Available online at www.sciencedirect.com

ScienceDirect

Polymer Testing 26 (2007) 779–787

POLYMER TESTING

www.elsevier.com/locate/polytest

Material Properties

Polypropylene-based blends containing waste tire dust: Effects of *trans*-polyoctylene rubber (TOR) and dynamic vulcanization

M. Awang, H. Ismail*, M.A. Hazizan

School of Materials and Mineral Resources Engineering, Universiti Sains Malaysia, Nibong Tebal, 14300 Penang, Malaysia

Received 26 January 2007; accepted 10 April 2007

Abstract

Blends of polypropylene/waste tire dust (PP/WTD) with and without *trans*-polyoctylene rubber (TOR) and dynamic vulcanization were prepared, and the effects of TOR and dynamic vulcanization were investigated. By using WTD of 500–710 μm, five different compositions of PP/WTD blend (i.e. 80/20, 70/30, 60/40, 50/50 and 40/60 wt%) were prepared in an internal mixer at 180 °C and 50 rpm rotor speed. The results indicate that the incorporation of TOR and dynamic vulcanization improved the tensile properties of PP/WTD blends. Chemical and oil resistance of the PP/WTD blends with TOR and dynamic vulcanization was enhanced. Scanning electron microscopy of the fractured surfaces proved that TOR and dynamic vulcanization promoted good adhesion between the PP matrix and WTD. Thermograms support the finding that TOR and dynamic vulcanization improved the interaction of PP and WTD and, hence, their compatibility.

Keywords: Polypropylene; *Trans*-polyoctylene rubber; Waste tire dust; Dynamic vulcanization; Blend

---

1. Introduction

Polymer modifications have been carried out in many ways [1–3] resulting in various properties depending on factors such as the blend composition, processing conditions, additives and the temperature of application. Perhaps this versatility and other advantages have contributed to 57% of engineering resins being blended [4] and the fact that polymer blends constitute more than 30% of overall polymer consumption [5]. However, a number of setbacks were reported in polymer modification attempts due to several constraints, such as diminution of mechanical properties, lack of thermodynamic compatibility between polymers and so forth [6,7]. One of the options is to incorporate a suitable third polymeric component to minimize the constraints [8,9].

Trans-polyoctylene rubber (TOR) is a low-molecular-weight polymer, made from *cyclo*-octene by metathesis polymerization, and has been known as a compatibilizer for incompatible blends as well as a processing aid. It can provide good processability in the temperature range of rubber processing (100–150 °C) as well as good collapse resistance below the melting temperature, 54 °C, due to recrystallization [10]. It has linear and cyclic macromolecules which are un-branched and contain one double bond for every eight carbon atom with prevalently *trans* isomeric double bonds [11].

Polypropylene (PP)-based materials are known to attract attention due to their low cost, processability

---

*Corresponding author.

E-mail address: hanafi@eng.usm.my (H. Ismail).

0142-9418/$ - see front matter © 2007 Elsevier Ltd. All rights reserved.
doi:10.1016/j.polymertesting.2007.04.007

and good balance of properties [12]. One of the possibilities is to blend it with abundant waste rubber, and it has attracted a number of researchers to investigate the properties it has to offer [2,13,14]. Recently, the authors [3] highlighted the effects of waste tire dust (WTD) size and partial replacement of PP by WTD on the properties of PP/WTD blends. A number of works have also been reported by several researchers on TOR [11,15]. However, no attempt has been made to investigate the effects of TOR and dynamic vulcanization on the properties of PP/WTD blends.

In this work, TOR acting as a processing aid and a rubber component itself was incorporated into PP/WTD blends with the presence of a conventional vulcanization agent, sulfur. The variations of tensile properties, oil and chemical resistance, morphology and thermal properties are reported and discussed.

2. Experimental

2.1. Materials and preparation of blend

The materials used in this study were PP homopolymer, WTD—a recycled product from mechanically ground scrap tires, TOR, sulfur, zinc oxide, stearic acid and *N*-cyclohexyl-2-benzothiazole-2-sulfenamide (CBS). Their characteristics are illustrated in Table 1.

Table 1
Characteristics of materials

Material	Description	Source
Polypropylene (PP)	TitanPro 6331 Homopolymer MFR at 230 °C = 14 g/10 min	Titan PP Polymers, Malaysia
Waste tire dust (WTD)	Size: 500–710 μm	Mega Makmur Saintifik, Malaysia
Trans-polyoctylene rubber (TOR)	Vestenamer 8012 ML_{1+4} at 100 °C < 10 MW = 100,000 $T_m = 51\,°C$, $T_g = -65\,°C$ Crystallinity at 23 °C = 27%	Huls, Germany
Sulfur, zinc oxide, stearic acid and CBS (*N*-cyclohexyl-2-benzothiazole-2-sulfenamide)		Bayer, Malaysia

The PP/WTD blends were formulated based on 80/20, 70/30, 60/40, 50/50 and 40/60 (wt%). The amounts of sulfur, zinc oxide, stearic acid and CBS were varied accordingly so that all blend compositions have the same concentration of vulcanization agent and curatives. The blends were melt-mixed in an internal mixer (Haake Polydrive R600/610) at a temperature of 180 °C and rotor speed of 50 rpm. The mixing sequence for blends with and without TOR and dynamic vulcanization is enumerated in Table 2. For both systems, PP was melted in the mixer for 2 min prior to the addition of WTD. For the system without TOR and dynamic vulcanization, the mixing was continued for another 7 min. In the case of the system with TOR and dynamic vulcanization, additions of TOR, curatives and vulcanization agent were done at 6 min, 8 min and 10 min, respectively, and the process was considered complete after a total time of 13 min. Then, the blends were left to cool down at ambient temperature prior to molding.

Table 2
Summary of mixing sequence

Time (min)	Blends and operation	
	PP/WTD *without* TOR and dynamic vulcanization	PP/WTD *with* TOR and dynamic vulcanization
0	Addition of PP	Addition of PP
2	Addition of WTD	Addition of WTD
6		Addition of TOR[a]
8		Addition of curatives[b]
9	Remove	
10		Addition of vulcanization agent[c]
13		Remove

[a] TOR (10 phr).
[b] Zinc oxide (5 phr), stearic acid (1.5 phr), CBS (1 phr).
[c] Sulfur (2 phr).

About 36 g of PP/WTD blends were placed in a mold and pressed between smooth sheets and the moving platens of an electrically heated hydraulic press to produce a 2 mm sheet. The blends were preheated for 6 min and compression-molded for 4 min at 180 °C. The blends were subsequently cooled under running tap water and pressure for 2 min at ambient temperature. Then, dumb-bell-shaped test specimens were punched from the sheets.

2.2. Measurement of properties

Tensile properties were determined using a tensile tester (Instron 3366) according to ISO 37. The tests were performed at a temperature of 25 ± 3 °C and