# Summary

        Injection molding is an extremely important molding process for plastics. It is used more than any other type of molding equipment for plastics processing. Its popularity is due to the wide variety of shapes that are possible with this process, the high degree of repeatability that can be attained, and the high level of automation possible. Almost all thermoplastic and many thermoset resins can be injection molded.



**Table 12.5 Economic Factors in Choosing Mold Size**

        The major drawbacks to injection molding are the relatively high cost of the equipment and the high cost of the molds. The high cost of the equipment suggests that as many parts as possible be made in very high volumes so that equipment cost can be spread over many parts and not represent too high a portion of the total cost of each part. A key element in the cost of injection molding is the cycle time, that is, the time the machine takes to complete the part and become ready to begin the next part. Cycle time should be minimized.

          Except for service lines, injection molding machines are self-contained units. The resin is introduced into a hopper, either manually or automatically. Some resins need to be dried to remove the moisture that is absorbed naturally, which is often done by blowing hot (low-humidity) air through the resin, either in the hopper or in a separate drying step prior to introduction. Colorants and other additives can be added in the hopper and/or also in a previous mixing step. The resin feeds from the hopper into the feed throat by gravity.

          Two types of injection molding machines have been in common use, the ram and the reciprocating screw machine. Today, the reciprocating screw machine dominates the market. Reciprocating screw machines have better melting characteristics, are easier to control, require less thermal heat because they also induce mechanical heating, have a more uniform melt, and can inject smaller quantities from the same machine. In reciprocating screw machines, a screw with three zones is used to convey the material forward (feed zone), to melt the material (compression zone), and to add pressure and ensure that the resin is completely melted (metering zone).

        After passing along the screw, the molten material collects in a pool at the end of the screw in a region called the injection zone. At the appropriate part of the cycle, the screw stops turning and advances forward, thus pushing the resin in the pool out through the end of the barrel. A sliding check valve prevents the resin from flowing backward along the screw. This step is called injection. The resin flows through a nozzle that is mated to the surface of a mold. It then flows through a passageway in the mold (called a sprue) and into a channel system (runners) that connect the sprue to the mold cavities. Just as the resin enters the cavity it passes through a narrow opening called the gate. The resin then sits in the cavity until it has cooled sufficiently to be solid.

         Injection molds are much more complicated than extrusion dies. The molds are made from several plates that are assembled together. Some of the plates give support so that the assembly can withstand the pressure of the injection, some contain the cavities, and some operate the ejection system. The entire assembly is the mold base. Generally, the plates of an injection mold are made of hard tool steel. Other materials such as beryllium-copper, stainless steel, and aluminum can also be used and are even preferred in some applications.

        The runners, gates, and cavities are cut into the mold so that the plastic material flows smoothly and does not freeze off until the mold is completely filled. The patterns and styles of these components can be of several designs, depending on the number of parts to be made, the need for close tolerances, the need to have the part automatically removed from the runner system, and the appearance of the part.

        The cavities can be made by several methods. Machining is the oldest and is still the most common. However, electrical discharge machining (EDM) has some major advantages and is now emerging as a major method for cutting cavities. Hobbing is an old method that is now in decline, especially with the growth of EDM.

        After solidification, the mold opens, which activates some ejector pins that assist in removing the part. In most cases, the runners and sprue are also ejected with the part. These are removed, usually by clipping them off, and are reground to make additional parts.

        In most injection molding operations, the ejected part is nearly the final shape and little additional shaping is needed. However, several types of secondary operations may be done to get the finished assembly. For instance, the part may have some additional part attached (as in the case study in this chapter) or may be welded or attached into an assembly. Many of these secondary operations can be done automatically or semi automatically to reduce the costs of labor involved in the total operation.

        Controlling the injection molding process is complex because so many of the variables are interrelated. In general, the material should be injected into the mold at the fastest rate and with the highest pressure practical. The limits on these parameters are the clamping capacity of the machine, the physical limitations of the nozzle, runners, gates, cavities, and the characteristics of the resin. The temperature selected should produce a resin with a relatively low viscosity so that it will flow easily and fill the mold but not be so hot that the time to cool is excessively long. Other variables, such as cycle time, temperature profile, time the pressure is held against the filled mold, and treatments to the resin such as drying or use of additives, are all secondary parameters but can be important in obtaining good quality parts.

        Computer simulation programs have been developed to assist in the building of molds. These programs model the filling of the mold and predict key parameters associated with the molding process, such as shrinkage, warpage, venting requirements, orientations, and runner and gate system sizes.

        The costs of an injection-molded part depend on the costs of (1) the resin, (2) the tooling, (3) the machine, (4) the secondary labor, and (5) shipping and packaging. All of these costs are outlined in the first case study.

## 12.11.1. Questions

1. Why are injection molding machines not as effective for mixing additives or other resins as are traditional extrusion machines?
2. Where is the normal separation point between the material that is removed with each cycle and the material that is in the machine and used in the next cycle?
3. What feature in a mold will allow a hollow, cylindrical part to be made?
4. What two measures are used in rating the size of an injection molding machine?
5. What is packing the mold, and why is it important in obtaining good injection molded parts?
6. What is a vent in the mold, what problems are prevented by the presence of a vent, and what parameters control its size?
7. How does high crystallinity in a resin affect the way the resin is injection molded, including any post molding operations that might be done?
8. Explain the purpose of a preplasticizing unit.
9. Why is it important to have the sections of the molded part as uniform in thickness as possible?
10. If nonmelted resin particles are noted in the molded part, what corrections might be made?
11. Assume that you are assigned to determine the minimum clamping force for a part to be molded out of polystyrene. The part cross-sectional area is 10 x 14 inches. What is the clamping force required if, as a general rule, 2.5 tons of force are needed for each square inch of cross-sectional area?
12. Why is good weldability desirable in a mold cavity material?
13. Why is low specific heat capacity desired in a mold cavity material for some applications and a high specific heat capacity desired in others?
14. Why are ejector pins made of hard yet shock-resistant materials?
15. Identify four advantages and two disadvantages of using aluminum rather than tool steel to make cavities for injection molds.
16. Identify one major advantage or use of the following gate types: submarine, edge, and ring.
17. What is the purpose of cold-well extensions?
18. Identify three ways to ensure that an injection-molded part stays on the B side of the mold when the mold opens.
19. Identify two advantages of using inserts in injection molds.

## 12.11.2. References

Ashby, Steven, "Molding Stronger Plastic Parts," Mechanical Engineering, Nov. 1993, pp. 56-59.

Beall, Glen L., "Plastic Part Design for Economical Injection Molding," Seminar notes prepared for Storage Technology Corporation, Littleton, CO, 1993.

Brydson, J. A., Handbook for Plastics Processors, Oxford, UK: Heinemann Newnes, 1990. DeGrospari, John, "Low-Pressure Alternatives for Molding Large Automotive Parts," Plastics Technology, Sept. 1993, pp. 60-65.

Frados, Joel (ed.), Plastics Engineering Handbook (5th ed.), Florence, KY: International Thomson Publish-ing, 1994.

"Gas Injection Molding of an Automotive Structural Part," Plastics Engineering, Oct. 1991, pp. 21- 26.

I-DEAS Master Series, Student Guide (2nd ed.), Milford, OH: Structural Dynamics Research Corporation,1994.

"Injection Method May End Troubles with Anisotropy", Modem Plastics, Jan. 1990, pp. 12- 14.

Kamal, M. R., and Thanasis D. Papathanasiou, "Filling of a Complex-Shaped Mold with a Viscoelastic Poly-mer. Part II: Comparison with Experimental Data," Polymer Engineering and Science, Mid-April 1993 , pp. 410-417.

Menges, Georg, and Paul Mohren, How To Make Injection Molds (2nd ed.), Munich: Hanser Publishers, 1993.

Milby, Robert V., Plastics Technology, New York: McGraw-Hill Book Company, 1973.

"Mold Analysis Software Developing at a Rapid Pace," Plastics Technology, Jan. 1993, pp. 21- 25.

"Moldmaking: A Statistical/Heuristic Approach to Estimating Mold Costs," Plastics Engineering, June 1989, pp. 51-53.

Morton-Jones, D. H., Polymer Processing, London: Chapman and Hall Ltd, 1989.

"Multinational Producibility: Plastic Molded Parts," Xerox, MN2-104 .l Revision 6, Sept. 1987.

"New Mold-Analysis Software for Beginners and Sophisticated Users," Plastics Technology, August 1993, pp. 17-21.

Papathanasiou, Thanasis D., and M. R. Kamal, "Filling of a Complex-Shaped Mold with a Viscoelastic Poly-mer. Part I: The Mathematical Model," Polymer Engineering and Science, Mid-April 1993, pp. 400-409.

Richards, Peter, and Ed Galli, "Estimating: Putting Method in the Madness," Plastics Machinery & Equipment, Feb. 1982, pp.15-18.

Richardson, Terry L., Industrial Plastics: Theory and Application (2nd ed.), Albany, NY: Delmar Publications, Inc., 1989.

Rosato, Donald V., David P. DiMattia, and Dominick V. Rosato, Designing with Plastics and Composites: A Handbook, New York: Van Nostrand Reinhold, 1991.

Spier, I. Martin, "The Economics of Mold Selection," PM&E Mold and Die Comer Collection.

Stoeckhert, Klaus (ed.), Mold-Making Handbook, Munich: Hanser Publishers, 1983. "Troubleshooting Guide for Injection Molding," DuPont, E-67417.

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