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HYBRID COMPOSITE MATERIALS MADE OF POLYPROPYLENE WITH WOOD AND POLYETHYLENE TEREPHTHALATE FIBERS

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Abstract

We aim to manufacture injection molded components which consist of thermoplastics reinforced with fibers and which have improved properties (high strength and high notched impact strength). Thus, we intend to access new application fields for the not readily visible area of the automobile interior.

Introduction

Due to an increasing importance of environmental awareness, especially in the automobile industry, newest trends are incorporating increasing use of natural fiber reinforcement, such as materials made of wood plastic composites (WPC). WPC are composite materials, which consist of a thermoplastic with varying ratios of wood as well as additives. The thermoplastics polypropylene (PP) and also polyethylene (PE) are primarily used for the manufacture of WPC. The areas of application for WPC are manifold. Their application is particularly interesting in the automobile industry, because they have many positive properties [1]. For one, there is large potential to conserve both cost and weight in comparison to conventional materials. Moreover, the addition of wood proportions clearly increases the strength properties, making the material group a competitive alternative to traditional incumbent materials. Furthermore, the low tendency to splinter in case of a car accident is another great advantage. From an ecological perspective, wood fiber reinforced polymers have excellent properties. With a density of approximately 1.5g/cm³, natural fibers are a very good basis in contrast to glass fibers, which have a density of 2.6g/cm³. Owing to the correlating reduction of weight, which, in turn leads to energy saving in practice, these composite materials possess great light-weight potential, and are therefore ideal for application in automobile construction when employed in the interior of the automobile. NFC (Natural fiber composites) are composite materials, which consist of a thermoplastic with varying ratios of natural fiber. WPC/NFC additionally provides more safety than, for example, glass fiber reinforced composite materials. This is due to their lower tendency to splinter [2].

Additional positive reasons for the application of WPC are, for instance, automobile light-weight construction, and unlike other methods, a lower CO_2 emissions [3]. WPC/NFC display high strength and stiffness properties, however the impact behavior of this material group is relatively low. The extra addition of organic, synthetic fibers, i.e. polyethylene terephthalate fibers, can significantly enhance the notched impact strength of these materials [4]. Thus, a hybrid material is created that possesses an improved balance of properties.

Objectives

We aim to manufacture injection molded components which consist of thermoplasts reinforced with fibers and which have improved properties (high strength and high notched impact strength). Thus, we intend to access new application fields for the not readily visible area of the automobile interior.

Experimental

In the first step, the materials were selected and formulas were developed that were subsequently processed to agglomerates using a hot-cool mixer produced by Henschel (Figure 2). During the development of the formula, the fiber and matrix ratios were varied, but the bonding agent ratio remained the same. After production, the agglomerate was dried in a convection oven for a minimum of 24 hours at 80°C. In the following step, it was further processed into tensile test specimens by means of injection molding.

The determination of the raw material combination consisting of matrix and filling materials is shown in Table 1.

The following materials were employed for the below shown experiments (Figure 1):

Figure 1: Utilized materials (A: Polypropylene; B: Wood fibers; C: Polyethylene terephthalate fibers D: Bonding-agent

Polypropylene: PP Sabic 575P
Wood fibers: (mixture spruce/oak), medium fiber length 75µm
Bonding-agent: MAH-PP (maleic anhydride)
Polyethylene terephthalate fibers: synthetic, organic fiber, length: 5mm, cross-section: 30µm

Table 1: Formula Development

	PP	*Wood fiber*	*PET*	*Bonding-agent*
1	60%	40%	/	5% of fiber fraction
2	50%	50%	/	5% of fiber fraction
3	50%	40%	10%	5% of fiber fraction

Figure 2: Hot-Cool Mixer

All materials were added into the hot mixer, which had by then reached the desired temperature. The mixing tool in the hot mixer initiated the agglomeration process, and was kept at an increased rotation speed until a completely homogeneous mixture was obtained. Subsequently, the created material was directed into the cool mixer via an outlet, and abruptly cooled to about 20°C. The result was a pourable granulate (Figure 3) that was then let out of the cool mixer via the outlet. The manufactured material was then ready to be further processed using injection molding.
Afterwards, tensile test specimens (160mmx 20mm x 4mm) were produced and utilized for further experiments.

Figure 3: Agglomerate after the hot-cool mixing process

Examinations

Microscopy

In order to be able to assess the fiber distribution and bonding between the matrix and the fibers, morphological examinations were carried out. These were completed using a scanning electron microscope and incident light microscopy.

- Standard tensile test specimens were used for scanning electron microscopy (SEM). The test specimens were stored in nitrogen for 20 minutes. The next step consisted of creating a predetermined breaking point. Afterwards, the specimens were prepared for examination.
- The specimens were observed in both longitudinal and transverse directions while using incident light microscopy. A plastic saw was used to shorten the samples to the according, correct length. The specimens were then embedded in a mixture consisting of resin and hardener. Subsequently, the specimens were sanded and polished. Varying resolutions were used while employing the incident light microscope manufactured by Keyence. A distinct orientation of the wood and PET fibers was visible as well as the fiber distribution.

Tensile Test According to DIN EN ISO 527-4

The tensile test was carried out at room temperature. Six specimens were examined at a testing speed of 2mm/min.

3-Point Bending Test According to DIN EN ISO 178

Six specimens were tested at a testing speed of 2mm/min. These examinations were also carried out at room temperature.

Notched Impact Bending Test According to DIN EN ISO 170-2

The examinations were completed using a Zwick Charpy impact testing machine. Ten specimens were examined at room temperature, and an A-notch was made on each one. A 1 Joule hammer was used in the examinations.

Results and Discussion

Scanning Electron Microscopy Results

While assessing the specimens, the fiber-bonding between the fiber and matrix were clearly visible. Moreover, numerous fiber pull-outs, which occurred due to the abrupt strain induced by the creation of the predetermined breaking point, were detectable.

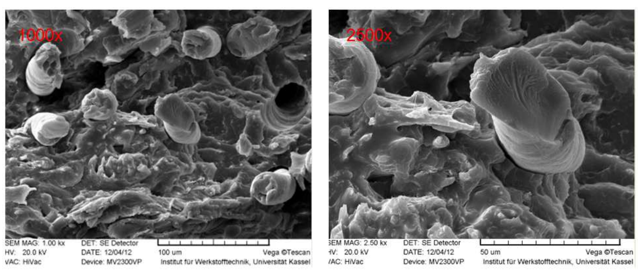

Figure 4: SEM image: PP + 40% wood + 10% PET fibers + 5% bonding agent; resolution 1000x (left) and 2500x (right)

Incident Light Microscopy Results

Figure 5 shows the distribution of the wood- and PET fibers (resolution 100x). The fiber distribution is relatively homogeneous.

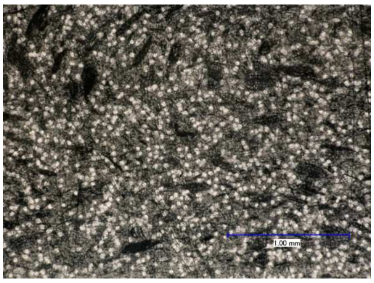

Figure 5: Incident Light Microscopy PP + 40% wood + 10% PET fibers + 5% bonding agent; resolution 100x

When examining the fiber orientation (Figure 6), it is evident that all fibers are oriented in the direction of the flow due to the injection molding process.

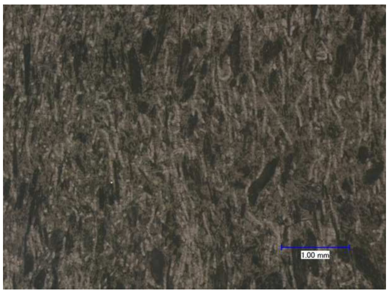

Figure 6: Incident Light Microscopy PP + 40% wood + 10% PET fibers + 5% bonding agent; resolution 50x

Tensile Test Results

The addition of wood fibers leads to an increase of the strength and stiffness of the material. This is further enhanced by utilizing a bonding agent, and results in an improved matrix-fiber-adhesion [5]. The values decrease after the addition of PET fibers due to an insufficient adhesion between the matrix and the PET fibers. This is most likely due to the surface properties of the fibers, which influence the adhesion in the composite. Similar tendencies can be observed for the E-modulus.

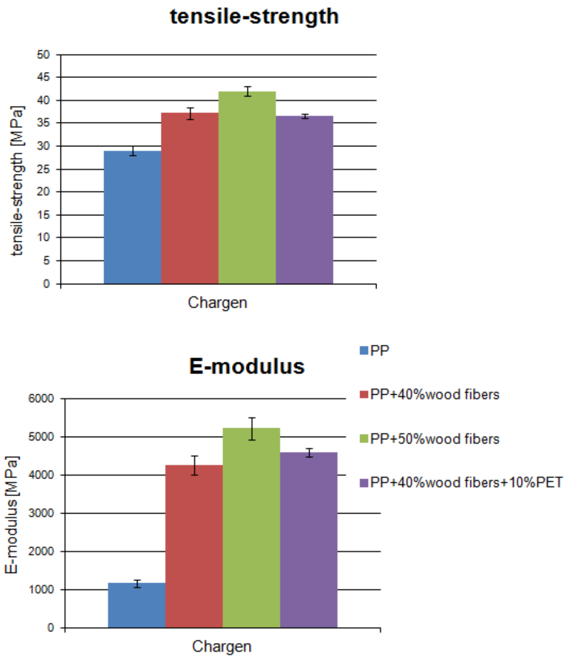

Figure 7: Tensile test results: tensile strength (left) and E-modulus (right)

3-Point Bending Test Results

Analogous to the results obtained for the tensile tests (Figure 7), similar results were acquired in the 3-point bending tests (Figure 8). The addition of wood fibers enhances the bending strength and the E-modulus. The values also decrease when PET fibers are added.

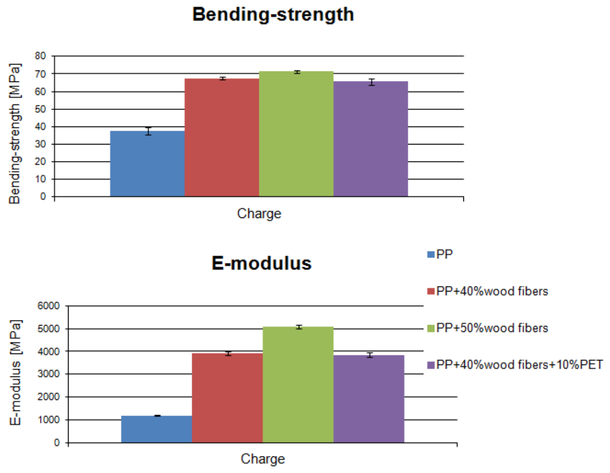

Figure 8: Results of the 3-point bending test: bending strength (left) and E-modulus (right)

Results of the Notched Impact Bending Tests

As expected, the notched impact strength values increase in correlation with the addition of PET fibers (Figure 9). Due to the induced fiber pull-outs (Figure 4), enhanced notched impact strength can be achieved. The fibers are torn out of the matrix by the abrupt strain. Accordingly, a higher impact energy is needed, which, in turn, leads to an increase of the impact strength.

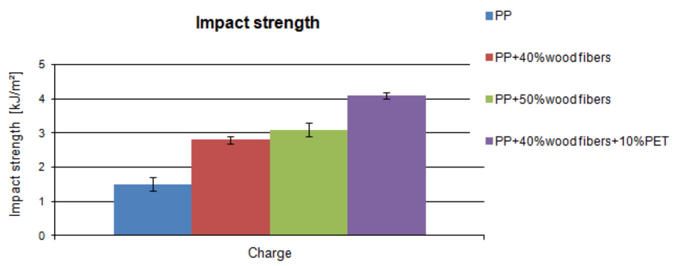

Figure 9: Results of the notched impact bending test

In conclusion, the results show that the hybrid materials achieve high strength values, and display good impact behavior. Thus, they offer great potential for application in the field of automobile construction, in which weight and cost savings play an essential role. Owing to the fact that the use of energy is lower when manufacturing these components than when using conventionally employed material groups, it is imaginable that these hybrid materials will be able to compete on the market in the future.

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