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Tribo-mechanical properties of glass fibre reinforced polypropylene composites

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ABSTRACT

Fibre reinforced polypropylene (PP) composites are frequently used for structural applications. In this context, it is of particular importance how much the tribological properties of PP can be improved by fibre reinforcement. Based on experimental investigations, this issue is discussed in the article by studying the tribo-mechanical properties of different PP composites. The relevant parameters of friction and wear are presented in order to provide a comprehensive data set for applications. Additionally, the wear mechanisms are studied phenomenologically by means of optical microscopy. It was shown that the tribo-mechanical properties of PP can be significantly influenced with a suitable reinforcement.

1. Introduction

Polypropylene (PP) as a standard plastic material possesses a diversified technical application spectrum due to its adjustable material parameters. However, the absolute values of the thermo-mechanical properties limit the application range of PP to structures with a low and medium stress level [1]. In order to provide cost-effective solutions especially for the automotive industry, research in the last years focusses on reinforcing PP with short or endless fibres [2–4]. Clear advantages compared to short fibre reinforced PP composites manufactured for example by injection moulding can be obtained by using hybrid-yarn based textile preforms that are manufactured to composites by press technology [5,6]. In comparison to other materials, such composites show a high degree of flexibility in the adaption of the reinforcement with respect to the acting loads. Therefore, this material is predestined for composite lightweight applications [7]. In recent years, efficient manufacturing technologies for hybrid yarn textile thermoplastics (HYTT) have been established [8–10]. Different HYTT have also been characterised under quasi-static, dynamic and highly dynamic loading conditions [11–15]. Beside their high specific properties, versatile possibilities of integrating additional functions can be found for HYTT composites. Based on the enormous progress in recent years, it has already been proven that structural components with complex geometries can be manufactured. Such components are often characterised by possible relative movements during their operating conditions or (metallic) load transmission elements. Tribological stressed components due to relative movements are shown in Fig. 1. Additionally, Fig. 2 shows the concept of a HYTT joint-system for structural applications with the accompanying process steps: heating of the deformed zone (1), positioning of the metallic insert (2), welding of the loop (3) and installation of the attachment parts (4). The resulting hinge is characterised by large relative movements between the metallic insert and the composite. Both examples illustrate that the tribological properties of the materials used for such components need to be known in order to design such structures sufficiently well.

As a side effect of the short fibre or endless fibre reinforcement, the low tribological properties of unmodified polypropylene are also improved [16,17]. Nevertheless, the tribo-mechanical characteristics of fibre-reinforced PP are relatively less studied since its tribological properties are expected to be relatively low as well. Hence, previous studies on the tribological behaviour of fibre-reinforced thermoplastics investigate other material combinations [16–26]. This study concentrates on the experimental determination and interpretation of the tribological properties of different PP composites in order to create a reliable and secured database with tribo-mechanical properties. This database can be used to establish scientifically based design drafts for HYTT composites and to ensure the use of such materials for high-level applications.

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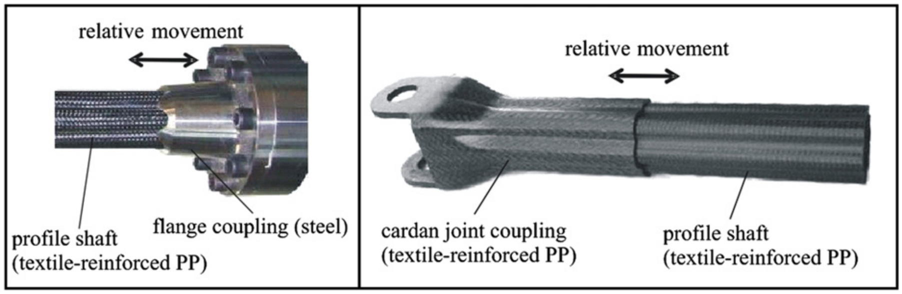

Fig. 1. Tribologically loaded HYTT structures: profile shaft with steel flange (left) and flexible shaft-hub joint (right) [7].

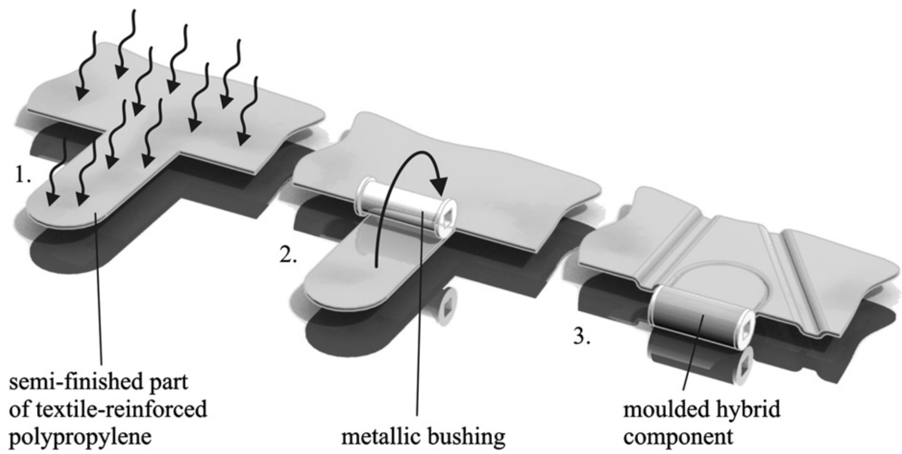

Fig. 2. Concept of a HYTT hinge-joint-system.

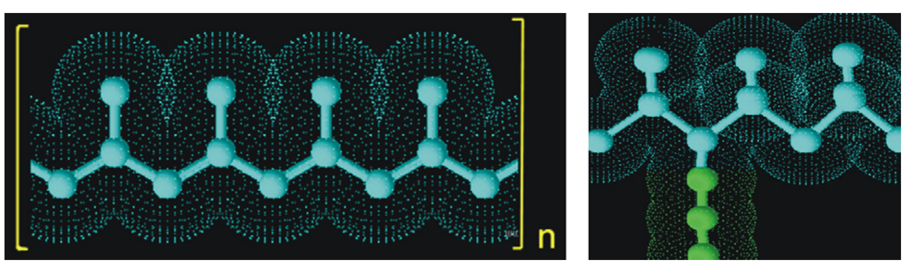

Fig. 3. Structure of isotactic polypropylene and PP-block-copolymer.

2. Materials

2.1. Materials and manufacturing

A commercially available polypropylene (PP1 HD 120M from Borealis) was chosen as the basic polymer in this study because it shows a well-balanced property level. In order to realise a good fiber/matrix adhesion, this PP-homopolymer was compounded with a maleic anhydride modified PP (5 weight-% Exxelor 1020 from Exxon mobile) analogously to [27]. Additionally, the PP-copolymer Moplen EP240T (from LyondellBasell Industries) has been taken for comparative purposes and modified with the same adhesion promoter.

Three types of fibre-reinforced PP were chosen for the tribo-mechanical characterisation: a short fibre-reinforced PP, a PP compound reinforced with endless unidirectional (UD) fibres and a commercially available woven hybrid preform. E-glass fibres with an aminosilane model sizing spun with a glass fibre spinning device at the Leibniz-Institute of Polymer Research Dresden were used for the first two materials. The manufacturing of the short fibre-reinforced PP specimens (30 weight-% glass) was performed by injection moulding. Thereby, the PP granulated compound was produced by a twin-screw extruder. The UD-reinforced PP (67 weight-% glass) was manufactured using the so-called hybrid yarns (PP filaments commingled with glass fibres in a spinning process) and hot isostatic pressing for consolidation. The unidirectional reinforcement was realised using an adapted winding process. Finally, a woven flat-shaped PP-semi-finished fabric (Twintex by OCV Reinforcements) was used as a bidirectional reinforced PP composite. In particular, a plain weave Twintex P PP60 2970 1/1 BF fabric (50% fibres in warp and 50% in weft directions) with 60 weight-% glass and an areal density of 1485 g/m^2 was chosen.

2.2. Mechanical properties

2.2.1. Matrix materials

As a preliminary investigation for the tribological characterisation, the PP-homopolymer and the PP-copolymer have been extensively analysed. PP-homopolymers show an isotactic (partly crystalline structure), a syndiotactic and/or atactic arrangement of the side methyl group in the macro-molecule (Fig. 3). The syndiotactic and atactic PP are comparatively less stiff, slighter crystalline, but more transparent, ductile and impact-resistant. In