Development of low-cost flax fibre preforms for high-performance composites

FlaxPreComp

NANOFORCE research program
## The consortium

<table>
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<tr>
<th>Industrial partners (SMEs)</th>
<th>Research partners</th>
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<td>Wavalin cvba</td>
<td>KU Leuven</td>
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<td>Vlasbedrijf Verhalle nv</td>
<td>• MTM</td>
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<td>Vanacker Rubmeke bvba</td>
<td>• CIT – KULAK</td>
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<td>Eurolino bvba</td>
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<td>Soieries Elite nv</td>
<td>UGent</td>
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<tr>
<td>Flipts &amp; Dobbels nv</td>
<td>• Bioscience Engineering - Woodlab</td>
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- Flax fibre production
- Yarn spinning
- Weaving
Outline

Why flax?

Project goal: From plant to low-cost preforms

Project results

- Scutched flax fibre performance?
- How to assess the fibre potential?
- Monitoring UD preform quality
- Low-twist & low-crimp yarns and weaves

Conclusions & outlook
Flax: a natural and durable material

Why flax?

✓ Renewable resource
✓ Recyclable (thermal)
✓ Biodegradable
✓ CO$_2$ neutral

Flax: a natural and durable material

Why flax?

- Renewable resource
- Recyclable (thermal)
- Biodegradable
- CO$_2$ neutral
- Low embodied energy

![Graph showing production energy comparison between natural fiber mat, glass fiber mat, and carbon fiber. The graph indicates that carbon fiber has the highest production energy at 286 MJ/kg.](image-url)
Composites: embodied energy/liter

Embodied Energy (MJ/liter) vs. Fibre volume fraction (%)

- Only polymer
- Only carbon fibres
- Hybrid CF + flax
- Only Glass fibres
- Only flax fibres
Flax fibres: light and stiff

Specific stiffness = stiffness / density

- Key design parameter for **lightweight** constructions
- Indicates weight benefit → energy reduction during use phase
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Conclusions & outlook
Location of the fibres in the stem

Charlet et al., 2011
Extracting flax fibres for non-technical preforms

Retting → Scutching → Hackling → Doubling/stretching → Roving bench → Spinning → Weaving

Random mat 2D
Extracting flax fibres for technical preforms

Retting

Scutching → Hackling → Doubling/stretching → Roving bench → Spinning

Random mat 2D

Misalignment

NOT IDEAL FOR COMPOSITE APPLICATIONS

Increasing cost – fibre damage - misalignment
Extracting flax fibres for technical preforms
Extracting flax fibres for technical preforms
Extracting flax fibres for technical preforms

- Retting
- Scutching
- Hacking
- Doubling/Stretching
- Roving bench
- Spinning
- Weaving

Novel method of alignment
Novel fixation methods

Increasing cost – fibre damage - misalignment
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Conclusions & outlook
Assessing the fibre potential

Four main factors:

1. Fibre diameter
2. Purity (amount of shives)
3. Fibre damage
4. (Intrinsic fibre quality)

Scutched flax fibre screening protocol

Also applicable for other flax fibres
Protocol

- Fibre diameter distribution
- Purity of the fibre
- Mechanical properties of the fibre
Assessing the fibre potential – fibre diameter

• Fineness index
  • Single value
  • No real diameter distribution

• Gravimetric method

• Optical method
  • Manual
  • automated
Assessing the fibre potential – fibre diameter
Assessing the fibre potential – fibre diameter
Assessing the fibre potential – fibre purity

- Combing(hackling) of scutched flax
  - 20 combings
  - 3 combs
  - Manual or using mechanical device
- Weight loss ≈ impurity
Assessing the fibre potential – fibre strength

- Stelometer test
  - Bundle strength
  - Not relevant for composites

- Single fibre test
  - Technical fibre
    - Large variation
    - Not relevant for composites
  - Elementary fibre
    - Difficult sample preparation
    - Results not fully representative for composites

- Impregnated fibre bundle test
Composite performance of scutched fibres

Longitudinal properties/performance
Impregnated fibre bundle test

• Embedding fibres in matrix system

• Loading the composite material in tension

• Calculate stiffness, strength and failure strain
Composite performance of scutched fibres

Transverse properties/performance
Longitudinal performance of scutched fibres is (nearly) identical to hackled fibres.
Assessing the fibre potential – fibre damage

No significant effect on composite properties

Thygesen et al. 2006
Assessing the fibre potential – fibre damage
Extracting flax fibres for technical preforms

Retting

Scutching → Hacking → Doubling/Stretching → Rovine bench → Spinning

 Novel method of alignment

 Novel Fixation methods

Weaving

UD-preforms

Increasing cost – fibre damage - misalignment
Monitoring Fibre orientation in UD preforms

Optical (surface)

CT (thickness)

Input to predict composite properties

Excellent longitudinal performance of composites
Transverse performance of scutched fibres

Transverse performance of scutched fibre composites is lower.

A mild refinement operation increases performance by 25%.
Low-twist yarns and low-crimp weaves

**Low-twist yarns** → decreased misorientation of the fibres
→ reduced dry yarn strength!

Lower twist in yarns → decreased crimp in weaves

- Elliptical yarn shape
- Winding filament

- High crimp
- Low crimp
Performance of low-crimp weaves

Normalised to Vf = 40%
Except for random mats = 30%

\( V_f = 30\% \)

F. Bensadoun, 2016
Performance of low-crimp weaves

Normalised to Vf = 40%
Except for random mats = 30%

Mats

FlaxPreComp
Weaves

Tensile Modulus (GPa)

0° UD

0/90 UD

Vf = 30%
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Conclusions & outlook
Conclusions

Retting

Scutching → Hacking → Doubling/stretching → Roving bench → Spinning

Novel method of alignment

Novel Fixation methods

Increasing cost – fibre damage - misalignment
Conclusions

✓ Developed a novel alignment and fixation method to produce low-cost preforms, starting from scutched flax fibres

✓ Properties equal that of hackled fibre composites
Conclusions

Retting → Scutching → Hacking → Doubling/Stretching → Roving bench → Spinning → Weaving

Novel method of alignment
Novel Fixation methods

Increasing cost – fibre damage - misalignment
Conclusions

- Developed a **novel alignment and fixation method** to produce **cost competitive** preforms, starting from scutched flax fibres.

- Properties equal that of hackled fibre composites.

- **Fibre orientation** in the preforms *can be monitored* through surface scans.

- **Low-twist yarns and low-crimp weaves** have been produced successfully.
Outlook

✓ Optimization of tape quality needs **dedicated machinery** where fine tuning of several parameters is possible

✓ Industrial **upscaling**

✓ Development of an **appropriate business model**