3 Cost Factors Affecting Productivity

A mold's productivity is ultimately measured by how many good parts it can produce over time. A mold that runs very fast but is frequently down for maintenance or repair will not produce at lowest part cost and highest productivity. Conversely, a mold that runs too slow but produces parts consistently over time is not optimal. The same can be said for each component in the injection molding system.

One way to quantify productivity is to measure the total equipment productivity (TEP):

$$\text{TEP} = \frac{\text{Production hours (auto cycling)}}{\text{Available hours}} \times \frac{\text{Parts made}}{\text{Hour}} \times \frac{\text{Scrap parts}}{\text{Parts produced}}$$

A good custom molder can achieve TEP's greater that 80% and good dedicated systems achieve values higher than 90%.

Figure 3.1 Total equipment productivity (TEP)

3.1 Where Will the Mold Be Operated?

3.1.1 Condition of Ambient (Shop) Air

We tend to assume that the mold will be operated under "ideal" conditions, but this is typically not the case. The environment in the molding shop can vary from very cold to very hot, from dry to very humid, from clean to dusty and dirty. With sudden changes in any of these conditions, a molding operation can be affected significantly. High humidity will affect the mold itself (corrosion) and will affect the cycle time (productivity) of the mold. Rapid temperature changes may even affect the operation of a machine and mold and lead to breakdowns and loss of production.

A typical example (A): a molding shop operated eight identical machines in each of two parallel rows; all were molding the same or very similar products with the same type of mold. They all worked fine, except the last machine in one row, which stopped frequently, without apparent reason. After checking for machine problems, such as possible power fluctuations, poor cooling water supply, etc. it was noted that this last machine was close to an emergency exit door, which was supposed to be closed all the time; however, on some days, the workers kept the door jammed open to improve the shop ventilation. The draft from the entering cooler outside air was enough to affect to operation. After ensuring that the door stayed closed at all times, there were no more problems reported with this machine.

Figure 3.2 Plan of molding plant in Example A

Another example: a mold and machine worked perfectly, but occasionally, for several hours, produced pieces with surface blemishes that looked like blisters. Investigation showed that it happened only on very humid days. This particular operation required a rather long mold open cycle. On humid days, the water in the air condensed in tiny droplets on the cold mold cores during the few seconds the mold was open and the cavities and cores were exposed to the shop air; the droplets appeared as blisters on the surface of the product. After slightly increasing the cooling water temperature to bring it above the dew point the problem disappeared. The "penalty" was a slightly longer cycle time, but it ensured continuous production of quality products.

Corrosion Prevention

It is important to decide how the mold will be protected from corrosion if it is evident that the mold is operated and stored in a humid environment. This can affect the mold cost. A common approach in many shops is to protect the molding surfaces before the mold is put into storage by using silicon spray ("Mold Saver") or to just apply plain, clean machine oil. Many shops paint the outside of the mold shoe with a permanent oil paint to protect the outside of the mold against corrosion.

Mold shoe material options:
- **Pre-hardened plate steel, painted**
- **Plate steel with ENP**
- **Stainless steel**

Another approach is to flash chrome plate the stack parts or to make them from stainless steels; both methods will of course add to the mold cost. For the mold shoe (the mold plates) itself, instead of using oil paint, it can be protected against corrosion with electro-less nickel plating (ENP), which has the additional advantage that it also protects some of the inner surfaces of the mold shoe, which would not normally be covered when the mold is just painted on the outside. ENP also enters the cooling channels to some extent and protects them against corrosion caused by the coolant, but the penetration is limited and does not cover the walls of the channels deep inside the plates. ENP is hard (70Rc) but thin and not resistant to scratches and wear.

Always consider the total costs when comparing mold material costs

The best method may be to make the entire mold shoe from stainless steel (SS). The basic cost of SS is higher than the cost of mild steels or pre-hardened machinery steels. However, when SS is bought in large quantities, the cost difference can be much less. When molds are expected to run for a long time, the advantage of SS over other steels can justify the higher cost. We must not forget that chrome plating or ENP also cost money. We must also consider the costs of transportation to and from the nickel or chrome plater, the additional time required for these operations, the lack of control over the transport, and the dependence on an outside supplier.

Another problem with chrome plating is that any change (requiring re-machining) of a chromed surface requires that the chrome must first be removed from the steel part. This requires shipping the part to the plater for removing the coating by a process similar to plating. After re-machining, the changed part must again be shipped to be plated. This is an expensive and time-consuming procedure.

Note that corrosive plastics such as rigid PVC always require chrome plating or, better yet, SS for the stack parts.

The use of full-hardened (or pre-hardened) SS for cavities, cores, and inserts is quite common today, even though the steel cost is higher. When considering the expenses and risks with chrome plating of mold steels and the time saved, the total cost could be more than using SS.

Another solution for all these issues is to provide the molding plant and the mold storage facilities with air conditioning or at least with controlled, low humidity air. Some modern molding plants have this equipment, although this means added expense and may not be needed or cannot be justified economically unless in cases where delicate products are mass-produced. Occasionally it can be useful to surround the machine with a shroud to keep the environment immediately around the mold and machine at a desired low humidity with a portable dehumidifier.

3.2 Coolant Supply

The available cooling water supply (quantity, quality, and pressure of the coolant) must also be considered. Also, remember, for water-cooling to be effective, the water must flow fast enough to establish turbulent flow. Turbulent flow removes significantly more heat per liter (or gallon) and can be calculated (see [5], Chapter 13).

3.2.1 Is the Coolant Supply Large Enough for the Planned Mold?

There is no point to design a mold with an expensive, elaborate cooling system if there is not enough coolant flow and pressure available to take full advantage of it. I have seen some mold plants that developed from only a few to a high number of machines, but neglected to increase the cooling water supply to grow with the rest of the operation. This resulted in the molds running much slower than they could if the cooling water supply had been sufficient.

Good cooling of a mold depends not only the coolant *temperature* but also on the *volume* of coolant that flows through the mold, measured in liters or gallons per minute. This volume depends essentially on the pressure differential between IN and OUT of the cooling channels in the mold and on the method of distribution through the mold (see [5], Chapter 13).

Table 3.1 Calculating Chiller Requirements

Resin	Chiller lb/h/ton
HDPE	30
LDPE	35
PMMA	35
PP	35
PA	40
PPE	40
ABS	50
PS	50
Acetal	50

Tons required =
Resin lb/h/ton × lb/h of resin consumed

For highest productivity ensure that the cooling channels in the mold are free from sediments (lime, rust, etc.)

3.2.2 Is the Cooling Water Clean?

Cooling water must be clean, i.e., free from contaminants and/or oxidizers, which corrode the inside of the cooling channels. This is where stainless steel

Figure 3.3 Rusted mold components

is of great advantage. The coolant must also be free from lime and dirt, which will gradually settle in corners of the cooling system and plug the cooling channels, especially if the channels are small and in elaborate circuits, as is often required in high production molds to cool small mold parts. Under such bad conditions, a mold will probably run satisfactorily and produce as planned for the first few months, but because of buildup of dirt in the cooling channels, the mold will gradually lose its cooling efficiency and run slower than it could with good, clean coolant. Dirt in the water will also require more mold maintenance, as the channels will have to be cleaned from time to time. Such mostly unnecessary costs are often overlooked while worrying about the high initial mold cost.

Rust is an insulator and will eventually slow the molding cycle as it builds up.

3.3 Power Supply

Electric power supply is not always as stable as required, especially outside the larger industrial areas of North America and Europe. In many parts of the world, especially in developing countries, there are often considerable voltage fluctuations because of weak and overloaded power lines; molders experience occasional, and sometimes even daily, “brownouts” (periods of lower voltage) and are often plagued with complete power failures (blackouts) lasting anywhere from just minutes to many hours. To say the least, these stoppages are annoying, but they can also be very expensive if a mold stops frequently just because of failure of the machine controls.

Voltage fluctuations affect molding operations for two main reasons.

- *Logic controls* are sensitive to voltage fluctuations and may require voltage stabilizers. Although this is a machine requirement, it needs to be pointed out. Every time the machine stops, the mold also stops producing. In general, electronics are quite sensitive to high ambient temperature.

A drop of 10% in voltage will reduce heat output by 20% if not thermostatically controlled

- *Melt temperature*. Virtually all heaters in molds and molding machines today are electric *resistance* heaters. The heat output of a resistance heater is proportional to the *square* of the voltage applied. A drop of just 10% in voltage will reduce the heat output by 20%. While the barrel heaters of the extruder are always thermostatically controlled, a transformer, without feedback, often controls the machine nozzle heaters. With heat controls, any reduction in voltage (and temperature) will be automatically compensated by having the heaters ON for longer time periods. In hot runner molds, the hot runner manifold heaters are always equipped with thermocouples; however, because of the high initial costs (in the mold, and for the associated external controls required) many molds do not have heat controls on the nozzle tip heaters and can therefore experience