Injection Molding Of Elastomeric Alloy Thermoplastic Elastomers

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Introduction

A major processing method for both thermoplastics and thermoplastic elastomers (TPEs) is injection molding. Approximately 32% by weight of all thermoplastics is processed through injection molding machines. Injection molders continue to expand their capabilities and modernize their equipment. Their goal is to produce molded parts that meet the performance requirements of the end user at a cost that insures profit for both the molder and end user.

Injection molded TPE parts can be manufactured economically and efficiently in unlimited quantities. This paper will explore the advantages of injection molding TPEs versus the molding of thermoset rubber parts.

Thermoplastic Elastomers

TPEs combine the properties of thermoplastics and conventional thermoset rubbers. They can be processed on standard thermoplastic processing equipment, such as that used for injection molding, blow molding and extrusion, using the same processing techniques. Conventional thermoset rubbers require compounding and vulcanization which implicitly results in longer cycles times and higher fabrication costs.

Compared to conventional thermoset rubbers, TPEs offer many advantages:

1. ***Very little or no compounding*** **--** *Most TPEs are fully compounded and ready for processing, with no additional blending required.*
2. ***Faster processing time*** **--** *Most TPEs can be processed in less than one minute while thermoset rubbers require several minutes. This difference provides improved productivity and major cost savings.*
3. ***Recycling of scrap*** *(regrind)* **--** *Conventional thermoset scrap is commonly discarded, yet it must be charged to fabrication costs. In processes such as injection molding, TPEs can be recycled, with little or no scrap. This can generate massive cost savings.*
4. ***Tighter tolerances*** **--** *Part dimensional tolerances can be more closely maintained and quality improved.*
5. ***Lower energy consumption*** **--** *This results from the faster cycle times and simpler processing methods.*

6. ***New processing methods*** *-- Because of their thermoplastic nature, TPEs can be fabricated by novel methods such as heat welding, thermoforming, blow molding -- methods that are not practical for thermoset rubbers.*

TPEs also have some disadvantages when compared to conventional thermoset rubbers:

1. ***Different processing equipment*** *-- Unfortunately, the thermoset rubber processor is not familiar with thermoplastic processing equipment, nor does he have personnel trained in this area.*

2. ***TPEs sometimes require drying*** *-- This is a common practice in thermoplastic processing but is not required for thermoset rubbers. Again, additional equipment is necessary for this step.*

3. ***Low hardness TPEs are limited in number*** *-- Commercial availability under 70 Shore A is somewhat limited. Thermoset rubbers are amply available in the 30 to 60 Shore A hardness range.*

4. ***New technology*** *-- This is foreign to many thermoset rubber processors unfamiliar with the thermoplastics industry. On the other hand, markets for TPE products are familiar to the rubber fabricator but not the thermoplastics processor.*

The importance of these advantages and disadvantages will vary depending on the specific rubber part being fabricated. As seen by the rapid growth of TPEs, it is very obvious the advantages will outweigh the disadvantages in many cases. The major obstacles for the thermoset processor are the capital investment to purchase new equipment for processing TPEs and training of personnel to operate this equipment. Performance and quality of TPE molded parts can be equal to or even better than that of thermoset rubbers.

Injection Molding

Thermoplastic injection molding consists of conveying a pelletized quantity of material from the hopper into a heating (plasticating) chamber where it is melted and then injected through channels into a closed mold. Figure 1 shows a cutaway view of an injection molding machine. The injection process utilizes a comparatively cool or even cold mold to chill the material rapidly, so the molded part can be ejected without distortion. There are no chemical changes which take place in the mold or during injection. This description sounds relatively simple, however, complexities arise due to the variety of TPEs and thermoplastics used, and the diversity of product designs that may be chosen.

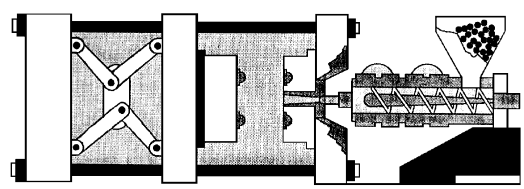

Figure 1
Typical injection molding machine

There are two major types of injection molding machines -- the plunger straight ram and the reciprocating screw. All machines are rated by shot size in ounces and clamping pressure in tonnage. The major methods for producing clamp pressure are the hydromechanical (toggle) system and the hydraulic (straight ram) system. Figure 2 depicts a typical in-line reciprocating screw. Regardless of the make, model or size of an injection molding machine, all have common engineering features. After an understanding of the basic molding sequence is achieved, any machine can be operated after a short indoctrination on its special features.

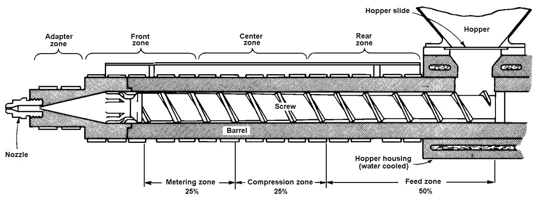

Figure 2
Typical in-line reciprocating screw

As in all processing techniques, there are parameters which must be closely monitored during the molding cycle -- melt temperature, injection pressure, mold temperature. The typical molding sequence has four basic elements -- mold closing, material injection, mold opening, part ejection.

TPE entering or filling the mold cavity can be broken down into three processing phases:

1. ***The filling phase*** -- *As the injection screw moves forward at a steady velocity, material flows into the cavity. This phase lasts until the mold is just filled (Figure 3).*

Figure 3
Filling

2. ***The pressurization phase*** -- *When the mold is filled, the ram velocity will slow down but continue to move forward. This is because TPEs are very compressible. During this phase, 15% of additional material can be forced into the cavity (Figure 4).*

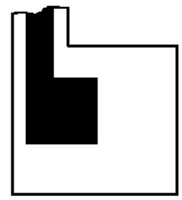

Figure 4
Pressurization

3. ***Compensating phase*** -- *After pressurization, the ram does not stop completely but will continue to creep forward for a short distance. TPEs have a large volumetric change (about 20%) from the melt stage to the solid stage. If short shots are taken, the end flow often shows a wrinkled and shriveled effect. The difference in volume between the molding and the cavity is due to this volumetric change (Figure 5).*

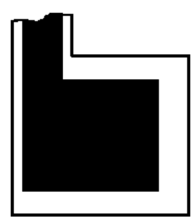

Figure 5
Compensation

All injection molding cycles are timed on the number of shots that can be obtained per hour. All phases of the cycle are controlled by electronic timers and each timer has a specific function for completing a successful molding cycle. The overall cycle is controlled by factors such as part thickness, part geometry, ease of part ejection and adequate cooling channels on the mold.

The processing of thermosets and TPEs via injection molding is different. In thermosets, the injection unit is usually heated by water or oil and the molds are heated with electrical cartridge heaters. Due to the chemical crosslinking necessary for curing the part, the cycle time can last several minutes before the molded article is ejected from the mold. However, in TPE processing the injection units are heated electrically and the molds are cooled by water. There is no chemical crosslinking required, thus the molded part can be ejected from the mold in a matter of seconds.

Molds used for thermosets differ from those used for thermoplastics. Figure 6 shows a typical injection mold. Thermoset molds require a hardened tool steel and the surfaces usually require a highly polished chrome finish. A thermal insulation between the mold and press platens is also necessary to minimize heat loss. Thermoset parts often need to be deflashed due to the low viscosity of the material. Deflashing is an added operation which amounts to additional cost on the piece price. Thermoplastic molds are somewhat higher in cost but provide flash-free parts, which eliminates the deflashing operation. The tool steel selection can have greater variety. The mold finish requirements are not as critical, and a #3 SPI/SPE finish usually is used. Figure 7 is an example of a typical molded part.

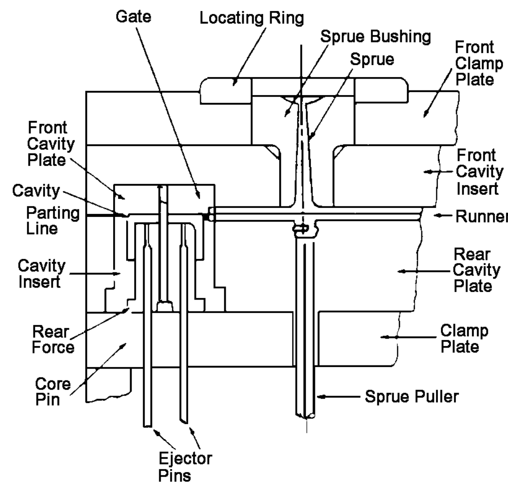

Figure 6
Typical injection mold

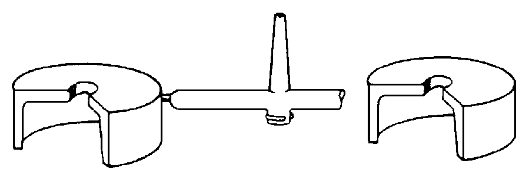

Figure 7
Typical molded part

There is another type of mold system which can be used for TPEs -- a hot runner mold. Molds of this construction are often used for producing a high volume of small parts without the need to regrind runners. Mold costs are much higher for this type of mold, and they are used mainly for fully automatic operations. Figures 8 and 9 show cutaway views of hot runner tooling.

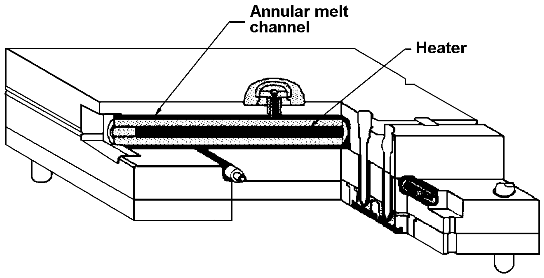

Figure 8
Internally heated manifold

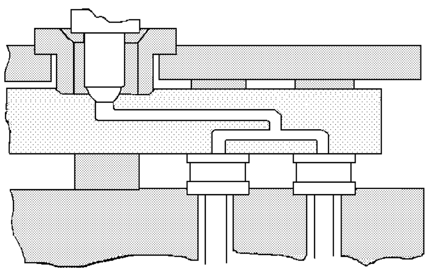

Figure 9
Externally heated manifold

Applications

The impact of TPEs on rubber part economics and performance can best be seen in the attached case studies. The examples listed in Tables I, II and III are from an elastomeric alloy (Santoprene rubber).

Summary

It is abundantly clear that the injection molding process will continue to grow as a major process for producing TPE parts. This process will also enable the molder to produce parts of higher quality with better economics. With the rapid machine advancement using higher technology and computers, this process will truly be a major method for fabricating elastomeric parts.

References

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TABLE I

SYRINGE PLUNGER TIP

Raw Material Cost	**Santoprene Rubber Grade 171-55**
Price per pound	$2.07
Specific gravity	0.97
Part weight	0.28 grams
Raw material cost per part	$0.00124
Processing Cost	
Cycle time	20 seconds
Number of cavities in mold	12
Machine processing cost	$4.695/hour
Machine efficiency	95%
Total process cost per part	$0.00228
Cost per part using thermoset rubber	$0.00734

SANTOPRENE SAVINGS= $0.00734-0.00124-0.00228 = $0.00382 per part or 48%

TABLE II

AUTO OVERSLAM BUMPER

Raw Material Cost	**Santoprene Rubber Grade 101-64**
Price per kilo	$3.08
Specific gravity	0.97
Part weight	13.9 grams
Raw material cost per part	$0.043
Processing Cost	
Cycle time	30 seconds
Number of cavities in mold	4
Machine processing cost	$4.695
Machine efficiency	90%
Total process cost per part	$0.087
Cost per part using thermoset rubber	$0.26

SANTOPRENE SAVINGS= $0.26-0.043-0.087 = $0.13 per part or 50%

TABLE III

WINDSHIELD WIPER RESERVOIR SEAL

Raw Material Cost	**Santoprene Rubber Grade 101-73**
Price per kilo	$1.96
Specific gravity	0.97
Part weight	3.2 grams
Raw material cost per part	$0.0138
Processing Cost	
Cycle time	30 seconds
Number of cavities in mold	4
Machine processing cost	$4.605
Machine efficiency	90%
Total process cost per part	$0.156
Cost per part using thermoset rubber	$0.30

SANTOPRENE SAVINGS= $0.30-0.0138-0.156 = $0.1302 per part or 57%