THERMOSET BONDED NATURAL FIBER PREPREGS
A NEW APPROACH FOR AN ECO-COMPOSITE

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ABSTRACT

During the last years natural fibres as reinforcements for polymers held entrance in the automobile interior. A disadvantage of non-impregnated thermoplastic prepregs are the long processing cycle times, which result from heating up the enclosed air in the prepreg during the process. Alternatively pure natural fibre based non-woven fabrics are impregnated with thermoset systems. This variously applicable composite material is not only limited to automotive applications, but may also be used for product manufacturing in other industries. Due to the simple handling compared to alternative procedures the thermoforming of natural fibre reinforced, thermoset bonded prepregs are a very promising method for manufacturing flat components. In addition, high-strength and high-rigid structure components also can be manufactured with this processing method. Within the present study several needle punched natural fibre fleeces with different specific weights were used. The prepregs were manufactured in such a way, that the bonding agent portion amounts to only 19 wt.-%. The impregnated prepregs were heated and consolidated to components in a one-step-process. Within the scope of a parameter study the influence of major process parameters on the mechanical characteristics of manufactured components was examined, and the production process was optimised. The property profile of the investigated material is comparable to those of other thermoplastic or thermoset based natural fibre reinforced materials, typically used in automotive applications. The low fogging behaviour will make this material especially interesting, not only for the automotive industry.

1. INTRODUCTION

Since the beginning of the 80's bast fibres are established as reinforcement fibres in composite materials in the automobile industry. Numerous publications refer to the us of natural fibre polymers in the automobile interior [1 – 6]. The natural fibre composite materials used at present are mainly compression moulded. They consist of natural fibre non-woven materials and of a binder (thermoset or thermoplastic material). Typical components are door panels, rear parcel shelfs, instrument boards, trunk lining, etc.

An survey of the Nova-Institute [7] showed that despite the relatively weak economic situation in the car industry the utilization of natural fibres for composites, without wood and cotton, increased in 2001 and 2002. Current state of the art allows the use of 5 – 10 kg natural fibres per car (without seat upholstery). Natural fibres have due to their low density (approx. 1.5 g/cm³) a very good lightweight potential. The processing characteristics and acoustic properties are further advantages of the natural fibres.

The main application areas of natural fibre reinforced composites are limited almost exclusively to the passenger car range. In the future these composite materials shall not only be limited to automotive applications, but also can be used in trucks, buses, trains, and airplanes. Natural fibres can also be applied to furniture [9 – 11].

2. NATURAL FIBRE PREPREGS

Kenaf-hemp-fleeces (mixing ratio 50 : 50) with an area weight of approx. 1.800 g/m² was used. As bonding agents different polymer systems from diverse manufacturers were available. The bonding agents were applied to the kenaf-hemp fleece according to adjusted recipe. All matrices which were examined were brought into dispersion and the mixed fleeces where equipped with them in a dripping process. The polymer quantity was adjusted for all prepregs to 22 wt.-% in a reproducible manner.

An regular matrix distribution on the prepreg fibres is reached by the new developed impregnation procedure. Investigations with the scanning electron microscope show how homogeneous the matrix particles cover the fibres (Fig. 1).

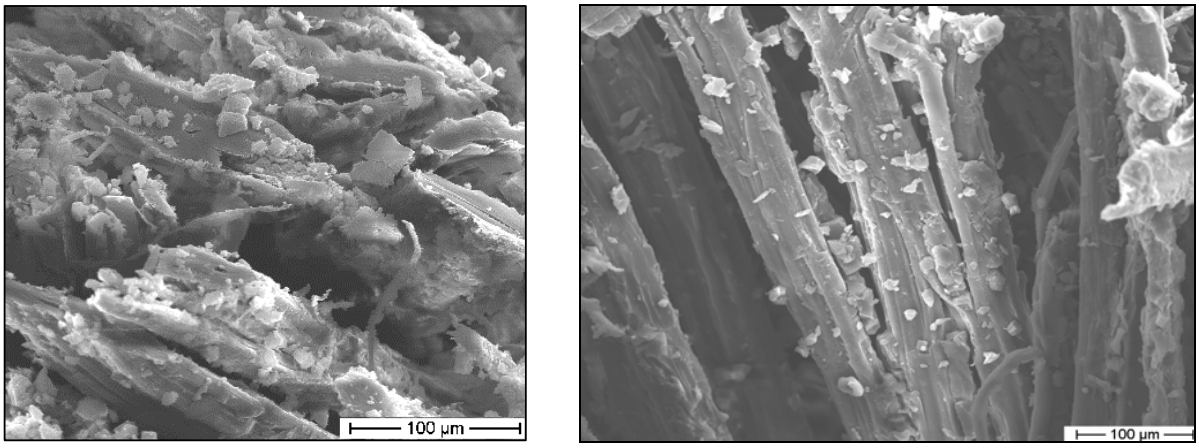

Fig. 1. SEM picture of the impregnated fibres.

Fig. 2. SATIM laboratory press (left) and moulded test plate (right).

3. PRESS PROCESS

The prepregs were press moulded in a laboratory mould (Fig. 2). Three press moulding series were accomplished and the characteristics of the manufactured composites were compared to optimise the press moulding parameters (Table 1).

The prepregs are added to the moulding process without any additional conditioning. Due to the residual moisture content in the prepregs and the condensation products of the curing reaction the cavity had to be ventilated several times briefly during the press cycle.

Table 1. Parameters during pressing series.

	Tool temperature [°C]	Pressure [bar]	Time [s]
1. Series	200	15	60
2. Series	200	60	60
3. Series	230	15	45

4. TESTING AND RESULTS

Tensile tests, three-point bending tests, and impact strength tests were carried out at room temperature to determine the mechanical properties of the composites (Table 2).

Table 2. Test procedures.

Test	Standard	Geometry	Parameter
Tensile test	DIN EN ISO 527-4	Type 2	Velocity: 2 mm/min
Three-point bending test	DIN EN ISO 14125	Class II	Velocity: 2 mm/min
Impact (Charpy)	DIN EN ISO 179-1	Type 2	Energy: 4J

The test results of the mechanical investigations show the contrary tendencies of the materials concerning the quasi-static (Fig. 3 and Fig. 4) and the dynamic mechanical properties (Fig. 5). Reason for this is the different binding between the fibres and the different matrix systems. At the materials with the better result in the tensile and bending tests a very good fibre-matrix adhesion can be observed, which lead to among other things to a fibrillation of the fibres (Fig. 6).

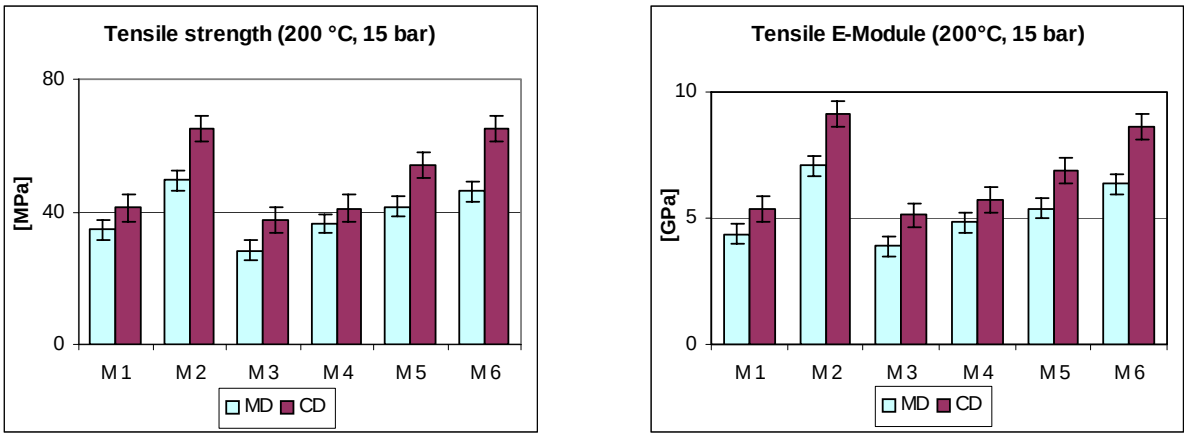

Fig. 3. Tensile test results (MD: machine direction, CD: cross direction).

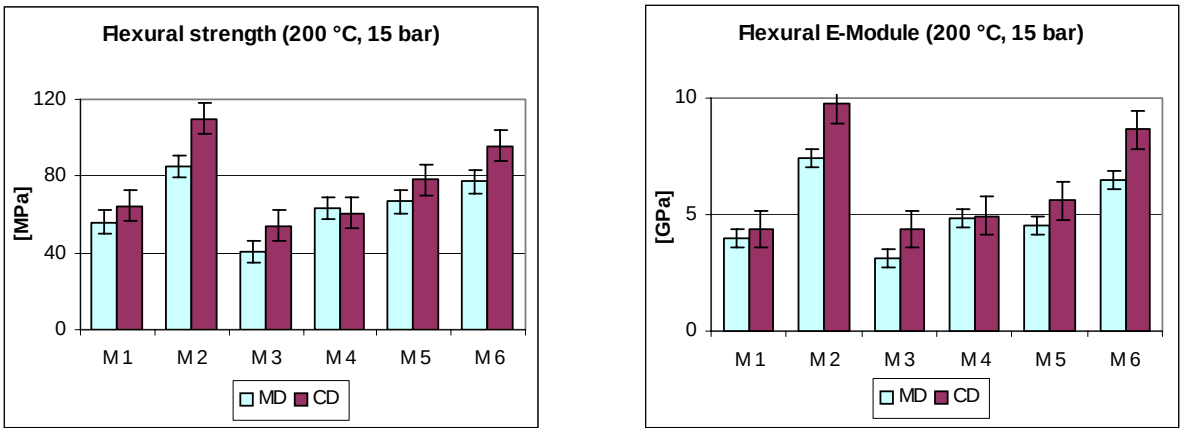

Fig. 4. Three-point bending test results.

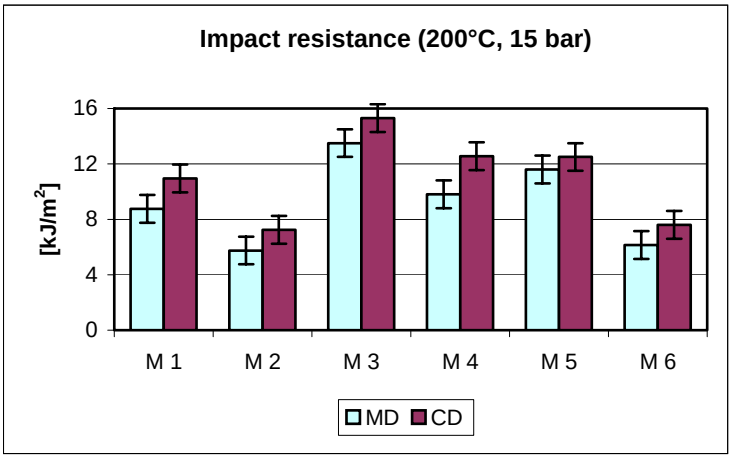

Fig. 5. Impact testing results.

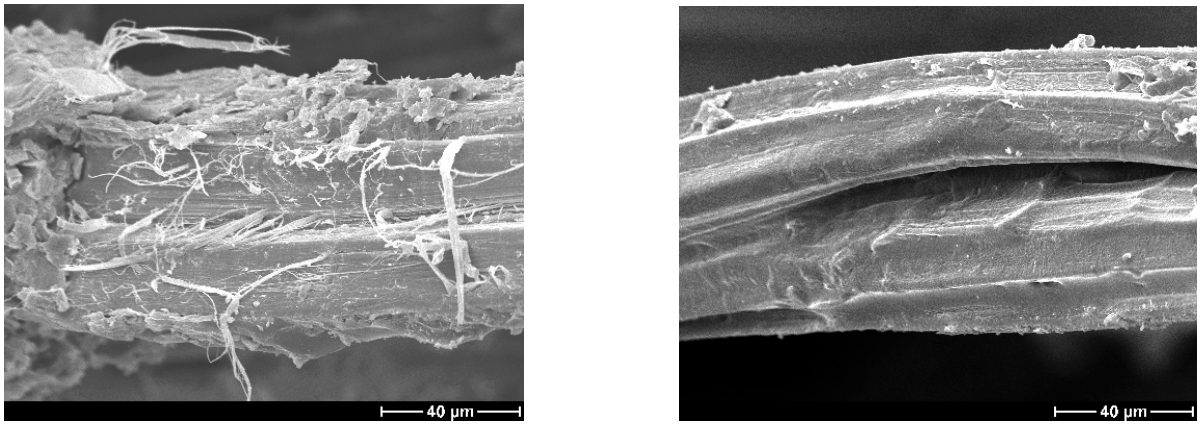

Fig. 6. Fiber surface after tensile testing of materials exhibiting good (left) and poor (right) fiber matrix adhesion.

Generally a rather brittle breakage behaviour can be observed at materials with good fibre-matrix adhesion. However the samples with low fibre-matrix adhesion show a complex fracture with energy-consuming fibre pull-out (Fig. 7). The materials do not show an smooth fracture under impact stress but a fan-out fracture, more dominated by fibre pull-out than by fibre breakage.

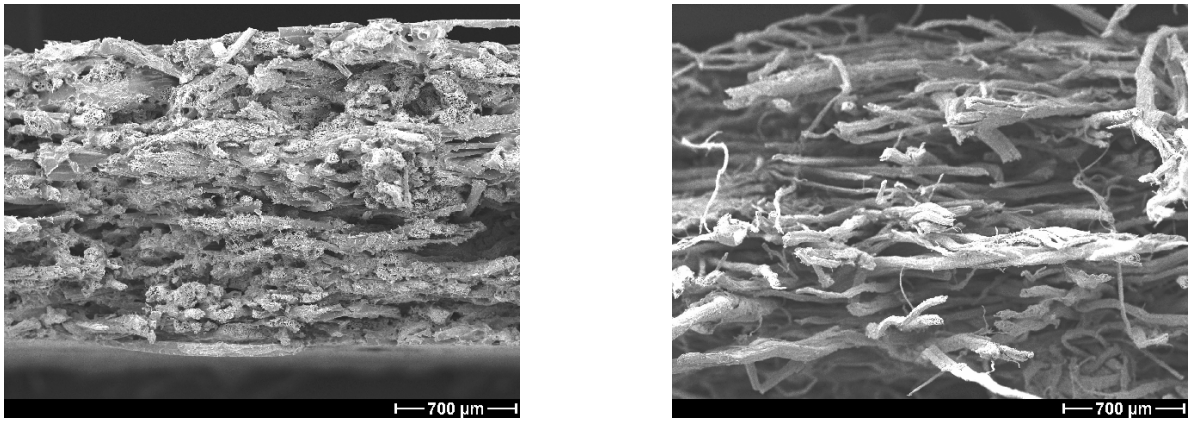

Fig. 7. Fracture surface of samples exhibiting good (left) and poor (right) fibre matrix adhesion.

By the variation of the process parameters in the second and third test series the influence of the component properties by the processing conditions were examined. The mechanical characteristics clearly depend on the press conditions (Fig. 8). The microscopic tests indicate clearly, that an optimisation of individual characteristics is not appropriate. The rigidity improvement at higher moulding pressure shows clearly a fibre structure damage which leads among other things to worse acoustic properties. Here it is visible that the hemp fibres are more pressure sensitive than kenaf fibres (Fig. 9). All examined material combinations show despite the low matrix amount a very good impregnation of the single fibres in the fibre bundles with the matrix material (Fig. 10).

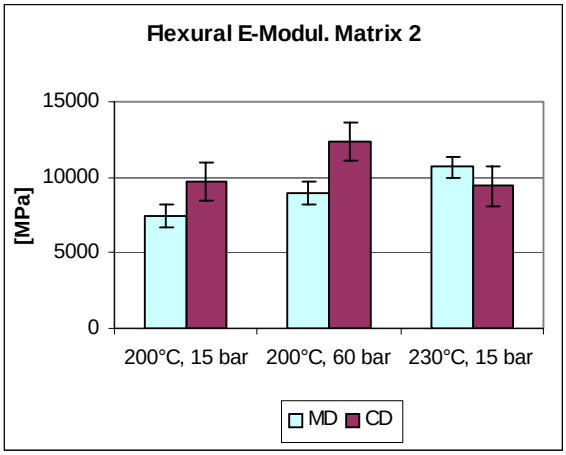

Fig. 8. Effect of pressing parameters on bending test results.

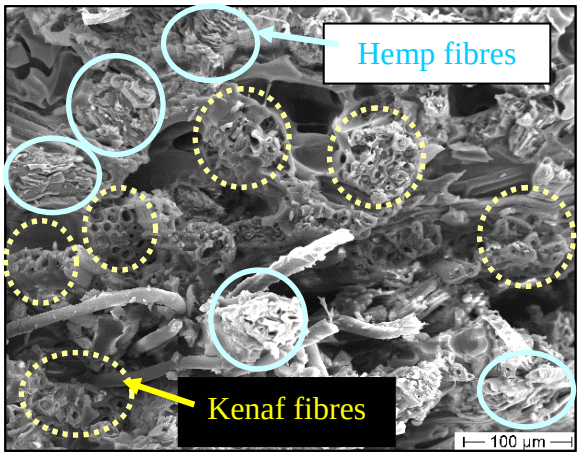

Fig. 9. Fracture surface of a sample manufacture with high pressure (60 bar).

5. APPLICATION

The new developed prepreg on the basis of natural fibres and with low matrix contents can be processed in the compression moulding technology with low cycle times. Apart from the test sheets also trays and case half-shells were manufactured at the Institut fuer Verbundwerkstoffe GmbH. But the development target are the applications in the automotive field. In co-operation with system suppliers hat racks were manufactured on mass production moulds under standard conditions (Fig. 11). The moulded components did not show any warpage or deformation after demoulding and cooling. The technical test almost resulted in conformity with the technical specifications and this in a weight saving of approx. 15%.

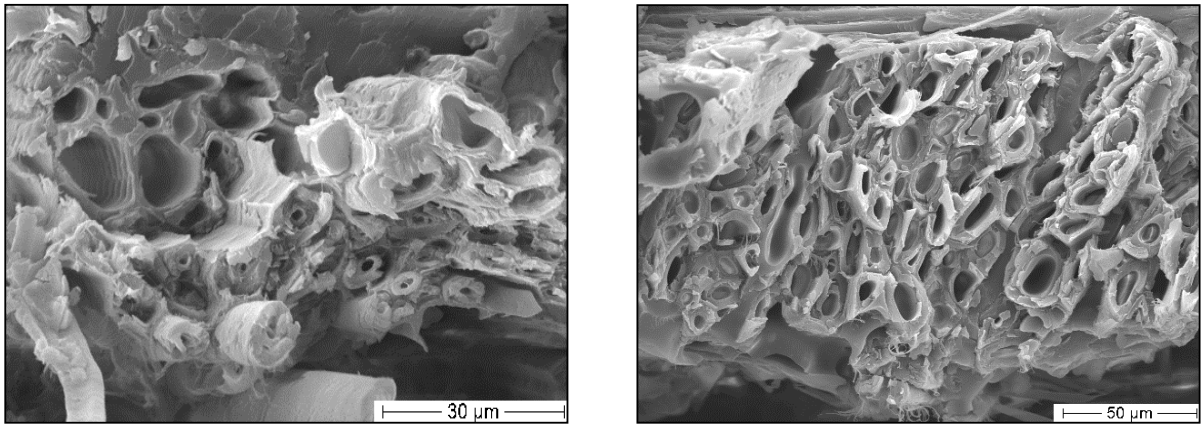

Fig. 10. Good impregnation of the fibres in case of poor (left) and good (right) fibre matrix adhesion.

Fig. 11. Parts manufactured on production lines under series conditions, hat rack (left, courtesy Johann Borgers GmbH & Co. KG) und door panel lining (right, courtesy JCI GmbH & Co. KG).

6. CONCLUSIONS

In the context of this work the reproducibility of the new developed impregnation process was examined. Different matrix systems with different chemical compositions were applied on the fibre prepregs and in all cases matrix contents of approx. 22 wt.-% could be achieved. During the impregnation the matrix distributes between the fibres so that an equal distribution of the matrix is achieved during the moulding process, and a good component consolidation is possible despite of the low matrix content.

The mechanical properties of the components fulfil for different matrix materials the technical specifications for natural fibre reinforced polymers for use in the car interior. The characteristics show a dependence on the mould parameters. Higher values of tensile and flexural properties are recognized at higher mould pressure. Here the fibre structure, depending on the fibre, is damaged. The process parameters are to be optimised depending on the use. The isolating properties of the composites are of great importance for the automobile industry. That is the reason that they are usually moulded at lower pressure (15 bar), so that the lumens of the fibres are not damaged (the cavities serve as isolation in the component). For other components, e.g. brief cases the mechanical characteristics are in the centre of interest and here they can, therefore, be moulded with higher pressure (60 bar).

Another advantage for processing of the new prepregs are the low cycle times. During the investigations moulding times of 45 – 60 seconds for three-dimensional components with a high moulding temperature were realised.

References

1. **Widdecke, H.** and **Marek, A.**: "Herstellung von Polypropylen- Naturfasercomposites", *3. Internationales Symposium Werkstoffe aus Nachwachsenden Rohstoffen*, Erfurt, ewk-Verlag, (2001), Vortrag Nr. 214
2. **Breitel, J., Schledjewski, R.** and **Mitschang, P.**: "Flow Moulding of Plasticised Natural Fibre Reinforced Thermoplastics", *Proc. 23rd Riso International Symposium on Materials Science: Sustainable Natural and Polymeric Composites - Science and Technology*, Roskilde, Denmark, (2002), p. 159-166.
3. **Karus, M.** and **Kaup, M**.: "Naturfasereinsatz in der europäischen Automobilindustrie", *Technische Textilien*, **44**/11, (2001), 258-262
4. **Thomason, J., Cheney, T.** and **Williams, J**., "Injection Mouldable Long Natural Fibre Reinforced Polypropylene for Automotive Applications", *5. Internationale AVK-TV Tagung*, Baden-Baden, (2002), D4-1 ff.
5. **Merten, T.**: Akustisch wirksame Vliesstoffe für die Automobil-Innenverkleidung. *Technische Textilien*. **43**/3 (2000), 36-40.
6. **Beckmann, A.** and **Kleinholz, R.**: "Anforderungen an Naturfasern aus der Sicht eines Kfz-Zulieferers für Innenraumteile.", *Proc. „2nd International Wood and Natural Fibre Composites Symposium"*, Institut für Werkstofftechnik Kunststoff- und Recyclingtechnik Universität Gesamthochschule Kassel (Ed.), Kassel, (1999), 30-1 – 30-10.
7. **Karus, M., Kaup, M., Knöbl, S., Müssig, J.** and **Ortmann, S**., "Naturfasereinsatz in Verbundwerkstoffen in der deutschen und österreichischen Automobilindustrie", *6. Internationale AVK-TV Tagung*, Baden-Baden, (2003)
8. **Riedel, U., Nickel, J.** and **Wonneberger, M.**: "Bio-Verbunde im Schienenfahrzeugbau", *6. Internationale AVK-TV Tagung*, Baden-Baden (2003)
9. **Köhler, E., Odenwald, S.** and **Bergner, A.,** "Naturfasergerechte Konstruktion. Bauweisen und Materialauswahl", *3. Internationales Symposium „Werkstoffe aus nachwachsenden Rohstoffen"*, Erfurt, 5.-6. September 2001
10. **Riedel, U.**, "Aus für naturfaserverstärkte Verbundwerkstoffe nicht nur im Automobilbau? Altautorichtlinie – Konsequenzen für den Automobilbau der Zukunft", *Fachkonferenz für die Automobilindustrie*, Köln, 26.-27. Juni 2001

11 **Müller, M., Sedlacik, G.** and **Bergner, A.,** "Rotorblätter für Windkraftanlagen in naturfasergerechter Bauweise." *10. Internationale Tagung „Stoffliche Verwertung nachwachsender Rohstoffe"*, Chemnitz 09.-10. Oktober 2002