A COMPARATIVE STUDY OF HIGH-PERFORMANCE NATURAL FIBRE REINFORCED BIOCOMPOSITES

- PP, PLA, AND PA 6.10 AS COMPOSITE MATRIX -

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1. Introduction

Environmentally friendly alternatives to petroleum-based plastics continue making inroads. Nowadays, the leading biopolymer is still polylactid (PLA). Lower prices, improved material performance and increased processors and consumer acceptance lead to growing expansion rates, which are above 30% p.a. The worldwide production capacity for PLA has been estimated to be above 200 thousand tons in 2010 [1].

Most applications for biopolymers, especially if they are biodegradable, are still in packaging and agricultural industries. Unfortunately, most biopolymers still possess a very low heat distortion temperature (HDT), low toughness (impact resistance) and some processing drawbacks, which disable a successful implementation into technical areas. Some of these shortcomings could already be optimized via different synthesis pathways (e.g. producing PLA stereocomplex with improved HDT; fig. 1).

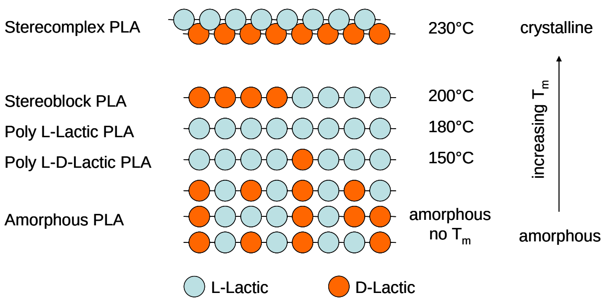

Figure 1: Dependence of the PLA melting point in relation to its chemical structure [2].

Another possibility of improvement is blending PLA with other polymers [3] or reinforcing it with fibres [4].

Currently, several companies offer bio-based engineering plastics with improved processability, thermal stability and mechanical performance. For instance, BASF introduced polyamide 6.10 (Ultramid Balance) ,which is bio-based up to 65%, in 2007. Evonik offers a whole range of PA 6.10, PA 10.10 and PA 10.12, under the trade name Vestamid Terra. Further global players are Arkema with its Rilsan® Polyamide 11 and DuPont with its poly(trimethyl-terephthalate) (PTT). All these polymers are derivatives from renewable raw materials, and they are predestinated for high-performance application, e.g. in construction, high-tech parts, technical textiles, etc.

Natural fibre reinforced PP (PP NF) already belongs to “commodities” under biocomposites. The ever increasing popularity of this material results from its very good mechanical properties, i.e. the low density (relative mechanical parameters are often better than PP GF) and the excellent split-out performance during crashing. It also possesses very nice acoustic properties and a relatively low price. However, there is still a significant improvement potential regarding processability, water absorption, interphase, uniform fibre distribution etc.

2. Motivation

The motivation for this study was to optimize diverse biocomposite materials with improved mechanical performance for a wide range of technical applications. Furthermore, new matrix systems on PA 6.10 basis are of further innovative contribution regarding bio-based composites.

3. Materials and procedures

The investigation is concentrated on three polymers: polypropylene, polylactid and polyamide 6.10.

As reinforcement two various cellulose fibres (abaca and man-made cellulose) were used. The fibre load was in the range 10 – 30% by weight.

In the beginning, the biopolymers and rein-forcement fibres used are characterized; the characterization is then followed by a demonstration of the applied processes and the process parameters. Subsequently, the mechanical properties of PLA and PA 6.10 biocomposites as compared to adequate composites based on PP are presented.

The addition of continuous filament took place in a twin-screw extruder (L/D=32, D = 25mm) fitted with a coating tool. The pellets, manufactured with this process were dried (16h at 80°C in a convection oven; moisture content <0,3 %) and in a second step compounded on the single-screw extruder to increase the bulk density and to guaranty a better fibre distribution. The pellets were then injection moulded into norm test specimen (nominal clamping force 850 kN, screw diameter 40 mm, L/D = 21, screw speed 120 rpm). The

temperature in the melt was 190°C for PP and PLA and approx. 240°C for PA 6.10.
The manufactured test specimens were tested in tensile test in line with DIN EN ISO 527. The test was evaluated on a Zwick/Roell UPM 1446 universal testing machine. The test results were summarised via a computer supported software testXpert®. The following mean values consist of an average of 10 separate measurements. Standard injection moulded tensile bars type 1A were used.
To investigate the toughness of the composites an A-notch Charpy impact strength test according to DIN EN ISO 179 was carried out. Beforehand, the test specimens were cut out of the parallel length of the norm 1A test bar. The A-notch was realized with a test specimen notching machine NOTCHVIS from CEAST.
PA 6.10 polymer and its composites were tested after accelerated conditioning in line with DIN EN ISO 1110.

4. Results and Discussion

In Figure 2 the stiffness of composites with man-made cellulose is presented. It is expressed by E-modulus obtained from flexural test.

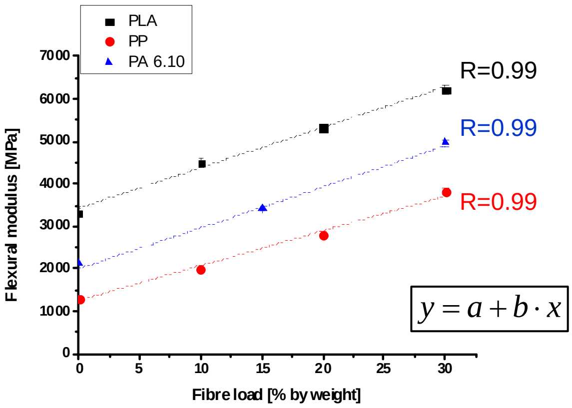

Figure 2: E-modulus of biocomposites with man-made cellulose fibres.

As is shown in Figure 2, the increasing fibre load enhances the E-modulus significantly. Furthermore, the improvement is almost perfectly linear, indicating a very good agreement with the rules of mixtures. Figure 3 shows flexural strength of composites reinforced with man-made cellulose fibres. It is obvious that by adding man-made cellulose a significant reinforcement in both stiffness and strength can be achieved. The inclination for PP seems to be higher. This is due to use of coupling agent, which strengthens the interfacial bonding and, in consequence, the composites strength. For both biopolymers no coupling agent was used. The stiffness of abaca composites is, because of fibre nature, noticeably higher than that of man-made cellulose composites; however, the strength is due to fibre aspect ratio and performance lower (results will be shown in the oral presentation).

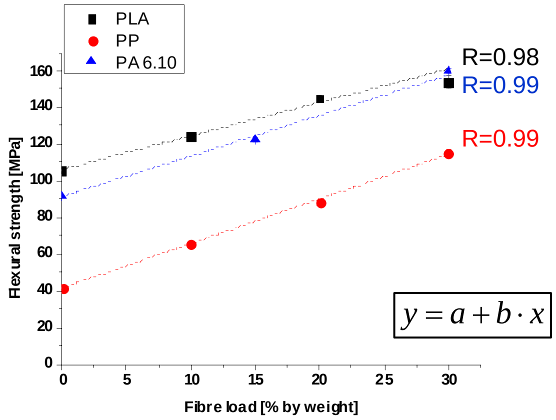

Figure 3: Tensile strength of man-made biocomposites.

In Figure 4 the A-notch Charpy impact values are presented.

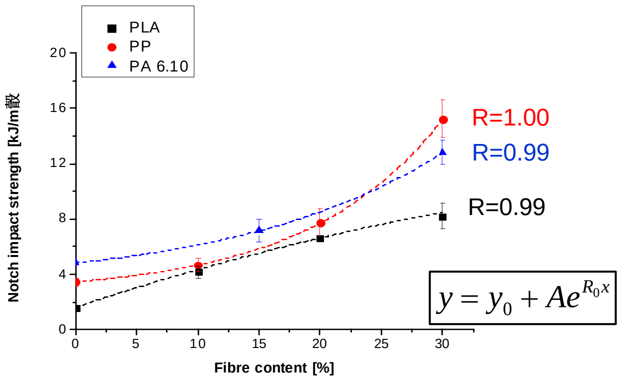

Figure 4: Charpy A-notch impact strength of man-made composites; testing temperature +23 °C.

The addition of man-made cellulose fibres results with an obvious increase in the impact strength. The significant enhancement is by factor 5.2, 5.4 and 2.7 for PLA, PP and PA composites respectively.

5. Summary

Biocomposites based on three different polymers were reinforced with different loads of man-made cellulose and abaca fibre. In both, a noticeable improvement of mechanical parameters was achieved. A significant enhancement in tensile, flexural and impact strength can particularly be achieved by reinforcing composites with man-made cellulose fibres.
The results obtained with abaca fibre will be presented in the oral presentation.

5. Literature

1. www.european-bioplastics.org / **2.** PLA Biopolymers, Schut J.H., Plastics Technology, www.ptonline.com / **3.** Processing and Properties of PLA/Ecoflex Blends and Composites with Chain Extender, Bledzki A.K., Jaszkiewicz A. 7. Internationales Symposium „Werkstoffe aus Nachwachsenden Rohstoffen“ September 09-10 2009, Erfurt / Germany / **4.** Jaszkiewicz A., Bledzki A.K., Hochleistung PHA und PLA Biocomposite für Technische Anwendungen, 7th Global WPC and Natural Fibre Composites Congress, June 18-19 2008, Kassel/Germany