Thermoplastic Polyurethane (TPU) Processing Guide

Injection Molding of TPU

Foster Corporation formulates, manufacturers, and markets thermoplastic polyurethane elastomers (TPU's). These TPU materials can be, and are, processed by a variety of techniques including thermoplastic injection molding.

TPU's are easily molded into shapes such as grips, gaskets, caps, orthotics & prosthetics, as well as many other applications. However, for this to be done effectively you need the right equipment and the right injection molding parameters. In addition, TPU's exhibit a few "TPU-centric behaviors" regards processing, pre-process preparation, and post-processing of the polymers.

Below is a summary of "best practices" regarding the injection molding of TPU's.

Drying

Drying is a critical step in ensuring TPU's process effectively and that a good part is obtained upon molding. If moisture is not removed from the polymer effectively before processing, the material can lose molecular weight in the machine barrel. Parts molded with material that has not been dried effectively before processing can exhibit loss of properties and brittleness.

While many individuals insist that drying TPU at a specific temperature for a specified amount of time will ensure effective drying of the materials. We believe that drying TPU to a "water content" specification is the only way to ensure that the material is dry and is moldable to an optimum level. TPU should be dried to a water content level that should not exceed 0.02% at time of processing. In order to ensure the material stays dry in-process a hopper dryer should be used.

As a secondary option drying recommendations for time and temperature is below:

Hardness	Drying Time	Drying Temperature	
		Circulating Air Dryer	Dehumidified Air Dryer
Shore A 75 to 90	3 to 4 Hours	100°C to 110°C	80°C to 90°C
Above Shore A 90	3 to 4 Hours	100°C to 120°C	90°C to 120°C

If color masterbatches or additives are used premix the TPU pellets with the masterbatch/additive(s) before the drying process to make sure the aggregate contents are dried optimally.

Machine

TPU's can typically be injection molded on reciprocating screw injection molding machines.

Screw Design

The melting curve regards a TPU depends on the amount of crystallinity a specific TPU has. In general the harder the TPU product, the more crystalline the product is. Single flighted 3-zone screws are recommended. Compression ratios of 1:2 and no more than 1:3 are adequate. A check-ring (shut-off valve) should be used. Avoid dead spots in the barrel and the nozzle channels as the material can degrade if residence time is too long.

Nozzles, Sprues, Runners

Conventional nozzles, nozzles with reverse tapers or nozzles employing a means of positive shutoff are acceptable for molding TPU's. TPU's can withstand short stationary periods of time in the nozzle without significant degradation.

Large diameter full round runners are preferred for carrying the TPU melt to the mold cavity. Balanced flow is highly preferred. Abrupt transitions should be avoided. Insulated, heated runner, or hot tip systems can be used with TPU's.

Standard round sprues with draft angles of at least 6^{o} are recommended. Because these materials are soft materials the type of sprue puller is advisable for easier demolding. The maximum sprue diameter should not exceed the maximum wall thickness of the molded part.

Gates

Common gate types are fine for TPU's with a draft angle of 2.5^{o}. Thickness of the gate should be maximized to about 15% to 25% of the part thickness so as to ensure adequate holding pressure. Land length should be kept as short as possible. Multiple gates are acceptable as long as they are close enough to each other to avoid weld line issues.

Mold Design

Most conventional mold designs will work with TPU's. You can expect a mold shrinkage percentage of between 0.4% and 1.4% depending on the hardness of the TPU being used and the wall thickness of the part being made.

The following mold design tips are recommended:

- *Avoid wide variations in material thickness*
- *Provide radii at all edges and tips*
- *Avoid thin cores*
- *Avoid highly polished mold surfaces; EDM textured surfaces hide part imperfections and allow for easier de-molding*
- *Avoid pins or obstructions that cause weld lines*
- *Use judicious use of ribs and reinforcing sections in order to avoid sinks in the part*

Venting
Good venting practices are necessary with TPU's to prevent compressed air causing burn marks.. Vents can be taper ground or relived directly into air. Typical vents should be 0.02 to 0.05 mm in depth and are best located at the parting line, at inserts and at pins.

Part Ejection
TPU's are soft flexible materials. Because of this undercuts can be engineered into the mold design. Soft materials can be difficult to eject or de-mold. Ejector pins should be as large as possible and air assist ejection can be preferable. Draft angles of 3^{o} to 5^{o} should be adequate for part ejection.

Mold Temperature
Molds should have ample cooling built in. Typical mold temperatures are 15^{0} F to 70^{0} C depending on the TPU molded.

Annealing
Annealing of parts made out of TPU can be an advantageous process for optimization of the physical properties of a part made out of TPU.

Recommended annealing time & temperature is 20 hours at 100o C

Typical injection molding processing temperatures of TPU materials are as follows:

IM Zone	60A to 75A	80A to 90A	95A to 75D
Rear	315 – 340 °F	345 - 370 °F	375 - 400 °F
Middle	340 – 365 °F	365 – 390 °F	385 – 410 °F
Front	360 – 385 °F	375 – 400 °F	395 – 420 °F
Nozzle	365 - 390 °F	380 - 405 °F	405 - 430 °F

Miscellaneous

TPU's are generally uncolored and transparent/translucent in their original form. They come from the manufacturer in a consistent round/oval underwater pelletized or lentil shaped pellet configuration for easy feeding from the hopper into the injection molding machine.

Softer TPU should not be kept for an extended period of time in extreme high temperature environments as the material may "clump" in the box...this can make feeding difficult.

TPU's are easily colorable using a pelletized color master-batch. We recommend using a TPU based carrier for the master-batch, Foster universal medical grade color concentrates and also be used effectively. Letdown ratios range from 1% to 5%.

While regrind TPU polymer can be presented in a melt, make note that TPU's can lose molecular weight as a result of processing. This being the case, reprocessed material could suffer end property loss.

If a decision is made to use regrind, recommended levels should not exceed 30% with residence times in the barrel as low as possible.

PP or HDPE is recommended for purging the extruder after the extruding TPU's.

Extrusion of TPU

TPU's can be, and are, processed by a variety of techniques including thermoplastic extrusion.

TPU's are easily extruded into shapes such as tubing, profiles, wire & cable, and film and sheet. However for this to be done effectively, you need the right equipment and the right extrusion parameters.

Below is a summary of "best practices" regarding the extrusion of both of these versatile materials.

Drying

Drying is a critical step in ensuring TPU's process effectively and that a good part is obtained upon molding. If moisture is not removed from the polymer effectively before processing, the material can lose molecular weight in the machine barrel. Parts molded with material that has not been dried effectively before processing can exhibit loss of properties and brittleness.

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If color masterbatches or additives are used premix the TPU pellets with the masterbatch/additive(s) before the drying process to make sure the aggregate contents are dried optimally.

Machine

TPU's can typically be extruded on machines that have a compression ratio of 1:2, 1:3, and preferably 1:2.5 with 25/1 to 30/1 preferred. Use of breaker plates and screen packs are recommended.

Screen packs are recommended when extruding TPU materials. A screen pack construction of 20-40-80-20 mesh screens is optimal but higher mesh screen packs can be used if necessary.

Melt pumps are successfully used for constant and consistent flow.

Screw Design

The melting curve regards a TPU depends on the amount of crystallinity a specific TPU has. In general the harder the TPU product, the more crystalline the product is. Other dependencies include screw configuration and screw speed. Screws with and L/D of 25 to 30 are suitable. The clearance between the screw and the barrel should be 0.1 and 0.2 mm. Barrier screws are suitable but they do put extra work in the polymer which may break down the molecular weight of the polymer resulting in lower physical properties.

Mixing screws or mixing pins can also be used when blending color concentrates or other concentrate functionalization into the melt stream.

TPU's are shear sensitive so excessively high screw speeds may also lead to a reduction in product properties. Screw speeds up to 100 RPM are used successfully.

Die

As noted above, TPU's can be extruded into any number of configurations. Dies with a relatively long land are recommended to reduce shear stresses. Land length should be two to four times nozzle diameter.

Cooling

Effective cooling of a TPU extrudate is critical as TPU's have low melt strength out of the die head. Chilled water is preferred and spray nozzle cooling is suitable also. Longer cooling baths are required so the extrudate has a chance to cool and set-up adequately. It is also recommended to provide a lubricating film of water between the surface of the extrudate and the calibrating die.

Output

TPU production output rates are comparable to those of other thermoplastic materials. Lower durometer TPU's production rates may be less than higher durometer TPU's because of lower crystallinity in the materials which extends the set-up time of the extrudate.

Material

For best results, use extrusion grade TPU materials.

Typical extrusion processing temperatures of TPU's are as follows:

Extruder	60A to 75A	80A to 90A	95A to 75D
Rear	315 - 340 ºF	345 - 370 ºF	375 - 400 ºF
Middle	340 – 365 ºF	365 – 390 ºF	385 – 410 ºF
Front	360 – 385 ºF	375 – 400 ºF	395 – 420 ºF
Die	365 - 390 ºF	380 - 405 ºF	405 - 430 ºF

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