PREPARATION, CHARACTERIZATION AND PROPERTIES OF POLYPROPYLENE/WASTE TIRE DUST (PP/WTD) BLENDS

MOHAMAD BIN AWANG

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Preparation, characterization and properties of polypropylene/waste tire dust (PP/WTD) blends / Mohamad Awang.

Lihat Sebelah

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by

MOHAMAD BIN AWANG

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DEDICATION

to my parents, wife, and kids….

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LIST OF ABBREVIATIONS

A-HDPE	acrylic-modified HDPE
ATR	attenuated total reflection
AU	polyester urethanes
BR	butadiene rubber
CBS	*N-cyclohexyl-2-benzothiazole-2-sulfenamide*
CR	chloroprene rubber
DCP	dicumyl peroxide
DCPD	dicyclopentadiene
DSC	differential scanning calorimetry
DTDM	dithiodimorpholine
DTG	derivative thermogravimetric
ECO	epichlorohydrin rubber
ENB	5-ethylidene norbornene
ENR	epoxidized NR
EPDM	ethylene-propylene-diene terpolymer
EU	polyether urethanes
EVA	ethylene-vinyl acetate
FTIR	Fourier-transform infrared (spectroscopy)
h	hour
HDPE	high density polyethylene
HVA-2	*N, N'-m-phenylenebismaleimide*
IIR	isobutene-isoprene rubber (butyl rubber)
IPN	interpenetrating polymer network
IR	infra red
LDPE	low density polyethylene

LLDPE	linear low density polyethylene
LNR	liquid natural rubber
MA	maleic-anhydride
MIDA	Malaysian Industrial Development Authority
min	minute
NBR	acrylonitrile-butadiene rubber
NMR	nuclear magnetic resonance
NR	isoprene rubber (natural)
PE	polyethylene
PET	poly(ethylene terephthalate)
phr	part(s) per hundred rubber
PMMA	poly(methyl methacrylate)
PP	polypropylene
PS	polystyrene
PU	polyurethane
PVC	polyvinyl chloride
rpm	revolution(s) per minute
SBR	styrene-butadiene rubber
SBS	styrene-butadiene-styrene triblock copolymer
SEBS	styrene-ethylene-butylene-styrene
SEBS-g-MA	maleic-anhydride grafted SEBS
SEM	scanning electron microscopy
TDF	tire derived fuel
TG	thermogravimetric
TGA	thermogravimetric analysis
TMTD	tetramethylthiuram disulfide
TOR	*trans*-polyoctylene rubber

TPE	thermoplastic elastomer
TPO	thermoplastic olefins
TPV	thermoplastic vulcanizates
UV	ultraviolet
UV/VIS	ultraviolet-visible-spectroscopy or ultraviolet-visible-spectrophotometry
WRHA	white rice husk ash
WTD	waste tire dust
WTD_{EPDM-M}	EPDM modified WTD
WTD_{ML}	NR latex modified WTD
WTD_{NR-M}	NR modified WTD
WTD_{P-HVA2}	modified WTD with HVA-2 and DCP dynamic vulcanization
WTD_{T-SDV}	modified WTD with TOR and sulfur dynamic vulcanization
YBPO	ether-ester block co-polymer (thermoplastic polyether-ester)

LIST OF SYMBOLS

C	carbon
E	energy (Joule)
E_b	elongation at break
H	Plank's constant
kg	kilogram
kJ/kg	kilojoule per kilogram
O_2	oxygen
O_3	ozone
S	sulfur
S_x	polysulfidic
T	temperature
T_m	melting temperature
v	frequency (Hertz)
W_1	weight of sample before immersion
W_2	weight of sample after immersion
wt%	weight percent
ZnO	zinc oxide
ΔG_m	Gibbs free energy change on mixing
ΔH_m	enthalpy change on mixing
ΔS_m	entropy change on mixing
λ	wavelength (m)

PENYEDIAAN, PENCIRIAN DAN SIFAT-SIFAT ADUNAN POLIPROPILENA/SERBUK SISA TAYAR (PP/WTD)

ABSTRAK

Termoplastik dan getah sisa daripada tayar terbuang telah dicampurkan bagi menyediakan adunan polipropilena/serbuk sisa tayar (PP/WTD). Semua adunan disediakan di dalam pencampur dalaman pada suhu 180°C, putaran 50 rpm untuk suatu tempoh adunan di antara 9 dan 13 minit. Pencirian telah dilakukan untuk mengenalpasti sifat-sifat adunan dan menyelidik kesan-kesan saiz serbuk sisa tayar, penggunaan pemvulkanan dinamik dan ko-agen, penambahan bahan polimer lain dan pendedahan pencuacaan semulajadi selama 6 bulan terhadap sifat mekanik, morfologi, rintangan pembengkakan, dan sifat-sifat haba adunan tersebut. Tanpa mengira saiz, sisa getah yang tersambung silang dan mengandungi kandungan karbon yang tinggi telah didapati berfungsi seperti pengisi tanpa-menguat. Peningkatan penyebaran zarah WTD dan interaksi dengan matriks PP menyumbang kepada sifat yang lebih baik bagi adunan yang mengandungi WTD halus. Peningkatan interaksi antara muka di antara matriks PP dan WTD akibat daripada penambahan getah *trans*-polioktilena (TOR) bersama sulfur, dikumil peroksida (DCP) dan *N, N'-m-fenilenabismalemida* (HVA-2) kepada adunan adalah punca utama peningkatan keseluruhan morfologi, sifat-sifat mekanik, rintangan pembengkakan, dan sifat-sifat haba adunan. Penambahan WTD yang terubahsuai dengan lateks getah asli (NR) merintis kekusutan zarah getah tersambung-silang dengan matriks PP yang menggalakkan peningkatan rekatan dengan WTD dan menyebabkan peningkatan terhadap sifat-sifat mekanik, rintangan pembengkakan, dan sifat-sifat haba adunan. Sementara itu, penambahan WTD yang terubahsuai dengan

getah asli (NR) dan WTD yang terubahsuai dengan etilena-propilena diena terpolimer (EPDM) meningkatkan keanjalan rantaian adunan PP/WTD. Penambahan bahan-bahan berkenaan telah menggalak pembentukan kawasan antara muka dan seterusnya meningkatkan lagi interaksi di antara matriks PP dan WTD sebagaimana yang dibuktikan oleh sifat-sifat adunan yang lebih baik. Selepas 6 bulan pendedahan kepada pencuacaan semulajadi, keseluruhan adunan telah menunjukkan kemerosotan sifat. Sementara adunan yang mengandungi WTD halus telah menunjukkan sifat mekanik yang lebih baik daripada adunan yang mengandungi WTD kasar, kebanyakan adunan yang mengandungi WTD terubahsuai telah mempamerkan sifat mekanik yang lebih unggul dan penahanan sifat yang pelbagai beserta sifat haba yang lebih baik daripada adunan asal tanpa sebarang pengubahsuaian terhadap WTD. Ini menunjukkan kewujudan interaksi yang lebih baik di antara matriks PP dan WTD yang terubahsuai.

PREPARATION, CHARACTERIZATION AND PROPERTIES OF POLYPROPYLENE/WASTE TIRE DUST (PP/WTD) BLENDS

ABSTRACT

Thermoplastics and waste rubber from scrap tires were mixed to prepare polypropylene/waste tire dust (PP/WTD) blends. All blends were prepared in an internal mixer at a temperature of 180°C, a rotor speed of 50 rpm and a mixing period between 9 and 13 min. Characterization was done to determine the properties of the blends and to investigate the effects of WTD size, application of dynamic vulcanization and co-agents, addition of other polymeric materials and a 6-month exposure to natural weathering on the mechanical properties, morphology, swelling resistance and thermal properties of the blends. Irrespective of size, the highly cross-linked waste rubber with a high content of carbon black behaved like non-reinforcing fillers. An improved distribution of WTD particles and hence interactions with the PP matrix rendered superior properties to the blends with fine WTD. Formations of enhanced interactions across the interface of the PP matrix and WTD as a result of addition of *trans*-polyoctylene rubber (TOR) together with sulfur, dicumyl peroxide (DCP) and *N, N'-m-phenylenebismaleimide* (HVA-2) to the blends were the pivotal ascriptions to the overall improvements in morphology, mechanical properties, swelling resistance and thermal properties of the blends. Addition of natural rubber (NR) latex modified WTD initiated the creation of entanglements of vulcanized rubber particles with the PP matrix promoting improved adhesion with WTD resulting in enhanced mechanical properties, swelling resistance, and thermal properties of the blends. Meanwhile, the addition of NR modified WTD and ethylene-propylene diene terpolymer (EPDM) modified WTD improved chain flexibility of

the PP/WTD blends. Their addition to the blends favored formations of interfacial region and hence improved interaction between the PP matrix and WTD as evidenced by superior properties of the blends. After the 6-month exposure to natural weathering, all blends exhibited deteriorations in properties. Whilst, blends with fine WTD demonstrated higher mechanical properties after the exposure than those with coarse one, mostly all blends with WTD modification exhibited higher mechanical properties with variations of retention and unveiled better thermal properties than those without any modification alluding to the presence of improved interactions between the PP matrix and modified WTD.