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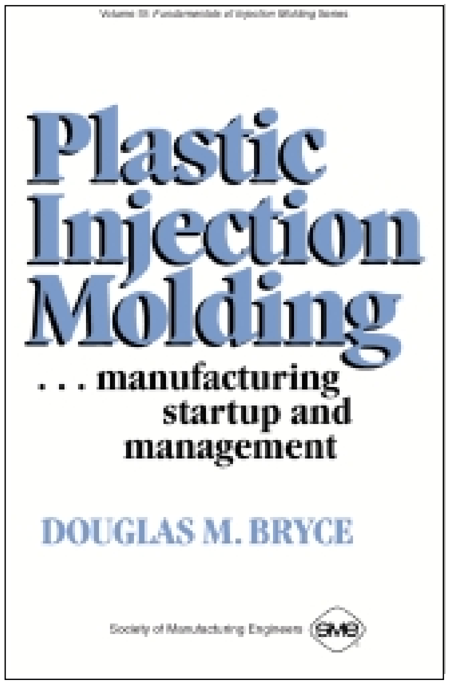

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Injection Molding Concepts 1

This chapter describes the history and basic operating process of injection molding.

HISTORY

In 1868, John Wesley Hyatt developed the plastic material called celluloid and entered it in a contest created by a billiard ball manufacturer (celluloid was actually invented in 1851 by Alexander Parkes, but Hyatt perfected it). The contest was held to find a substitute for ivory, which was becoming more expensive and difficult to obtain. He used celluloid to replace the ivory used for making a billiard ball and won the contest's grand prize of $10,000 (a rich man's sum in those days). Unfortunately, after the prize was won, some billiard balls exploded on impact during a demonstration because of the instability and high flammability of celluloid. Undaunted, new improvements were made allowing its use in commercial ventures and the plastics industry was born. John Wesley Hyatt and his brother Isaiah patented the first injection-molding machine that made celluloid plastic parts in 1872. During the next 40 to 50 years, others began to investigate this new process and used it for manufacturing items such as collar stays, buttons, and hair combs.

By 1920, the injection molding industry was even more popular and during the 1940s, the plastic injection molding industry grew tremendously because World War II created a demand for inexpensive, mass-produced products. New materials and technical advances resulted in improved applications and even more use.

From its birth in the late 1800s, to recent developments and applications, the injection molding industry has grown at a fast and steady rate. It has evolved from producing combs and buttons to molding products for all production fields, including automotive, medical, aerospace, construction, and consumer goods, as well as toys, plumbing, and packaging.

Table I-1 shows some of the important dates in the evolution of the injection molding industry.

PROCESS DESCRIPTION

Injection molding is a process that softens a plastic material with heat and causes it to flow into a closed mold. Then, the material cools and solidifies, forming a

Table I-1. Evolution of Injection Molding

1868	John Wesley Hyatt injection-molds celluloid billiard balls.
1872	John and Isaiah Hyatt patent the injection molding machine.
1937	Society of the Plastics Industry founded.
1938	Dow invents polystyrene (still one of the most popular materials).
1940	World War II events create huge demand for plastic products.
1941	Society of Plastics Engineers founded.
1942	Detroit Mold Engineering, Inc. (DME) introduces stock mold base components.
1946	James Hendry builds first screw injection-molding machine.
1955	General Electric begins marketing polycarbonate.
1959	DuPont introduces acetal homopolymer.
1969	Plastics land on the moon.
1972	The first parts-removal robot is installed on a molding machine.
1979	Plastic production surpasses steel production.
1980	Apple uses acrylonitrile-butadiene-styrene (ABS) in the Apple IIe computer.
1982	The JARVIK-7 plastic heart keeps Barney Clark alive.
1985	Japanese firm introduces all-electric molding machine.
1988	Recycling of plastic comes to age.
1990	Aluminum molds introduced for production injection-molding.
1992	Metallocene catalysts give impressive properties to polyolefins.
1994	Cincinnati-Milacron sells first all-electric machine in U.S.

specific product. The action that takes place is much like the filling of a jelly donut. A hypodermic-style cylinder and nozzle injects the heated plastic into the opening of a closed container (mold). The material is allowed to harden again, a finished part is ejected, and the cycle is repeated to produce the total number of pieces required, as shown in Figure 1-1. This description oversimplifies the actual process because there are more than 100 parameters that must be controlled to ensure production of a good low-cost part. These parameters are discussed in *Volume One* of this series, *Plastic Injection Molding—Manufacturing Process Fundamentals*, and should be reviewed for more information. To better understand the relationship between the process and proper material selection, some of the parameters must be well understood.

Categorizing the Parameters

Although there are many parameters to control, they can be detailed within the confines of four major categories. These are *temperature, pressure, time, and distance*, as shown in Figure 1-2.

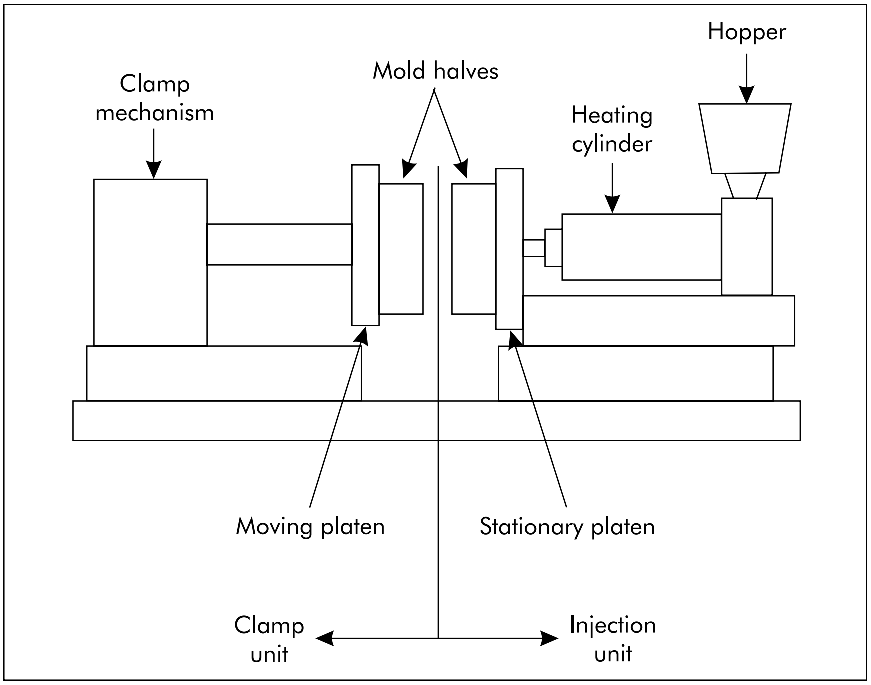

Figure 1-1. The injection molding process.

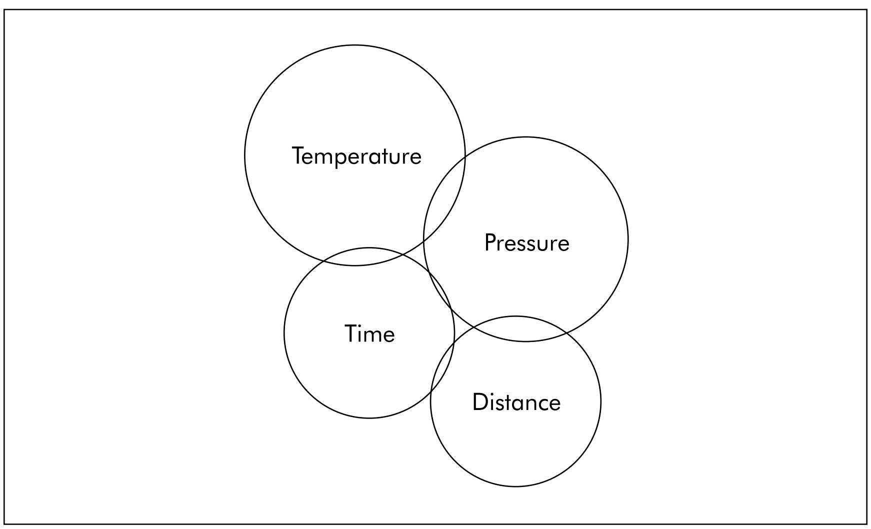

Figure 1-2. Categories of parameters.

Note that the circles in Figure 1-2 are interconnected and of different sizes. The interconnections show that each parameter is affected by, and affects, other parameters. A change in one may have a major effect on another. The different circle sizes represent the order of importance placed on each set of parameters. For example, temperature and pressure normally are more important to the process than time and distance.

Temperature

The level of heat or cold is a factor affecting the material, mold, and oil used.

Temperature of the material. The primary concern is the amount of heat that the plastic material must have for proper injection into a mold. All materials have a range of the most efficient injection temperature to maintain maximum physical properties. For amorphous materials, this range is rather broad, while for crystalline materials this range is fairly narrow (the differences between amorphous and crystalline materials are discussed in Chapter 2). However, with both types of materials there is a temperature point that the plastic flows the best and still maintains proper physical properties. This is called the *ideal melting point* and must be attained through trial-and-error activities. While this may seem primitive, it is required as a fine-tuning adjustment after a specific production run is initiated and as part of establishing particular process specifications for specific products.

The guessing process actually begins by setting the heating cylinder temperature so that the injected material is at the recommended temperature. The temperature of the plastic is measured as it leaves the heating cylinder to determine if it is within the proper range. Then, it is adjusted up or down depending on cycle times, pressure requirements, mold temperature, and other parameters. These adjustments are made during the pilot run of the process and until acceptable parts are produced. Then, a setup sheet is created, which lists parameter values that are stored for running the job again. Table I-2 shows the recommended melt temperature for some common materials. This is the temperature that should be found when measuring the material, as shown in Figure 1-3.

The softening (or melting) of the plastic is achieved by causing the individual molecules within the material to go into motion. This is accomplished by applying heat to the molecules. Generally, the more heat that is applied, the faster the molecules move. This is true until too much heat is applied. At that point, the plastic material starts to degrade and break down into its main constituents.

Heat is applied by using electrical heater bands wrapped around the outside of the injection molding machine's heating cylinder, as shown in Figure 1-4. The heater bands, which resemble hinged bracelets, are assembled with individual groups of three or four bands to control the temperature of a single zone. There are three basic temperature zones for the heating cylinder: rear, center, and front. Each zone is monitored by a thermocouple, which is connected to a temperature controller. The thermocouple determines whether or not the zone is at the correct

Table I-2. Suggested Melt Temperatures for Various Plastics

Material	Temperature, °F (°C)
Acetal (copolymer)	400 (204)
Acetal (homopolymer)	425 (218)
Acrylic	425 (218)
Acrylic (modified)	500 (260)
ABS (medium-impact)	400 (204)
ABS (high-impact and/or flame retardant)	420 (216)
Cellulose acetate	385 (196)
Cellulose acetate butyrate	350 (177)
Cellulose acetate propionate	350 (177)
Ethylene vinyl acetate	350 (177)
Liquid crystal polymer	500 (260)
Nylon (Type 6)	500 (260)
Nylon (Type 6/6)	525 (274)
Polyallomer	485 (252)
Polyamide-imide	650 (343)
Polyarylate	700 (371)
Polybutylene	475 (246)
Polycarbonate	550 (288)
Polyetheretherketone (PEEK)	720 (382)
Polyetherimide	700 (371)
Polyethylene (low-density)	325 (163)
Polyethylene (high-density)	400 (204)
Polymethylpentene	275 (135)
Polyphenylene oxide	385 (196)
Polyphenylene sulfide	575 (302)
Polypropylene	350 (177)
Polystyrene (general purpose)	350 (177)
Polystyrene (medium-impact)	380 (193)
Polystyrene (high-impact)	390 (199)
Polysulfone	700 (371)
PVC (rigid)	350 (177)
PVC (flexible)	325 (163)
Styrene acrylonitrile (SAN)	400 (204)
Styrene butadiene	360 (182)
Tetrafluorethylene	600 (316)
Thermoplastic polyester (PBT)	425 (218)
Thermoplastic polyester (PET)	450 (232)