APA®
Advanced Polymer Alloys

# Guide To Overmolding With Melt Processible Elastomers (MPEs)

A wide range of molded industrial and consumer goods employ composites that combine the structural strength of rigid plastics with the aesthetics, warm feel, sure grip and abuse resistance of a melt processible elastomer (MPE). These overmolded designs are valuable in applications ranging from encapsulants for shock-sensitive portable electronics to handles and grips on vehicles, tools, applicances and athletic equipment.

Overmolding is a process where a melt processible elastomer like a TPE is molded directly onto a rigid component, known as the insert or substrate. Bond may be achieved by several methods including:

**Mechanical Lock:** This is a design where the soft material encapsulates or flows into holes and undercuts in the rigid component before solidifying providing the connection between the overmolded rubber and the rigid substrate. With proper design a mechanical lock can provide very high bond strength. It also provides the greatest latitude in the selection of the soft overmold material. As long as the overmolded polymer does not require processing temperatures too high for the substrate to tolerate, almost any TPE may be molded over any rigid substrate, including non-plastic substrates. Since the rigid substrates are generally higher melting than the TPEs, that is seldom a limitation. Overmolded parts should be designed to derive as much contribution to the bond from mechanical lock as possible.

**Melt and/or Chemical Adhesion:** Alternatively, the bond may be derived entirely from melt and/or chemical adhesion between the surfaces of the two components. The former requires both a close match in the melting points of the two components and some degree of similarity in chemical nature wherein the two components mutually solvate at the interface and form a bond. The latter depends entirely on a very high degree of chemical compatibility. A chemical reaction occurs at the material interface to form the bond. The specific requirements of these bonding techniques sharply narrow the choices of which TPEs can be adhered to which rigid substrates. Often the nature of the forces holding the two components together is complex and may actually have contributing elements of all three types of bond.

Regardless of how the bond is achieved, bond strength cannot exceed the internal strength of the weaker of the two materials. Hence, maximum bond strength is achieved when a measured force, pulling the two components apart, results in "stock failure," also known as cohesive failure. Under these circumstances, higher bond values can only be achieved by increasing the strength of the weaker component.

## The Major Overmolding Processes

**Insert Molding:** By far the process most often used for overmolding TPEs onto rigid plastics, insert molding requires the least hardware reconfiguration and investment. In this design the rigid insert, molded separately, is placed into the tool and the TPE is injected onto it. The TPE is the driving force in creating the bond, which can be mechanical, melt, chemical or any combination of these. To achieve a chemical or adhesive bond, the TPE must be sufficiently hot to melt the surface of the rigid substrate. Alternatively it must activate that surface to achieve a chemical bond. Stronger bonds can be achieved in this process by preheating the insert before overmolding, but that is often not a practical or desireable option in most plant operations. A major advantage to insert molding versus co-injection and two-shot molding is that there are fewer issues with thermal expansion and shrinkage, as these are accounted for in the tooling design. Disadvantages include generally weaker bonds, the need for two separate molding steps and the need to inventory the substrates, often for days or weeks before they are needed.

**Two-Shot Molding:** This process requires two injection molding machines and an expensive, complex tool, with several gates and activated slides. The rigid material is injected first, then the mold is indexed to the TPE injection machine where the rubber is injected onto the rigid substrate. Since the hot substrate is usually in a semi-solid, gel phase at this point, melt and chemical bonding is generally better than can be achieved by insert molding over an unheated substrate. These molds can be designed with undercuts and overhangs in the rigid part to ensure that a stable mechanical bond is attained. However, with proper material selection, excellent adhesion can be achieved between the components, eliminating the need for undercuts and overhangs.

**Co-Injection Molding:** In the co-injection process, both substrate and and TPE are injected simultaneously into the same tool, and the TPE migrates to the outer layer. The degree of compatibility between materials is critical to this process, and it must be carefully controlled. Co-Injection Molding is so expensive and difficult to control that it is the least used of the three overmolding processes. However, since both the rigid and TPE materials are completely in the melt state at the time they are combined within the tool, this process is capable of providing the greatest melt and chemical adhesion between materials.

## MPE Products for Overmolding from Advanced Polymer Alloys (APA)

APA has a very diverse product line comprised of two families of melt-processible elastomers, both well suited for overmolding rigid plastics. Alcryn® Melt-Processible Rubbers (MPR™) provides the warm feel of a tough, abrasion-resistant, high-quality rubber over a very broad use temperature range (-70°C to +130°C). Available in clear, neutral and black, the injection moldable grades range in hardness from 40 to 90 Shore A. Alcryn also brings properties like resistance to heat, weather, oils, fuels and a wide range of chemicals to any overmolding application. Alcryn MPR has outstanding resistance to dirt pick up, which is unique among TPEs. As a relatively polar polymer, all grades of Alcryn form strong chemical bonds to rigids like polyvinyl chloride (PVC), polycarbonate (PC) and PC/ acrylonitrile butadiene styrene (ABS) blends, even when insert-molding over unheated substrates. Specialized Alcryn grades also adhere well to ABS, PC/ABS blends, acrylic/styrene/acrylonitrile (ASA) and thermoplastic polyurethane (TPU).

The more economical DuraGrip® TPE line also provides the warm feel of a high-quality rubber over a broad temperature range (-40°C to +70°C). The injection-moldable grades, ranging from 20 to 90 Shore A, are well suited to applications where exposure to weather and non-aqueous fluids is minimal. The various grades of the relatively non-polar DuraGrip will form strong chemical bonds to polypropylene (PP), polyethylene (PE), Nylon 6, Nylon 6,6 (filled or unfilled), ASA, polybutylene terephthalate (PBT), polystyrene (PS) and high-impact polystyrene (HIPS).

## Testing Methodology

The generally accepted method for generating meaningful comparative bond-strength data requires the preparation of a two-component test specimen, where the TPE is overmolded onto the unheated rigid insert. Bond strength is measured by pulling the two components apart at a 90° angle. To enable a pull, it's helpful for the test specimen to have pull tabs for each component. Since the completed test piece with tabs resembles the letter "T," it is commonly referred to as a "T-Bar." (See Figure 1.)

One side of the T-Bar tool is shut off and the rigid material is injected into the other side, completing half the T-Bar. After the ejected rigid substrate has been cooled to room temperature, in a controlled environment, it is inserted into the other side of the T-Bar mold. When the soft material is injected onto the rigid insert, it completes the T-Bar specimen.

Figure 1
The ½ T Bar on the right, is a premolded rigid substrate. On re-insertion into the tool, the black MPE is injected onto it, completing the T bar, ready for 90°peel testing.

The two tabs of the T-Bar are placed into the jaws of a modified tensile tester and pulled apart to measure bond strength. The force required to pull the two materials apart is recorded in pounds per linear inch (pli) or kilo Newtons per meter (kN/m). The detailed methodology of the 90° peel test conforms to ASTM D429, Method B. Figure 2 shows the T Bar being peeled apart on the tensometer.

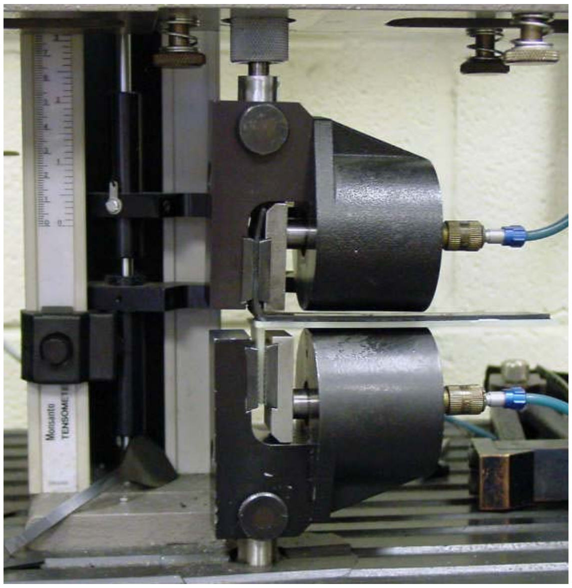

Figure 2

## Bond Strengths of APA MPEs Overmolded Onto Various Rigid Substrates

Utilizing the sample preparation and testing methodology detailed above, APA has determined the bond strengths of its overmoldable MPEs to a variety of typical rigid substrates (see Table 1). All testing was based on overmolding onto room temperature rigid substrates. Since there can be no contribution from mechanical lock in this test, the results clearly show which combinations of MPE and substrate are sufficiently compatible to form a melt and/or chemical bond. Certain combinations were so incompatilble that no measurable bond was obtained. Where a numerical bond strength is reported, only those with values of 10 pli (1.8 kN/m) or greater should be considered adequate for most overmolded applications. However even with minimal chemical or melt bond, good designs with substrate undercuts that provide a significant contribution from mechanical lock can ensure good bond will be achieved.

# T-Bar 90° PEEL STRENGH OF APA MPE OVERMOLDED ON VARIOUS SUBSTRATES

### ASTM D429, Method B

### Units: pli (kN/m)

| Rigid Substrate Classification | Rigid Substrate Tested | Alcryn® 2000 Series | Alcryn® 2100 Series | DuraGrip® 6000 Series | DuraGrip® 6100 Series |
|---|---|---|---|---|---|
| **Polyethylene** | LDPE | NO BOND | NO BOND | 29 (5.1) | NO BOND |
| **Polypropylene** | 0.7 MI | NO BOND | NO BOND | 32 (5.6) | NO BOND |
| **Ferro PP, 30% Glass Filled** | GHH20CN05WH | NO BOND | NO BOND | 32 (5.6) | NO BOND |
| **PVC** | Geon Rigid PVC | 8 (1.4) | 7 (1.2) | NO BOND | NO BOND |
| **ABS** | Cycolac MG47 | NO BOND | 15 (2.6) | NO BOND | 16 (2.8) |
| **PC** | Lexan 141 | 4 (0.7) | 9 (1.6) | NO BOND | 17 (3.0) |
| **PC / ABS** | Cycoloy 1200 | 10 (1.8) | 12 (2.1) | NO BOND | TBD |
| **ASA** | Geloy P4034 | NO BOND | 25 (4.4) | NO BOND | 23 (4.0) |
| **ASA** | Geloy CR7510 | NO BOND | 12 (2.1) | NO BOND | 29 (5.1) |
| **ASA** | Geloy 4025BK | NO BOND | 14 (2.5) | NO BOND | 34 (6.0) |
| **PC / PBT** | Xenoy 1760E | NO BOND | 9 (1.6) | NO BOND | 25 (4.4) |
| **PBT** | Valox 4930 | NO BOND | NO BOND | NO BOND | 20 (3.5) |
| **PBT** | Valox DX 508 | NO BOND | NO BOND | NO BOND | 24 (4.2) |
| **PA 6** | Ultramid B3EG3 | NO BOND | NO BOND | NO BOND | 16 (2.8) |
| **PA 6 / Mineral filled** | Capron 8267 | NO BOND | NO BOND | NO BOND | 26 (4.6) |
| **Nylon 6/6** | Zytel 101 | NO BOND | NO BOND | NO BOND | 19 (3.3) |
| **Nylon 6/6, 33% Glass** | Zytel 72G33L | NO BOND | NO BOND | NO BOND | 20 (3.5) |
| **Cellulose Acetate Butyrate** | Tenite 530E 37200 CL | NO BOND | NO BOND | NO BOND | 12 (2.1) |
| **Copolyester** | EASTAR BR003 | NO BOND | NO BOND | NO BOND | 11 (1.9) |

**Table 1**

Alcryn® and DuraGrip® are registered trademarks of Ferro Corporation.
Capron® is a registered trademark of Honeywell.
Zytel® is a registered trademark of E.I. DuPont.

Geloy®, Cycoloy® and Lexan® are registered trademarks of G.E. Plastics.
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## Selecting the Right Combination of Rigid Substrate/TPE for Each Application

Ideally, the first step in material selection should be making a list of the minimum and preferred performance characteristics required from both the rigid substrate and the soft component, including cost constraints. Then meshing together those two lists to select a compatible pair of rigid and soft materials which will achieve all of the requirements and most of the preferred properties. In reality, many times the rigid substrate material is selected first and then an attempt is made to find a compatible TPE. With this approach the material engineer often finds that none of the TPEs having the right characteristics to perform-in-use will bond to his pre-chosen rigid. If he is willing to design the insert with considerable opportunity for melt penetration of openings and undercuts, he may still be able to mate the chemically incompatible pair with the right combination of performance. If not, he will have to either redefine acceptable performance or move to another rigid material that will be compatible with his preferred TPE. We suggest that a better approach is to choose the ideal MPE for the part's intended use, and then identify a compatible rigid material for the substrate. This ensures a successful user expereince.

Even when a compatible rigid/TPE pair is available, at the concept stage the part designer must make the intent to overmold a major focus of his rigid component design. He must provide protection for the overmolded soft component to obtain a durable composite part. The most vulnerable part of the design is the interface between the rigid and soft components- the exposed edge. Total encapsulation is one method of eliminating edges, however that approach may not be compatible with the required design. Wherever possible, the molded edges of the TPE component should be recessed into the rigid, rather than just blunt or feather-edged to the rigid surface. This technique essentially creates a raised rubber inlay of the desired dimensions, which will provide the required appearance and performance of the soft component, while creating a highly durable bond.

Beyond bonding, each class of TPEs has its own combination of physical and chemical properties which will play a major role in the selection of the best material combination for an overmolding application. The designer must go beyond as-made appearance, soft-touch, color and other aesthetics for sales appeal. He must also know how the final overmolded product will be used, in what type of environment and what the expectation is for durability in service. Such applications range from inexpensive toothbrushes, which need only last six months, to grips on construction-quality power tools, which are expected to last for years under very severe conditions of use, weather and fluid contact.

The two families of MPEs supplied by APA, Alcryn and DuraGrip, will provide the following properties to upgrade the performance of any rigid part:

- A resilient, soft, warm feel and satin texture.
- Aesthetically pleasing colorability and smooth surface that complements the rigid.
- High friction for a secure grip, wet or dry.
- High resistance to scuffs, scrapes, scratches and complete resistance to denting.
- Ergonomic design improvements.

Additionally Alcryn MPR provides these unique features:

- Resists dirt pick up and staining,
- Has excellent durability and resistance to wear and tear.
- Resists weather, heat, oils, fuels and many chemicals.

APA products can be used in a variety of overmolding applications. Table 2 shows various end use overmolding market applications, along with the recommended APA products for each use.

| Rigid Substrate | Market Application | APA Products Used |
|---|---|---|
| | | |
| **ABS** | Housewares, Grips, Handles, Knobs | Alcryn 2100, DuraGrip 6100 |
| | | |
| **PC & ABS** | Household Appliances, Grips, Handles, Electronic Handheld Devices | Alcryn 2000, 2100, DuraGrip 6100 |
| | | |
| **PVC / TPU** | Wire & Cable Connectors, Jackets, Grips, Handles, Toys, Telecommunications | Alcryn 2000, 2100 |
| | | |
| **PP / PE** | Personal Care - Toothbrushes, Razors, Power Tool Grips, Knobs, Handles | DuraGrip |
| | | |
| **Nylon** | Automotive, Power Tool Grips, Knobs, Handles | DuraGrip 6100 |
| | | |
| **FDA Compliant** | Medical, Tubing, Infant Care, Food Contact parts | DuraGrip |

**Table 2**

## Injection Molding Equipment

### Materials of Construction

**DuraGrip® Thermoplastic Elastomers** are generally non-abrasive and non-corrosive. The tool steel selected should be determined by part appearance, dimensional tolerance requirements and the required service life of the tool.

**Alcryn® Melt-Processible Rubber** requires injection molding equipment and tools of corrosion-resistant materials to maximize equipment life. As is typically used for other chlorinated polymers such as PVC or CPE, Hastalloy C-276 is recommended for screws; Xaloy 306 is recommended for barrel liners. Molds for prototyping and small production runs can be aluminum. Tools for longer runs and higher tolerance requirements should be made from H-13, A-2, S-7 or 420 SS.

### Barrel Design

Either hot oil or electric band heaters are suitable for barrel heating. Plastic injection molding machines should be equipped with at least three-zone heating control of the barrel for close control of melt temperature and optimum output rates.

### Screw Design

General purpose, gradual transition screws with compression ratios between 2.5 and 3.5 and an L/D of > 20:1 are usually suitable for molding DuraGrip® and Alcryn®. Screws with a short compression zone (two flights) and long metering zones (six flights) with very shallow flights should be avoided. They may overheat the melt at high screw speeds (rpm).

Screws equipped with full flow ring check valves or smear tips may be used. Flow passages must be carefully streamlined to eliminate melt stagnation and potential degradation. Ball type check valves are not recommended.

### Nozzle Design

Separately heated, short reverse tapered nozzles with uninterrupted flow patterns are suggested. See figure 3 below.

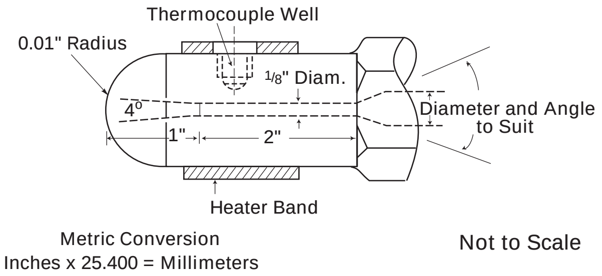

**Figure 3**

A nozzle with reverse taper is recommended for molding.

## Mold Design

### Mold Surface Finish

Slightly textured or matte finished mold cavity surfaces are recommended for DuraGrip® and Alcryn®. They will minimize the appearance of flow lines on molded parts and improve ease of demolding.

Highly polished or chrome plated mold surfaces are required for all grades when high gloss is desired, and should always be used to preserve clarity for our transparent and clear grades.

### Sprue Bushing and Nozzle Design

Properly designed sprue bushings are required to avoid sprue sticking. The diameter of the sprue at the larger end should be equal to the diameter of the runner it feeds. Bushings of higher than standard taper (approximately 0.044 rad [2.5°]) are preferred.

A properly mated injection nozzle and sprue bushing facilitates removal of the sprue. The nozzle should have a 0.75 in (19 mm) spherical radius at the tip with a diameter slightly less (0.031 in. [0.8 mm]) than that of the sprue bushing. Since Alcryn® and DuraGrip® are elastomeric, very positive type sprue pullers (e.g. "Z" pullers, sucker pins, or offset undercut types) are required for automatic sprue removal.

### Runners and Sprues

Runners and sprues should be streamlined to reduce melt turbulence. A full round or trapezoidal runner should be used whenever possible to minimize pressure drop and sticking. Cold slugs are also recommended at each transition. In designing the runner system, make sure balanced layouts are used, and minimize number and length of runners and radiused turns. A draft of 3° to 5° is required to minimize sticking. To improve flow and facilitate automated removal, the surface of the runners should be smooth, but not polished.

Both insulated and hot-runner runnerless molding is possible with DuraGrip® and Alcryn®. Sufficient heat and temperature control must be provided to insure that neither freezing nor degradation of the polymer occurs.

### Gates

**Pin gates** are particularly effective for solid, round parts. **Diaphragm gates** are preferred for open, round parts. **Film gates**, along the long or longer edge are preferred for rectangular, flat parts.

Gates must be designed to maximize shear to minimize viscosity as DuraGrip® or Alcryn® enters the mold cavity. The gates must be short and have a small cross-sectional area relative to mold volume. Specifically, the gate cross-sectional area should be in the range of 0.2% to 1.0% of the part volume when measured in inches, and in the range of 0.012% to 0.048% of the part volume when measured in millimeters. A good starting point for a gate opening would be 0.015 in. (0.381mm).

Gates should be located in the thickest section to avoid incomplete fill and sink marks, to minimize flow lengths, and to facilitate laminar flow within the mold. This will also minimize or eliminate the formation of weld lines. Gates should be located so that the flow length is as short as possible, avoiding obstructions where possible.

### Venting

The importance of adequate venting cannot be overemphasized for producing quality injection molded parts of DuraGrip® and Alcryn®. Lack of sufficient venting may cause:

- Surface imperfections from trapped air.
- Underfill.
- Discoloring or burning of the molded part.
- Poor weld line strength.
- Excessively high injection pressures.

Venting provides a path for the air to escape from the cavity as the injected melt displaces it. Melt flow into any cavity can be seriously reduced by inadequate venting of the cavity. It is advisable to make the vent openings into the mold cavity broad and thin. Typical vent openings are 0.0005" to 0.0010" (0.012mm to 0.0.25mm) deep. The width is not as critical as depth, as the width is dependent upon part size and type of gate being used. Always locate a vent opposite the gate, as this will be the point of final fill will prevent part burning from trapped air.

### Shut Off's and Slides

A shut off or slide is extremely important in any overmolding process. A properly design slide will allow for a smooth, sharp transition between the two materials and reduce the potential for the soft substrate to peel away from the rigid. In addition, if the shut off is not adequate, flashing of the soft substrate will occur.

### Part Shrinkage

The degree of shrinkage for injection molded parts of DuraGrip® or Alcryn® can be affected by both molding parameters and part geometry. Molding variables include mold temperature, injection time (fill time), injection pressure, and hold pressure (second stage pressure).

Mold temperature is the over-riding variable affecting shrinkage of parts. Mold temperatures in the range of 70°F to 120°F (21°C to 49°C) are recommended for overmolding. Higher mold temperatures will cause higher shrinkage.

Hold pressure (2$^{nd}$ stage pressure) can also affect the degree of shrinkage (particularly in the flow direction) in overmolded parts. Suggested ranges are 150 to 300 psi for the DuraGrip® **6000 Series** and 300 to 500 psi for the DuraGrip® **6100 Series**. Suggested ranges for the Alcryn® **2000 Series** are 450 to 650 psi, and 300 to 500 psi for the **2100 Series**. Higher hold pressures will result in higher shrinkage in the flow direction. Part geometry, variables include part thickness, gate thickness and gate layout/location.

Please refer to the individual data sheets for shrinkage values on each grade.

### Part Ejection

Ample draft angles of 3° to 5° taper per side can ease part ejection, especially when a core is removed from a deep part or when a part is removed from a deep cavity. When a molded part must have very little or no draft, stripper plates are recommended for ejection. When pin ejectors are used, they should have a large surface area and act on the thickest sections of the part. Ejector mechanisms should be located to provide uniform stripping of the part from the mold. The diameter of the ejectors should be as large as possible to minimize marking on the part surface.

If the part is small, the knockouts should be shaped proportional to the part (i.e. ring, disc, etc.). If the part is large, use 13-25 mm (0.5-1 in.) diameter pins if design permits.

Undercuts should have room to flex during ejection.

### Mold Temperature

The suggested range for mold temperatures is 90°F to 130°F (32°C to 54°C). Mold temperature is critical to insure that the cycle time is optimized. The mold should have adequate cooling to achieve the designed shrinkage, which will aid part ejection. Individual chillers for each side of the tool are also recommended to help retain parts on the movable side.

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