HIGH-STRENGTH BIO-COMPOSITES FOR TECHNICAL APPLICATIONS

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Introduction

The ever rising price of crude oil and its price fluctuations during the last years have aroused increased interest in bio-polymers and their industrial applications. Renewable raw materials offer an almost inexhaustible basis for new materials. Newly developed biogenic plastics already have been available on the European market for several decades. They were first employed in the medical area, and bio-trash bags and loose fill were produced later. The market for packaging films has developed dynamically since 2002. Usage in agriculture and technical areas is continuously increasing.
The actual worldwide production capacity of bio-polymers is approximately 300,000 tons, still growing at a significant rate.
In the given contribution, the processing and production of natural fibre reinforced biopolymers will be presented.

Experimental

Materials

The actual investigations concentrated on two polymers of aliphatic polyester, polylactid (PLA) and poly-(3-hydroxybutyrat-co3-hydroxyvalerat) (PHBV). Various natural fibres (abaca, jute, flax) and a semi-chemical fibre (man-made cellulose) were used as reinforcement.
At the beginning the bio-polymers and reinforcement fibres used are characterized; this is followed by a demonstration of the applied processes and the process parameters. Subsequently the mechanical properties of the bio-composites as compared to adequate composites based on PP are presented.
All composites were produced with a matrix/fibre weight ratio of 70/30. No coupling agent was used in the bio-composites. In the PP composites, however, 5 wt/% (in relationship to fibre content) malein acid anhydride grafted polypropylene (MAH-PP) from Clariant company (TP Licocene PP MA 6452) was added for better adhesion.

Specimen preparation

The composites were manufactured in a two-step extrusion process.
In a convection oven, the pre-dried polymers (at least 16 h at 80° C, moisture content PLA and PHBV < 0.02%) were processed on a single (L/D= 25, D=30mm for PHBV) resp. twin screw extruder (L/D=32, D = 25mm PLA). To achieve an appropriate melting stability and a better ductility of the PHBV composites, the PHBV was blended with Ecoflex and processing aids. The PHBV content in the blend was approx. 70 wt/%.

Procedures

The introduction of continuous filaments was done with an extruder fitted with a coating nozzle as it is used in cable industry. The manufactured pellets were dried (16 h at 80°C in a convection oven, humidity content < 0.25%) and, as a second step, compounded in a single screw extruder to guarantee a better distribution of the fibres. Afterwards, the pellets were formed into norm test specimen in an injection moulding process (injection moulding machine Kloeckner Ferromatik FM 85 with a clamping force of 850 kN, a screw with a diameter of 40 mm and L/D =21, with a screw rotation speed of 120/min). In addition, the hopper of the injection moulding machine was heated to 80°C and rinsed with nitrogen.

Result and discussion

Mechanical analyses covered the tensile strength test and notch impact strength according to Charpy. In addition, the results of the thermo-mechanical analysis are shown below.

The tested bio-compounds clearly show characteristic values better than or comparable to common natural fibre reinforced PP. The application of natural fibres leads to a significant improvement of all characteristic mechanical values. Besides, the typical increase in stiffness as well as a noteworthy increase in strength (>50%) and notch impact strengths (>500%) was realized. This obvious material- and process optimization is an innovative contribution since properties such as strength and notch impact strength through addition of NF to bio-polymers have shown no influence or only slight improvements so far. Here, man-made cellulose has proven to be an optimal combination. The reason is its advantageous geometry as well as the polarity of the fibre.

Dynamic-mechanical analyses were also made to investigate the behaviour of the material at cyclical strains and higher temperatures. The fibres cause a typical increase of the storage module as a result of the better transfer of tension and reduction in the polymer chain mobility. Semi-crystalline PHBV can be compared with PP composites and replace them if necessary. PLA composites show much higher mechanical characteristic values in comparison with

PP; however, the material does lose its capacity to transfer tensions as soon as the glass transition temperature is exceeded. The combination of PLA and NF can only be used as construction material at temperatures up to 50C, and this only for a short term.

Market Developments

The bio-technological department of the Japanese corporation Toyota constructed a 1,000 ton capacity pilot plant for poly-lactic acid (PLA). Toyota estimates the market potential for bio-polymers to reach 38 billion Dollars by 2020 and will increase its manufacturing capacities in preparation for the future. The Japanese electronic corporation Pioneer developed an optical data storage medium made of corn starch, supposedly usable for the developing blue-ray disc generation. Already in 2003, Sanyo introduced a CD sample based on PLA.

NEC Corporation, in conjunction with UNITIKA LTD, announced the intensification of research in the area of bio-composites. As an example, a housing for cell phones that consists of a PLA matrix with natural fibre reinforcement (kenaf fibres) was introduced.

Various producers of bio-based polyesters, type PHA, plan to increase their production capacities in the coming three to five years. The corporations Archer Midland Company (ADM) and Metabolix announced that the planned production capacity should be approx. 50,000 t yearly. DuPont and Tate & Lyle start in that time frame with the production of a polyester that consists of approx. 40% 1.3-Propandiol which is bio-technically produced (50,000 ton capacity). Du Pont de Nemours recently introduced Zytel® 610 nylon resin for automotive radiator end tanks. This material was derived from castor oil plants (Ricinus communis) and exhibits remarkable heat resistance and good road salt resistance. The first commercial plant to produce PHB was annonced to be built by the end of 2008 in the USA (Clinton, Iowa). The Swiss/German company Pyramid BioPlastics is constructing a new plant for the production of PLA with a planned capacity of 60,00 t/y by 2012 in Guben, Germany.

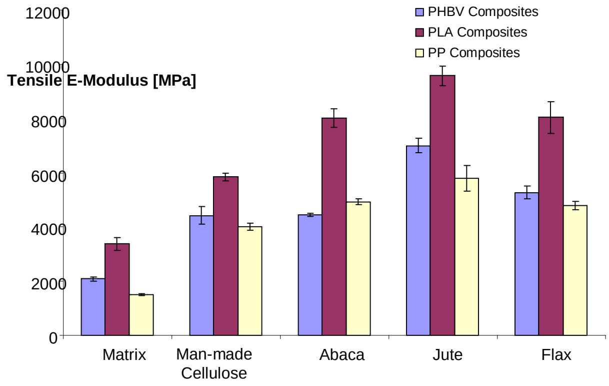

Fig. 1: Comparison of Tensile E-Modulus of different fiber types vs. matrix

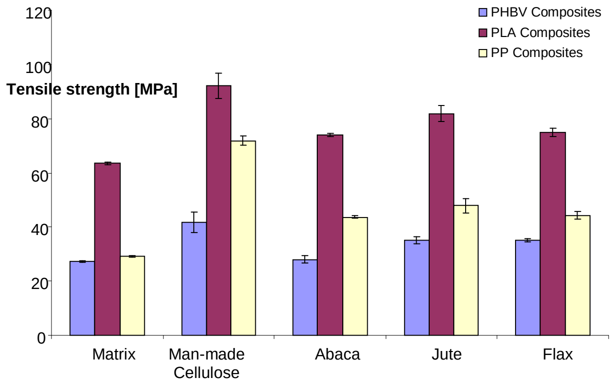

Fig. 2: Comparison of Tensile strength