Once again, molding using the process graphs is a powerful tool; utilize it. It is a fast and effective method of verifying the processes even when you are not a molder.

Questions

1) During the injection stage we control injection pressure.
   a. True. We control pressure and temperature.
   b. False. We control injection velocity.

2) We can fill 100% of the cavities during the injection stage.
   a. True. 100% is completed in the transfer.
   b. False. 100% is completed during the hold stage.

3) The injection stage should end when
   a. the injection time expires.
   b. when the pressure limit is reached.
   c. when the transfer position is reached.

4) In the hold stage we get
   a. thermal dimensions.
   b. mass dimensions.
   c. constant velocity.
   d. a homogeneous melt.

5) In the hold stage we control
   a. backpressure.
   b. fill velocity.
   c. hold pressure and time.

6) The hold stage should end
   a. when the gates solidify.
   b. by position.
   c. by pressure.

7) In the cooling stage we control
   a. fill time and the pressure limit.
   b. the flow of oil in the hydraulic cylinder.
   c. cooling time and the mold temperature.

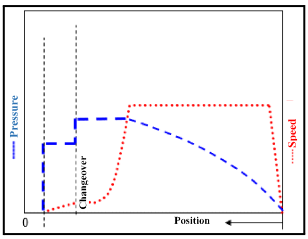
8) In the cooling stage we want
   a. to eject parts with adequate mass dimensions.
   b. the external dimensions.

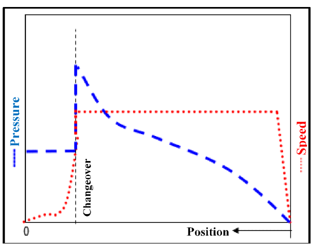
c. to eject parts with adequate thermal dimensions.

9) The cushion can equal zero.
    a. True. That way we control mass dimensions.
    b. False. We could not control mass dimensions.

10) Can the cushion equal zero?
    a. Yes. That way you will control mass dimensions.
    b. No. The cushion should always exist so that hold can work.

11) Pair up the graphs of out-of-control processes with their respective flaw description.





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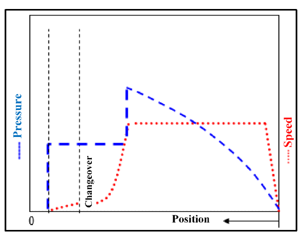
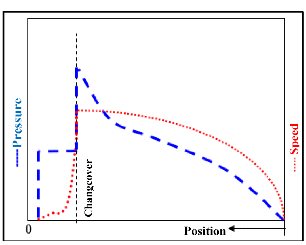




a. Zero cushion

b. Programmed velocity was not reached

c. Premature transfer

d. Limited pressure

IV. Plastic Morphology

- **Types of Plastics**
- **Mechanical Properties**
- **Common Materials and their Characteristics**
- **Some Experiments**

Types of Plastics

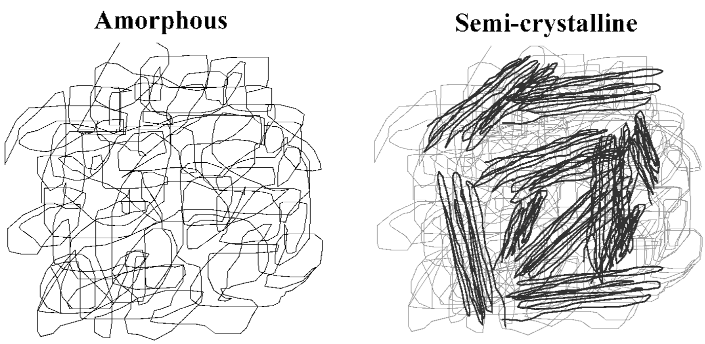
Basically, there exists two types of plastics: thermosets and thermoplastics.

Thermoset materials are those materials that can be molded only once. The injection molding of thermosets is somewhat different than the molding of thermoplastics; therefore, Universal Molding™ for thermosets such as liquid silicon, polyester compounds, bulk molding compounds (BMC), epoxy, rubber, melamine, etc., will not be discussed in this text.

Thermoplastic polymers are those materials that can be repeatedly melted, and consequently can be reground and molded multiple times. Their molecular organization falls into two types, amorphous and semi-crystalline.

Amorphous materials are thermoplastics that do not offer any type of molecular organization; in other words, their molecules have a totally random organization, like a clump of spaghetti.

Semi-crystalline materials are a combination of organized segments (crystals) surrounded by disorganized (amorphous) segments.

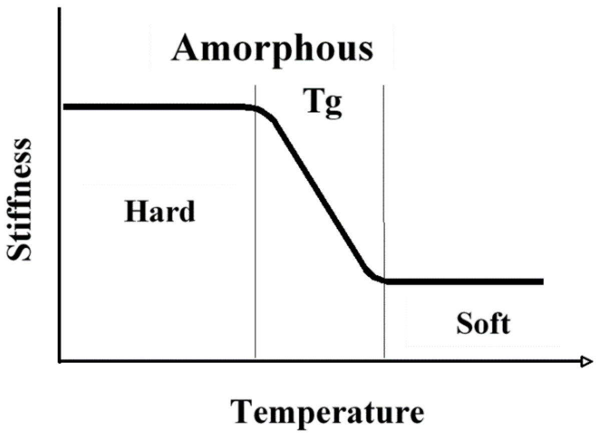


IV-1. Illustration representing amorphous and semi-crystalline molecular organization

The molecular structure of semi-crystalline material is like organized noodles with some type of orientation. These groups are known as crystals. These crystals are surrounded by disorganized (amorphous) molecules. This partially organized mix of amorphous and crystalline material is known as semi-crystalline.

Mechanical Properties

A material's molecular orientation brings mechanical properties which can affect the injection molding process. The mechanical characteristic of these materials can be illustrated with a graph of stiffness versus temperature. Look at the graph of amorphous material below.

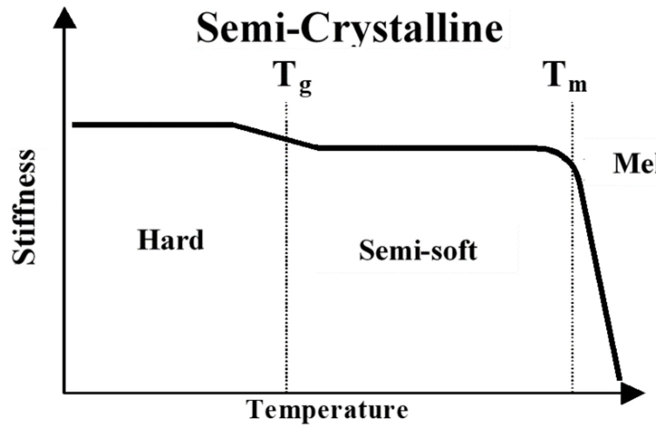


IV 2. Graph illustrating stiffness versus temperature in amorphous materials

The vertical axis indicates the stiffness, in which the origin represents soft or melted material and any increase represents a rise in stiffness. The horizontal axis indicates the material's temperature, in which the origin represents a material at room temperature and any increase represents a rise in temperature.

The profile graph of an amorphous polymer illustrates that, at certain low temperatures, the material will stay in a solid state. With an increase in temperature the material will reach a glass transition temperature T_g. After the glass transition temperature is reached, the material enters a transition zone that is known as the glass transition zone, where it will gradually lose its stiffness. If you continue to increase the temperature you will obtain a totally soft material. Think of it as an elastic or putty-like melt that is not a liquid. It is in this softened state that amorphous polymers are injected.

The graph of a semi-crystalline material offers a distinct picture.



IV-3. Graph illustrating stiffness versus temperature in semi-crystalline materials

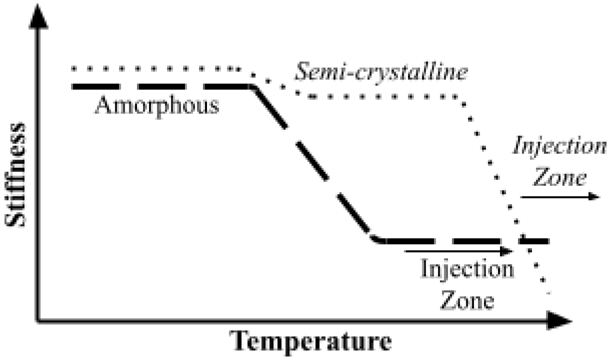
The graph profile of a semi-crystalline polymer shows that, just like amorphous polymers, the material will remain in a solid state at lower temperatures and reaches a glass transition zone at temperature T_g when the temperature is increased. With semi-crystallines, the glass zone corresponds to the amorphous part of the material and is so insignificant that the term T_g is rarely used.

If the temperature continues to increase beyond the glass transition zone, the material will lose some stiffness. Even then, it will remain in a solid state.

If the temperature continues to increase, melt temperature T_m will be reached. At temperatures greater than T_m semi-crystalline materials will melt. After T_m the material becomes liquid; for this reason, it is said that semi-crystallines melt and do not soften like amorphous materials. It is after temperature T_m that semi-crystallines are molded.

Note that semi-crystalline materials do not have the advantage of as large an injection zone as amorphous materials, making them harder to melt.

Semi-crystalline materials change from melted to solid more quickly than amorphous materials do.



IV-4. Overlaid graphs of stiffness versus temperature of semi-crystalline and amorphous materials

Once the material has been identified, make the pertinent injection molding process adjustments, taking into consideration that amorphous materials soften and semi-crystalline materials melt

Common Materials and their Characteristics

Amorphous	Semi-crystalline
ABS	PA (nylon)
Polystyrene	Acetate
Acrylic	Polyethylene
PVC	Polyester
Polycarbonate	Polypropylene

IV-5. Common amorphous amd semi-crystalline materials

Semi-crystallines are only opaque in their solid state, since in their melted state the crystals become disorganized like an amorphous material and permit the passage of light. If you ever have the opportunity to observe a purge of a semi-crystalline melt, for example, polyethylene with no

additives, you can appreciate how the material changes from translucent to opaque as it cools and solidifies.
Not all melted materials have amorphous morphology; there are some that form crystals in their liquid state. These materials are called liquid crystal polymers.

The formation of crystals in semi-crystalline materials can be controlled through adjustments in the molding process. In other words, as a molder, you can control the quantity of crystals formed during the cooling stage. Being able to control the formation of crystals by adjusting the molding process is an opportunity. For example:

- With the objective of maximizing clarity in the fabrication of PET preforms, which will later be stretched and blown to form bottles, crystal formation needs to be reduced as much as possible. If you ever look at PET pellets you will notice that they are white and opaque, the PET having been crystallized to its maximum. Remember that crystals block the passage of light. That is why during cooling a thermal shock is given, using a super cold mold, with the objective of halting the formation of crystals.
- When ultrasonically assembling thermoplastics, the sound can be damped by the material's crystalline structure. This is another reason why some molders control the formation of crystals.
- Some products molded with semi-crystalline resin, such as tie wraps, require control of mechanical properties such as flexibility and toughness. A crystalline structure makes a material more rigid and inflexible; because of this, some molders control the formation of crystals.

Know the type of material you are using before trying to mold a product and identify the mechanical properties that most affect your product.

Remember that hold pressure and cooling temperature combine to affect the final dimensions of a molded product. The cooling temperature represents the effect on the thermal dimensions, and the hold pressure represents the effect on the mass dimensions. In addition, the temperature and pressure could create a combined effect; this is when the temperature and the pressure combine within a certain range, creating a particular effect on the dimensions. Although the combined contribution is difficult to visualize, it does exist.

For example, the time it takes to solidify the gates could be affected by the mold temperature.

Amorphous	**Semi-crystallines**
They soften When you inject an amorphous melt, it has a putty or gummy consistency. A purge of this type of melt will clump like a paste with little intention to flow.	*They melt* When you inject a semi-crystalline melt, it has a liquid consistency. In other words, a purge of this type of melt will run like a liquid.
These materials are less resistant to chemical attacks. When amorphous materials are exposed to a chemical like a solvent, they might decompose. Even a polycarbonate that is used as bulletproof glass will decompose if it is exposed to gasoline.	*These materials are more resistant to chemical attacks.* Semi-crystalline materials have a better resistance to solvents. For example, a HDPE container can store gasoline.
Transparent Melted or solid amorphous materials without additives are translucent or clear. Note: Beware of confusing the “material clarity” property with the term “crystalline morphology”.	*Opaque* Semi-crystalline materials in their solid state have organized segments (crystals), which divert the passage of light and thus are opaque.
Low shrinkage Amorphous materials shrink less since the disorganized molecules occupy more space. Note: it is said that mass dimensions are more significant with amorphous materials.	*High shrinkage* The crystals in semi-crystallines are groups of organized molecules that tend to take up less space. This is why they shrink more during cooling and crystal formation. Note: thermal dimensions are said to be more significant with semi-crystalline materials.

IV-6. List of mechanical characteristics of amorphous and semi-crystalline materials

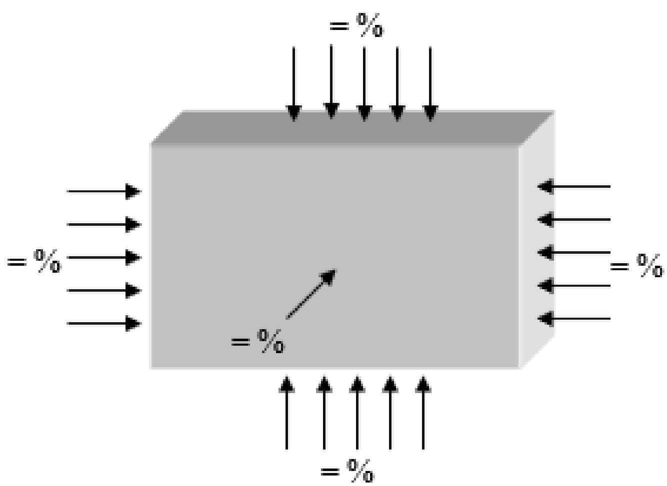
The contributions to dimension of each of these effects will depend upon the type of material being used. Because of this you should understand your material before trying to correct dimensions or any attribute.

Amorphous	Semi-crystalline
Problems of overpacking due to low shrinkage.	Problems with incomplete packing due to too much shrinkage.
Problems with flash due to overpacking the mold.	Parts with sink marks due to high shrinkage.
Parts breaking during ejection since little shrinkage causes parts to stick to the cavity walls.	Easy part ejection since high shrinkage helps separate parts from the cavity walls.

IV-7. List of process characteristics of amorphous and semi-crystalline materials

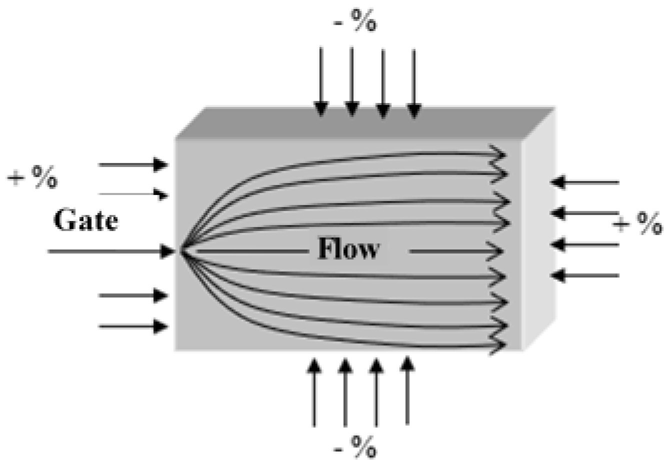
Shrinkage

Amorphous materials, for practical purposes, shrink proportionally in all directions.



IV-8. Amorphous material shrinkage

Semi-crystalline materials shrink more in the direction of injection flow rather than in the direction perpendicular to the injection flow.



IV-9. Semi-crystalline material shrinkage

During injection, the polymeric chains orient themselves to the direction of flow, crystals included, and are forced to maintain some orientation as they solidify. During shrinkage, these molecules seek to conform into a less uncomfortable position; because of this, the shrinkage will be greater in the direction of flow.

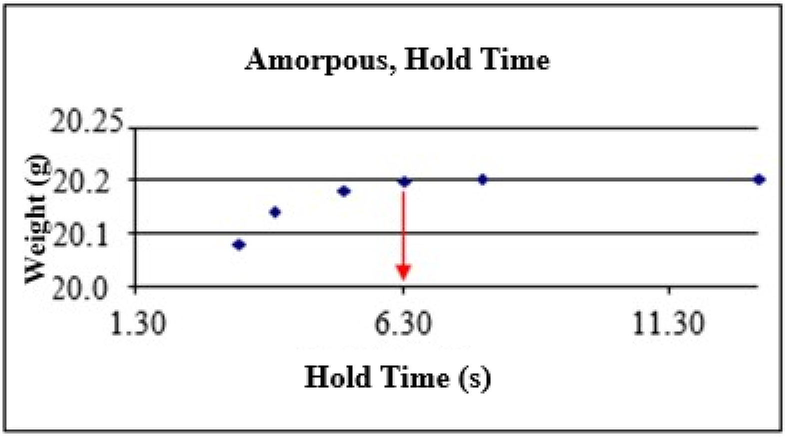
When a semi-crystalline is reinforced with fiberglass its shrinkage becomes inverse, less in the direction of injection flow and greater in the perpendicular direction of flow. This is because the glass fibers orient themselves to the direction of injection flow and, during shrinkage, the glass fibers act as steel bars inside concrete, resisting shrinkage in the direction of their orientation.

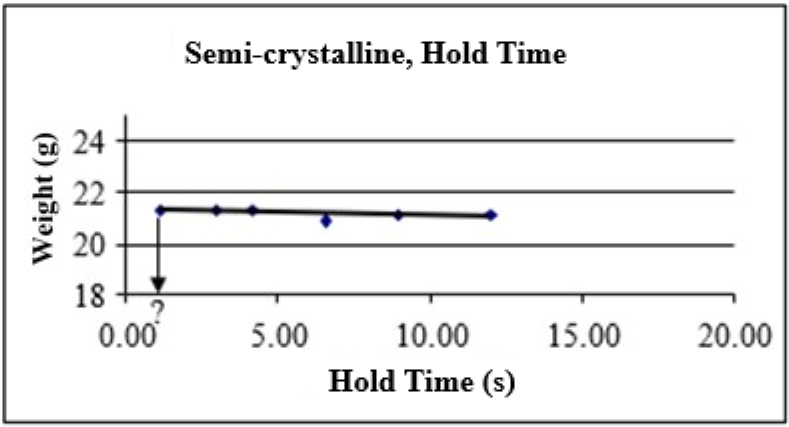
Some Experiments

Let us review some experiments performed by ***Universal Molding***TM students.

Experiment #1

Using the same mold, injection molding machine and auxiliary equipment, the effect of hold time upon gate freeze was tested using two materials, one amorphous (polystyrene) and the other semi-crystalline (nylon).





IV-10. The effect of hold time on the part weight in amorphous and semi-crystralline materials

The graphs of part weight versus hold time reveal that the amorphous material solidified in the gates in close to 6 seconds, which consequently caused the weight of the part to stop increasing. With the semi-crystalline material, the students stopped the experiment after one second of packing with the gates solidifying, showing that the gate freeze occurs in less time than with the amorphous material.