Molding Materials and Process Troubleshooting

LESSON 6: Dimensional and Physical Problems

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The phrase "dimensional and physical problems" refers to the tendency for a part to change shape or loose strength after molding. There are many reasons why a part might warp, bend, crack, or break. Most dimensional problems happen when one surface of a part cools and shrinks at a different rate from another. In this lesson we will examine some of the common dimensional and physical problems and some of the most common solutions.

Objectives of Lesson 6

1. Learn about molded part shrinkage and dimensional control.
2. Learn about the causes of, and solutions for, warpage and distortion.
3. Learn about causes of poor part strength in molded parts.

Objective One

Shrinkage

All plastic parts shrink as they cool as shown in Figure 1. Problems arise when the part shrinks too much, or shrinks more in one section than another.

back pressure can keep the plastic in the barrel too long. The screw shears the melt longer, raising the temperature.

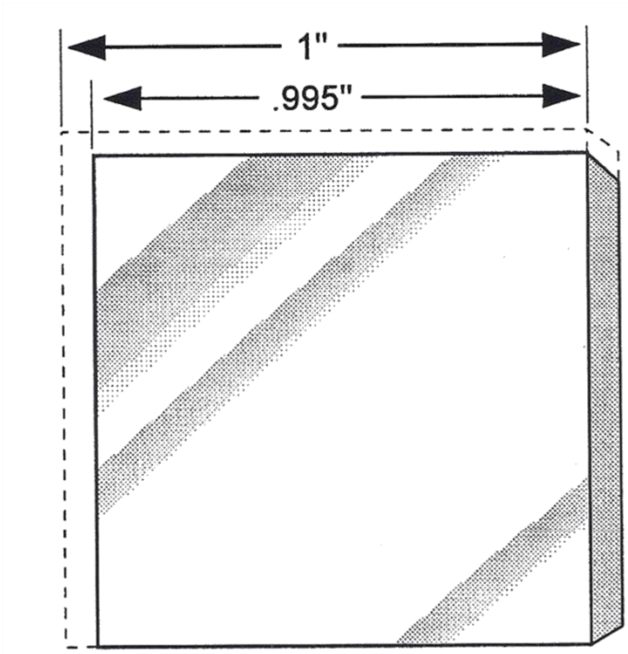

Figure 1 - Part Shrinkage

Excess shrinkage usually means there are not enough molecules of plastic in the cavity. If the cavity is not fully packed, there will be more space between the molecules. As the part cools, the plastic molecules move closer together and the part shrinks.

Exercise One

Shrinkage

List several plastics used in your shop, and any fillers or reinforcements they have in them. What is their average mold shrinkage rate?

Plastic Name	Fillers Used	Average Mold Shrinkage Rate

Instructor Date

Melt Temperature

If the melt temperature is too high, the molecules of plastic will expand away from each other. Hotter molecules expand away from each other and take up more space. Without additional pressure, the warmer melt will take up more space in the cavity. As the melt cools, the fewer molecules of plastic settle to their original spaces, shrinking the part. Melt temperature needs to be hot enough to allow for good flow into the cavity, but cool enough to prevent excess shrinking. You can decrease the melt temperature by lowering the barrel temperature, lowering the back pressure, or decreasing the screw rpm.

Injection Pressure and Holding Time

Hotter melt temperatures usually result in greater packing. In the case of shrinkage, however, the extra shrinkage from the hotter melt temperature usually offsets the extra packing effect. The injection pressure determines how hard the melt will be pushed into the cavity. If the pressure or holding time is low, the cavity will not be packed with as many molecules as possible. When the cavity is under packed, the molecules of plastic close up the extra space, shrinking the part.

Even if the injection pressure is correct, the holding time may be too low. Plastic in the cavity needs to be held under pressure long enough to solidify. Good holding time keeps the melt compacted until the part solidifies. This minimizes the amount of space between the molecules. Injection pressure and holding time need to be high enough to pack the cavity completely without flashing.

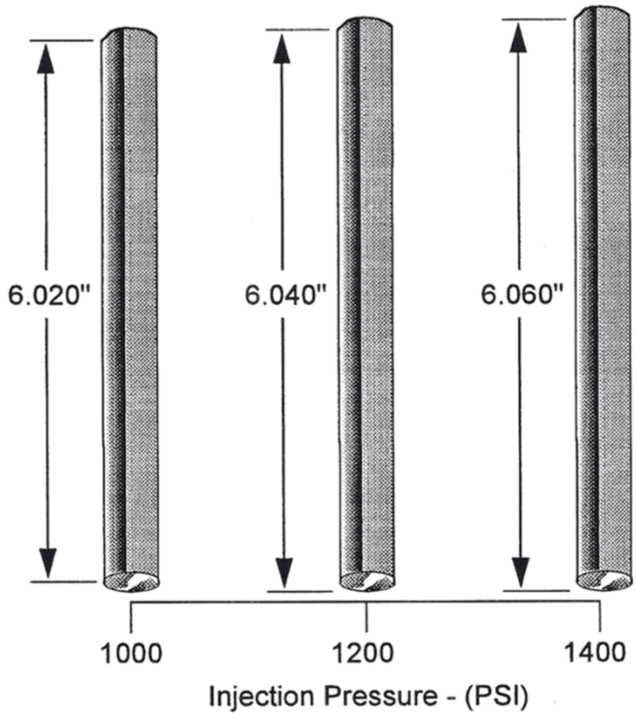

Figure 2 - Injection Pressure

Non-return Valve

The screw does not completely empty the barrel with each injection. After the shot, a small amount of material stays behind. The screw tip presses against this leftover melt, keeping pressure on the melt in the cavity. The extra melt is called the cushion. If there is no cushion, the screw head cannot keep pressure on the melt in the cavity. The non-return valve keeps melt in the barrel from slipping back into the screw flights. If the non-return valve is worn, or damaged, melt can leak around the valve. The cushion will actually slip back behind the screw tip. Without a cushion, the screw will not be able to hold the melt under pressure. Fewer molecules of plastic will pack the cavity, leaving the door open for shrinking.

Cooling Time

The part is supposed to shrink and cool inside the cavity. This ensures that the part shrinks to the shape of the cavity. If the mold opens too soon, the part may continue to shrink outside the mold. Make sure the mold stays closed long enough to allow the part to shrink properly. When the mold does open, it is important to keep the mold opening speed slow.

Exercise Two

Shrinkage

Find a mold and measure a key cavity dimension. Then locate a part from that mold, and measure the same dimension, using a micrometer or caliper. Calculate the mold shrinkage using the fallowing formula:

$$\frac{Cavity\ Dimension - Part\ Dimension}{Cavity\ Dimension} = Shinkage\ \left({}^{in.}/_{in.}\right)$$

Description	Study 1	Study 2	Study 3
Part Name & Number			
Material			
Cavity Dimension			
Part Dimension			
Calculation			
Mold Shrinkage			

Instructor Date

Objective Two

Warpage and Distortion

Warpage

Warpage is a change in the shape of the part after ejection. Most of the time, parts warp because they are under packed or because of uneven cooling.

Warping due to Under Packing

Under packing means the cavity does not contain as many molecules of plastic as it should. When the part cools, the molecules of plastic come together. Any extra space between the molecules gives the part room to form differently. Filling the cavity correctly means keeping the extra space in the cavity to a minimum. A good part usually comes from filling the cavity completely without flashing.

The cavity will be under packed if the injection pressure or holding time is too low. The injection pressure determines how much force to use to push melt into the cavity. If the pressure is too low, the cavity will not fill completely. The part may look complete, but really it is not as dense as it could be. The extra space between the molecules leaves room for warping or other distortions. With the mold open, different sections of the under packed part can cool and shrink on their own, without the cavity walls to contain them. This is a prime cause of warping.

Anything that slows down the flow of melt into the cavity can cause under packing. Cooler melt is more resistant to flow. Less plastic will make its way into the mold during injection. You can raise the melt temperature by increasing the back pressure, increasing the screw rpm to increase the shearing effect, or raising the barrel temperature.

The nozzle also has an effect on melt flow. The nozzle heater is the last definite temperature control before the melt enters the mold. Even if the nozzle does not freeze off, the temperature in the nozzle may be cool enough to slow the flow of plastic. The nozzle temperature needs to be cool enough to prevent drooling, but warm enough to allow good flow of material into the cavity.

Under Pack with No Cushion

The cushion is the melted plastic that stays in the barrel after injection. Even a long injection stroke will not completely empty the barrel. The leftover plastic is in contact with the plastic in the cavity through the sprue bushing. The screw tip keeps pressure on the molded part by pushing the cushion until the plastic in the mold freezes. If there is no cushion, the screw tip will not be able to maintain pressure on the part as it cools and shrinks. Frequently the part will become under-packed. Fewer molecules of plastic will be injected and held in the cavity until solidification.

The extra space that would have been packed with plastic leaves room for the part's molecules to maneuver as they cool. This causes warping. Be sure the shot size indicator is large enough to allow for enough cushion to pack and hold the part properly.

Uneven Cooling

In general, parts warp when one section shrinks faster or slower than another. Differential shrinking is usually a result of surfaces cooling at different rates.

Mold design is a leading cause of uneven cooling. A part made of thick and thin walls is very prone to warping. In general, the thick walled sections will not cool at the same rate as thin walled sections.

Mold temperature also has a lot to do with uneven cooling. Usually a hot mold promotes better flow of melt into the cavity for proper filling. On some parts, however, the warmer mold will keep thick walled sections molten longer. When the mold opens, thick walled sections may continue to cool after thin walled sections have already cooled and shrunk. The different cooling rates cause differences in shrinkage, which results in warping.

Uneven mold temperature can make a big difference. A mold with hot spots or cold spots will make the part cool and shrink at different rates. A hot spot might keep one surface of the part molten longer than the others. If the mold opens before the hot surface has finished cooling, it will shrink without the cavity walls to shape it. The result is warping.

Exercise Three

Temperature Difference

Try to find a mold that is running with different temperatures on its two halves. Find out why the two different temperatures are being used, and if this situation is affecting part warpage.

Part Name and Material		
Unintentional Mold Temp. Difference	Cavity Temperature	
	Core Temperature	
	Is this causing problems?	
Intentional Mold Temp. Difference	Cavity Temperature	
	Core Temperature	
	Is this causing problems?	

Instructor Date

Warpage due to Molded-in Stress

Sometimes, warpage can result from stresses molded into the part. Orientation happens during injection. The action of melting, mixing, and injecting the melt can line up the plastic chains. As the part cools, the chains normally return to their random state. When the part solidifies, the chains are "frozen".

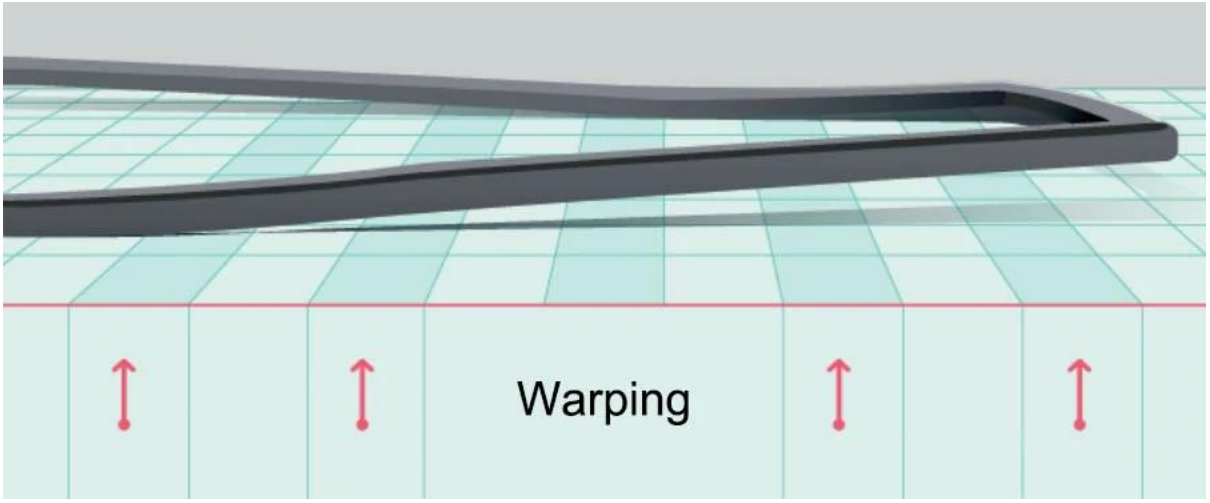

Figure 3 - Warp

Any lingering orientation will be molded into the part. Parts with internal stress can warp, because of the plastic's natural desire to change shape. Figure 3 shows a part warping due to internal stresses. You can avoid orientation by filling the part quickly, and allowing enough time for the part to cool and shrink properly.

Distortion or Bowing

When one surface of a part cools at different rate than the other surface you get bowing. Bowing is a curve or distortion in the part.

Slow Mold Breakaway

Slow mold breakaway is the speed at which the mold opens after injection. As the mold opens, the part is supposed to separate from the stationary half of the mold, and be ejected from the core half or moveable half of the mold.

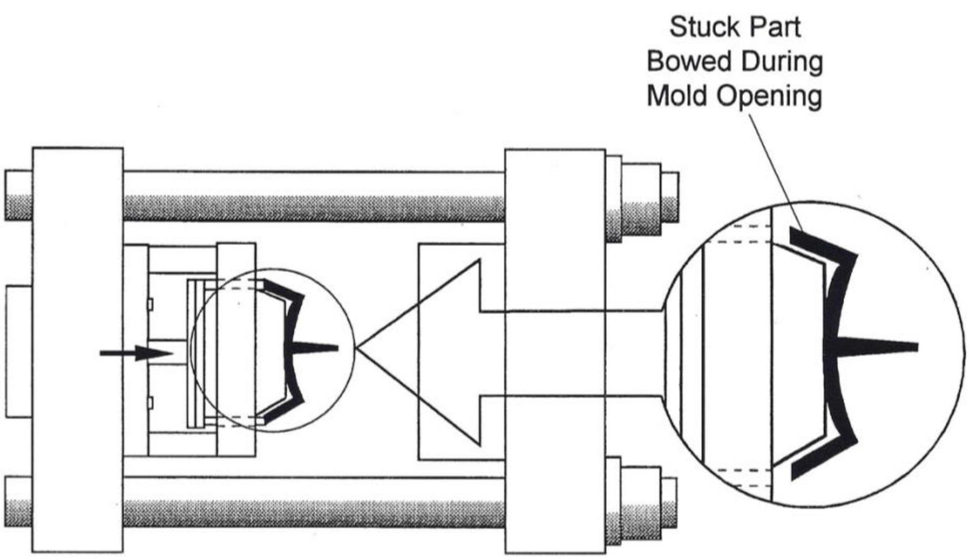

Figure 4 - Part Bowing During Mold Opening

If the mold opens too quickly, the part can hang up momentarily in the stationary half of the mold as shown in Figure 4. As the mold continues to open, the part snaps onto the moveable half. The pulling and snapping action can leave a bow in the part. Keep slow mold breakaway speeds low enough to separate the part cleanly.

Faulty Ejection

Bowing also happens when the ejector pin pushes one side of the part out at a different angle from the other side. If the ejector pins are cocked, one section of the part may be pushed away from the core before the other causing a permanent bow in the part during ejection.

Mold Temperature and Design

Faulty mold design and short cooling times can also contribute to bowing. If the mold contains hot spots or cold spots, some sections of the part will cool faster or slower than others.

For highly crystalline resins, the mold temperature is also very important. If the mold temperature is too low, the part will cool and solidify before the plastic molecules have recrystallized. Crystalline plastics have a denser, more ordered structure. When heated and melted, the plastic molecules lose their crystallinity and flow as molten material. When the part cools and solidifies in the mold, the plastic molecules try to recreate a denser, more structured alignment. This is why crystalline resins shrink more than amorphous resins. If the part is not given time to shrink and cool correctly, one side of the part may achieve a more crystalline structure than the other sides. One side of the part will be denser than the other. Avoid bowing and distortion by keeping cooling time long enough to allow the part to cool properly.

Exercise Four

Warpage

Locate a part that is warped or distorted. Can you determine the main cause of the problem?

Attributes	Study 1	Study2
Part Name & Mold #		
Material		
Under packed?		
Under cooled?		
Molded in stress?		
Distortion from ejection?		

Instructor Date

Objective Three

Poor Part Strength

Cracks, such as those shown in Figure 5, usually show up around projections, bosses, or holes. Cracks are also likely to form near weld lines.

Figure 5 - Crack

Stresses from Molded-in Orientation

Molded-in stress is the most likely cause of cracking. Normally, the chains in molten plastic are not aligned. They form a random, spaghetti-like mass. Injecting the plastic through the gates tends to stretch out, and line up the chains. This is called orientation.

Orientation happens during injection. If the part cools slowly, the chains have a chance to relax and return to their normal state. When the part solidifies, the chains are "frozen" in whatever position they find themselves. If the part has a very short cooling time it will solidify quickly. Any molded in orientation will be preserved in the part.

When plastic is preserved in a state in which it would not ordinarily remain, internal stress results. Orientation adds inter-nal stress to the part. Parts with internal stress can crack after molding because of the chains natural desire to return to a more relaxed pattern. You can prevent orientation cracking by allowing enough time for the part to cool properly.

Cracking due to Hot Parts

Parts are supposed to cool and form inside the cavity. The cavity walls hold the shape of the part and help it cool correctly. If the part is ejected while it is still hot, it cools and shrinks at different rates without the cavity wall to contain it. One surface may stretch, while the rest of the part continues to shrink as it cools. The surfaces will each pull plastic in a different direction, causing a crack. Let the part cool and solidify completely before opening the mold.

Crazing

Crazing is a series of very fine cracks on the part surface as shown in Figure 6. It has many of the same causes as larger cracks.

Sometimes crazing is caused by a cold mold. In a cold mold, the plastic material solidifies before the mold is completely full. The surface of the part shrinks away from the cavity wall

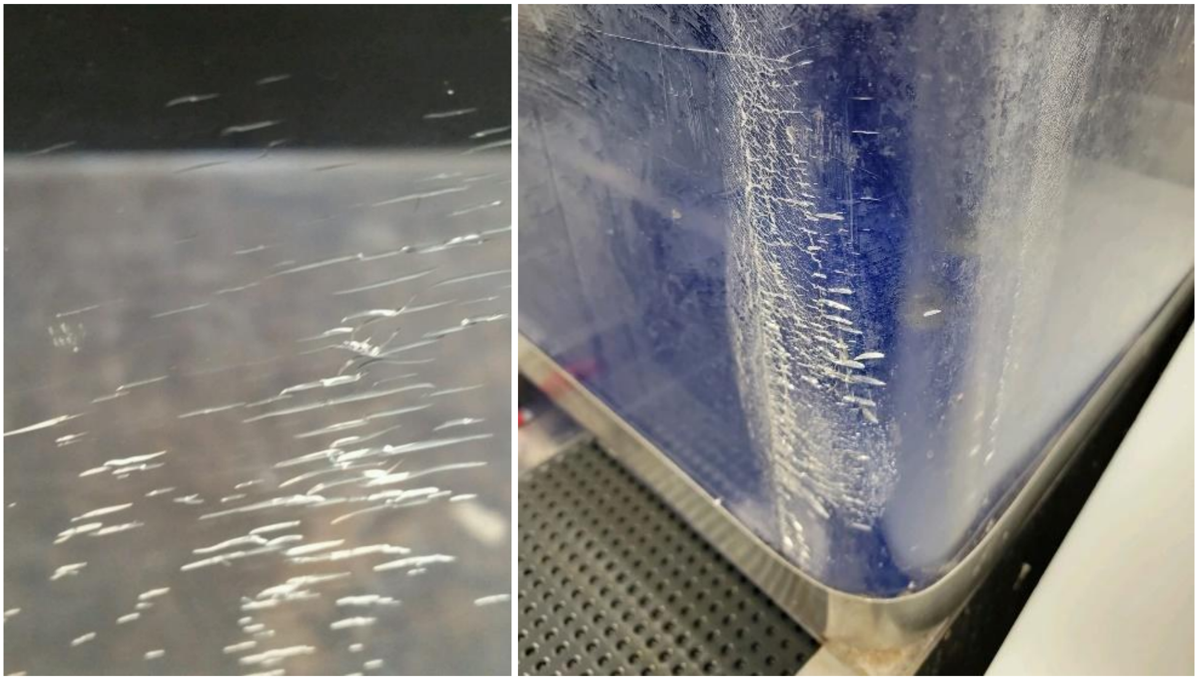

Figure 6 - Crazing

and cools on its own. Tiny cracks open where expanding and contracting sections of the part's skin pull in different directions. You can prevent this kind of crazing by raising the mold temperature.

Brittleness

Brittle parts have a tendency to break or crack, as illustrated in Figure 7. The primary cause of brittleness is water in the resin. If water is molded into the part, it often turns to steam. When the steam evaporates, it leaves voids behind. The voids prevent the material from being very dense. The part comes out light and brittle.

Different plastics need different drying times. Some plastics are highly hygroscopic. Hygroscopic means they have a tendency to absorb moisture, even from the air. Almost all plastics need some kind of drying to mold properly. Some plastics are dried in large ovens. Other plastics are stored in a special low humidity environment.

Figure 7 - Brittleness

Sometimes an over-packed part can tum out brittle. Even though the density of the plastic may be adequate, an over packed cavity does not give the plastic room to shrink correctly. Without any room to shrink, the bonds between the plastic molecules will be weaker than they should be. The part will come out brittle and easy to break.

Some brittle parts are made from melt that was not mixed properly. If the melt is too cold, clumps of plastic will not smooth out and bond with each other. The plastic pellets also need enough time in the barrel to mix properly. You can increase the mixing action by raising the screw rpm. You can increase the time the melt spends mixing by raising the back pressure setting.

Exercise Five

Part Defect

Find parts that are cracked or broken, or have craze marks in them. Describe the defect, and list three probable causes.

Plastic Name & Mold#	Probable Cause 1	Probable Cause 2	Probable Cause 3

Instructor Date

Self-Test

1. Excess shrinkage usually means:
    a. The part is over packed
    b. The part is under packed
2. One way to correct excess shrinkage is:
    a. Lower the injection pressure
    b. Decrease the back pressure
    c. Decrease the screw RPM
    d. Increase the cooling time
3. The most likely cause of cracking is molded in stress
    a. True
    b. False
4. Which of the following is NOT a likely cause of warping
    a. Small cushion
    b. Low nozzle temperature
    c. Low injection pressure
    d. Molded-in stress
    e. None of the above

5. Bowing or distortion can occur when the mold
    a. Opens too fast
    b. Opens too slow
    c. Doesn't open at all
6. Cracks usually appear near:
    a. Bosses
    b. Weld lines
    c. Projections
    d. All of the above
    e. None of the above
7. The primary cause of brittleness is:
    a. Over packing
    b. Under packing
    c. Contaminated plastic
    d. Moisture in the melt
8. Which of the following will lower the melt viscosity:
    a. Decrease screw RPM
    b. Decrease barrel temperature
    c. Decrease the back pressure
    d. Increase the back pressure

9. A worn or damaged non-return valve can cause:
    a. Under packing
    b. Over packing
10. Faulty ejection is likely to cause
    a. Bowing
    b. Cracks
    c. Splay
    d. Silver streaks

Glossary

Crazing - a series of very fine cracks on the surface of the part.

Cushion - the melted plastic that stays in the barrel after injection.

Distortion - a curve or distortion in the part. Also called bowing.

Warping - a change in the shape of the part after ejection.