Injection-molded polyethylene/natural rubber blends

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Abstract. The present research aims to develop polyethylene/natural rubber (PE/NR) blends, with a weight proportion of PE:NR of 60:40, for injection-molded articles. Two types of PE, i.e. high density polyethylene (HDPE) and linear low density polyethylene (LLDPE) were used. The blends were fabricated by melt processes and then converted into dumbbell-shaped specimens using an injection molding machine. The effect of NR on properties of PE was investigated. The blends showed lower melt flow ability than the corresponding PE. Although PE/NR blends exhibited lower tensile strength and Young’s modulus than PE, their elongation at break and impact strength tended to be higher. In addition, hardness and heat distortion temperature of PE decreased by blending with NR. The obtained PE/NR blends are thermoplastics, which can be further converted into product prototypes using injection molding process.

1. Introduction

Thailand is up to now the largest producer and exporter of natural rubber (NR) in the world accounted for ~40% of global production. However, only around 18% of midstream NR products were consumed in Thailand as raw materials in the manufacture of downstream vulcanized NR products including tires, elastic, latex gloves, rubber bedding and elastic bands, etc., while the rest (82%) is exported for additional processing to produce end products in factories abroad. This makes Thailand loss a chance to enhance its income. Furthermore, NR price decreases should due to its oversupply. Therefore, the development of downstream high value-added NR products is very important at this stage.

Most NR products are fabricated by vulcanization during forming their shapes under applying heat. This process requires many types of chemicals including sulphur to crosslink NR structure, the resulting vulcanized NR products are thus not recyclable. In addition, vulcanization is also time- and energy-consuming process.

Therefore, the present work aims to fabricate thermoplastic natural rubber (TPNR) based on the blending of NR with thermoplastic materials for injection-molded articles. Polyethylene (PE) was chosen as a thermoplastic in this study. Two types of PE, i.e. high-density polyethylene (HDPE) and linear low-density polyethylene (LLDPE), were melt blended with NR at a weight fraction of PE:NR of 60:40. The effect of NR on properties of PE was investigated and discussed.

2. Experimental
Two types of PE, i.e. HDPE (InnoPlus, PTT Global Chemical) and LLDPE (InnoPlus, PTT Global Chemical), were melt blended with NR (STR 5, Natural Art and Technology, Co., Ltd.) in the presence of other additives using a weight fraction of PE:NR of 60:40. The blending was performed in an internal mixer at 160°C for HDPE/NR blend and 140°C for LLDPE/NR blend with a screw speed of 50 rpm until homogeneous mixtures were obtained. The resulting materials were then injection-molded into dumbbell-shaped specimens using an injection molding machine (TUPARL TR80S2A, Sodick Plastech, Japan) at a temperature range of 165–185°C. The processed HDPE and LLDPE were also prepared using the same protocol as the blends, but without NR, and used as controls.

Melt flow index (MFI), tensile properties, impact strength, hardness and heat distortion temperature (HDT) of HDPE, LLDPE, HDPE/NR blend and LLDPE/NR blend were determined. MFI was measured at 190°C with a load of 2.16 kg and a preheating time of 7 min. Tensile strength, Young’s modulus and elongation at break were obtained from a Universal testing machine (H50KS, Hounsfield, England) at a crosshead speed of 50 mm/min, a load cell of 50 kN and a gauge length of 109 mm. Impact strength was tested using a Universal impact tester (QC-639, Comotech Testing Machines Co., Ltd., Taiwan) at a load of 12 J. Shore D hardness was measured using a TECLOCK durometer rubber and plastic hardness tester (GS-702N, Japan). HDT was determined by a VICAT AUTO model 69770 (CEAST, USA) using a load cell of 0.455 MPa, a heating rate of 2°C/min and a deformation of 0.25 mm.

3. Results and discussion
Herein, the effect of NR on MFI, tensile properties, impact strength, hardness and HDT of HDPE and LLDPE was investigated. Figure 1 shows that HDPE/NR and LLDPE/NR blends possesses lower MFI than the corresponding HDPE and LLDPE. The result implied that melt flow ability of HDPE and LLDPE decreased by blending with NR or the plastics became more viscous when blended with NR. The reason might be relevant to the higher molecular weight of NR [1] and/or the molecular weight reduction of thermoplastics during the blending process. It should be pointed out that LLDPE had higher melt flow ability than HDPE due to the lower crystallinity or looser packing structure of LLDPE. Similarly, the blend of LLDPE and NR also showed higher MFI than the blend of HDPE and NR.

![Figure 1. MFI of HDPE, LLDPE, HDPE/NR blend and LLDPE/NR blend.](image-url)

Concerning to the mechanical properties of the materials, their tensile strength, Young’s modulus, elongation at break, impact strength and hardness were reported in Figure 2. HDPE/NR and LLDPE/NR blends exhibited lower tensile strength, Young’s modulus and Shore D hardness, but higher elongation at break than HDPE and LLDPE, suggesting that NR reduced tensile strength, stiffness and hardness of the plastics, but provided extensibility. The effect of NR on those mechanical properties was more outstanding in the case of harder plastic like HDPE than that of softer plastic like LLDPE. Similar trend was observed for the impact testing result. It is clearly seen that impact strength
of HDPE/NR blend was much higher than that of the corresponding HDPE and the blend showed no break after testing. For the case of LLDPE and its blend, although LLDPE/NR blend had lower impact strength than LLDPE (Figure 2), both materials did not break after receiving the load. The result reflected that NR significantly enhanced toughness of HDPE, but this improvement was not that much pronounced in the case of LLDPE, since the material itself is soft and tough.

![Figure 2](image_url)

**Figure 2.** Tensile strength, Young’s modulus, elongation at break, impact strength and hardness of HDPE, LLDPE, HDPE/NR blend and LLDPE/NR blend.

HDT of the materials is shown in Figure 3. It was found that HDT of HDPE and LLDPE decreased by blending with NR, implying that HDPE/NR and LLDPE/NR blends distorted at lower temperature than the corresponding plastics. This might be a result of softness of the materials when NR was incorporated. The reduction of HDT was more significant in the case of HDPE than that of LLDPE.
Figure 3. HDT of HDPE, LLDPE, HDPE/NR blend and LLDPE/NR blend.

The resulting HDPE/NR and LLDPE/NR blends could be injection-molded into product prototypes as shown in Figure 4, similar to most thermoplastic materials, however their surfaces had more friction and softer touch similar to elastomers.

Figure 4. Injection-molded product prototypes of HDPE/NR and LLDPE/NR blends.

4. Conclusions
HDPE/NR and LLDPE/NR blends with a weight proportion of PE:NR of 60:40 were successfully fabricated and could be converted into product prototypes using an injection molding machine. HDPE/NR and LLDPE/NR blends were more extensible and tougher, but possessed lower melt flow ability, tensile strength, stiffness and HDT than the corresponding PE. The effect of NR on the properties of HDPE was more pronounced than that of LLDPE.

5. References
[1] Nakason C, Jamjinno S, Kaesaman A and Kiatkamjornwong S 2008 Polymers for Advanced Technologies 19 85.
[2] Kuriakose B and De S K 1985 Polymer Engineering and Science 25 630.

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