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EFFECT OF THERMO-OXIDATIVE AGING ON THE TENSILE AND MORPHOLOGICAL PROPERTIES OF PP/NR AND PP/RRP BLENDS

SURYADIANSYAH[1] & HANAFI ISMAIL[2]

Abstract. The effect of thermo-oxidative aging on the tensile and morphological properties of polypropylene (PP)/natural rubber (NR) and PP/recycled rubber powder (RRP) blends at different rubber content (80/20, 50/50 and 40/60 wt./wt.) were studied. The blends were melt mixed using a Brabender Plasticorder torque rheometer at a temperature of 190°C and rotor speed of 50 rpm. The results indicated that at a similar rubber content, PP/RRP blends exhibited higher degree of retention of tensile strength (91–99% compared with 85–93% for PP/NR blend) and Young's modulus (71–86% compared with 55–80% for PP/NR blend) but exhibited lower elongation at break (72–85% compared with 75–87% for PP/NR blend). Scanning electron microscopy (SEM) examination of the tensile fractured surface of PP/NR blends showed a more smooth fractured surface than PP/RRP blends after thermo-oxidative aging. This observation supported the higher tensile strength retention after thermo-oxidative aging of PP/RRP blends compared with the PP/NR blends.

Keywords: thermo-oxidative; polypropylene; natural rubber; recycled rubber powder.

Abstrak. Kesan penuaan termo-oksidatif ke atas sifat tensil dan morfologi untuk adunan polipropilena (PP)/getah asli (NR) dan PP/serbuk getah kitar semula (RRP) menggunakan pelbagai kandungan getah (80/20, 50/50 dan 40/60 berat/berat) telah dikaji. Adunan dicampur menggunakan Brabender Plasticorder pada suhu 190°C dan kelajuan 50 rpm. Keputusan menunjukkan bahawa pada kandungan getah yang sama, adunan PP/RRP mempunyai peratus retensi kekuatan tensil yang lebih tinggi (91–99% berbanding 85–93% untuk adunan PP/NR) dan juga modulus Young (71–86% berbanding 55-80% untuk adunan PP/NR) tetapi pemanjangan pada takat putus yang lebih rendah (72–85% berbanding 75–87% untuk adunan PP/NR). Mikrograf elektron penskanan menunjukkan permukaan rekahan selepas penuaan termo-oksidatif adunan PP/NR adalah lebih licin berbanding permukaan rekahan adunan PP/RRP. Pemerhatian ini menyokong keputusan retensi kekuatan tensil selepas penuaan termo-oksidatif bagi adunan PP/RRP yang lebih baik berbanding adunan PP/NR.

Kata kunci: termo-oksidatif; polipropilena; getah asli; serbuk getah kitar semula.

1.0 INTRODUCTION

The emergence of thermoplastic elastomers bridges the gap between conventional elastomers and thermoplastics. They have performance characteristics of crosslinked elastomers at room temperature and enjoy the ease of processing of thermoplastic

[1&2]School of Materials and Mineral Resources Engineering. Universiti Sains Malaysia, 14300 Nibong Tebal, Pulau Pinang, Malaysia. Tel: +60-4-5937788 x 6113, Fax: +60-4-5941011. E-mail: suryadian@yahoo.com and hanafi@eng.usm.my

materials. Thermoplastic elastomers have been described in several recent books [1-3]. Chowdhury and Bhowmick described the preparation and properties of several thermoplastic elastomeric natural rubber (NR)-plastic blends in an earlier communication [4]. It was observed that the mechanical properties of the blends (i.e., the tensile strength or elongation at break) are inferior to either plastics or vulcanised rubbers.

Increasing environmental concerns and legislation have resulted in significant pressure to reduce, reuse or recycle various waste rubber products. Different methods have been used to dispose or reuse scrap rubber. Waste rubber powder is one of the materials which may be converted into several useful products [5-7]. Various processes were effected by mixing the rubber powder or scrap latex rejects with new rubber and subsequent vulcanising of the component. Acetta and Vergnaud [8] tried to upgrade scrap rubber powder by vulcanisation without new rubber. Mathew *et al*., [9] reported the recycling of natural rubber latex waste and its interaction in epoxidised natural rubber. The feasibility of using activated tyre rubber as a modifying ingredient in thermoplastic elastomers was studied by Osborn [10] whereas the preparation of thermoplastic elastomers from reclaimed rubber and waste plastic was reported by Nevatia *et al*., [11].

In our previous work [12], we have compared the properties of thermoplastic elastomers based on polypropylene (PP)/natural rubber (NR) and polypropylene (PP)/recycled rubber powder (RRP) blends. Fine rubber powder obtained from the sanding process of polishing rubber balls and artificial eggs (recycled rubber powder, RRP) was used to prepare PP/RRP blends. In this work a thermoplastic elastomer based on polypropylene/natural rubber and polypropylene/recycled rubber powder blends were prepared. The percentage retention of tensile strength, Young's modulus and elongation at break after thermo-oxidative aging were compared. Results of scanning electron microscopy of tensile fractured surface of both PP/NR and PP/RRP blends before and after thermo-oxidative aging were also examined.

2.0 EXPERIMENTAL PROCEDURE

2.1 Materials

Polypropylene homopolymer used in this study was of injection moulding grade, with a MFI value of 14.0 g/10 min at 230°C. Natural rubber (SMR L) was purchased from a local vendor. The recycled rubber (powder) is a waste product from the sanding process (polishing) of rubber balls and artificial eggs. The range of particle size used in this study was 250–500 μm.

2.2 Mixing Procedure

Thermoplastic elastomers were prepared on a Brabender Plasticorder model PLE 331. Mixing was done at 190°C and 50 rpm. PP was preheated for 6 min and was melted in the mixer for 2 min and then NR or RRP was added and the mixing was continued for 5 min. The mixing study was conducted for neat polypropylene and blends with increasing rubber content (20, 50 and 60 wt%) as shown in Table 1.

Table 1 Formulas of PP/NR and PP/RRP blends

Materials	Blends (wt%)					
	1	2	3	4	5	6
Polypropylene (PP)	80	50	40	80	50	40
Natural Rubber (NR)	20	50	60	*	*	*
Recycle Rubber (RRP)	*	*	*	20	50	60

2.3 Compression Moulding

Sample of the blends were compression moulded in an electrically heated hydraulic press. Hot-press procedures involved preheating at 190°C for 6 minutes followed by compression for 4 minutes at the same temperature and subsequently cooling under pressure for 4 minutes.

2.4 Tensile properties

Tensile tests were carried out according to ASTM D 412 on a Testometric tensometer M 500. Two millimeter thick dumbbell specimens were cut from the moulded sheets with a Wallace die cutter. A cross head speed of 50 mm/min was used and the test were performed at 25°C.

2.5 Thermo-oxidative aging

Thermo-oxidative aging studies were carried out according to BS 7646. The tensile samples were placed in an air oven and aged at 100°C for 24 hours. Retention in properties is calculated as shown below:

$$\%\,\text{Retention} = \frac{\text{Value after aging}}{\text{Value before aging}} \times 100 \qquad (1)$$

2.6 Morphological Study

Studies on the morphology of tensile fracture surface of PP/NR and PP/RRP blends were carried out using a scanning electron microscope (SEM), model Leica Cambridge S-360. The fracture ends of the specimens were mounted on aluminum stubs and sputter-coated with a thin layer of gold to avoid electrostatic charging during examination.

3.0 RESULTS AND DISCUSSION

The effect of thermo-oxidative aging on tensile properties in PP/NR and PP/RRP blends is shown in Figures 1 to 3. It can be seen that the tensile strength and Young's modulus of the blends decrease with increasing rubber content before and after thermo-oxidative aging whereas elongation at break shows increasing trend. Both blends exhibit the above properties after aging are lower than before aging. This observation indicated a poor retention properties of aged PP/NR and PP/RRP blends which highlights that the aging process has resulted in permanent damage. Figure 3 shows that percentage of retention on tensile strength and Young's modulus of the blends decrease with increasing rubber content but elongation at break exhibits the opposite trend. This is due to the increasing of rubber content which increases the ductility of the blend. Blackman and Mc Call [13] reported the reduction in strength after aging for rubber vulcanisates cured with sulfur is due to structural change of the rubber chain. Oxidative processes not only result in the scissioning of the main rubber chain but also sulfuric crosslink. Hanafi *et al.*, [14] also reported that thermo-oxidative aging increased the Young's modulus and hardness of white rice husk ash and various commercial fillers filled ENR compounds while other properties, *i.e.*, tensile strength, elongation at break and tear strength decreased. Figures 1 to 3 also show that at a similar rubber content, PP/RRP blends exhibit higher percentage of retention of tensile

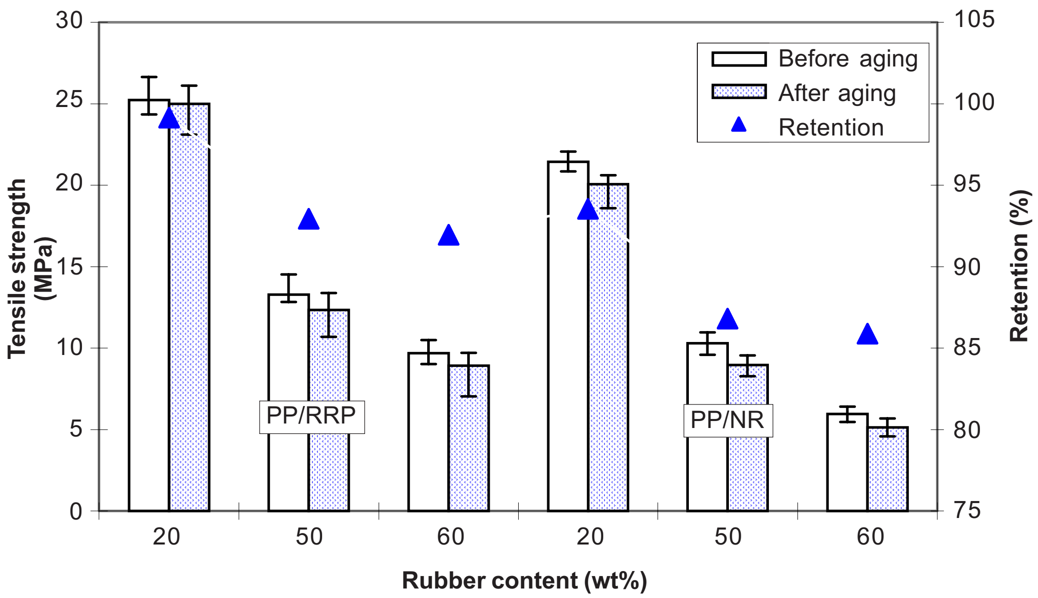

Figure 1 Effect of thermo-oxidative aging on tensile strength of PP/RRP and PP/NR blends

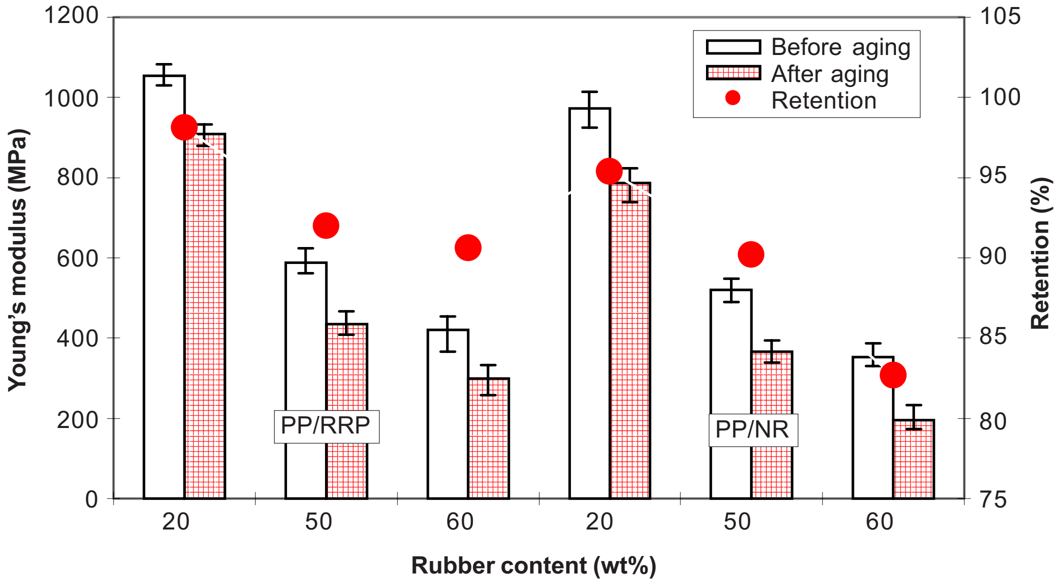

Figure 2 Effect of thermo-oxidative aging on Young's modulus of PP/RRP and PP/NR blends

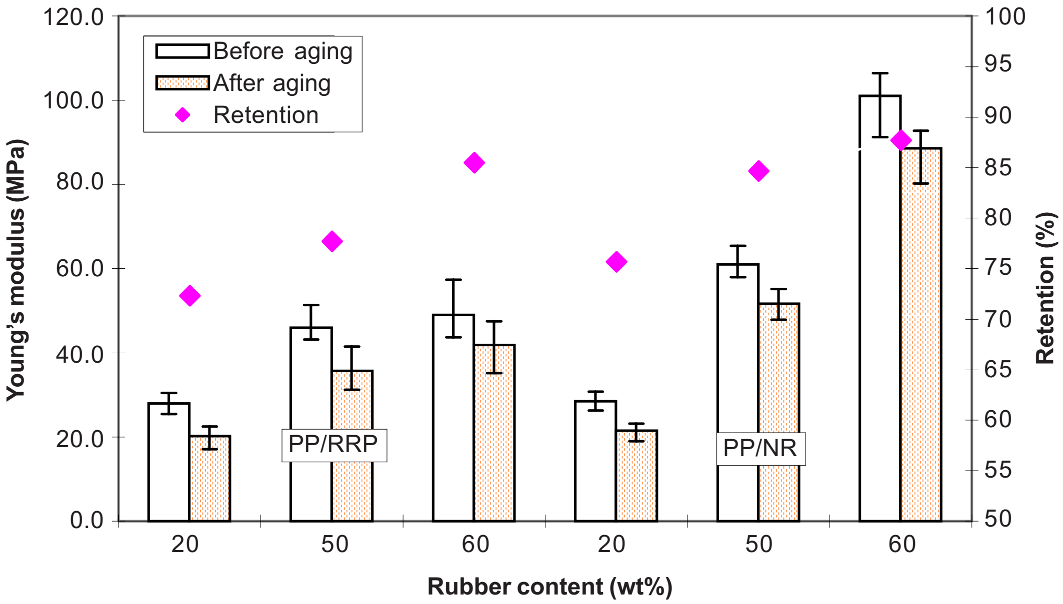

Figure 3 Effect of thermo-oxidative aging on elongation at break of PP/RRP and PP/NR blends

strength and Young's modulus but lower elongation at break than PP/NR blends. This observation is due to the presence of recycled rubber powder which is already crosslinked. We have reported [12] that at a similar blend ratio the mechanical properties of PP/RRP blends are better that PP/NR blends.

Scanning electron microscopy (SEM) micrographs in Figures 4 to 7 exhibit the thermo-oxidative aging process has transformed the appearance of the fracture surface of PP/RRP 50/50 and PP/NR 50/50 blends. The fractured surfaces after aging are smooth (Figures 6 and 7) compared with those before aging (Figures 4 and 5) which show evidences of matrix tearing indicated by their rough appearance. This implies that brittle failure has occurred in the aged samples. Comparison of the fracture surface of PP/NR 50/50 and PP/RRP 50/50 blends show that PP/NR 50/50 blends exhibit

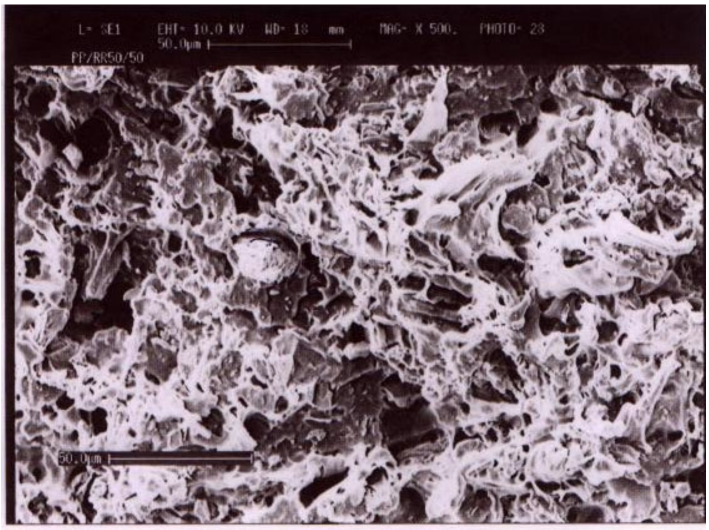

Figure 4 Scanning electron micrograph of tensile fracture surface of PP/RRP (50/50) blend (wt%) before aging at magnification of 500X

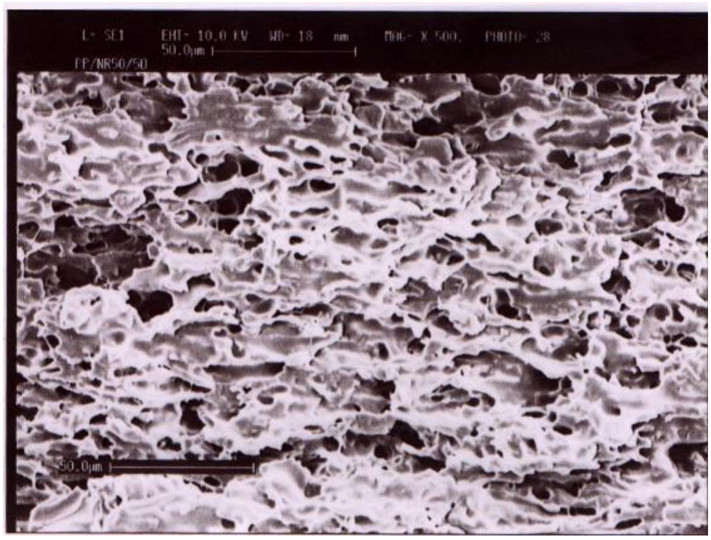

Figure 5 Scanning electron micrograph of tensile fracture surface of PP/NR (50/50) blend (wt%) before aging at magnification of 500X

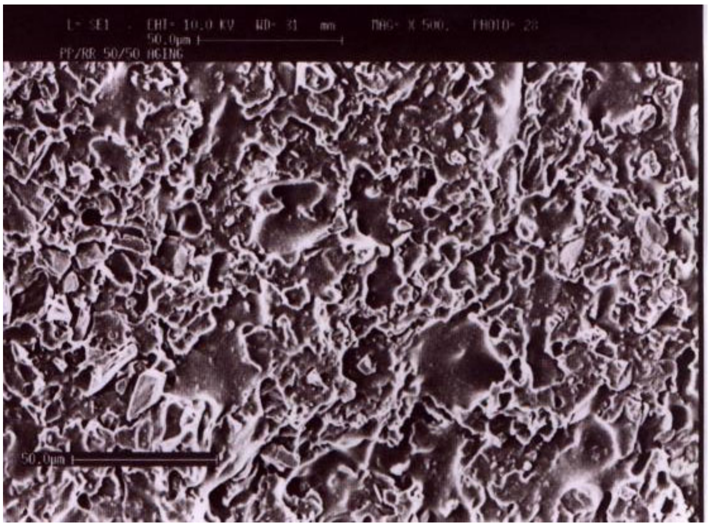

Figure 6 Scanning electron micrograph of tensile fracture surface of PP/RRP (50/50) blend (wt%) after aging at magnification of 500X

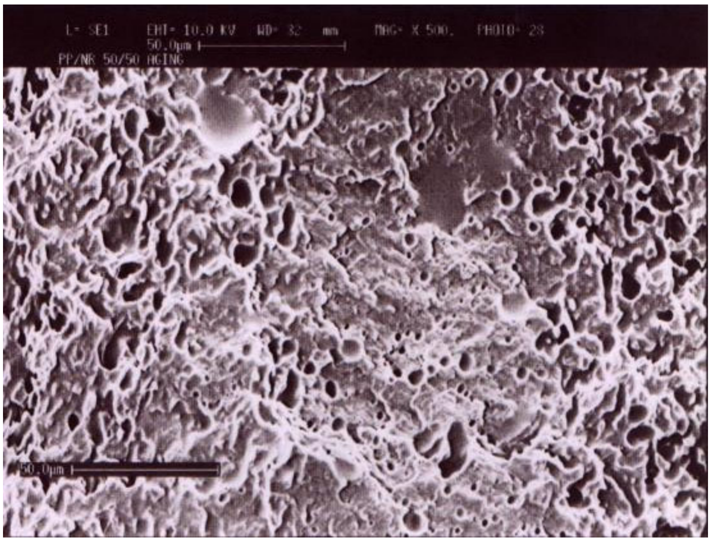

Figure 7 Scanning electron micrograph of tensile fracture surface of PP/NR (50/50) blend (wt%) after aging at magnification of 500X

more smooth surfaces than PP/RRP blends, which indicates that the tensile strength of PP/RRP blends is better than PP/NR blends.

4.0 CONCLUSION

Thermo-oxidative aging has reduced the tensile strength, Young's modulus and elongation at break of PP/NR and PP/RRP blends. At a similar rubber content, PP/

RRP blends show better retention of tensile strength and Young's modulus than PP/NR blends except the elongation at break. Morphological examination of tensile fractured surfaces after thermo-oxidative shows that PP/RRP blends have a rougher surface than PP/NR blends.

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