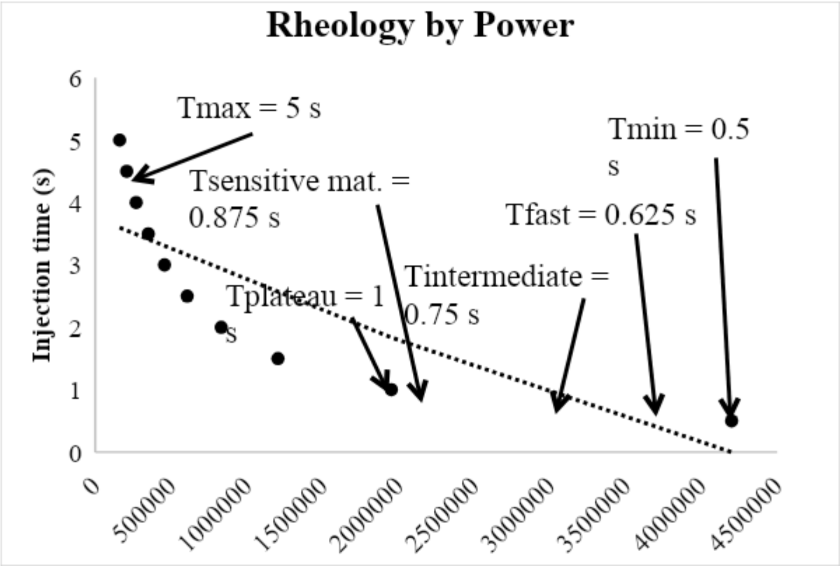
$$\mathbf{T_{Sensitive\ mat.}} = T_{min} + (T_{max} - T_{min}) / 12$$
$$= 0.5s + (5s - 0.5s) / 12 = 0.875 \text{ seconds}$$

$$\mathbf{T_{fast}} = T_{min} + (T_{max} - T_{min}) / 36$$
$$= 0.5s + (5s - 0.5s) / 36 = 0.625 \text{ seconds}$$

$$\mathbf{T_{plateau}} = T_{min} + (T_{max} - T_{min}) / 9$$
$$= 0.5s + (5s - 0.5s) / 9 = 1.0 \text{ seconds}$$



VIII-13. Rheology graph indicating injection times by industry type

These equations help standardize the selection of injection time; even so, they are only a reference.

c) Determine the ideal injection speed.

Once you have determined the injection time, find the corresponding injection speed. This is done by adjusting the injection speed until it approximately equals the ideal injection time found.

With the ideal speed found, verify that the mold (parts and runner) fills about 95% of its total weight. If not, adjust the recovery position until both the ideal injection time and a fill of about 95% are achieved.

Remember that not every mold can be filled to 95% during the injection stage; some because of a condition of their design and in some cases, because the mold must be repaired.

Injection speed may cause defects. There are several scenarios:

- Burns at the end of fill - the vents are likely to be plugged or defective.
- Burns around edges or corners - could be caused by an edge or flash of metal in the mold.
- Burns in the form of streaks that extend along the fill or from the gate - it is likely that the material is degrading by friction.
- etc.

Consult the mold maintenance department; it will probably recommend some type of maintenance or repair. Follow the recommendations and return to molding at the determined injection speed.

Unfortunately, not every material, mold, and molding equipment is at its best design condition. What is worse, for whatever reason, is being forced to mold with these deficiencies.

In the event of not being able to do the rheology as a result of material limitations (e.g. degradation) or equipment limitation (e.g. inability to rapidly inject), if parts must be molded under these conditions, follow this simple procedure:

- Inject by incrementing the speed until it reaches the specific limitation.
- Then reduce it by 5% of the maximum speed found and inject with this new speed; if the defect disappears this will be your injection speed or time.

d) Note the values found for:

- injection time
- injection speed and its corresponding injection flow
- transfer position and its corresponding transfer volume

- plastic pressure limit and hydraulic pressure limit (if applicable)
- recovery position and its corresponding recovery volume.

Summary of the steps:

a) Using the completed rheology table, create the rheology graph.
b) Select the ideal injection time for your application.
c) Select the ideal injection speed corresponding to the injection time found.
d) Note the values found for:
- injection time
- corresponding injection flow
- corresponding transfer volume
- plastic pressure limit
- corresponding recovery volume.

Notes:

- Do not try to maximize the fill, just guarantee something close to 95%. Trying to get to the maximum can result in flash problems.
- Be sure to produce parts without flash.
- Ensure that pressure during injection is maintained at least 5% lower than the set pressure limit.
- There is a relatively linear relationship between injection flow and peak power.
- Remember that you are working with expensive equipment: do not rush the work and follow the safety rules established by your factory and government agencies.

Questions

1) During a ***Universal Molding***^{TM} lab, what do you do if some limitation or defect in equipment appears, such as limited injection speed?
   a. If the limitation requires a modification or a simple change of equipment, do it. If the modification or change is not feasible, or is economically unsustainable, you will have to run the laboratory with the equipment you have.
   b. If the limitation requires a modification, do it. The laboratory must be carried out under ideal conditions.

2) All programmed injection speeds, whether slow or fast, are always reached by the injection unit.
   a. True.
   b. False. The speed entered may be limited by an inadequate injection unit.

3) While determining the injection speed, hold pressure should be set to an average pressure.
   a. True. Hold is used during the determination of injection time.
   b. False. Hold is turned off so that it does not interfere with the determination of injection speed.

4) While determining the minimum injection time, the injection unit should be adjusted to produce parts that are 20% incomplete.
   a. True. This is done to prevent damage to the mold, the machine, or both.
   b. False. It is necessary to fill the total volume.

5) With fill of incomplete parts, for example to 80%, you will notice that the weight of the parts decreases with an increase in injection speed.
   a. True.
   b. False. The weight of the parts increases with an increase in injection speed.

6) Select all the correct statements.

a. The fastest speed used in the rheology table is 95% of the maximum speed (V_{max}) found during the determination of the minimum injection time.
b. The rheology table is created by injecting at different speeds, all with an incomplete fill of 80%.
c. Ensure that the pressure during injection is maintained at least 5% lower than the set pressure limit.

7) Select the correct statement.
a. The power rheology graph coordinates are viscosity versus changing speed.
b. The power rheology graph coordinates are injection time versus peak power.
c. The conventional rheology graph coordinates are fill flow versus peak power.

8) Select all the correct statements.
a. There is a relatively linear relationship between viscosity and injection flow.
b. There is a relatively linear relationship between injection flow and power.
c. With approximated rheology by power we use the equation of a line, $Y = Y_o + MX$, where Y is the flow, Y_o is the intercept in the injection flow coordinate, M is the slope and X is the injection's peak power.

9) Materials sensitive to injection speed, such as rigid PVC, need an injection time
a. between $T_{plateau}$ and $T_{min.}$
b. close to T_{min}.
c. close to $T_{plateau.}$

10) Once you have determined the ideal injection time, find the corresponding injection speed.
a. Also, verify that the mold (parts and runner) fills to about 80% of its total weight.
b. Hold continues to be turned off until this part of the lab.
c. Ensure that the pressure during injection is maintained to at least 5% lower than the set pressure limit.
d. All the above are correct.

IX. Verifying Fill Balance

- **Effect of Injection Time on Fill Balance**
- **Laboratory - Fill Balance**
- **Thermal Imbalance**
- **Unbalanced Fill in Molds with Cold Runners**

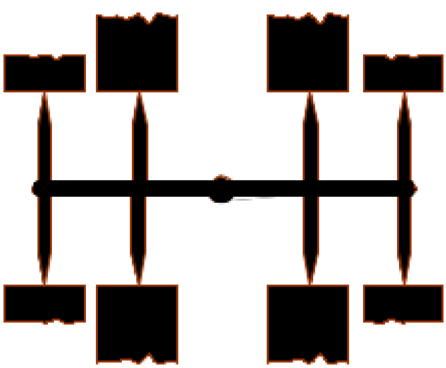
Again, before proceeding with this ***Universal Molding***™ laboratory remember that:

- Auxiliary equipment should be properly installed and correctly operating.
- Temperatures should already be reached.
- Barrel adjustments should have been programmed.
- The required clamping force should have been set.
- The press openings, their movement, speeds, and mold protection should have been carefully and precisely adjusted.
- Extended cooling time should have been set, in order to prevent it from interfering in the determination of other parameters.
- The ideal injection speed should have been determined, adjusted and should be filling about 95% of the required fill for the mold.
- The injection pressure limit should have been determined and adjusted.
- The hold stage should stay off.

Important -- only qualified personnel who have read the operational manuals of the equipment and understand the functionality of the equipment should operate and/or adjust them.

Multi-cavity molds increase productivity. However, their fabrication, as well as their operation, is complicated; the melt's flow path must be balanced, and cooling is more elaborate.

Imagine a multi-cavity mold with distinct fill times for each cavity, or with some cavities that fill before others.

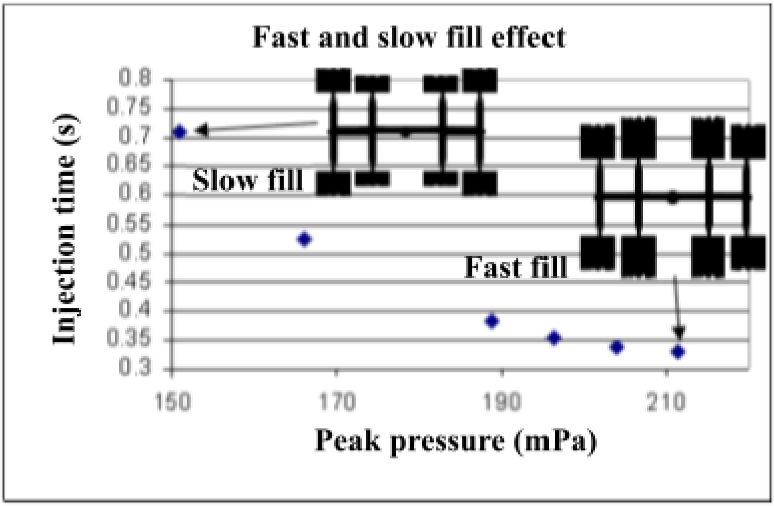


IX-1. Multi-cavity mold with unbalanced fill

This situation defeats the objective of maintaining constant flow and viscosity per cavity; it is like accepting the molding of distinct parts for each cavity.

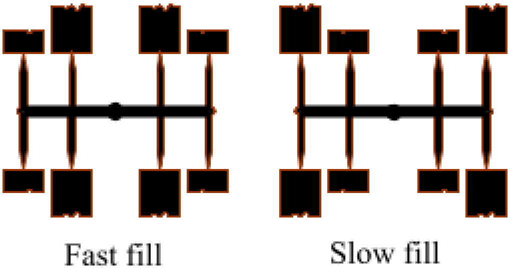
Effect of Injection Time on Fill Balance

The "Determining Injection Speed" chapter mentioned the multiple effects of injection time on fill. In the injection stage, the volume of melt in the parts increases with an increase in injection speed. Look at the illustration.



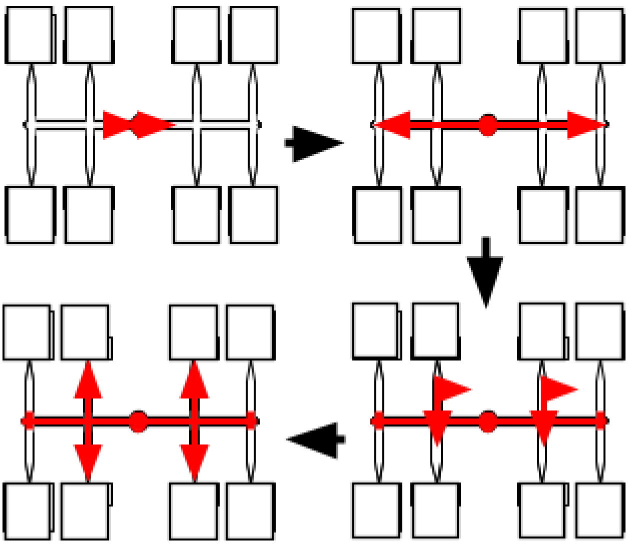
IX-2. Graph of the effect of injection speed on the fill of incomplete parts

In addition, it can be noted that with a fast fill, the interior cavities will be filled sooner than the exterior ones.



IX-3. Fast and slow fill

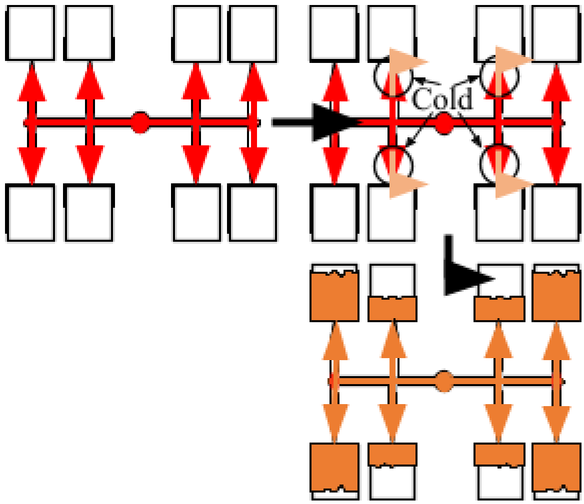
Let's see why; during the start of fill, the flow is divided between both sides of the sprue. Melt flow will always prefer the least restriction, so it will continue in a straight line and not turn into the first intersections where the runner branches out. Once it reaches the end of the main branch and is forced to turn, it prefers filling the previous intersection, since the melt pressure will be greater at that intersection.



IX-4. Example of flow sequence

Now, once the melt reaches the first gates, it encounters the restriction of those narrow openings. Then, the melt will prefer to continue flowing through the unfilled runners, since it is the path of least restriction, until it encounters the same difficulty, the restriction of small gates.

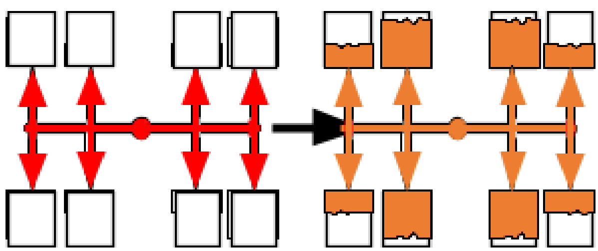
Let's assume the fill is slow. The melt in these outer gates is still hot and has less viscosity than the melt in the inner gates, as it has been in contact with the cold metal for longer.



IX-5. Example of slow fill

Consequently, the exterior cavities will be filled first. During injection, the melt in contact with the cold metal is the first to harden, and the thickness of this hardened layer will depend on the amount of time the melt is in contact with that cold metal. When the injection is slow, the hardened layer is thicker and, as a result, the melt path is narrower.

Now let's do the same exercise, but this time do it assuming the flow is fast. Initially the runner will fill in the same manner as before. The difference is that the time that the melt sits in the first runners is less.



IX-6. Example of fast fill

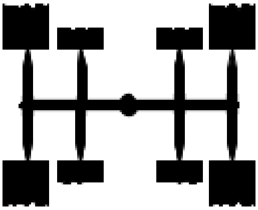
Consequently. its viscosity will stay low and the melt will prefer to fill the interior cavities, since the required pressure will be less.

Injection time has a lot to do with the flow balance, which is why the injection speed must be determined and adjusted before carrying out a study of flow balance.

Laboratory - Fill Balance

This section will present the procedure for verifying flow imbalance:

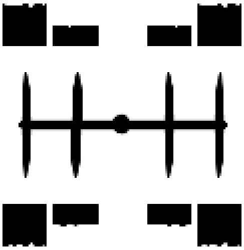
1. Adjust the injection unit to produce incomplete parts and make sure that hold is still turned off.



IX-7. Example of incomplete fill

This experiment is carried out with incomplete fill so that we can evaluate the fill of each individual cavity. If one or more cavity completely fills, it would be impossible to determine the fill balance. Try to achieve a fill of 80%, then verify that each cavity is incomplete; if any is not, reduce the recovery volume even more and reverify.

2. If the parts are attached to the runner, separate them.



IX-8. Parts separated from the runner

3. Weigh the parts separately and identify them with W_i (i = 1 to # of cavities). Add all the W_i weights and call this W_T.