TPE Overmolding Solutions for Engineering Thermoplastics

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Abstract

Demands continue to increase in various consumer applications for ergonomically designed products. To enhance the performance in the end use application and marketability of such consumer products the use of a thermoplastic elastomers as an overmold, onto the engineering plastic has continued to grow.

The market trends in combination with the innovative molding techniques have available has placed a high demand on thermoplastic elastomer suppliers to produce compounds capable of bonding to the different engineering plastics available. TPE suppliers have responded developing a variety of compounds with the attributes to bond to several engineering plastics such as nylon (PA), polycarbonate (PC), Acrylonitrile-butadiene-styrene (ABS), and PC/ABS alloys

This paper elaborates different TPE technologies developed to bond to various rigid substrates i.e. Nylon (PA), Polycarbonate (PC), Acrylonitrile-butadiene-styrene (ABS), and PC/ABS alloys

Introduction

A wide variety of thermoplastic materials are used to make molded products. The choice of the thermoplastic depends on the functional performance needed in the end-use application. If the requirements are not met by one specific material, two or more thermoplastics can be combined to close the gap. In the past different methods including mechanical fastening, solvent bonding, welding, adhesive bonding, press/snap fit assembly have been used for combining materials. All of these methods are good options to combine materials however they are limiting when it comes to productivity rate because of the secondary process involved. In addition, they also have limitations when it comes to combining material of different chemistries.

In the last two decades faster output has forced the industry to look into other ways of combining materials. Two-component injection molding has gained popularity because of its faster process time and versatility of combining wide variety of materials. The two-component injection molding, also referred to as two-shot molding, consists of a machine with two independent injection units, each of which shoots a different material in series. The first material is injected through the primary runner system white the mold volume to be occupied by the second material is shut off from the primary runner system. The mold is then opened and the core plate is rotated and the second material is injected from the secondary rubber system. A more economical but not as fast in output is insert molding. In insert molding, a pre-molded rigid plastic substrate or metal part is inserted into the cavity via robotics or an operator. The second (over-mold) material is either injected onto one side of the insert or sometimes completely surrounds the insert. Insert Molding can be done using conventional injection molding equipment.

These methods of processing thermoplastic materials have been practiced since 80’s primarily by the automotive industry. However, most of the combinations were limited to hard thermoplastics only. Only in the last one decade applications have emerged which demand combining hard and soft thermoplastic materials. In applications such as power tools and other appliances hard and soft thermoplastic material combinations are used to provide functional properties such as vibration dampening, wet grip etc. This is achieved by molding a soft skin of thermoplastic elastomer over a hard engineering plastic. Hard and soft combinations are also used for ergonomic considerations, for example hand-held electronics such as cell phones have used hard and soft combinations to give a soft touch feel to their product and to differentiate their products with their competition.

The focus for this study was to develop thermoplastic elastomer compounds that would overmold onto substrates made from Nylon (PA), Polycarbonate (PC), Acrylonitrile-butadiene-styrene (ABS), and PC/ABS alloys.

Adhesion Testing and Results

The adhesion between hard engineering plastics and soft elastomer depend on a lot of variables. Matching the surface energy on both materials is critical for building specific interactions between materials. Another important variable to consider is wettability of TPE on substrate surface. For specific interactions to occur between the TPE and the substrate both have to come in intimate contact to each other and wet-out the surface. The TPE chemistry and the type of engineering plastic play a critical role in influencing wettability. In addition the diffusion and viscoelastic properties of the elastomer has an influence on the adhesion properties.

The bond strength between the TPE and the engineering plastic was measured by performing a “90^o Peel Test”. We have modified ASTM D903 method for plastics to evaluate the adhesion of soft TPE onto rigid thermoplastic. A schematic diagram of this test procedure is shown in figure 1. The testing is done on a molded substrate with a TPE skin insert molded on it. An inch wide strip of TPE is cut and pulled at 90^o to the substrate using an Instron tensile tester. The substrate is locked in its place on wheel in order to maintain the 90^{o} angle while the elastomer is being pulled. The adhesion strength is measured by the force required to pull the elastomer from the substrate and is reported as an average over 2 inches of pulling. The adhesion is categorized based on adhesive failure (A)- if no TPE residue is left on the substrate, or cohesive failure (C)- if the failure is in TPE. The reported values are an average of three different adhesion tests. Based on adhesion strength required by the consumer we have categorized an adhesion value higher than 13 pli to be acceptable for adhesion.

Table 1 summarizes the physical properties of GLS TPS suitable for overmolding. The type of the rigid substrate determines the choice of the TPE. As an example, for ABS as the rigid substrate, both OM1060 and OM1262 can be used for overmolding. In addition selection of the overmold TPE depends on the end-use application and environment.

Table 2 lists the GLS TPE products that were developed to overmold onto different substrates along with their adhesion test data. Table 3 gives the adhesion performance of other commercially available TPE products for overmolding on various substrates. Comparing data from Table 2 and 3 it can be seen that the developed product perform at par or better compared to all other commercially available TPE materials in terms of adhesion performance.

Table 4 shows processing conditions for the developed products along with the other commercially available TPE's. The other commercially available TPE's were processed as per the recommendations made in their respective data sheets. Molding TPE at higher processing temperatures helps in wetting out of elastomer to the engineering substrate and improves adhesion performance but it is interesting to observe that the products developed at GLS had better adhesion even though they were processed colder than other commercially available TPE materials. All products were dried as per the recommended conditions including the developed products which were dried in Desiccant oven at 70 C for 2 hr.

In most cases the elastomer in two-shot molding is limited to think walls molding which requires the elastomer to have high flow properties. Spiral flow testing which has been traditionally used for thermoplastics provides a comparative analysis of a material's ability to fill a part. Spiral flow testing of developed products was conducted and is reported in Table 5 along with a conventional TPE and TPV of similar hardness. From the data it can be observed that these overmold products show high flow compared to conventional TPE and TPV products.

Design Considerations

The material requirements of bondable TPE's are different from conventional TPE's and it is the same for designing parts. Unlike conventional part design, two component part design has to take into consideration shrinkage's from two different thermoplastic materials. Both have their own gate and runner system and need to be tailored to the specific material properties used.

The wall thickness of the substrate and over-mold should be as uniform as possible to obtain the best cycle time. Wall thickness in the range from 1 mm to 3 mm will ensure good bonding in most over-molding applications. If the part requires the use of thick sections, they should be cored out to minimize shrinkage problems and to reduce the part weight and cycle time. Transitions between wall thickness should be gradual to reduce flow problems such as back fills and gas traps. The use of radii (0.5-mm minimum) in sharp corners helps reduce localized stress. Deep unventable blind pockets or ribs should be avoided. Long draws should have a 3-5^{o} draft to help ejection. Properly designed deep undercuts however are possible with GLS over-mold compounds if an advancing core is used when the mold opens and the part does not have sharp corners and the elastomer is allowed to deflect as it is ejected.

Most TPE compounds have fairly high mold shrinkage in the flow direction with minimal shrinkage in the cross flow direction. This can lead to the over-molding compound contracting more than the substrate after the part is ejected from the tool. This, in turn, can result in a warping or cupping of the substrate part, usually in the direction of flow of the overmolding material. This is especially true for long, thin parts or parts where the substrate is thinner than the over-mold or if a low modulus substrate material is used. This can be partially counteracted by using higher modulus substrate materials and providing stiffening ribs in the substrate. Thinner coatings and the selection of a lower hardness over-mold grade will also help. Relocating the gate to influence the TPE flow pattern may also be of assistance.

Shut-off's should also be designed for the following reasons:

1. Reduce the potential of peeling and provide a sharp transition between the TPE and the substrate.
2. Provide a distinct cavity for the TPE, which is capable of being vented.
3. Prevent the TPE from flashing over areas on the substrate.
4. Provide a 0.003" to 0.005" interference when using plastic inserts or substrates, to take into account shrinkage, sinks and tolerances.
5. Provide a spring-loaded area if the inserted substrate is metal or other non-compressible material.

TPE materials are quantified based on Shore hardness, which is a materials resistance to indenture on a 6.3-mm minimum thickness molded plaque (ASTM D2240). A lower hardness product has a softer feel on the surface for the same thickness product. But since overmolding is usually limited to thin skin of TPE, the softer feel is influenced by the hard substrate underneath. If a hardness test is done in this case a lower indenture will be observed resulting in higher hardness even though the skin may be soft. Figure 2 illustrates some common GLS Materials, their supplied hardness, and the relationship between hardness and thickness. In the selection of TPE hardness the thickness should be taken into account to get the right feel and esthetics on the product. It is important to understand that the material does not really change hardness and it is only the feel on the surface that is influenced by the skin thickness.

Conclusions

The products developed have excellent adhesion performance on various substrates compared to other commercial bondable TPE materials. The products also demonstrate processability similar to conventional TPE materials without sacrifice on cycle time. The products also have excellent engineering physical properties and acceptable compression set at room and at elevated temperatures.

The new material gives an improved rubber-like feel to finished overmolded parts. The new material can be colored and does not need to be pre dried before processing.

The developed overmolds TPE compounds have already been used to make parts for a number of application areas i.e., personal care, hand held-electronics, powertools and housewares.

Figure 1: Schematic diagram of peel adhesion testing. Data is reported in pounds per linear inch (pli).

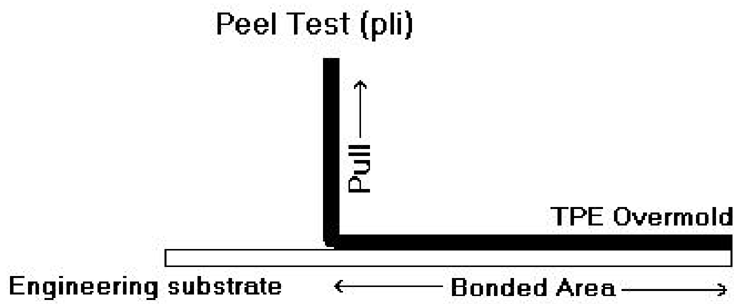

Table 1: Physical properties of developed overmold compounds.

	OM1040	OM1060	OM1245	OM1255	OM1262	OM6050	OM6065
Hardness:	40	60	45	55	62	50	65
Specific Gravity:	0.92	0.93	0.97	1.07	1.17	1.17	1.15
Flow 300% Modulus:	292	472	379	340	583	423	587
Flow Tensile Strength:	587	628	687	462	1847	473	592
Flow Elongation:	593	532	589	604	589	485	236
Flow/Cross Tear:	107	148	140	178	274	156	186
Comp. set 22hr. @ 23 C	18	28	27	25	18	24	33
Comp. Set 22hr. @ 70 C	88	85	86	85	85	91	73

Table 2: Adhesion data of developed products in pli units.

	OM1040	OM1060	OM1245	OM1255	OM1262	OM 6050	OM 6065
Cycoloy C2950 (PC/ABS)	12.4	16.7	15	15.5	26.4		
Cycolac T1000 (ABS)	11.9	17.8	14.5	15.1	27.2		
Lexane 141 (PC)	12.2	14.5	13.5	17.2	27.1		
Zytel 7331F (PA6)						21	23.5
Zytel 73G33L (33% GF PA6)						17.2	19.8
Zytel 101L (PA66)						22.1	20.7

Table 3: Adhesion test results on other commercial available TPE products.

	B-TPE-65A	B-TPV-55A	B-TPE-35A	B-TPE-50A	B-TPV-55A	B-TPV-70A
Cycoloy C2950 (PC/ABS)	12.8	8.1	10.4	15.1		
Cycolac T1000 (ABS)	10.2	9.1	9	12.4		
Lexane 141 (PC)	11.7	10.2	8.1	15		
Zytel 7331F (PA6)					7.2	8.8
Zytel 73G33L (33% GF PA6)					8.1	8.2
Zytel 101L (PA66)					6.8	7.2

All TPE's processed at the recommended conditions from their respective data sheets.

Table 4: Processing conditions of all overmold compounds.

Materials	Temperature, C, Nozzle/Front/Middle/Rear	Mold Temperature, C	Injection Hi Pressure, psi
OM1040	430/430/410/390	80	500
OM1060	430/430/410/390	80	600
OM1245	430/430/410/390	80	500
OM1262	430/430/410/390	80	800
OM6050	480/480/460/440	80	1000
OM6065	480/480/460/440	80	1200
B-TPE-35A	450/450/430/410	80	500
B-TPE-50A	450/450/430/410	80	800
B-TPE-65A	450/440/430/420	80	800
B.TPV-55A	480/480/470/460	80	800
B-TPV-55A	525/520/510/490	110	1500
B-TPV-70A	535/530/520/500/	110	1500

Table 5: Typical Flow lengths achievable with GLS compounds. Spiral Flow Tests performed on 0.0625 in thick, 0.375 in wide channel at 400°F

Product Name	Flow Length, in. @Injection velocity, 5 in/s
OM-1040	360
OM-1060	417
OM-1255	246
OM-1262	379
OM-6050-9	253
OM-6065-9	221
60A S-TPE	329
64A TPV	228

Table 5:

Materials	Temperature, C, Nozzle/Front/Middle/Rear	Mold Temperature, C	Injection Hi Pressure, psi
OM1040	430/430/410/390	80	500
OM1060	430/430/410/390	80	600
OM1245	430/430/410/390	80	500
OM1262	430/430/410/390	80	800
OM6050	480/480/460/440	80	1000
OM6065	480/480/460/440	80	1200
B-TPE-35A	450/450/430/410	80	500
B-TPE-50A	450/450/430/410	80	800
B-TPE-65A	450/440/430/420	80	800
B.TPV-55A	480/480/470/460	80	800
B-TPV-55A	525/520/510/490	110	1500
B-TPV-70A	535/530/520/500/	110	1500

Figure 2: Effect of overmold thickness on surface hardness on TPE products.