DECOUPLED MOLDING

What is decoupled molding?

Decoupled molding is simply a setup whereby the molder separates fill from pack: the first state is used only for filling and not for packing. This is checked by setting subsequent stages of pressure to zero and weighing the parts. The shot should appear to be short and weight should be approximately 95% of what the fully packed shot weighs. To accomplish decoupled molding, we must have the machine controls to accomplish the transfer from first stage speed control to second stage pressure: This is usually accomplished by a linear position transducer on the linear stroke of the injection ram (that which drives the screw forward). Our goal is for first stage to be speed control (as fast as the mold will permit, but this might be relatively slow) and second stage to be pressure control. This is the basis for most machine controls; thus, the term ***V-P transfer***, point of velocity control to pressure control.

Why utilize decoupled molding techniques?

One advantage of decoupled molding is that the fill may become more consistent by not being pressure limited. We want to have more pressure available than is needed, so that the fill is truly controlled by the velocity set points selected, This velocity often requires more pressure (or a different pressure) than that chosen for packing purposes. When the process is decoupled, the fill is separated from the pack and each can be adjusted without effecting the other (within reasonable limits... large increases in fill speed might cause inertial effects on packing). The other advantages of using decoupled molding is its potential to achieve faster injection fill rates. Decoupled molding allows the molder to set first stage injection pressures higher than would be set otherwise. If "traditional" molding techniques were used whereby the first stage performed fill and pack, and second stage accomplished the hold pressure...the first stage pressure would have to be limited to an amount that does not flash the mold or overpack parts to the point of part damage during injection. If we are able to use higher hydraulic pressures during fill, then we typically are able to obtain faster injection rates and probably more consistent fill rates. The maximum machine rated fill rate is dependent on pressure being available, which normally is in excess of the desired packing pressure.

There are two main advantages of faster fill rates:

1. Any fill time savings will reduce the overall cycle by that amount.
2. The more important benefit is its effect on resin velocity during fill. The viscosity of the resin can become significantly less at the high shear rates realized during fast injection rates. As the viscosity becomes less, it also becomes more stable (more stable meaning less variation as seen on a relative viscosity curve).

Why do fast fill rates (high shear rates) reduce viscosity?

Plastic molecules are extremely long relative to their width. Plastic molecules are sometimes described as being like a bucket of worms or spaghetti. This comparison is given primarily to describe the amount of entanglement and randomness of a molten polymer. When the polymer is forced to flow quickly by large amounts of pressure, the molecules are forced to align themselves in a more parallel fashion which allows them to flow more easily. This alignment results in a significant drop in the viscosity of the resin (for most resins).

Potential Disadvantages of decoupled molding.

If fill speeds are pushed too fast and/or through too small an orifice, then melt fracture may occur whereby molecular chain length is reduced. The strength of the plastic can be adversely affected if too many chains are broken. Since the transfer switch controls the amount ***not*** injected on first stage, the plasticized shot must be consistent and closely controlled by the plasticizing stop switch and the actual plasticizing. A good check ring, screw and barrel are thus required to plasticize the shot and not allow leakage back up the screw flights during injection.

If the mold's shot size is small relative to the machine's injection capacity, then the resolution of control can be unfavorable. For example: if a 6 inch stroke injects 6 ounces and we move the transfer switch 1/16 inch we have made and adjustment equal to 1/96 of the shot, but if the stroke is 2 inches due to an oversized barrel / shot capacity, then the adjustment equals 1/32 of the shot.

If cavitation is low and a cavity is lost due to gate blockage, then too much resin may exist at the elevated fill and pressure for the remaining cavities and an overpacked situation will likely result. Consideration must be given to the consequences of overpacking the mold, some molds are adversely affected and others may be more forgiving or overpacking.

Planning for decoupled molding.

The following will make decoupled molding a more reliable and feasible technique for injection molding:

1. Improve gate reliability (reduce gate self blockages)
   - reduced mold open time (improves hot runner gate's ability to reopen).
   - Improve balance of fill.
   - Reduce or eliminate gate blockage by contamination.
   - Reduce gate drooling or sub-gate vestiges which may cause blockage.
   - Reduce thermal differential across mold face (improves balance of fill).
   - All gate orifices should be same, as should probe tip locations.
2. Proper machine sizing and selection.
   - Select molding equipment so that the machine's shot size results in

the mold using approximately 25 - 75% of capacity: this will improve linear resolution of control. A rule of thumb is to use a greater percentage of the shot size the more heat sensitive the material. Note: Avoid having barrel size control cycle due to slow screw recovery.

- Closed loop machines may exhibit better control of the fill rate. This is especially true in setups where the resin is very changeable due to virgin resin variations or presence of regrind. The better fill rate control is also seen after cycle interruptions: the melt temperature and mold temperature are changed significantly during a cycle interruption. If maximum speed is used, verify that the machine/mold are not pressure limited. <u>If pressure limited, adjust velocity set point so that pressure required is less than pressure available.</u>
- A machine with faster injection rates has more performance potential.
- Digitized ram control set points are more repeatable and easily set.
- A transfer switch is required to control transfer by screw position, cavity pressure or hydraulic pressure during injection.

3. Proper machine setup.

- <u>Make plasticizing consistent</u> by using some back pressure and using maximum time available for plasticizing (w/o reducing cycle time).

Once a good process is established, <u>always run with the same fill time</u> regardless of cavitation. If setup is good, then each cavity needs to see the same fill time each shot. The viscosity of the resin entering the cavity will be directly related to the fill time.

<u>V-P Transfer (VPT)</u>

The V-P transfer is the transfer from 1st stage filling (under normal machine velocity and pressure controls) to the 2nd stage which is pressure control. Many modern injection molding machines have closed loop control of the injection molding fill rate or fill speed. A linear position transducer is used to track the screw position. The information from the position sensor is fed to a controller which also reads the fill speed set points entered by the operator. The controller may ask for higher injection (line) pressures so as to maintain the set/requested injection molding fill speed. The pressure may increase as the resistance to flow increases during mold fill. **At a certain point in the injection molding stroke (i.e. when the mold is full or nearly full) the resistance to flow becomes very high and it becomes unrealistic to expect the screw to maintain the desired rate.** At this point, control is shifted from being velocity controlled to being pressure controlled. This point is known as Velocity Pressure Transfer or VPT.

NOTE: If and when the machine becomes pressure limited, there will be no more velocity/speed increases. If the machine's 1st stage pressure (P6) is set to 50% and the velocity is set to 85%, we <u>may or may not</u> achieve 85% velocity - it depends on pressure required. As the mold fills and the resistance becomes higher, more pressure is required. The resistance increases as the flow front is constantly being cooled by the mold once it exits the heated barrel and nozzle.

If a car is being driven with the cruise control set at 65 mph; when the car comes upon a hill, it will begin to automatically depress the accelerator in an attempt to maintain the set speed. If the car has low horsepower, eventually the car will be power limited and the set speed will not be maintained. Imagine, how effective the cruise would be if we limited the throttle (and resulting horsepower) to only 35%.

A machine should fill under control and not be pressure limited <u>for best consistency</u>. If the machine is not pressure limited, then the velocity control can vary oil volume to achieve the desired fill rate (if closed loop). This does not mean the hydraulic fill pressure must be set to 99 or 100%. We can determine when a reduction in fill pressure begins to increase fill time for a given fill velocity set point. By reducing fill pressure (P6) in increments, we can quickly determine how much pressure is required. We would then <u>set the pressure approximately 300 - 400 psi higher than needed for the desired fill rate</u> setting and fill time received. This combination may still result in flash if the mold packs at this pressure. We must accomplish a V-P transfer prior to this point of mold flashing. This can be done via the methods described below.

<u>VPT Options:</u>

The control to transfer speed control to pressure control requires a signal or switch to accomplish. Changeover at the VPT may be set, or triggered, in the following ways:

1. Screw position - a.k.a. position control
2. Timer
3. Hydraulic pressure - a.k.a. pressure control.
4. Cavity pressure control - a.k.a. CPC or as cavity pressure changeover control.
5. External Devices - i.e. mold opening position sensors detect <u>slight</u> separation in mold parting line or clamp opening which would indicate pressure rise in cavity.
6. Melt Pressure - a.k.a. nozzle pressure

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