II. Injection Molding Process Parameters

- **Machine and Universal Parameters**
- **Injection Parameters**
- **Transfer Position**
- **Hold Parameters**
- **Gate Freeze**
- **Cooling Parameters**
- **Recovery Parameters**
- **Mold Movement**

Machine and Universal Parameters

Machine parameters are those that can be programmed into the machine control. These might not exactly describe the dynamics of the melt before it enters the mold; these could be:

- injection speed
- position of the screw
- the injection's hydraulic pressure
- revolutions per minute during recovery

Universal parameters are those values that the melt experiences before entering the mold, which could be:

- injection time
- melt volume
- plastic (or melt) injection pressure
- recovery time

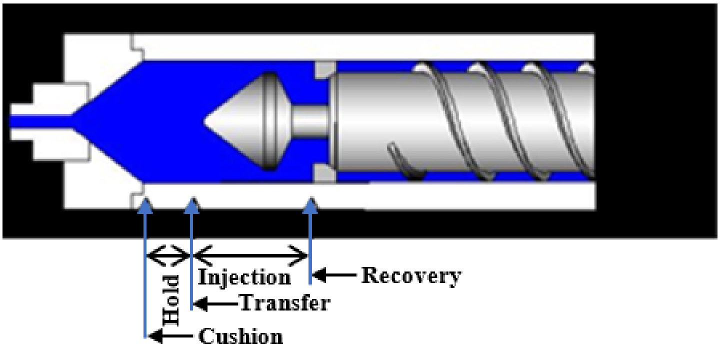
Both sets of parameters, ***Universal*** and machine, must be understood; of course, the parameters that should make more sense for ***Universal*** molders are ***Universal*** parameters. A ***Universal*** parameter better describes the physical function of filling a mold. Let's look at some examples:

- The ideal filling time of a mold is independent of the injection unit diameter and of its corresponding injection speed.
- Hydraulic injection pressure is distinct from and less than the melt pressure or the plastic pressure.
- The screw position represents a volume, a cubic quantity of melt that will occupy a space inside the mold after being injected. This melt volume can only be related to the injection screw's position when the screw's diameter is provided.

Not all injection molding machine controls utilize ***Universal*** parameters; even so, many manufacturers have recognized this as necessary and are starting to convert. In some newer machines, it is common to see that the control has the option to work with either ***Universal*** values (sometimes called "absolute") or machine values.

Injection Parameters

We previously mentioned that, during the injection stage, we want to fill the mold close to 95% of its total volume.



II-1. The injection stage

In this stage, filling is achieved with a quick injection flow that provides the best melt properties.

The injection machine parameter is:

- injection speed (in/s or mm/s)

Universal injection parameters are:

- injection time (seconds)
- injection flow (in^3/s or mm^3/s)

We the ***Universal*** molders utilize only one injection speed; there are molds that require speed profiles. For example, there are molds whose fill is not balanced, like family molds which create distinct parts at one time. Remember that many existing molds were manufactured years ago and are probably not in the best condition.

We have found that some molders have the habit of using a slow speed at the end of the injection stage in order to avoid screw bounceback. This situation is corrected by properly programming the transfer and recovery positions. Later we will explain how to determine those positions.

Again, we do not control injection pressure nor time in the injection stage. They are not controlled; however, during the injection stage we do program pressure and time *limits*. These limits should not be reached during the injection stage since their purpose is to protect the mold and the press.

Remember:

- The injection stage is known as the speed control stage.
- Do not try to fill the mold 100% during the injection stage; filling close to 95% is the goal.
- During injection, the screw acts like a piston.
- During injection, the check ring moves against the injection screw seat, creating a seal so that melt cannot return to the screw.

Transfer Parameters

Transfer is what determines the end the injection stage. Once the injection unit fills close to 95%, the injection stage ends and the next stage, hold, begins.

Injection machines can initiate transfer in four ways:

- time
- position
- pressure
- cavity sensor

Let us review each of these four ways:

- Transfer by time measures the time from the beginning of injection until reaching the programmed transfer time.
- Transfer by position measures displacement from the beginning of injection until reaching the programmed transfer position.
- Transfer by pressure monitors the actual pressure until reaching the programmed pressure.
- Transfer by means of a temperature or pressure sensor placed near the end of a cavity or cavities in the mold. When the melt enters the cavity and reaches the sensor set adjustment, the sensor sends a signal to the press' controls, indicating to transfer.

Universal molders prefer to transfer by position, since this best guarantees the injection volume required by the mold.

Some molders believe that the most reliable transfer method is by cavity sensors. Nowadays, few molds possess this technology. This is why we recommend transfer by position. Although it had gained some popularity, the investment in this type of cavity sensor technology cannot be justified for many applications. If your mold is equipped with them, then transfer by cavity sensor.

Machine transfer parameter:

- transfer by position (inches or millimeters)

Universal **transfer parameters:**

- transfer volume (cubic inches or cubic millimeters)
- transfer by cavity sensor(s) (temperature or pressure)

Hold Parameters

In this stage, the screw continues acting as a piston, compressing additional melt into the cavities until filling the remaining space that was not filled during the injection stage.

The hold stage is known as the pressure control stage. During this stage, we control the pressure in order to achieve the proper weight of the molded parts, which ***Universal*** molders call "mass dimensions". Remember that mass dimensions are only a function of the quantity of material and should not be confused with dimensions that are an effect of shrinkage. The objective is to manipulate the hold pressure to guarantee dimensions that are a function of the quantity of material.

Machine hold parameter:

- hydraulic hold pressure (psi or bars)

Universal **hold parameter:**

- plastic (melt) hold pressure (psi or bars)

Remember:

- Cavity pressure is also a ***Universal*** parameter.

- Shrinkage will be controlled mainly during the cooling stage.
- During hold we only control mass dimensions, the dimensions that are a function of the quantity of material.

Gate Freeze

Once the parts are packed, the melt is held in place until the material in the gates solidifies, creating seals that trap the melt within the cavities.

In some molds with hot runners, gate valves are integrated into the runners. These valves remain open during filling and close when holding is complete. The signal that would correspond to the hold time is what activates the closure of the valve. The main objective of these valves is to achieve an aesthetic finish at the filling point of the cavities. However, although this type of valve usually reduces hold time, it does not necessarily improve the overall process cycle. This is because the time saved during hold is offset by a longer cooling time. Additionally, caution is important, as excessive holding time could cause the material to solidify at the filling point and damage where the valve sits.

The parameter that controls this gate freeze is hold time, whose units are seconds. Hold time is both a ***Universal*** and machine parameter.

It is possible to find controllers that divide hold into two parts, pack and hold. These separate the stages of pressure control and gate freeze. In addition to pressure and time, they consider hold speed.

In ***Universal Molding™*** we do not divide this stage into two parts. We believe that hold time starts when injection finishes and ends after the gates have solidified.

In ***Universal Molding™*** we do not consider hold speed. For the ***Universal*** molder, hold is the stage used to control pressure and speed is a result, since it is physically impossible to simultaneously control both pressure and melt velocity. One is the result of the other:

- if you control pressure, the result will be melt speed and
- if you control speed, the result will be melt pressure.

If you find a machine that has both options, pack and hold, turn one of them off (if possible) or adjust the secondary stage to zero.

We recommend only one pressure, though there are some older molds that still require a second pressure. For example, a mold could require a first hold pressure in order to guarantee mass dimensions and a second pressure to guarantee the demolding of the runner. Normally, the runner is the last part to solidify, and even though they are not what we are molding, the process may require the runners to be packed for them to demold properly.

Cushion
The cushion is the small amount of plastic that always remains in front of the screw after hold ends and should never be equal to zero. If the position of the screw reaches zero it will invalidate the hold stage and, consequently, there will be no control over mass dimensions. The cushion should always exist.

Remember:

- If you prematurely remove the hold pressure, the melt will return to the runner and possibly go as far as into the injection unit.
- If hold time extends too long, the molder ends up "molding runners".
- During the hold stage, the check ring moves against the screw seat, sealing it and ensuring that the melt doesn't return to the screw.

Cooling
In this stage, we remove heat from the parts until we obtain parts that can be demolded with acceptable thermal dimensions. The idea is to manipulate the removal of heat from the melt, in order to control the thermal dimensions. Remember that rapid cooling results in thicker walls and slow cooling results in thinner walls.

Cooling Parameters

- temperature of the mold (ºF o ºC)
- cooling time (seconds)

These are both ***Universal*** and machine parameters.

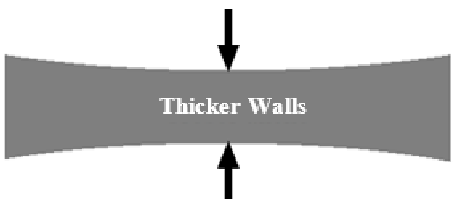
Familiarize yourself with your machine's controls since some controls include hold time inside of cooling time.

Be careful with this stage, extensive cooling times can result in costly processes. The idea is to manipulate both parameters, temperature and cooling time, in order to obtain the optimal thermal dimensions. Also, a change in mold temperature could affect hold time, since any change in the way heat is removed from the melt will affect the time it takes for the gate to freeze.

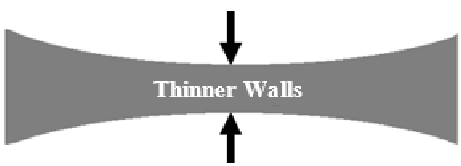
The mold temperature is controlled by changing the temperature of the water that cools the molds and sometimes by modifying its flow. It is important to understand that the temperature of the water that enters the mold and the temperature of the mold's metal are distinct.

Remember:

- Cold molds and extended cooling times will result in thicker walls.
- Hot molds and shortened cooling times will result in thinner walls.



II-2. Walls with cold molds and extended cooling times



II-2a. Walls with hot molds and shortened cooling times

- Some mechanical properties, like rigidity, translucency, and crystallinity, can also be functions of the rate at which the heat is removed.
- Thermal dimensions are a function of shrinkage and not a function of the amount of the packed mass.

Recovery Parameters

The main objective of recovery is to consistently produce a homogenous melt. During recovery the check ring moves to the front, permitting melt to pass in front of the screw.

Remember that recovery happens at the same time as the cooling stage. Under normal conditions, recovery ends before cooling does; if the cooling finishes first, the control will not allow the mold to open. This condition will extend the cooling time and consequently, will affect the thermal dimensions.

Machine recovery parameters:

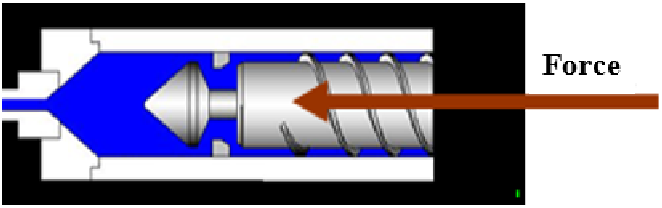
- recovery speed (rpm)
- hydraulic backpressure (psi or bars)
- barrel temperature profile (ºF or ºC)
- screw recovery position (in or mm)
- decompression (in or mm)

***Universal* recovery parameters:**

- recovery time (seconds)
- melt backpressure (psi or bars)
- melt temperature (ºF or ºC)
- recovery volume (in^3 o mm^3)
- decompress volume (in^3 o mm^3)

Backpressure

Backpressure's objective is to create an opposing force against the free displacement of the screw during recovery. This force will show in the form of melt pressure.



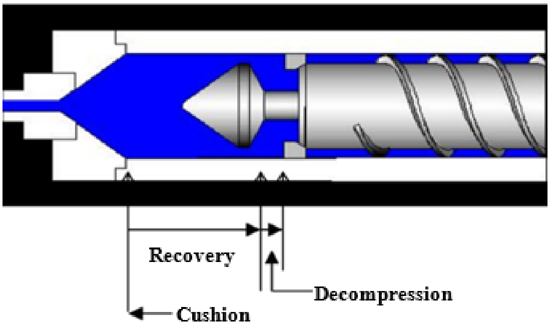
II-3. Backpressure

An increase in backpressure results in an increase in friction and an increase in the mixing capacity.

An increase in recovery speed results in an increase in friction and a reduction in the recovery time.

Thermoplastic melts are compressible and some of these materials can be compressed over 20%. Consequently, an increase in backpressure results in an increase in the amount of injected material since more plastic will be compacted into the same volume inside the injection unit.

Decompression after recovery
Decompression reduces the melt pressure after recovery. This is done with a slight screw displacement in the direction of the screw's recovery.



II-4. Decompression

During recovery, the mold is closed and full of material; it is this material that keeps the melt inside the injection unit. After recovery, the melt is compressed; if the mold opens and demolds the finished parts, the melt could drool inside the open mold. For this reason, there must be decompression after recovery. The only exception would be when the mold includes valve gates, or the injection unit includes a shutoff nozzle; in this case, the decompression after recovery could be set to zero.

There can also be decompression before recovery. Although it is not so common, since the injection barrel is practically empty, this movement helps with sprue removal and makes it easier to close the valve gates in hot runner molds.

Remember:

- If the mold opens during recovery, and neither the injection unit nor the mold include some type of valve system for closing, the melt will drool inside the mold.
- As a general rule, recovery should end about one second before cooling does.
- It is important to know that the injection unit uses two heat sources in order to melt the plastic: heater bands and friction.
- Although the operator programs the heat zones of the barrel, the melt temperature is the most significant factor.

Press Movements

The movements of the press are simple; however, you must be careful during their adjustments or expensive breakage could occur. Each machine has unique programming, and you are responsible for learning and understanding your control's operation before using it.

Let's look at a basic sequence:

- The mold opens.
- The cores, if they exist, open.
- The molded parts are ejected.
- The cores, if they exist, go back into place.
- The mold starts closing.
- The mold protection stage begins.
- The clamping force is completed.

Opening the mold
Permission to open the press occurs after the cooling stage ends and, in most molds, after recovery has ended. The most significant parameters are speed and opening position.

Removing the cores
Not all molds need this option. Cores are mostly used in molds in which the cavity must open or disarm for the parts to be ejected. This type of disarming is operated by an external mechanism, be it hydraulic or electromechanical. This operation can occur as the mold opens.

Ejecting the parts
Normally the molded parts and their runners are held by the mold, and their removal depends upon some type of ejection mechanism. The finished parts are ejected by means of ejector pins, ejector plates, etc. This operation can occur while the mold is opening ("ejecting-on-the-fly") or after the mold is completely opened. It is common to see robots remove the molded components. The most significant parameters are ejection speed and displacement.

Relocating the Cores
Any molds containing cores must have them return to their position before the mold can close. It is important to connect all signals that guarantee that the core assembly is completed. Mold closure with the cores out of place could cause major damage to the mold.

Closing the Mold
Once the cores and the ejection plates are in place, the mold begins to close. The most significant parameters at this stage are the speed profile and the positions.

Mold Protect
Protecting the mold is extremely important and must be set in such a way as to detect any clamping difficulties which may be due to some trapped object, so that the mold does not get damaged. Some of the most significant parameters are the protection zone, time limit and force limit. For example, during the protection zone, the press will stop closing if the force limit or the time limit is reached.

Reaching the Clamping Force
Once the mold protection stage has passed, the press will continue to close until reaching the adjusted clamping force. Clamping force is adjusted according to the mold's requirements.

You can never be too careful; understand your mold and the machine controls before trying to operate the press. Follow all safety rules provided by the equipment manufacturer and established by your company.

Questions

1) Some ***Universal*** parameters are
    a. injection speed, screw position, hydraulic injection pressure and revolutions per minute.
    b. injection time, melt volume, plastic injection pressure and recovery time.

2) Select the correct sentence:
    a. Machine parameters are those values that the melt sees before entering the mold.
    b. ***Universal*** parameters are those values that the melt sees before entering the mold.

3) The ***Universal*** parameters of the Injection stage are
    a. injection pressure.
    b. injection speed.
    c. injection time and flow.

4) Select the correct sentences:
    a. Injection speed is a ***Universal*** parameter.
    b. Flow is the division between injection volume and injection time.
    c. During the injection stage we want the mold to fill close to 95% of its total volume.
    d. The units for injection speed are cubic millimeters/second.

5) How many speeds are recommended during the injection stage?
    a. Only one, whenever the transfer position is properly adjusted.
    b. Two, with a slow ending.
    c. Three: start slow, continue quickly, and finish slow.

6) Do we control injection pressure and time during the injection stage?
    a. Yes, we control them in order to guarantee the injection speed.
    b. No, we limit them in order to protect the mold and the machine.

7) Select the correct statements:
    a. Transfer by time measures displacement from the beginning of injection until reaching the entered transfer position.

b. Transfer by position measures displacement from the beginning of injection until reaching the entered transfer position.
c. Transfer by pressure monitors the time from the beginning of injection until the entered time expires.
d. ***Universal*** molders prefer transferring by position.

8) Select the correct statements:
   a. The transfer position ends the injection stage and starts the hold stage.
   b. Transfer by position is a ***Universal*** parameter.
   c. The units of transfer by volume are inches or millimeters.
   d. ***Universal*** molders prefer transfer by position, and if the machine is capable to transfer by volume, then transfer by volume.

9) Select the correct statements:
   a. The hold stage is known as the pressure control stage.
   b. The mold should be filled 100% during the injection stage.
   c. The hold stage is known as the speed control stage.
   d. We should always use multiple hold pressures.

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

11) Select the correct statements:
   a. In the cooling stage, we can correct mass dimensions.
   b. The temperature of the water entering the mold and the temperature of the mold's metal are equal.
   c. The control parameters for the cooling stage are the mold temperature and the cooling time.
   d. The mold temperature and the cooling time are both ***Universal*** and machine parameters.

12) Select the correct statements:
   a. In the recovery stage we can correct mass dimensions.
   b. The barrel heat zones measure the temperatures of the metal and not of the melt.
   c. Melt temperature is a ***Universal*** parameter.
   d. Melt temperature is more significant than the barrel heat zones.

13) Recovery's ***Universal*** parameters are
   a. recovery time, plastic backpressure, melt temperature, and recovery volume.
   b. recovery speed, hydraulic backpressure, temperature profile, and recovery position.

14) An increase in backpressure will result in
   a. an increase in friction and a reduction in recovery time.
   b. an increase in friction and an increase in the mixing capacity.

15) Decompression after recovery
   a. reduces melt pressure before recovery.
   b. reduces melt pressure after recovery.
   c. seals the check ring against the screw, keeping melt from passing to the front of the screw.

16) An increase in backpressure means an increase in
   a. the amount of melt during recovery, friction, and velocity (rpm).
   b. the amount of melt during recovery, friction, and mixing capacity.

17) Thermoplastic melt is compressible.
   a. True, because melt quantity increases with backpressure.
   b. False, it is not compressible, and melt quantity decreases with backpressure.

18) Select the correct statements:
   a. Decompression increases the amount of melt.
   b. Decompression at the end recovery reduces melt pressure after recovery.
   c. There can also be backpressure before recovery.
   d. During recovery, the mold is closed and full of material and it is this material which keeps the melt inside the injection unit.