Process Monitoring Guidelines for the MuCell® Process

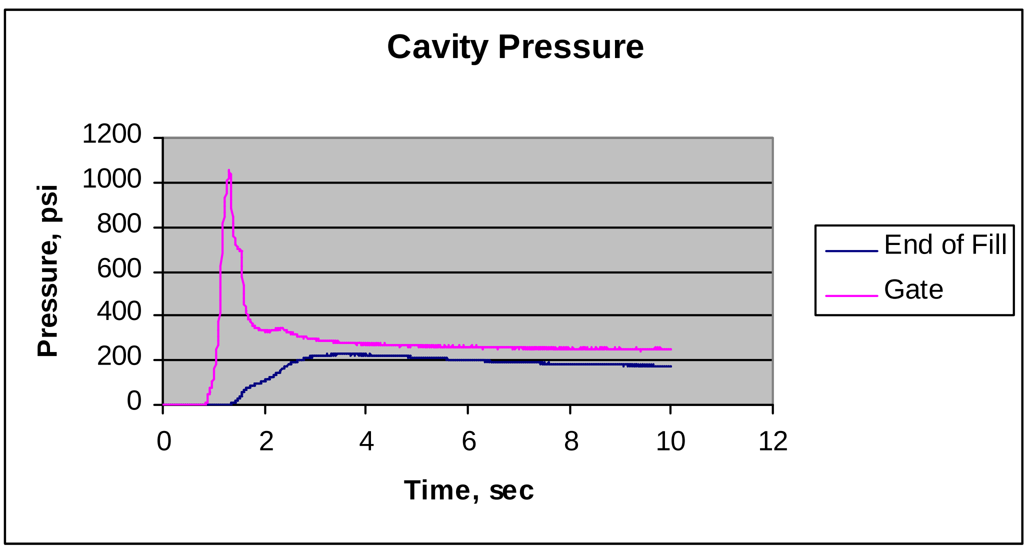
Monitoring of the injection molding process through cavity pressure sensors is a common practice in injection molding. The most common application is to use pressure monitoring at or near the end of fill as an indicator of a consistent process. In some cases, a combination of pressure at the gate and pressure at the end of fill are used.

The general application of the technology consists of establishing a pressure profile that equates to an acceptable part. This pressure profile is then used as a control mechanism for accepting or rejecting a part in real time. If the pressure profile for the part in the mold is within a predetermined range of the control curve, the part is judged to be acceptable and the normal part removal process applies. If the pressure curve is outside of the acceptable range, the part is rejected.

Discussion:

A series of studies have indicated the same monitoring techniques can be applied to the MuCell process. However, there are two specific issues that need to be considered when implementing cavity pressure monitoring. First, the typical cavity pressure curve for the MuCell process is much different than that for solid molding. Graph 1 shows a typical cavity pressure curve for the MuCell process.

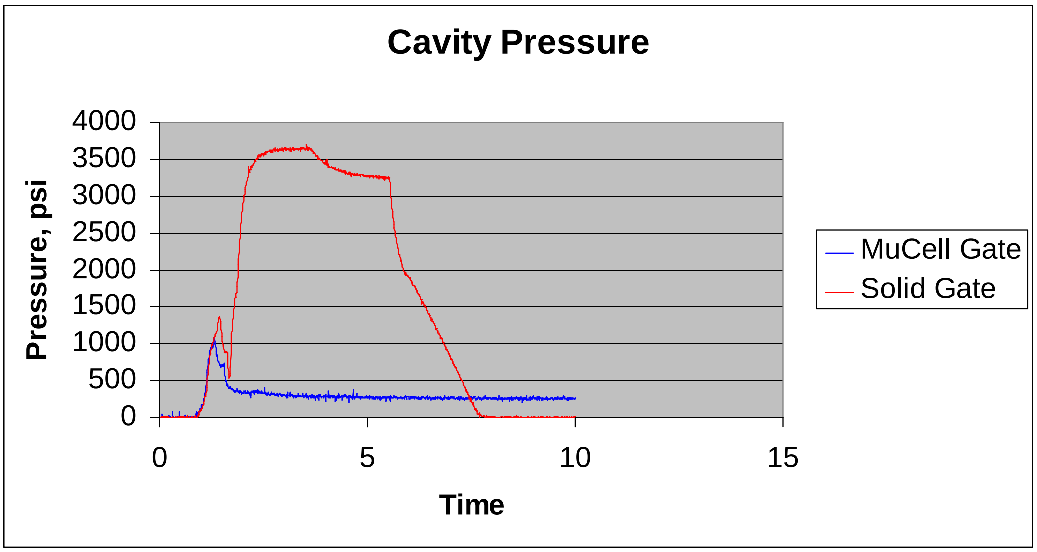
Graph 1: Cavity Pressure Profiles for the MuCell Process



As can be seen from Graph 1, the typical cavity pressure curve with the MuCell process shows a gate pressure that rises quickly until transfer from the injection phase to a very short pack/hold phase. The gate pressure then decreases rapidly to a value that is close to that of the end of fill. At the same time, the end of fill pressure rises relatively slowly reaching a stable pressure just below that of the gate.

In Graph 2, this can be contrasted with an end of fill cavity pressure curve for a solid process. As can be seen, the solid cavity pressure continues to increase through the pack/hold phase and then decreases rapidly at the end of hold pressure.

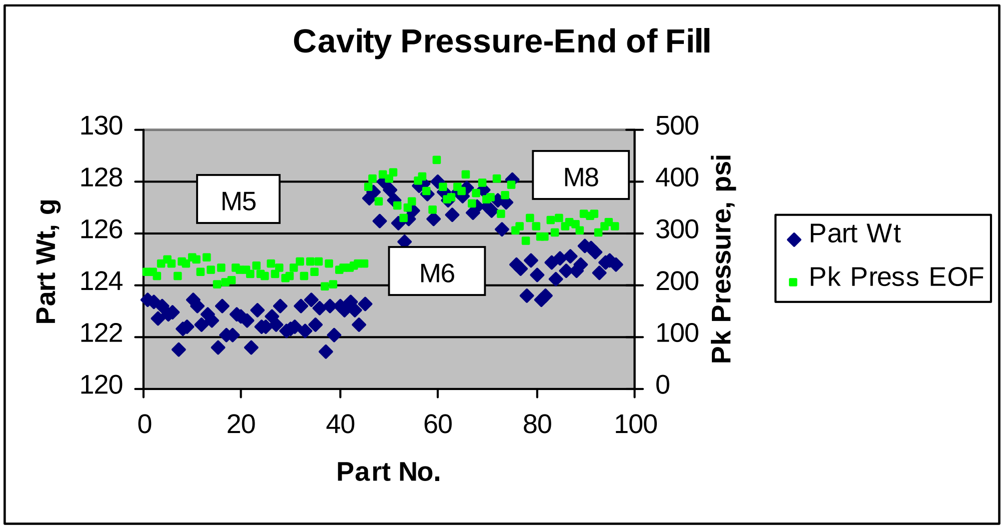
Graph 2: End of Fill Cavity Pressure MuCell vs Solid



In addition, the end of cavity pressure for a solid process can be as much as 10 times the end of cavity pressure for the MuCell process. Therefore the pressure transducers should be specified with a pressure range appropriate for the process.

Graph 3 shows the comparison of cavity pressure at the end of fill vs part weight. As can be seen, changes to part weight caused by changes to the injection molding process result in changes to the cavity pressure at the end of fill. Specifically cavity pressure is directly proportional to part weight. Therefore, monitoring cavity pressure at the end of fill will directly indicate changes to part weight and therefore changes to the MuCell process.

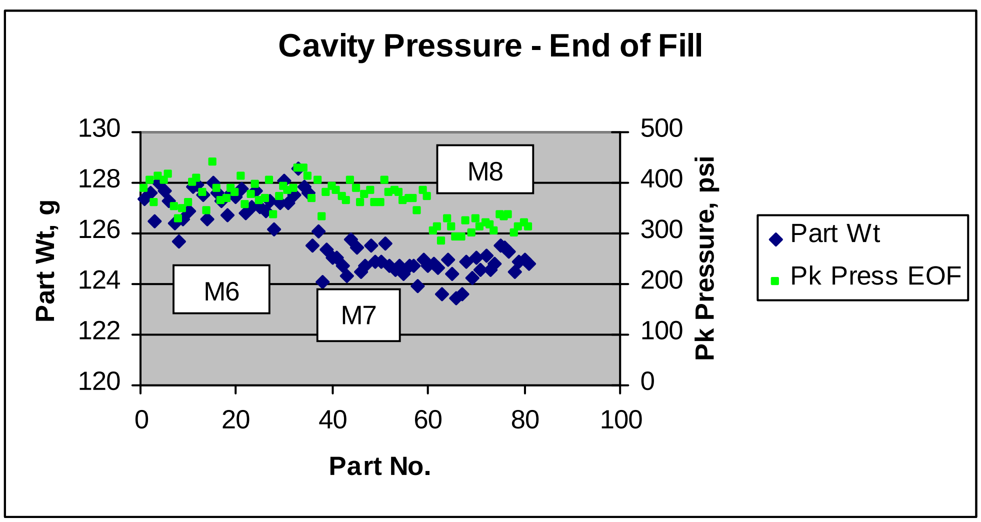
Graph 3: End Of Fill Cavity Pressure vs Part Weight



There is one exception to the statement above. This exception is a change in the process driven by a change to the SCF level. As SCF level increases, polymer melt density decreases which results in a decrease in part weight but cavity pressure remains constant due to a higher level of residual pressure in the cells.

Graph 4 shows this behavior. Process M6 and M7 are identical except for SCF level. M7 is at 0.25% nitrogen as opposed to 0.15% for M6. The higher SCF level results in a lower part weight due to the change in melt density but the cavity pressure remains unchanged as the residual pressure in the cells is higher. This is as compared to process M8 which has the same part weight as M7 but at a lower SCF level, 0.15%. In this case, both the part weight and the cavity pressure react as expected when compared to M6, both decrease.

Graph 4: Glass Filled PA6 with the MuCell Process.



Based on this effect of changing SCF level, it is necessary to monitor both peak cavity pressure at the end of fill as well as % SCF to fully monitor the MuCell process.

Implementation Procedure:

Here are the basic concepts for implementing in- mold process monitoring with cavity pressure transducers.

1) Identify the end of fill location for the mold
2) Locate a pressure transducer, either direct mount or behind an ejector pin, in this location
3) Establish an end of fill pressure profile that corresponds to the desired molded part
    a. For the MuCell process, part acceptance is typically at a given target weight reduction
4) Determine the correct tolerance for the end of fill peak cavity pressure that represents the desired final part
5) In parallel to the peak cavity pressure, monitor total % SCF by charting SCF flow rate and SCF injector open time
    a. These values are available for monitoring through the SCF delivery system.

Summary:

Studies were conducted evaluating the use of cavity pressure sensors to monitor the MuCell process and more specifically the ability to monitor changes in the MuCell process. The results of this study show that the process can be monitored through:

- A pressure transducer at or near the end of fill can be used in conjunction with %SCF to indicate changes to parts being produced with the MuCell Process
    a. Pressure transducers and amplifiers need to be specified based on end of fill cavity pressures of less than 1000 psi.
- % SCF is monitored by tracking SCF flow rate and SCF dosing time
- Injection molding machine parameters such as peak injection pressure, injection pressure at transfer, fill time and cushion are not good indicators of changes to the MuCell process

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