

TPVs in automotive

Benefits for consumers, OEMs, and the environment

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Thermoplastic vulcanizate (TPV) elastomers are increasingly accepted as preferred alternatives to thermoset rubber and standard thermoplastics for flexible or elastic automotive components such as sealing systems, ducts, bellows, interior or exterior trim, and other parts.

Manufacturers of such components must address the complex and often conflicting requirements of consumers, government regulations, environmental mandates, and OEMs, not to mention their own economic and quality requirements. TPVs provide the surface appearance, tactile properties, and attractive colors desired by consumers. Unlike thermoset rubber, they are fully recyclable, and their greater processability and design freedom helps reduce weight – and CO₂ emissions – through parts consolidation, thin walling, and other innovations. OEMs looking for a “greener” image through lighter cars and greater use of recycled materials appreciate these advantages of TPVs. Teknor Apex is committed to continuing the growth of Sarlink TPVs in the automotive industry through achieving more conversions from standard materials in existing applications and developing applications that are new. This report focuses on four broad application areas where Sarlink TPVs are already widely used: sealing systems, under-bonnet (under-hood), interior and exterior.

1. Introduction

For specific application areas in automotive, Sarlink TPVs have proven themselves to be an excellent solution. These materials are a distinct type of elastomer based on patented technology and differing from other TPVs. Consisting of dynamically vulcanized EPDM rubber in a polypropylene matrix, they combine the outstanding elastic properties of rubber with the processing ease of thermoplastics. In comparison with the thermoset rubber that historically has dominated

automotive applications like sealing systems, Sarlink TPVs exhibit superior UV stability, long-term sealing performance, aesthetics, and colorability. At the same time they reduce production costs as a result of shorter cycle times, faster part production time with lower energy usage, and a very high material efficiency as a result of its full recyclability. These features provide an excellent balance of the consumer, environmental, and OEM expectations for components, and are a main driver for the continued expansion of TPV usage in automotive manufacturing (fig. 1).

In comparison with other TPEs such as those based on SEBS, Sarlink TPVs exhibit much better high-temperature resistance, sealing properties, and weatherability. In addition, the presence of EPDM as a critical constituent has been an important factor in their acceptance for automotive applications where EPDM has played a dominant role.

2. Sealing systems

An automotive sealing system by definition is a flexible interface between parts of the car body or between metal and glass to prevent the passage of air, water, and noise. A well functioning sealing system must be durable over the life of the car, light in weight, aesthetically pleasing to the consumer, and above all else functional. Overall vehicle performance requirements have increased dramatically over the years, and this trend has translated into much higher expectations of sealing systems. TPV has gained wide-scale acceptance in automotive sealing system applications due to the material's performance as a durable air, water, and noise barrier, while also addressing a wide array of consumer, environmental, and OEM requirements.

There are currently three basic material technologies commonly used in automotive sealing system applications. These material families include thermoset EPDM (both solid and sponge), TPV, and PVC. In some less critical applications, SEBS (TPE-S) can be found as well. As the historical standard for automotive sealing systems, EPDM con-

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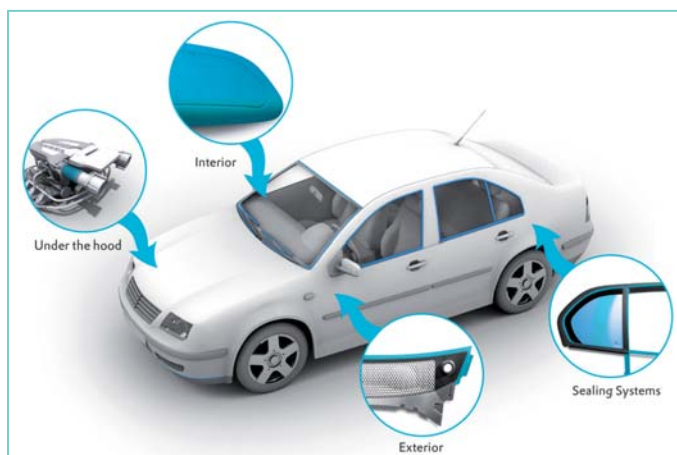
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Fig. 1:
TPVs are already widely used in sealing systems, under-bonnet (under-hood), interior and exterior applications



tinues to hold the largest share of the market, although TPV now dominates several specific application areas. The continuing shift toward TPV is evidence of the material's ability to meet the changing dynamics that drive automotive manufacturing. While thermoset EPDM rubber is able to meet the sealing requirements of today's vehicles, it falls short relative to overall aesthetics, weight, recyclability, design flexibility, and cost. Seals produced from Sarlink TPVs offer solutions in all of these areas, without sacrificing sealing performance. **Table 1** offers some detail in regards to the benefits, outside of critical sealing performance, that TPV materials bring to automotive weathersealing.

2.1 TPV applications in automotive sealing systems

As outlined above, the benefits of TPV-based weathersealing systems range well beyond simple functional requirements. Due to this, TPV continues to gain share as more and more sealing system application areas are converted from EPDM systems. While material development and application development activities continue to evolve to support this expansion, there are a number of application areas where the value of TPV is firmly established. The following outlines what these typical applications are, as well as the inherent value that has allowed such significant penetration.

2.1.1 Inner and outer waist belt seals

Waist belt seals were one of the first application areas in automotive sealing to fully embrace TPV technology. Both outer and inner waist belt seals require very similar performance characteristics, with outer belts being slightly more complex as they are a visual part with key aesthetic requirements. Because of this, this section will focus on outer waist belt seals, as all of the benefits of TPV in these applications (outside of aesthetics) also translate to inner belts.

TPV usage for outer waist belt seals provides a good blueprint as to how TPVs address the performance, cost, weight, recyclability, and aesthetic requirements of automotive sealing systems. Outer waist belt seals significantly impact the appearance and functionality of the vehicle. These seals must maintain proper sealing dynamics while accommodating window movement, must attach firmly to the door panel (through temperature extremes), and must provide a good aesthetic breakpoint where the painted door meets the window glass.

Traditional EPDM seals utilized flocked lips to control friction on the moving glass, used encapsulated metal for attachment, and provided an uneven, oily outer surface appearance that had the propensity to chalk over time. Additionally, these seals were not recyclable and required enormous energy out-

lay in manufacturing. TPVs have been able to address these shortcomings through their compatibility with olefins as well as the flexibility inherent in thermoplastic processing. For instance, flocked sealing lips can be replaced with olefin based slip coatings, and metal carriers can be replaced with rigid polypropylene. This design flexibility keeps the recyclability of the entire system intact, and also creates significant economic advantages through the elimination of the traditional metal carrier. Additionally, the lower viscosity of TPV allows thinner wall sections, and the energy outlay in manufacturing is significantly reduced.

The end result is a cost-effective system that exhibits full recyclability and significant weight reduction. As an added benefit, Sarlink TPVs have a very good surface appearance and weathering characteristics, and can even be combined with various appearance coatings for a higher-end look where required.

2.1.2 Glass run channels

Glass run channels are another application area in automotive sealing systems where the benefits of TPV have paved the way for significant market penetration. Many of the same attributes that have made TPV successful in waist belt seal applications also apply to glass run channels: recyclability, olefinic slip coats, extruded-on appearance coatings, weight reduction, and full system cost improvements. However, there are also some additional challenges inherent to glass run channel applications where TPV technology has proven its worth.

By design, glass run channel applications must conform to the interface between sheet metal and moving window glass. This is often accomplished by extruding the flexible sealing material over a metal substrate, and then stretch bending the finished part into a geometry that matches the window dimensions. For very tight corner radiuses, the glass run channel is often finished through a corner-moulding process, in which the extrusion is placed into a mould and new material is moulded onto opposing ends, effectively filling the gap with a corner detail and bonding the two straight sections together. In ei-

Tab. 1: Benefits of TPVs for automotive weathersealing

Manufacturing or end product issues	Comparative advantages (green) and disadvantages (red)	
	EPDM	TPV
Capital cost	High: Compounding, shaping, and curing	Moderate: Conventional thermoplastic
Processing energy	High: Long heat curing process	Moderate: Short cooling cycle
Recyclability	Poor: End-of-life reclaim can be ground as additive for asphalt, etc.	Excellent: Reuse in-cess and end-of-life reclaim; retain properties
Part weight	High: Higher density, thicker cross sections needed	Low: Lower density, thinner cross sections with same CLD
Attachment	High cost: Encapsulated metal for stiffness	Low cost: Use of stiff polyolefins for rigidity / attachment
Glass interface	One option: Reduce friction with electrostatic flock	Three options: flock, flock tape, or recyclable extruded olefin slip coat
Colorability	Low: Specialty compounds with low fidelity	High: Inherently colorable, with high brightness possible
Aesthetics	Fair: Oily, uneven surface, long-term weathering concerns	Excellent: Colorable, consistent matte finish, highly weatherable
Decoration	Limited: Exposed encapsulated metal decoration	Extensive: olefin-based gloss coats, paint films, attached bright strips
Foaming	Excellent: Technology well established	Poor: Technology in development

ther of these scenarios, TPV-based designs create tangible value for the OEM.

TPV can be extruded over the metal carrier materials typical to glass run channels, and specific olefin-based slipcoats have been developed that are flexible enough for stretch bending without sacrificing the friction properties necessary for specified glass movement and durability. Additionally, the viscosity of TPV allows more complex and thinner profile design, leading to lighter parts incorporating additional sealing features that aid in reducing cabin noise and air egress.

In applications where corner moulding is a design requirement, TPV materials can be used to significant benefit. Specialty corner-moulding grades of Sarlink TPVs have been developed that allow cycle times that are significantly lower than traditional EPDM moulding processes, so much so that in some cases the number of moulding machines needed to support a single production extrusion line have been more than halved. When used in conjunction with a TPV profile these corner-moulds create a very strong bond between sections, and their matching olefinic chemistry allows full system recyclability. Specialty Sarlink corner-mould materials are also available with internal lubricant to aid in glass friction, and specific grades have been formulated for compatibility with traditional EPDM extrusions.

It is worth noting that the next generation of TPV glass run channel development is already underway, as at least one major Tier I producer of TPV weatherseals has developed and is actively marketing a unique, stretch bendable, olefin-based carrier for the replacement of metal in these applications. Much as in waist belt seal applications, this creates significant additional value for TPV in these applications by further reducing weight and system cost, while also allowing full system recyclability without separation.

2.1.3 Glass encapsulations

Although not as technically challenging from a sealing perspective as other areas on the vehicle, fixed window encapsulations offer a unique challenge from a processing

perspective. These applications are typically injection moulded around a piece of window glass inserted directly into the mould, resulting in a number of challenging criteria that must be met for success. The insertion of glass into the tool necessitates a material with a low enough viscosity to avoid glass breakage, and the material must be compatible with the adhesive used to bond to the glass. Additionally, the surface finish must be good over a wide range of part geometries, complex radiuses, and knit line configurations.

The widespread use of PVC for glass encapsulation has led to issues in gloss standardization, recyclability, overall weight, and processing flexibility. Applications utilizing TPV have been successful in addressing these issues, but processability over a wide range of part designs has been a limiting factor. To address these shortcomings, Teknor Apex has developed a range of high flow window encapsulation grades that allow a much wider process window for producing aesthetically acceptable parts, without sacrificing the recyclability, weight reduction, and matte finish required by automotive OEMs. While the optimization of these formulations is ongoing, the launch of several recent production models using this technology is evidence of significant progress in TPV penetration into the glass encapsulation market.

2.1.4 Auxiliary seals

The success of TPV materials in meeting the consumer, environmental, and OEM requirements for waist belt seals and glass run channels has also made them preferred materials for a variety of auxiliary automo-

tive seals. Examples include rocker seals, hood to cowl seals, sunroof seals, IP-seals, B-pillar seals, and a host of other smaller, yet design-critical, sealing application areas on automobiles (fig. 2).

3. Under-bonnet/under-hood

TPV penetration into the automotive under-the-bonnet category has been driven by three major applications: air ducts, boots and bellows, and HVAC (heating, venting, air conditioning) systems. These non-visible parts are often overlooked by the consumer, but they are key areas for meeting environmental and manufacturing requirements.

Applications within this category require elastomeric materials with excellent long term resistance to automotive fluids, oils and road grime, as well as sustained performance in an environment that is increasingly higher in temperature and smaller in cooling space model after model. Flexibility, especially in anti-vibration part connections, is also of great importance when it comes to under-the-bonnet applications.

Traditional materials were able to meet all of these performance requirements, but did so at the expense of weight, recyclability, and total cost. Conversely, Sarlink TPVs allow lower part weights, are fully recyclable, and can eliminate costly subassembly operations. This is because Sarlink TPVs are olefin-based materials, and they can be processed together with other polyolefin materials. Furthermore, they are able to be processed in all traditional thermoplastic equipment, including 2K and 3K blow moulding, injection

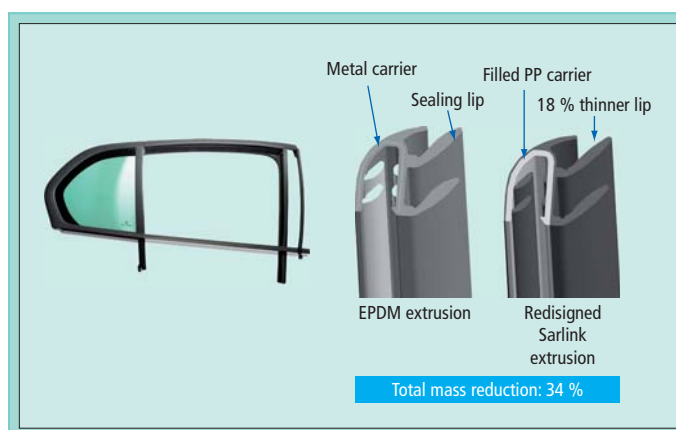


Fig. 2:
TPV materials in sealing
system applications

tion moulding and extrusion. The end result is a material solution that is uniquely adaptable to a wide range of parts regardless of geometry, size, performance, and hardness requirements.

3.1 Air duct applications

A good example of the dynamics that have led to broad TPV proliferation in under-the-bonnet applications can be found by looking specifically at air duct applications. These have a well defined set of technical criteria that need to be met to ensure acceptable performance. The criteria include anti-vibration, noise management, flex fatigue, performance at elevated temperatures of 100–120 °C, and high charge pressures. These components typically consist of a rigid main body mated to flexible inlets, outlets, and joints. Traditional parts would be made by assembling individual sections made of different materials into the final subassembly. This was costly and labour intensive, created the opportunity for human error, and also precluded easy recycling. Solutions based on Sarlink TPVs take advantage of the thermoplastic nature of TPVs and their compatibility with other olefins such as polypropylene. The end result is a part with fully airtight melt bonds between rigid and flexible sections, made entirely in one step using a multi-component blow moulding process. This leads to an elimination of off-line assembly (and cost), lower overall weight, and full component recyclability without separation.

3.2 Boots, bellows, and beyond

The same principles described above for air ducts are applicable to the broad area defined as boots and bellows. Included in this broad characterization are specific application subsegments such as rack and pinion boots, steering bellows, door boots, dust

covers and cable covers. These applications not only demand high physical property performance in regards to flexibility, fatigue, and durability, but also good oil and chemical resistance.

TPV usage in traditional under-the-bonnet applications has migrated into applications that have similar technical requirements but do not quite fit the location-centric descriptor of under-the-bonnet. Examples of this include automotive HVAC systems, where the sealing, processing, and olefin compatibility properties of Sarlink TPVs lend themselves to flapper seals, air diverter valves, and register adjustment components. The durability and flexibility balance of TPV materials has also lead to widespread use in control cable coverings and grommets, and inner door access plugs and fasteners. A more recent trend has been the use of TPVs in fuel filling systems, where both fuel filler housing seals as well as fuel filler tubing in trucks have been moving to Sarlink technology.

Because of the varied design, location, and application requirements of these parts, different processing methods can be employed to create the most economical solution for each. In support of this, Teknor Apex has developed a full range of products of varying hardnesses that are suitable for injection moulding, compression moulding, blow moulding, and extrusion-blow moulding. Specialty products are also available for injection moulding applications requiring long flow lengths, and for sheet extruded or blow moulded applications requiring unusually high melt strength. This full-line product offering combined with knowledgeable and responsive application development capabilities is why Sarlink TPVs are currently in use for under-the-bonnet applications on a global scale, with market coverage that extends to every major automotive OEM (fig. 3).

4. Exterior and interior

The drivers behind TPVs used in interior and exterior automotive applications are much more diverse than in under-the-hood and sealing systems, and as such there is not one central performance factor that binds these applications together. However, all these applications address the same basic consumer, environmental, and OEM requirements detailed throughout this article.

In some cases, the consumer and OEM requirements of performance and safety are addressed, as in the use of durable high impact/low temperature TPV materials for air-bag covers and virtually unbreakable front air deflectors. In other cases, environmental drivers are at the forefront. In all of these cases, the TPV material being used displays one common trait: performance equal or superior to the material it is replacing.

To provide some insight on the critical factors that make TPV the material choice for a wide range of interior and exterior applications, we will review a small number of specific application areas that best define the many desirable characteristics of the material. While this is by no means a comprehensive list, it does provide some insight into the performance, aesthetic, and environmental capabilities of TPV.

4.1 Exterior

4.1.1 Bumper extensions

For years, automotive OEMs have been adding bumper extensions to the front fascia of the vehicle to improve aerodynamics (fuel efficiency) and create a visual break at the front of the car. These parts are separate mouldings from the front fascia that lower the profile of the front of the vehicle while isolating the decorative front trim from impact areas such as snowbanks and parking curbs. Traditional soft PP/TPO materials used in these applications had acceptable processing and UV properties, but tens of thousands of cracked spoilers have led some major OEMs to look for a more durable option. Sarlink TPVs have capitalized on this by developing highly processable moulding materials that provide the same level of aes-



Fig. 3:
TPVs in air ducts (left)
and boots and bellows
(right)

thetics and UV protection as their predecessors, while utilizing the flexibility and impact properties inherent to TPV to create a much more durable front spoiler, especially in cold temperatures. In addition to being formulated to make visually appealing parts that in some cases extend to over 2 m in length, Sarlink front spoiler materials can be two-shot moulded in concert with stiffer PP/TPO materials to reduce cost, add stiffness where needed, and facilitate easy attachment to the primary front fascia.

4.1.2 Roof ditch mouldings

Another area of the vehicle exterior where TPV materials are making significant inroads is roof ditch mouldings. Roof ditch mouldings are used to cover the area of the vehicle where the roof metal is welded to the pillar junctions (frame). These parts traditionally utilized PVC extrusions, which although durable tended to be high in weight, non-recyclable, and high gloss in finish – not a good aesthetic match to the matte finish of glass encapsulations and weather seals used on the same vehicle. TPV is now commonly being used in these applications, as their extrusion quality, long term weathering properties, and durability matches or exceeds that of vinyl. Additionally, TPV has the benefit of reducing weight, promoting recyclability, and providing a consistent matte finish that is a good aesthetic match to other exterior transition areas of the vehicle.

4.1.3 Cowl to glass seals

TPV has been widely accepted in cowl to glass seals, and is now used in a majority of these applications on global automotive platforms. These applications are a strong example of how the elastomeric properties of TPV combined with its thermoplastic processing and compatibility with olefins can be leveraged to create final assemblies of much lower cost.

While traditional cowl seals made of TPO or filled PP had to be fitted with thermoset rubber seals made at another location, TPV seals can be added directly to the part in a two shot moulding process. This not only eliminates assembly and attachment costs, but also allows a part that is fully recyclable.

Additionally, the aesthetics of the part are greatly improved by using this two-shot approach – on most modern cowl screens it is very difficult to pick out the transition from the stiff substrate to the TPV sealing portion of the part.

4.1.4 Gaskets and gap hidrs

Each individual vehicle has its unique design requirements, and each manufacturer has its own unique way of addressing them. In areas where exterior accessories or features need to transition to painted metal, Sarlink TPV has proven to be a good fit due to its ability to meet functional, aesthetic, environmental, and manufacturing cost criteria. Examples of these diverse applications include exterior mirror gaskets, headlight gimps and seals, door handle interface gaskets, roof rack gaskets, and A-pillar seals.

4.2 Interior

4.2.1 Interior skins and consoles

High-end automotive interiors require materials that meet or exceed a consumer's expectations for look, feel, and fit and finish. A long term trend in these designs has been the use of soft-touch materials on IPs, consoles, and door panels. While PVC systems have long been the industry standard

for these applications, olefin based systems are receiving more and more visibility as an alternate choice.

Specialty Sarlink TPV materials have been developed specifically for the interior skin market, focusing on processing requirements, durability, colorability and overall feel. While PVC has a number of features that make it a very good fit for these types of applications, these specialty Sarlink materials are making inroads on the performance aspects of these applications, with the added benefits of recyclability and weight savings.

TPV for usage in soft touch centre consoles has evolved more quickly, as the ability to two-shot mould over PP/TPO is a huge factor in reducing overall part cost. Advancements in the colorability and processability of TPVs have allowed significant penetration into this market, with additional vehicle platforms being specified in this entirely olefinic system at every refresh cycle. As two-shot moulding capability continues to evolve, these types of applications are likely to continue their growth.

4.2.2 Cockpit: Bin mats and gap hidrs

As with automotive exterior, the types of ancillary applications for TPV on the inside of the vehicle are widely varied and often



Fig. 4:
TPVs in soft touch interior applications

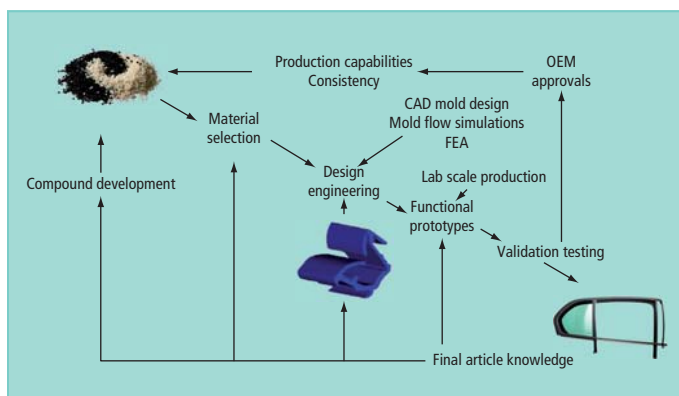


Fig. 5:
Sarlink application development – automotive sealing system

depend on the design preferences of individual manufacturers. TPV can often be found in areas where flexibility or a soft feel are required, or in areas where gaps need to be filled after the adjustment of controls. Application examples include bin mats, air register controls, adjustable steering column trim, hand brake channels, shifter boots, and cupholder trim, amongst others. In all of these areas, TPVs are able to provide a superior balance of manufacturer, environmental, consumer, and part cost criteria when compared to other elastomeric materials (**fig. 4**).

In November 2010 Sarlink TPVs became a new product family within the Teknor Apex Company. Teknor Apex is a privately held company, founded in 1924 and based in Pawtucket, RI, USA.

5. Facilitating the change

Developing material technologies that meet the consumer, environmental, and OEM requirements of the 21st century is one thing, and successfully proving them out and implementing them in new application areas is another.

Facilitating a change from incumbent materials that meet performance requirements but fall short in other critical areas requires substantial process development, design review, and performance validation.

Sarlink TPVs have a proven track record in replacing incumbent material technologies, and ultimately becoming the new standard for future design. This success is based on two important competencies:

- **OEM intimacy**
Teknor Apex maintains and continuously looks to strengthen its relationships with all major automotive OEMs around the world. Its cooperative work ranges from long term development initiatives that prove out new materials technology to specification reviews to help fill gaps in current material performance.
- **Customer support**
Implementing a material into a new application can be a daunting task. Teknor Apex has structured its customer support resources specifically to help customers through this process. The steps in a typical application development process are shown in **figure 5**. In many cases, a fully functional prototype part can be produced by Teknor Apex in their labs in Leominster, MA, USA.