BIO-UPTAKE

Melt extrusion of biobased thermoplastics

Ruben Geerinck - Centexbel

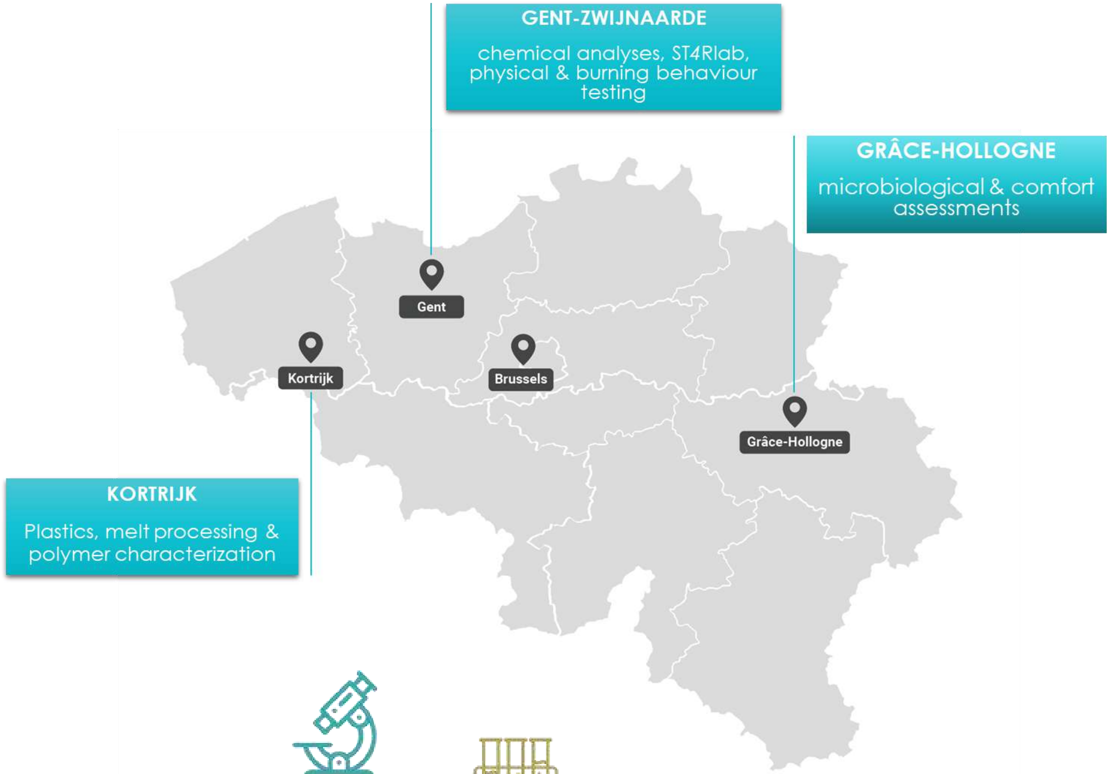
Funded by the European Union

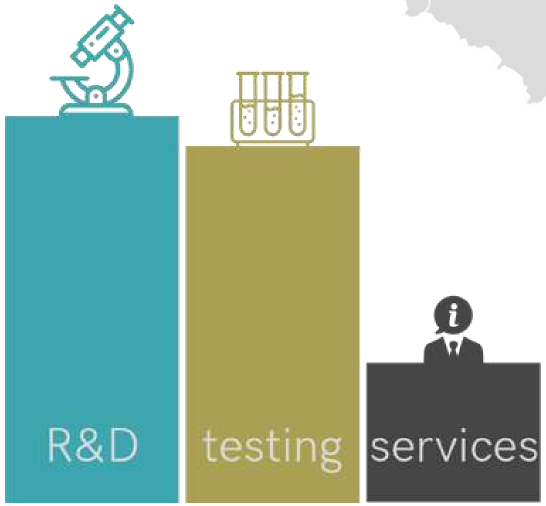
BIO-UPTAKE

CENTEXBEL

Centexbel

- Collective research and technical centre
- Focus on ‘Textiles’ and ‘Plastics’
- Non-profit membership organization
- ± 180 employees - 3 sites in Belgium
- Well-equipped testing laboratories: physical – chemical – fire – microbiological
- Pilot platforms: Plastics/extrusion – textile intermediates – coating & finishing





Outline

- Intro demonstrators
- Objective
- Composite formation
- Extrusion bico monofilament
- Extrusion multifilament
- Commingling
- Weaving
- CWA

Intro demonstrator

Raw material → Intermediate product → Final product → End of life

PCL

PLA

Filament extrusion

Filament yarns

Press consolidation

UD tapes

Organosheets

Thermoforming

Feet insoles

Intro demonstrator

Raw material → Intermediate product → Final product → End of life

PLA

Filament extrusion

CENTEXBEL

Filament yarns

Press consolidation

COMFIL

UD tapes

Organosheets

BioPA

Wood&short carbon fibre

Extrusion compounding

aitiip

Pellets

CANs

SPECIFIC POLYMERS

Over-injection

moses advanced materials

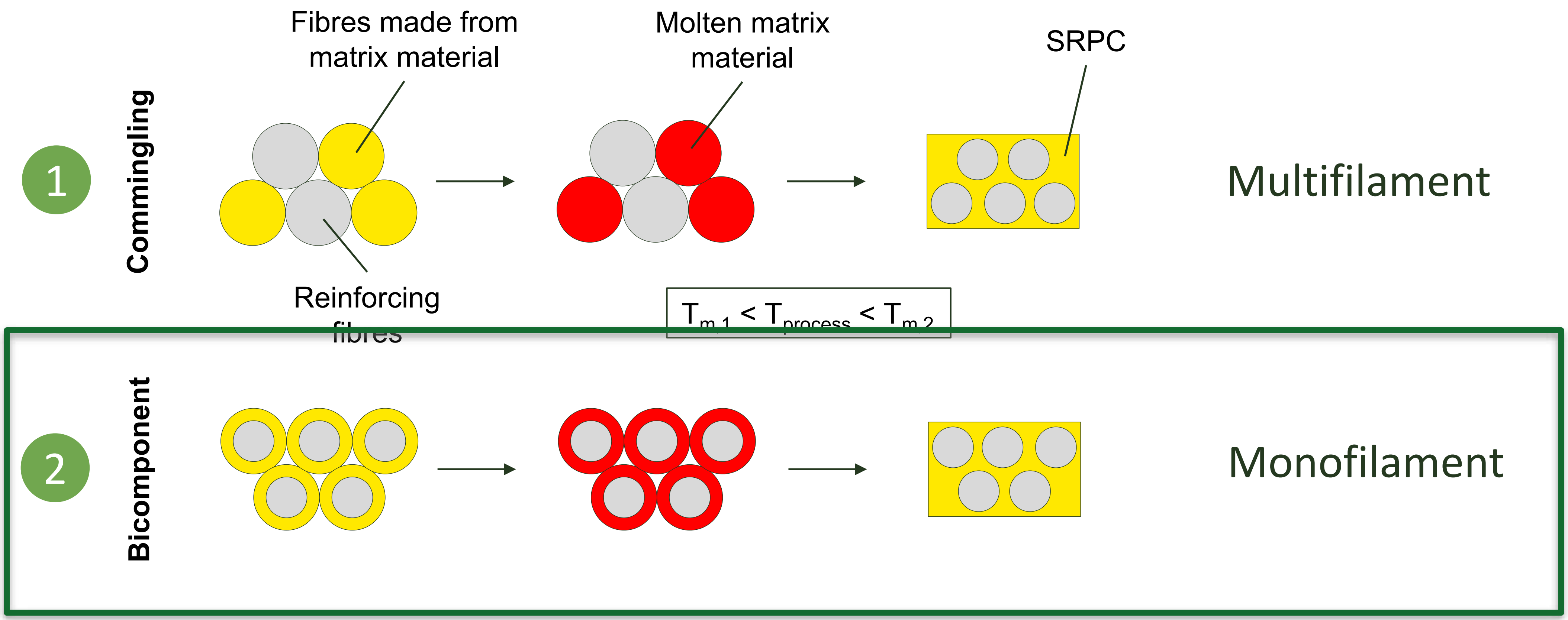
Lid for a garbage container

Objective

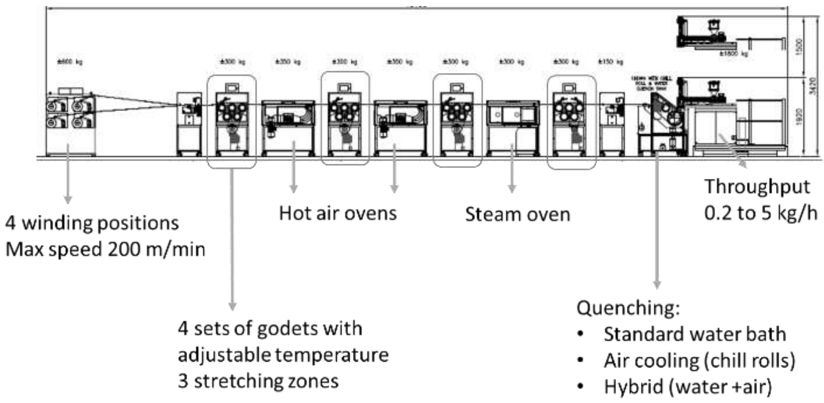
- **Objective**: production of high and low melting yarn to be used in fibre reinforced composites

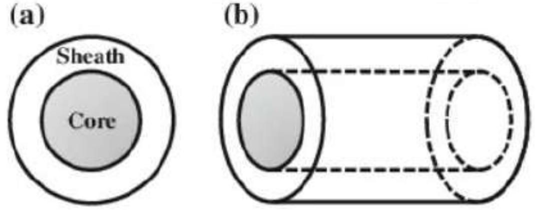
- Requirements filament
  - Reinforcement: high melting PLA
    - Tensile strength > 4N/tex
    - Young’s modulus > 8 GPa
  - Matrix: PCL or low melting PLA grades
    - Processable into comingling and filament winding step

Composite formation

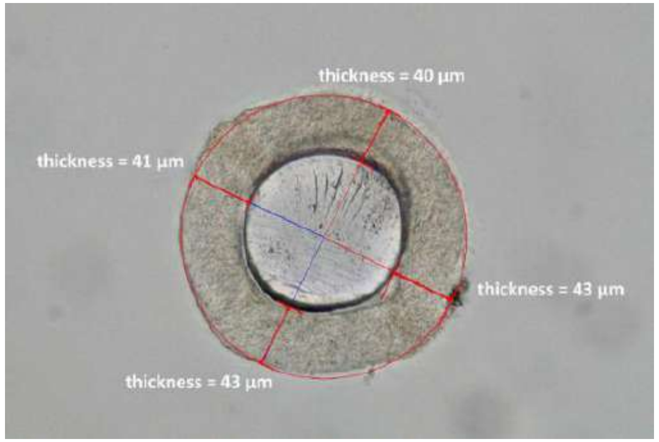


Extrusion bico monofilament

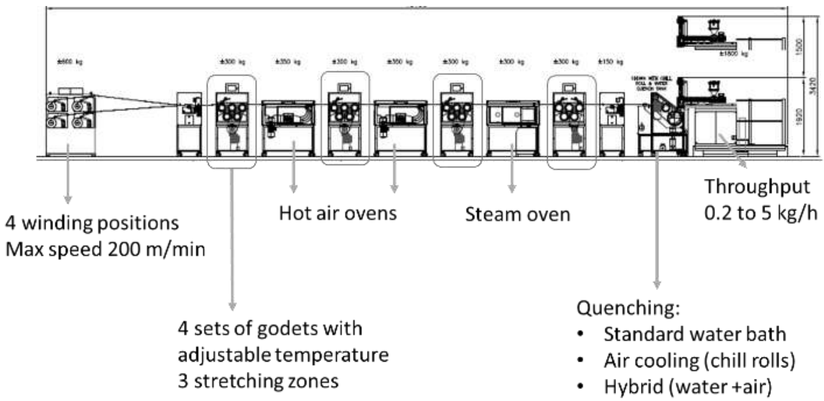




- Core/sheath structure
  - 20 tex - 4 winding positions
- Two types (50/50)
  - PLA/PLA
    - 4 combinations tested
    - Strength 3.4N/tex
  - PLA/PCL
    - Optimisation of adhesion necessary
    - Strength 2.5N/tex

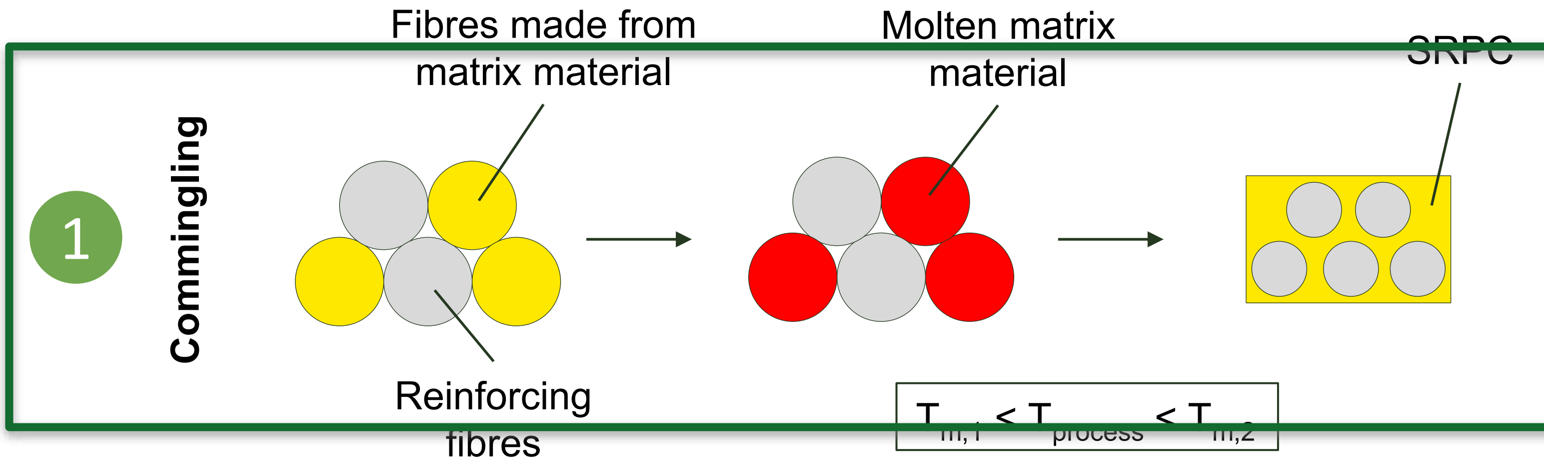


Extrusion bico monofilament



- Benefits
  - Each reinforcement yarn is fully covered in matrix
  - No other processes needed
- Attention points
  - More challenging to decrease shrinkage
  - Difficult to assess the mechanical properties

Composite formation



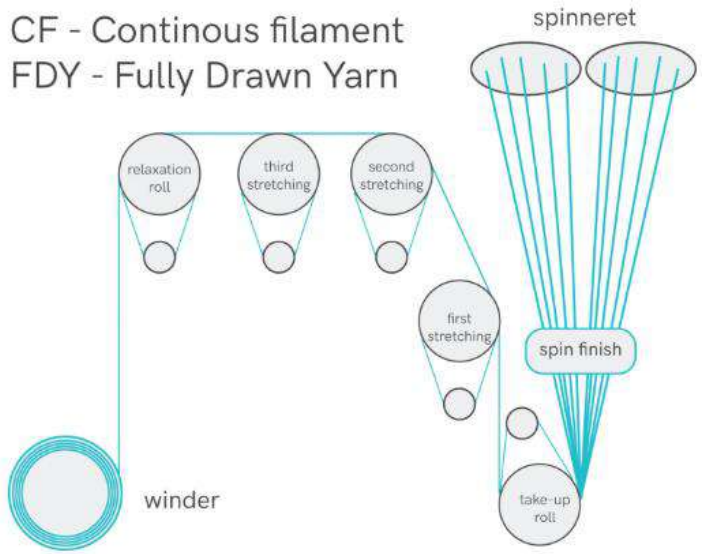
Multifilament

One-step drawing proces – FDY

Two-step drawing proces

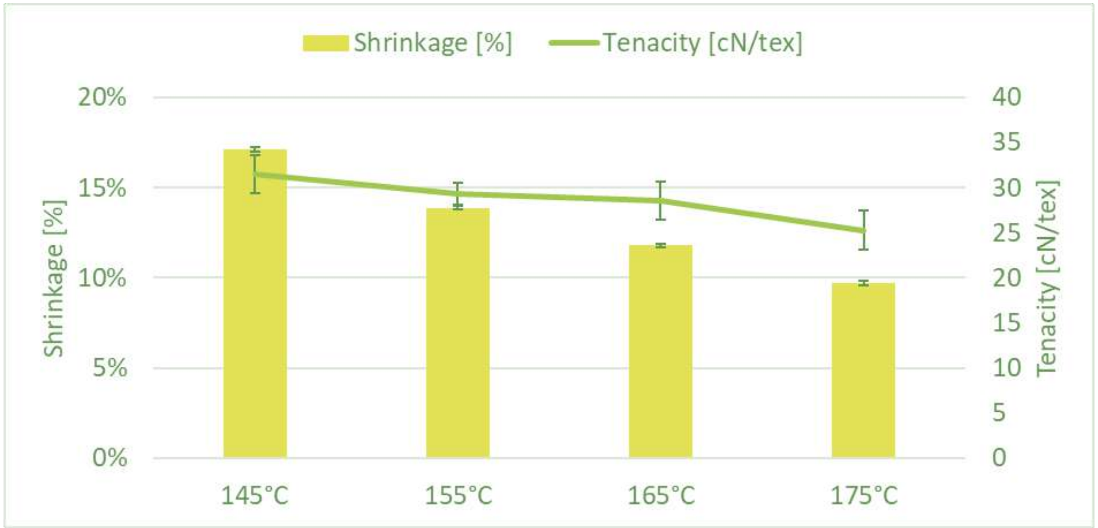
Extrusion multifilament

- One-step drawing process
  - Melt draw ratio ($T > T_m$)
  - Cold draw ratio ($T_m > T > T_g$)
- Matrix yarn
  - 40-50tex
  - Strength does not matter
- Reinforcement yarn
  - 20-30tex
  - 3.5N/tex
  - Shrinkage 15% – 22% @150°C



Extrusion multifilament

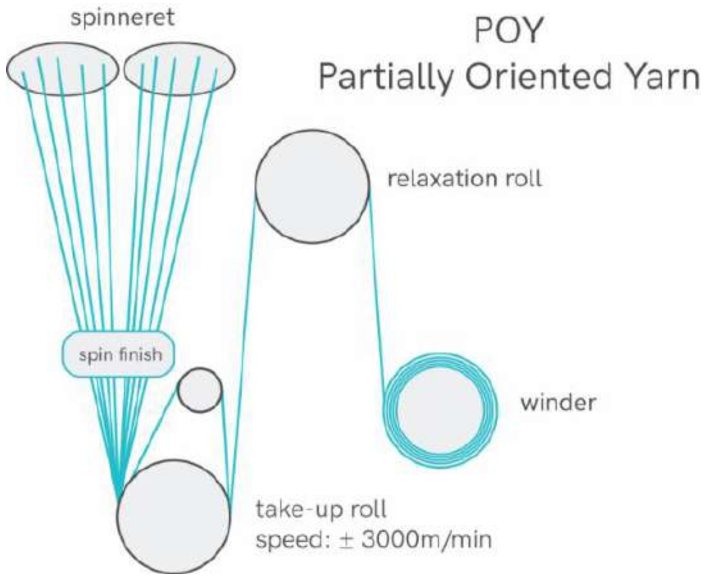
- Importance of shrinkage
- One-step drawing process
  - Limited control of shrinkage
  - Shrinkage ↘ causes strength ↘

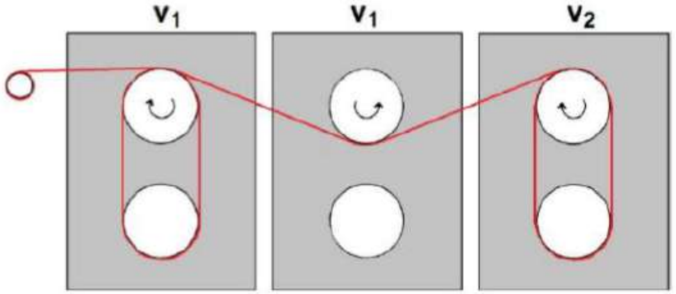


Extrusion multifilament

- Two-step drawing process
  - POY (only melt drawing)
  - 2nd separate stretching process
  - Better control of shrinkage

- Only for reinforcement yarn
  - Strength up to 5N/tex
  - Shrinkage 7% @150°C

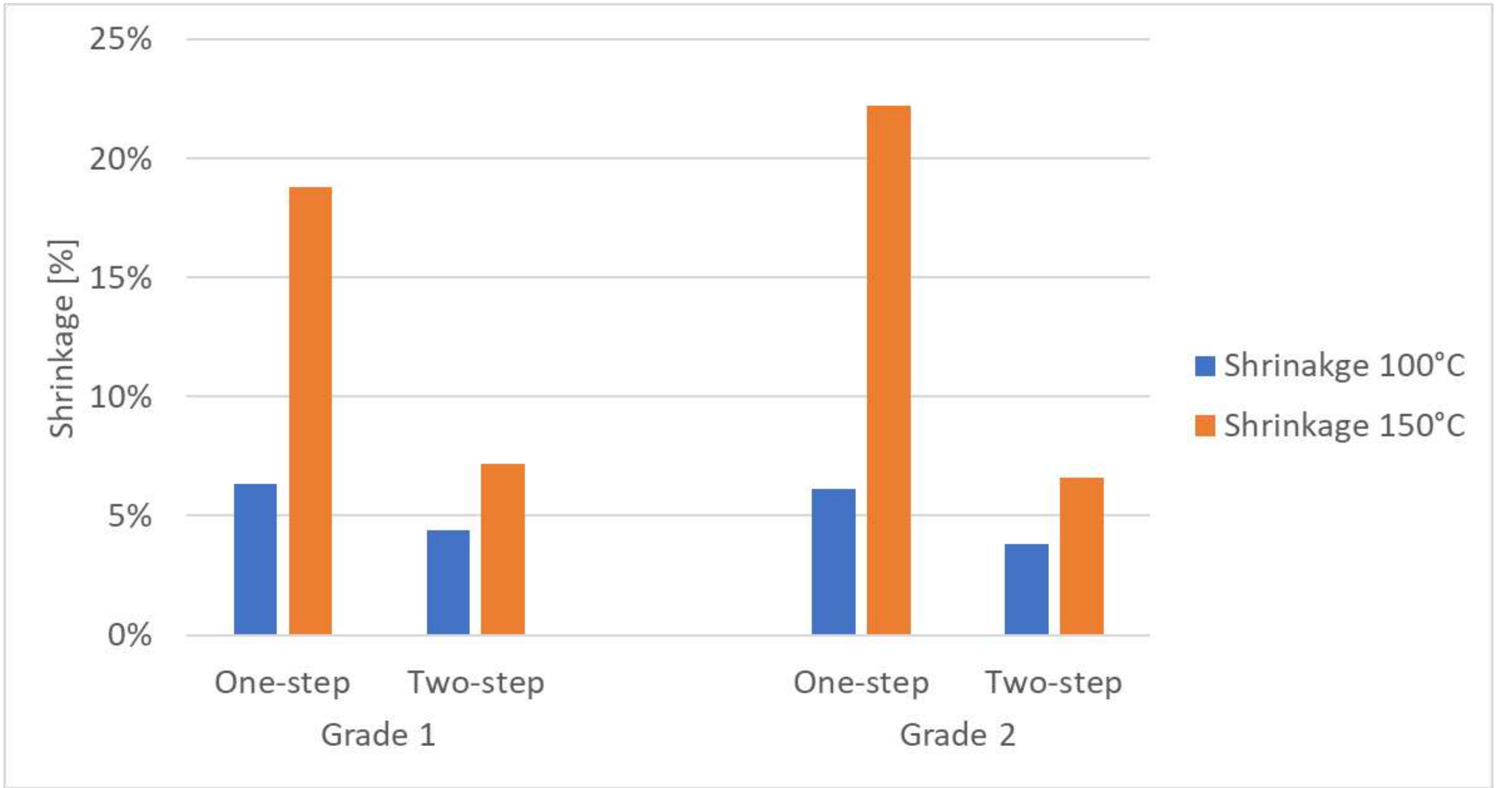




Post-stretching process

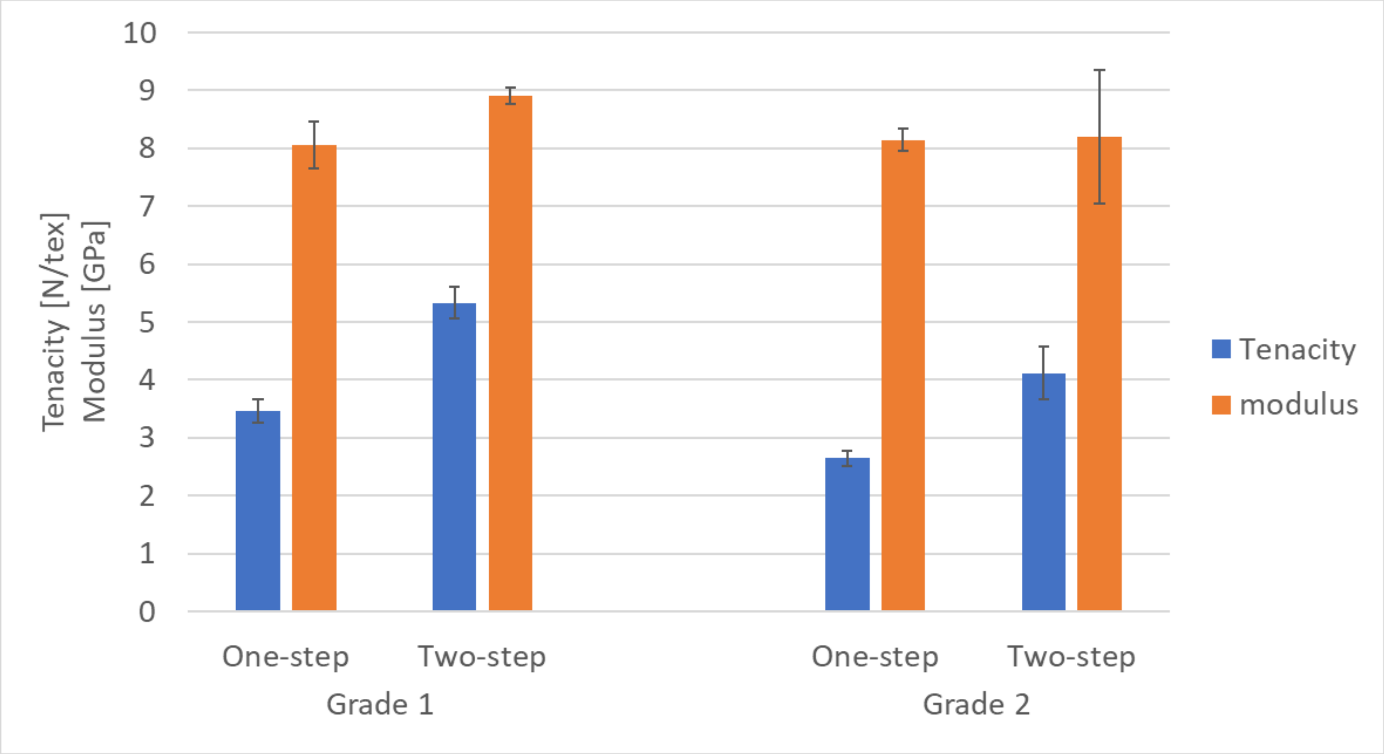
Extrusion – overview properties

- Shrinkage lowers to 7% @150°C
- Heated ovens ≠ heated rolls



Extrusion – overview properties

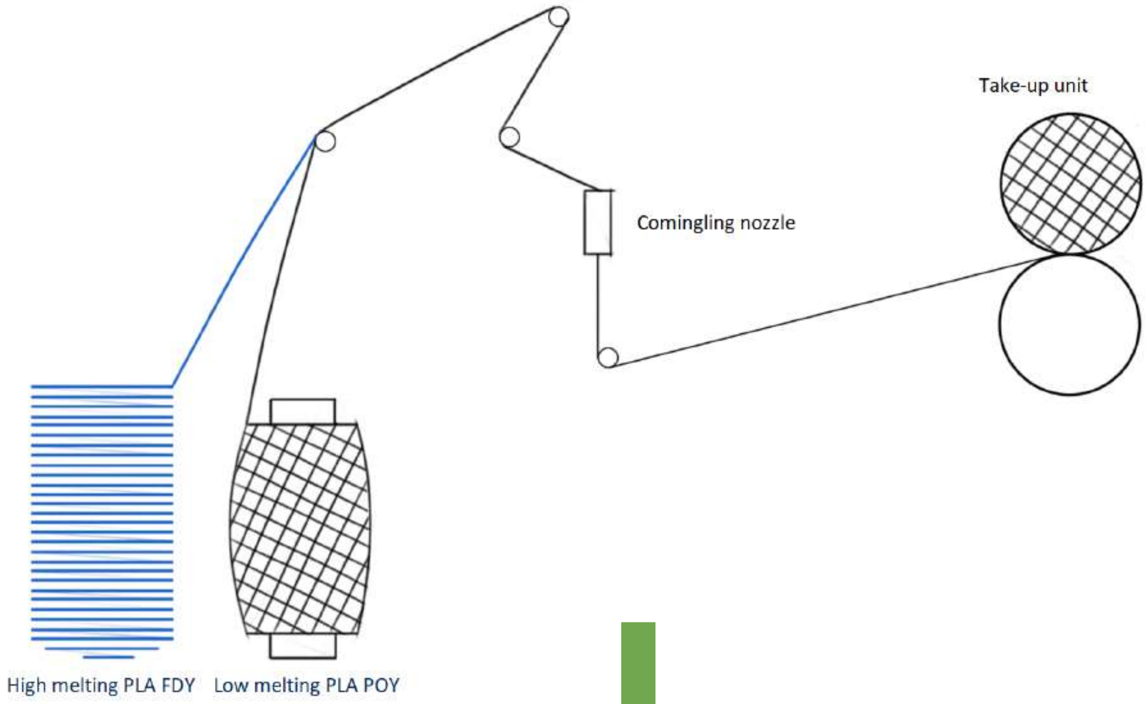
- Strength increases to 5N/tex
- Modulus increases to 9 GPa

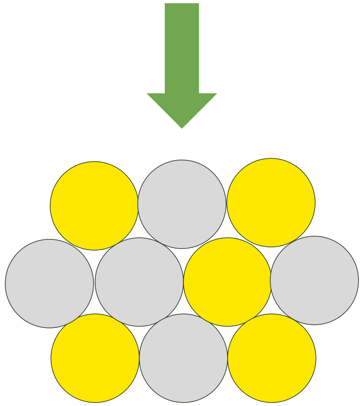


Commingling

- Materials
  - High melting PLA FDY
  - Low melting PLA POY

- Producing a single yarn with both high and low melting PLA

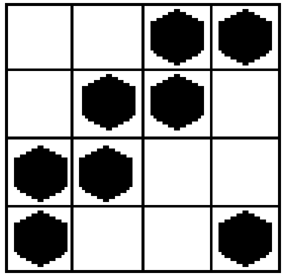
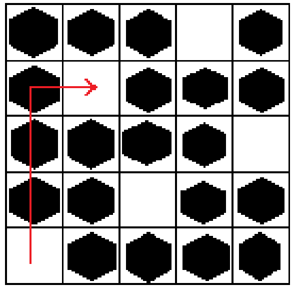




Cross-section of a yarn bundle

Weaving

- Dobby weaving machine
  - Width 50cm
  - 11 yarns/cm warp
  - 10 yarns/cm weft
  - Two patterns
    - Twill 2x2
    - Satin 5 (warp effect, shift 3)


Standardization - CWA

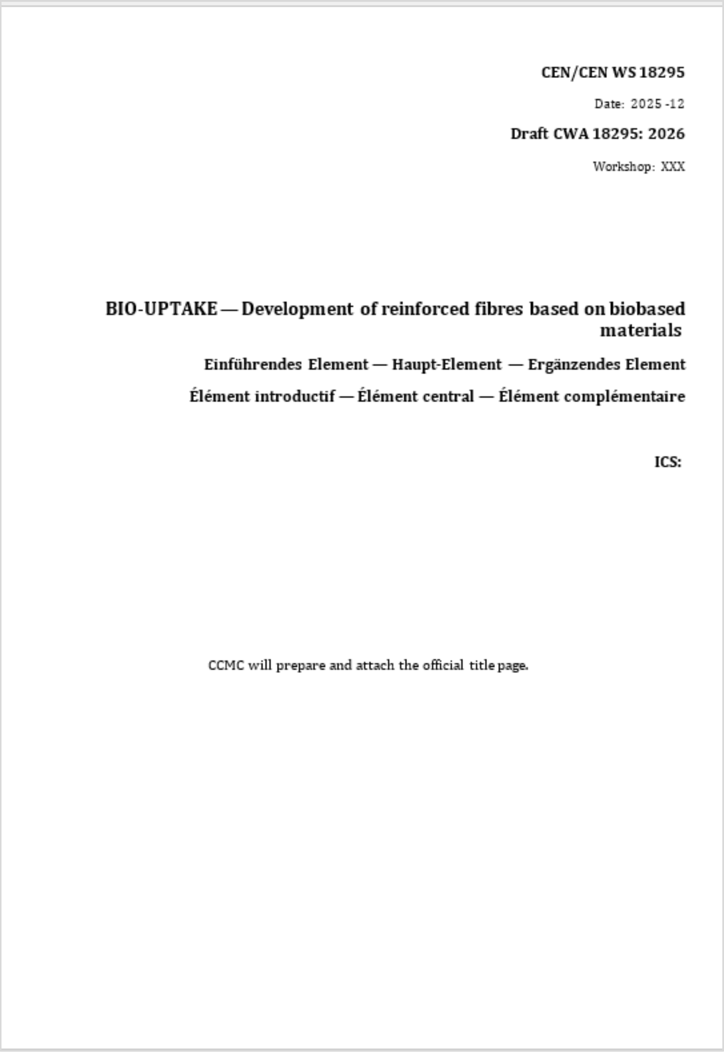
1 **Development of reinforced fibres based on biobased materials**

leader CENTEXBEL
KOM to start drafting of standard on 1st July
Submitted for public commenting phase

Expected publication date beginning of February 2026

SCOPE

This document describes the process for optimizing the process for filament extrusion for biobased materials with respect to obtaining the filament properties required for their intended applications.


CEN/CEN WS 18295

Date: 2025-12

Draft CWA 18295: 2026

Workshop: XXX

BIO-UPTAKE — Development of reinforced fibres based on biobased materials

Einführendes Element — Haupt-Element — Ergänzendes Element

Élément introductif — Élément central — Élément complémentaire

ICS:

CCMC will prepare and attach the official title page.

Conclusion

- Possible to produce a PLA yarn with high strength (5N/tex) and modulus of 9 GPa
- Possible to decrease the shrinkage of the PLA yarns
- Successful commingling and weaving
- CWA standardisation ongoing regarding the processing of PLA reinforced yarns

Thermoforming of Biobased Thermoplastics

Hans Knudsen- COMFIL

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BIO-UPTAKE

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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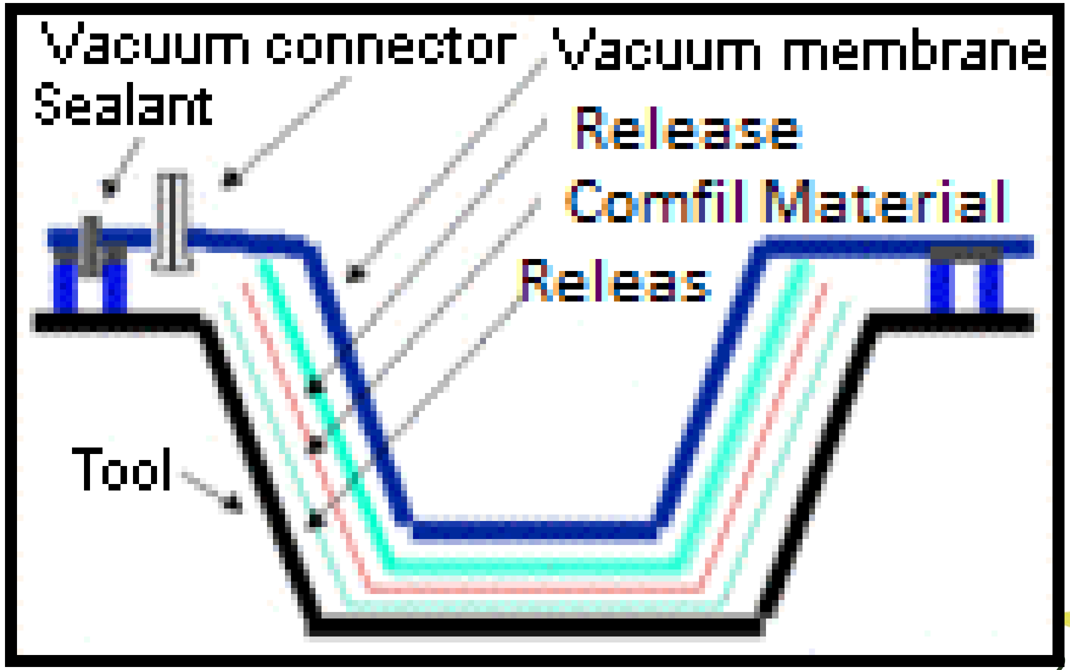
Vacuum consolidation

- Also called vacuum bag consolidation.

- Vacuum consolidation is a “simple”, flexible and “easy” process to consolidate a composite part in.

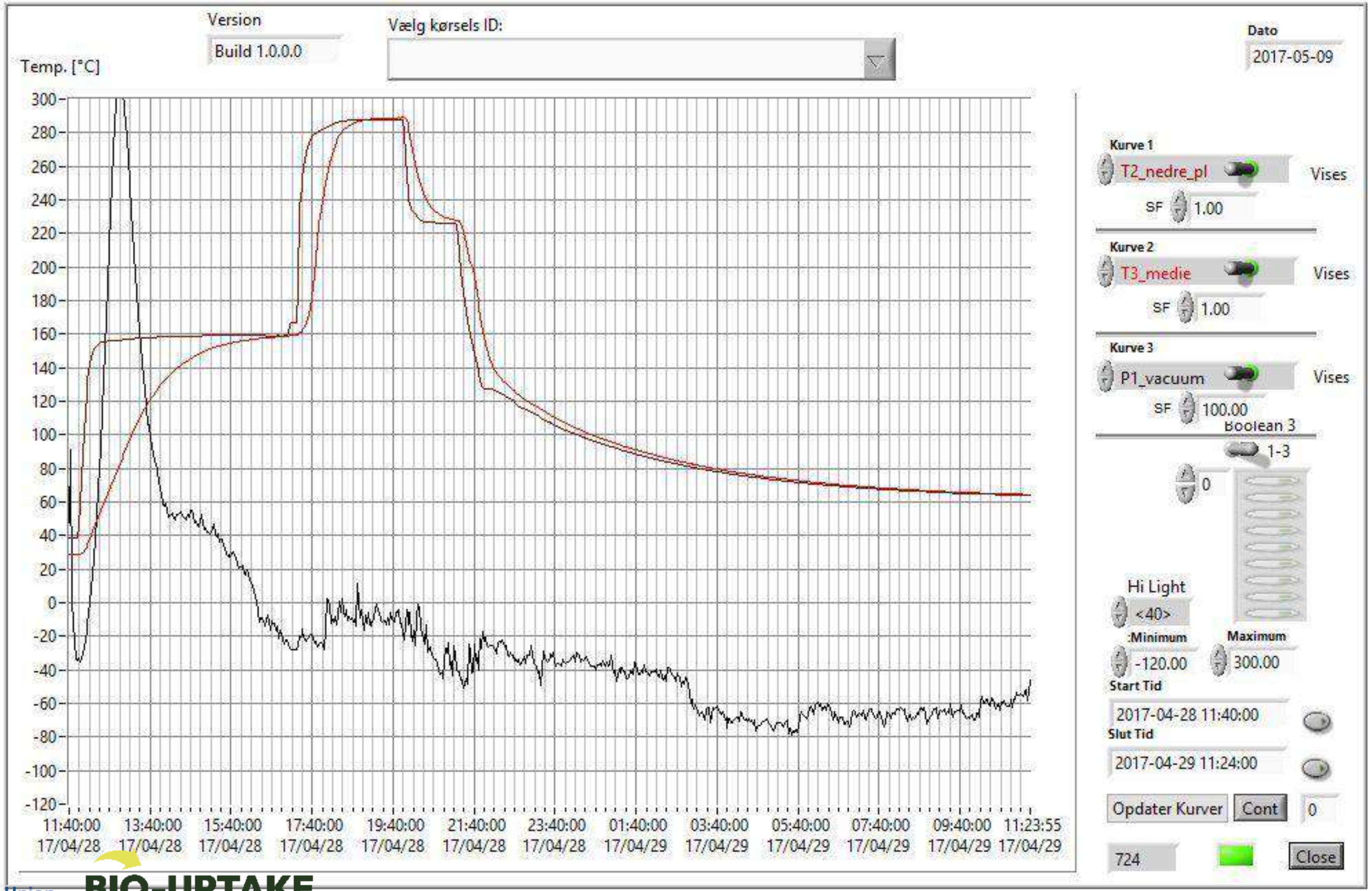
- Works with vacuum only



Vacuum consolidation

- Like baking a cake
- Recipe with layup of materials
- Time at temperature(s)
- Temperature measurements
- Drying.

Vacuum consolidation



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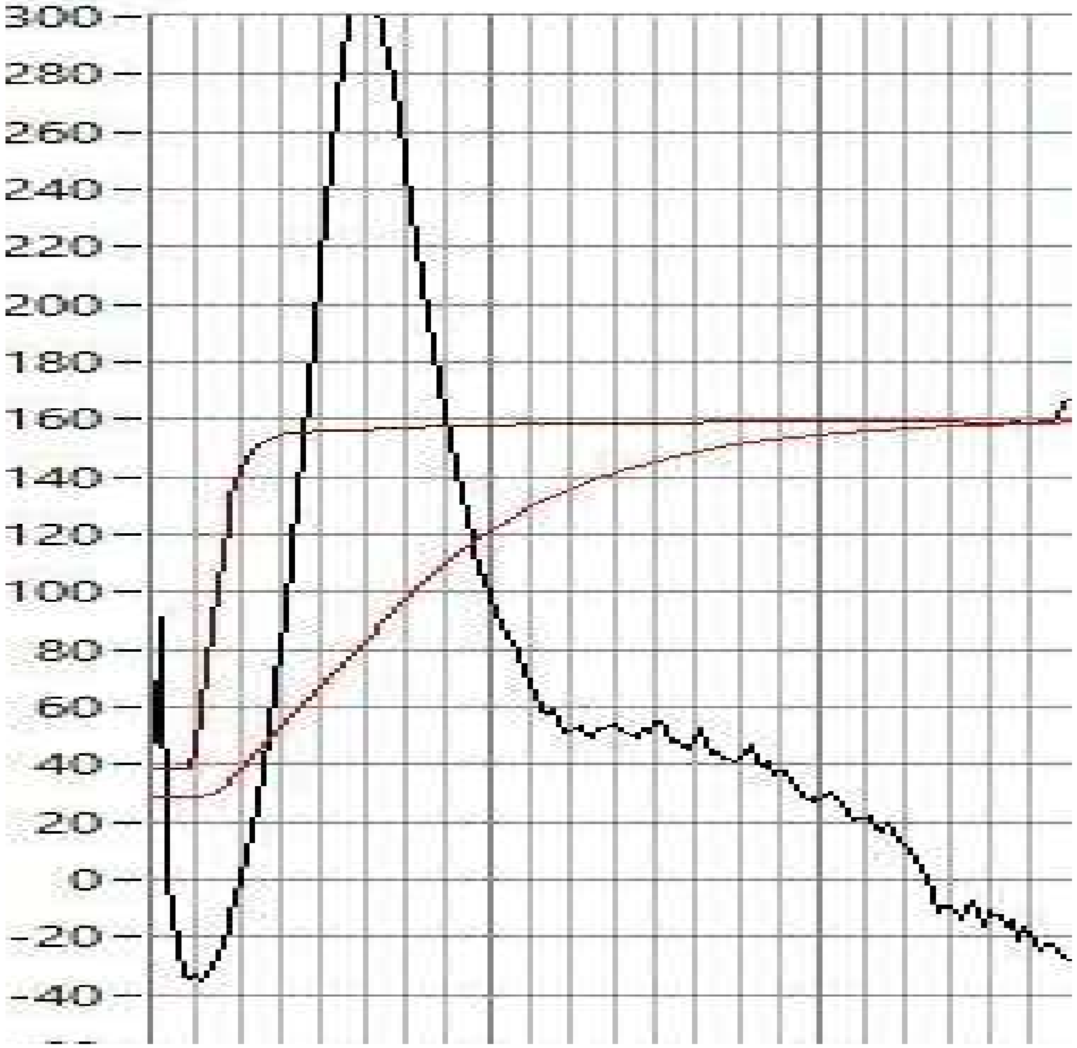
Vacuum consolidation - drying



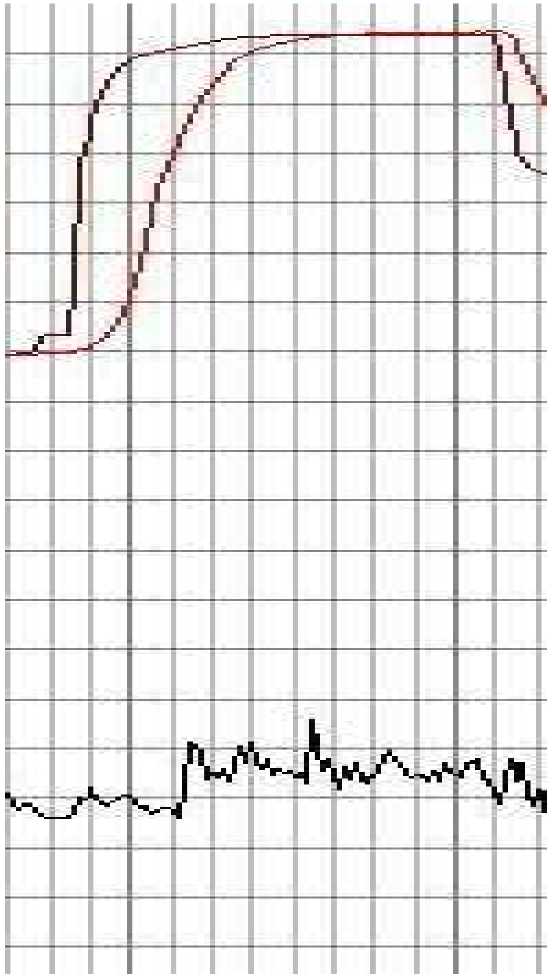
Here the materials is dried if necessary.

Black curve is the vacuum level (*100)

Lower red curve is temperature in middle of laminate

Top red curve is temperature on heating plate

Vacuum consolidation – wetting out fibre



Melting the matrix for wetting out the fibres.
Here the middle temperature is app. 45 min after the outer layer temperature.

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 – 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)

Lower red curve is temperature in middle of the laminate

Top red curve is temperature on heating plate

Vacuum consolidation – System

System has a max temperature of 350ºC

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Vacuum consolidation – overview

Pro:

Easy process

Flexible

Can be low cost

For lower numbers (<10.000)

Con:

Slow

Not easy to automize

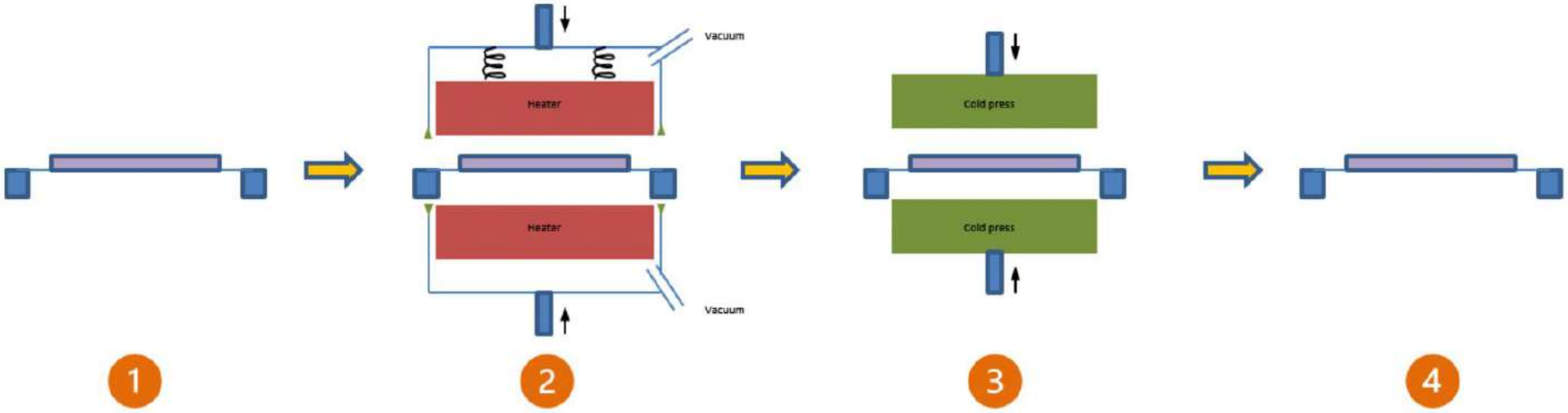
Press consolidation

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 system for this.

Press consolidation

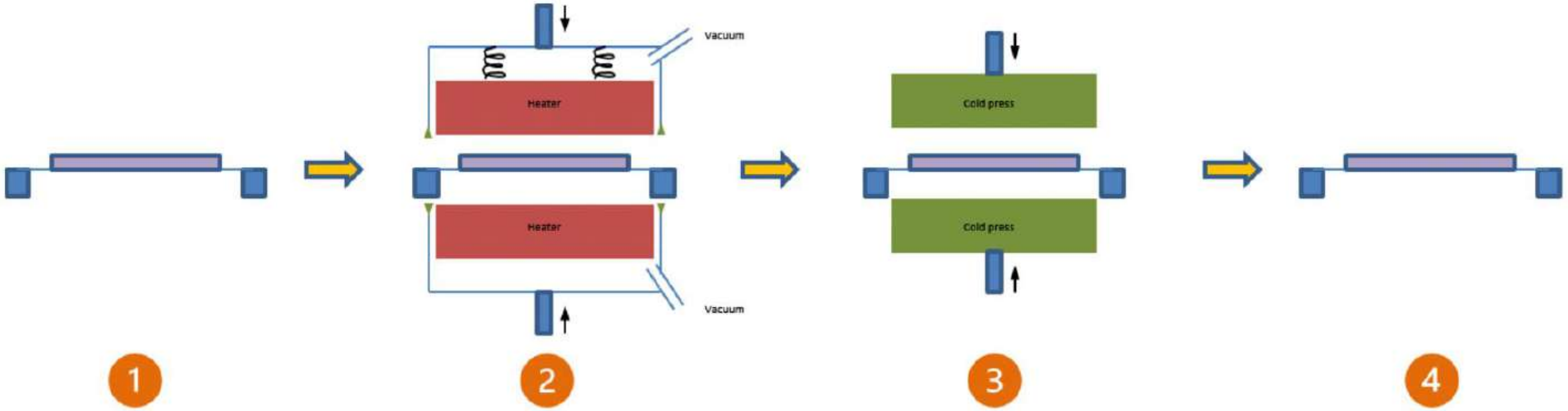
We have choosen a 4 step system



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

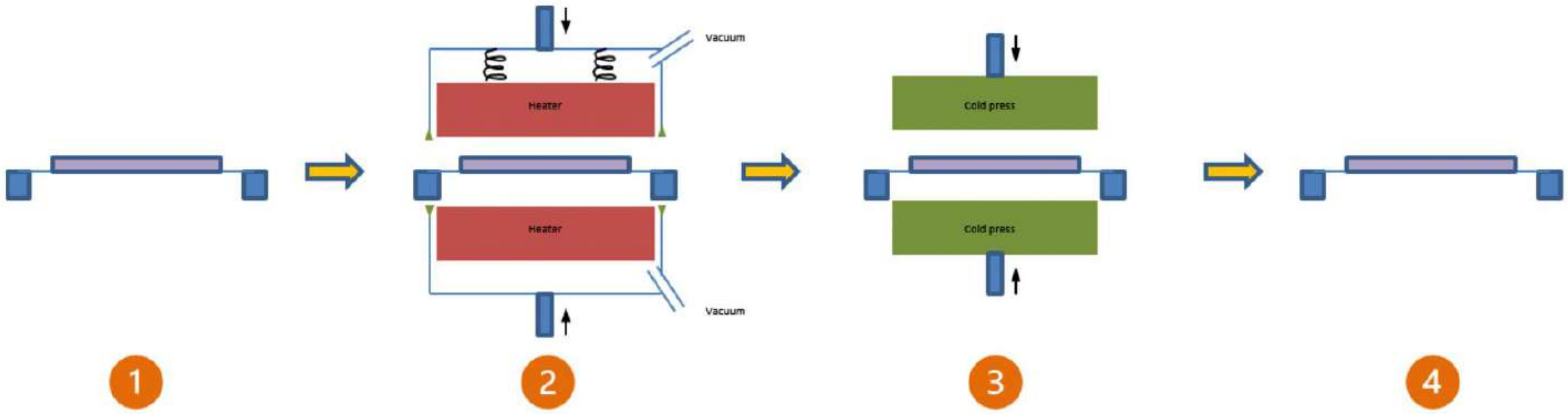
Press consolidation

First step 1 the layup on the transport unit



Press consolidation

Second step 2 is the heating/wetting out



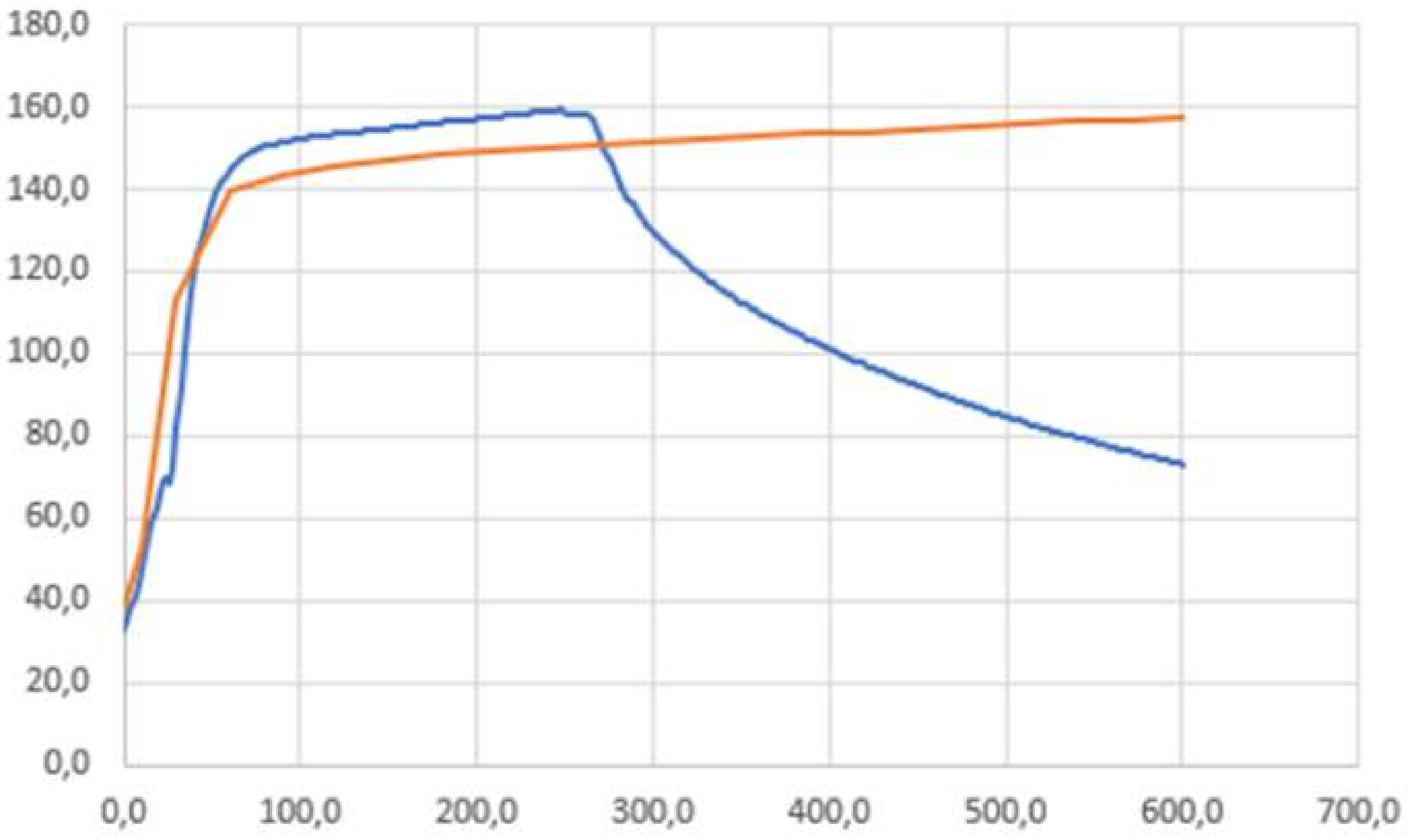
Here the parameters are:

a) temperature
b) pressure on layup
c) degree (percent) of vacuum

Press consolidation

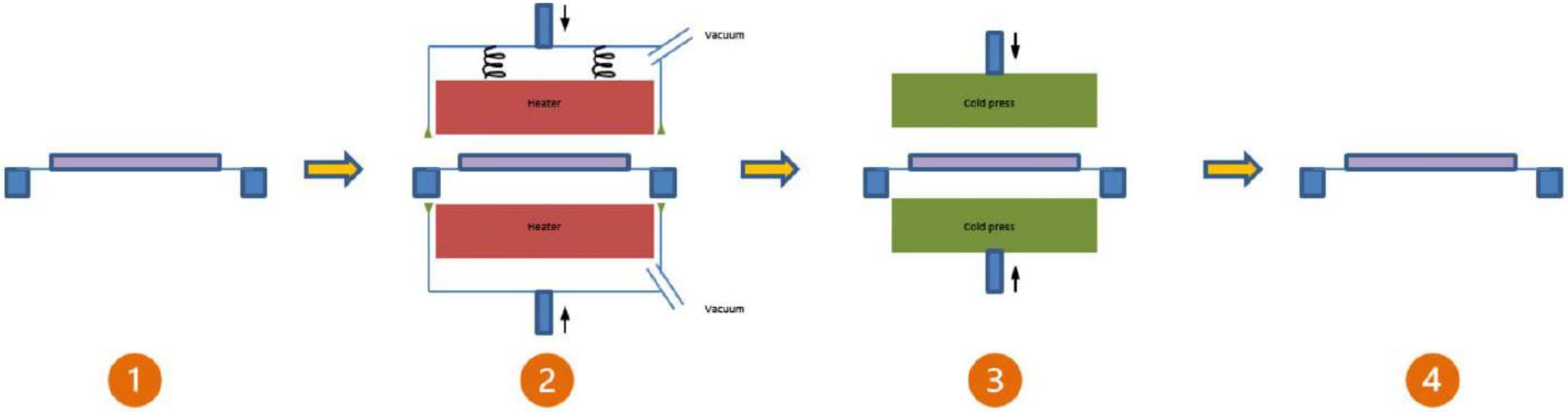
Heating up the laminate.

Here we are talking seconds



Press consolidation

Third step 3 forming/cooling down the lay-up



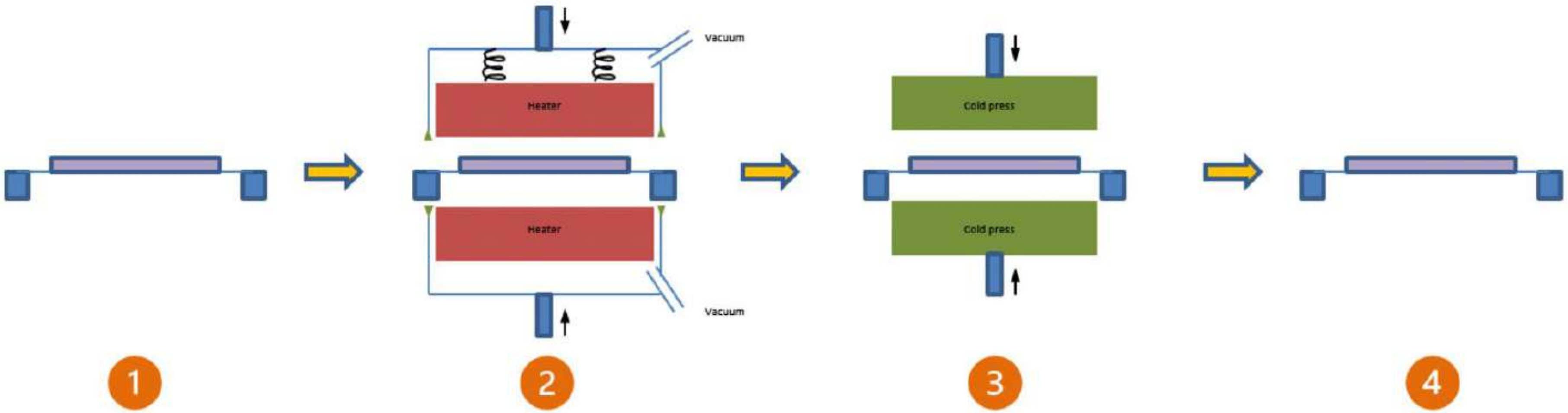
Here the parameters are:

a) pressure on layup

b) temperature on die

Press consolidation

Fourth step 4 remove part



Press consolidation

Press consolidation

- **This system only heats up the laminate => minimize energy**

- **Toolings have been made of:**
  - **Wood**
  - **POM**
  - **HM-PE**

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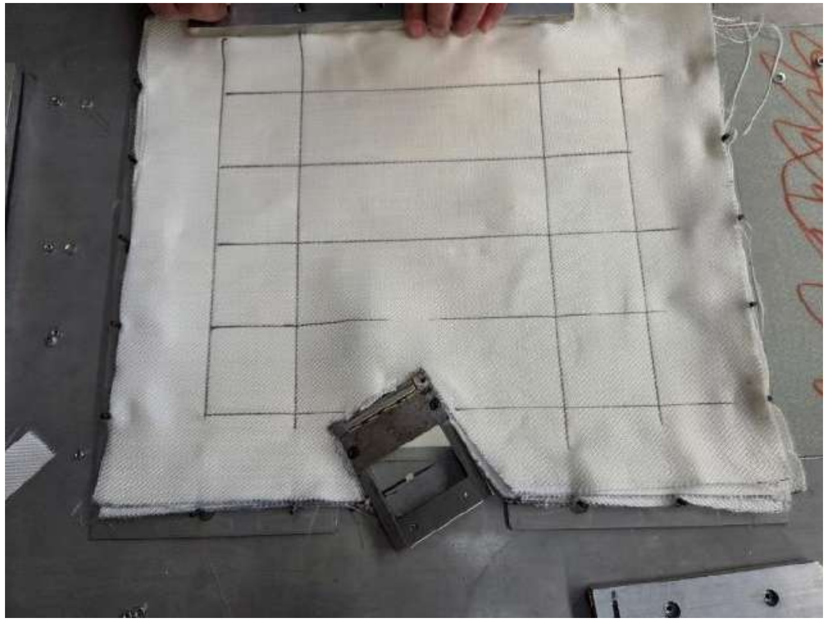
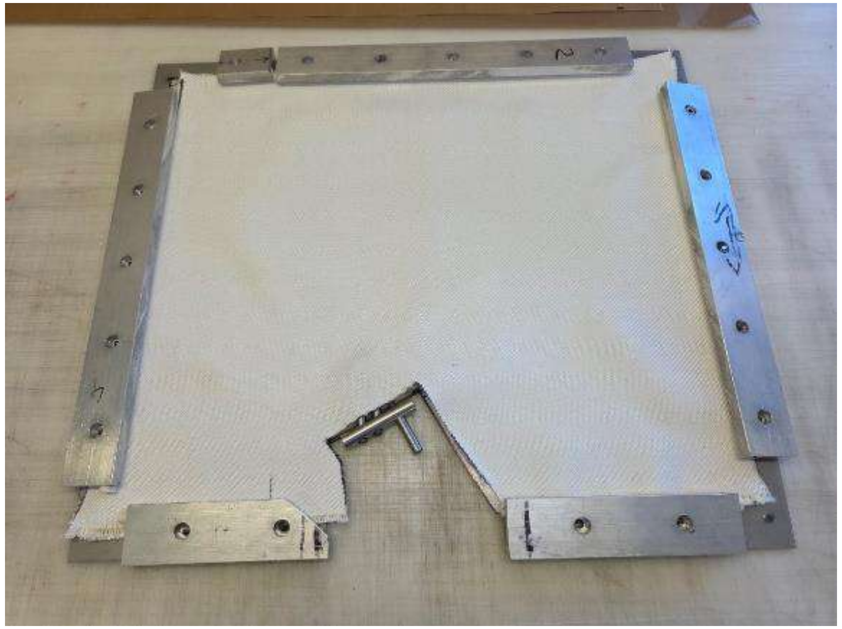
Press consolidation

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





Press consolidation

- After moulding:

Press consolidation – overview

Pro:

Fast

Can be automized

Low on energy consumption

For higher numbers (>10.000)

Con:

Require more systems working together

Expensive system

Require designed tools

Overview

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

Conclusion

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

Thermoforming of Biobased thermoplastics - FAQ

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Hans Knudsen

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Break

See you all at 11.00!