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Jurnal Sains Materi Indonesia
Indonesian Journal of Materials Science

Vol. 12, No. 2, Februari 2011, hal : 106 - 109
ISSN : 1411-1098

Akreditasi LIPI Nomor : 452/D/2010
Tanggal 6 Mei 2010

THE EFFECTS OF IMPACT MODIFIERS ON THE PROCESSABILITY AND THE TOUGHNESS OF POLY VINYL CHLORIDE PROFILES

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ABSTRACT

THE EFFECTS OF IMPACT MODIFIERS ON THE PROCESSABILITY AND THE TOUGHNESS OF POLY VINYL CHLORIDE PROFILES. Extruded Poly Vinyl Chloride (PVC) door profile and window profiles often fail at the bend. This research aims to reduce such problem by enhancing the toughness of the PVC profiles while still maintaining their load bearing function and stiffness. Three impact modifiers namely methacrylate-butadiene-styrene (MBS), chlorinated polyethylene (CPE) and nano-scaled nitrile butadiene rubber (NBR) were employed in the PVC profiles at 1-11 phr. The processability assessed by rheometric study revealed only a slight increase in the torque required to process the melt PVC dosed with CPE and nano NBR while that required for the PVC with MBS was raised quite significantly. Although the PVC modified with MBS melted faster at a lower temperature, a rapid rise of temperature was observed during processing. The heat was probably due to the higher friction and shear induced by the rather viscous PVC melt dosed with MBS. Mechanical tests in terms of impact energy, stiffness and hardness revealed that the toughening efficiency of all three impact modifiers were close at low content, but at around 9 and 11 phr, the MBS and the CPE enhanced the impact energy quite rapidly by four folds while their corresponding hardness and stiffness were lowered considerably.

Key words : Impact modifier, Processability, Toughness, Poly vinyl chloride

ABSTRAK

EFEK DARI *IMPACT MODIFIER* PADA KEMUDAHAN PROSES DAN KEULETAN DARI PROFIL POLIVINIL KHLORIDA. Profil Pintu dan jendela dari Polivinil khlorida (*PVC*) hasil ekstrusi seringkali gagal pada bagian lengkungan. Penelitian ini bertujuan untuk mengurangi masalah kegagalan hasil ekstrusi dengan meningkatkan keuletan dari profil berbahan *PVC* dengan tetap menjaga kemampuan menerima beban dan kekakuannya. Tiga jenis bahan untuk memodifikasi kemampuan menerima impak (*impact modifier*) yaitu *methacrylate-butadiene-styrene* (*MBS*), *chlorinated polyethylene* (*CPE*) dan *nano-scaled nitrile butadiene rubber* (*nano-NBR*) digunakan dalam profil *PVC* pada 1 *phr* hingga 11 *phr*. Kemudahan proses torsi yang terukur dari hasil studi rheometrik menunjukkan bahwa hanya sedikit peningkatan *torque* yang diperlukan untuk memproses lelehan *PVC* yang telah ditambahi dengan *CPE* dan *nano-NBR*. Namun untuk *PVC* yang telah ditambahi dengan *MBS* dibutuhkan peningkatan torsi yang lebih tinggi. Meskipun *PVC* yang dimodifikasi dengan *MBS* meleleh lebih cepat pada suhu yang lebih rendah, peningkatan suhu yang lebih cepat terobservasi selama pemrosesan. Panas ini mungkin terjadi karena gesekan yang lebih besar serta *shear* yang disebabkan oleh lelehan *PVC-MBS* yang lebih kental. Tes mekanik dalam bentuk energi impak, kekakuan dan kekerasan menunjukkan bahwa efisiensi peningkatan keuletan dari ketiga jenis *impact modifier* memiliki kemiripan pada konsentrasi rendah, namun pada sekitar 9 *phr* hingga 11 *phr*, *MBS* dan *CPE* meningkatkan energi impak secara lebih cepat hingga empat kali lipat, sedangkan tingkat kekerasan serta kekakuannya menjadi lebih rendah.

Kata kunci : *Impact modifier*, Kemudahan proses, Keuletan, Polivinil khlorida

INTRODUCTION

PVC profiles formed by extrusion gain added value when they are employed in the building and construction sector to replace wood or aluminum door and window frames. Problems arised during the use of such PVC profiles in the form of cracks at the bent corners. As a remedy, impact modifiers are generally added to

PVC compound to improve the impact properties. Current commercial impact modifiers include methacrylate-butadiene-styrene (MBS) and chlorinated polyethylene (CPE), they are available in particles of micro scaled. Earlier studies remarked that they tend to affect the processability of the PVC as well by reducing the fusion time and changing the torque required for processing [1-2].

The present study proposed to use elastomeric nano NBR to improve the toughening of the PVC profiles. NBR was selected because of its flexibility and its extremely low glass transition temperature. Two types of the commercial impact modifiers namely MBS and CPE were applied to toughen the PVC and to compare their toughening efficiencies with the nano-scaled NBR particles.

EXPERIMENTAL METHOD

Materials and Sample Preparation

The raw material used in this study was PVC compound (K66) with melting temperature ranges from 160 to 190 °C. It composed of $CaCO_3$ 5 phr, TiO_2 1 phr, processing aid 1.5 phr, stabilizer 5.5 phr and lubricant 1.4 phr. Three types of impact modifiers to be applied to the PVC at 1, 3, 5, 7, 9 and 11 phr were MBS, CPE and NBR. The commercially available MBS and CPE were both of micro-scaled with average particle sizes of 50 µm and 10 µm respectively while that of the nano NBR was 90 nm.

The PVC compound was firstly mixed with each impact modifier by using a high speed laboratory mixer (Thermo electron, PRISM Pilot 3) at the speed of 3,000 rpm at 30 °C. PVC compound was devided for processability assessment by rheometric test and for further blending by using 2-roll mill at 160 °C. Test specimens were compression-molded and notched for izod impact test according to the dimensions specified by ASTM D256-06.

Thermal and Mechanical Tests

The degradation temperature of the PVC compound and of each impact modifier was evaluated by Thermo-Gravimetric Analyzer (Diamond TG/DTA) in nitrogen atmosphere. The processability was studied by using a Torque rheometer (Brabender, type 815606). Notched impact strengths were measured at room temperature by using an impact tester (Yasuda Impact Tester) according to ASTM D256-06.

RESULTS AND DISCUSSION

Degradation

The degradation temperature of the PVC and of each impact modifier was shown in Figure 1.

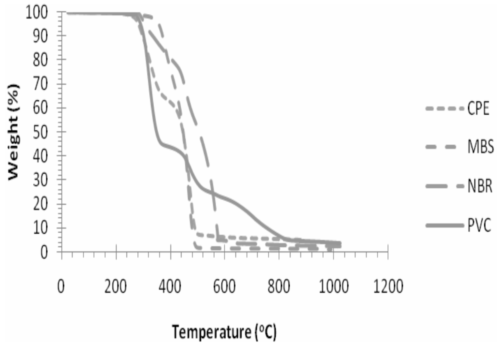

Figure 1. Degradation temperature of PVC and each impact modifier.

The first range of degradation of the PVC compound occurred between 260 and 360 °C, it was associated with the release of HCl and was accompanied by 55% of weight loss. The CPE degraded at 260-360 °C, this was associated with the release of HCl which was accompanied by 35% of weight loss. The decomposition of the MBS appeared at 320-480 °C. The NBR was found to degrade at 300-560 °C.

Processability

Figure 2(a) shows that the torque required for processing the modified-PVC melt increased with the content of the impact modifiers. The processing torque for the melt PVC modified with CPE and nano NBR increased only slightly while that for the PVC with MBS was raised quite significantly.

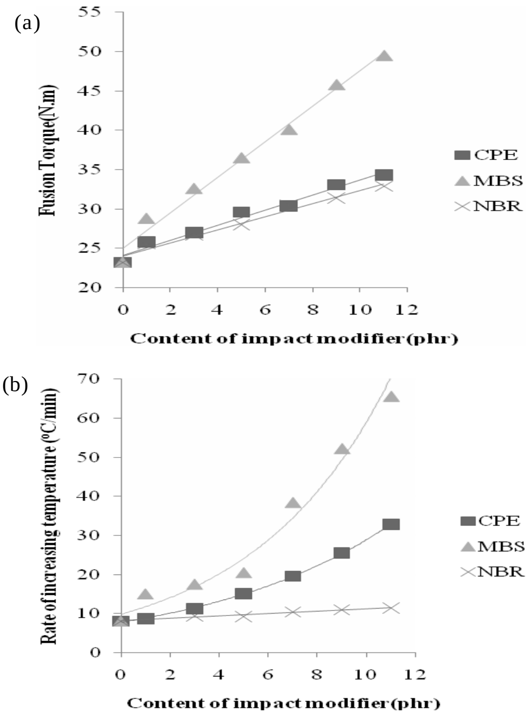

Figure 2. Influences of MBS, CPE and nano NBR impact modifiers and their content on (a) the torque required to process and (b) the rate of temperature rising in the modified-PVC melt.

Vol. 12, No. 2, Februari 2011, hal : 106 - 109
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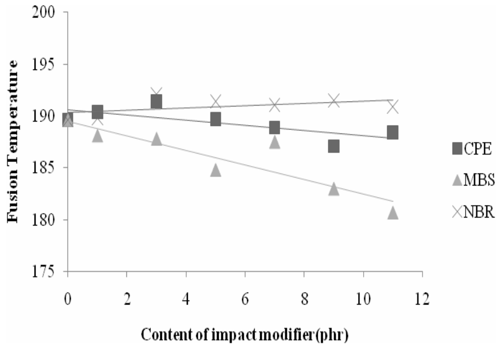

Figure 3. Melting temperatures of the impact- modified PVC.

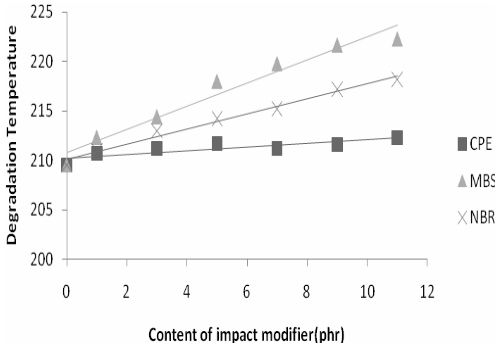

Figure 4. Degradation temperature obtained from rheometric study of the PVC modified with MBS, CPE and nano NBR impact modifiers.

During processing, the MMA shell of the MBS was believed to have melted first and reacted with the PVC molecules through polar-polar interactions [3]. The higher torque suggested that the melt PVC modified with MBS had greater melt viscosity [4] and was more difficult to process.

As a result, the rate of temperature rising in the MBS-modified PVC melt was found notably high, as demonstrated in Figure 2(b), due to the extra heat arised from the friction and shear between the viscous PVC melt and the rheometric test chamber.

The melting temperature of the PVC with each impact modifier is shown in Figure 3. The temperature required for melting the PVC modified with MBS was lowered rather significantly with the MBS content while those for the PVC dosed with CPE or NBR hardly changed.

The degradation temperatures detected upon processing the impact-modified PVC by rheometric study are shown in Figure 4. The degradation temperature increased with the modifier content because the degradation of all modifiers were inherently higher than that of the PVC compound.

The degradation temperatures detected by the rheometric study were lower than those obtained from the TGA because the degradation of the modified PVC in the rheometric study was induced by both the heat applied and the heat arised from frictional shear force while the that in the TGA occurred purely from the heat applied.

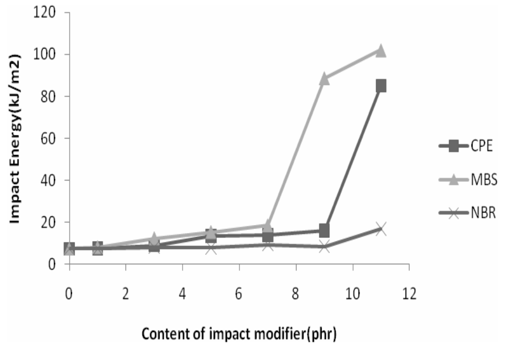

Figure 5. Influences of MBS, CPE and nano NBR impact modifiers and their content on the impact strength of modified PVC.

Impact Property

The impact energy at 30 ^{o}C, as shown in Figure 5, depicts clearly the efficiency of each modifier. The fracture of the PVC modified with 9 phr of MBS and 11 phr of CPE clearly transformed from a brittle mode with rather low impact energy to a more ductile one with the impact energy enhanced by ten and eight folds respectively. At 11 phr, the nano NBR improved the impact energy only slightly.

CONCLUSION

The MBS impact modifier influenced the processability by raising the torque required. MBS was the most efficient impact modifier among those studied, yielding toughened PVC with the highest impact energy as compared with CPE and NBR.

ACKNOWLEDGMENT

The authors acknowledge the research grant (MRG-WI525E010) from The Thailand Research Fund (TRF). Thanks are extended to Nawa Plastic Industries Company Limited for facilitating the torque rheometer and to and Siam Extek Company Limited for the provision of the nano-scaled NBR.

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