Molding Materials and Process Troubleshooting

LESSON 2: Plastics Processing Behavior

Lesson 2: Plastic Processing Behavior

Every plastic resin is a unique substance that responds differently to outside forces. Some families of plastics, however, have generally predictable behavior. In this lesson we will discuss the major process conditions and characteristics of some of the plastics you are likely to encounter.

Objectives of Lesson 2

1. Learn the names of the principle process parameters and conditions
2. Learn the processing characteristics of common plastics
3. Learn about processing resins with regrind, additives, fillers, and colors
4. Learn about the behavior of plastics after molding

Objective One

Process Parameters and Conditions

There are four main molding parameters which affect the quality and size of the finished part. The four main molding parameters are: plastic temperature, flow rate, cavity pressure, and cooling rate. Each of the fifteen or twenty machine process controls have an effect on the molding parameters. Process controls are temperature, pressure, and speed settings on the machine that affect the main molding parameters.

Plastic Temperature

Plastic temperature has a great effect on viscosity. Viscosity is a material's resistance to flow. High viscosity means a material is thick and slow flowing, like honey. Low viscosity means a material is runny, like water. Higher melt temperatures usually decrease viscosity. The warmer the plastic, the "runnier" it gets. Viscosity greatly affects the fill rate, and the cooling rate, of the part. Plastic temperature is most affected by barrel temperature and back pressure.

Flow Rate

The flow rate of plastic has a tremendous effect on the viscosity. The faster the plastic is pushed into the cavity, the more likely the plastic will get "runnier". Flow rate is most affected by the injection speed and the plastic temperature.

Cavity Pressure

Cavity pressure determines how the cavity is ultimately packed. Cavities under high pressure will pack more molecules of plastic into the same sized part. This will obviously affect part size and quality. Cavity pressure is dependent on the injection pressure setting, the material temperatures, and the injection forward time.

Cooling time

Cooling time affects the rate at which the part shrinks. The longer a part cools, the more it contracts to its minimum possible size. The cooling rate is primarily determined by the mold temperature and the plastic temperature.

Melt Behavior

Viscosity

Viscosity is a material's resistance to flow. Low viscosity means a substance flows easily, like water. High viscosity means a substance flows slowly, like honey. Figure 1 illustrates the different viscosities of water and honey.

Figure 1 - Difference in Viscosity

Viscosity is one of the most important melt characteristics. Technicians who understand viscosity are closer to understanding how the molding process works.

Viscosity is very dependent on the temperature of the melt. As a general rule, most plastics lose viscosity as they heat up. Think of maple syrup. Hot maple syrup is much runnier than cold syrup. The same is true of motor oil, and plastic for injection molding.

Viscosity is also dependent on shearing action. If a plastic melt is forced through a gate quickly, the molecules will temporarily align and slip past each other more easily. This can cause a large decrease in the viscosity of the melt. This phenomenon is referred to as shear thinning. The viscosity of the melt can be reduced (made runnier) by increasing injection speed.

Viscosity also depends on the molecular weight of the plastic. Earlier, we described plastic resins as a collection of long chains made from carbon, hydrogen, and other elements. The molecular weight of a plastic is a measure of how long the chain is. The more elements in one link of the chain, the heavier the plastic's molecular weight. The higher the molecular weight, in general, the higher the viscosity. In a sense, a chain made of longer links will not flow as easily as a chain made of smaller links.

Melt Index

A plastic's viscosity is often rated according to its melt index. A resin's melt index is a measure of how many grams of plastic will flow through a set orifice, during a ten minute period at a standard temperature and pressure. Plastics with a high melt index number have low viscosity.

The melt index number is a useful way of comparing plastics in the same family. Comparing very different sorts of plastic is not always accurate. The melt index tends to depict viscosity at lower temperatures where shearing may not have much effect. Different plastics have very different viscosity at higher temperatures. In general, use the melt index to make viscosity comparisons amongst resins in the same general family. Avoid comparing melt indexes on radically different resins.

Exercise One

Viscosity

List the most common plastic used in your shop, and the various grades of that plastic. Determine whether each grade has a high, medium, or low flow rate. If possible, record the melt index number.

Plastic	Flow Rate (High/Medium/Low)	Melt Index Number

Instructor Date

Orientation

Orientation is the alignment of the chains of plastic. Normally, the chains in molten plastic are not aligned. They form a random, spaghetti-type pattern. Injecting the melt through the runners and gates tends to stretch out, line up, and orient the chains.

Orientation happens during injection. The forces that push the melt into the mold stretch out the chains of plastic until they are oriented with one another. As the part cools, the chains have a chance to return to their normal state. The chains can only relax while the part is cooling. Once the part solidifies, the chains are "frozen" in whatever position they find themselves. If the part solidifies quickly, with a very short cooling time, any lingering orientation will be preserved in the final part.

The alignment in oriented plastic acts almost like the grain in a piece of wood (Figure 2). The material is stronger along the grain than across the grain. In plastics, the material is stronger in the direction of orientation. Highly oriented or aligned parts will have a stronger and weaker direction. Designers usually want the part to have good uniform strength in all directions .

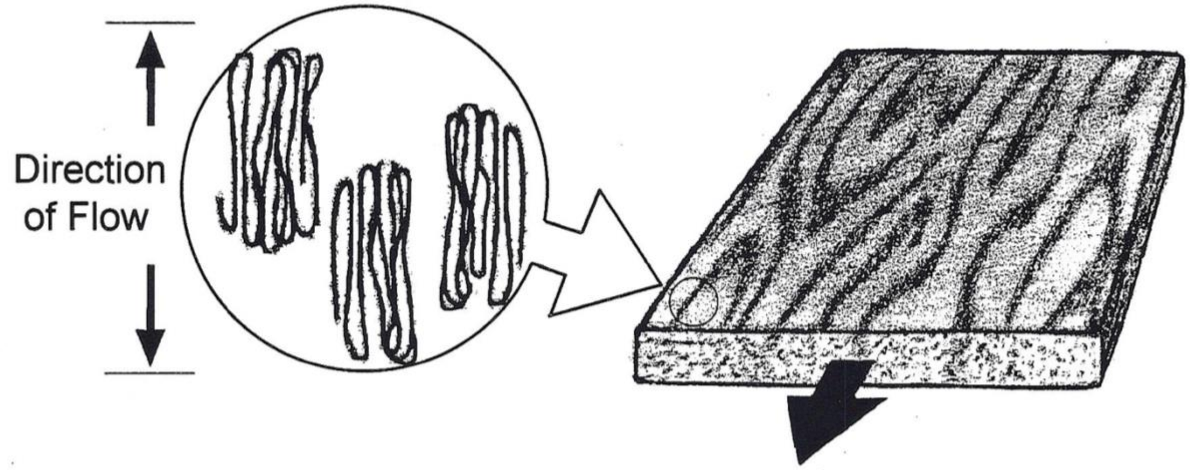

Figure 2 - Plastic Orientation

Parts with high orientation are generally weaker and more subject to warping and stress. Any time plastic is preserved in a state in which it would not ordinarily rest, internal stress results. This makes for a weaker part.

Degradation

Degradation is a harmful change in the chemical nature of the plastic. The plastic behaves differently because, chemically, it is a different substance.

Degradation is usually caused by high melt temperature, keeping the melt hot too long, or over-shearing. Over-shearing means the plastic chains are squirted through the gate so fast that some of the chains are broken down. It may also mean that some of the side-chains are broken off, causing by-products.

One of the first signs of degradation is color change. Plastics starting to break down sometimes take on a yellowish or brownish color. Plastics that are completely degraded may even tum black and charred.

Parts made from degraded plastics will not have the same physical properties as correctly made parts. The degraded part often will differ in strength, hardness, dimensions, and impact resistance .

Material Behavior in the Cavity

Packing

Packing is the application of pressure on the part from the moment of injection to the moment the gates freeze off. Parts need the right amount of packing in order to fill out properly.

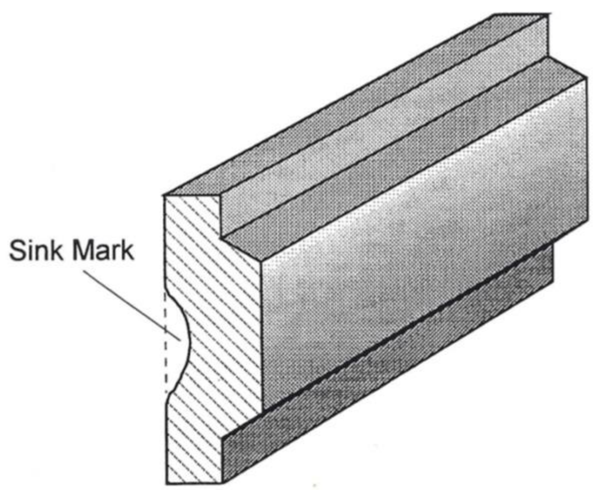

Figure 3 - Sink Mark

Too little packing means the melt was not injected with enough pressure. The part may have sink marks. Figure 3 shows a plastic part with a sink mark caused by under-packing the cavity. The part may not have a good surface finish.

Under-packed parts sometimes have porosity. Porosity comes from the word porous. It means having small holes or pockets. If there is not enough plastic to fill the cavity, small holes and pockets can form in the walls of the part.

Over-packing can cause a number of problems. Over-packing can lead to flashing on the part or on the mold face. It may also cause cracks on or near the gates. Over-packed parts can stick in the cavity, and cause ejection problems.

Some molding shops use a rule of thumb that says every extra l000lbs. of injection pressure will pack another one half percent of plastic into the cavity.

Internal Stress

Plastic is not a perfectly obedient material that will take and keep any shape you give it. If you ignore the natural tendencies of the plastic, you will make a part with an internal desire to change shape. Internal stress is often caused by over-packing. Internal stresses can also be caused by sections of the part cooling at different rates. If a thin walled section and thick walled section of the part are very close together, the thin walled part may become over-packed in order to get enough plastic to fill the thicker walled section. The different packing weights and the different cooling rates of the two walls will cause very different tendencies in the part.

Internal stresses can also be caused by orientation. Normally, the chains of molecules in molten plastic are not aligned. They form a random, spaghetti-type pattern. Forcing the chains though the narrow runners and gates tends to orient the chains. The chains stretch out and run more parallel to each other. As the part cools, the chains have a chance to relax and return to their natural state. If cooling time is too quick, the part will solidify with a high degree of orientation. This will create an internal stress. Left to its own devices, the part would like to return to the spaghetti pattern. If the part is heated during use, the chains will attempt to re-shape and the part may. This internal stress makes for a weak and unreliable part.

Crystallization

Crystalline resins have tightly packed chains of molecules. The molecules have a natural tendency to form into very tight crystals. Since the crystals have a definite shape and structure, they can pack together closely. This makes crystalline resins cloudier than amorphous resins.

Generally, crystalline resins are more heat resistant than amorphous resins. Crystalline resins have a narrower melting range than amorphous resins. Crystalline resins have tightly packed chains of molecules.

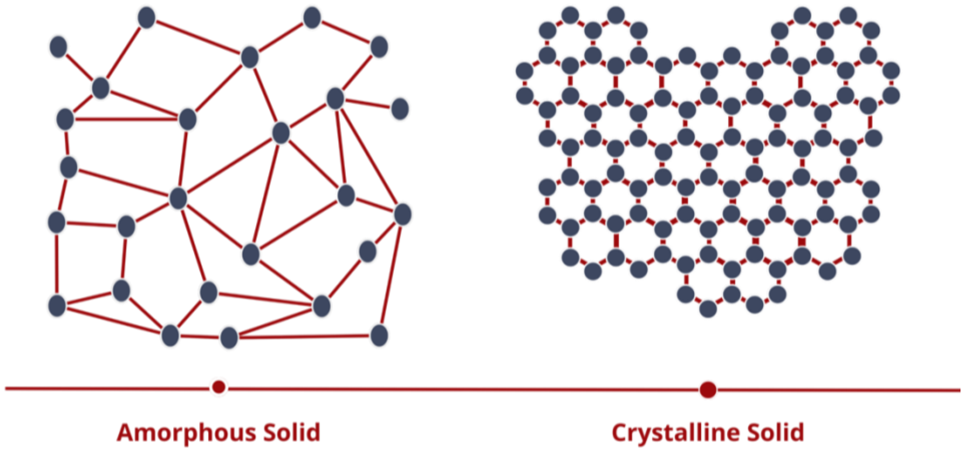

Figure 4 - Amorphous and Crystalline Structures

Amorphous resins are made of long chains that stay relatively far apart. Amorphous plastics have a broader melting range, and are generally easier to process than crystalline plastics. Figure 4 shows amorphous and crystalline structures.

Crystalline resins form crystals as the part cools. The crystals are more tightly packed than ordinary amorphous resins. Therefore, crystalline resins show much more shrinkage than amorphous resins. It is harder to predict the final dimensions of a part made from a crystalline resin. The rate at which the molecules crystal-lize determines the amount of shrinkage, the cooling time of the part, and ultimately the overall cycle time.

Shrinkage

Shrinkage is the natural result of heating a solid plastic until it is molten, then allowing it to cool under pressure. Plastic resins each have their own rate and percentage of shrinkage. The size of the cavity is not exactly the size of the finished part.

The molded plastic part will shrink slightly as it cools, as shown in Figure 5. To make a part of specific dimensions, designers must be able accurately to predict how much a part will shrink during cooling.

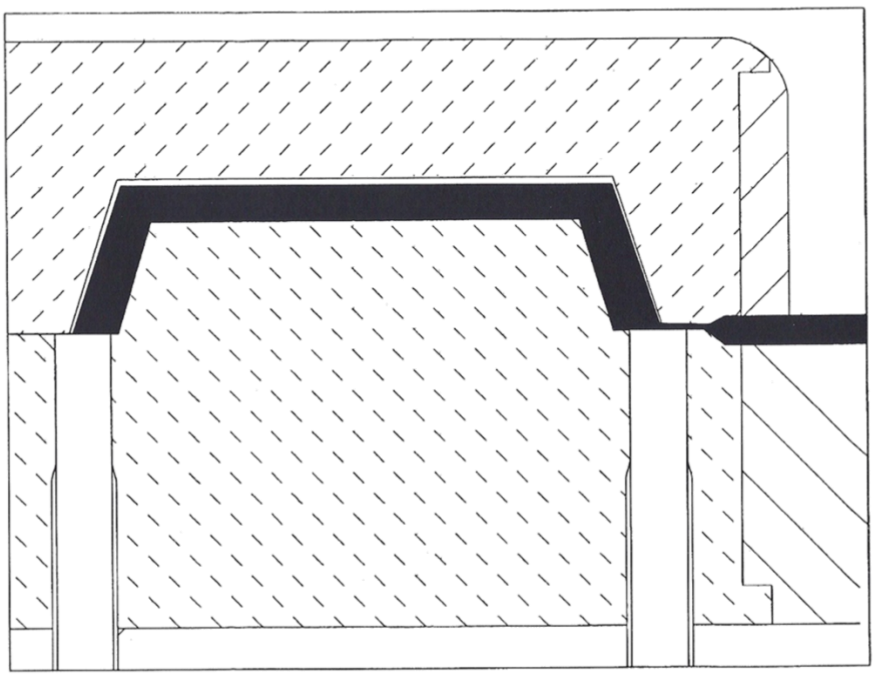

Figure 5 - Part Shrinkage in a Mold

Objective Two

Processing Specific Plastics.

In this part of the lesson we will discuss the general processing characteristics of some of the most common plastics. Some grades of plastic may differ greatly from the general descriptions in this lesson. For detailed information, refer to the materials processing manual from your plant's plastic supplier. Materials processing manuals have specific information on recommended safe temperatures, processing tips, and purging procedures.

Volume Plastics

Volume plastics are generally the easiest and most economical resins available today. They usually do not need to be dried before molding. Volume plastics are heat stable. (One exception is PVC, Polyvinyl Chloride]. Most volume plastics have low melting points. They also can be molded with cooler mold temperatures. Table 1 shows typical process conditions for commodity plastics.

Table 1 - Commodity Plastics Data

Plastic	Melt Temp. (F)	Mold Temp. (F)	Screw Speed (RPM)	Back Pressure (PSI)	Shrink (in./in.)	Drying Required
LDPE	375-500	50-100	Max	50-100	.015-.025	No
HDPE	400-600	50-150	Max	50-100	.025-.040	No
PP	425-550	50-150	Max	50-100	.015-.020	No
PS	375-550	100-150	50-200	50-100	.004-.005	No
Flex PVC	310-550	100-150	150-200	50-100	.004-.010	No
Rigid PVC	330-360	100-150	50-75	100-150	.005-.006	No

Polyethylene and Polypropylene

These two similar plastics are classified as semi-crystalline. They exhibit processing characteristics of both crystalline and amorphous plastics and have a wide melt range. This means there is a wide temperature range where the plastic is molten and can be used to make good parts.

Neither of these resins creates much frictional heat during screw rotation. Both of these plastics will show a large change in viscosity when the temperature changes. Polyethylene and polypro-pylene exhibit high rates of shrinkage.

Polystyrenes

Polystyrene is one of the simplest materials to mold. It also has a wide useable melt range. Although polystyrenes as a group have a wide melt range, High Impact Polystyrene (HIPS) can lose a great deal of impact strength if molded at too high a temperature. Polystyrenes create a great deal of shearing during screw rotation. Crystal styrene's are fairly brittle, and can crack easily during ejection if over-packed or over-cooled.

Polyvinyl Chlorides

Polyvinyl Chloride (PVC) is a heat sensitive plastic. It quickly degrades if left in the barrel too long. When PVC degrades, it gives off corrosive and noxious gases. Many manufacturers recommend keeping the barrel temperature below 420° Fahren-heit. For shutdown, or a change in materials, always purge out PVC with a heat stable plastic or a purging compound.

PVC is usually molded in stainless steel or nickel plated molds because of its corrosive qualities. If the temperature is properly controlled, PVC molds well. Some pipe fittings require grades of PVC with very high molecular weight. The shearing action of a normal nozzle check ring is enough to degrade these types of PVC. These grades require a special smear type screw tip that minimizes the shearing effects.

There may be times you need to decrease the viscosity of PVC (make it runnier). To decrease the viscosity without increasing the barrel temperature, increase the back pressure or the screw speed. The added shearing effect will decrease the viscosity with a minimal increase in melt temperature.

Amorphous Engineering Resins

Engineering resins are plastics that can make stronger, tougher, more durable parts than volume plastics. Engineering resins are used to make parts with stricter engineering specifications. That is why they are called engineering resins. Typical process conditions for a variety of engineering resins are discussed in Table 2.

As a class amorphous engineering resins have good clarity and strength with very little shrinkage-usually between .004 and .008 inches per inch. Most amorphous engineering resins are hygro-scopic, meaning they absorb water easily, even from the surround-ing air. Hygroscopic plastics need to be dried before use.

Table 2 - Engineering Resins

Plastic	Melt Temp. (F)	Mold Temp. (F)	Screw Speed (RPM)	Back Pressure (PSI)	Shrink (in./in.)	Drying Required
PMMA	450-525	150-200	50-100	50	.004-.007	Yes
ABS	475-525	100-200	50-100	75-125	.005-.007	Yes
PPO	475-600	150-225	25-75	50	.005-.006	Usually
PC	525-625	175-225	25-50	50	.006-.007	Yes

Acrylic

Acrylic (PMMA) is a very transparent resin often used to make lenses, light fixtures, and outdoor advertising. Acrylic has very dry surface characteristics. This causes it to generate high frictional heat as it melts. You can minimize frictional heat by keeping back pressure and screw rpm low.

Acrylic makes a very good purging compound. Acrylic is a very viscous plastic. This means it is inherently thicker, and less likely to flow. Acrylic often needs a larger nozzle orifice to help it flow properly.

Acrylonitrile Butadiene Styrene

Acrylonitrile Butadiene Styrene (ABS) is one of the few resins that combines toughness with hardness. It is also one of the least expensive engineering resins. Its molding properties are very similar to HIPS. ABS can make a very glossy surface on a part, especially with a hot mold and high packing pressure.

ABS is available in many different grades, each with its own processing characteristics. Check with your supervisor, or the materials processing manual from your plastic manufacturer, to find the processing characteristics for the grades used in your shop.

Polyphenylene Oxide

Polyphenylene Oxide (PPO) has a higher melting point than many other plastics. Despite its high melting point, it is still considered heat stable. PPO can occasionally be molded without drying. There are many different grades of PPO. Each grade is based on the amount of styrene in the resin.

Recommended starting temperatures can be anywhere from 440° to 560° Fahrenheit. Most manufacturers also recommend higher mold temperatures, in the range of 150° to 250° Fahrenheit.

Polycarbonate

Polycarbonate (PC) is one of the toughest of all resins. It is also highly hygroscopic and prone to hydrolytic attack. Hydrolytic attack means it will degrade in the hot barrel if moisture is present. Be sure to dry polycarbonate resins properly before using.

Like acrylic, PC is a relatively hard flowing resin. It requires a large nozzle orifice. Use low back pressure and screw speeds. PC requires high mold temperatures in the range of 200°. PC usually requires high injection pressure to fill and pack the cavity properly.

Crystalline Engineering Resins

Typical process conditions for crystalline engineering resins are shown in Table 3. Crystalline engineering resins have tightly packed, structured chains of molecules. Crystalline resins have a narrower melting range than amorphous resins. Crystalline resins have a high rate of shrinkage, usually .015 to .035 in./in. Generally, you can use shorter hold times with crystalline resins because they solidify quickly in the mold. Crystalline resins work best with reverse taper nozzles. Often an otherwise correctly heated nozzle will lose heat at the tip. With crystalline resins, this heat loss can be enough to re-solidify a small portion of the melt. Normal taper nozzles would become clogged. With a reverse taper nozzle, the small solid portion can easily be removed with the sprue.

Table 3 - Crystalline Plastics

Plastic	Melt Temp. (F)	Mold Temp. (F)	Screw Speed (RPM)	Back Pressure (PSI)	Shrink (in./in.)	Drying Required
PA6	450-525	100-200	Max	50-100	.006-.014	Yes
PA6/6	500-550	100-200	Max	50-100	.012-.020	Yes
POM	400-450	150-250	100-150	50-100	.018-.025	Usually
PBT	450-500	150-225	50-100	50	.016-.020	Yes

Nylon

Nylon (PA) is strong and tough, with good temperature resistance. It is one of the most popular resins used today. There are many different types of nylon. Nylon 6/6 is the most common.

Nylon is very crystalline in structure. This gives it a sharp transition point between solid and liquid. As a liquid, nylon is one of the runniest plastics. Nylon almost always requires a reverse taper nozzle. The transition from liquid to solid is very quick. If the temperature falls a few degrees, nylon can easily freeze in the nozzle.

Barrel heat for nylon is usually set with a reverse heat profile. Nylon barrels use a heat profile coolest at the nozzle tip and warmest at the feed throat. Nylon can use full screw speed and injection speed.

Acetal

Acetal (POM) is one of the strongest of all plastics. It has a very narrow melt range, typically 380° to 440° Fahrenheit. Acetal degrades very easily if heated above 440°, or if left at normal melt temperature for more than fifteen to twenty minutes. When acetal degrades, it gives off noxious, corrosive gases. Always purge acetal out of the barrel with a heat stable material before shut-down. Acetal can be molded with relatively high mold temperatures, often around 200° Fahrenheit. Acetal can use a wide range of injection speeds and pressures without harm. It can sometimes be used without pre-drying.

Polyester

Polyester (PBT) is a hard resin that is resistant to heat and chemicals. It has a molding temperature range between 430° and 500°. Polyester will degrade above 520°. It must be well dried before using. Reverse taper nozzles will work with polyester, but are not necessary. Typical mold temperatures are between 150°and 200° Fahrenheit. Polyester solidifies quickly, so fast injec-tion speeds are common. Very little back pressure or screw speed is needed. Do not leave polyester in the barrel more than fifteen or twenty minutes without purging.

Exercise Two

Handling Problems

Determine which plastic in your shop is the most difficult to process. Give several reasons why this plastic is difficult to handle.

Name of Plastic:______________________________

Reasons Difficult to Handle	
1	
2	
3	
4	

Instructor Date

Objective Three

Special Processing

Many different materials can be added to the plastic to enhance, improve, or change its properties. Some of these additives are already incorporated into the plastic pellets fed into the hopper. Other materials must be added into the hopper and mixed at the machine. These materials may be batch mixed by hand, or auto-matically added through a metering unit on the hopper.

Regrind

Regrind can be made from the sprues, runners, and gates of earlier good parts. Sometimes scrap parts are also reground to be melted and used again. Save and grind up only clean, uncontaminated runners and parts. A part made from degraded or contaminated plastic should be discarded and not reground. Many shops try to add regrind at the same rate at which it is being generated. Often the part specification limits the amount of regrind that can be added. Many specifications limit regrind to ten to thirty percent of the plastic content.

Virgin resin with some regrind will often behave very much the same way as the base resin. Previously over-heated regrind, however, may lower the viscosity, which will change the process. If the regrind material is fed into the hopper, watch for unground sprues or chunks that could clog the feed throat. Do not use regrind with contaminants.

Exercise Three

Regrind

Find three plastic products that use regrind. What is the maximum amount of regrind you can use in each part?

Product	Maximum Amount of Regrind

Instructor Date

Color Concentrates

Color concentrates are used to change the color of the part. Color concentrates are pellets that are mixed with the plastic pellets to make colored parts. They can be mixed by the batch, or metered into the hopper. An additive metering unit is shown in Figure 6.

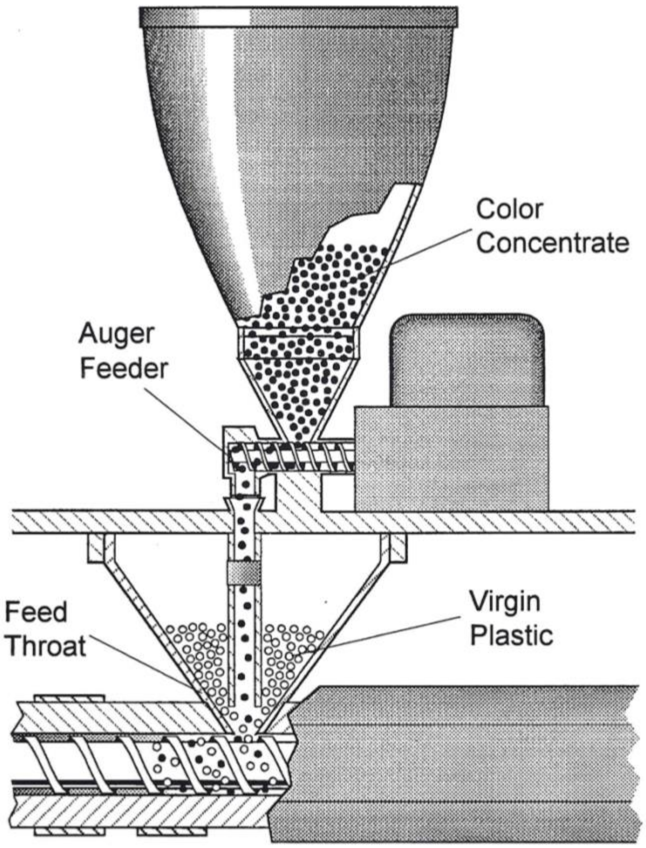

Figure 6 - Additive Metering Unit

For batch mixed colors, weigh out the proper percentage of concentrate, and completely mix the concentrates into the base resin. Metered systems dispense the color concentrate in a pre-set ratio. Be sure the proper ratio or percentage is set on the metering device.

If the parts come out with colored swirls, sometimes extra back pressure will improve the mixing action. Extra back pressure may increase the cycle time and change the process, however. Some color pigments have an upper melting range that is lower than the plastic's upper melting range. It is possible to fade the color by running the process too hot.

Fillers and Reinforcements

Plastics often contain materials added to improve the strength or other properties of the final part. Like plastic, fillers and rein-forcements can easily be damaged during processing.

Fillers

Fillers are materials that have been blended into the plastic pellets. Fillers such as calcium carbonate are often added to extend expensive plastics. Other fillers, such as mineral powders and silica, are added to increase hardness and reduce shrinkage.

Reinforcements

Reinforcements are materials added to the plastic, usually to make the plastic stronger or tougher. The most common reinforcements are glass fibers, or graphite.

Table 4 shows the typical process conditions for plastics with glass reinforcements.

Table 4 - Glass Reinforcements

30% Glass Filled Plastics	Melt Temp (F)	Mold Temp (F)	Mold Shrinkage (in/in)
ABS	400-550	175	.001
POM	400-450	225	.005
PA 6/6	500-575	200	.004
PC	550-650	250	.001
PE	400-600	100	.004
PP	400-550	125	.004
PS	400-550	125	.001
PPO	525-600	225	.001

Exercise Four

Fillers

Find several plastic parts in your shop that contain fillers. List the plastic, the part being produced, and the filler.

Plastic	Part Being Produced	Filler

Instructor Date

Processing Requirements

The key to successful processing of reinforced plastics is to keep the fibers from being ground up during injection. Reinforced fibers are subject to the same shearing problems as the plastic resin. The same actions that can break down the long chains of plastic molecules can also break the glass fibers.

One way to prevent shearing is to use higher melt temperatures. Plastics with reinforcements are commonly molded at temperatures that are 50° hotter than normal. The higher melt temperature makes the plastic less viscous (runnier). The melt can then be injected at lower pressures and speeds, minimizing the chances of shearing breaking the fibers.

Higher mold temperatures will also decrease viscosity with the same consequences. Hotter molds can also improve the surface gloss of the parts. Fibers and fillers often cause a poor surface. A higher mold temperature will often give a better surface finish.

Another way to fight shearing is to keep speeds and pressures low. Use lower back pressures and screw speeds to minimize shearing of the fibers in the barrel. Slower injection speeds will minimize shearing as the fibers pass through the gates.

One advantage of reinforced plastic parts is that they can be ejected from the mold before they are completely cooled. This is because the fibers help hold the parts together while the part is cooling, preventing it from warping. This can help lower the cycle time.

In general, reinforced plastics are more viscous (thicker, less runny). Parts made from reinforced plastics need to be packed at higher pressures. This usually requires higher clamping pres-sures on the mold.

Filled and reinforced parts are often very abrasive. They can cause premature wear on the screw, the rings, the gates, and even the cavity walls. Feed problems and screw drift during injection are early signs of excessive wear due to abrasive fillers.

Additives

Additives are chemical agents that have been added to the plastic to modify a physical property, or compensate for a deficiency in the base plastic. There are many types of additives that can affect the molding process.

Flame Retardants

Plastics like ABS do not have much natural resistance to flame. Molders add flame retardants to ABS to make the material more resistant to bums.

Like plastic resins, flame retardants can degrade if left in the barrel too long. The flame retardant can give off its own gaseous by-products that cause surface defects in the part. When molding ABS with flame retardant, keep in mind this additional processing problem.

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Objective Four

Behavior of Resins after Molding.

Post Molding Shrinkage

Parts shrink after molding because they are not completely cooled or completely crystallized. One way to control post molding shrinkage is to increase the mold cooling time. Some parts may even need an extra cooling step outside the mold. Parts are occasionally dropped into a water cooling bath.

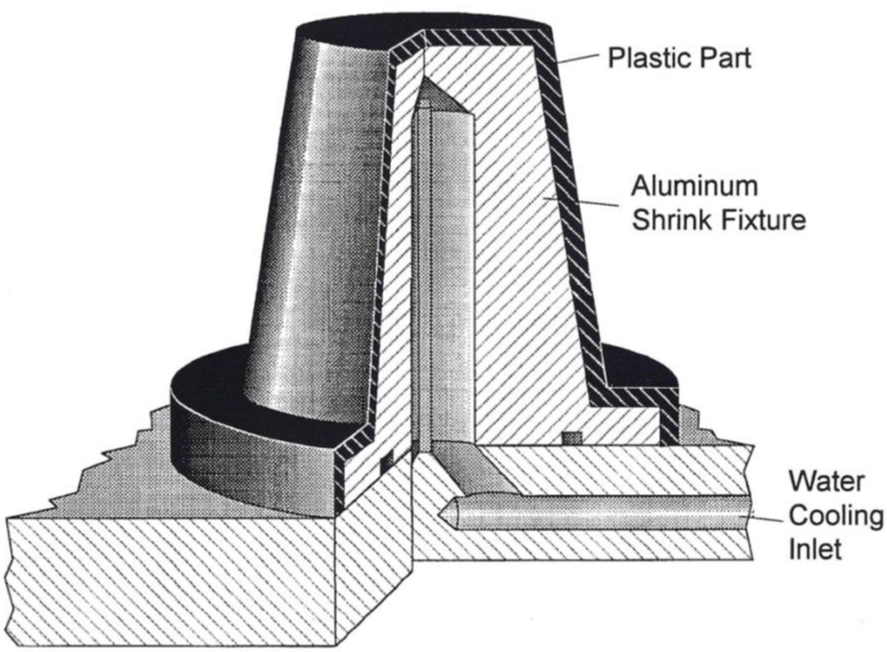

Figure 7 - Shrink Fixture

Shrink Fixturing

Some parts cannot be dropped in cold water as they will warp and shrink too much. Shrink fixtures are water cooled devices that are the same shape as the core in the mold, as shown in Figure 7. Parts can be removed from the mold and placed on the shrink fixture to continue to cool while the machine moves on to the next cycle.

Annealing

Some parts are exceptionally prone to molded-in stress. These parts need a longer cooling time to allow the chains of plastic molecules to return to their strongest, most natural state. Annealing is the process of heating the part slightly outside the mold to give the plastic chains more time to relax before final solidification. Parts are annealed by immersing them in hot oil or water. Sometimes, parts are even cured in a special oven.

Moisture Absorption

Nylon parts can actually re-absorb moisture from the atmosphere after molding. Added moisture can actually change the dimen-sions of the part after it is molded. Part designers use great care when choosing nylon for parts with very precise dimensions.

Exercise Five

Part Cooling

Find several plastic parts in your shop. Can they be immediately stacked or packaged after molding, or do they need to cool and harden first?

Part Number	Stacked/Packed Immediately	Stacked/Packed After Cooling
______________	☐	☐
______________	☐	☐
______________	☐	☐
______________	☐	☐
______________	☐	☐

Instructor Date

Self-Test

1. Which of the following is NOT one of the four main molding parameters?
   a. Plastic temperature
   b. Cooling rate
   c. Flow rate
   d. Cavity pressure
   e. Oil pressure
2. Cooling rate is primarily determined by:
   a. Injection forward time
   b. Mold temperature and plastic temperature
   c. Injection speed and injection pressure
   d. Back pressure and screw rpm
3. As melt temperature increases, the melt viscosity
   a. Goes up
   b. Goes down
   c. Stays the same
   d. None of the above

4. A high melt index number means the plastic has:
   a. High viscosity
   b. Low viscosity
   c. No viscosity
5. Which of the following is a heat sensitive plastic?
   a. Polystyrene
   b. Polyethylene
   c. Polyvinyl Chloride
   d. Polypropylene
6. Which plastic is often used in lenses, light fixtures, and outdoor advertising?
   a. Polystyrene
   b. Acrylic
   c. Polyvinyl Chloride
   d. Polypropylene
7. Which resin is one of the few to combine toughness and hardness?
   a. Polystyrene
   b. Acrylic
   c. Acrylonitrile Butadiene Styrene
   d. Polyvinyl Chloride
   e. Polypropylene

8. The most common plastic reinforcements are glass fibers and graphite.
    a. True
    b. False
9. Which resin also makes a good purging material?
    a. Polystyrene
    b. Acrylic
    c. Acrylonitrile Butadiene Styrene
    d. Polyvinyl Chloride
    e. Polypropylene
10. Our technique for controlling shrinkage after molding is:
    a. Annealing
    b. Bronzing
    c. Plasticizing
    d. Adding filler

Glossary

Color Concentrates - color pellets mixed with plastic pellets to make colored parts.

Degradation - a harmful change in the chemical nature of the plastic.

Filler - a material blended into plastic pellets to improve its properties.

Melt Index - a measure of the number of grams of material that will flow through a set orifice during ten minutes at a standard temperature and pressure.

Orientation - the alignment of the chains of plastics.

Plasticizer - an additive used to increase the flexibility and impact resistance of a plastic resin.

Reinforcement - materials added to plastic, usually to make it tougher or stronger.

Viscosity - a material's resistance to flow. High viscosity substances are thick and slow-flowing, like honey. Low viscosity substances are thinner and runnier, like water.