New Era Of Thermoplastic Vulcanize Alloy For Sponge Application

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Abstract

The main objective of this review is to describe some of the important topics related to the thermoplastic vulcanize alloy sponge for automotive application. Thermoplastic vulcanize (TPV) is a special class of thermoplastic elastomers (TPEs) made of a rubber/plastic polymer mixture in which the rubber phase is highly vulcanized. TPVs represent the second largest group of soft thermoplastic elastomers, after styrenic-based block copolymers. TPVs have undergone evolutionary changes in terms of the selection of polymers, design of crosslinking, compounding techniques, and methods of production, and have achieved better elastic recovery, easy processability and low hardness etc. Currently, TPV is replacing EPDM rubber dramatically because of the impressive advantages for automotive sealing applications. Some of the advantages of TPV compared to that of EPDM rubber are good gloss, recyclability, improved color ability, shorter cycle time, and design flexibility. The development of TPV foaming technology is to fulfill the requirement of achieving lower cost, lighter weight, and better fuel economy. Foaming of TPV has not been investigated extensively. The complete dissolution of the blowing agent in the molten polymer is the most critical step in TPV foaming processing, and this strongly depends on the solubility of the blowing agent, the saturation pressure, the degree of mixing, and residence time. Experimental results will be used to determine optimized TPV formulations to ensure good foamability, while retaining the properties of TPV.

Keywords - TPE, TPV, EPDM, Blowing agent

I. INTRODUCTION

A thermoplastic is a class of polymer that repeatedly can be softened by heating and hardened by cooling through a temperature range characteristic of the polymer. Further, it can be shaped into products in the softened flowable state. Whereas elastomers or, alternatively, rubbers (usually thermoset) are soft, flexible, and highly elastic materials that are applied in a wide range of applications, such as tires, seals, tubes, and gloves. Rubbers are composed of highly flexible, long chain molecules and have a glass transition temperature (Tg) below room temperature. [1] The formation of covalent cross-links between the chain molecules prevents melt (re)processing, which gives cross-linked rubbers a distinct disadvantage compared to thermoplastics. The other class, called thermoplastic vulcanizates (TPVs) is produced by a special technique known as dynamic vulcanization, where the selective crosslinking of rubber phase is carried out during the melt-blending with thermoplastic resins. Most of the TPEs meet the standard definition of a rubber according to. Roughly, (1) they would recover quickly and forcibly from large deformations, (2) they can be elongated by more than 100%, and (3) their tension set should be less than 50%. The literature survey indicates that at present TPVs fall in the fastest growing segment of thermoplastic elastomer market with a global annual growth rate of about 15%. [2]

II. EXPERIMENTAL MATERIALS

All the TPV formulations considered are identical in overall composition and only change in the ratio of EPDM and PP. Important criteria for making the TPV sponge are selection of EPDM proper grade and selection of the PP. [3] In these experiment EPDM rubber in which high grade of propylene content is to be selected and in PP select the random grade of PP. Melting points are reported as the peak position of the second heating endotherm (10°C/min) from a Differential Scanning Calorimeter (DSC) experiment. In addition to PP and EPDM, Caco3 and other additives are also present in the TPV formulations. Four different formulations are considered.

III. EXPERIMENTAL EQUIPMENT

For the foaming of the TPV sponge different types of extruder is used for making the sponge product. There are injection moulding machine and special design twin screw extruder is also used for making the foam product. But in these experiments by using the two roll mill also foam product made. [4] The rolls are electrically heated with cartridge heaters for optimum heat distribution over the entire roll surface with programmable PID auto tune type temperature controllers. Temperature of two rolls can be sensed individually by a separate thermocouple system. The maximum roll temperature up to 300°C can be achieved. The surface of the rolls is hard chrome plated, ground and mirror polished. [5] The drive system consists of AC geared motor with programmable variable frequency drive to give very high starting torque. The cooling of this roll is done by water cooling arrangement and water is collected in a stainless steel water collecting tank which is at the other end of roll shaft. This system will help in cooling of the rolls rapidly during the shutdown or change over requirement.

IV. RESULTS

A. Extensional Viscosity

The transient extensional viscosity of the three polypropylene homopolymers as measured with the RME rheometer at 180°C. Three different extensional rates were considered, 0.01, 0.1 and 1.0 s-1. The linear polypropylene shows a transient extensional behavior consistent with the linear viscoelastic regime over the entire range of strain rates considered. On the other hand, both branched polypropylenes show a deviation from the linear viscoelastic behavior. After a total strain of 1.0, stain hardening is observed in both materials at all strain rates as the extensional viscosity increases above the linear viscoelastic viscosity. [6] It is this strain hardening, also known as extensional thickening, which is indicated to prevent cell coalescence and improve foam expansion.

The transient extensional viscosity of PP blends at the same proportions as in the four TPV formulations. The strain
hardening is still very apparent in these homopolymer blends, and it is expected that any benefits of the branched polypropylene should be noticeable in the TPV formulations. RME extensional viscosity measurements were attempted on the full TPV formulations, but all samples broke at strains of less than 0.5, with no appreciable differences between the samples. Additional experiments using the Rheotens tensile tester also showed no significant differences between the TPV formulations.

B. Foam density

The four PP/EPDM TPV formulations were foamed with the chemical blowing agent (ADC). In that if the dosages of the blowing agent change it will also affect the foam density. So for the checking of the foam density takes the trial and error method for that change the dosage of the B.A. [10]

If the polypropylene is liner so that it will give the high crystallinity structure and also same time foam density will also affected. In case if using branched polypropylene so it will give good compression set and low temperature flexibility and also give good foam density. TPV1, which contains only linear polypropylene, attained a final density of 0.52 g/cm³. In TPV2 if we take branched polypropylene so density of foam 0.45 g/cm³.

C. Foam Structure and Appearance

The cellular structure and foam skin appearance varied appreciably between the four TPV formulations. The exterior of the foamed strands, appeared similar in both the high and low water content test. TPV1 achieved a relatively low density, yet the skin appearance was poor, with several blisters breaching the skin of the foamed strand. TPV2a achieved the lowest density and also had the best skin appearance, with a relatively smooth, unblistered skin. TPV2b and TPV3, containing 50% branched polypropylene, had unacceptable skins with numerous blisters.

### Table 1: Properties of polypropylenes used in various TPV formulations.

<table>
<thead>
<tr>
<th>Sr.no</th>
<th>Name</th>
<th>Tm (°C)</th>
<th>MFI</th>
<th>ρ b (g/cm³)</th>
<th>Tr c</th>
</tr>
</thead>
<tbody>
<tr>
<td>PP1</td>
<td>Linear</td>
<td>162.7</td>
<td>0.7</td>
<td>0.905</td>
<td>3.30</td>
</tr>
<tr>
<td>PP2</td>
<td>Branched</td>
<td>163.9</td>
<td>0.3</td>
<td>0.9</td>
<td>6.54</td>
</tr>
<tr>
<td>PP3</td>
<td>Branched</td>
<td>130.2</td>
<td>8.5</td>
<td>0.9</td>
<td>33.4</td>
</tr>
</tbody>
</table>

![Figure 1: Extensional viscosity of linear polypropylene PP1 and branched polypropylenes PP2 and PP3 at various Strain rates at 180°C.](image1)

![Figure 2: Extensional viscosity of blends of branched and Linear polypropylenes at various strain rates at 180°C.](image2)

V. DISCUSSION

The results above indicate that foaming of soft TPVs with chemical blowing agent is possible and can even be improved with the replacement of linear PP with some branched PP. It is somewhat surprising, although desirable, that substituting just 25% branched material for linear polypropylene achieved better foam than blends containing 50% branched material. It is possible that the extensional thickening is too strong at the greater branched polypropylene content, leading to premature cell rupture and coalescence.

Finally, it is worth mentioning that in separate experiments using a two roll mill and using the chemical blowing agent we can get the desire foam density as well as the good foam structure and appearance. We can further improve in the formulation and changing the B.A we can improve in the foam density as well as foam structure.
CONCLUSION
The foaming of several TPV formulations containing various amounts of branched polypropylene resin with ADC as the blowing agent is reported in this work. While these softer formulations proved more challenging to foam, it is shown that the replacement of a small amount of linear polypropylene with branched polypropylene improves the foam density and cellular structure. There appears to be an optimal amount of branched content, as increasing the content of branched polypropylene resulted in poorer foamability. Furthermore, the results indicate that foaming of softer TPVs with ADC as the chemical blowing agent can be improved even further through process optimization.

REFERENCES