**F I M M T E C H , I n c .**

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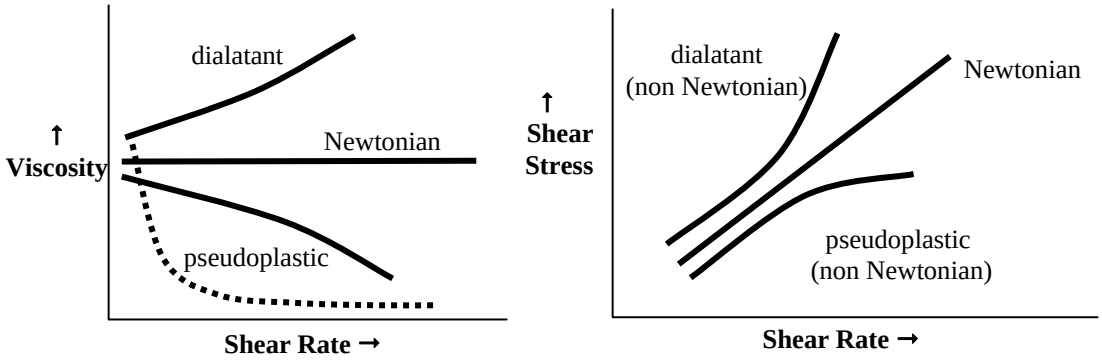
## ESTABLISHING A ROBUST INJECTION MOLDING PROCESS, PART 1:

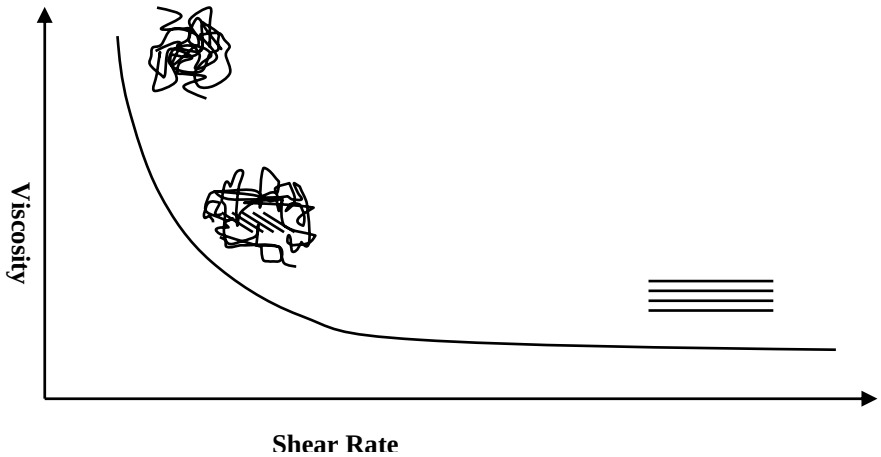
## The Viscosity Curve and The Injection Speed.

**Definitions:**

1) Newtonian Fluid: A fluid whose viscosity is not influenced by the shear rate that is being applied to it. The viscosity remains constant as the shear changes.
2) Non-Newtonian Fluid: A fluid whose viscosity changes with the change in the shear rate that is being applied to it. The viscosity does not remain constant as the shear changes.
3) Rheology: The study of fluid flow of non-Newtonian Fluids.




All plastics are non-Newtonian. This means that their viscosity does not remain constant over a given range of shear rates. In the strict sense, the rheological behavior of a plastic is a combination of non – Newtonian and Newtonian behavior. At lower shear rates, the plastic is non-Newtonian but as the shear rate increases, the plastic tends to exhibit a Newtonian behavior. This happens because with increasing shear rate, the polymer molecules start to untangle from each other and start to align themselves in the direction of flow. Refer to the picture on the next page.




**Importance to Injection Molding:**

During Injection Molding, the material is subjected to large amount of shear forces during the cavity filling stage. The shear rate is proportional to the injection speed. If the shear rates are in the non-Newtonian region of the curve, then small variations in the shear rate will cause a large shift in the viscosity. This will make the mold filling inconsistent resulting in shot to shot inconsistency. It is therefore important to find the Newtonian region of the curve and set the injection speed (therefore shear rate) in this region. The viscosity curve can be generated at the molding machine for any given mold. The term 'In-Mold Rheology' is another term used for developing the viscosity curve.

The effect of shear rate on viscosity is far greater than that of temperature. Therefore as long as the actual melt temperature is in the within the recommended range you will get a similar profile during the development.

**Developing the Viscosity Curve at the Molding Machine:**

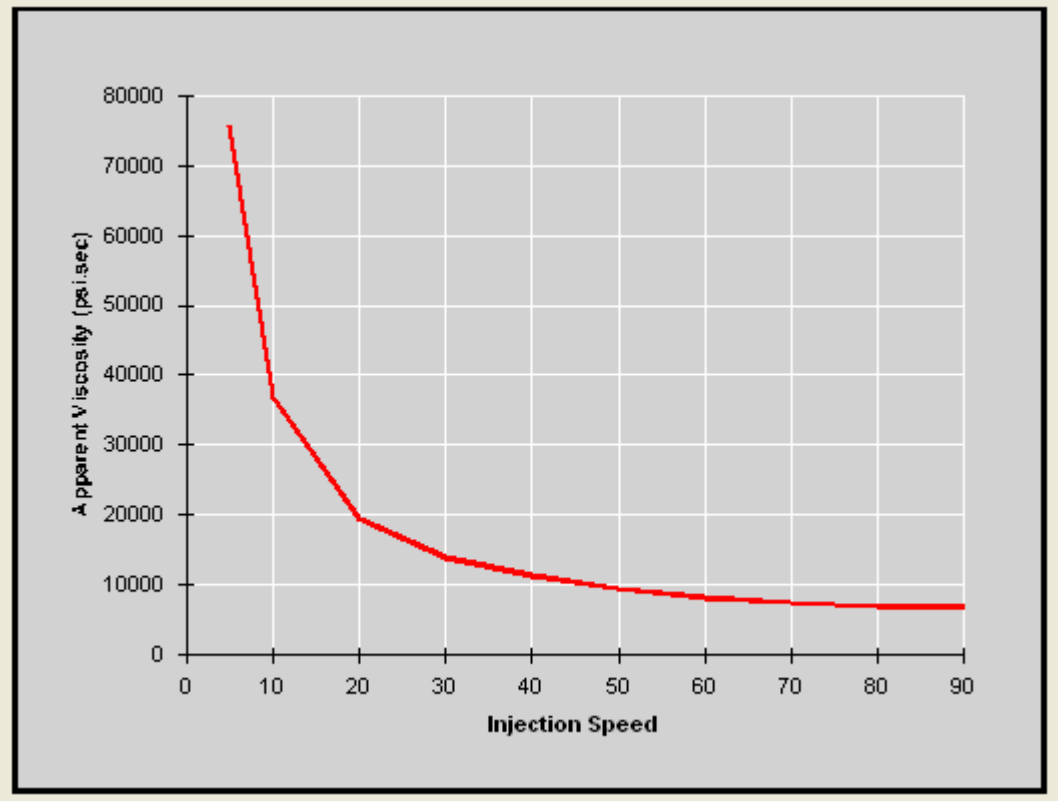
1) Set the melt temperatures to those recommended by the manufacturer. If there is a range, set the temperatures to the center of the range.
2) Set all the holding phase parameters to zero. This means that there will not be any holding phase and only injection.
3) Set the injection pressure to the maximum available.
4) Set the cooling time to a safe value such that the part will be cool and has reached the ejection temperature before mold opening.

5) Set the injection speed to ‘slow’ and make a part. The part should be short. If not adjust the transfer position to make the part such that it is filled only about 50%.
6) Increase the speed in steps and make sure that the parts are still short. Mold a part with close to the maximum injection speed and make sure that it is still short. If it is full, then adjust the transfer position, such that it is about 95 % full part. If it is less than 95 % full, then also adjust such that the part is 95% full. This means that at close to the maximum injection speed you have a 95% full part with no holding time or pressure.
7) Make another shot and record the fill time and the peak hydraulic pressure required to fill the part.

   Note: The peak hydraulic pressure will be the pressure required to move the screw at the set injection speed. This is taken from the available pressure from the machine. For example, the machine is set to 2200 psi but may require only 1850 psi to move the screw at the maximum speed of 5 in/sec.
8) Next, lower the speed by a small amount, for example from 5 in/sec to 4.5 in/sec or from 90% to 80%. Note the fill time and the peak injection pressure.
9) Repeat the above step all the way till you get to the lowest injection speed possible. Divide the available injection speed range into about 10 - 12 speeds so that you get as many data points.
10) Find the Intensification Ratio of the screw from the machine manufacturer. If this number is not available, pick it to be 10. It does not really matter since this is a constant used in the equation and will factor the viscosity proportionately.
11) To get the viscosity, use the following formula:

    Viscosity = Peak Injection Pressure X Fill Time X Screw Intensification RatioPlot the graph of viscosity vs injection speed. The figure below shows a typical viscosity curve that as generated at the molding machine.

A typical graph is shown on the next page.




**How to use this information:**

Looking at the above curve, one can notice that the viscosity stays fairly constant after about 60% of the injection speed. Therefore, setting the injection speed to 70% would ensure that the filling stage of the process will stay consistent. Any small natural variations will not cause large changes in viscosities resulting in shot to shot variations.

Shot to shot variations should be reduced in order to achieve repeatable quality of parts. This is especially important in case of tight tolerance parts and multi cavity molds. Optimizing the injection speed through In-mold rheology is only the first step to achieving a robust process. Later, the holding phase and the cooling phase must also be optimized.

**About FIMMTECH:**

FIMMTECH is a consulting firm that provides services in the area of Injection Molding of Plastics. FIMMTECH is also in the process of developing products that will increase efficiency of the molding process, educate personnel and better manage the molding facility. One of the first products to be released is the software 'NAUTILUS' that helps in the development of robust and optimized processes. Suhas

Kulkarni also teaches a course on Injection Molding at the University of California, San Diego that can be offered as In-House seminars. For more information please visit www.fimmtech.com

Thank You.

Sincerely

Suhas Kulkarni.