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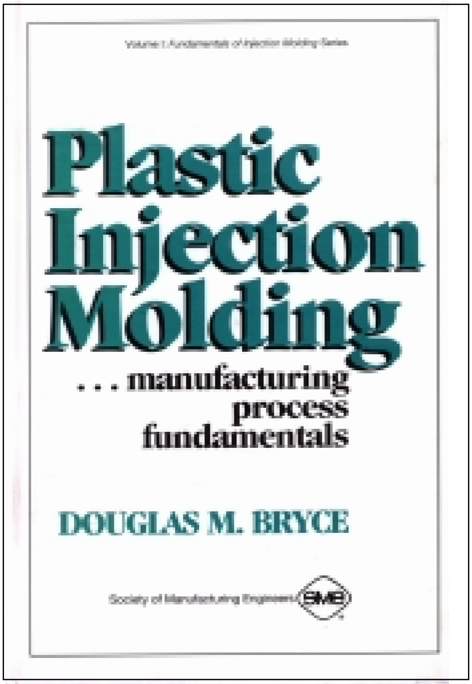

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Society of
Manufacturing
Engineers

1 Overview of the Industry

HOW IT ALL BEGAN

In 1868, an enterprising young gentleman by the name of John Wesley Hyatt developed a plastic material he called *celluloid* to enter in a contest created by a billiard ball manufacturer. The company was looking for a new material to substitute for ivory, which was becoming expensive and difficult to obtain. Celluloid was actually invented in 1851 by Alexander Parkes, but Hyatt improved it so that it could be processed into finished form. He created a celluloid billiard ball and won the contest's grand prize of $10,000, a rich sum in those days. Unfortunately, after the prize was won, some billiard balls exploded on impact during a demonstration (due to the instability and high flammability of celluloid) and further perfection was required before it could be used in commercial ventures. But the plastics industry was born and began to flourish when Hyatt and his brother Isaiah patented the first injection-molding machine in 1872. With this machine, the brothers were able to mold celluloid plastic. Over the next 40 to 50 years, others began to investigate this new process for manufacturing such items as collar stays, buttons, and hair combs. By 1920, the injection-molding industry had set its foundation, and it has been building ever since.

During the 1940s, the plastic injection-molding industry exploded with a bang (*not* because of the instability of celluloid) as World War II created a demand for inexpensive, mass-produced products. New materials were invented for the process on a regular basis and technical advances resulted in more and more successful applications.

EVOLUTION OF THE SCREW

The machine that the Hyatt brothers invented was primitive, but performed well for their purposes. It was simple in that it acted like a large hypodermic needle and contained a basic plunger to inject the plastic through a heated cylinder into a mold. In 1946, James Hendry began marketing his recently patented screw injection machine. This auger design replaced the conventional Hyatt plunger device and revolutionized the processing of plastics. Screw machines now account for approximately 95 percent of all injection machines.

The auger design of the screw creates a mixing action in material being readied for injection. The screw is inside the heating cylinder and, when activated, mixes the plastic well, creating a homogenized blend of material. This is especially useful when colors are being added or when *regrind* (recycled material) is being mixed with virgin material. After mixing, the screw stops turning and the entire screw pushes forward, acting like a plunger to inject material into the mold.

Another advantage of the screw is reduced energy requirements. As in a plunger machine, the cylinder that holds the plastic for injection has a series of electrical heater bands around the outside. When energized, these bands heat up and soften the plastic. However, the screw creates friction when it turns within the cylinder and thus generates additional heat. Therefore, the material is also heated from the inside, and less heat is required from the electrical heater bands to soften the plastic.

Although the screw machine is by far the most popular, there is still a place for the plunger-type machine. A plunger does not rotate. It simply pushes material ahead, then retracts for the next cycle. It, too, resides within a heated cylinder. Because there is no rotating, there is no shearing or mixing action. So, in a plunger machine, heat is provided solely by the external heater bands because there is no friction from the plunger as there is from a screw. If two different colored materials are placed in the heated cylinder, they are not blended together. The plunger simply injects the materials at the same time. If the two colors are, for instance, white and black, the resulting molded part will take on a marbled appearance with swirls of black and white. This may be the desired finish for certain products, such as lamp bases or furniture, and the plunger machine allows that finish to be molded into the product. Use of a screw machine would result in a single-color (gray) product being molded because the two colors would be well mixed prior to injection.

INDUSTRY EVOLUTION

From its birth in the late 1800s to the present time, the injection-molding industry has grown at a fast and steady rate. It has evolved from producing combs and buttons to molding products for varied industries, including automotive, medical, aerospace, consumer, toys, plumbing, packaging, and construction.

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

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 creates large demand for plastic products.
1941	Society of Plastics Engineers founded.
1942	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 part-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 of age.
1990	Aluminum mold introduced for production molding.
1994	Cincinnati-Milacron sells first all-electric molding machine in the U.S.

A VISION OF TOMORROW

The future will see some major changes in the way injection-molding companies operate. In particular, changes will take place in four principal areas: processes, materials, molds (tooling), and business concepts.

Processes

Energy Efficiency

Energy-efficient machines will be developed to better utilize available resources. At present, injection-molding machines use vast amounts of electricity to heat the plastic, power the hydraulic pumps and motors, and control the temperature of the molds. The cost of this energy is steadily rising and the resources used to create the electricity are becoming more scarce and consequently more expensive. Thus, it is necessary to find ways to reduce the amount of energy required to produce products.

Some of the innovations being considered to reduce energy requirements include internally heated injection screws, insulated molds, and insulated heating cylinders. The combined use of these three items alone could result in energy savings of 60 percent or more when efficient models become available.

In addition, work is being done to develop all-electric machines. This concept takes the electricity now being used to power hydraulic systems and uses it directly to power electric motors instead. The motors then provide the motions normally provided by hydraulics, and the result is a more energy-efficient total system. At present, these systems are available only on small machines but as they become larger and less expensive, their popularity will increase, especially in clean-room environments and areas where noise must be reduced.

Desktop Manufacturing

The concept of “desktop manufacturing” (DM) has given rise to a brand new approach to injection-molding processes. DM can be defined in this case as molding products by using just a few cavities on high-volume equipment, small enough to fit in an area no larger than a desktop.

Although desktop manufacturing is already available for several types of production, the DM discussed here refers only to injection-molding processes. It is now possible to set up a large bank of small, benchtop injection-molding machines, each running only a one- or two-cavity mold, pumping out products much faster than the bulky, multicavity systems traditionally employed. With DM, a molder may elect to run several presses to make the same product, or only a few at a time, depending on immediate requirements. This allows more flexibility in the overall scheduling process. DM can also reduce manufacturing costs owing to less energy needed and faster cycles possible because of the smaller size of the equipment. Mold repairs can be made on one cavity while the rest of the cavities continue to run, unlike common injection processes today.

Desktop manufacturing is ideal for prototyping. In this situation, DM allows fast manufacturing of a few samples of a product, which then can be used for form, fit, and function evaluation prior to investing in production tooling. And DM is perfect for small-volume production where only a few hundred (or thousand) pieces are needed.

Molds

Tooling

Because of advances in molding machines and moldmaking equipment, there will be a trend to build both larger and smaller molds.

Molding machine manufacturers are building larger machines to accommodate product designs that were not possible in the past because of molding-machine size constraints. Products such as automotive fenders and wraparound bumpers will be molded on machines that are the size of small houses. The more this is done, the more it will drive manufacturers to build larger and larger machines. Of course, every machine must have a mold. So the molds will be built larger and larger to accommodate product design requirements.

Conversely, advances in materials and processing systems have led to the production of small parts that formerly were not candidates for injection molding. Products such as miniature electronic connectors and tiny medical valves are now being designed. The tolerance requirements and small size of these components require extremely accurate, sophisticated molding machines; these are being built now in sizes that will fit on the top of an ordinary desk. The machine tool manufacturers are striving to build even smaller machines as the demand increases. So, the molds for these machines are also smaller and smaller. There are molds now that can fit in the palm of a human hand, and the trend is toward even smaller molds to accommodate future product requirements.

Lead Times

Lead time is defined as the total amount of time required to obtain a product, from purchase order to finished item. In other words, the lead time for a mold extends from the moment a purchase order is received by the moldmaker to the moment the mold is delivered to the company ordering the mold. A typical lead time today ranges from 12 to 16 weeks for an average mold. (This does not include time to debug the mold or try it out in a production environment.)

A lead time of 12 to 16 weeks may not seem like much to those who have been in the business a while. In fact, it is a great improvement over what prevailed before. In earlier days, the lead time may have been 36 weeks or longer. Nonetheless, in today's competitive environment, lead times are critical because they dictate when a product can get to its market. The earlier the product can be introduced, the faster it can begin bringing in profits, and the quicker the company can begin investing those profits in new product development.

There are numerous ways to minimize lead times, and many are being pursued today. Certain of these promise to bring lead times down to unheard-of numbers:

- *Computer-generated data.* Computers allow moldmakers and product designers to work closely together even if they are in different cities, states, or countries. As computers become faster and more powerful, and as computer programs become more versatile, product designs can be generated and tested faster, and the same data can be