Rubber-Toughened Long Glass Fiber Reinforced Thermoplastic Composite

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ABSTRACT

A rubber-toughened thermoplastic composite was produced by alternating long glass fiber reinforced polypropylene prepregs and rubber particles. Several composite laminates were obtained by changing the number of plies, the rubber powder size distribution, and the stacking sequence. Quasi-static mechanical tests (tensile and flexure) and time dependent tests (dynamic mechanical analysis and cyclic flexure) were carried out to evaluate strength and damping properties. As expected, 10 wt% rubber-filled laminates showed lower strengths than rubber-free laminates but the effect of the rubber on the composite damping properties was evident. At low rates, the rubber particles can also double the dissipated energy under cyclic loading, even if this effect disappears by increasing the test rate.

Keywords: Composite Molding, Recycled Rubber, Rubber-Toughened Laminate, Thermoplastic Matrix Composite, Thermoplastic Prepregs, Toughening

INTRODUCTION

Thanks to their unique properties, thermoplastic matrix composites are potential candidates to substitute traditional long glass fiber (GF) composites made with a thermosetting matrix (polyester or epoxy). The production of small parts for aerospace is one of the application field for this class of materials. Thermoplastic matrix prepregs show very high shelf life in comparison with thermosetting prepregs. Moreover, by using thermoplastic prepregs, it is possible to set up highly reliable forming processes which are conceptually similar to the case of thermosetting materials without the disadvantage of handling an uncured resin. A key-factor for the success of this technology is now the development of new materials with tailored functional performances, depending on the desired application. In this study, a way to improve the damping behavior of thermoplastic matrix composites...
is proposed by intercalating rubber particles between adjacent composite laminae.

Polypropylene (PP)/long glass fiber composites have been used to produce functional laminates as this combination of thermoplastic matrix and reinforcing fiber seems to be the best solution in terms of strength and stiffness due to the good fiber/matrix adhesion. Among several thermoplastic matrices, polypropylene leads to higher mechanical properties of glass filled composites (Schossig et al., 2009). The challenge is providing higher performances by changing process conditions or material formulations. Short GF reinforced polypropylene composites show high mechanical properties with a tensile strength about 80 MPa in quasi-static conditions (Schossig et al., 2008). Maleic anhydride can be used as coupling agent for better adhesion between fibers and matrix. Xie et al. (2005) enhanced the mechanical properties of PP/short GF composites by using the combination of different solutions: treating the glass fibers with a coupling agent; mixing with maleated PP for compatibilization and adhesion; mixing with a nucleating agent for improvement the polymer crystallization. The final blend was melted in a mold and hot pressed for the consolidation: in the best cases, final composites (30 wt% glass filled) showed mechanical properties twice higher than the un-treated filled composites in terms of tensile, impact, and flexural strength.

In such cases, rubber particles have been added to the polymer blend to enhance the composite ductility. Fu et al. (2006) studied the effects of the polyamide/polypropylene ratio on the mechanical properties of short glass fiber and rubber toughened composites. The glass fiber content was 40 wt% and the polymer blends contained a mixture of 10 wt% styrene-ethylene-butylene-styrene (SEBS) and 10 wt% maleic anhydride grafted SEBS. Thermoplastic composites were made by compounding all the materials in a twin-screw extruder and subsequently by injection molding the reinforced blend. Mechanical tests showed that higher failure strains were reached due to the presence of the rubber and a maximum of 80 MPa of tensile strength was observed in the best case. Sui et al. (2001) also observed a similar behavior by studying injection molded composites made of rubber-toughened nylon 6,6 and short glass fibers at 0, 10, 20, 30 and 40 wt.%. Results showed that the composites under one-step injection molding sufficed to provide superior strengthening and toughening. Also thermosets can be efficiently rubber toughened by adding rubber particles: Tsai et al. (2011) investigated the interlaminar fracture toughness of glass fiber/epoxy composites, which consisted of the silica nanoparticles and the rubber particles. In order to enhance the fracture toughness of the fiber composites without sacrificing their stiffness, silica nanoparticles in conjunction with the rubber particles were introduced concurrently into the epoxy matrix to form a hybrid nanocomposite.

Recently, Balkan et al. (2010) have studied the properties of a ternary composite containing isotactic PP, glass beads, wollastonite and SEBS. At the end of the compounding and injection molding operations, they found that the composite exhibited separate dispersion of the rigid filler and elastomer particles. Up to now, rubber particles have never been used with long GF/PP composites because of the different molding technology. Latest innovations for this composite material deal with new processing solutions. Ogale and Alagirusamy (2008) have proposed to enhance the impregnation quality of GF/PP composites by commingling fiber and matrix yarns before to compression mold. In the case of unidirectional laminates with a filler content about 50 vol%, a tensile strength about 350 MPa has been reached. Robert et al. (2010) have deepened the effect of the environment on GF/PP laminates produced in a similar way. Composite plates consisted of four layers of commingled bi-directional fabrics consolidated by roll forming, giving a 4 mm thickness and a 60%wt reinforce. Flexure tests were performed on as-formed and aged specimens, and results showed that the durability of GF/PP composite is related to the quality of their consolidation.

In the current study, a new procedure is shown for the production of rubber toughened thermoplastic matrix composites. Rubber par-
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