Santoprene™ TPV Corner Molding for EPDM Weatherseal: New Approach for Optimum Adhesion Performance

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I - Introduction

Weatherseals are among the primary elements for the insulation of the automotive passenger compartment from noise, water and dust. These profiles are generally complex parts integrating aerodynamic and aesthetic requirements. They generally use selected sets of raw materials to fulfill all the requirements. The most important raw material is EPDM rubber, which imparts to the weatherseal its elastic and sealing attributes. These are not just simple extruded profiles but require a number of finishing operations, in particular the addition of moldings to provide full functionality to the seal. Figure 1 below illustrates (a) end caps for draining water and (b) connectors between two belt line seals, including the outside mirror seal. Another example would be a corner molding joining two parts of a glass run channel.

Figure 1: typical weatherseal moldings: end cap (a) and connector (b)

These finishing operations contribute in large part to the overall cost of the seal. A significant productivity improvement can be brought by simplifying the molding operation. In particular, a reduction in cycle time can save not only on direct cost but also on capital since the number of molding presses is therefore reduced.

Recent trends show increased usage of Thermoplastic Elastomer Vulcanizate (TPV) in overmolding onto thermoset EPDM profiles. With TPV, the curing stage is eliminated and post trimming is simplified, so the total cycle time becomes shorter. Therefore productivity gains contribute to reduced cost of the finished part. Overall part quality is also better, since TPV uses a cold mold which prevents damage to the profile surface treatment (flock, coating). However, this improvement should not be detrimental to the adhesion between molded part and profile, which is critical for the good sealing performance and the overall quality aspect of the glass run channel or the belt line seal.

Thermoplastic materials have historically not shown an adhesion performance similar to EPDM to EPDM cross-linked bonding. This drawback has prevented full conversion to the less expensive TPV molding onto an EPDM profile since the risk of delaminating was high at the different stages of the production, such as demolding from the press, mounting on the door at the assembly line or after aging on the car. This delaminating risk varies by the type of part, depending whether the application is static or
dynamic. For example, a water box seal is mostly static, so its end caps can be easily converted to TPV. A door or glass run seal is considered highly dynamic, so molding requires a more resilient TPV with more adhesion.

In this paper, we describe a new thermoplastic elastomer vulcanizate grade that provides improved adhesion to cured EPDM profiles. We compare this new material with other TPV grades through testing in various environmental and aging conditions. This new approach demonstrates the capability of TPVs for corner molding in critical parts such as glass run channels.

II - Experimental Technique

The test method used in this study to determine adhesion measures the pulling force on a dumbbell specimen comprised of both materials. For that, we have designed a mold and defined a molding protocol that mimics as close as possible the conditions encountered by processors during the molding process onto an EPDM glass run channel.

II. 1 - EPDM sample preparation

An EPDM compound was extruded in the shape of a flat ribbon and cured in a continuous vulcanization line that comprises a microwave unit followed by a hot air tunnel. The thickness of the ribbon is 3mm, consistent with the mold geometry used later for overmolding.

II. 2 - Overmolding

The EPDM sample is placed at the bottom part of the mold (reference 1). The TPV injection is made from the top of the mold, so that the TPV fully covers the cross-section of the EPDM specimen. The contact section has a small surface area, similar to glass run channel corner moldings.

![Figure 2: specimen preparation for overmolding TPV onto EPDM](image)

The injection conditions are similar to those used in the industry. The injection press is 150 tons. Temperature in the barrel and runner is set uniformly at 260°C (500°F). Mold is maintained cold at 40°C (100°F) for fixed part, and 30°C (80°F) for the moving part. Injection speed is about 8 cm/second (3 in/s). Injection pressure is 10 MPa (1500 psi) and the hold-on pressure is 3.5 MPa (510 psi).
Dumbbells type II ISO 37 are cut in the molded composition as shown in Figure 2, with the interface TPV – EPDM located in the middle of the narrow portion of the dumbbell.

The specimen is then pulled at least 16 hours after injection in a tensometer at the speed of 100 mm/minute. Tensile strength and the elongation at break are recorded, as well the type of failure. When tested under low or high temperature, the material is pre-conditioned for at least 1 hour before testing.

Three samples are tested in each series. Median value of tensile strength is reported.

II. 3 - Factors influencing adhesion performance

Adhesion performance is not only material dependant, but also influenced by processing conditions and sample preparation. For molding, the type of press and the mold design will determine the right processing parameters for optimum adhesion performance: pressure during and after injection, filling time, venting efficiency, cooling time and mold temperature. Another important factor is the profile preparation: cleanliness and age of the section cut as well as the microstructure of the cut.

In this paper, we will focus on the TPV material and how its composition can influence adhesion performance.

III - Materials

III.1 - EPDM thermoset rubber compounds

A reference EPDM compound was prepared as a 70 Shore A formulation based on Vistalon® 9500, containing 11% diene for fast cure and high cure state. The compound contains 30 % EPDM and is a typical formulation for an excellent quality, resilient glass run channel.

| Vistalon® 9500 | 100 |
| Carbon black FEF N-550 | 130 |
| Parafinic oil Flexon® 815 | 80 |
| Zinc Oxide | 5 |
| Stearic Acid | 1 |
| Calcium Oxide 80% | 5 |
| Sulfur | 1.5 |
| DPG | 0.3 |
| MBT (75%) | 0.5 |
| MBTS (80%) | 0.3 |
| ZDBC 80% | 1.3 |
| Vulkalent® E/C | 0.2 |
| DPTT (75%) | 1.3 |

Total phr 326.4
% EPDM 30.6%
Density 1.144

Table I: Reference Thermoset EPDM compound

A second EPDM compound was modified by the addition of a semi-crystalline propylene based polyolefin at the level of 15phr. The objective is to enhance the compatibility of the EPDM and TPV at their interface.
III.2 – TPV corner molding grades

A first grade used as reference is a commercial Santoprene ™ TPV, 121-65 W233 (W233), currently used as a molding grade for hybrid compositions, comprising an EPDM cured profile and a TPV overmolding.

The second grade is a new developmental Santoprene™ TPV, X 121-65 B200 (B200). Its formulation has been specially designed for low hardness (65 Shore A) and high tensile strength, close to typical EPDM glass run channels. In addition, B200 has a gloss level similar to EPDM profiles, improving the color match and continuity between extruded and molded portions.

<table>
<thead>
<tr>
<th>Properties</th>
<th>121-65 W233</th>
<th>121–65 B200</th>
<th>Test Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hardness, Shore A</td>
<td>70</td>
<td>65</td>
<td>ISO 868</td>
</tr>
<tr>
<td>Tensile Strength, MPa</td>
<td>5.7</td>
<td>8.7</td>
<td>ISO 37</td>
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<tr>
<td>Elongation at Break, %</td>
<td>560</td>
<td>590</td>
<td>ISO 37</td>
</tr>
<tr>
<td>Compression Set 25% defl., 22 hrs @ 70 °C, %</td>
<td>50</td>
<td>41</td>
<td>ISO 815</td>
</tr>
<tr>
<td>Gloss at 60° (EMC reference mold)</td>
<td>9.5</td>
<td>28</td>
<td>ISO 2813</td>
</tr>
</tbody>
</table>

Table 2: TPV grades

We have also introduced in the comparison study an SEBS grade (Uniprene™ 7200.64), since SEBS material can be used in weatherseal applications.

Figure 3: Physical properties of TPE grades

B200 offers the highest tensile strength in combination with the lowest hardness, consistent with typical EPDM compound performance (Tensile Strength > 7 MPa).
IV – Adhesion performance

Adhesion tests were prepared and performed as described in paragraph II.

IV.1 – Adhesion EPDM - TPV

At room temperature, B200 provides an adhesion of 4 MPa, which is about 40% better than the performance of the reference grade. Using an EPDM compound modified with a semi-crystalline polyolefin, adhesion is further enhanced by 10%. This adhesion value is generally the target accepted by weatherseal producers for a corner molding.

In laboratory conditions, an EPDM to EPDM overmolding, 60 Shore A, cross-linked, has an adhesion tensile strength of 5.3 MPa, on average, tested by the same method.

At 70°C, B200 offers an adhesion retention which is almost twice that of the referenced TPV. This adhesion performance at high temperature is critical for glass run channel corners exposed to the sun and maintained under stress when closing the window.

At -20°C, B200 offers very high adhesion force in relation to a high elongation at break > 500%

Although the modified EPDM compound does not provide improvement at 70 °C, it further enhances the adhesion at low temperature.

IV.2 - Adhesion TPV - TPV

In order to assess the new TPV grade adhesion performance, we also tested the adhesion of TPE onto TPV. We used a commercial Santoprene™ TPV, 121-67 W175, that is a typical grade for extruded TPV profiles. We overmolded in the same mold and conditions and tested with the same method as described in paragraph II.
We observe that B200 offers a higher bonding strength, about 20% higher than the reference grade. This confirms the importance for the TPV composition to generate a better interfacial compatibility between the cold material and the hot and molten TPV during the injection process. It may be that co-crystallization occurs at the interface during the cooling period, which results in a higher physical bonding force.

This compatibility is related to the olefinic nature of the two materials. When we used an SEBS as the overmolded TPE, adhesion strength was low, showing poor material interaction at the interface.

**IV.3 - Adhesion EPDM – TPV after climatic aging**

As shown in Figure 6, there is no change in adhesion after air aging at 70 and 100°C or after aging in saturated humidity at 70°C. There is even an increase in adhesion after 100°C aging, which may be related to re-crystallization of the plastic phase.
IV.4 - Adhesion EPDM – TPV performance related to elastic properties

**Figure 7:** Adhesion TPV to TPV, B200 offers a higher elongation at break

Comparing B200 adhesion properties with W233, we observe that the elongation at break of B200 is higher at room temperature and eventually greater at 70°C. Weatherseals containing B200 are expected to resist higher strains when handled by operators at part de-molding, at the mounting in the door, and in service when closing the window.

V – Rheology for optimum molding performance

B200 adhesion performance is related to unique re-crystallization properties during cooling in the mold.

**Figure 8:** TPV Rheology in cooling mode (RPA measurement)

To illustrate this, we have performed a rheology test with the Rubber Process Analyzer (RPA), which is a rheometer used to measure elastic and viscous properties of an elastomeric material (reference 2) at
various temperature and deformation modes (amplitude and rate). In this study, we have measured the evolution of the material elasticity during the cooling time (EMC test method). This is to mimic the TPV behavior in the mold, after injection, when cooling in contact with the EPDM profile. In Figure 8, the graph representing the tangent delta function of the temperature, we observe that the re-crystallization rate is slower with B200, compared to the TPV reference grade. The crystallization eventually levels out at a lower temperature than the reference. This suggests that better physical interactions are developed at the interface between B200 TPV and EPDM. Therefore higher adhesion strength is obtained.

We also observe that even with a lower hardness than the reference W233, B200 offers a higher adhesion strength. This illustrates the superior bonding performance of B200.

Finally, B200 has lower tangent delta than W233 at temperatures less than 70°C. This shows that B200 has a high elastomeric behavior, closer to EPDM. This is a benefit for weatherseal dynamic applications, like glass run channels.

**VI – Part Development Support and Benefits**

TPE parts can be overmolded on EPDM profiles with potential system cost savings. Those savings are generally a balance between higher TPE raw material vs. EPDM compound price, and lower processing costs like shorter cycle, less energy and reduced post trimming operations.

According to equipment manufacturer and processor calculations (Reference 3 and 4), cost savings by substitution of EPDM by TPV increase when the part becomes bigger and more complex, such as for mirror seals and water drainage seals.

![TPE Cost Benefits for Overmolded Parts](image)

**Figure 9: TPV molding cost model**

This is related not only to the molding cycle time reduction, but also to the trimming time. Processors estimate that this saving on trimming can represent up to 20% on a part cost like an end cap.

TPV material molding onto cross-linked EPDM profile is not only a question of TPV or EPDM raw material properties. Processing conditions and equipment play a key role, so full cooperation between raw material suppliers, equipment manufacturers and processors can insure the success of such techniques.

Adhesion performance is highly dependant on the mold design and the material flow. The optimum interaction at the interface of the two materials requires a processing operation under precise temperature settings and shear control.
VII – Conclusion

There is a trend in the automotive weatherseal market for converting from thermoset EPDM to TPV parts that are overmolded onto EPDM profiles. The incentive is the lowest total part cost because TPV processing simplifies such complex operations. Therefore reduced cycle time and fewer injection presses per extrusion line can be expected. Quality also improves since the cold molding does not damage the surface treatment applied on the profile.

The adhesion performance on cured EPDM has historically limited this conversion to mostly static parts. In this study, we have shown that a TPV grade, specially developed to offer an improved bonding to EPDM compounds, can expand the TPV overmolding applications to more dynamic profiles. This improved adhesion is not only observed at room temperature but also at higher temperatures, which is critical in the automotive environment and after aging. This higher bonding energy is related to higher tensile strength, but also higher elongation at break, which reduces the risk of breakage when handling the weatherseal after molding.

References

1. Neue TPV Materialen fuer Karosseriedichtsystem – Leander Kenens - TPE in der Prozesskette - VDI Jahrestagung Elastomertechnik- April 02


3. Corner Molding Kombiniertes TPE - EPDM Spritzgiessen – Peter Steinl - TPE in der Prozesskette - VDI Konferenz- April 05


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