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Recycled High Density Polyethylene / Ethylene Vinyl Acetate / Tyre Dust / Caprolactam Composites: The Effect of Filler loading on Tensile Properties and Thermal Degradation

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Abstract – *The effect of caprolactam as a compatibilizer on the tensile properties and thermal degradation of recycled high density polyethylene/ethylene vinyl acetate/tyre dust (r-HDPE/EVA/TD) composites was studied. r-HDPE/EVA/TD composites and r-HDPE/EVA/TD/CL composites with different tyre dust loadings were prepared using Brabender Plasticorder at the temperature of 160°C and rotor speed of 50 rpm. The results indicated that r-HDPE/EVA/TD composites with caprolactam showed higher tensile strength and modulus of elasticity than r-HDPE/EVA/TD composites. The r-HDPE/EVA/TD/CL composites exhibited good thermal stability compared to r-HDPE/EVA/TD composites as evidenced from the thermogravimetric analysis.* ***Copyright © 2014 Penerbit Akademia Baru - All rights reserved.***

Keywords: Recycled high density polyethylene, Ethylene vinyl acetate, Tyre dust, Caprolactam

1.0 INTRODUCTION

High density polyethylene (HDPE) is suitably used as packaging and manufacturing products due to its properties. As it is known, HDPE is stronger than the standard PE that can act as an effective barrier against moisture and remain solid at room temperature [1]. Recycling contributes to reduction in resource consumption and pollution. Recycled high density polyethylene (r-HDPE) is used to manufacture lawn, garden products, buckets, crates, office products, and automobile parts. Application of r-HDPE is often limited due to its low impact strength and Young modulus properties, particularly at low temperature and high temperature loading conditions [2]. Blending r-HDPE with different polymer is an economic and effective way to improve these drawbacks [3].

r-HDPE/EVA blends are widely used in many applications such as multilayer packaging, shrinkable film, and wire and cable coating [4]. Blending EVA onto different ratios of r-HDPE may improve the toughness, transparency, environmental stress cracking resistance (ESCR), and the capacity of filler carrying [5].

Tyre represents a big challenge to the sustainability of environment as waste rubber does not easily degrade. A number of possible applications of various form of waste rubber in broad disciplines have been studied and reported [6-9]. Formulating a new usable material using reused tyre dust possess economic and environmental advantages. Awang et al. [10] reported that the addition of waste tyre dust seems to be effective in improving the overall tensile properties, swelling resistances, and morphology of polymer blends. Polymer modification has been carried out in many ways, resulting in a variety or properties depending on factors such as blend composition, processing conditions, additives, and temperature of applications [11-12]. The agent modifies the interface by interacting with filler and polymer, thus forming a link between the components [13]. In this paper, the effect of caprolactam as a compatibilizer on tensile properties and thermal degradation of r-HDPE/EVA/TD composites was investigated.

2.0 METHODOLOGY

2.1 Materials

Recycled high density polyethylene (r-HDPE) with a melt flow index of 0.7 g/10 min (190°C) and a density of 939.9 kg/m3 was used. Tyre dust (particle size = 177 μm) was obtained from Mega Makmur Sdn. Bhd., Penang, Malaysia. Ethylene vinyl-acetate copolymer (EVA) and toluene with the density of 0.93 g.cm-3, melting point of 95°C, and melt flow index of 2.5 g/10 min (80°C; 2.16 kg) were obtained from AR Alatan Sdn. Bhd. Caprolactam (1-aza-2-cycloheptanone) [CL] and toluene were also obtained from AR Alatan Sdn. Bhd., Kedah Darul Aman, Malaysia.

2.2 Composites Preparation

The mixing was carried out using Brabender Plasticorder at 160°C and rotor speed of 50 rpm for 10 min. r-HDPE/EVA and CL were first charged into Brabender Plasticorder. After 4 min of preheat, tyre dust (TD) was added into the soften r-HDPE/EVA blends. The mixing processing was allowed to take place for 6 min in order to obtain homogenous composites. The soften composites were removed from the chamber and pressed into thick round pieces.

3.0 RESULTS ANS DISCUSSION

Figure 1 shows the effect of tyre dust loading on the tensile strength of r-HDPE/EVA/TD composites with and without caprolactam. The result shows that as the loading of tyre dust increased, the tensile strength of r-HDPE/EVA/TD composites decreased due to incompatibility of r-HDPE/EVA and trye dust. This incompatibility results in reduced tensile strength because fracture would be initiated from the weak interface of the composites due to their poor interfacial adhesion. At a similar filler loading, r-HDPE/EVA/TD/CL composites show higher tensile strength than r-HDPE/EVA/TD composites. This is due to the presence of caprolactam, which enhanced the compatibility between r-HDPE/EVA blends and tyre dust. The improved interfacial adhesion between r-HDPE/EVA and tyre dust has a positive impact on stress transfer, thus reducing the change in interfacial debonding and leading to improved tensile properties. A similar observation was reported by Supri and Ismail [6] using the combination of isophorone diisocyanate and polyhydroxyl as a compatibilizer in LDPE/acrylonitrile butadiene styrene-water hyacinth fiber composites to overcome dispersion problem and also to enhance the mechanical strength of composites by improving interfacial adhesion.

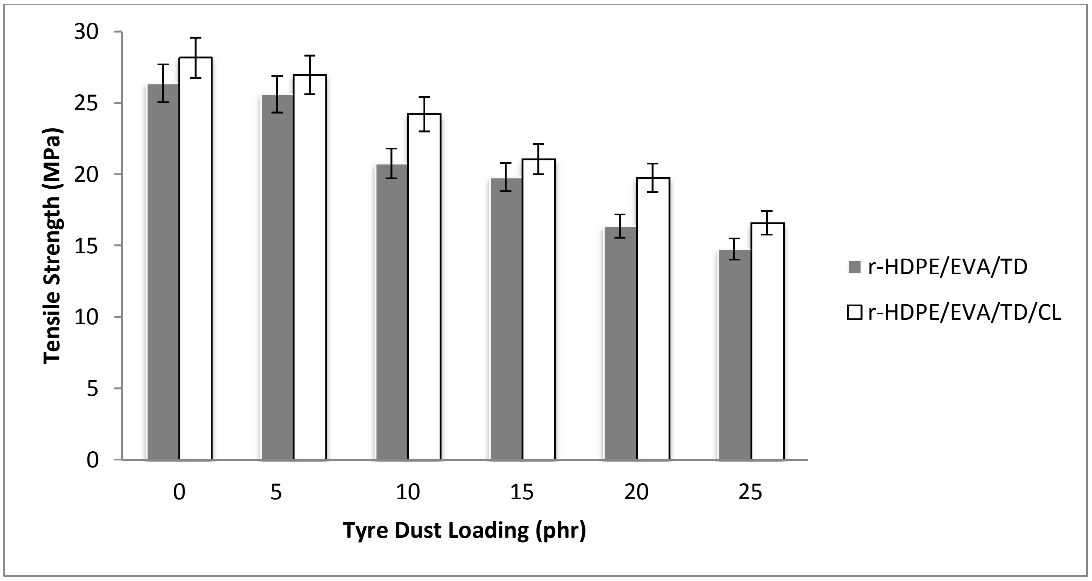

Figure 1: Tensile strength versus tyre dust loading of r-HDPE/EVA/TD and r-HDPE/EVA/TD/CL composites

Figure 2 shows typical thermal degradation curves of r-HDPE/EVA/TD/CL composites with different filler loadings. Table 1 shows that the temperature of 50% weight loss ($T_{-50\%wt}$), the final decomposition temperature (FDT), and residual mass for r-HDPE/EVA/TD and r-HDPE/EVA/TD/CL composites increased with the increase of filler loading. The result indicated that higher filler loading gives r-HDPE/EVA/TD composites more thermal stability than lower filler loading. A similar observation was reported by Supri and Ismail [1] due to the presence of large content of tyre dust loading in the composites.

However, it can be seen that the temperature of 50% weight loss, final decomposition temperature, and residual mass of r-HDPE/EVA/TD/CL composites are higher than r-HDPE/EVA/TD composites. This is due to the presence of good interfacial adhesion between r-HDPE/EVA and TD phase as a result of uniform dispersion of filler throughout the r-HDPE/EVA polymer matrix with the presence of CL. Better dispersion of filler acts as a barrier against the release of volatile gases during thermal degradation. It may also attribute to an adsorption effect of these gases at filler surface, which slows down polymer degradation [13].

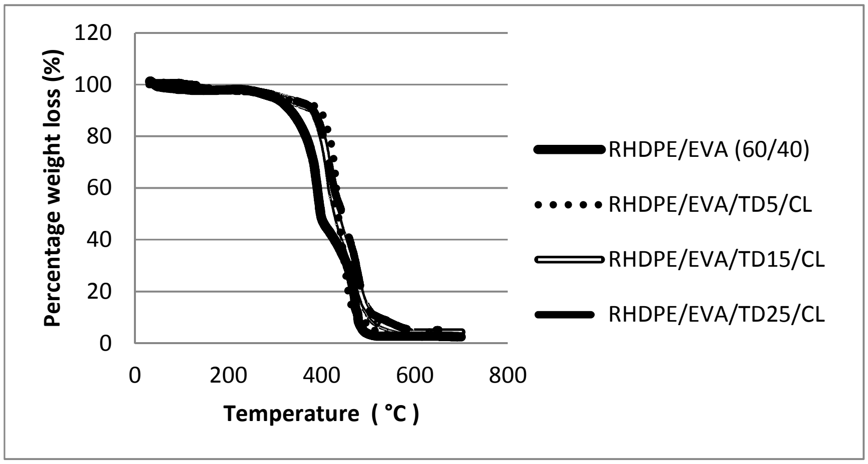

Figure 2: TGA thermogram of r-HDEP/EVA/TD/CL composites with different filler loading

Table 1: Data of thermogravimetric analysis of r-HDPE/EVA/TD and r-HDPE/EVA/TD/CL composites with different filler loadings.

Composite code	T - 50%wt (°C)	FDT (°C)	Residual Mass (%)
RHDPE/EVA (60/40)	398.01	609.73	1.38
RHDPE/EVA/TD5	423.13	701.03	1.92
RHDPE/EVA/TD15	424.33	701.14	2.65
RHDPE/EVA/TD25	426.67	702.26	5.11
RHDPE/EVA/TD5/CL	435.28	701.62	2.91
RHDPE/EVA/TD/CL15	435.65	701.85	4.28
RHDPE/EVA/TD/CL25	444.21	702.91	5.20

4.0 CONCLUSION

r-HDPE/EVA/TD/CL composites showed higher tensile strength and modulus of elasticity than r-HDPE/EVA/TD composites. r-HDPE/EVA/TD/CL composites exhibited higher thermal stability compared to r-HDPE/EVA/TD composites. These results were observed due to better interfacial adhesion between r-HDPE/EVA phases and TD with the presence of caprolactam as a compatibilizer.

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