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Experimental Study for Mechanical Properties of Thermoplastic Vulcanizates

Han Seong-Ryoel* and Choi Kye-Kwang

Department of Metal Mold Design Engineering, Kongju National University, 1223-24, Cheoan Daero, Seobuk-gu, Cheoan-si, Chungnam, 331-717, Korea; srhan@kongju.ac.kr

Abstract

Thermoplastic Elastomers (TPEs) have been widely applied in the injection molding industry based on their advantages. TPEs are gradually being used instead of engineering thermoplastic polymers, which are adopted for precision parts. It is therefore necessary to study the mechanical properties of TPEs molding, which are influenced by the injection molding parameters. In this study, Thermoplastic Vulcanizates (TPV), which are a type of TPE, were molded by an injection molding process. The mechanical properties such as tensile strength, shrinkage rate and hardness were measured for molding carried out with variation of the injection molding parameters. In the experiment results, the injection pressure and melt temperature affected the strength of the molding. As these parameters increased, the tensile strength also increased. In the case of the shrinkage rate of molding, the shrinkage rate was decreased by increasing the injection pressure, holding pressure, and melt temperature. In the case of the hardness, the hardness was slightly increased by increasing the injection pressure. Appropriate injection molding parameters could then reinforce the tensile strength, hardness and improve the dimensional accuracy of TPEs molding.

Keywords: Thermoplastic Elastomers (TPEs), Thermoplastic Vulcanizates (TPV), Injection Pressure, Holding Pressure, Melt Temperature, Tensile Strength

1. Introduction

Thermoplastic Elastomers (TPEs) are rubbery with properties and functional performance similar to those of conventional vulcanized rubber at ambient temperature, but they can be processed in a molten condition in the manner of thermoplastic polymers at elevated temperature[1]. By this characteristic, the application of TPEs, rather than commercial thermoplastic polymers, has been rapid growth in the polymer industry, even faster than that of thermoplastic resin and rubber, respectively[2].

TPEs have found numerous unique applications and have been replacing cross-linked elastomers. TPEs offer fast processing speed and versatility in parts design. The scrap from TPEs and mismanufactured parts are reusable and recyclable[3]. Based on these advantages, the application of TPEs has rapidly expanded in the medical industry, electric home appliances, daily necessities, and other fields. Figure 1 shows applications of TPEs.

The applied TPE in this study was a Thermoplastic Vulcanizate (TPV). The TPV consists of a vulcanized Ethylene-Propylene-Diene-Copolymer (EPDM) and Poly Propylene (PP). This TPV has significantly improved properties as a result of research by Coran, Das, and Patel. Coran and Patel investigated the effects of EPDM and PP particles and high crosslink density of rubber on the tensile strength and elongation[4,5].

Most studies on TPVs have been related to the compounding ratio of materials and properties. This study, in contrast, focuses on the effect of injection molding parameters such as injection pressure, holding pressure, and melting temperature on the mechanical properties of TPV molding such as tensile strength, and shrinkage rate.

** Author for correspondence*

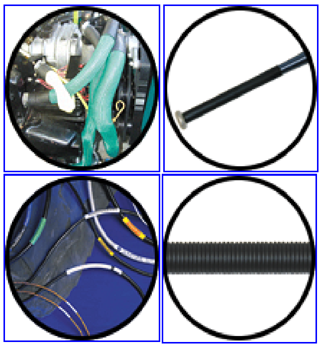

Figure 1. Applications of TPE..

2. Experiment

TPV is blend of Ethylene-Propylene-Diene-Monomer (EPDM) and polypropylene (PP), combining the excellent resistance and flexibility characteristics of vulcanized rubber with the processing ease of thermoplastics. Three grades of TPV were applied for the injection molding experiment. The related blend ratios of EPDM and PP listed in table 1.

The adopted injection molding parameters were injection pressure, holding pressure, and melt temperature. The tensile strength and shrinkage rate of TPV moldings according to the blend ratio of EPDM and PP were also investigated.

In the experiment, the injection molding time was 5.0 second, the cooling time was 15 seconds, and the mold temperature was 40°C. Table 2 shows the range of each injection molding test parameter. The capacity of the experimental injection molding machine by (LG Cable Co. (IDE 75EN Ⅱ)) is 75 tons.

Table 1. Compounding ratio of EPDM and PP in TPEs

TPV	Compounding material	Compounding ratio(%)
EPA10	PP	10
	EPDM	90
EPA20	PP	20
	EPDM	80
EPA30	PP	30

Table 2. Injection molding parameters and range for experiment

Injection molding parameter	Unit	Range
Injection pressure	MPa	20, 25, 30, 35, 40
Holding pressure	MPa	12, 16, 20, 24, 28
Melt temperature	°C	190, 195, 200, 205, 210, 215, 220

Figure 2. Schematic of experiment mold.

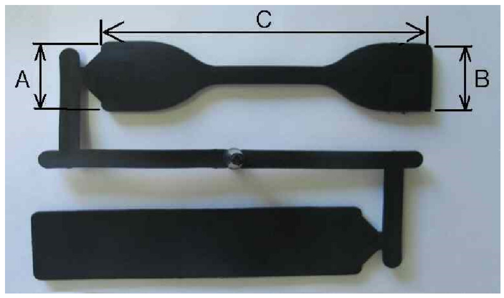

Figure 3. Injection molding specimens.

Figure 4. Universal testing machine.

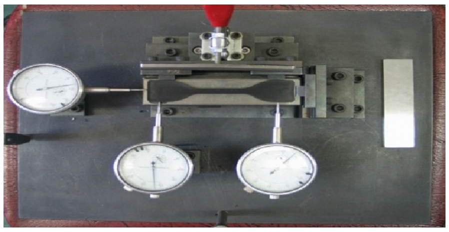

Figure 5. Shrinkage rate measurement jig.

Figure 2 shows a schematic illustration of the experiment mold, which can simultaneously mold specimens for the tensile strength tests (Figure 3). Figure 4 shows the experimental universal test machine used for evaluating tensile strength (H10KT, Hounsfield Co). Figure 5 shows the equipment employed for measuring the shrinkage rate. In the shrinkage rate study, the measured length was C (Figure 3.), which corresponded with the flow direction of the polymer melt.

3. Experiment Results

Figure 6 shows the relation between injection pressure and tensile strength. As the injection pressure is increased, the tensile strength slightly increased in all TPV grades. This is consistent with a former study on the tensile strength in a

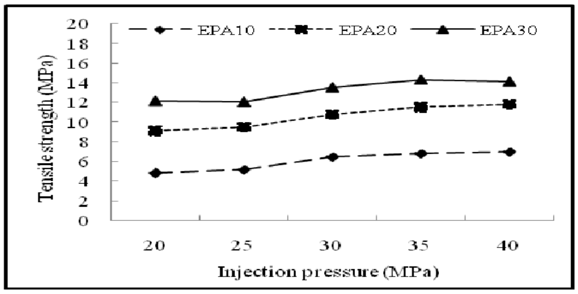

Figure 6. Variation of tensile strength according to injection pressure.

commercial plastic and TPV molding[6]. The injection pressure is thus an influential factor on the tensile strength of TPV molding. Furthermore, as the ratio of PP is increased, the tensile strength of the molding also increased.

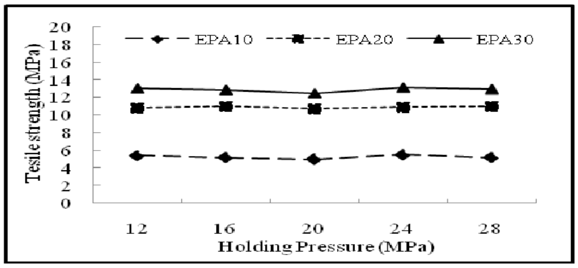

Figure 7. Variation of tensile strength according to holding pressure.

Figure 7 shows the relation between holding pressure and tensile strength. Although the holding pressure was increased, there was little variation of the tensile strength. This signified that holding pressure is not an effective factor for improving the tensile strength of TPV molding.

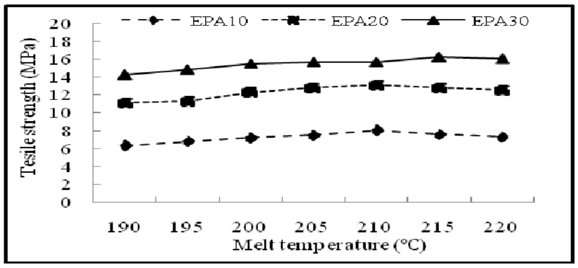

Figure 8. Variation of tensile strength according to melt temperature.

Figure 8 shows the relation between melt temperature and tensile strength. As the melt temperature increased, the tensile strength slightly increased in all TPV grades. However, the tensile strength of EPA10 and EPA20 declined at temperature beyond 210°C. This phenomenon was attributed to thermal decomposition of the PP or EPDM material. The total increased value of the tensile strength was greater than that in the case of increasing the injection pressure.

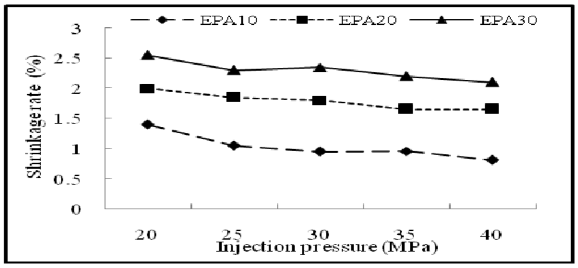

Figure 9. Variation of shrinkage rate according to injection pressure.

Figure 9 shows the relation between injection pressure and shrinkage rate. As the injection pressure was increased, the shrinkage rate decreased slightly in all TPV grades. EPA30 showed the biggest shrinkage rate. The average shrinkage rate was 2.3%. The lowest shrinkage rate was observed in the EPA10 specimen. The results signified that the injection pressure was an effective parameter for controlling the shrinkage rate.

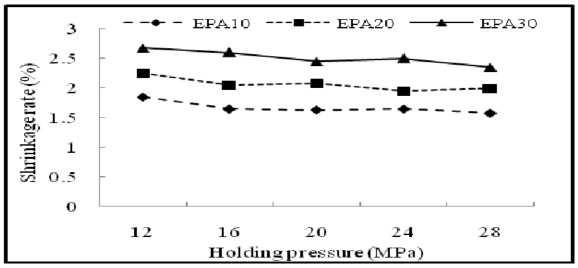

Figure 10. Variation of shrinkage rate according to holding pressure.

Figure 10 shows the relation between holding pressure and shrinkage rate. As the holding pressure was increased, the shrinkage rate decreased slightly in all TPV grades. The results signified that the holding pressure was also an effective parameter. Furthermore, figure 9 shows that the shrinkage rate linearly decreased by increasing the PP ratio.

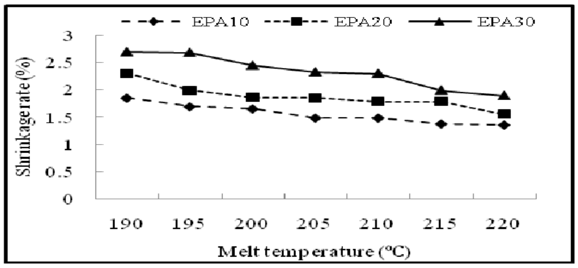

Figure 11. Variation of shrinkage rate according to melt temperature.

Figure 11 shows the relation between melt temperature and shrinkage rate. As the melt temperature was increased, the shrinkage rate decreased. This result was consistent with the findings of a former study. By increasing the melt temperature, the viscosity of the TPV melt decreased. Decreased viscosity in turn improves pressure transmissibility. The density per unit area of TPV in the cavity is thereby increased and the shrinkage rate of the molding is decreased [7].

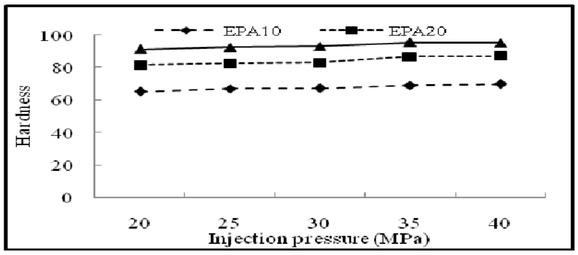

Figure 12. Variation of hardness according to injection pressure.

Figure 12 shows the relation between injection pressure and hardness. As the injection pressure melt temperature was increased, the hardness slightly increased. The reason was considered as the one of the results for tensile strength and injection pressure in this study.

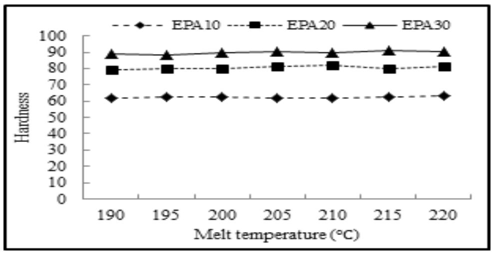

Figure 13. Variation of hardness according to melt temperature.

Figure 13 shows the relation between melt temperature and hardness. Though the melt temperature was increased, the hardness was very little changed.

4. Conclusion

Injection molding experiments were conducted for a Thermoplastic Vulcanizate (TPV), which is a kind of Thermoplastic Polymer (TPE). The variation of mechanical properties such as tensile strength and shrinkage rate, which are related with the dimensional accuracy of TPV molding, was studied by changing the injection molding parameters.

Among the injection molding parameters, the tensile strength of molding was increased by increasing the injection pressure and melt temperature. However, the holding pressure hardly influenced the tensile strength. In the case of the shrinkage rate, all of the injection molding parameters affected the molding parameters. The injection molding was the most influential parameter.

When the injection molding parameter was increased, the lowest shrinkage rate value, on average, was obtained. These results signified that appropriate injection molding parameters can improve the mechanical properties of TPE molding.

5. Acknowledgement

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