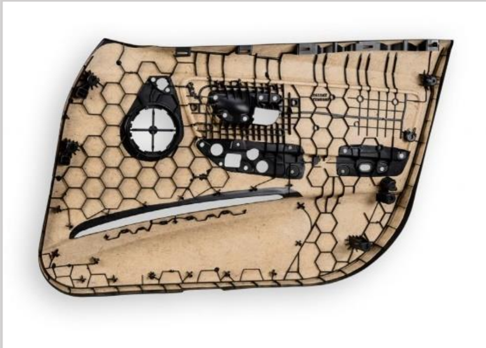
Lightweight construction with natural fibers

Thermoplastic hybrid composites with wood fibres

17.03.2020 - Weight reduction is one of the key challenges in developing sustainable vehicles. The use of renewable raw materials in the form of natural fibres, such as flax, kenaf or hemp, is state of the art and is mainly used in the automotive industry. The reasons are numerous. Natural fibres are much cheaper than carbon fibres and lighter than glass fibres. This results in cost and weight advantages. Excellent mechanical properties can also be achieved. Finally, the use of natural fibres offers a clear ecological advantage. [1, 2] Hybrid composites are often used for this purpose. Hybrid composites make it possible to combine the advantages of injection molding and pressing processes (functionalization with high inherent rigidity).

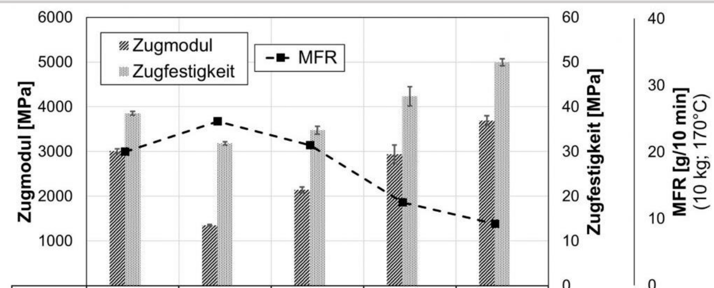
Wood fibres have not yet been extensively investigated in this area and are therefore hardly used in the automotive industry. The main applications in the plastics industry are Wood-Plastic-Composites (WPC) in which wood chips are used as filler. 4] However, wood fibres have considerable advantages over classic natural fibres such as flax or kenaf. They can also be generated in Western Europe and do not have to be imported from Asia. This makes it easier to ensure quality and reduces dependency on raw material risks (price and availability fluctuations). Furthermore, wood fibres can be produced with defined and optimal properties for the respective application. [5]



Door trim in automotive interiors (hybrid composite of natural fibers and plastic) [3] (Picture source: TH Rosenheim)

In-mould compounding of wood fibres

Wood fibres can be produced in the technical centre of the TH Rosenheim. Wood chips from spruce are thermo-mechanically digested to fibres on a 12'' laboratory refiner plant from Andritz, Grau, Austria. The processability of the wood fibres using an in-mould compounder (KraussMaffei 300 CX IMC) was investigated using a multi-test-specimen tool. A WPC available on the market was used as a benchmark.



Material	WPC	PP	PP	PP	PP
Holzanteil	30 Gew.-%	0 Gew.-%	10 Gew.-%	20 Gew.-%	30 Gew.-%
HV (Haftvermittler)	n.a.	0 Gew.-%	3 Gew.-%	3 Gew.-%	3 Gew.-%
ρSchmelze [g/cm³]	0,83 ± 0,01	0,78 ± 0,02	0,81 ± 0,01	0,87 ± 0,01	0,89 ± 0,01

Tensile test (ISO 527-1/1B) and MFR measurement of compounded wood fibers with different degrees of filling compared to a WPC. (picture source: TH Rosenheim)

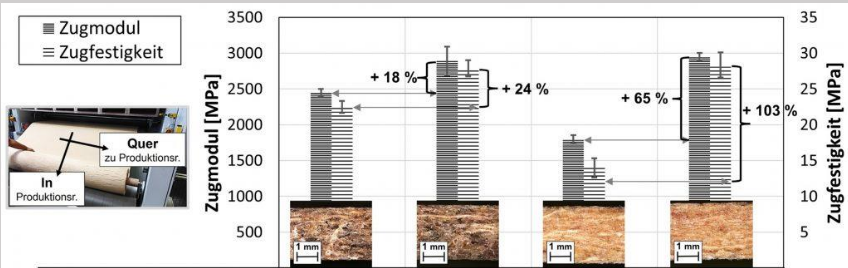
The wood fibres were compounded with polypropylene (PP) and adhesion promoter in various filling-degrees. An increasing degree of filling results in continuously improving properties in the tensile test. With a wood fibre content of 30% by weight, considerably higher strengths can be achieved than with the WPC available on the market. The test specimens were also subjected to an MFR (melt-flow-rate) measurement. The viscosity and density of the melt were determined at 170°C and a test weight of 10 kg. Thus, an increasing wood fibre content results in a reduction of the melt-flow rate and an increase in density. The density of the test specimens in the cooled state increases from approx. 0.9 g/cm³ with pure PP to approx. 1.2 g/cm³ with a wood content of 30 % by weight.

Nonwovens with wood fibres

In cooperation with the Austrian Autefa Solutions Nonwovens Competence Center in Linz, trials for nonwoven formation with wood and PP fibers were carried out. The fibres were laid into a nonwoven by an airlay system and thermally bonded into a semi-finished product by a double belt heating system.

Winding station for the wood fiber nonwoven after a double belt heating system [6] (Bildquelle: TH Rosenheim)

In a second step, the semi-finished products were consolidated into boards to the desired thickness using a hot press and a cooled press. The mechanical properties of the wood fibre nonwoven were compared with a needled thermoplastic natural fibre nonwoven available on the market as a benchmark.



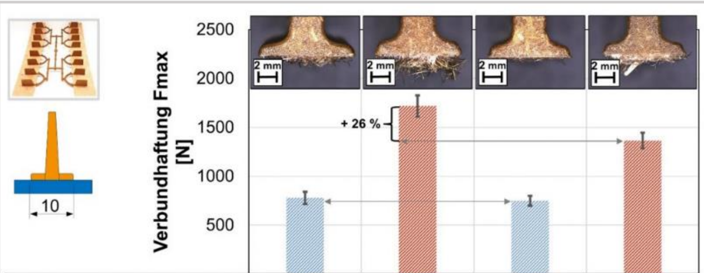
Orientierung	In Produktionsr.	Quer zu Produktionsr.	In Produktionsr.	Quer zu Produktionsr.
Einleger	**Naturfaservlies** (Benchmark)		**Holzfaservlies**	
Material	PP-Faser, Kenaf, Hanf		PP-Faser, Fichte	
HF/NF-Anteil [Gew.-%]	50		Ca. 50	
Flächengewicht [g/m²]	1800 ± 50		1920 ± 40	
Dicke [mm]	2 ± 0,1		2,3 ± 0,1	

Tensile test (ISO 527-4) of a natural fiber nonwoven (benchmark) and a wood fiber nonwoven (picture source: TH Rosenheim)

The specimens for the tensile test according to ISO 527-4 were taken in and across direction of production. The values across to the production direction for stiffness and strength of the natural fibre nonwoven are within the scope of the standard deviation comparable to those of the wood fibre nonwoven. For samples which were taken in direction of production, significant differences could be observed. The values for the wood fibre nonwoven deviate significantly higher one to another depending on the direction of production compared to the natural fibre nonwoven. Minimizing this deviation is the subject of future investigations.

Further processing to hybrid networks

The natural fiber nonwoven as a benchmark and the wood fiber nonwoven were combined into hybrid composites. A hybrid tool was used as tool, having two different rib geometries. The bond's adhesion from rib to nonwoven is tested with a pull-off device by using a head pull test.



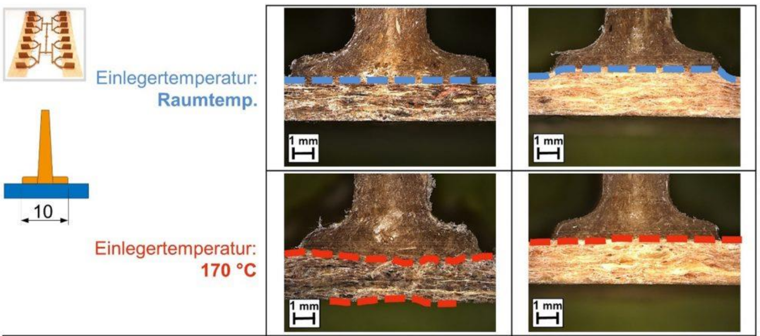
Einlegertemperatur	RT	170 °C	RT	170 °C
Einleger	**Naturfaservlies** (Benchmark)		**Holzfaservlies**	
Anspritzmaterial	PP / HV / 20 Gew.-% Holz		PP / HV / 20 Gew.-% Holz	
Einlegermaterial	PP-Faser, Kenaf, Hanf		PP-Faser, Fichte	
Flächengewicht [g/m²]	1800 ± 50		1920 ± 40	
Dicke [mm]	2 ± 0,1		2,3 ± 0,1	

Pull-off values of the ribs with foot on the natural fiber and wood fiber nonwoven at two insertion temperatures (picture source: TH Rosenheim)

From ribs with foot, pull-off values were determined on natural fiber- and wood fiber nonwoven using two insert temperatures. At the first investigated temperature (room temperature, short: RT) the inserts were placed in the hybrid mould without prior heating. At the second temperature, the inserts were brought to a core temperature of 170°C in an infrared oven. As injection material PP was directly compounded and injected with adhesion promoter (3 % by weight) and spruce fibers (20 % by weight).

The pull-off values of the ribs, which were injected at RT are significantly lower than those of the heated nonwovens. At RT there is almost no difference in the composite adhesion between wood and natural fiber nonwoven. The pull-off values after heating are about 26 % higher with the natural fiber nonwoven than with the wood fiber nonwoven. In all four cases shown, this is a mixed fracture. The rib remains undamaged. The fracture shows up in the interface between the nonwoven and the rib (adhesion fracture) and in the nonwoven (cohesion fracture). Heating the nonwoven increases the cohesive fracture percentage. At insert temperatures of 170°C, significantly more natural and wood fibers remain on the ribs, which indicates an increased cohesive fracture proportion.

Heating allows the melt to penetrate deeper into the natural fiber nonwoven. This can lead to optical impairments on the visible side of the nonwoven. The markings of the ribs can be visible even after a lamination process, for example in the case of door panels.



Einleger	Naturfaservlies (Benchmark)	Holzfaservlies
Anspritzmaterial	PP / HV / 20 Gew.-% Holz	PP / HV / 20 Gew.-% Holz
Einlegermaterial	PP-Faser, Kenaf, Hanf	PP-Faser, Fichte
Flächengewicht [g/m²]	1800 ± 50	1920 ± 40
Dicke [mm]	2 ± 0,1	2,3 ± 0,1

Microscopic images of microtome sections of the ribs with foot on natural fiber and wood fiber nonwoven at two insert temperatures (picture source: TH Rosenheim)

The cold inserted wood fibre nonwoven is post-compressed by the tool to about 2 mm, as the original thickness of the semi-finished product is about 2,3 mm. At the contact area with the rib, the nonwoven remains at around 2,3 mm. If the wood fiber nonwoven is heated before insertion, it is also post-compressed to about 2 mm at the rib area by the injection pressure. A deep penetration of the melt into the wood fiber nonwoven coud not be observed.

Summary and outlook

Wood fibers show great potential for thermoplastic hybrid composites. Due to their technical, ecological and economical properties, wood fibers are very interesting for the plastics technology. Further investigations are currently in progress to learn more about their properties.

Thanks to

We would like to thank all industrial cooperation partners who support this project (in alphabetical order): Brose Fahrzeugteile, Bamberg, Faurecia Autositze, Stadthagen, Frimo Sontra, Krauss Maffei Technologies, München, Krelus, Oberentfelden, Schweiz, Pfleiderer Deutschland, Neumarkt, und Pöppelmann, Lohne.

We would also like to thank Borealis Polyolefine, Linz, Austria, and J.H. Ziegler Natural Nonwovens, Lambrecht, who provided us with test materials. Furthermore, we would like to thank AUTEFA Solutions, Linz, Austria, fot the joint nonwoven laying trials.

Quellen:

[1] Müssig, J.: Industrial application of natural fibres, Structure, properties, and technical applications, Wiley series in renewable resources, Wiley, Chichester, West Sussex, U.K., 2010
[2] Bledzki, A.; Faruk, O.; Sperber, V.: Cars from Bio-Fibres, Macromolecular Materials and Engineering 291 (5), S. 449–457, 2006
[3] Yanfeng Automotive Interiors: Pressematerial IAA 2017, 2017
[4] Stadlbauer,W.: Wood Plastic Composites – Neues Eigenschaftsprofil durch Refinerfasern, Berichte aus Energie- und Umweltforschung 63/2010, BMVIT, Wien, 2010
[5] Schemme, M.; Michanickl, A.; Karlinger, P.: Neue Naturfaser – Kunststoffverfahren und -werkstoffe für den Fahrzeug-, Holz- und Möbelbau, 2. Kooperationsforum „Holz als neuer Werkstoff", Regensburg, 2015
[6] TH Rosenheim; Autefa Solutions Nonwovens Competence Center Linz: Versuchsprotokoll, Linz, 2019

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