

PLASTICS Machinery & Auxiliaries

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Words of Wisdom



Michael F. Durina, president of Md Plastics, has extensive experience in designing general purpose and special purpose screws for plastics processing.

Over the last 50 years there has been a considerable amount written about the plasticating screw designed for injection molding machines. From introductory plastics textbooks like *Processing of Thermoplastic Materials*, originally printed in 1959 when the plunger was still being compared to the reciprocating screw, to more recent publications such as *Melt Rheology and its Role in Plastics Processing*,

THE NEED FOR A GENERAL PURPOSE STANDARD SCREW

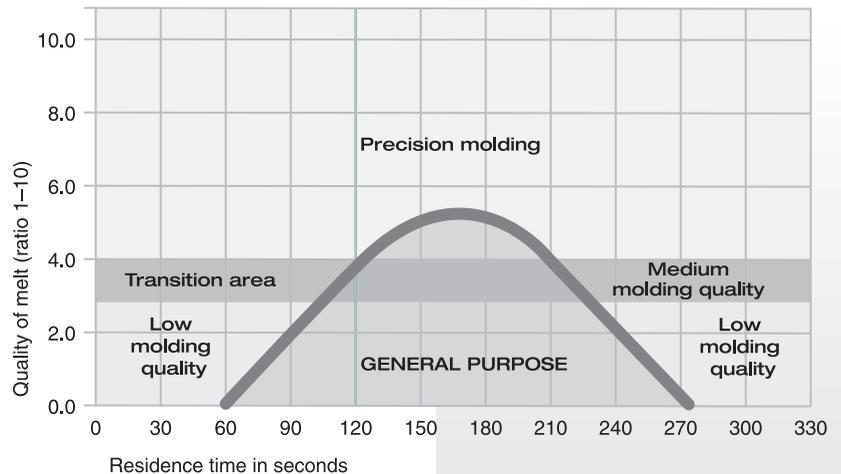


Figure 2. As indicated by the area under the heavy blue line, the conditions under which a general purpose screw will produce the quality of melt needed to perform precision molding are fairly limited.

printed in 1995, the subject matter focuses on a single stage compression screw known as the general purpose (GP) design.

Research into currently used designs shows how the GP design has evolved. The GP design (Figure 1) is a single flighted compression screw with a feed zone, a compression (transition) zone, and a metering zone, representing 50 percent, 25 percent, and 25 percent of the flighted length, respectively. The pitch or lead of the screw is equal to the diameter (square pitch) with the thread of

the screw having a flight width equal to 1/10 of the diameter. The taper of the compression zone is cut on an involute pattern, creating a compression ratio that varies from 2 to 3:1, calculated by dividing the flight depth in the feed section by the flight depth in the metering section. The L/D ratio, or the flighted length of the screw divided by the diameter of the screw, is between 16:1 and 23:1.

The feed and metering depths are missing in this description. Without these depths, the compression ratio is meaningless. It is not uncommon to see a 60-mm, 20:1 L/D GP screw from different suppliers with a feed depth range between 5 and 9 mm. The depths affect the feeding or solids conveying of the feed-stock, the volume of plastic present in the screw channel, the throughput

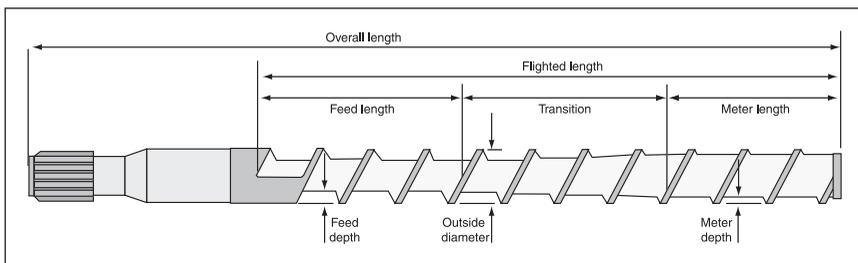


Figure 1. The overall configuration of the general purpose screw is long established in the injection molding industry, yet there is no benchmark by which variations on the design can be compared and contrasted by molders.

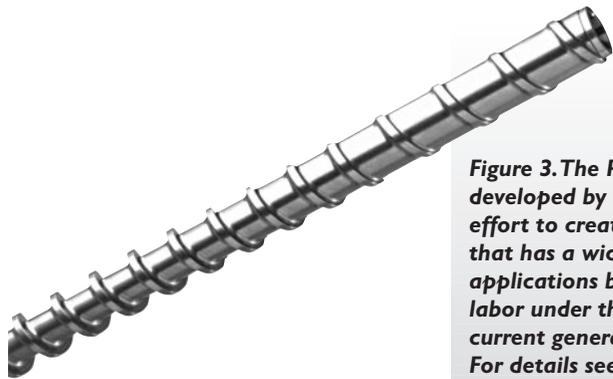


Figure 3. The Posi-Melt screw developed by the author is one effort to create an injection screw that has a wide range of applications but which does not labor under the limitations of current general purpose designs. For details see p.28.

rate, shear rate, and overall melt quality.

Regardless of the exact depths, lengths, and flight widths used, the GP screw brings value to the industry. The screw supplier and plastics processor both recognize two resilient characteristics of the GP design that are testament to its continued usage: The design can process a variety of resins in a variety of shot sizes and cycle times without destroying the properties of the polymer, and the GP design is the least expensive screw design to manufacture.

FUNCTIONS OF A PLASTICATING SCREW

Whether the molding application requires that we process an LCP material with a cycle time of 30 seconds or a rigid PVC with a cycle time of 95 seconds, every plasticating screw has to perform certain functions in order to process the polymeric material effectively and produce a high quality molded part. The functions are:

- Feed the resin consistently.
- Melt the resin uniformly.
- Pump the fluid steadily.
- Mix the resin homogeneously.

The GP screw, if designed properly, can perform these functions satisfactorily, but within a narrow processing window at best (see Figure 2).

Cycle time, shot size, pellet geometry, back pressure, and screw geometry determine residence time. Looking at the graph in Figure 2, when the cycle time/shot size relationship is outside of the curve, the GP design has a difficult time performing the melting and mixing functions. When the application is on the low side of residence time it is most likely that the design will not have enough melting capacity and/or mixing ability to properly prepare the melt pool.

Conversely, when there is too much residence time, the screw is most likely to be too deep in the metering section to ensure good melting and mixing, and a good melting strategy plays a major role in achieving an adequate melt pool.

DIFFICULT TASK

In defense of the GP screw, the injection process requires that the plasticating screw be very versatile. Not only does it have to perform the above-mentioned functions, but it has to reciprocate the equivalent of five diameters in length. Effective melting length is changed and the solids bed is disrupted. Cycle times generally vary from 4 to 120 seconds, which affects the residence time of the polymer. The RPM reaches 1000 mm/sec in circumferential speed to facilitate an extremely short cycle time, and the hydraulic back pressure control can reach 5000 psi of plastic pressure. This affects the pumping ability and the pressure flow of the drag flow equation.

If the application were similar to an extrusion process where most of the variables are known and the screw is in a fixed position, it would be easier to study the process and design a screw to meet the objectives. This explains why all of the math models and melt simulation packages are supplied for the extrusion process. In an injection application there are more variables involved and more importance put on adopting a melting strategy that requires good decisions by the technician.

THE NEED FOR A GP STANDARD

The GP design has been around for more than 50 years. There is no secret as to the geometry, there are no patent infringements to concern us, and there is

Developing a standard

Standard, as defined by *The New Merriam-Webster Dictionary* is: something set up as a rule for measuring or as a model to be followed. A standard as far as the Society of the Plastics Industry (SPI) is concerned is: a formally generated, approved, and published document that has third party (American National Standards Institute) certification. The process for obtaining an SPI standard is rigorous, exacting, and time consuming. Most standards are written with some safety consideration in mind. Another way to adopt a standard is to create a guideline through the SPI as well as with the European Committee of Machinery Manufacturers for the Plastics and Rubber Industries (EUROMAP), an institute that is well regarded throughout the international community.

A guideline is a document that is developed by industry for industry and simply outlines a recommendation on a recognized industry safety practice, a design recommendation, or a procedural recommendation. A guideline does not go through the rigorous approval procedure that an ANSI standard does. Typically, the guideline is developed by manufacturers and users and then balloted by each group. A guideline can in some cases be a first effort prior to a standard. For example, there is an SPI (AN-113) and EUROMAP (19) recommendation or guideline for determining the "plasticating capacity of an injection molding machine" that OEM's use to rate the screw performance on the injection unit. Another example is the work done by the Components Section of the Machinery Div. of the SPI that has published some guidelines giving direction for the manufacturing of single barrels (BI-105) and single screws (BI-106). Standards are a necessity for every industry.

no great difference in perceived value or performance, so why can't we adopt a standard?

A standard would do wonders for the industry, providing a benchmark against which all other iterations are measured. Let's discuss what a standard would consist of, how to achieve a standard throughout the industry, and the ultimate benefits to the molder. There is a mechanism in place to develop such a standard or guideline; the work has to be done by the group that stands to benefit the most from the document—the injection molding community.

THE GP DESIGN

The development of a standard for a GP screw requires considerable research and testing. Collaboration is needed among machinery builders, molders, screw designers, resin manufacturers, and independent testing laboratories.

A specific design would be available for all to see. It would have a known melt temperature, throughput, and melt quality rating, established by using a scale of between 0 and 10 (as shown

in Figure 2) for a specific residence time used on the molding machine over the full range of screw diameters and L/D's.

A graph similar to Figure 2 would be generated. With this graph, a molder could determine if the GP design is adequate to mold parts to requirements. Similar graphs would also help the molder decide what rpm, back pressure, and barrel temperature settings should be used. While melt preparation can be more of an art than a science, this work to develop a guideline would be a scientific step forward. Injection molding machinery builders as well as independent screw designers and manufacturers could also use the testing mechanism developed to evaluate proprietary designs.

A STANDARD BENEFITS THE INDUSTRY

The current situation in injection molding is not conducive for molding perfect parts for these reasons:

■ The typical molder does not know exactly what screw and valve design is installed on the injection unit, nor do

they know what to expect from the designs they receive until they have had time to run a few jobs with the equipment.

■ There is no standard screw design to use as a point of reference.

■ There is no standard testing method for making comparisons on the impact of plasticating screw design on the injection molding process.

Without these tools to work with, the molder can't formulate a precise scientific molding strategy.

It is my opinion that the molding community should insist that screw design guidelines be developed. The weak arguments that have been given in the past for not adopting a standard because of proprietary concerns or for the protection of intellectual property rights have to be overcome for the benefit of the injection molding industry.

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SCREW IMPROVES ON GENERAL PURPOSE DESIGNS

The Posi-Melt screw reportedly improves upon previous screw designs, while maintaining a competitive manufacturing cost. Single-flight, general purpose compression screws have limitations. In response, the industry developed barrier screws and compression screws with mixers, but these have some limitations as well.

The Posi-Melt multipurpose screw design reportedly delivers a more thoroughly melted and homogenized melt pool than a standard general purpose design. The design disrupts the predictable laminar flow Z-pattern that is typical of a general pur-

pose screw. The Posi-Melt keeps the volumetric compression ratio on the low side, but with a shallower than normal metering depth for more efficient heat transfer and an optimal shear rate for melting efficiency. It changes the pitch angle at the end of the traditional compression zone. This increases the relative velocity between the barrel and solids bed and enlarges the dissipation.

The pumping ability of the Posi-Melt screw is said to be better than that of the general purpose screw because the dominant channel depth is shallower. The Posi-Melt achieves its mix-

ing function via geometric characteristics that disrupt laminar flow. By changing the pitch angle, an increase in velocity takes place that imparts an extensional strain and a distributive mixing effect to the polymer. A change in the pitch accompanies a change in the root profile.

Most changes occur tangentially to one another. In the Posi-Melt design, the change occurs in a nontangential manner. This nontangential geometry produces a pressure change that imparts additional velocity changes and distributive mixing to a major portion of the fluid. The Posi-Melt design can incorporate multiple changes in the root and pitch angle depending on the requirements of the polymer and the L/D of the screw.

The Posi-Melt is said to reduce the standard deviation of the screw recovery time by a factor of between 1.5 and 3.0, decrease the screw recovery time by 35 to 60 percent, lower the melt temperature by 10 to 15 deg C, decrease the need for excessive backpressure, and reduce the overall cycle time. Screw diameters range from 16 to 203 mm. The Posi-Melt has processed materials from most commercially available injection-grade material groups. Zeiger Industries is a licensee and manufacturer of the Posi-Melt.

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