Meeting Modern Challenges in Bonding to Automotive TPO Materials

Author: Ananth Subramanya
ananthsubramanya@berryglobal.com
631-953-4279

December 2019

TPO materials belong to the larger group of TPE's or Thermoplastic Elastomers. As such, they come in many formulations and can be molded into parts with different surface finishes. Increasingly used in the automotive industry as an alternative to high cost, high weight metal materials, TPO plastics present unique bonding challenges for PSA (pressure-sensitive adhesive) manufacturers.

TPO's fall into the category of low surface energy (LSE) materials. Generally, pressure-sensitive materials have a lower affinity for LSE surfaces than, for example, stainless steel or glass. Over time, oils present in the TPO may migrate to the surface and interfere with the adhesive bond. Additionally, TPOs are selected by auto manufacturers in part due to their resistance to chemicals, UV, high/low temperature, oils, etc. that a vehicle would be exposed to over the course of its service. TPOs are impact resistant and highly moldable to create the shapes and custom pieces needed for today's automotive interior designs. Adhesives must be formulated to not only bond to this challenging material, but also to withstand the same operating conditions as the TPO materials.

Now consider that PSA manufacturers must not only bond to the TPO substrate, but also join a material such as a foam, vinyl, or other low energy surface material to the TPO, increasing the bonding challenge. Further complicating the development of new PSAs is the increasing demand for Low VOC adhesives that comply with JAMA (Japan Automobile Manufacturers Association) standards.

PSA manufacturers must address all of these issues when developing bonding solutions for the automotive industry and do so using a combination of adhesive formulation development, adjusting the caliper or thickness of the adhesive, or a combination of the two.

ADHESIVE DEVELOPMENT

Understanding all of the "failure modes" is critical for the PSA provider so that the most cost-effective bonding solution can be offered. In the world of pressure-sensitive adhesive chemistry, compromises are inevitable. For example, the nature of PSA chemistry is such that it is difficult to offer both high and low temperature resistance in one adhesive. Furthermore, the need for UV, chemical, and/or solvent resistance leans toward acrylic adhesive chemistry and yet, adhesion to low surface energy substrates like TPO's is better achieved using rubber-based adhesive chemistry.

Other material-specific performance requirements come into play especially when TPO's are involved. For example, what grade of TPO is being used and is it extended with oils? What about the other surface? Plasticizer resistance? Low fogging and, more recently, low VOC? The surface conditions of some molded TPO parts and some foam materials may warrant the use of heavier caliper adhesive systems.

Chart 1
180° PEEL @ 300MM/Minute; 24 Hour Dwell
Results are average value LB/IN Width

Product	Adhesive Type	Tape Construction	TPO 1402	TPO D1652GM
1142S	Acrylic	Reinforced Transfer	7.2 (CF)	7.5 (CF)
1142U	Acrylic	Transfer	6.3 (CF)	6.0 (CF)
4120U	Rubber	Transfer	9.0 (CF)	9.1 (CF)

4351M	LS Rubber	Differential DC Film	5.7 (CP)	4.6 (CP)
4377M	LS Rubber	Differential DC Film	4.4 (CP)	4.4 (CP)
652	Acrylic	Transfer	4.2 (CP)	3.2 (CP)
653	Acrylic	Transfer	5.1 (CP)	4.5 (CP)
654M	Acrylic	DC Film	5.0 (CP)	4.2 (CP)
654U	Acrylic	Transfer	6.2 (CF)	4.6 (CP)
754M	Acrylic	DC Film	5.2	4.6 (CP)
7744	Acrylic	Transfer	7.7 (CF)	8.1 (CF)

(CP) Clean Peel - Failure of the adhesive to the surface of the test panel.
(CF) Cohesive Failure - Failure of the adhesive film itself, splitting adhesive between backing and test panel, leaving residue on surface of test panel.

The above chart consists of acrylic, solvent rubber, and hot melt rubber adhesive chemistries as well as a variety of common tape constructions which reflect the wide array of possible customer considerations to meet their requirements. You can see significant variation in the peel adhesion values achieved from one adhesive type to the next as well as variation in the same adhesive system applied to different TPO substrates.

Testing is a critical part of the development process including bonding studies to a customer’s TPO material as well as to foam and non-foam substrates. Berry Global performs extensive bonding studies on their adhesives throughout the development process at their A2LA Accredited Lab in Riverhead, New York, to ensure compliance with automotive industry and manufacturing standards as well as end-user requirements.

UNDERSTANDING TAPE DESIGN

As depicted in the chart above, both adhesive chemistry and tape construction play a role in determining the best bonding solution for the TPO component. Because PSA materials are “converted”, offering several constructions provides the PSA tape converter maximum latitude in his processing operations. Double-coated tapes with PET carriers permit parts to be die-cut into complex shapes and still maintain dimensional integrity. On the other hand, if a flexible gasket must conform to a part with a complex shape, a double-coated tape with a tissue carrier or an unsupported transfer tape might be required. Double-coated foam tapes are employed for special applications such as mounting an automotive antenna base to the glass backlight or rear window.

Adhesive chemistry is equally critical to the success of a TPO bonding system. Adhesive systems are constantly evolving to meet the demands of not only the newest engineered plastics, but also to constant changes in foams and other substrate materials. Both acrylic and rubber-based chemistries can be employed depending on the end use requirements. Acrylic-based systems typically have better UV chemical and solvent resistance but rubber-based systems have more aggressive bonding characteristics and present better economies in most cases.

Even the paper or film release liner requires careful consideration. Kiss cutting operations may require the use of heavy paper board liners whereas high speed rotary die cutting can demand the use of poly-coated or film liners. The desire to recycle the discarded liner may also enter into the selection process. The ability of the adhesive tape to release properly from the liner requires special engineering especially with low surface energy materials like TPO’s which typically require the use of more aggressive adhesive systems - further complicating the release liner issue. PSA tape manufacturers sometimes devote more development resources to the engineering of the release liner - which is ultimately discarded - than to the adhesive itself. Clearly, without an effective release liner, even the best adhesive system is rendered useless.

MANAGING VOCs

For the last decade, a greater emphasis on reducing VOC content in materials has added a further challenge for PSA manufacturers. VOCs, or Volatile Organic Compounds, are organic compounds that vaporize and enter the atmosphere under normal, everyday conditions. The Japanese Ministry of Health, Labor, and Welfare (MHLW) issued exposure guidelines in 2002 limiting the detectable limits for 13 VOC’s found in confined areas such as homes and auto interiors. The automobile industry has largely adopted these standards, and now testing for VOC content has become part of the standard protocol for PSAs used in automotive bonding applications.

Confusion exists in the world of pressure-sensitive adhesives since no national or worldwide standards have been established. PSA's are called "Low Odor" or "Low VOC" without reference to any guidelines. Our firm has taken the position that for a PSA to be truly called Low VOC it must, at the very least conform to the Japanese MHLW standards which were adopted by JAMA for all new passenger and commercial vehicle production in 2007 and 2008 respectively.

Chart 2

Outgas Data
Test Piece Preparations: 66.5 g/m^2 dry on 50µm of PET Film
According to JIS A1901:2003

Substance Name	Guideline Value JIS A1901:2003	Outgas Report 650 Adhesive System (µg/m^3)
Formaldehyde	100µg/m^3 (0.08ppm)	<1.96
Toluene	260µg/m^3 (0.07ppm)	<0.84
Xylene	870µg/m^3 (0.20ppm)	<0.84
Paradichlorobenzene	240µg/m^3 (0.04ppm)	<0.84
Ethyl benzene	3800µg/m^3 (0.88ppm)	<0.84
Styrene	220µg/m^3 (0.05ppm)	<0.84
Cholorpyrifos	1µg/m^3 (0.07ppb)	<0.84
Di-n-butyl phthalate	220µg/m^3 (0.02ppm)	<0.84
Tetradecan	330µg/m^3 (0.04ppm)	<0.84
Di-2-ethylhexyl phthalate	120µg/m^3 (7.6ppb)	<1.4
Diazinon	0.29µg/m^3 (0.02ppb)	<0.0025
Acetaldehyde	48µg/m^3 (0.03ppm)	<3.92
Fenobucarb	33µg/m^3 (3.8ppb)	<1.12

Clearly having an extremely low VOC adhesive is only half the battle. Extensive testing must confirm that the PSA also meet the requirements of cohesive strength, temperature resistance, chemical and UV resistance, and other factors deemed critical by the end user. This particular adhesive referenced in Chart 2 has shown exceptional bonding characteristics to a variety of TPO materials, excellent high/low temperature performance, and significant resistance to chemical and UV exposure.

CONCLUSION

The use of TPO materials continues to expand in the automotive industry as well as other related industries. PSA suppliers must remain agile in developing adhesive systems that can not only meet high performance demands to a wide variety of TPO materials but also perform in stressful operating conditions. Combined with greater emphasis on low VOC, green materials, light-weighting of vehicles, and overall cost reduction, the challenge is a significant one. PSA manufacturers like Adchem have the opportunity to be a developmental partner with molders, TPO suppliers, and Automotive OEMs in developing new solutions for the next generation of automobiles.