

Effect of Discarded pPVC Contents on Thermal and Ultraviolet Resistance of Acrylonitrile Butadiene Rubber

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Abstract

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In this investigation, the discarded plasticized-polyvinyl chloride (pPVC) from the extrusion of weather-seal was added into acrylonitrile butadiene rubber (NBR). Subsequently, the effects of pPVC contents on the mechanical properties, thermal, ultraviolet and swelling resistances of NBR were studied. The results indicated that scorch and cure time, tensile strength, hardness and swelling resistance increased with the increasing amount of pPVC added. Considering the thermal and ultraviolet resistances, it was observed that the mechanical properties of unfilled NBR decreased due to the desulphurization of the sulphur crosslinks and chain scission during heat and ultraviolet aging. However, the mechanical properties of the NBR containing varying amounts of pPVC were higher than that of unfilled NBR. This was probably associated with the escape and/or degradation of plasticizer and the PVC gelation phenomenon during heat and ultraviolet testing.

Key words : Acrylonitrile butadiene rubber, Plasticized polyvinyl chloride, Thermal and ultraviolet resistance.

Introduction

Acrylonitrile butadiene rubber (NBR) or nitrile rubber is commonly considered the workhorse of the industrial and automotive rubber products industries. In the automotive area, NBR is used in fuel and oil handling hose, seals and grommets, and water handling applications. With a temperature range of -40°C to $+125^{\circ}\text{C}$, NBR can withstand all the most severe automotive applications. On the industrial side NBR finds uses in roll covers, hydraulic hoses, conveyor belting, and seals for all kinds of plumbing and appliance applications.^(1, 2)

Acrylonitrile (ACN) and butadiene (BD) ratios are varied for specific oil and fuel resistance and low temperature requirements. The ACN content is one of two primary criteria defining each specific NBR grade. The ACN level, by reason of polarity, determines several basic properties, such as oil and solvent resistance, low-temperature flexibility/glass transition temperature, and abrasion resistance. Higher ACN content provides improved solvent, oil and abrasion resistance, along with higher glass transition temperature. However, having the unsaturated backbone or the remaining double bond of the BD part can affect the property of NBR in terms of the aging resistance. In this

work, plasticized polyvinyl chloride was chosen as the strengthening and protective filler for NBR since PVC has a generally high resistance to the environment and ignition. Also, its mechanical strength is higher than that of NBR.⁽³⁾ This investigation used the discarded pPVC from the extrusion of weather-seal. In general, the defective part of pPVC usually occurs at the beginning of the process. In case that the size of product does not conform to the specifications of the customers, these defective parts will be buried or burnt. The disposal process can cause pollution to the environment, especially the burning of PVC, which can produce the toxic HCl gas due to the thermal disintegration of PVC.⁽⁴⁾ With the reasons mentioned earlier, the recycle or the reprocessing of the defective parts is very important. In addition to the possibility to improve the mechanical properties and aging resistance, the results of this work can also be used as guidelines to reduce production cost and environmental problems.

Materials and Experimental Procedures

Materials

The materials employed in this investigation were acrylonitrile butadiene rubber (NBR) and

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plasticized-polyvinyl chloride (pPVC) supplied by Polyseal Track Co., Ltd. and Thai Profile Interplas Co., Ltd., respectively. The discarded pPVC extruded weather-seal was pulverized by crushing machine (supported by Thai Mangkorn Plastic Industry Co., Ltd.). The rotor speed and crushing time were controlled with respect to the particle size of pPVC as compared to the particle size of commercial fillers (125-375 μm).

Experimental Procedures

NBR was masticated using the internal mixer at a temperature of 70°C for 3 minutes. The NBR was then mixed with the addition of the quantities of sulfur, pPVC, ZnO, and MBTS. Six compounds were produced according to the formulations in Table 1. Each compound was then rolled to produce a sheet approximately 3 mm thick by using a two-roll mill, and left at room temperature for 24 hours. The scorch and cure time were determined using the Oscillating Disk Rheometer (ODR) in accordance with a rubber standard test method (ASTM D 2084). The test specimens were prepared by the use of compression molding at a temperature of 160°C. Tensile and hardness tests were performed using an Instron tensile testing machine (ASTM D 412) and Shore hardness durometer (ASTM D 2240). The swelling, thermal and ultraviolet resistances were determined according to standard methods. The test procedures were specified in ASTM D 471-79, ASTM D 572, and ASTM D 4329, respectively.

Table 1. Formulations in part per hundred rubber (phr)

Ingredients	Mix 1	Mix 2	Mix 3	Mix 4	Mix 5	Mix 6
NBR	100	100	100	100	100	100
ZnO	3.4	3.4	3.4	3.4	3.4	3.4
Accelerator (MBTS)	1.7	1.7	1.7	1.7	1.7	1.7
Sulphur	10.0	10.0	10.0	10.0	10.0	10.0
Retarder	0.2	0.2	0.2	0.2	0.2	0.2
pPVC	0.0	10.0	20.0	30.0	40.0	50.0

Results and Discussion

Table 2 shows the influence of pPVC contents on the scorch and 90% cure time of NBR compounds at 160°C. It can be seen that as the pPVC content increased, the scorch time and cure time tended to increase. The increase in the scorch

and cure time possibly due to the pPVC fillers retarded the reaction between sulphur and accelerator. Figures 1 and 2 show the changes in maximum tensile strength and hardness of the NBR filled with various pPVC contents. It can be observed that both properties gradually increased with increasing pPVC content. This was due to the fact that pPVC had a higher tensile strength and hardness compared to the NBR.⁽³⁾ Therefore, adding pPVC into the NBR would lead to an increase in the tensile strength and hardness of the NBR.

Table 2. Scorch and cure time of NBR compounds at various pPVC contents

Formula	Scorch time	Cure time
Mix 1	3.75	7.58
Mix 2	3.50	10.33
Mix 3	3.67	8.50
Mix 4	4.00	9.75
Mix 5	4.33	10.42
Mix 6	4.42	10.67

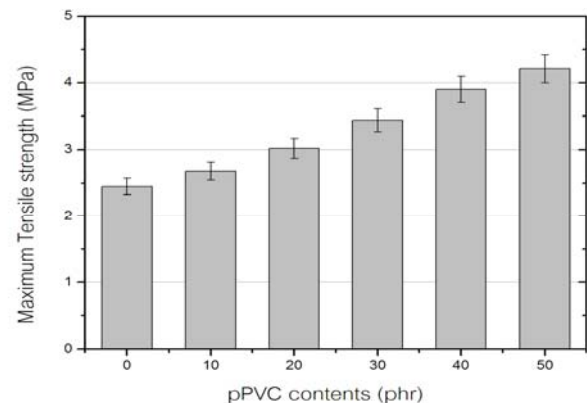


Figure 1. Effect of pPVC contents on maximum tensile strength of NBR

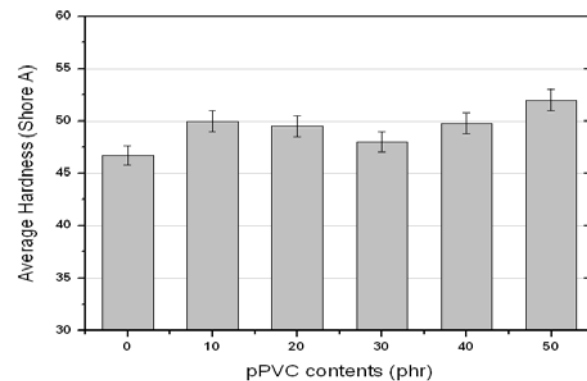


Figure 2. Effect of pPVC contents on hardness of NBR

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This study was further supplemented by scanning electron microscopic studies of the selected fracture surfaces. Figure 3 shows the selected fracture surface of the NBR sample filled with the highest pPVC content. It can be seen that the fracture surface of the sample shows the interfacial bonding between the pPVC particle and NBR matrix (as circled in Figure 3). Because the pPVC and NBR molecules were both polar, this made them compatible. As a result, the pPVC particles could effectively function as a reinforcing filler. The swelling behavior of NBR filled with various pPVC contents was measured by the sorption method as illustrated in Figure 4. It was found that NBR provided an excellent swelling resistance, with change in volume of NBR approximately was 14%. This was due to the polarity of NBR. As the pPVC content increased, the change in volume of NBR gradually decreased up to the pPVC content of 30 phr. An improvement of swelling resistance of NBR was thought to be caused by the high polarity of pPVC and the compatibility between pPVC and NBR, as mentioned earlier.

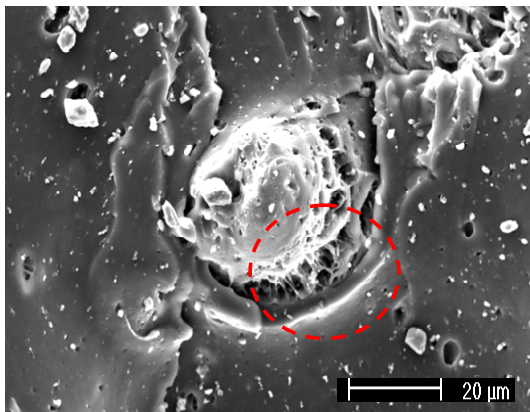


Figure 3. SEM micrograph of fracture surface for NBR filled with pPVC (50 phr)

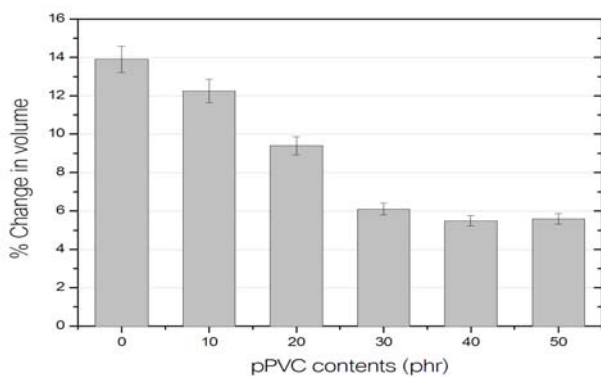


Figure 4. Change in volume after swelling test of NBR filled with various pPVC contents

The changes in the maximum tensile strength after thermal and ultraviolet aging tests for NBR filled with various pPVC contents are shown in Figures 5 and 6. It can be observed in Figure 5 that the maximum tensile strength of the unfilled NBR was slightly lower (in the case of heat aging) and much lower (in the case of UV aging, see Figure 6) than the values obtained for non-aging NBR. This was due to the remaining double bond and polysulphide crosslinks occurred in the conventional vulcanization, which can be attacked by heat and UV radiation, resulting in the chain scission of rubber molecules. However, it should be noted that the maximum tensile strength of NBR filled with pPVC was higher than that of unfilled NBR. Higher tensile strength was probably associated with the escape and/or degradation of plasticizer⁽⁵⁾ and the PVC gelation phenomenon⁽⁴⁾ which occurred during the processing of pPVC weather-seal, and subsequent compound preparation procedures (e.g. grinding, mixing and compounding). This could be related to the fact that the pPVC had a greater processing time and a more compact structure compared to the NBR matrix. Therefore, adding pPVC into the NBR would lead to an increase in the thermal and UV resistance of NBR.

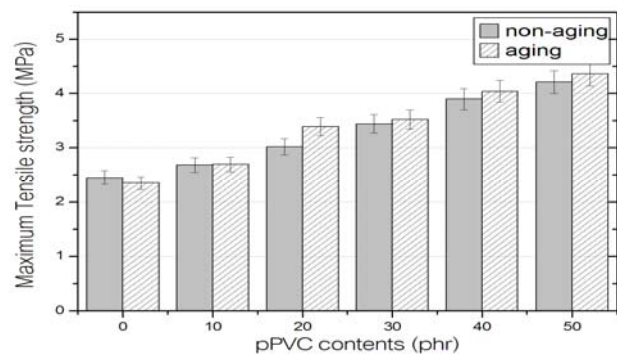


Figure 5. Comparison of maximum tensile strength for heat aging and non-aging NBR filled with various pPVC contents

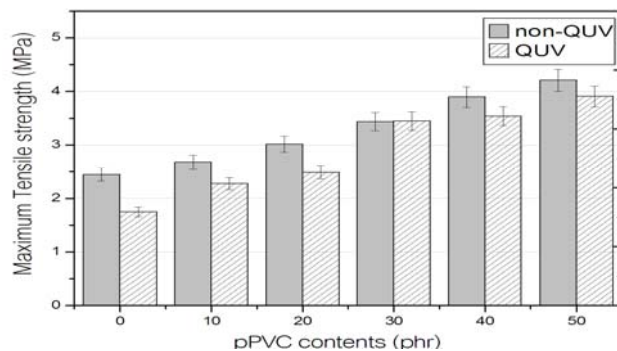


Figure 6. Comparison of maximum tensile strength for UV aging and non-aging NBR filled with various pPVC contents

Conclusion

Plasticized PVC has been employed to enhance the properties of NBR with respect to mechanical and aging properties. It was found that scorch and cure time, tensile strength, as well as hardness and swelling resistance increased with increasing amount of pPVC added. Considering the effect of adding pPVC on the thermal and ultraviolet resistances, it was observed that the maximum tensile strength of the unfilled NBR tended to decrease due to the desulphurization of the sulphur crosslinks and chain scission during heat and ultraviolet aging. However, the maximum tensile strength of the NBR containing various contents of pPVC was higher than that of unfilled NBR. This was probably associated with the escape and/or degradation of plasticizer and the PVC gelation phenomenon during heat and ultraviolet exposure.

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