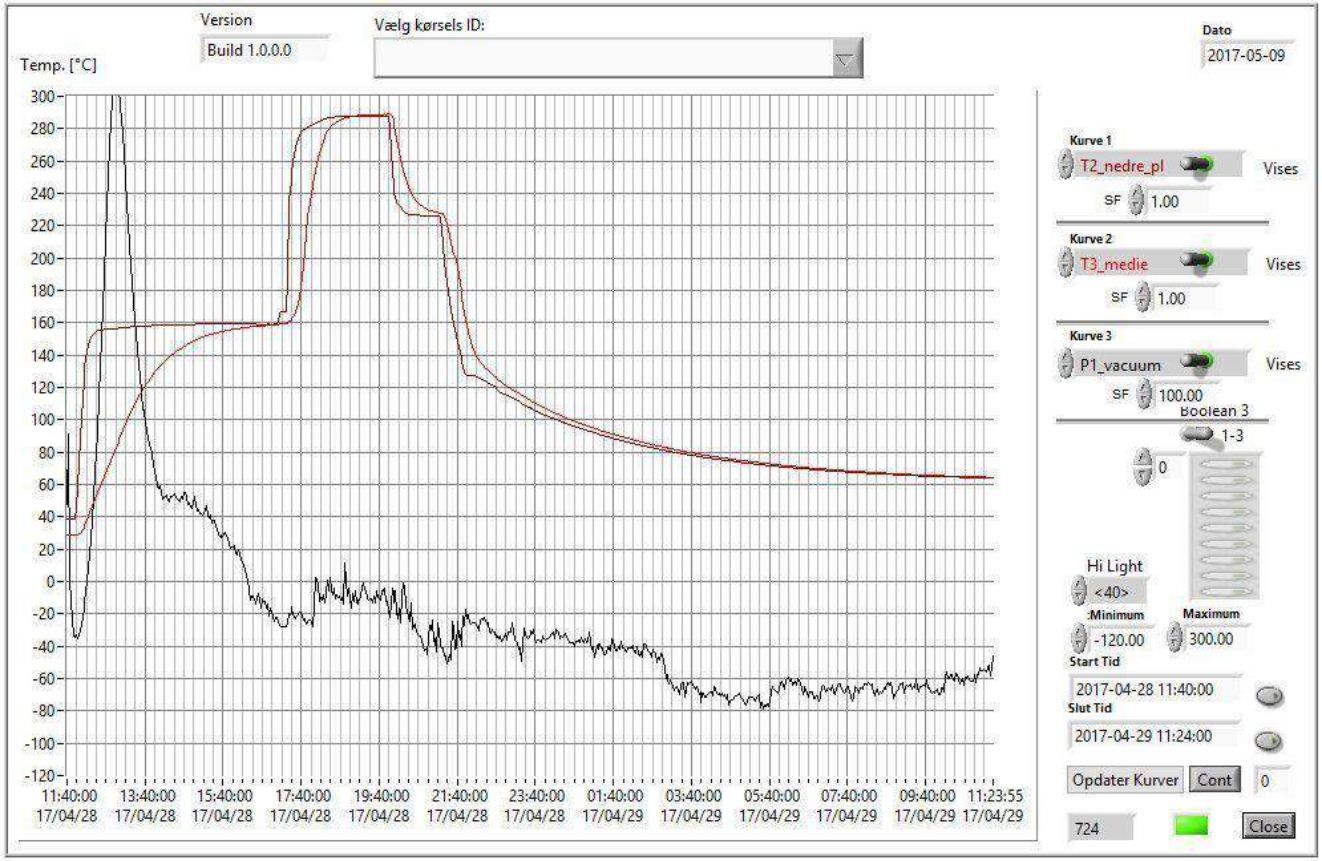
Vacuum consolidation



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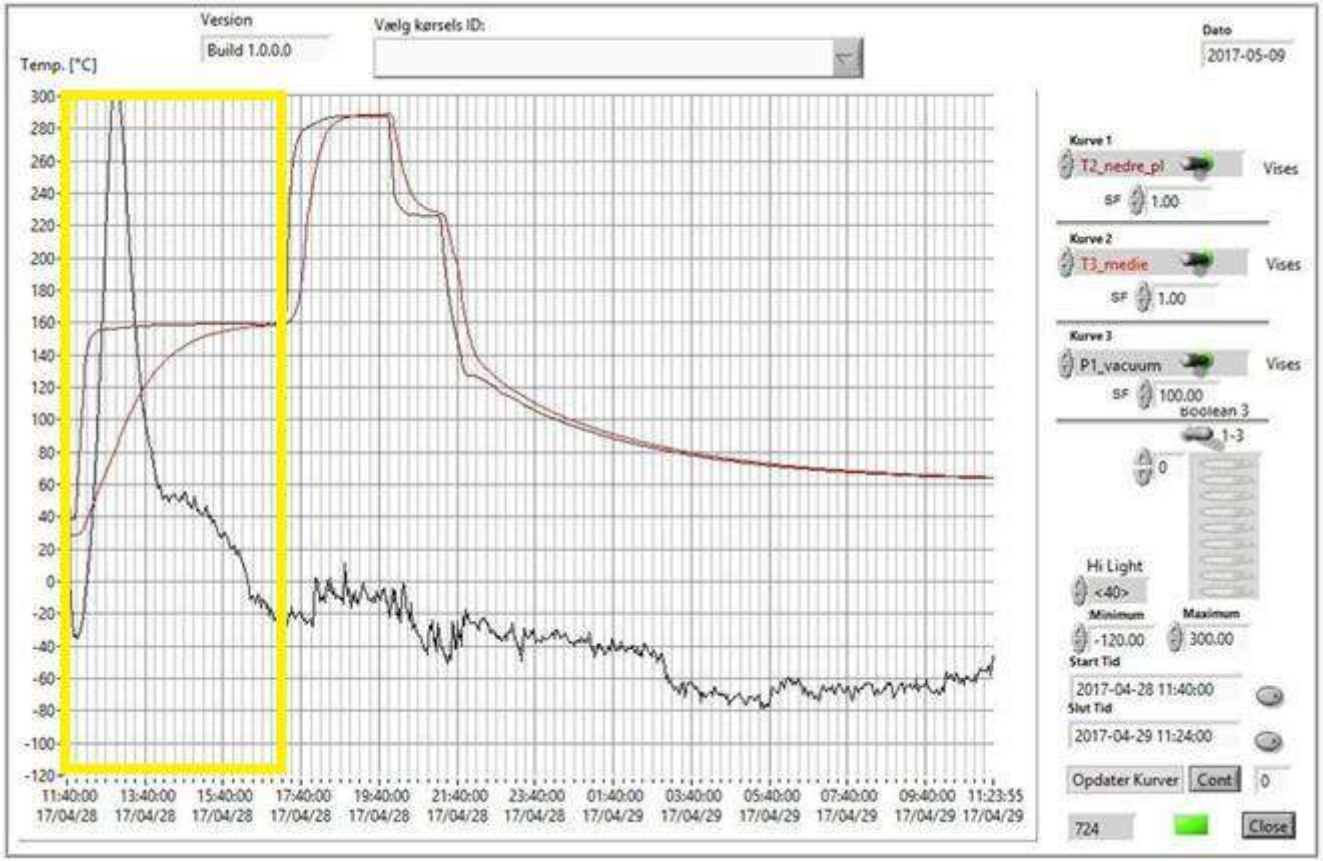
Vacuum consolidation



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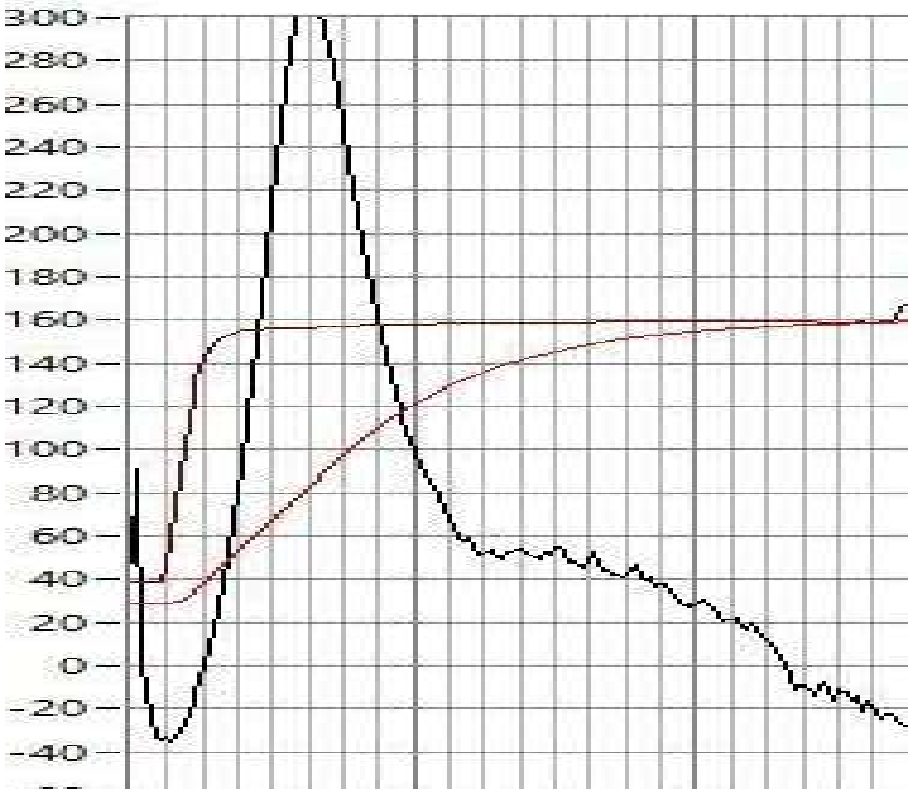
Vacuum consolidation - drying



Here the materials are dried if necessary.

Black curve is the vacuum level (*100)

Lower red curve is temperature in middle of laminate

Top red curve is temperature on heating plate

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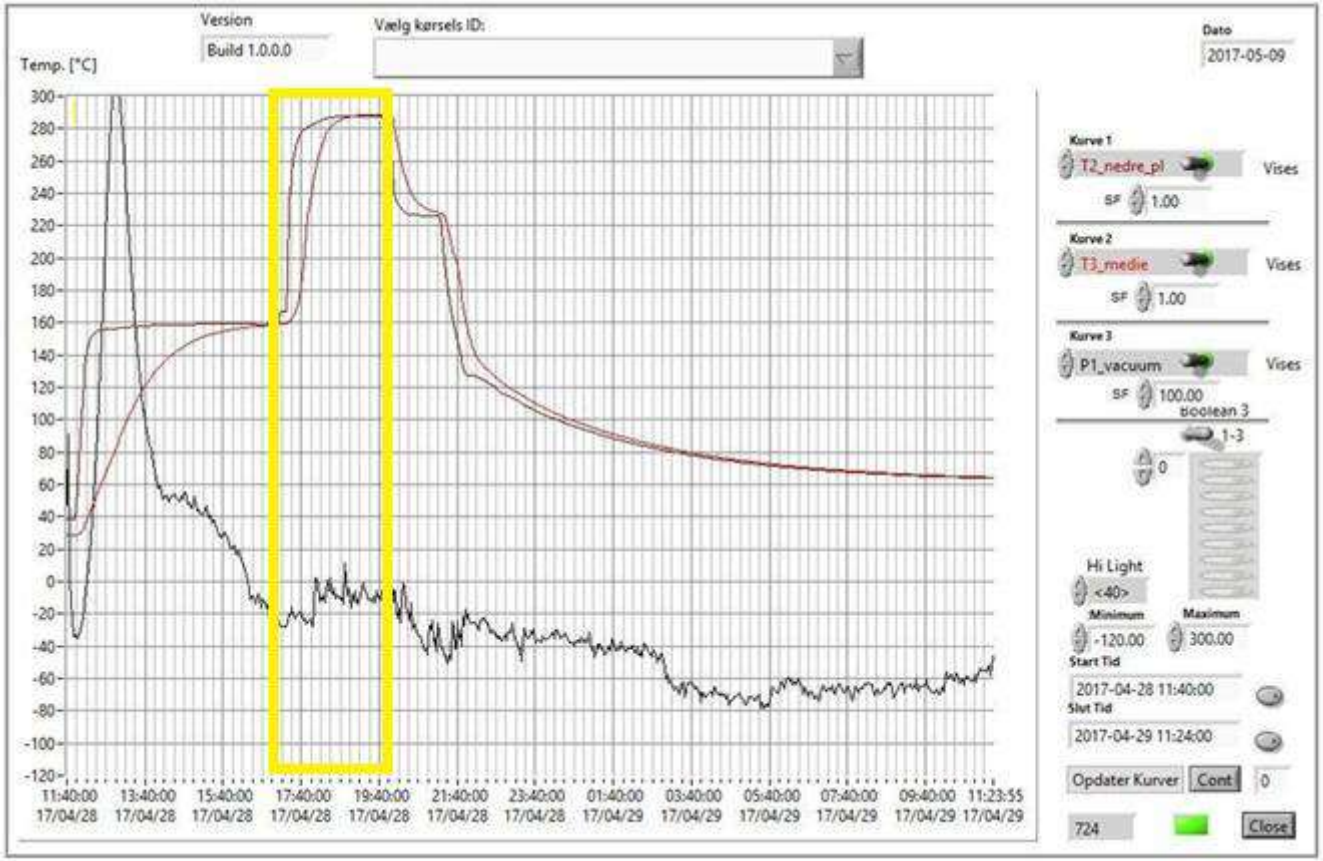
Vacuum consolidation



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Vacuum consolidation – wetting out fibre

Melting the matrix for wetting out the fibres.

Black curve is the vacuum level (*100)

Lower red curve is temperature in middle of laminate

Top red curve is temperature on heating plate

Here the middle temperature is reached app. 45 min after the outer layer temperature.

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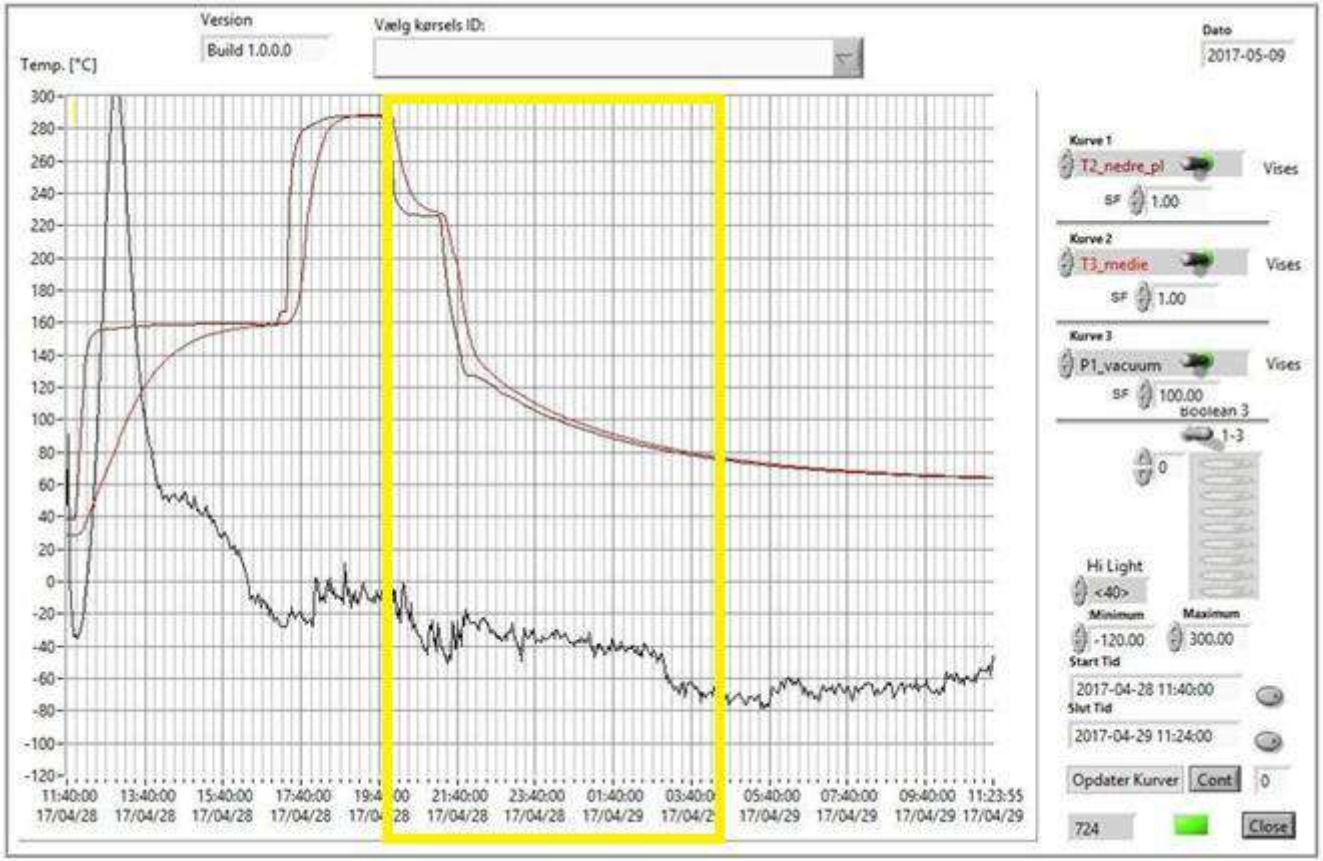
Vacuum consolidation



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Vacuum consolidation – cooling down

This is in many cases the overlooked part.

a) crystallinity is determined by the time in the crystallisation zone- **polymer dependent**
b) When having thicker laminates, it's a good idea to run slow over melting temperature.

Black curve is the vacuum level (*100)

Top red curve is temperature in middle of the laminate

lower red curve is temperature on heating plate

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Vacuum consolidation – System

System has a max tempera-ture of 350°C

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Vacuum consolidation – overview

Pro:

Easy process

Flexible

Can be low cost

For lower numbers (<10.000)

Con:

Slow (but the process itself can be down to 5min for 2mm laminate)

Not easy to automize

The Plastiki boat was manufacture this way!

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Press consolidation

The purpose is to melt the matrix and force it to wet out the filaments in the reinforcement like in the vacuum consolidation.

There are many different systems for this.

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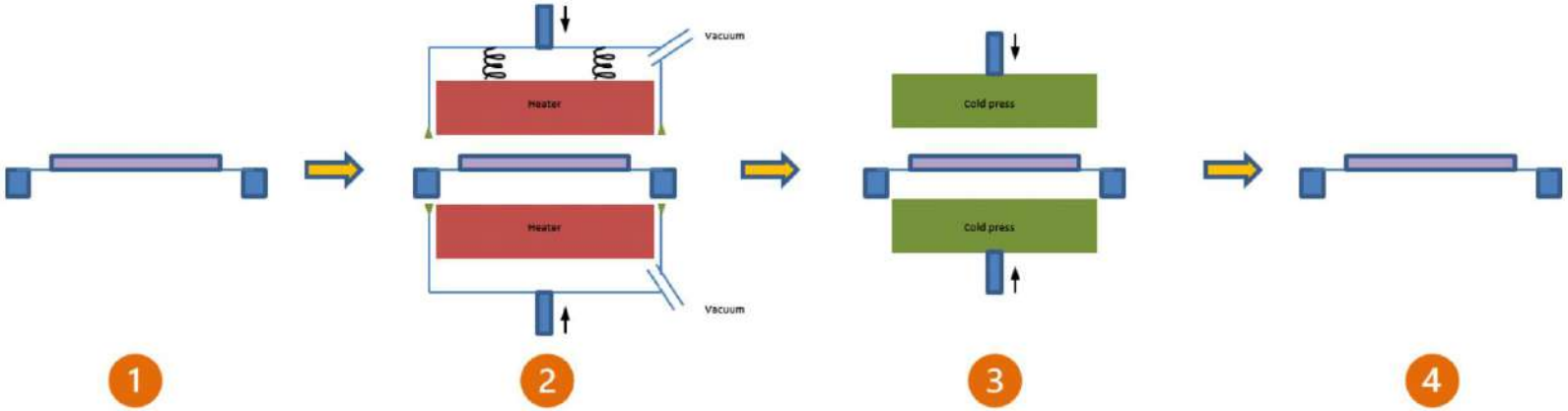
Press consolidation

We have choosen a 4 step system



In all steps you can choose the time in the step freely.

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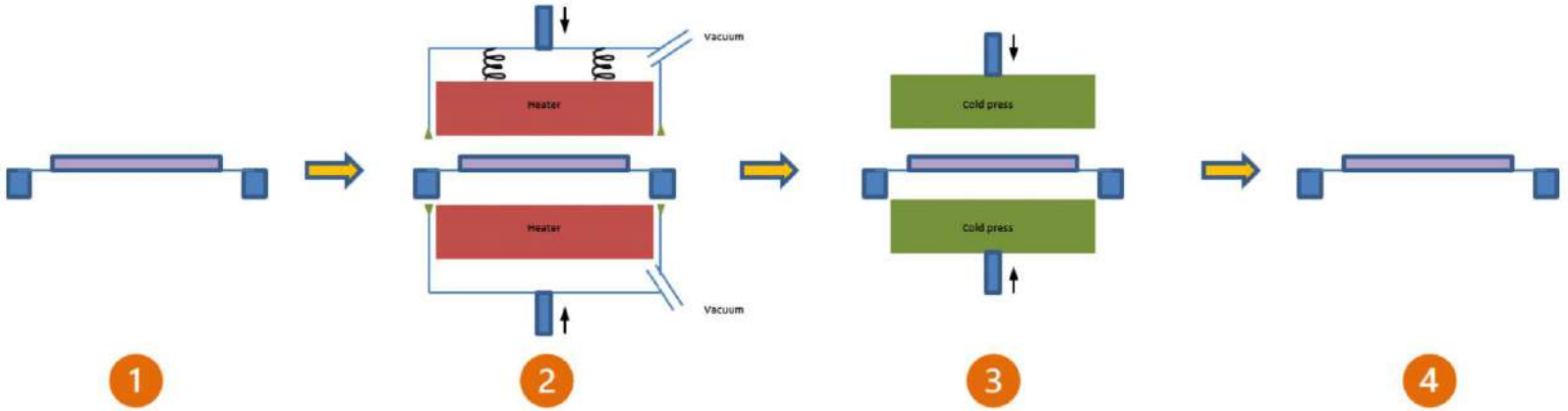
Press consolidation

First step 1 the layup on the transport unit



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Press consolidation

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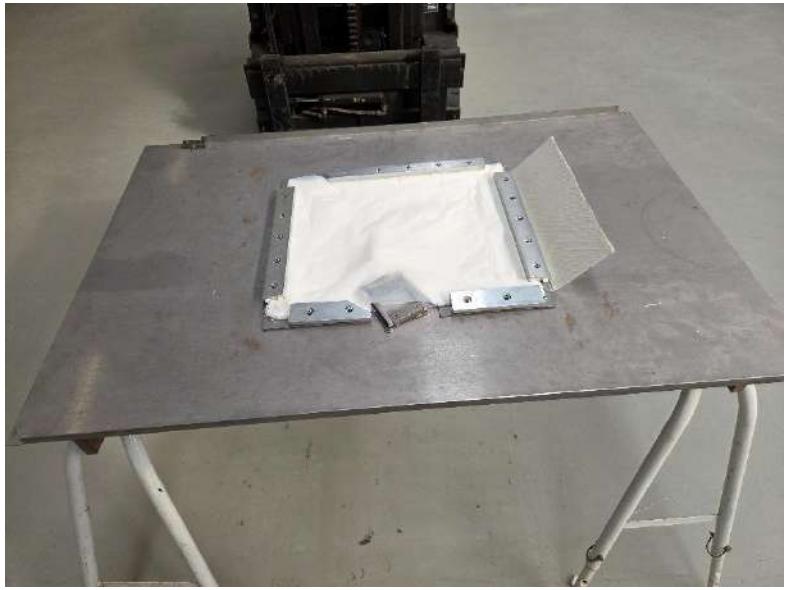

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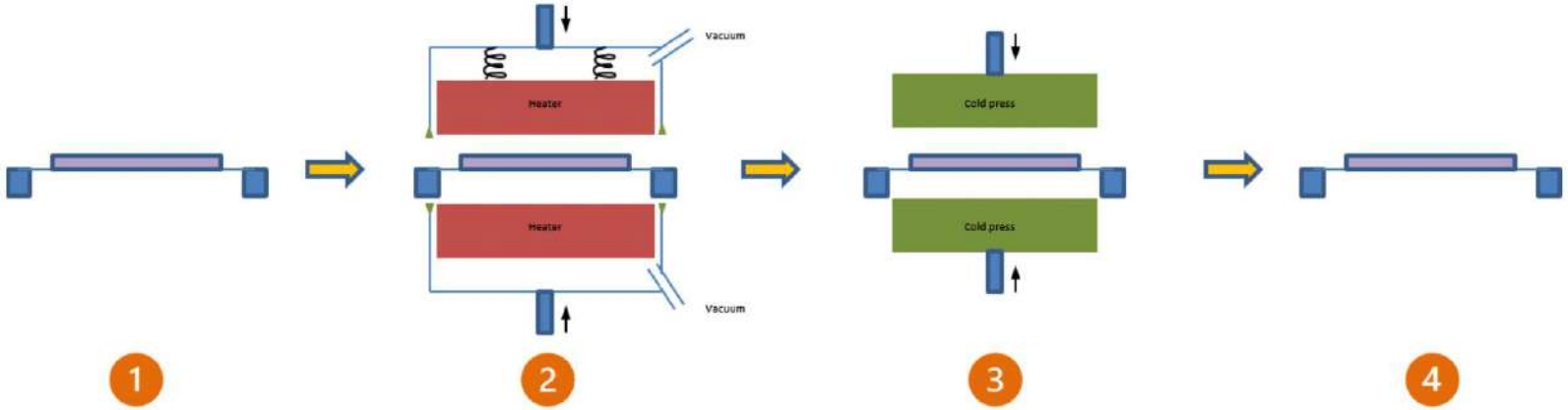
Press consolidation

Second step 2 is the heating/wetting out



Here the parameters are:

a) temperature

b) pressure on layup

c) degree (percent) of vacuum

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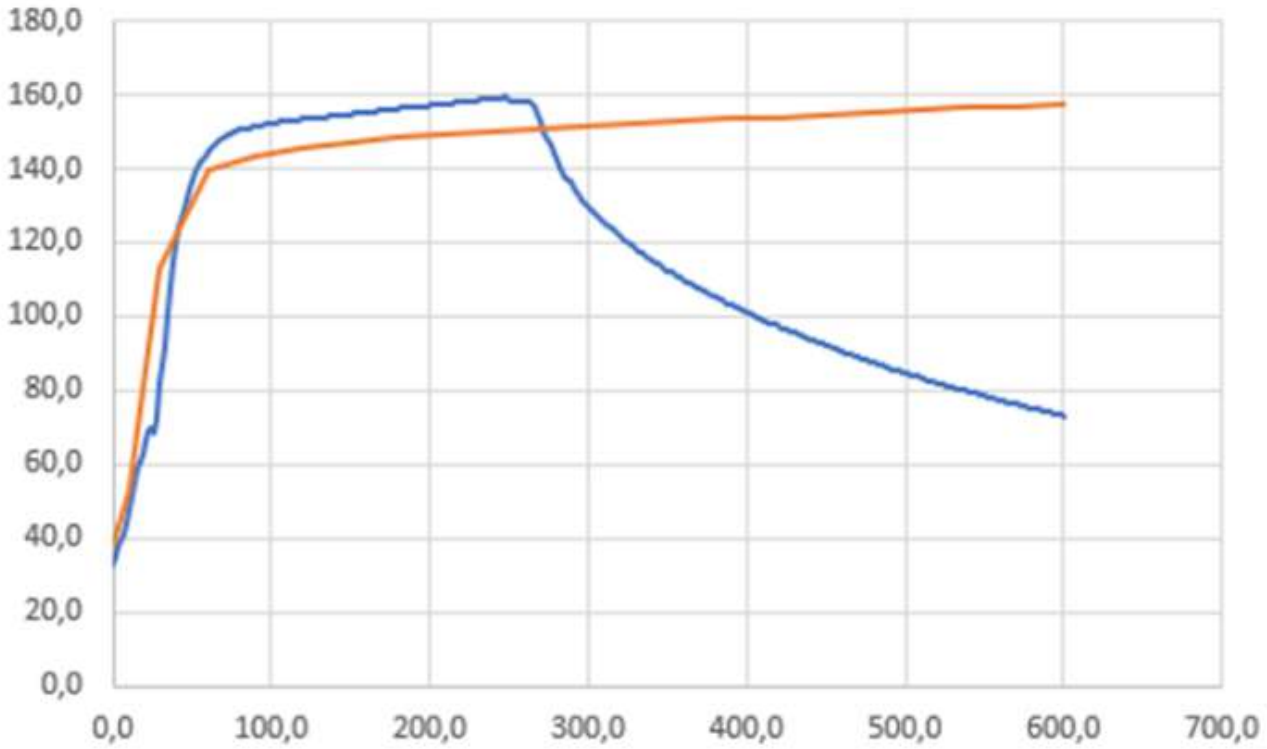
Press consolidation

Heating up the laminate.

Here we are talking seconds



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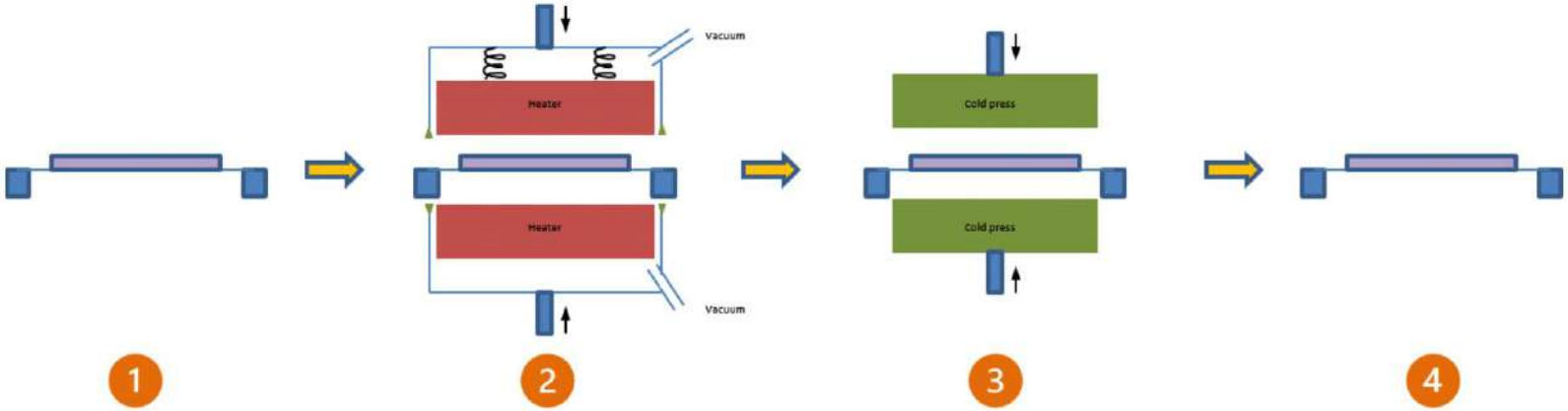
Press consolidation

Third step 3 forming/cooling down the lay-up



Here the parameters are:

a) pressure on layup

b) temperature on tooling

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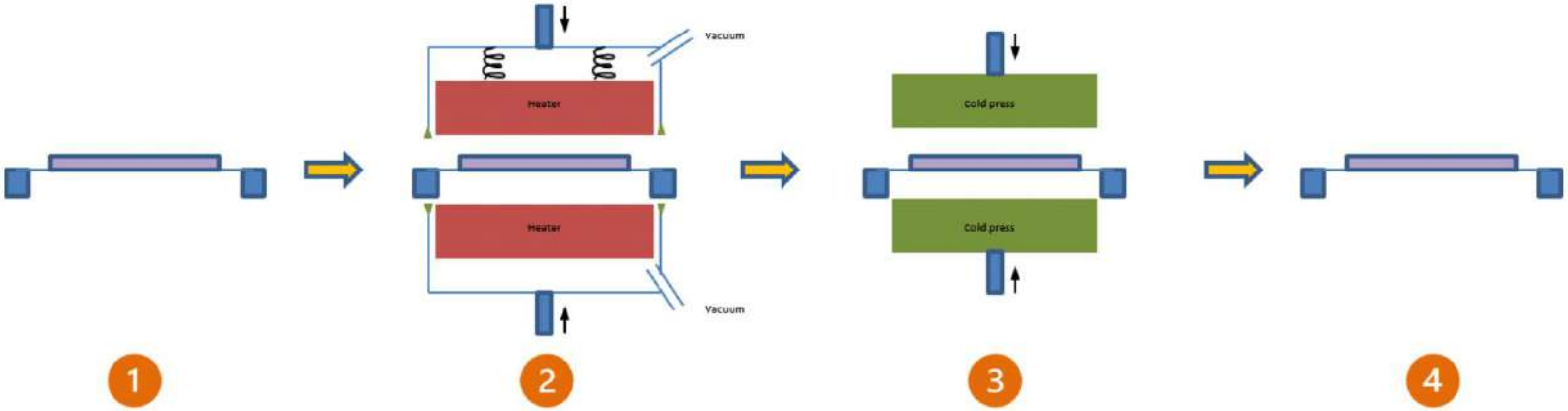
Press consolidation

Fourth step 4 remove part



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Press consolidation

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Press consolidation

- **This system only heats up the laminate => minimize energy**
- **Toolings have been made of:**
  - **Wood**
  - **POM**
  - **HM-PE**

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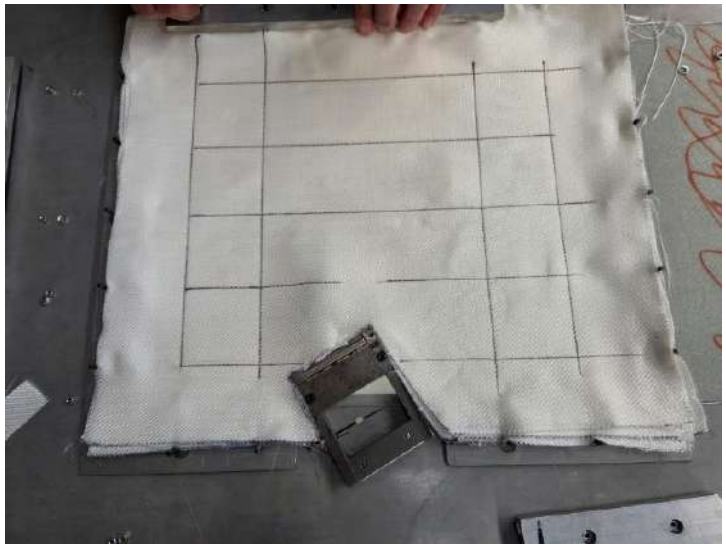
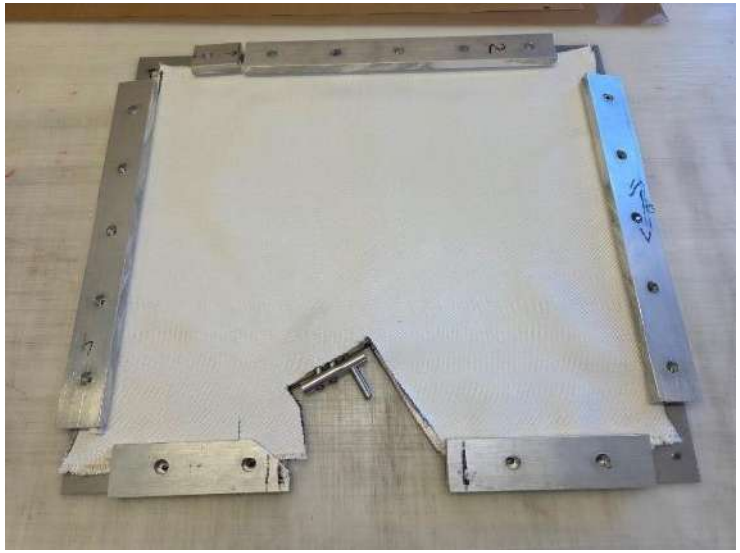
Press consolidation

- **A flexible transport unit**
  - For pre-mounting of layup, can be automated
  - Tensions to layup can be applied





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Press consolidation

- After moulding:

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Press consolidation – overview

Pro:

Fast (down to 25 seconds for 2 mm laminate)

Can be automized

Low on energy consumption

For higher numbers (>10.000)

Con:

Require more systems working together

More expensive system

Require designed tools

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Overview

- **Objective**: production of foot soles in SR-PLA

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Conclusion

- A process is established, which can manufacture foot soles in SR-PLA
- With holes for mounting of springs

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Thank you

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