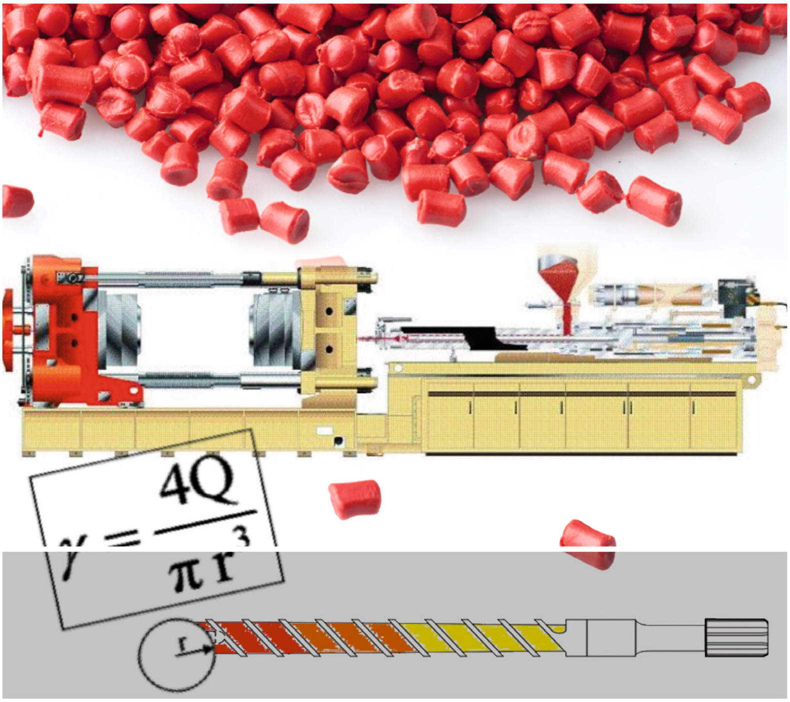
Gary F. Schiller

A Practical Approach to Scientific Molding



2nd Edition

HANSER

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Preface

This book is designed to help today's plastic molding technician deal with processing issues found day to day in the injection molding environment. It not only describes the functions of the molding machine, but also the auxiliary equipment associated with the process to produce quality parts. The chapters in this book will help the user to have a more thorough and hands-on understanding of the molding machine and the material.

It explains the process from the plastics point of view, and how the material is heated, flowed, packed, and cooled to produce the desired quality parts.

This processing guide not only shows users how to find a solution to the problem but also lets them understand why they are making the change, and what effect it has on the plastic. It details solutions from a hot runner/cold runner standpoint.

Each material has a different characteristic and will present problems in different ways, but through learning to read the part and analyzing the machine, the necessary insight will be provided to remedy most issues seen in everyday molding.

The most important thing to remember when processing or making adjustments to any machine is to make just one adjustment, review the effects on the part, and if that change has no effect, return to the previous set point, before implementing another change. By making a lot of changes in the hope of solving the molding issue, it becomes unclear which change had the effect on the part. Look at the parts, watch the molding machine, and observe what each change is doing to the process and machine.

There is a new chapter in this second edition, Chapter 13, covering the effects of making specific changes to the process. This reviews the downstream effects of a process change and how it can and will affect the process overall. These changes can have a huge impact on part quality. This chapter was written to inform the engineer/technician of the potential side effects to the change being made.

The first edition was well received and has provided insight to many in establishing scientific molding processes. The new insights of this second edition will allow the user to be more informed as to the cause and effects of a process change.

Never neglect the details:

- Walk around the machine and make sure the water is on to all lines going to the mold, or have any water lines been left off? Is the machine functioning properly (pressures, times, heating, with no unusual noises)?
- Make sure the mold is functioning as intended and able to produce the quality parts desired.
- Observe the material: make sure it is free of contaminants (dirt, foreign resin, or water) and is dried properly.
- Then review the process and make sure there are no shortcomings (process is not pressure limited, transfer position is being achieved, not timing out and cycle time achieved).

There are no magic solutions for eliminating all molding issues, but a solid understanding of these scientific molding principles will help eliminate the unnecessary waste and scrap generated from not knowing.

There are three major components to the injection molding process: the injection unit, the clamping unit, and the mold.

In the next chapters, we will discuss the different functions of each major component and how they affect the process and conditions of the material.

I would like to acknowledge and thank the following companies and people:

- RJG Inc. Traverse City, MI, especially Gary Chastain, Pat Mosley, and Shane Vandekerkhof.
- AIM Institute, Erie, PA, especially John Beaumont and Dave Hoffman.
- Technimark LLC, Asheboro, NC, especially Brad Wellington and Bruce Winslow.
- Milacron LLC, Batavia, OH, especially Kent Royer.
- I would also like to thank Gary Mitchell.

Gary Schiller

About the Author

- 43 years in the plastics industry
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- AIM Institute graduate and alumnus – Plastics Technology and Engineering
- Past AIM Institute Advisory Board
- Low Constant Pressure Molding (IMFLUX) Senior Applications and R&D Engineer
- Practical Rheology in Injection Molding – Penn State, Erie, PA
- Design of Experiments & Quality Engineering Methods – University of Colorado
- TQM – Front Range Community College, Denver, Colorado
- Certified Mechanical Inspector ASQ
- Certified Quality Technician ASQ
- Processing expert with a wide array of plastics

Core Competencies

- Stack molding
- Cube technology molding
- Two shot molding
- Insert molding
- High cavitation molding
- Engineering and commodity resins

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1 Injection Unit: Screw

In this chapter we will discuss the components and functions of the injection unit, and how each play a role in the preparation of the plastic.

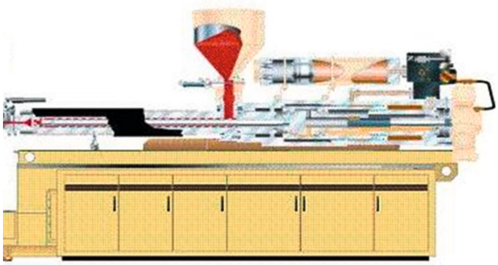

Figure 1.1 Injection unit

1.1 Prepares the Melt

There is mechanical heating, caused by the friction or shear inside the barrel, from the plastic pellets being rubbed against the barrel wall and compressed inside the flights of the screw.

There is electrical heating, from the heater bands on the barrel. They are used from a cold start to heat up the barrel and plastic. After a proper amount of soak time (30 minutes), start to rotate the screw. The barrel heater bands are to maintain the temperature in the barrel so the plastic does not hit any cold spots.

Once the barrel is up to heat, start to extrude plastic through the barrel. About 80% of the heat comes from the shearing process and 20% from the electrical portion. In Figure 1.2 you can see the shaded sections representing the different sections of the screw.

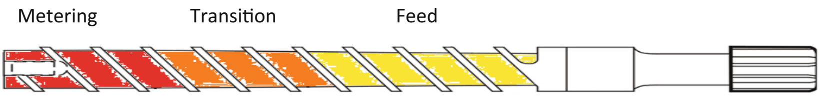

Figure 1.2 Reciprocating screw

In Figure 1.3 it is shown how the plastic in each section has a circular motion inside the flight. There is a melt pool on the back side so that as the screw rotates the melt pool pushes the unmelted pellets forward and up against the barrel wall. As the unmelted pellets rub against the barrel wall it creates friction, and that friction causes the pellet to melt and go into the melt pool.

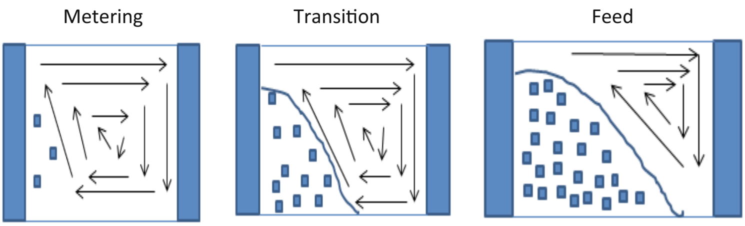

Figure 1.3 Melting of the plastic in different sections of the screw. Courtesy of AIM Institute

1.2 Flows the Melt

There is a hydraulic unit and valves that provide the oil flow and pressure needed to inject the plastic.

The injection velocity set point will give and maintain the speed of the ram coming forward and it must have ample pressure and flow to push the plastic. To ensure the injection high limit pressure set point is never reached (pressure limited) the valve is either restricted or opened depending on the feedback it receives from the linear transducer on what velocity or injection speed is desired. Also understand the influence the injection velocity has on the rheological properties of the material: plastics typically show non-Newtonian behavior, which means the faster the material is shot or the faster the flow rate of the plastic, the thinner the material becomes and the easier it will flow.

1.3 Pressurizes the Melt

The non-return valve (check ring) is what pressurizes the melt. It creates a seal on the inside of the barrel through the use of a sliding check ring, ball-check screw tip, and/or poppet check ring. There are also plunger-style screws that inject the plastic into the molds: there are no moving parts to this design.

And as the plastic is pushed forward the non-return valve seals off, not allowing any plastic to return behind it. If it does there is either a worn non-return valve or possible wear in the barrel. This will be discussed later in the book.

1.4 Sections of the Screw

There are many different screw styles available today, with a multitude of materials available. The reciprocating screw provides the function of conveying the material, and compressing and heating it to prepare it for the next shot.

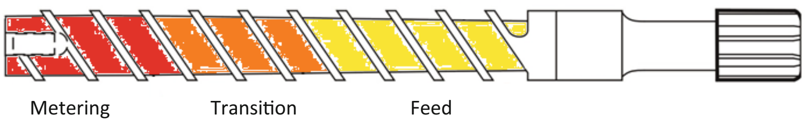

Figure 1.4 Sections of the screw

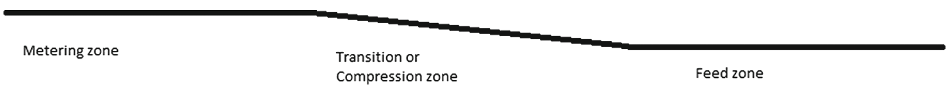

Figure 1.5 Root diameter changes in each sections of the screw

1.4.1 Feed Zone

The feed zone is used to convey the material from the feed throat and start the compaction process in the barrel. This section starts to compress the pellets within the flight and starts the friction process as the material rubs along the barrel wall as the screw rotates. Screws can have long or short feed sections depending on the material being run. Longer feed sections could be for shear sensitive materials or a material that melts easily with a low melt temperature.

1.4.2 Transition or Compression Zone

This is where the flight depth starts to get shallower. The material starts to receive greater compression and the friction or shearing of the material increases, contributing to the melting of the plastic. This is where most of the work is done on heating the material (see Figure 1.5).

1.4.3 Metering Zone

This zone has the shallowest flight depth. By the time the material gets to this point it should be melted, and ready to be conveyed past the non-return valve to position itself in front of the screw building the next shot.

1.5 L/D or Length/Diameter

Length (L) is measured from the front of the screw to the end of the flights. Diameter (D) is measured from the highest point on the flight of the screw to the corresponding other side (see Figure 1.6). Keep in mind the value of L/D for the screw in the press: too short of an L/D results on non-melted pellets, while too long of an L/D and the result is too much residence time, which can burn or degrade the plastic.

Figure 1.6 Where to measure length and diameter of screw

1.6 Compression Ratio

This refers to the depth of the feed section flight (Figure 1.8) divided by the depth of the metering section flight (Figure 1.7). If there is a 3 : 1 compression ratio screw this means that the depth of the feed section flight is three times the depth of the metering section flight. The measurement is taken from the root of the screw to the top of the flight.