Hemp fibre composite - potentials and applications

Jörg Müssig & Nina Graupner

Hochschule Bremen - University of Applied Sciences, Biomimetics,
The Biological Materials Group, Germany

12th International Conference of the European Industrial Hemp Association (EIHA)

EIHA European Industrial Hemp Association

nova Institut für Ökologie und Innovation

20 - 21 May 2015, Wesseling, Germany
nova-Institut (Organizer)

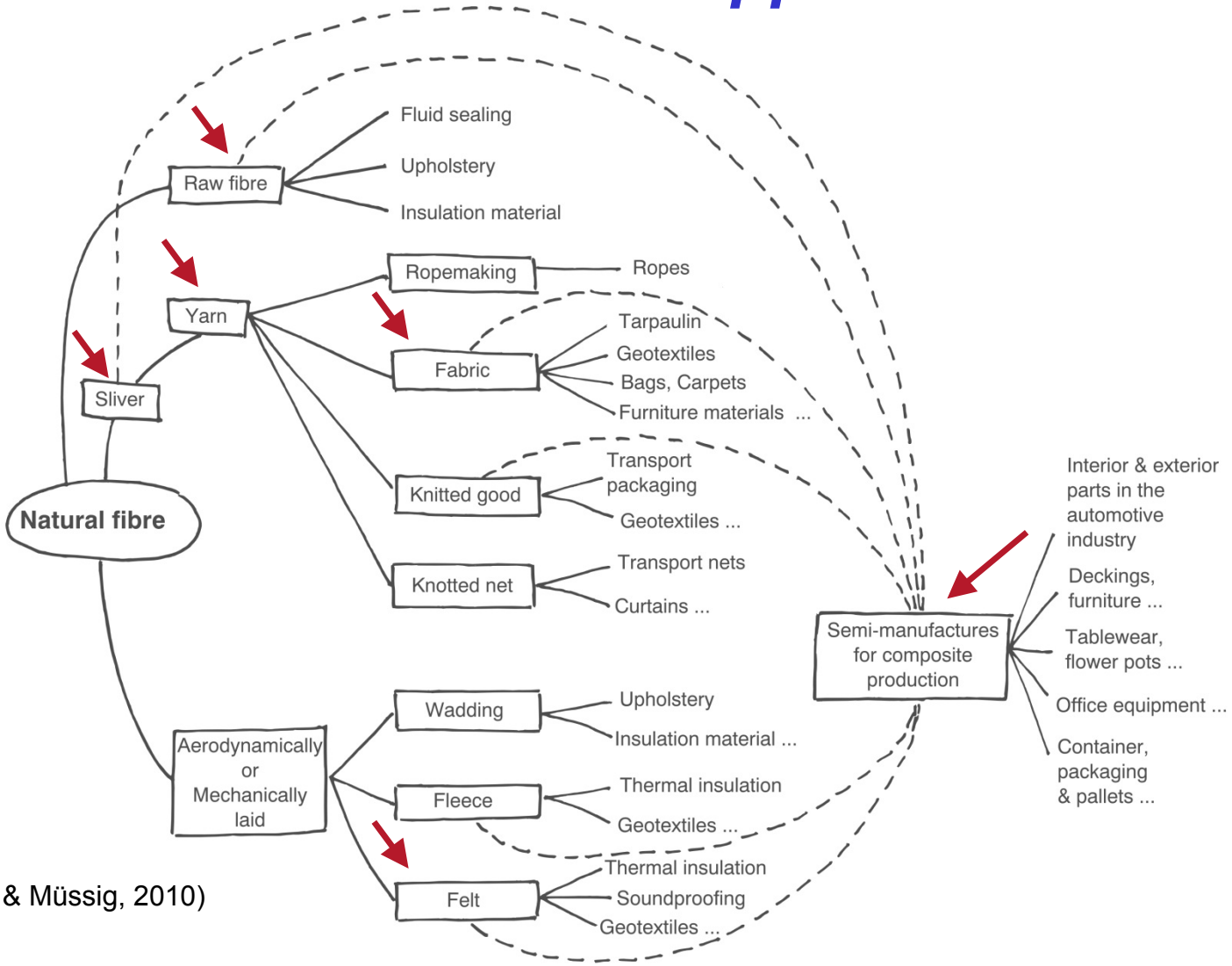
Outline

(JEC Conferences, 2012)

- Hemp Fibres for Technical Applications
- Reinforcement: Fibres
- Natural Fibre-Reinforced Composites - NFRC
- Compression & Injection Moulding and Pultrusion

Guiding Question: „For which applications is hemp suitable and what is the reinforcement potential of hemp fibres?"

Hemp Fibres for Technical Applications



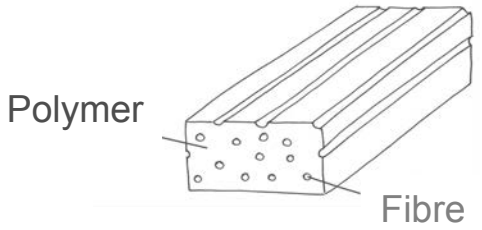
(Graupner & Müssig, 2010)

Different uses of natural fibres in industrial applications.

Fibres & Composites

(JEC Conferences, 2012)

Fibre & Composite Properties



Fibre properties	Composite properties		
	Strength	Young's Modulus	Impact
Length ⇑	+	≈	++
Diameter ⇓	+	+	+
Strength ⇑	++	++*	+
Young's Modulus ⇑	++*	++	--
Elongation ⇑	-**	-**	++
Interphase ⇑	++	+	-
Dislocations ⇑	-	-	--

- decrease / -- strong decrease / + increase

++ strong increase / ≈ low influence

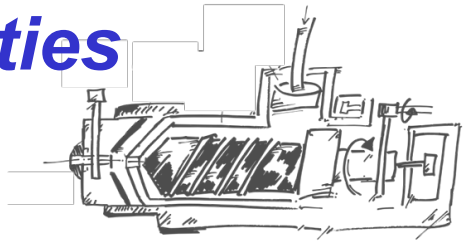
* in general fibres with a high Young's modulus show high strength values & vice versa

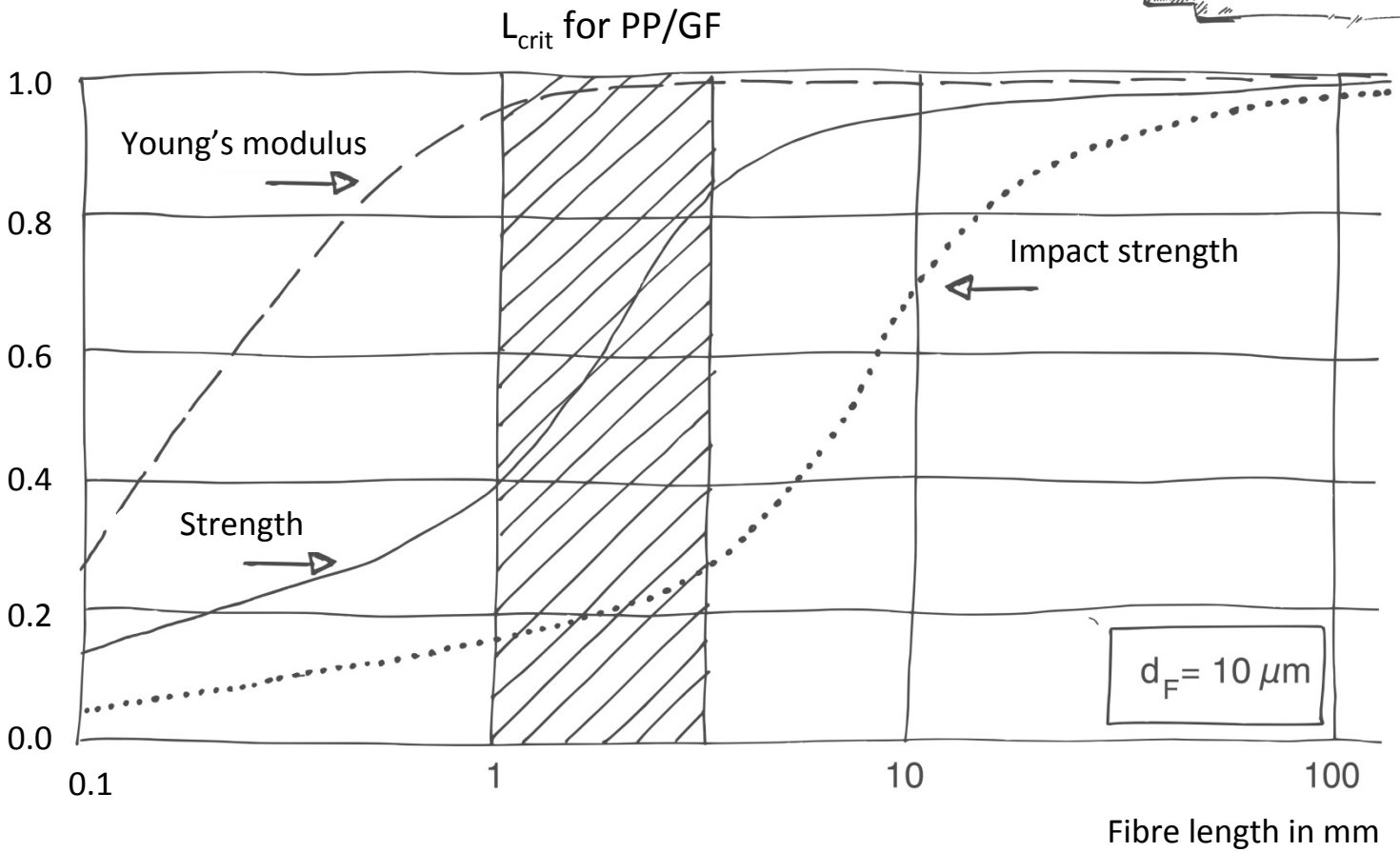
** in general fibres with high elongation show lower strength and Young's modulus values

⇨ Influence of fibre properties and characteristics on composite properties

(Müssig & Hughes, 2012)

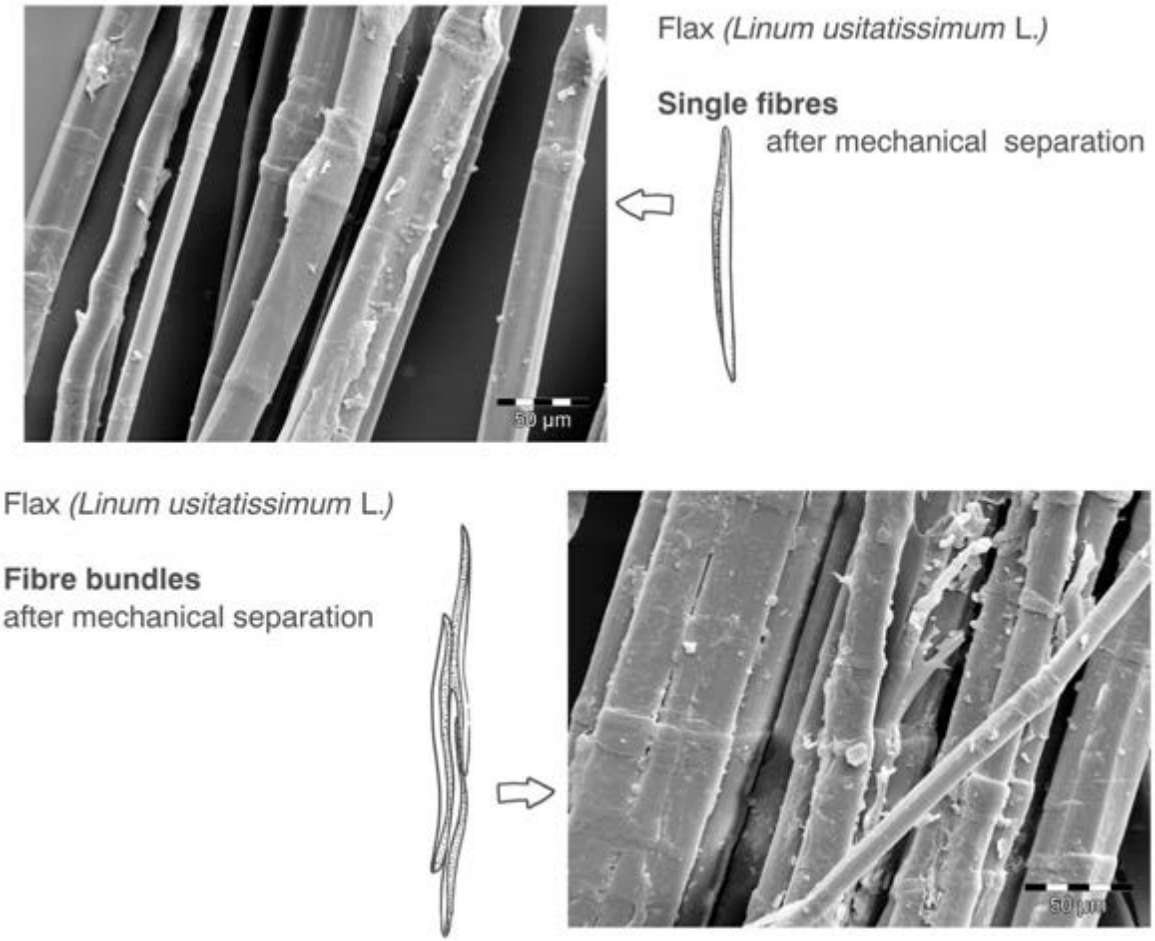
Fibre Length & Composite Properties





Influence of fibre length on the mechanical properties of glass fibre-reinforced polypropylene. (adapted from Bürkle et al., 2003)

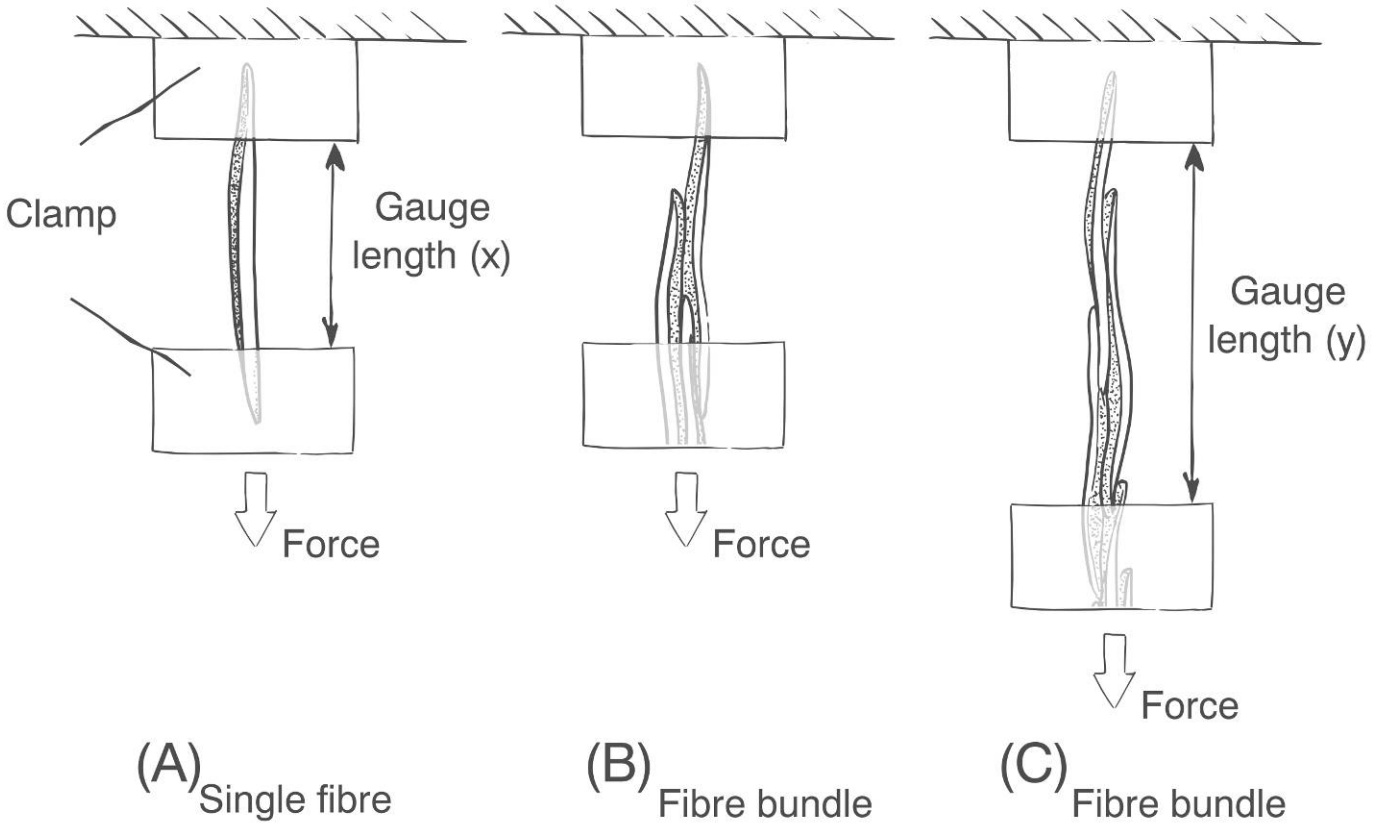
Fibre Morphology



Scanning electron micrographs of single flax (*Linum usitatissimum* L.) fibres (upper image) and flax fibre bundles of variable width and a single fibre in front (lower image).

(Müssig & Hughes, 2012)

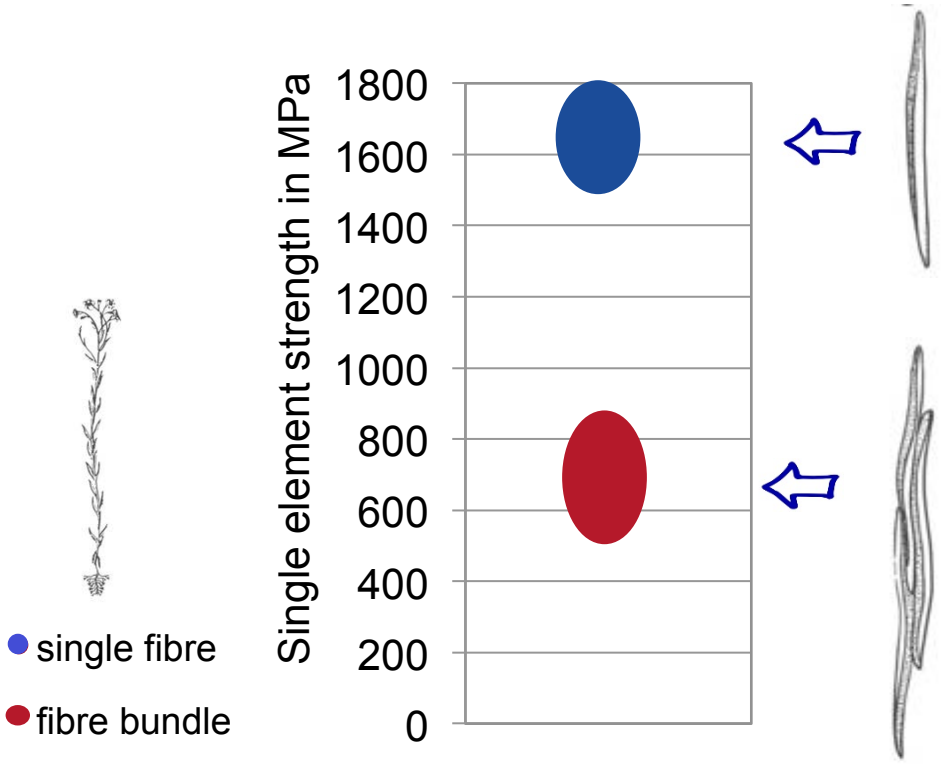
Mechanical Properties – part I



Various testing methods to determine the tensile properties of plant fibres and fibre bundles. (A) Single fibre fixed in clamps at a gauge length (x). (B) A fibre bundle prepared for tensile testing with the same gauge length (x) as the single fibre. (C) Fibre bundle with a greater gauge length (y).

(Müssig & Hughes, 2012)

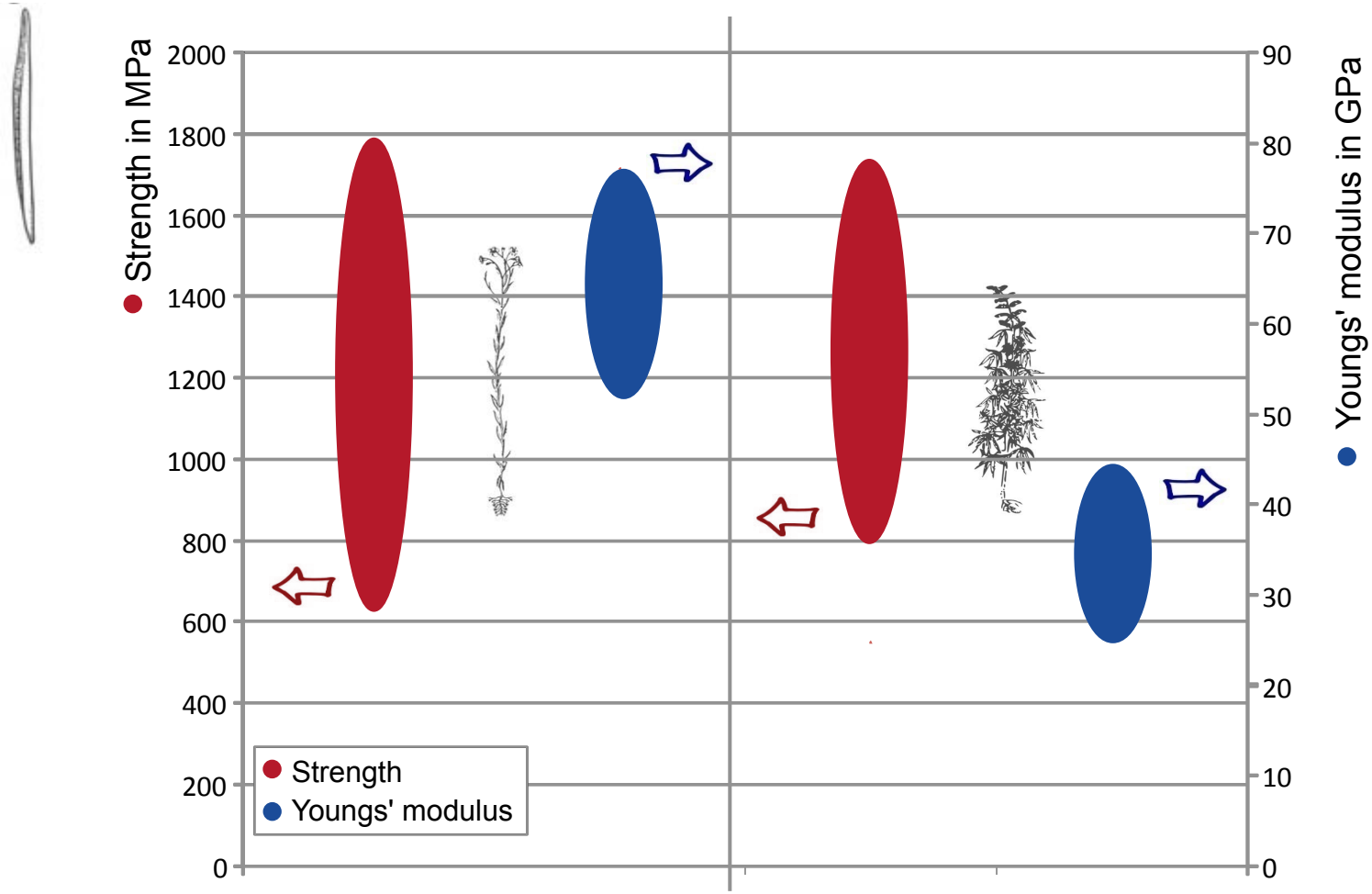
Mechanical Properties – part II



Strength values for single flax fibres and single flax fibre bundles.

(values taken from Bos et al., 2002)

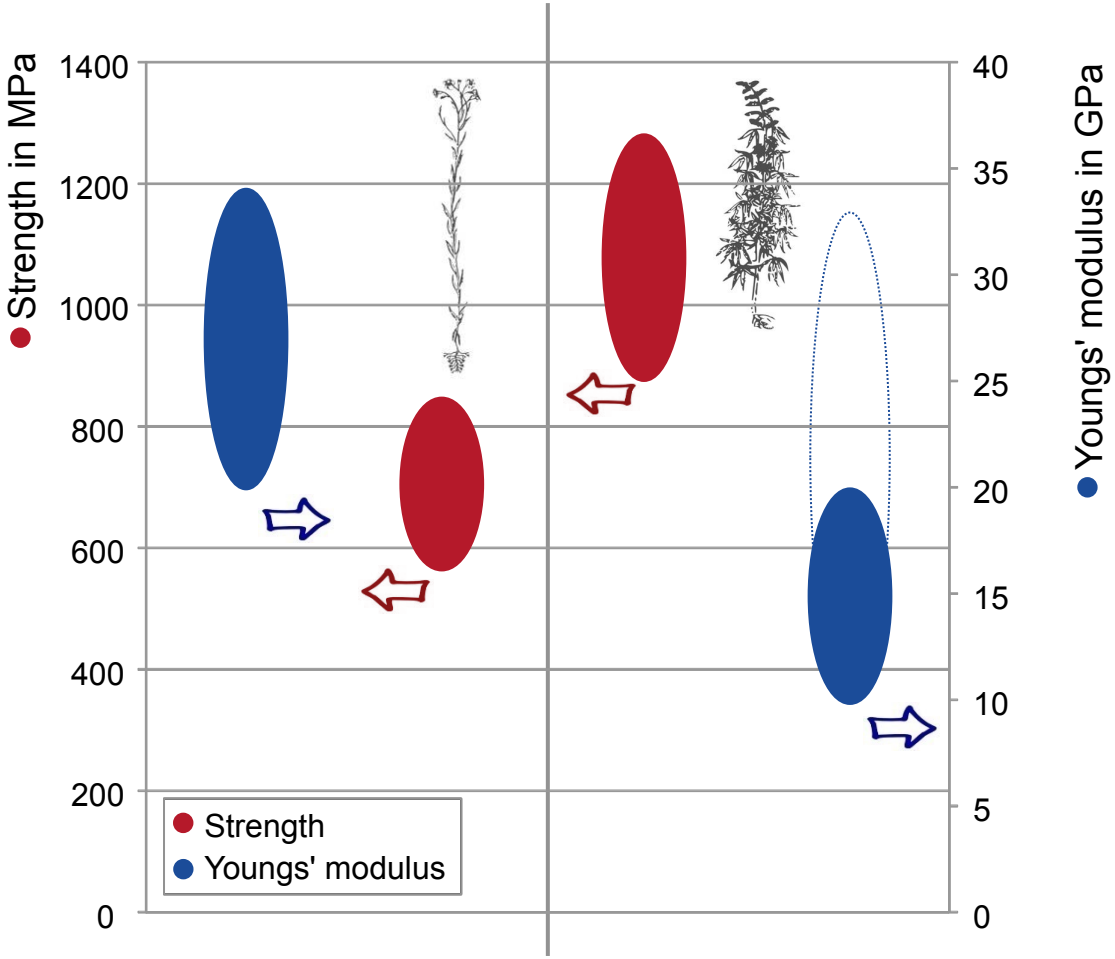
Mechanical Properties – part III



Tensile properties of single bast fibres – flax versus hemp.

(values taken from Bourmaud & Baley, 2009; Eder & Burgert, 2010 for hemp / Baley, 2002; Charlet et al., 2006 & 2007; Eder & Burgert, 2010 for flax)

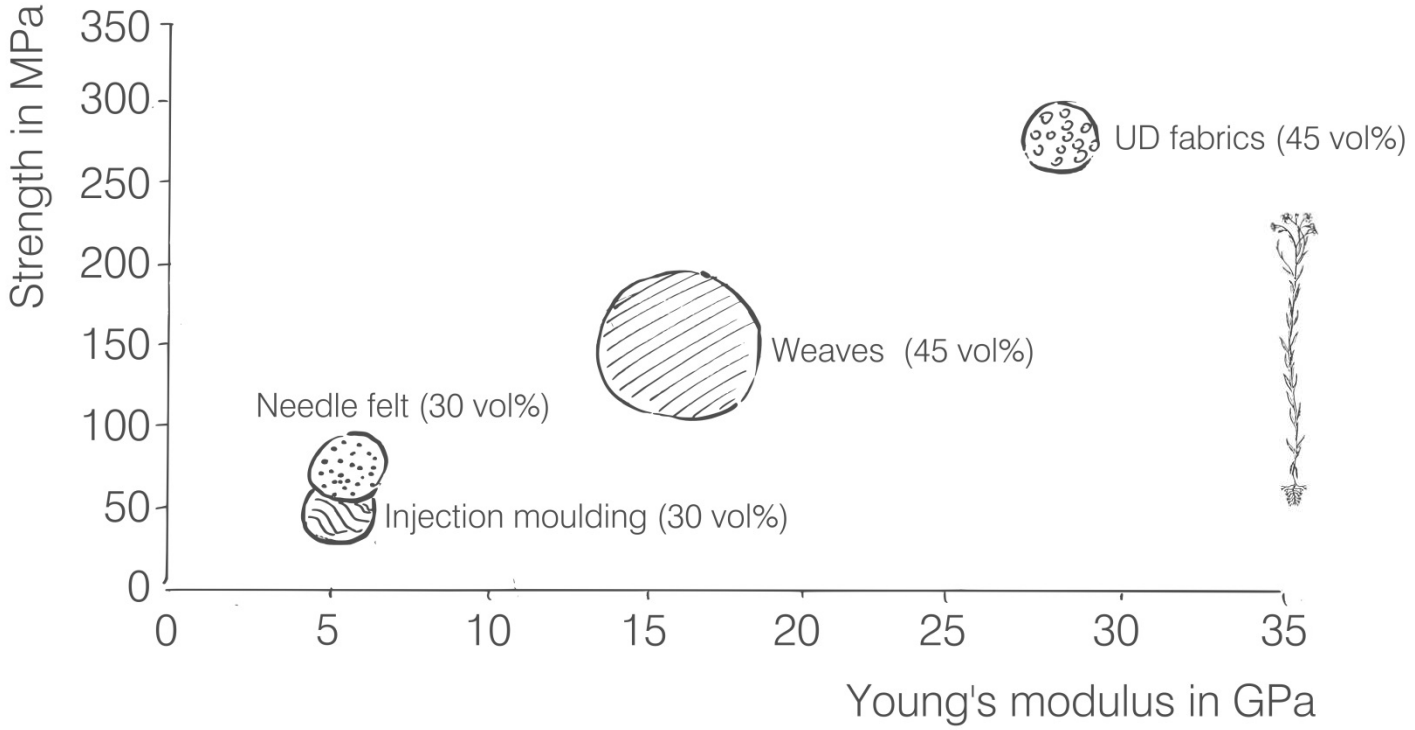
Mechanical Properties– part IV



Tensile properties of single bast fibre bundles – flax versus hemp.

(values taken from Haag & Müssig, 2012 & 2013 for flax / Graupner et al. 2009; not published own results for hemp)

Flax Fibre Reinforced Composites



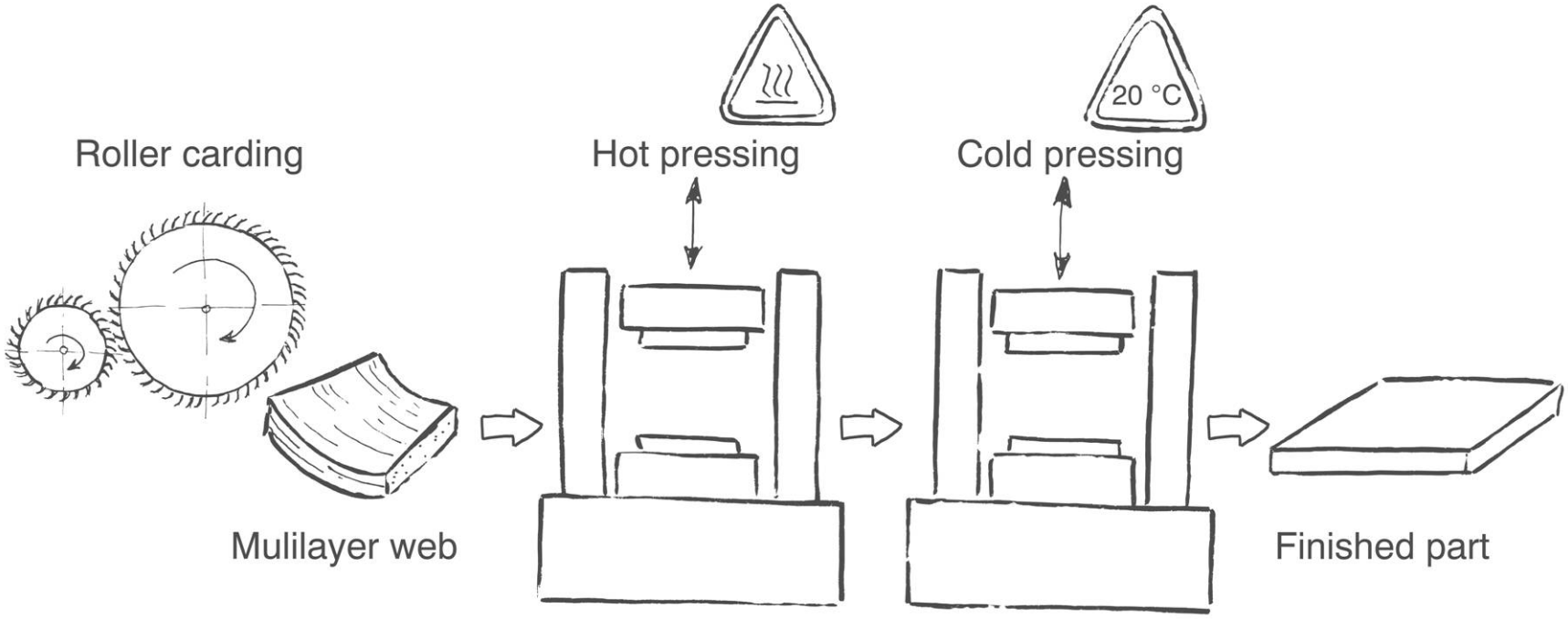
?

...

The performance playground for flax composites.

(adapted from Verpoest & Baets, 2012)

Compression Moulding using Hemp Fibres – part I



(Müssig et al., 2011)

Roller card to form hemp fibre bundles and PLA fibres to a multilayer web; compression moulding of PLA/hemp composites.

Compression Moulding using Hemp Fibres – part II

Hemp needle felts as a reinforcement for press moulded parts.

Compression Moulding using Hemp Fibres – part III

Projectdetails:

Year: 2012

Account: Hemp Chair

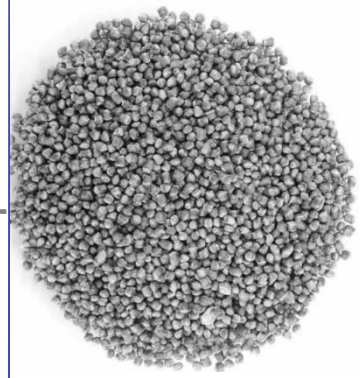
Design: Werner Aisslinger

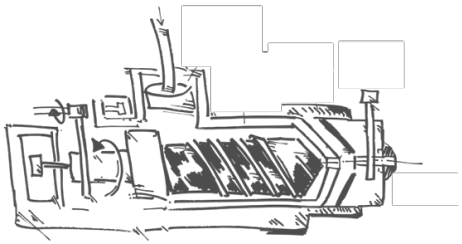
Producer: Moroso

Partners: BASF

Werner Aisslinger presents with MOROSO a natural fibre Monochair: Natural fibres like hemp are moulded under heat with a BASF Acrodur resin into a sustainable composite material. (Aisslinger, 2012)

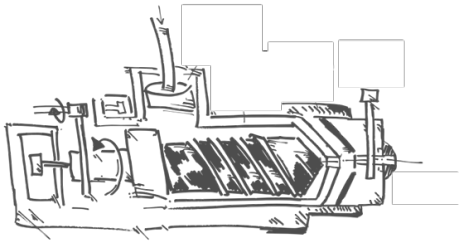
Injection Moulding using Hemp Fibres – part I

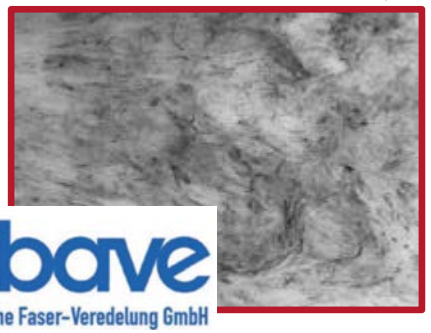




(CELC, 2010)

Rear view mirror insert; injection moulded part (compounded granules: 30 % Hemp/PP); Peugeot 207.





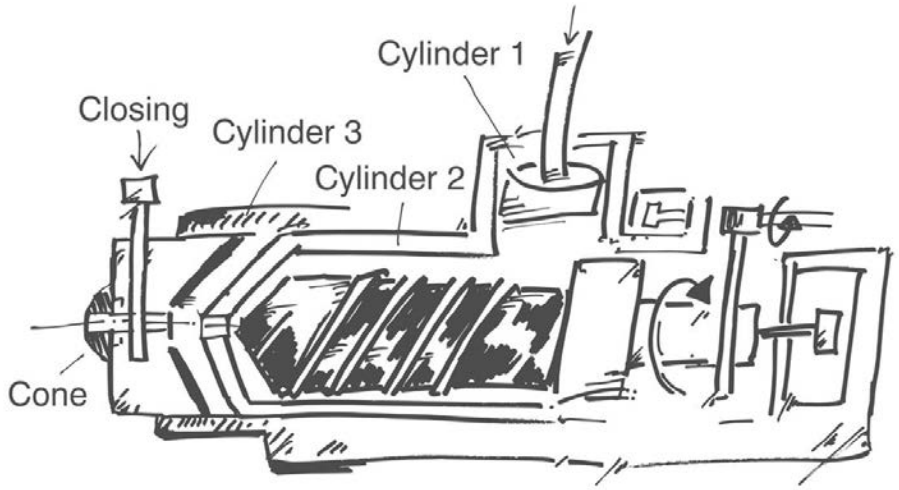
HIB TRIM PART SOLUTIONS

bave Badische Faser-Veredelung GmbH

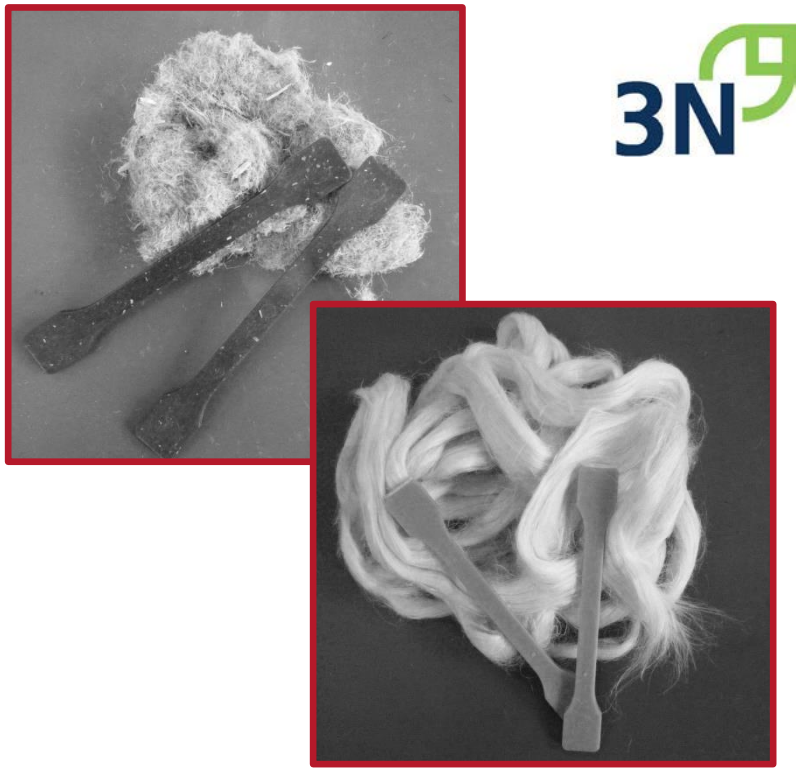
HIB Trim Part Solutions GmbH (DE): Nature 50 – Natural fibre-reinforced plastic (Hemp – PP) including a high fibre ratio > 50 %.

NFRC- potential & applications for hemp

Injection Moulding using Hemp Fibres – part II



(Huber, Graupner & Müssig, 2010, S. 414)

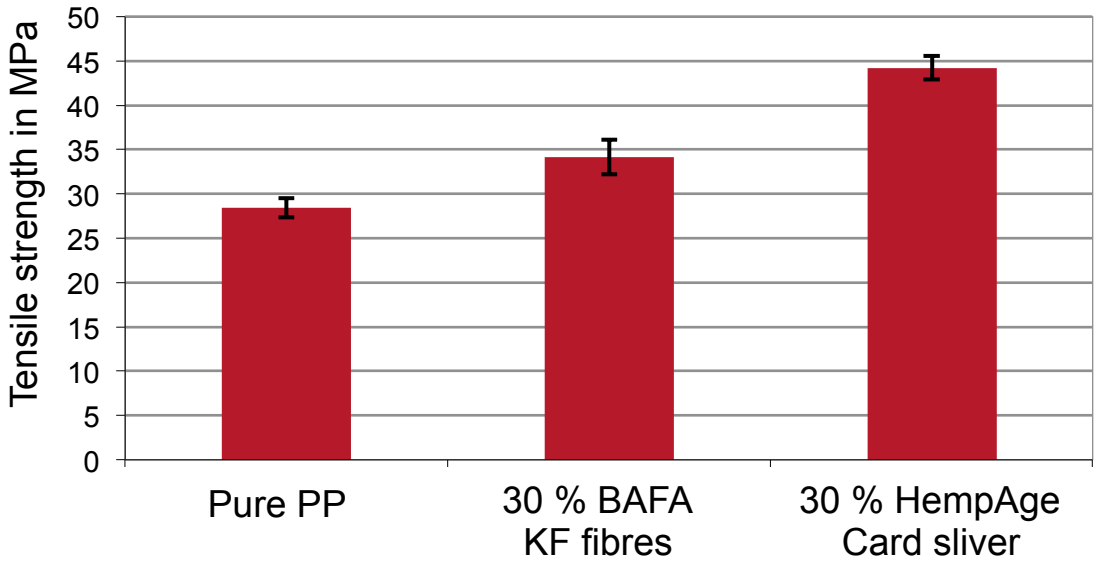


Processing parameters:

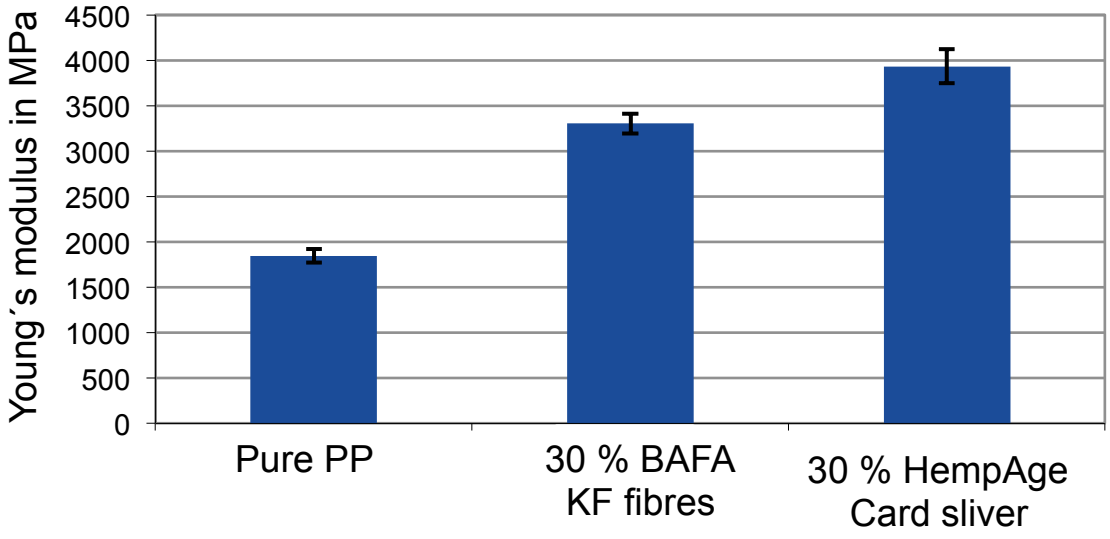
- Arburg 320C, Allrounder 600-250 (screw diam. 30 mm)
- Temperature profile in °C: 170, 172, 175, 177, 180 and 180 °C

Compounding & injection moulding of PP/hemp samples (30 mass-% of hemp fibre bundles; PP: LyondellBasell - Moplen EP600V + 5 % a.p.).

Injection Moulding using Hemp Fibres – part III

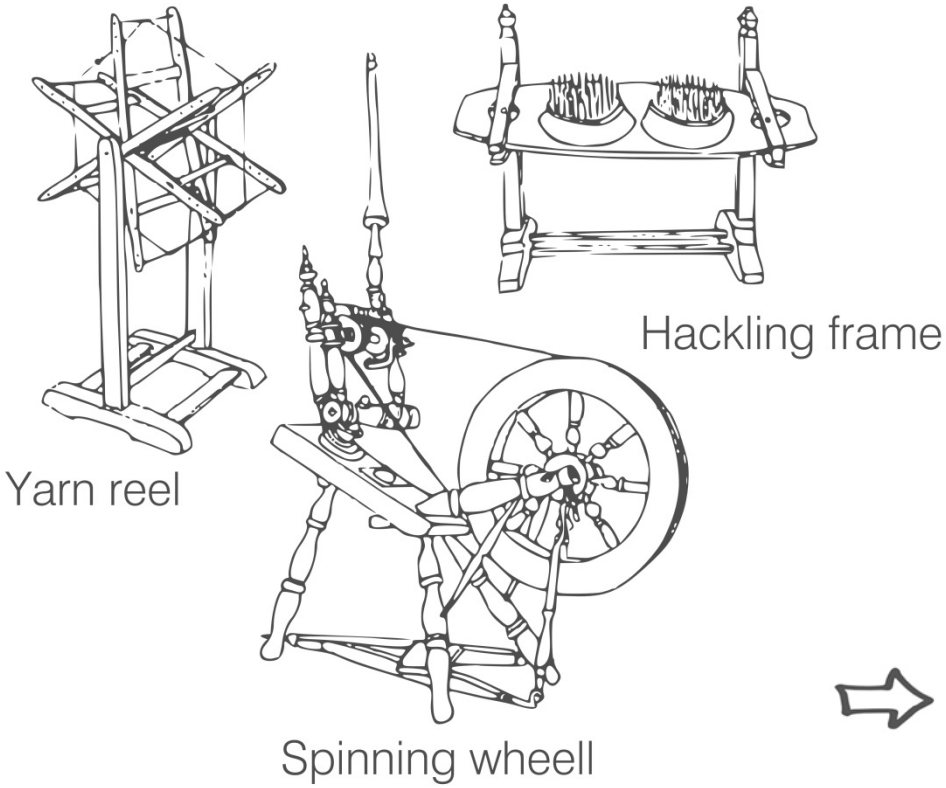


- DIN EN ISO 527
- Sample 1A / GL = 100 mm
- Zwick Z020 / 20 kN
- 2 mm/min
- Video extensometer
- 5 samples

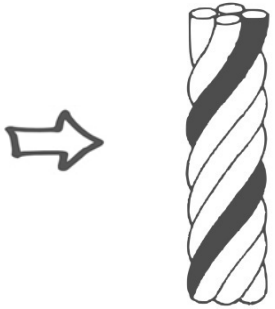


From Fibre to Yarn

(Vanneste, 2013)

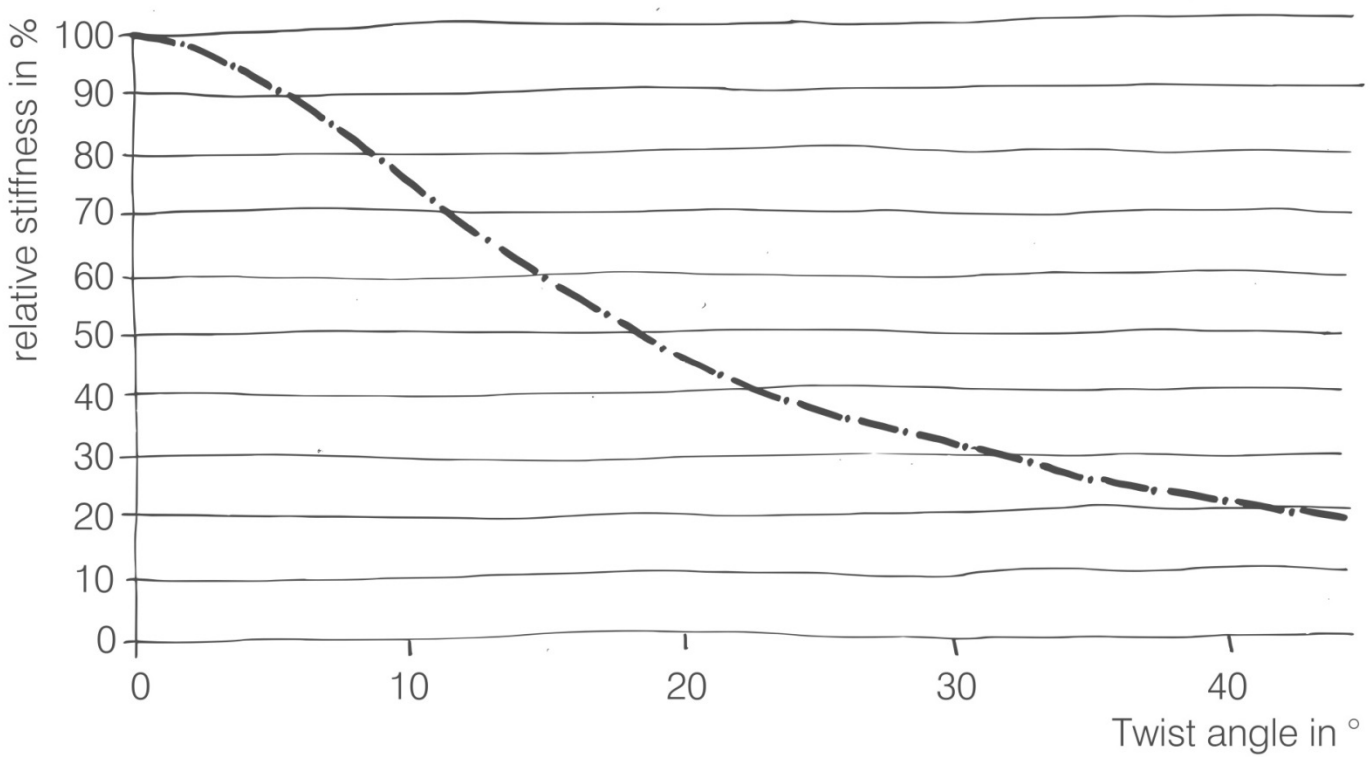


(adapted from Sendenhorster, 2011)



From plant fibre to textile structure for composite application.

Yarn Twist & Composite Stiffness



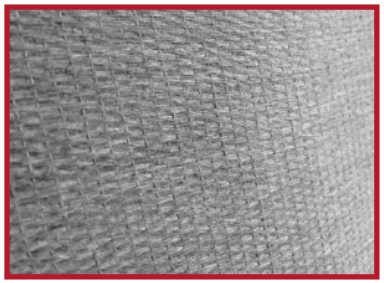
Yarn twist angle dependent stiffness values of composites.

(adapted from Verpoest & Baets, 2012)

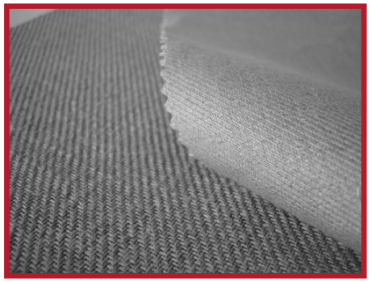
The higher the twist angle, the lower the strength & stiffness of the composite.

Optimised Yarns & Textiles for NFRC

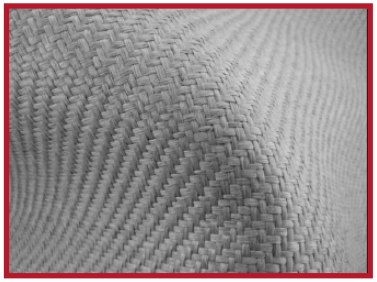

Roving




Pre-impragnated weaves

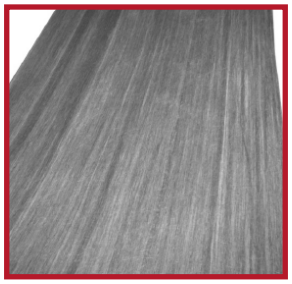



Weaves




Hybrid weaves


Non-crimp fabric



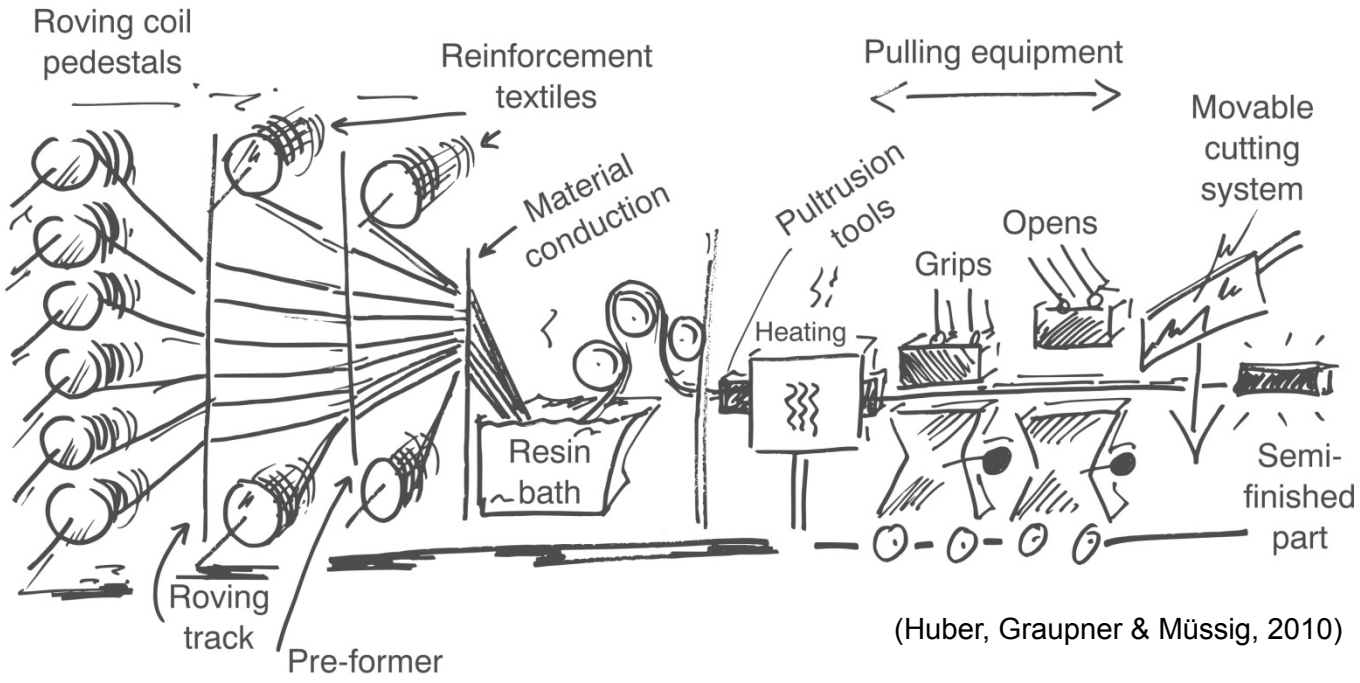
UD prepregs

⇨ Complete absence of twist and crimp

(Baets & Pariset, 2012)

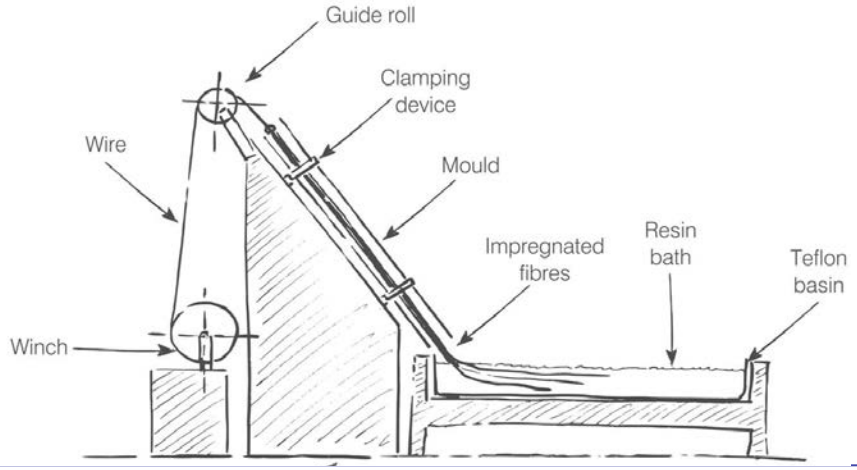
NFRC- potential & applications for hemp

Pultrusion



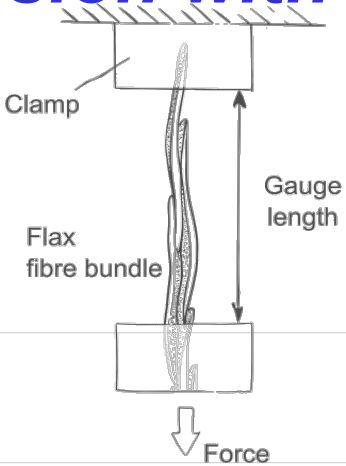
(Huber, Graupner & Müssig, 2010)

Schematic draw of a pultrusion line.

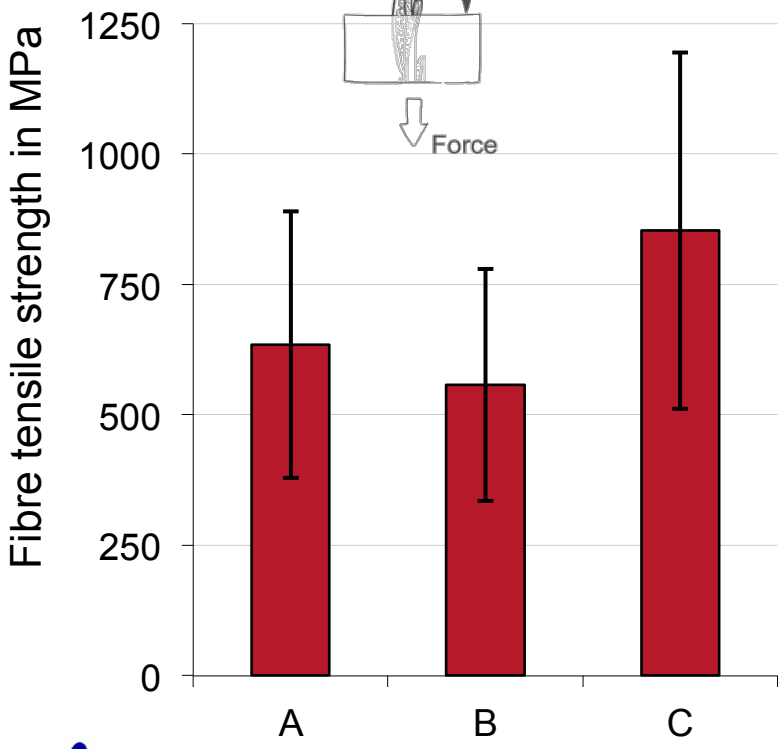


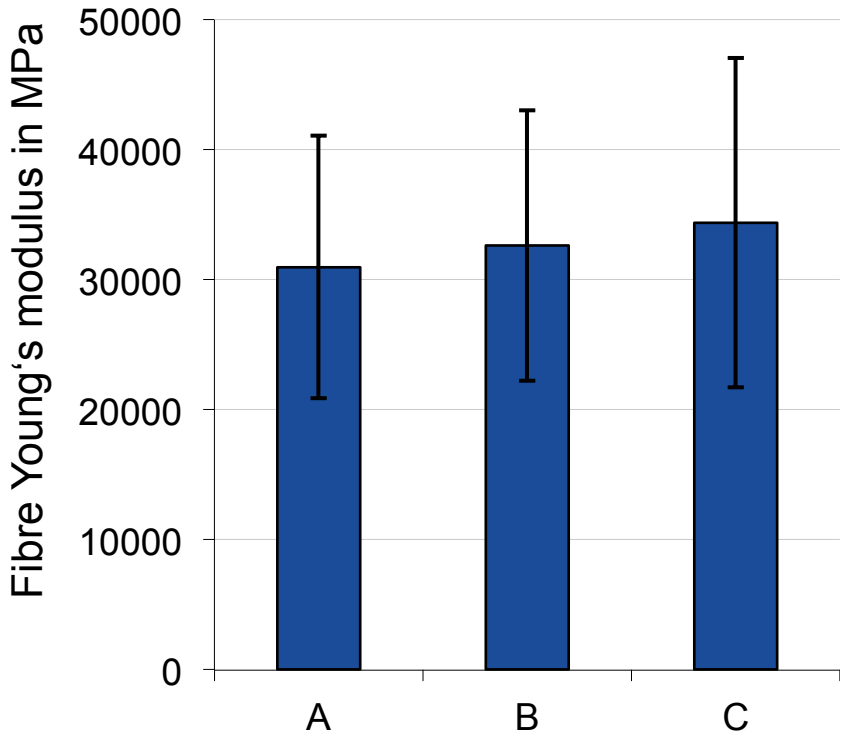
Pilot-scale pultrusion line.
(Mader et al., 2012)

Pultrusion with Flax – Fibre Properties



Fafegraph M (Textechno); gauge length 20 mm; testing speed: 20 mm/min.

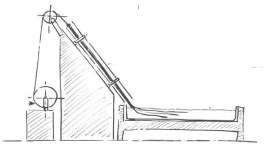


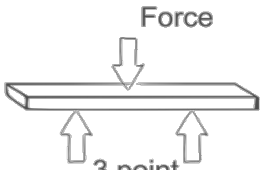


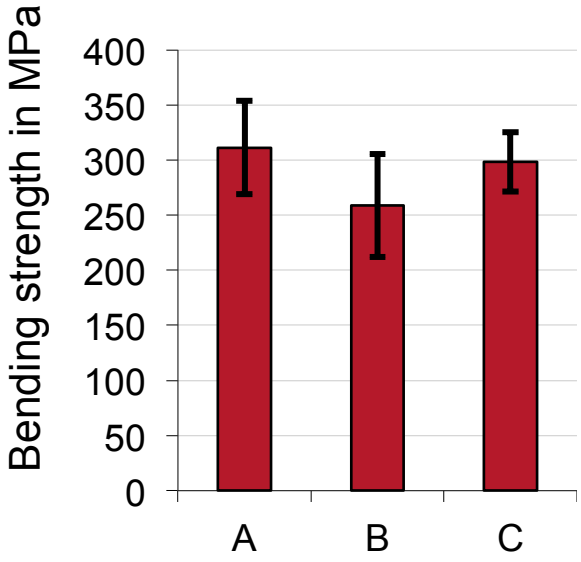
Tensile properties of single flax fibre bundles; field retted & scutched. Median ± MAD are shown.

(Haag & Müssig, 2012)

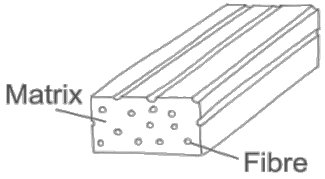
Pultrusion with Flax – Composites Properties



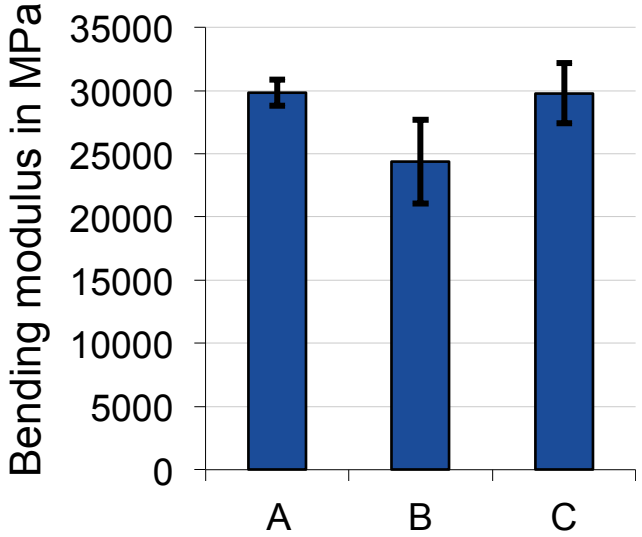




(Haag & Müssig, 2012)

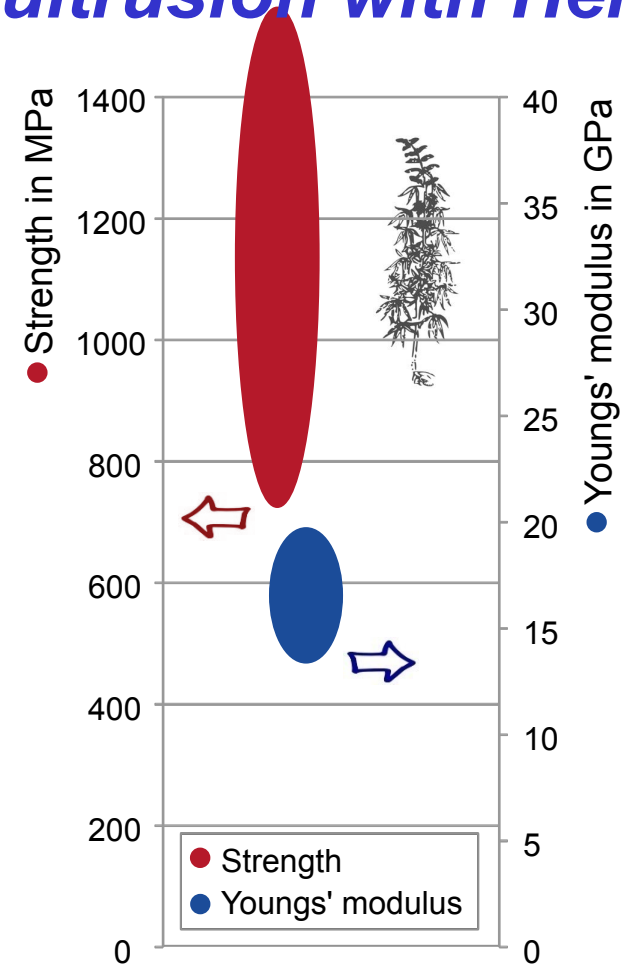


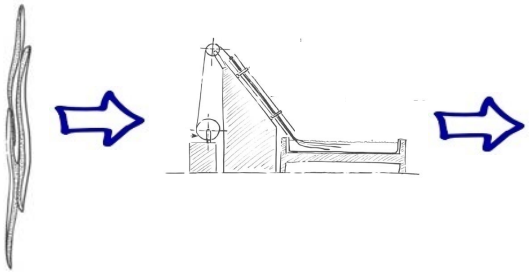
Epoxy infusion resin (RIM 135 & hardener RIMH 137i). Fibre content: 45 mass-%. Tests according to DIN EN ISO 14125 and ISO 3597-2 (bearing distance: 96 mm).



Mechanical properties of the composites with different flax types.
Arithmetic means ± standard deviations are shown.

Pultrusion with Hemp





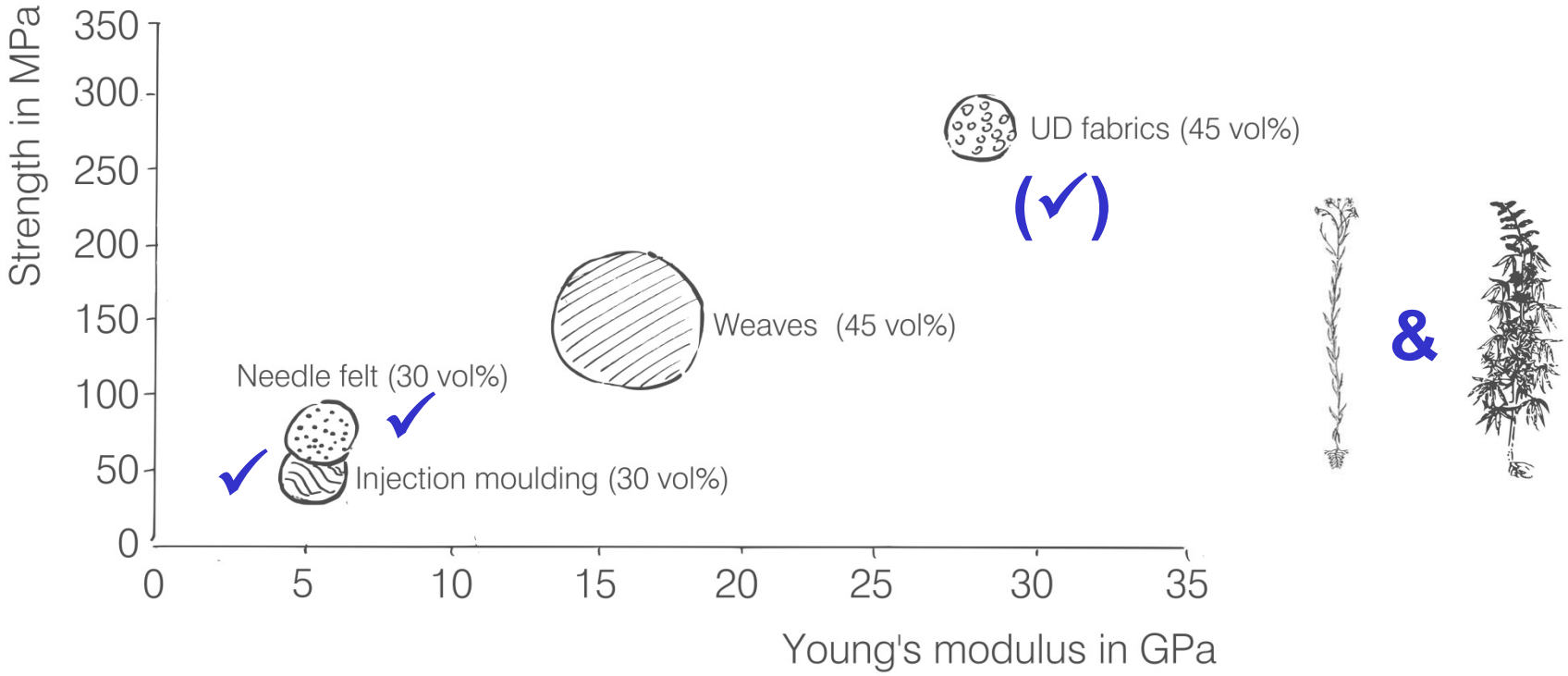
290 MPa bending strength: comparable to flax.

Bending modulus half of the flax UDs.

Tensile properties of single hemp fibre bundles & flexural properties of hemp fibre-reinforced UD pultrusion profile. (Low twisted carding sliver from HempAge, 45 %-mass hemp fibre bundles in Epoxy resin – RIM 135 & hardener RIMH 137i).

Conclusion

- NFRC have the potential to be used as a structural material to replace technical polymers or glass fibre-reinforced plastics.



The performance playground for flax & hemp composites.

(adapted from Verpoest & Baets, 2012)

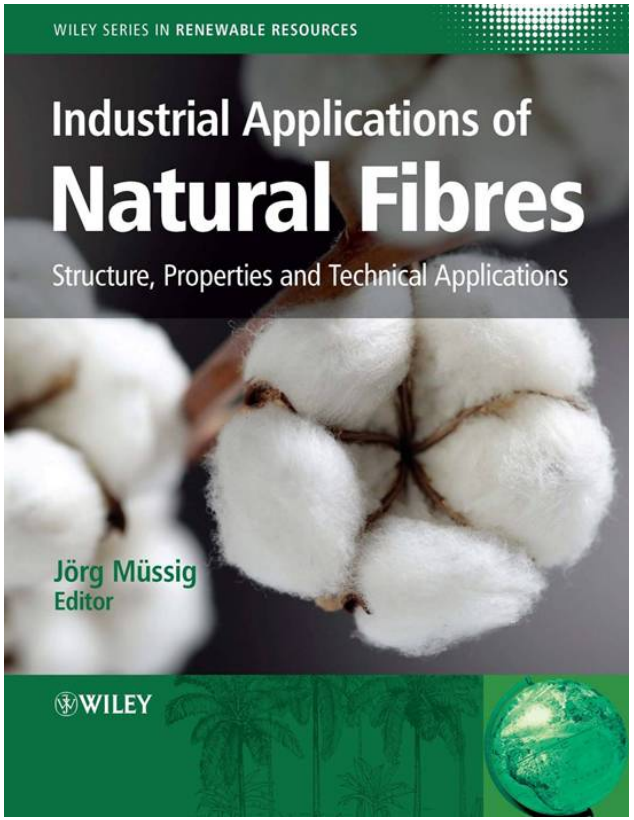
Many thanks!

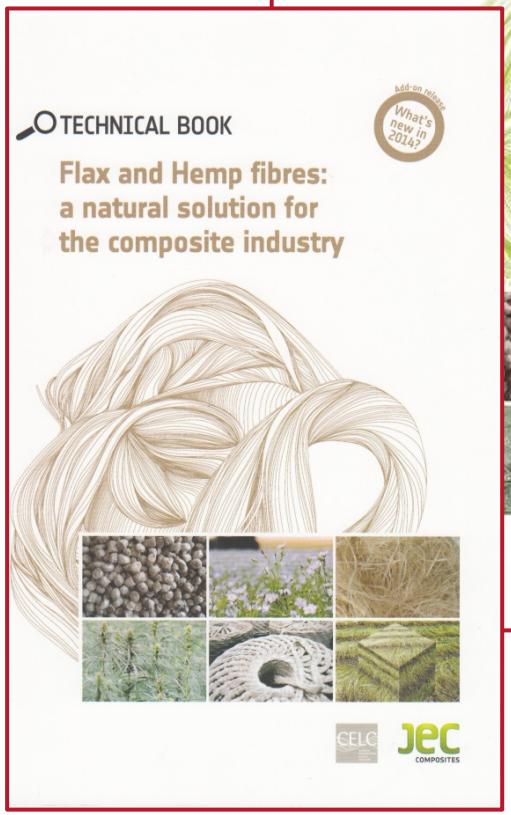
The compounding & injection moulding results were obtained within the project: INTERREG IV A-Project "Agrobiopolymere" – project number: I-2-01=175, funded by INTERREG/EDR, Bunde, Germany. The authors would like to thank Mr. Hansjörg Wieland (3N, Werlte), Mrs. Katharina Albrecht & Mrs. Katharina Haag (HSB, Bremen) and Herbert Enzler (TU Clausthal) for their support.

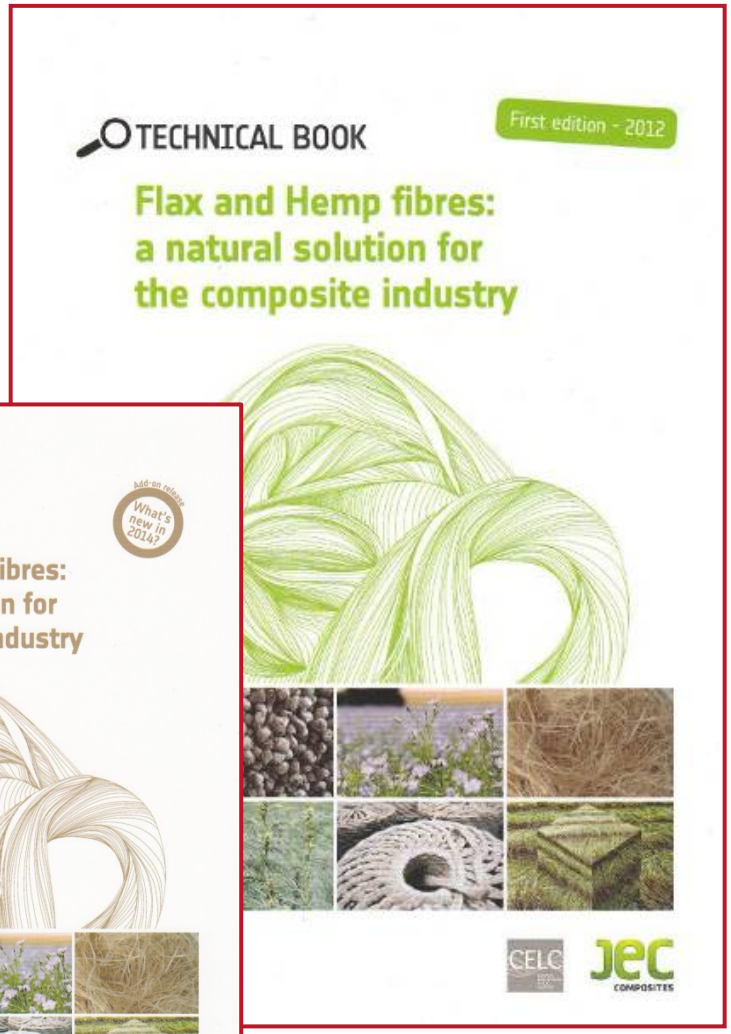
Prof. Dr.-Ing.
Jörg Müssig
Hochschule Bremen - University of Applied Sciences
Faculty 5 – Biomimetics
The Biological Materials Group
Neustadtswall 30
28199 Bremen, Germany
Tel.: ++ 49 - 4 21 - 5905-2747
Email: jmuessig@bionik.hs-bremen.de
Internet: www.bionik-bremen.de

Dr.-Ing.
Nina Graupner
Hochschule Bremen - University of Applied Sciences
Faculty 5 – Biomimetics
The Biological Materials Group
Neustadtswall 30
28199 Bremen, Germany
Tel.: ++ 49 - 4 21 - 5905-2719
Email: nina.graupner@hs-bremen.de
Internet: www.bionik-bremen.de

References


WILEY SERIES IN RENEWABLE RESOURCES
Industrial Applications of
Natural Fibres
Structure, Properties and Technical Applications
Jörg Müssig
Editor
WILEY


TECHNICAL BOOK
What's new in 2014?
Flax and Hemp fibres:
a natural solution for
the composite industry
CELC
JEC
COMPOSITES


TECHNICAL BOOK
First edition - 2012
Flax and Hemp fibres:
a natural solution for
the composite industry
CELC
JEC
COMPOSITES

References

Aisslinger, 2012: *Hemp Chair.* (2012) <http://www.aisslinger.de> (2015-05-14)

Baets, J. & Pariset, J. 2012: *The range of marketed semi-finished products / preforms, how they are industrialised, and their multisector applications*. In: JEC composites conference in partnership with CELC, (Organizers): FLAX AND HEMP FIBRES: A NATURAL SOLUTION FOR THE COMPOSITE INDUSTRY -- High-performance operational green-chemistry solutions (Leuven, Belgium, 2012-12-04) Paris, France: JEC & CELC, 2012 .- CD-ROM, Conference Proceedings, 24 pages

Baley, C., 2002: *Analysis of the flax fibres tensile behaviour and analysis of the tensile stiffnes increase.* Composites Part A, 2002. 33: p. 943-948.

Bobeth, W. (Hrsg.) 1993: *Textile Faserstoffe - Beschaffenheit und Eigenschaft.* Berlin: Springer-Verlag, 1993 (ISBN 3-540-55697-4) .- in German

Bourmaud, A. & Baley C. 2009: *Rigidity analysis of polypropylene/vegetal fibre composites after recycling.* Polymer degradation and stability, 2009. 94(3): p. 297-305.

Bos, H. L. / van den Oever, M. J. A. & Peters, O. C. J. J. 2002: Tensile and compressive properties of flax fibres for natural fibre reinforced composites. In: Journal of Materials Science 37 (2002), pp. 1683 – 1692.

Bürkle, E., Sieverdink M. & Mitzler J. 2003: *Spritzgießverabeitung von langfaserverstärktem PP.* In: Kunststoffe, (ISSN 0023-5563), Jg. 93, 3/2003, p. 47 – 50 .- cited pages: 47, 48

CELC. 2010: *THE NATURAL, FLAX AND HEMP VEGETATION FIBERS OF EUROPE: Double performance – technical and ecological.* Paris, France, CELC

Charlet, K., Jernot,J.P., Gomina, M., Bréard, J., Morvan, C., Baley, C. 2006: *Flax fibre reinforced composites: influence of the fibre position in the stem on its mechanical , chemical and morphological properties.* in ECCM 12. 2006. Biarritz.

Charlet, C.B., C. Morvan, J.P. Jernot, M. Gomina, J. Bréard, J. 2007: *Characteristics of Hermes flax fibres as a function of their location in the stem and properties of the derived unidirectional composites.* Composites Part A, 2007. 38: p. 1912-1921.

Eder, M.; Burgert, I. 2010: *Natural fibres –Function in Nature.* In: Müssig, J. 2010, pp. 22 – 39.

Graupner, N. & Müssig, J. 2010: *Technical Applications of Natural Fibres: An Overview.* In: Müssig, J. 2010, p. 63 - 71

Haag, K. & Müssig, J. 2012: *Comparison of tensile and flexural properties of different flax varieties and their composites.* In: PLANT KBBE 2: PLANT 2030 Status Seminar, Proceedings of the Seminar (Potsdam, Kongresshotel am Templiner See, 2012), Potsdam, Germany: 2012, Poster

References

Huber, T. / Graupner, N. & Müssig, J. 2010: *Natural Fibre Composite Processing: A Technical Overview.* In: Müssig, J. 2010, p. 407 – 421

JEC Conferences. 2012: *Flax and hemp fibres: A natural solution for the composite industry – High-performance operational green-chemistry solutions.* Programme to the conference, 4. December 2012, Novotel, Leuven, Belgium, JEC & CELC (Organizer).

Mader, A. / Volkmann, E. / Einsiedel, R. & Müssig, J. 2012: *Impact and Flexural Properties of Unidirectional Man-Made Cellulose Reinforced Thermoset Composites.* In: Journal of Biobased Materials and Bioenergy (ISSN 1556-6560), Vol. 6, No. 4 (2012), p. 481 - 492

Müssig, J.; 2001: *Untersuchung der Eignung heimischer Pflanzenfasern für die Herstellung von naturfaserverstärkten Duroplasten - vom Anbau zum Verbundwerkstoff -.* VDI Verlag GmbH, Düsseldorf, Germany 2001 (ISBN 3-18-363005-2), 214 pp. – in German.

Müssig, J. 2010 (Ed.): *Industrial Applications of Natural Fibres: Structure, Properties and Technical Applications.* Chichester, United Kingdom, John Wiley & Sons, Ltd, 2010, (ISBN 978-0-470-69501-1), 538 pages

Müssig, J. / Fischer, H. / Graupner, N. & Drieling, A. 2010: *Testing Methods for Measuring Physical and Mechanical Fibre Properties (Plant and Animal Fibres).* In: Müssig, J. 2010, pp. 269 – 309.

Müssig, J. & Hughes, M. 2012: *Reinforcements: fibres.* In: Reux, F. & Verpoest, I. (Editors): Flax and Hemp fibres: a natural solution for the composite industry. First edition - 2012, Paris, France, JEC composites, 2012, prepared for JEC by the European Scientific Committee of the CELC, (ISBN 978-2-9526276-1-0), p. 39 – 60

Müssig, J. / Graupner, N. / Oldemeyer, K.-E. / Mölleken, H. 2011: *Hemp fibre reinforced PLA from cultivation to the final product.* In: nova Institut GmbH (Organiser & Editor) 2011: 8th International Conference of the European Industrial Hemp Association. Hürth: nova-Institut GmbH, 2011, Documentation of the 8th International Conference of the European Industrial Hemp Association (EIHA). nova-Institut (Organizer), Hürth, 2011-05-18 till 2011-05-19

Sendenhorster, 2011: *Vom Flachs zum Leinenhemd.* (2011-02-13) <http://www.sendenhorster-geschichten.de/mainmenue/bilder/kap-3-handel-handwerk/kap-2-alltag-in-shorst/article/32-vom-flachs-zum-leinenhemd.html> (2013-04-07) .- in German

Vanneste, 2013: *Flax yarns.* (2013) <http://www.jos-vanneste.com/start/quality/en> (2013-04-07)

Verpoest, I. & Baets, J. 2012: *Flax and hemp fibre composites*. In: JEC composites conference in partnership with CELC, (Organizers): FLAX AND HEMP FIBRES: A NATURAL SOLUTION FOR THE COMPOSITE INDUSTRY -- High-performance operational green-chemistry solutions (Leuven, Belgium, 2012-12-04) Paris, France: JEC & CELC, 2012 .- CD-ROM, Conference Proceedings, 17 pages