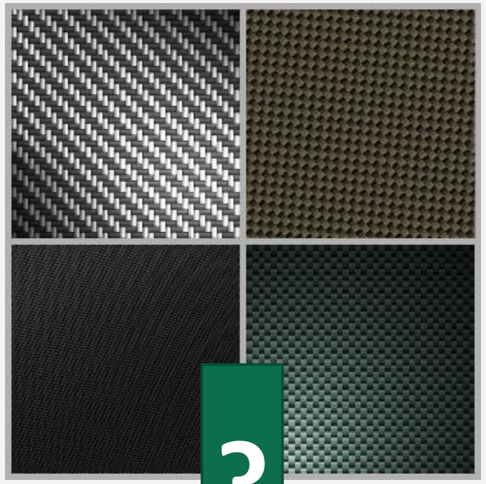
# Durable and resource-saving Composite structural components based on newly pre-treated and processed bast fibers

Cellulose Fibres Coference

13./14.03.2024 Cologne

Gefördert durch: Bundesministerium für Ernährung und Landwirtschaft aufgrund eines Beschlusses des Deutschen Bundestages (FKZ: 2220NR090E)

# Natural fibers as reinforcement in plastic materials



## Advantages:

- sustainable alternative to GRP/CFRP
- renewable raw materials
- low density
- low energy consumption during production
- low price
- $CO_2$ savings
- crash behavior
- sound damping
- biodegradable
- complete thermal recycling possible

## Drawbacks:

- mechanical properties
- moisture up-take

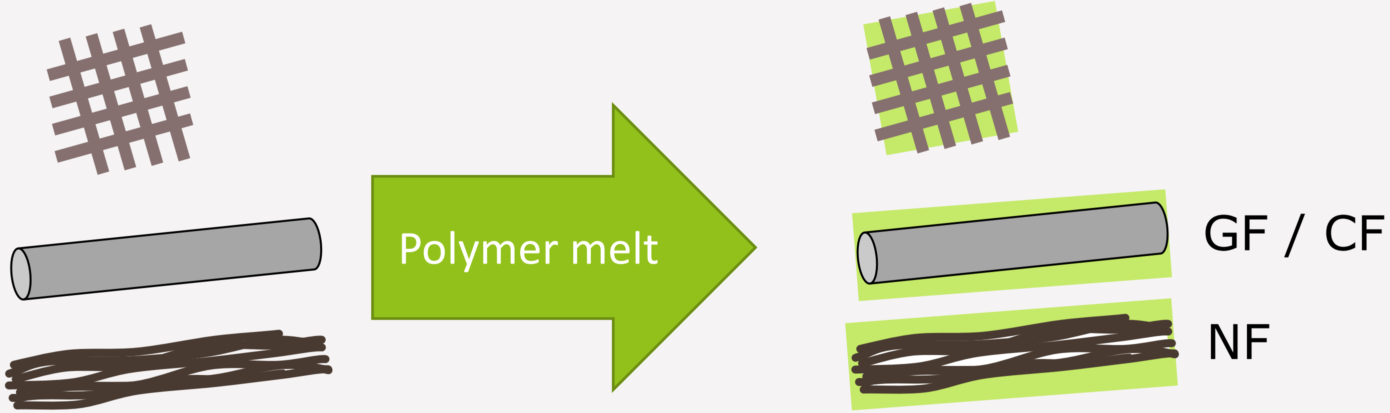
# thermoformable composites (organic sheets)

## Advantages:

- Can be produced as a semi-finished product
    - later forming into desired structure
- no "chemical reaction" during shaping
    - shorter cycle times than with thermosets
    - no curing required
- material recycling possible
    - granulation and use as short fiber-reinforced composites (extrusion, injection molding)
    - (theoretically reshaping possible)

## Drawbacks:

- Infiltration of fiber interstices with high viscous polymer melt



# Previous results from short project „BastFix“

**Fibers, filled inside with polymer**

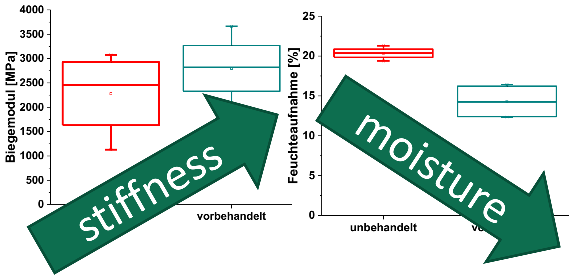

Cavity polymerization to reduce the moisture absorption of the fibres and to reinforce the sliver for further processing steps without / little twisting of the sliver

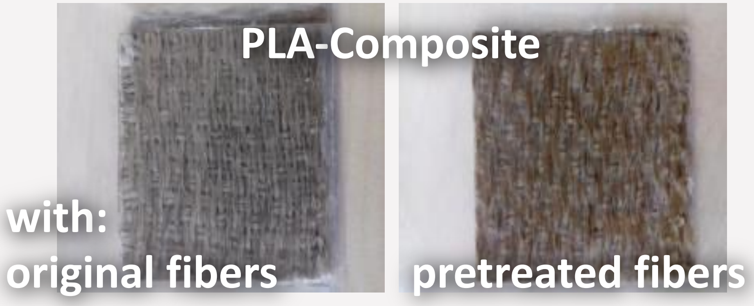
**Low-twist staple fiber yarns**


wrapper filament

Increased fiber orientation in the direction of force provides higher tensile strength due to lower warpage

**Aim:** Reduction of moisture uptake and increasing stiffness of NFRP




➔ **Starting point for „DuroBast“**

# Project consortium

**research partner**

Institut für Verbundwerkstoffe, IVW

RWTH Aachen ITA

Fraunhofer LBF

Werkstoffprüftechnik TU Dortmund, WPT

**Fiber producer and supplier**
eta

**Yarn producer**
Wagenfelder Spinnereien

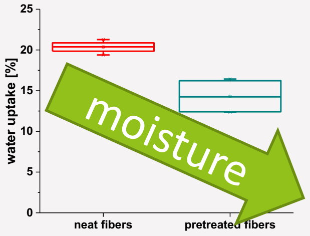
**Textile producer**
Gerster

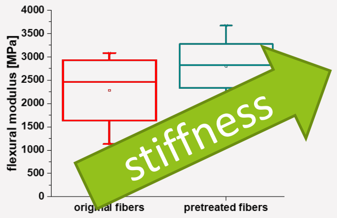
**Producer of semi-finished parts**
Rhenoflex

**End user**
Dräxlmaier
Hübner
Silbaerg

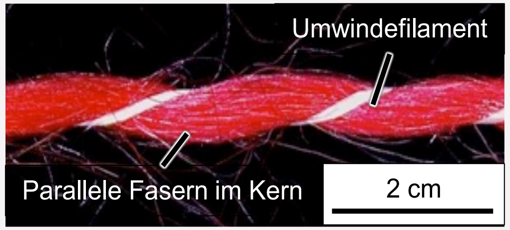
**Economic expertise, public relations,** nova-Institut

# Objectives in DuroBast

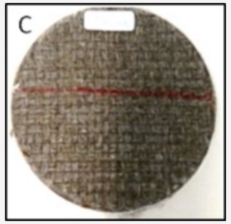


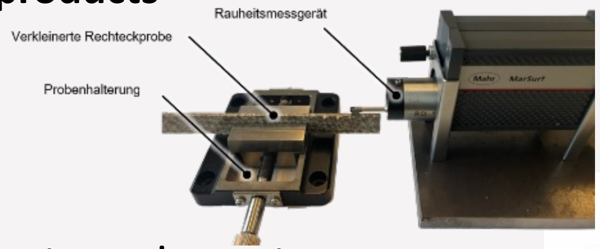




- **Production of thermoformable natural fiber-reinforced plastics (NFRP)**
    - Reduced moisture absorption
    - Improved mechanical properties
- **Use of domestic natural fibers**
    - Bast fibers (flax and/or hemp)
    - Modification of the fibers to extend the range of applications
- **Optimized production of reinforcement**
    - production of low-twist staple fiber yarns through wrap spinning
    - Comparison of different weave types in the fabric
- **Optimized production of semi-finished composite products**
- **Testing the mechanical properties**
    - Influence of the manufacturing parameters
    - Detection of failure mechanisms
- **Validation of the project results in demonstrators**
    - Automotive interiors, public transportation, sports equipment
- **Economic study**








## From fiber selection to innovative yarns

Decision on the fiber plant: hemp vs. flax

- **Flax**
    - Cannot be grown competitively in Germany for climatic reasons
    - Retting involves high risks
    - Harvesting requires expensive special machinery
- **Hemp**
    - More frugal plant
    - Experience in cultivation, harvesting and technology benefited from seed/leaf production
    - Harvesting can be done with a combine harvester

➔ **Decision in DuroBast: using hemp as feedstock**

# From fiber selection to innovative yarns

## Challenges in the production of hemp yarn

- Requirements from the end users:
  - Yarn measures of 200 and 400 tex
- Hemp fibers are currently mainly used for non-woven applications
  - Are obtained from whole stalks
  - Fibers are more lignified, coarser and more heterogeneous than flax fibers
  - Fine yarns only from fibers from the upper stem area
    - Combed tops are obtained from this as a preliminary stage for yarn production
      → Price-intensive

# From fiber selection to innovative yarns

**Use of hemp fibers in DuroBast**

- Carding of non-woven fibers and subsequent yarn production only successful on laboratory machine
- Too much fiber shortening on production line

**Solutions:**

- Procurement of combed top externally (price-intensive)
  - Successful production of 270 and 400 tex yarn
  - → Further processing into woven fabrics (plain weave and twill weave)
- Use of PP fibers as support fibers to compensate for fiber shortening
  - Successful production of hybrid yarn (400 tex; fiber volume content 50%)
  - → Further processing into hybrid textiles
- Carding at a partner of the Wagenfeld spinning mills
  - **Production of 330 tex yarn from hemp fibers (non-woven quality) successful for the first time!!!**

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  - 
- Use
  - )
  - 
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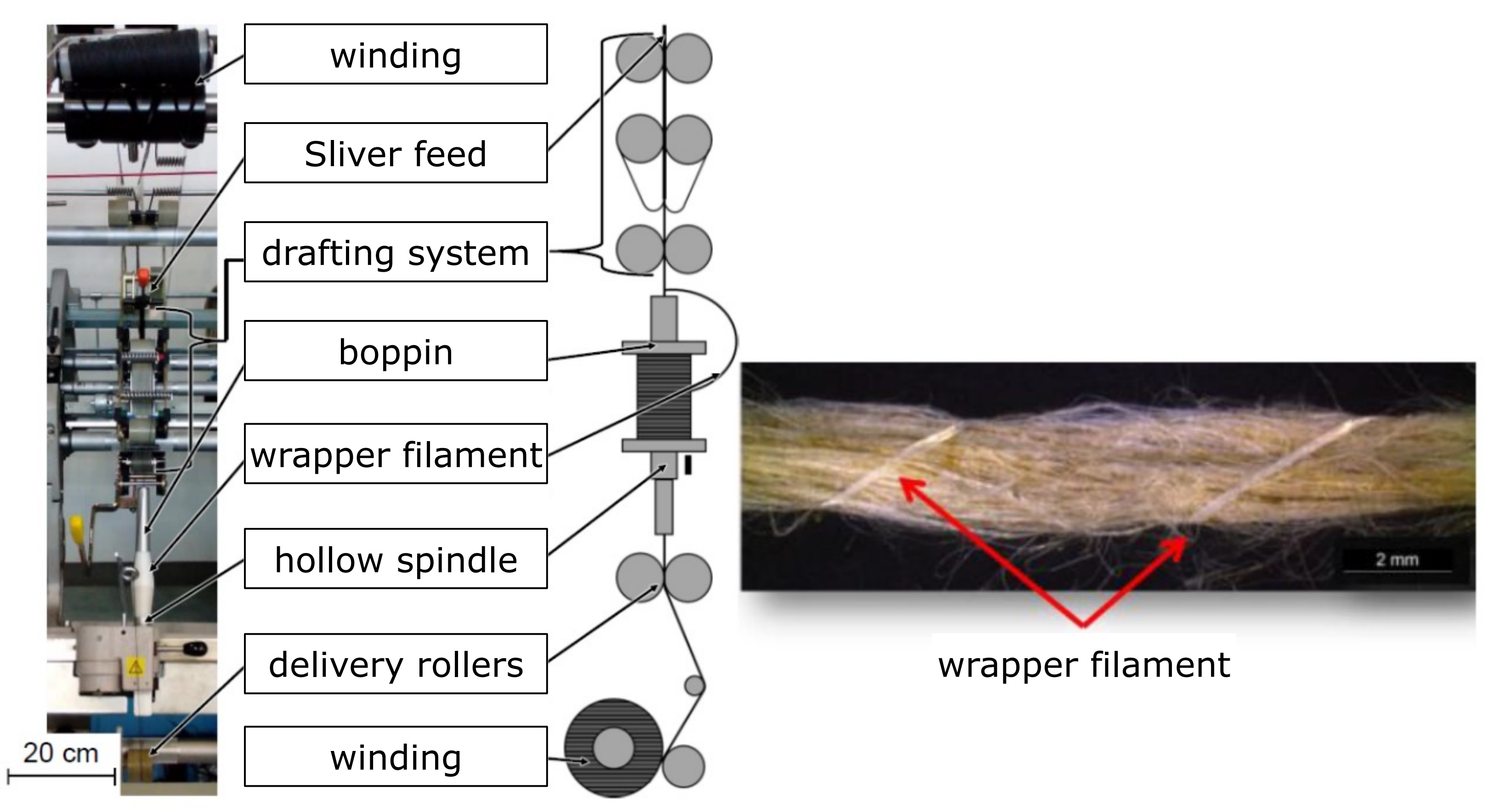
**All yarns produced in DuroBast:**
**low-twist staple fiber yarns through wrap spinning**

# Preparation of card sliver from PP and hemp for hybrid yarn

- Mixing of PP and hemp sliver by drawing
- Improved strength compared to 100 % hemp

# Manufacturing of low-twist yarn




## Advantages for NFRP:

- Higher fiber orientation in direction of force
- → higher strength of yarn, fabric and composite

## Manufacturing of fabrics

plain weave

twill weave

plain weave

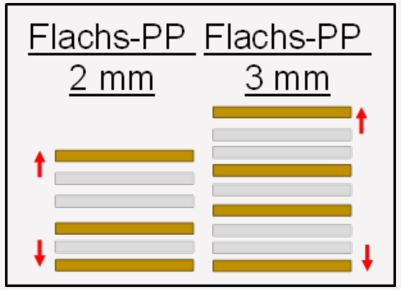
twill weave

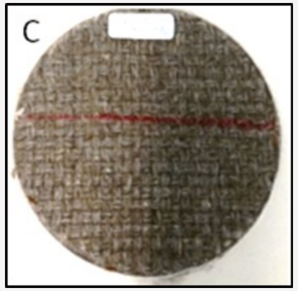
100% hemp

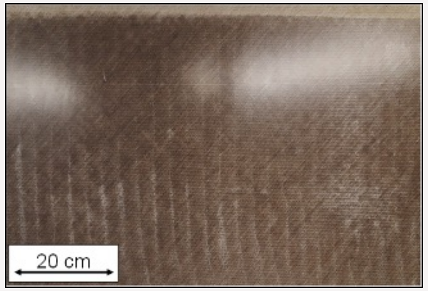
50% hemp / 50% PP

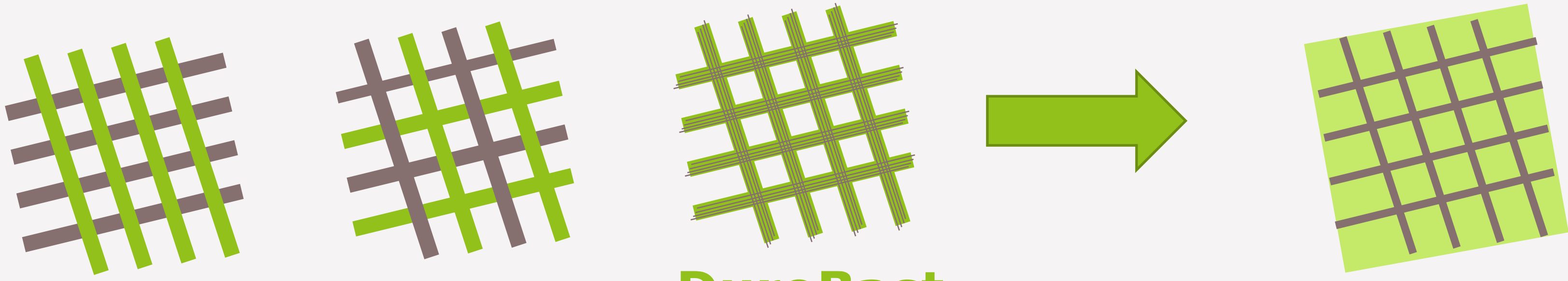
# Hybrid yarn und fabrics:

Hybrid yarn as new option for the preparation of composites as alternative to compression molding of natural fiber fabrics with polymer film or powder

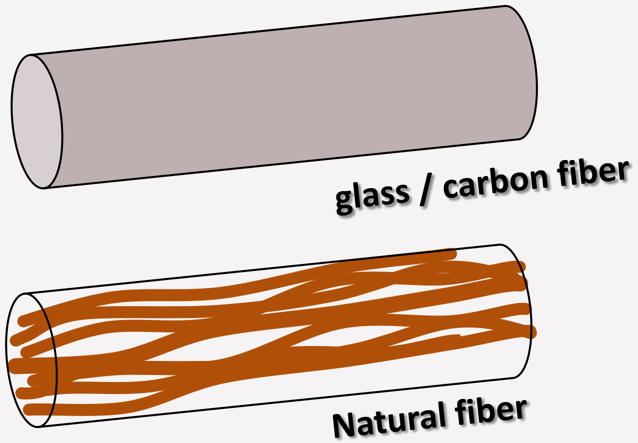



possible hybrid fabric structures **DuroBast**

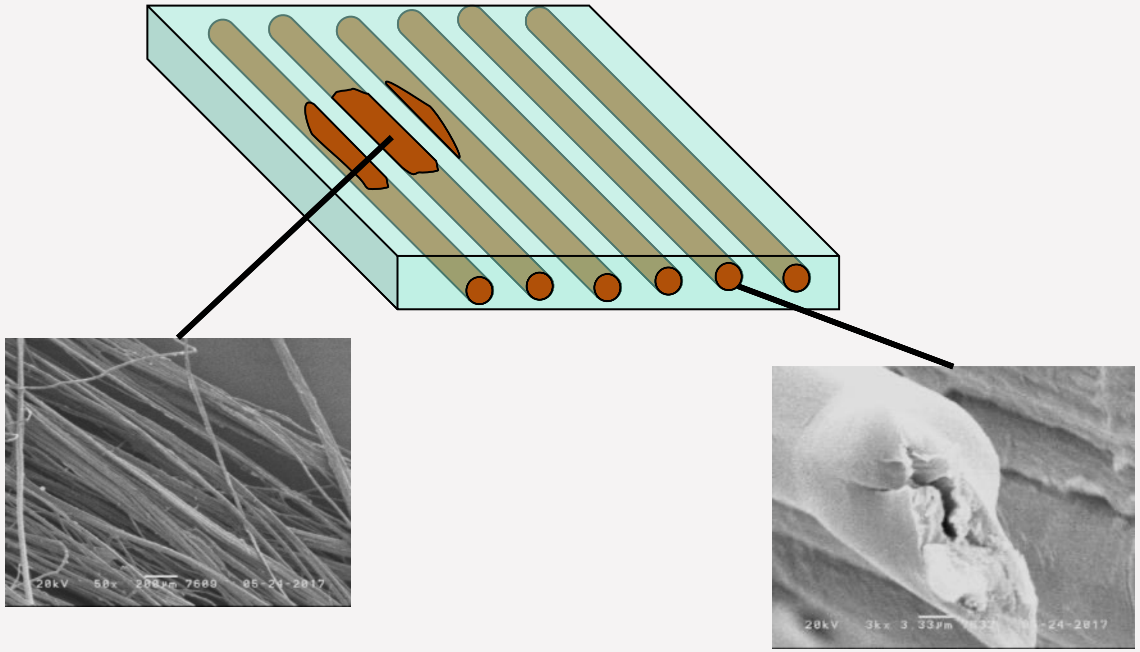
# Hydrophobisation of natural fibers




Natural fibers are no compact fibers like glass or carbon fibers

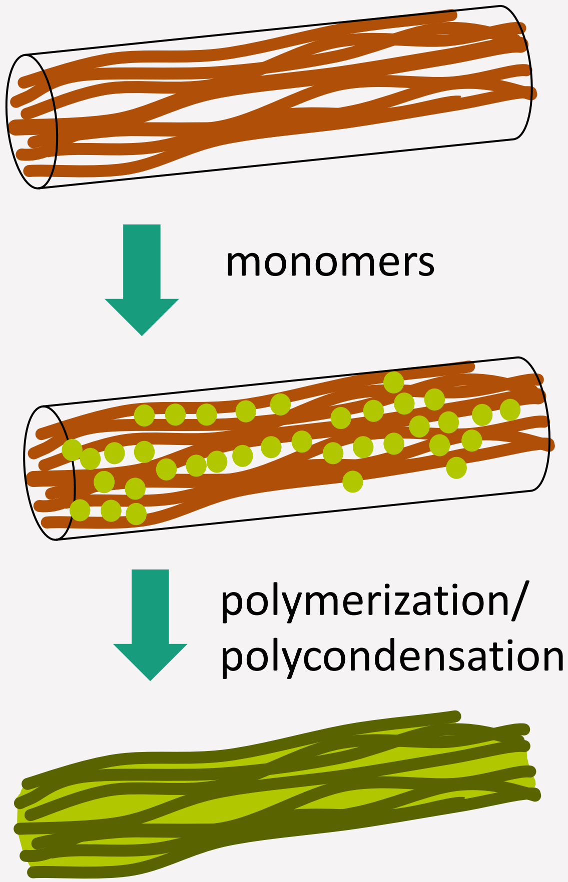
moisture can penetrate the fibers due to high polarity in the cavities and interstices by capillary forces

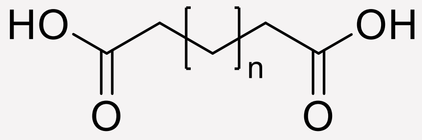
- In composites, fibers are protected by polymer under “normal” conditions
- “free” fibers at cutting edges and damages
  - → increased water uptake



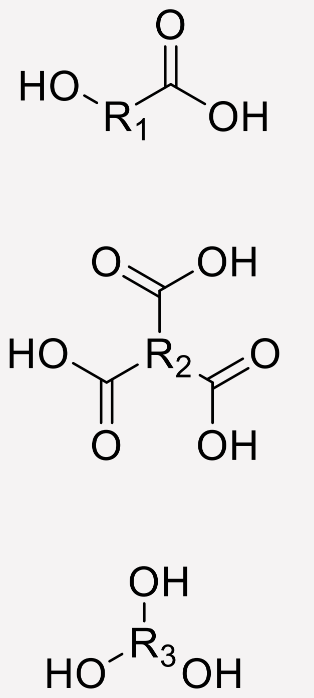
## Hydrophobisation of natural fibers

- Fibers can´t be filled completely by thermoplastics due to high viscosity
- Approach in „DuroBast“:
  - infiltration with hydrophilic monomers
    - bi- and multifunctional bio-based alcohols and carboxylic acids
  - interstitial polycondensation
  - After polycondensation:
    - Hydrophobic cross-linked poklymer network in the inner of the fibers



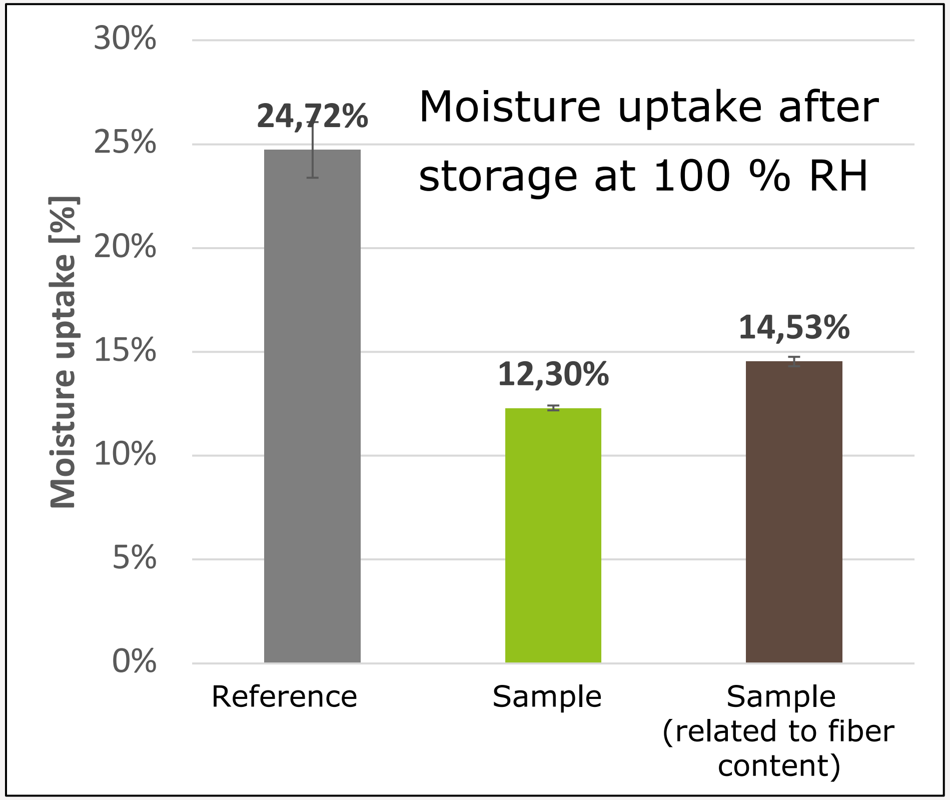




bifunctional acid

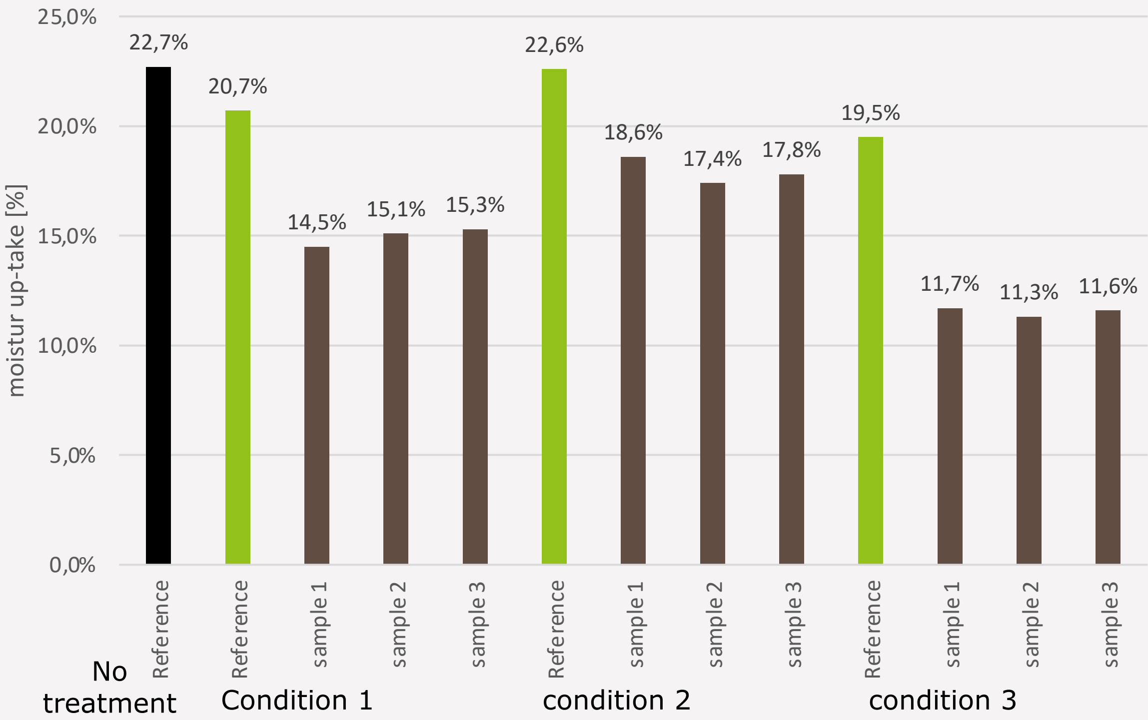


# Hydrophobisation of natural fibers

## After optimizing the formulation (-41%)

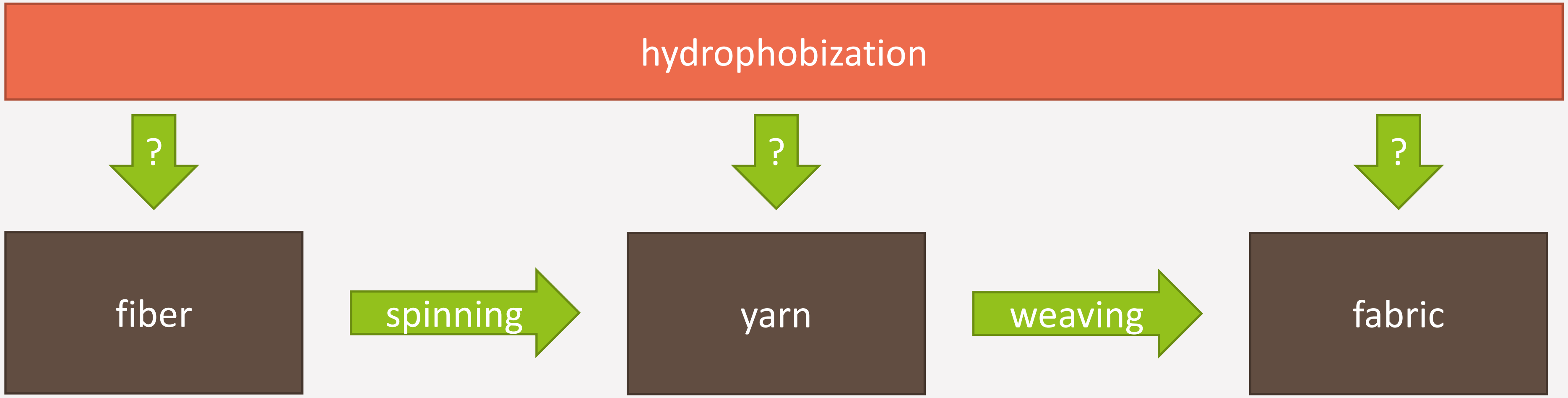



## After prozess optimization (-50%)



## Fiber hydrophobization:

Determining at which point in the process chain the modification takes place




- Increased stiffness observed after modification
  - → Spinning and weaving did not appear to be expedient in view of the existing challenges
  - **Decision in DuroBast: Fiber modification on the fabric**

# Fiber Impregnation during Hot Press Process

**Fiber impregnation as a multi-stage process**

Fiber and matrix stack is compacted (I+II)

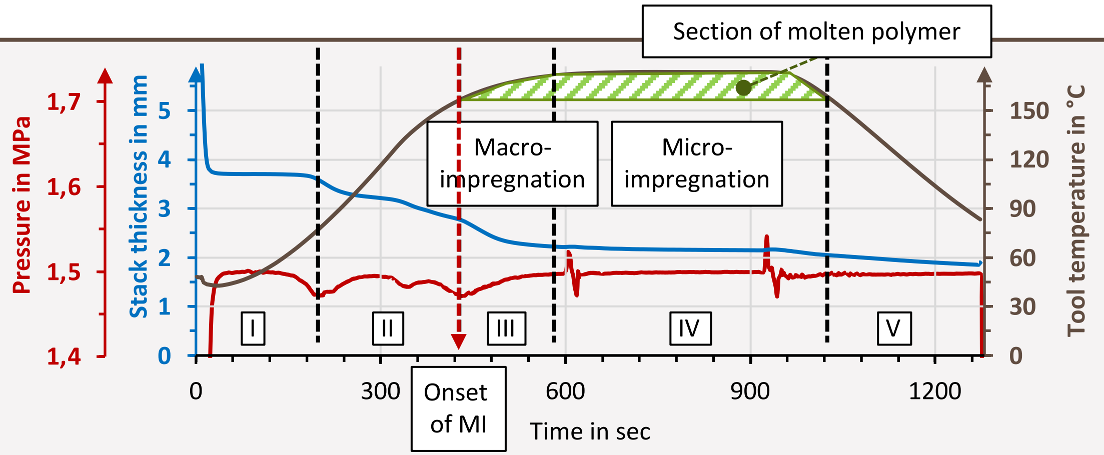
Macro-impregnation (III) starts with melting of the polymer

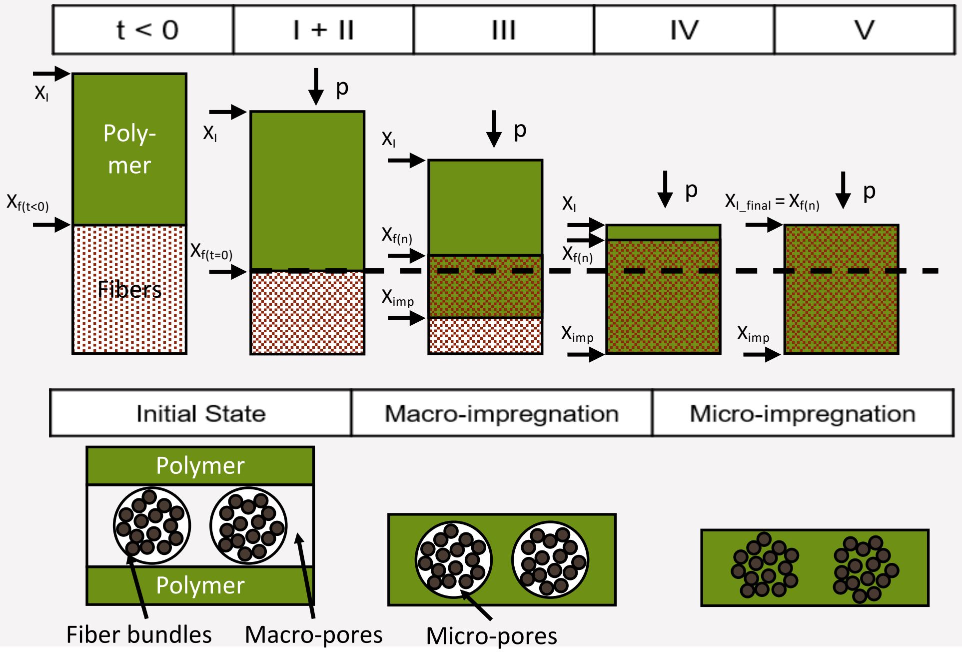
→ distribution around fiber bundles

→ Onset as a characteristic point

Micro-impregnation (IV) displaces air within fiber bundles

→ pore free composite



# Mechanical properties of organic sheets

**5 organic sheets with 3 bending specimen each**

**Effect of increasing pressure**

Increasing fiber volume content

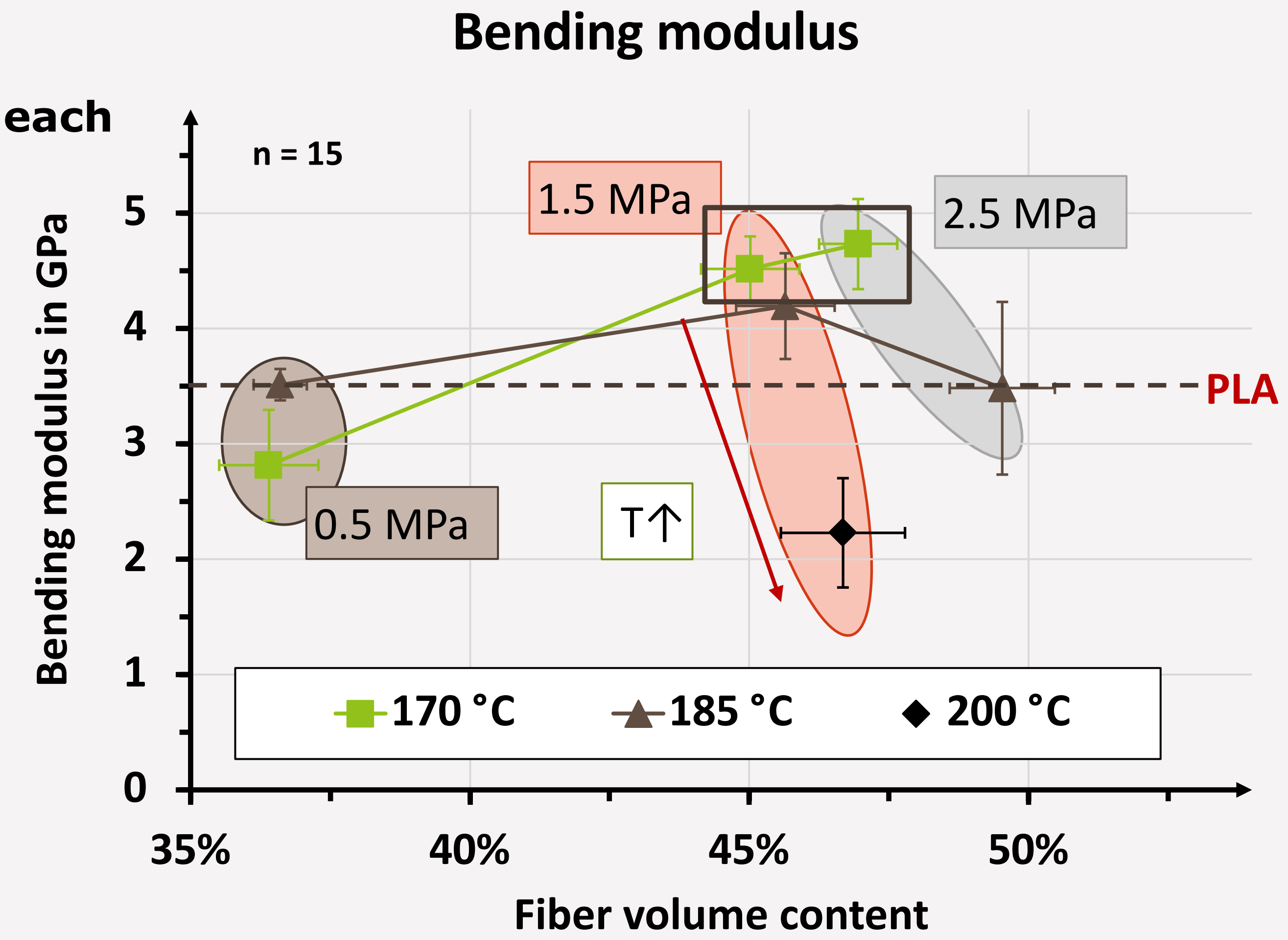
→ increasing bending properties

**Effect of increasing temperature**

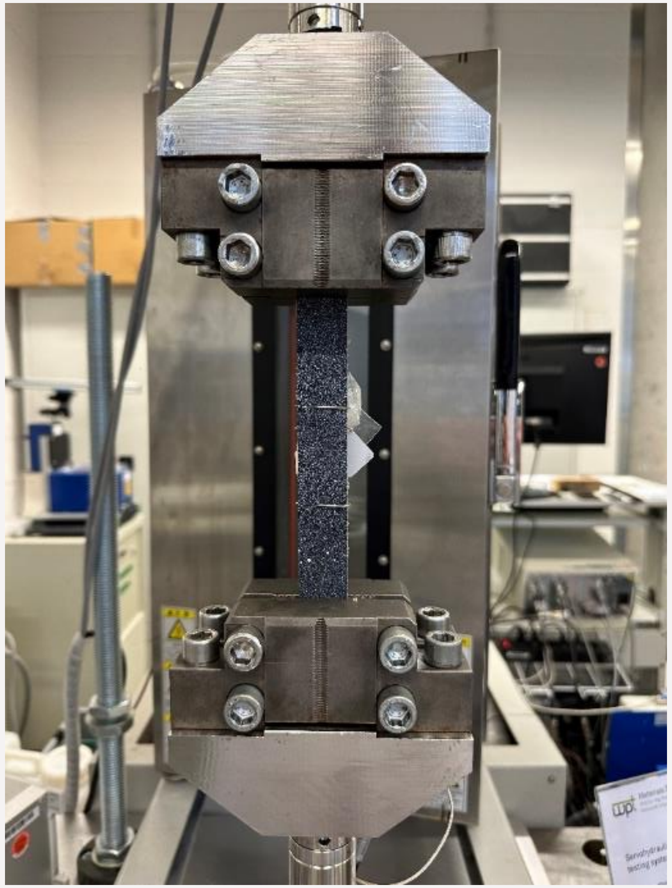
Decreasing bending properties

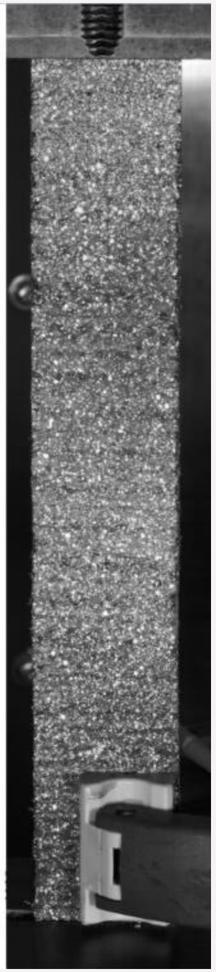
→ presumably due to matrix degradation

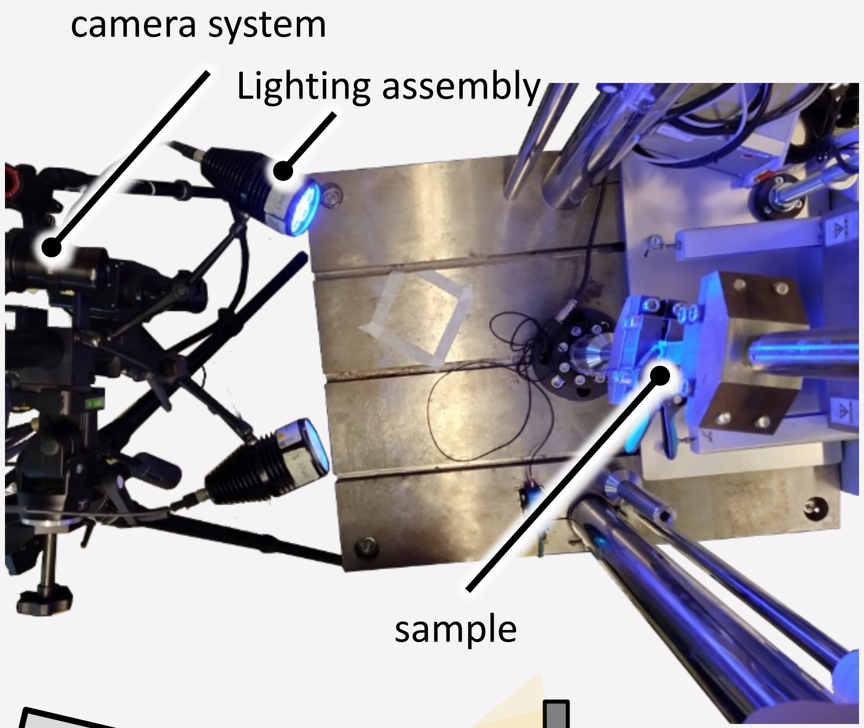
**Optimized process design leads to increasing properties**

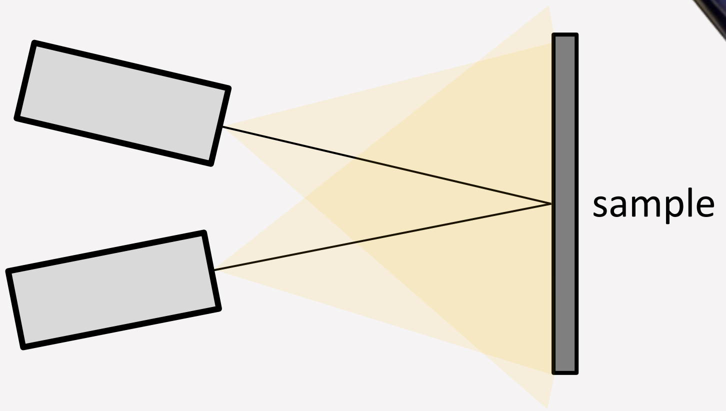


# Digital Image Correlation (DIC)

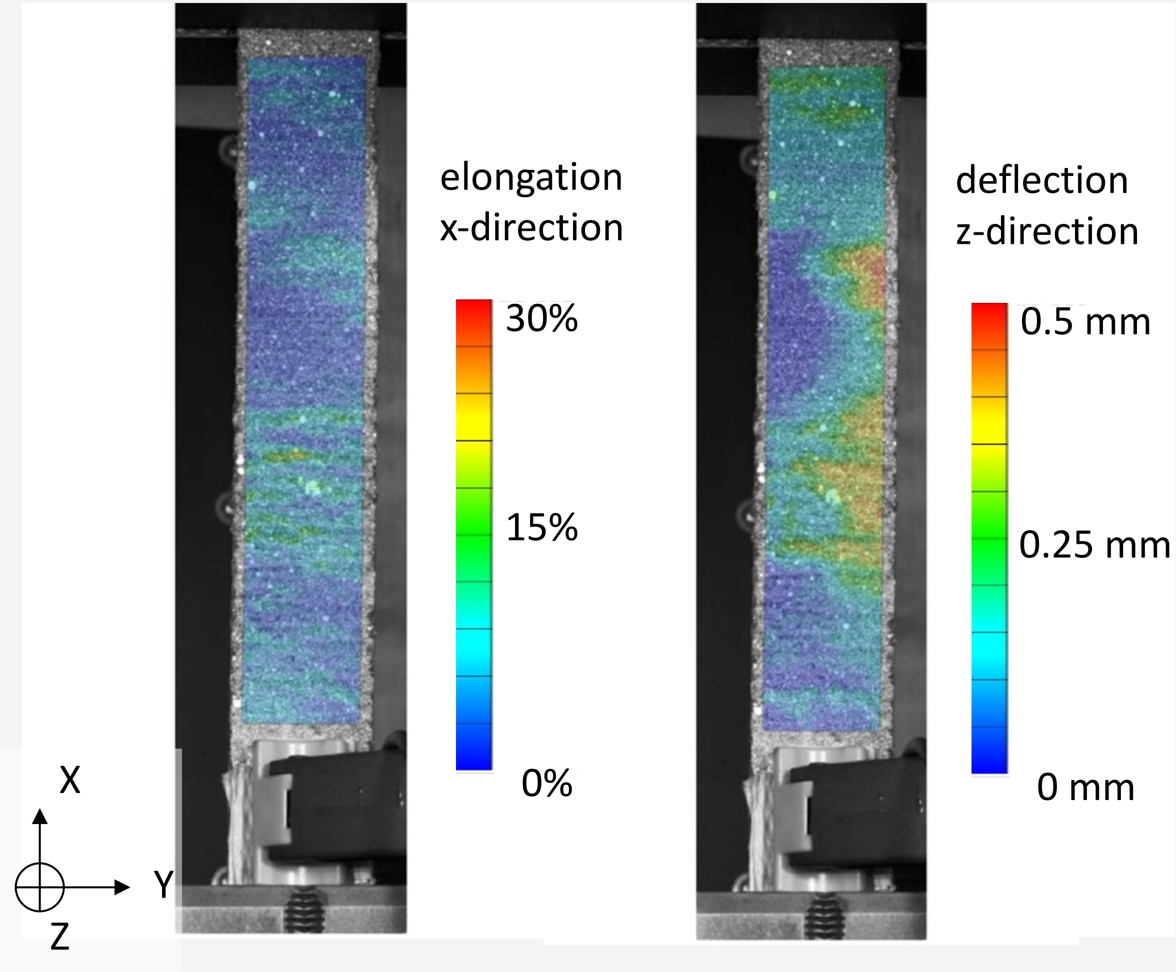




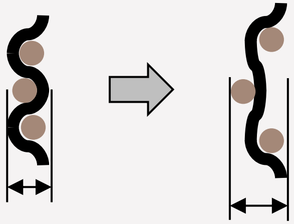


# Results from DIC




**Strain localisation in x-direction**



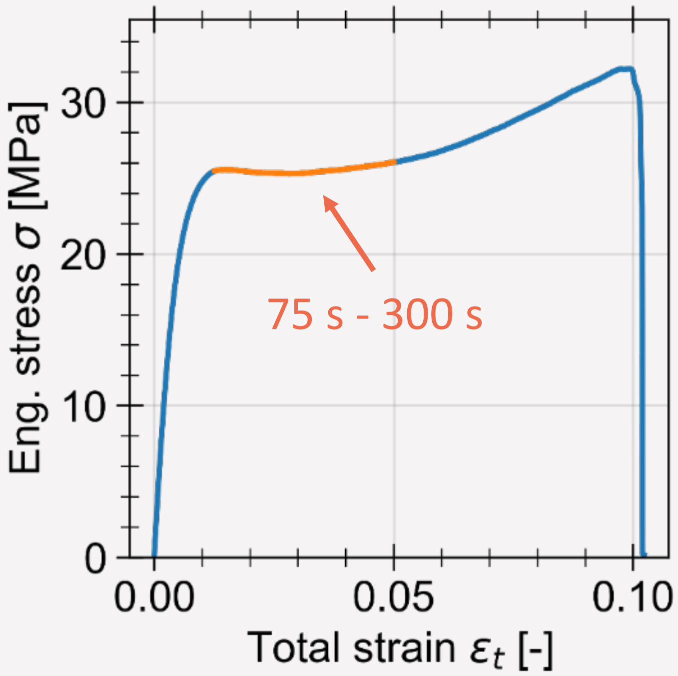
Decrease in ondulation at local sites

- Fiber-matrix delamination
- Local change of thickness

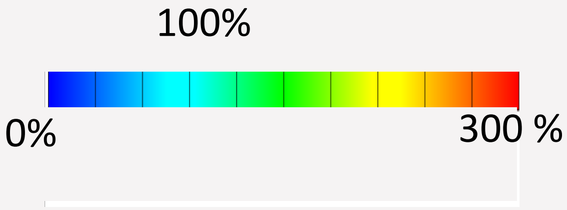
**Failure at points with low strains**

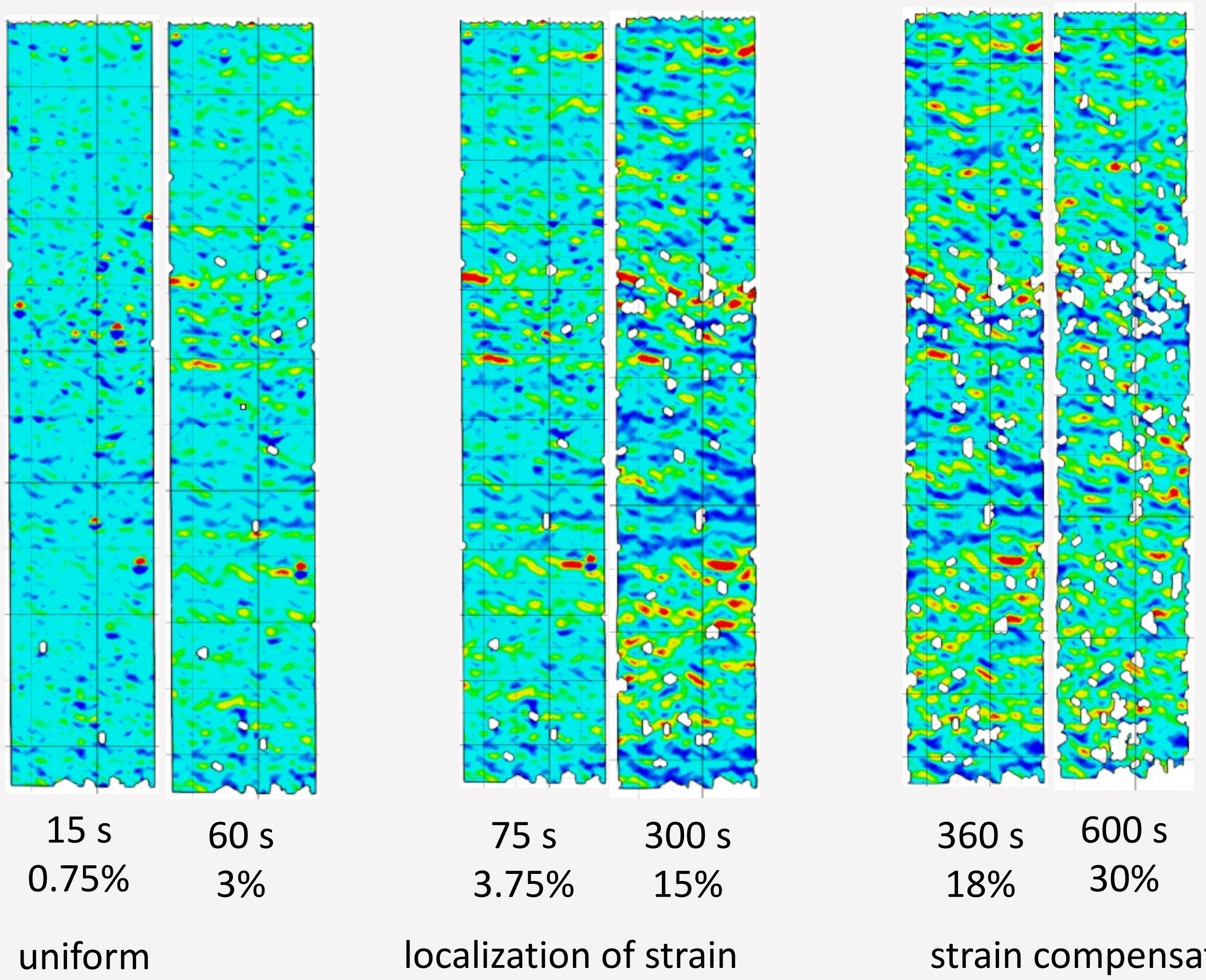
- Strain localization not an indicator of failure
- Decrease in ondulation does not lead to final specimen failure

# Results from DIC




strain [rel]
x-direction

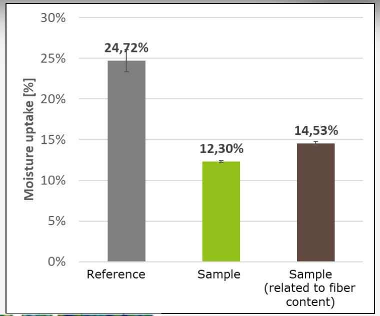


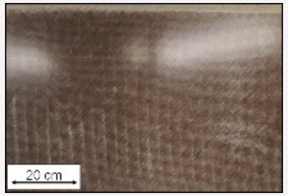



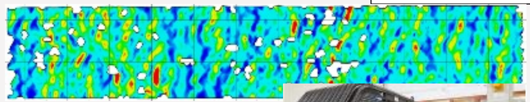
## Summary

- Use of hemp fibers advanageous
- First time production of fine no-twist yarns from non-woven fiber quality
- Manufacturing of different fabrics possible
- Fiber pretreatment (intersticial polymerization) → reduction of water up-take
- Manufacturing of organic sheets optimized (also possible with hybrid fabrics)
- New learnings about failure mechanisms
- Validation of the project results in demonstrators currently running
    - Automotive interiors, public transportation, sports equipment
- Economic study currently running







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