Working with the Machine

LESSON 4: Cycle Time and Productivity

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Making quality parts is only part of the challenge of injection molding. The key to success is making quality parts economi-cally. Productivity is the key to making economical parts. In injection molding shops, productivity is measured by the number of quality parts produced per hour, shift, or day.

There are two measurements of injection molding productivity. First, when the machine is running, it must produce good parts as soon as possible. Secondly, the machine must be kept running as much as possible.

This lesson focuses on the technician's role in reducing cycle time, downtime, and scrap.

Objectives of Lesson 4

1. Learn the definition of productivity and how it applies to you
2. Learn how to prevent downtime episodes
3. Learn how to minimize downtime episodes when they occur
4. Learn how to obtain the best rate of operation
5. Learn how to reduce scrap to a minimum

Objective One

Productivity

Productivity is a vital part of the molding technician's skill of craft. Good technicians know how to get the most good parts out of their machine on every shift. It is not enough to know how to operate the molding machine. You must also know how to operate the machine fast, while still making quality parts.

A good example of the relationship between skill of craft and productivity is a handyman framing a door in his house. A good handyman can frame a door in about two hours. The quality of the job is likely to be good, especially if it is his own house.

A journeyman carpenter can also do a good job framing the door. A journeyman carpenter can do the job in about twenty minutes because of his skill of craft. Productivity is measured in terms of quality and speed.

Making the machine run fast is one part of speed. The other part is keeping the machine running hour after hour. Getting the maximum number of quality parts every hour means running fast and running often.

Figure 1 shows the desired machine rate: the number of parts produced in a certain amount of time.

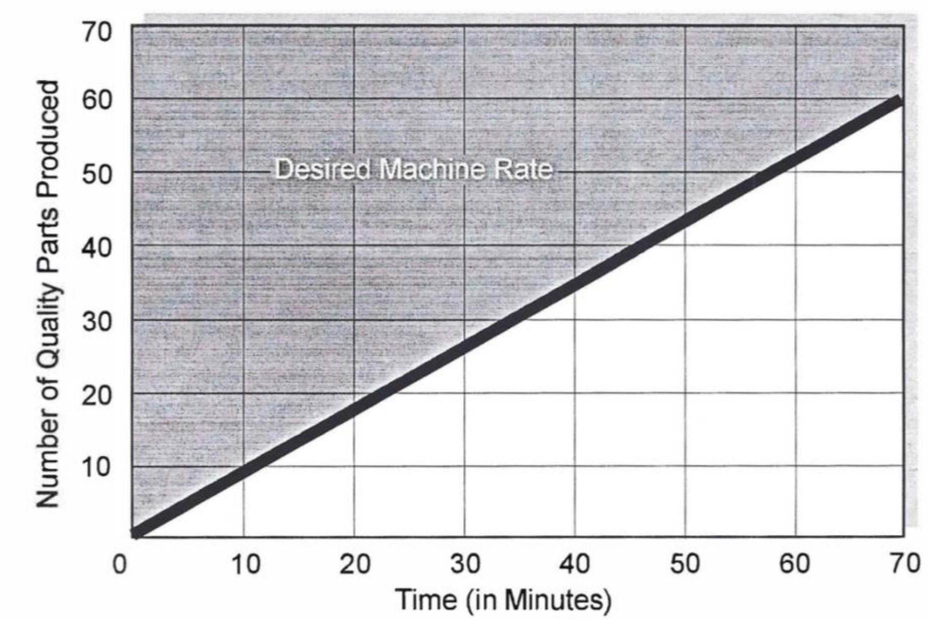

Figure 1 - Desired Machine Rate

Another important element of productivity is mental attitude. A technician with a good mental attitude will keep searching for ways to reduce the downtime and increase the quality of the parts. To do this you must always be alert, and aware of the entire process. Molding can be a repetitive process. Operators must challenge themselves to fight fatigue and boredom, and maintain a positive mental attitude.

Productivity comes from your knowledge and skill, not simply from working harder and moving faster. Some operators can run a machine very fast, but usually only for a short time because the process gets out of control, the machine goes down, or the operator gets tired. You must find the maximum rate the machine can operate with high reliability and a controlled process.

There are three important elements that add up to good productivity. These are shown in Figure 2.

Job Knowledge
Mental Attitude
Pride of Craft
PRODUCTIVITY

Figure 2 - Productivity

Objective Two

Preventing Downtime

One of the biggest contributors to lost productivity is machine downtime. Machine downtime is any time that is lost because the machine is not cycling and producing parts. There are many causes of downtime. The causes may be related to the machine, the molding technician, or any of the auxiliary equipment around the machine.

One of your responsibilities is to stay alert and aware of process conditions. The following list can help you predict when something is happening that may cause the machine to go down. The key to preventing downtime is to anticipate problems before they become major.

Downtime Warning Signals

Sticking Ejection

Sticking ejection systems are sure signs of impending downtime. The sticking may be caused by worn or bent pins, an obstruction in the system, or poor lubrication. If ignored, any of these problems could cause serious damage to the ejection system. Repairing the ejection system usually means taking the mold apart. A few minutes of maintenance will prevent this type of major downtime episode. Always keep a close eye on the movement of the ejector system.

Exercise One

Smooth Cycles

On several machines, watch the ejection system during several cycles. Is the movement smooth during ejec-tion and on return? Record your observations.

Machine Number	Smooth during Ejection	Smooth during Return
____________	☐	☐
____________	☐	☐
____________	☐	☐
____________	☐	☐
____________	☐	☐

Instructor Date

Bending Pins

Bent ejector pins, like the ones in Figure 3, can also cause serious downtime episodes. Often the pins will begin to bend because of sticking parts or a binding ejection system. Pins can also bend when the technician sequences the machine incorrectly. Use care when parts are being ejected. Be careful when running the machine in manual mode. Closing the mold or sliding cores onto the ejector pins could put the machine down for hours.

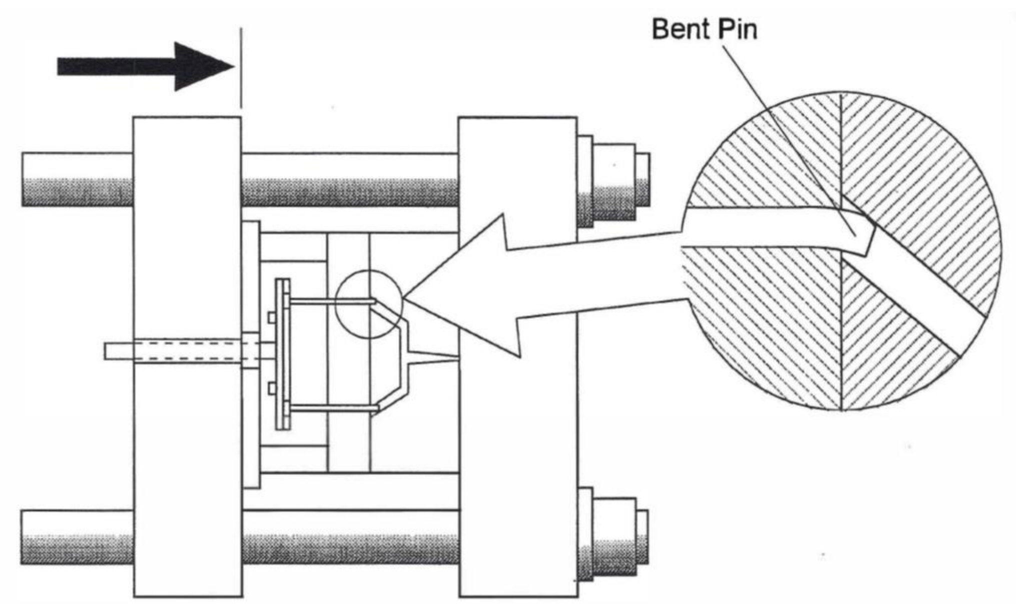

Figure 3 - Bent Ejector Pins

Sticking Parts

Parts stick in the mold for many reasons. Parts can stick because of improper mold temperature, incorrect cooling time, or many other reasons. It is often easy to correct sticking parts if the cause is discovered early enough.

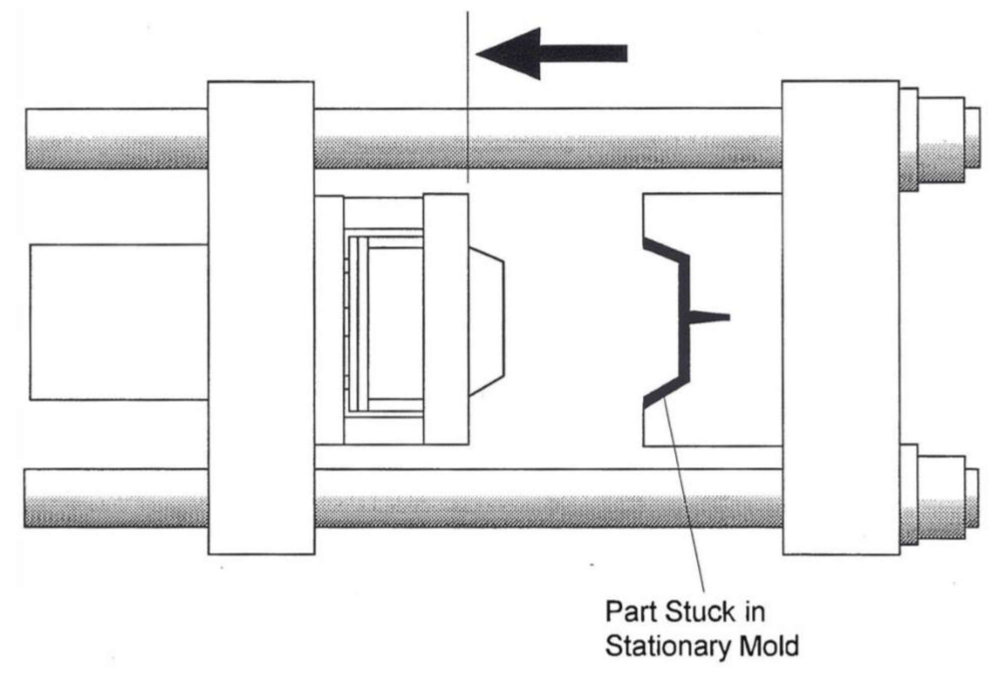

Figure 4 - Part Stuck on Stationary Half of the Mold

Stuck parts in the stationary half of the mold, as illustrated in Figure 4, may take a long time to remove. This will greatly reduce the productivity of the machine.

Flash

Flash on the mold face, or excessive flash on the part, is usually an early warning sign of trouble. If the flash line on the formed part is larger than normal (Figure 5), this could be impending mold face flashing.

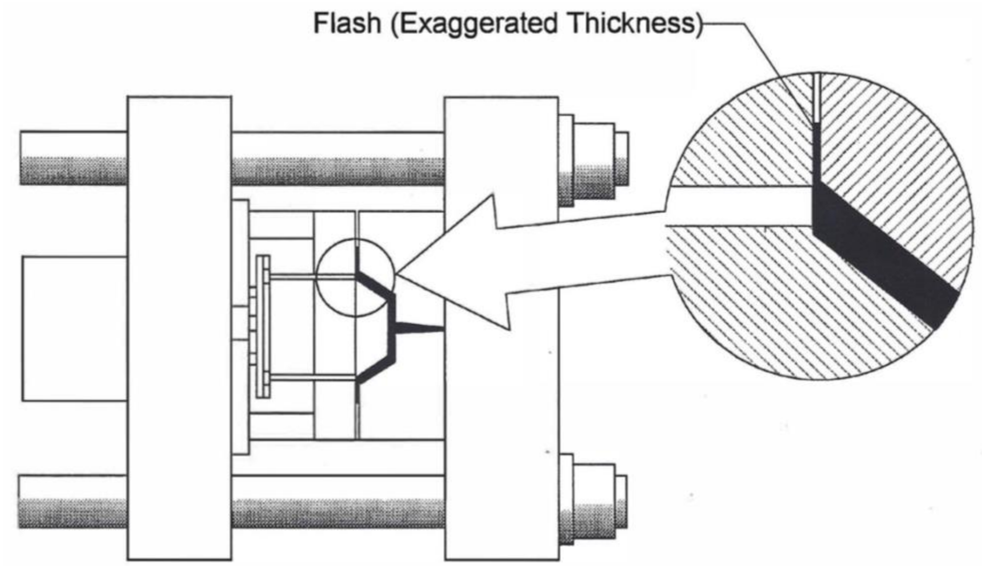

Figure 5 - Flash

Corrective action should be taken immediately to find the source of the problem. The mold face, clamping force, injection speed, and melt temperature should all be checked. The machine may have to be shut down if flash gets behind the cores or ejector pins. Some molds may even need to be removed and taken apart. Completely cleaning the mold could take hours, or even days. Solve flash problems quickly before they shut down the machine.

Exercise Two

Mold Temperature

On several machines, record the temperature of the mold with a hand held thermometer, and compare your readings to the temperature on the mold water heater.

Machine Number	What Caused the Part to Flash	What Was Done To Fix the Problem

Instructor Date

Lubrication Systems

Check the lubrication systems on the machine periodically. Some reservoirs may need to be filled. Other systems also need to be cleaned periodically. Lubrication systems that are not working properly can cause parts of the machine to wear out prematurely, causing downtime.

Process Control

Allowing the process to wander out of control can cause unnec-essary downtime. Excessive pressure or speed can damage critical parts of the machine so that repairs will be needed. Keep an eye on the process to make sure it does not drift out of the process parameter windows. A process window is a range within which a process parameter can fluctuate without affecting the quality of the part. Figure 6 is a statistical process control chart that shows a machine operating within its process window. Each of the process variables (temperature, pressure, speed) has a process window. Pay close attention to the process. Make sure you notice a change in the major process parameters before you start making bad parts.

Anticipate Problems
Steady Process
DOWNTIME PREVENTION

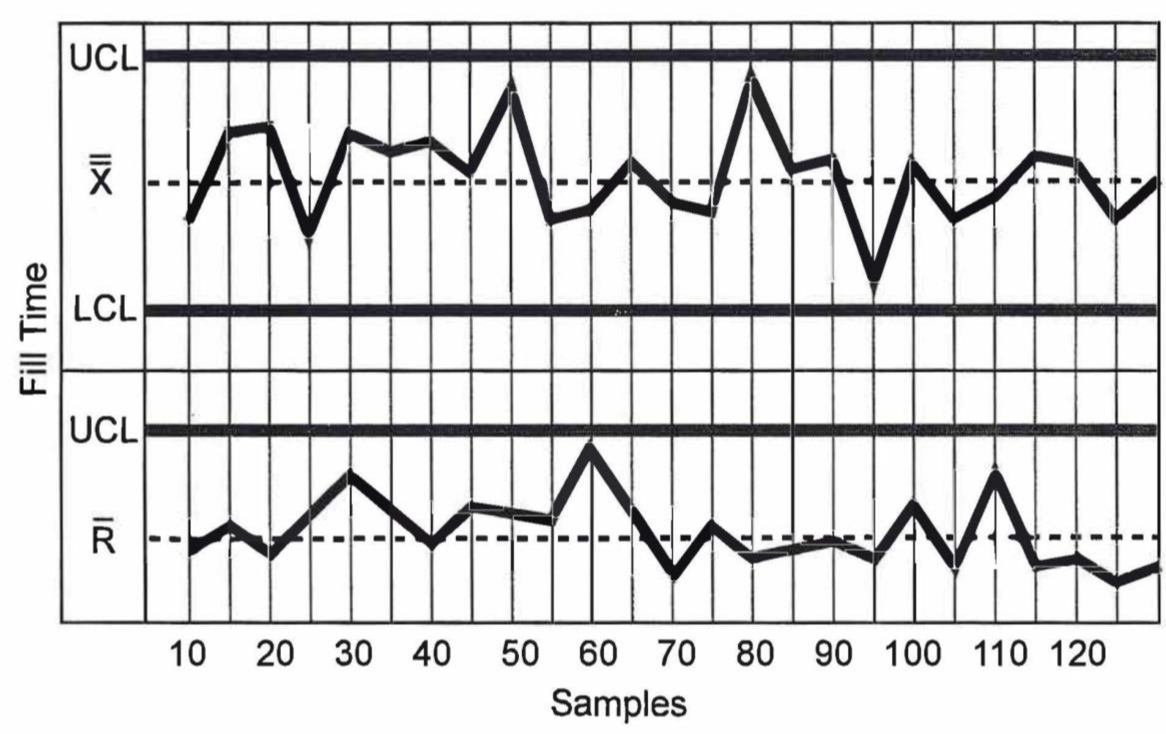

Figure 6 - Statistical Process Control Chart

Objective Three

Keeping Downtime Episodes Short

Even with the best downtime prevention techniques, all machines will occasionally go down. When the machine does go down, it is the technician's responsibility to take action to minimize the amount of downtime. The following list is a guideline of some of the things you can do to speed the machine back to production.

Close Up the Mold

Unless the machine is stuck open, or people need to work on the mold, close the mold as soon as the machine goes down. This will keep the temperature constant. Open molds will quickly deviate from their temperature settings.

Alert Your Supervisor

Notify your supervisor and maintenance personnel as soon as you need help on the machine. They are very experienced with machine problems and maintenance. They can help you predict how long the machine may be down.

Downtime for Setup

Any time the machine is down for setup, you have additional responsibilities to help the setup go as quickly as possible. Use the following list to help plan for the setup.

Have Tools Ready

Anticipate the tools you may need during setup. Have them ready. You will often need wrenches, pliers, screwdrivers, gloves and other protective clothing (Figure 7). Setup time is a critical downtime episode. Good planning and preparation can help minimize the time it takes to setup the new mold.

Figure 7 - Setup Equipment

Start the Heating and Cooling Systems

As soon as possible, start the heating and cooling system to the new mold. A large part of setup downtime is waiting for the mold to arrive at the proper temperature. Starting the heating and cooling fluids early will minimize this time.

Hot water heaters and hot oil heaters should be turned on as soon as possible. This will allow the heaters time to come up to the proper temperature. As soon as possible, hook up the oil and water lines.

Monitor the Heating and Cooling System

Figure 8 shows a water chiller, part of the cooling system of an injection molding machine. You should monitor the heating and cooling system with thermocouples, or by timing the heating and cooling fluids. Most shops have definite procedures for bringing a new mold to the proper temperature.

Figure 8 - Water Chiller

Exercise Three

Downtime

Tour your shop and examine any of the machines that have recently been shut down. If they are undergoing maintenance, or are expected to start again soon, check the list to see if the downtime episode will be minimized.

Machine Number	Mold Closed to a Gap?	TCU On?	Barrel Heats On?

Instructor Date

Objective Four

Best Rate of Operation

Another important element of productivity is running the machine at the fastest possible sustainable rate. Your responsibility is to make sure that each part of the cycle runs as fast as it can without upsetting the overall process. Many molding shops set standards for the cycle time (parts per hour). You should make sure your machine runs very near the standard. The following guidelines should help optimize each part of the cycle.

Minimizing First Stage Time

Ideally, first stage injection time should run just long enough to fill the cavity. If first stage time is too long, reduce it to just over the fill time. Time how long it takes to fill the cavity with a stop watch. Start your watch when the screw begins to move forward. Stop your watch when the screw stops moving forward. Set the first stage timer about one second longer than the fill time you recorded.

Minimizing Holding Time

Once the first stage timer is set correctly, reduce the holding timer until you start making poor parts. Check each subsequent parts for larger sink marks. Sink marks are depressions or dimples on the surface of the part. Sink marks happen when the plastic does not solidify enough. Large sink marks are a sign that the part is not getting enough holding time to cool properly on the cores. Molten plastic keeps flowing after injection has finished. In-crease the holding time until the sink marks disappear.

Minimizing Cooling Time

Cooling time is one of the longest parts of the molding machine cycle. It is one of the best places to look to reduce cycle time. However, cooling time can easily be set too short. If the part is too warm, it will warp or tear as it separates from the core. If the cooling time is very short, the ejector pins might punch holes in the part without ejecting it. Increase the cooling time to a point where the ejection works properly and the parts do not warp or tear.

Minimizing Mold Open Time

On machines running in automatic mode, reduce the mold open timer to cover the shorter cooling and ejection times.

Clamp Movements

Shorten the ejector stroke and clamp stroke so that the mold opens just far enough to eject the part safely (Figure 9). Do not over shorten the strokes, however. Be careful to allow enough time and room for the parts to eject safely.

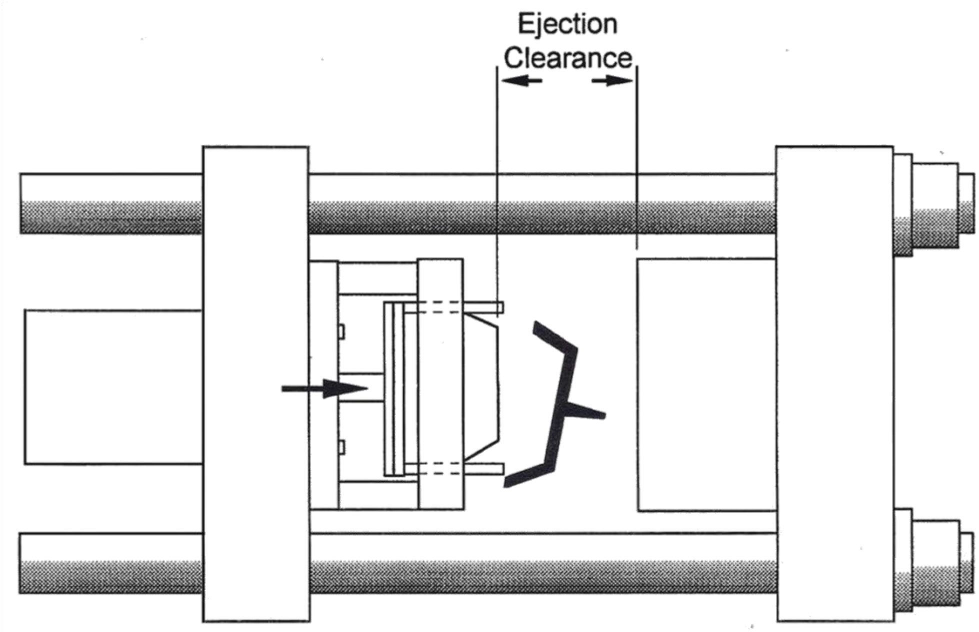

Figure 9 - Ejection

Screw Recovery Time

Dwell time is the time the screw spends fully recovered, turning and waiting for the next injection cycle. Some dwell time is unavoidable. Too much dwell time causes the plastic near the barrel walls to overheat.

Figure 10 illustrates the total Screw Recovery distance. Slow the screw recovery time by decreasing the screw rotational speed. The slower the screw turns, the longer it takes to move all the way back. If the screw takes too long to recover, it will still be moving and turning when the mold is ready to open. The mold will not open until the screw is all the way back. Set the screw rotation speed fast enough so the mold open timer does not have to wait for the screw. Set the screw rotation speed slow enough so the screw does not wait for the mold, and fast enough so the mold does not wait for the screw.

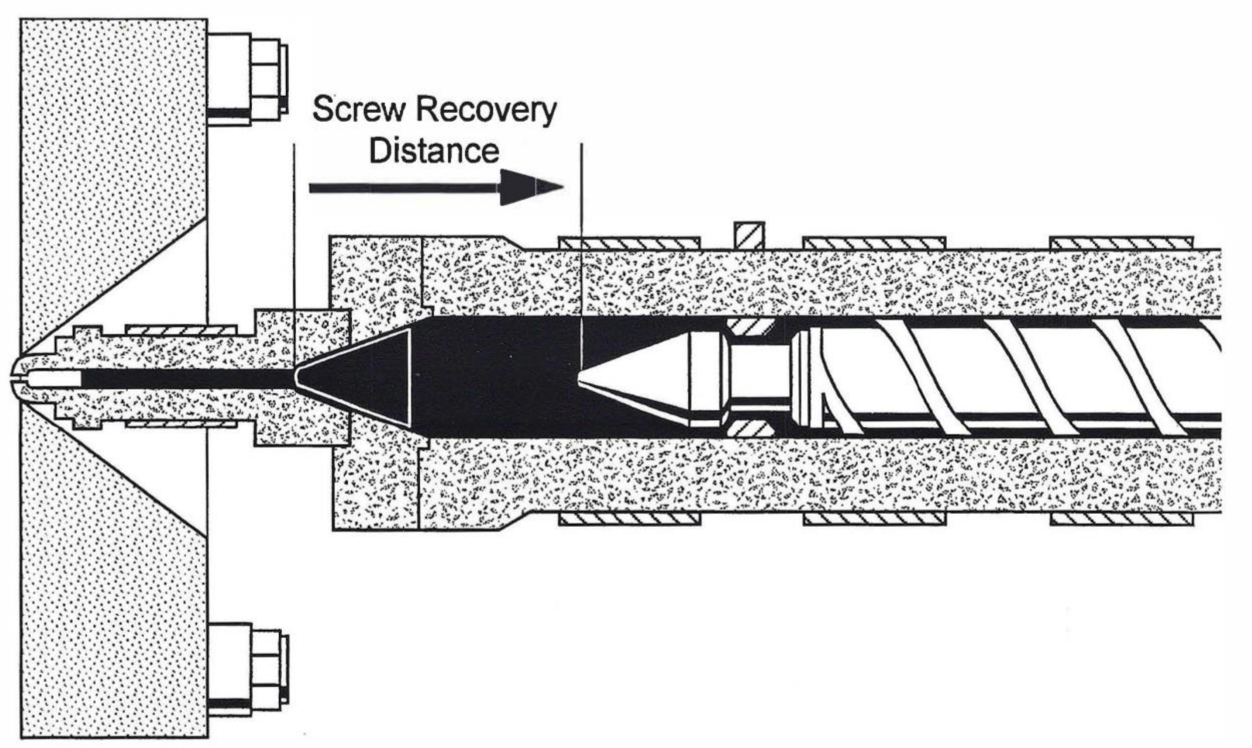

Figure 10 - Screw Recovery

Exercise Four

Cycle Time

On several machines, estimate, by counting or using a watch, the number of seconds for each part of the cycle.

Machine Number	Screw Recovery	Dwell Time	Cooling Time

Instructor Date

Objective Five

Reducing Scrap

In the first part of this lesson we stated that productivity is the number of good parts produced each hour, shift, or day. Scrap parts do not count toward productivity. Scrap is actually a double loss. When the machine is down, no good parts are being made, but the machine does not have to run. When scrap is being made, no good parts are being made, but the machine is running - using energy and materials and wearing out. In this sense the scrap castings are actually wasting machine cycles.

Scrap is usually made when the process is running out of the process window. This sometimes occurs when the process is out of control, or when the process window is not yet known. Each of the process variables, like temperature, pressure, and injection speed, has a window of acceptable values. Each of the process parameters is related to the others. When one parameter changes, it moves the window for the other parameters.

The following is a list of process parameters that can easily cause scrap if they are allowed to wander outside their range of acceptable values.

1. Melt temperature
2. Mold temperature
3. Injection speed
4. Injection pressure
5. Hold time
6. Clamp tonnage
7. Ejection speed
8. Ejection pressure (if hydraulic)

Most of these parameters can be monitored or controlled with modem process controllers. The parameters are interrelated, so each should be monitored independently.

Adjusting the process to increase the speed may also increase the scrap rate on the machine. This is a complicated problem -choosing between running slower without scrap or faster with more scrap. There is a delicate balance between the two. Be sure to consider the extra wear on the machine, and the extra cost of cycling the machine faster.

Exercise Five

Scrap

On several machines in your shop, find scrap parts. Investigate the defect to determine its cause. What should have been done to correct the problem?

Machine Number	Scrap Cause	Solution

Instructor Date

Self-Test

1. Productivity is measured by:
   a. The number of parts per hour
   b. The quality of the parts
   c. The number of quality parts per hour
   d. The number of machine cycles per hour
2. Having a good mental attitude means:
   a. Always acting cheerful and smiling a lot
   b. Scoring well on self-tests
   c. Always searching for ways to reduce downtime
   d. Always searching for ways to reduce scrap
   e. Both C and D
3. The key to preventing downtime is:
   a. To anticipate problems before they become major
   b. To solve problems before they occur
   c. Keeping the machine running as fast as possible
4. One sign of possible impending downtime is a sticking ejection system?
   a. True
   b. False

5. It is usually easy to solve sticking part problems if they are caught early enough.
    a. True
    b. False
6. Setup and startup time are considered downtime episodes.
    a. True
    b. False
7. First stage injection should run just long enough:
    a. To fill the cavity
    b. To pass the gates
    c. To pass the sprue
    d. To pass the nozzle
8. One of the first signs that the holding time is too short is:
    a. Flash
    b. An unplanned downtime episode
    c. Sink marks
    d. Short shots

9. The clamp and ejector stroke should open:
    a. Far enough to remove the mold
    b. Small enough to keep the mold warm during downtime
    c. Far enough to safely eject the part
    d. As far as the highest core
10. Too much dwell time:
    a. Causes the plastic near the barrel walls to freeze
    b. Causes the plastic near the barrel walls to overheat
    c. Makes the mold wait to open until the screw recovers completely
    d. Makes the mold open too soon

Glossary

Cycle time - the time it takes the machine to complete one full cycle of injection and ejection.

Downtime - any time when the machine is not cycling and producing parts.

Machine Rate - the number of parts produced per unit of time (usually parts per hour).

Productivity - making the maximum number of quality parts every hour.

Scrap - parts that do not meet quality standards.

Setup - the planned downtime for installing a new mold and setting the new parameters.

Statistical Process Control - a parameter charting method used to ensure that any parameter fluctuations are within acceptable limits.