Applying Plastic Flow Principles to Reduce Mold Debug & Qualification Time

By David Hoffman, Beaumont Technologies, Inc.

If a mold builder were to review many of the mold start-up and debugging problems he has encountered over the years, he might discover a recurring list of problems (flash, non-fills, unable to pack the parts, dimensional variations, warp, broken core pins, poor cosmetics, etc.). And for a specific mold, if that mold builder were to ask someone on the shop floor or in the quality department which cavity or cavities are causing a specific problem, the answer might be something like, "It's random. Sometimes the problems are in cavity six, other times in cavity three and other times in cavity seven."

But with such a common theme of recurring defects, one has to begin to wonder if those defects are truly random? Why do the same problems keep showing up in nearly every mold this moldmaker builds? How much time and money is spent fixing the same problems over and over? And what can be done to diagnose and fix the root causes? Or better yet, what can be done to prevent the problems from happening in the first place, thus improving delivery and quality while saving the mold builder and his customer time and money?

The missing link

To begin to answer these questions, one must look beyond the mold steel itself. Not all answers to mold debug lie within what can be seen and measured with calipers and gauges. After all, complex plastic materials are being molded inside of the molds. Plastic materials expand in the molding machine barrel and contract inside the mold steel. Their resistance to flow is affected by temperature, how fast they are pushed and the geometry through which they flow. And to make matters worse, these effects are not uniform throughout the mold. But it is this link, fundamental plastic flow principles, that often lie at the root of many of the part quality defects and process issues not only seen during mold debug but continuously throughout the life of the mold.

Unfortunately, and ironically, there is a general lack of proper education on understanding plastics and how they flow through a mold. And this is a problem not only in the moldmaking department of a company but also, within the processing and quality control departments as well.

Using plastic flow principles as a root cause analysis tool will allow the mold builder to see through all the noise encountered during the mold debug and troubleshooting phases by separating out the many confusing variables. And when done properly, all of this can be achieved at a lower cost and with a shorter lead-time.

Flow groups

Separating the root causes of mold filling and part quality variations is done using flow groups and regions. Figure 1 is a flow group and region map of a 16-cavity mold.

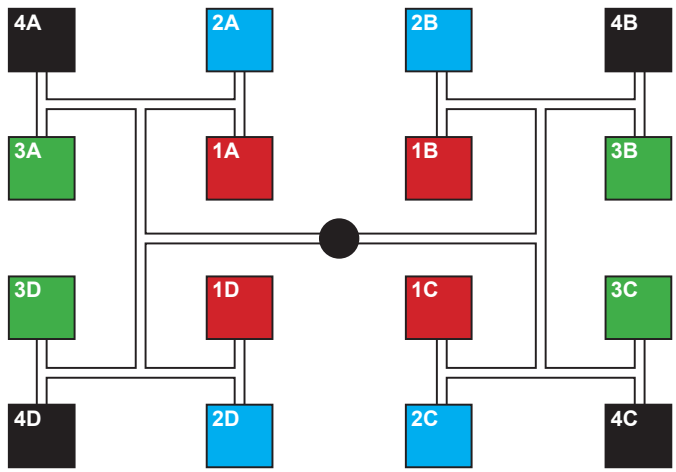


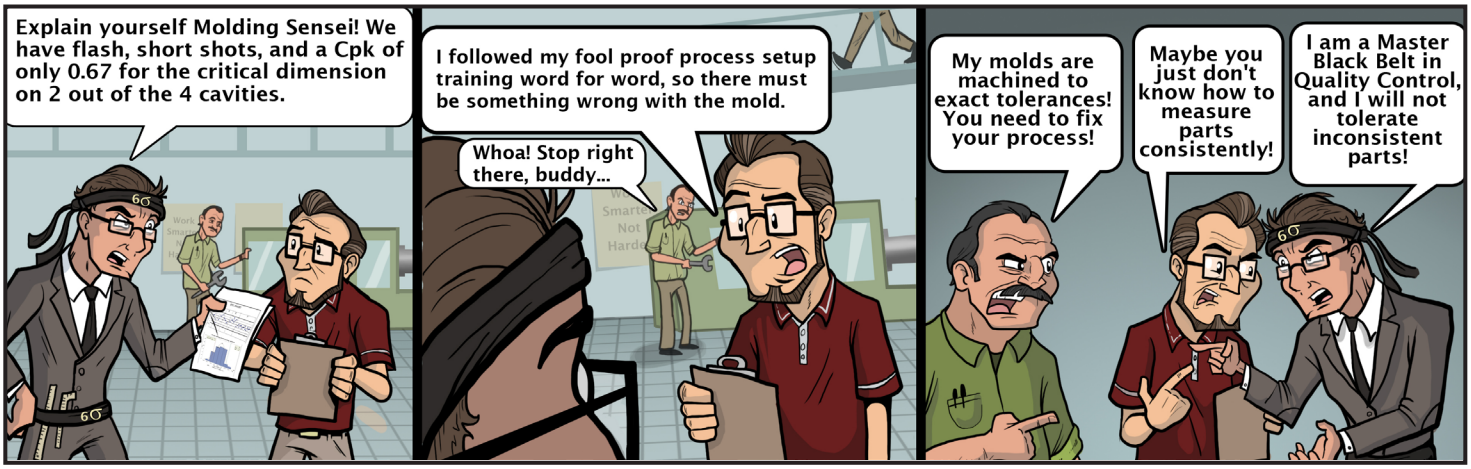
Figure 1

This methodology is based on the science of plastic flow using the simplified pressure drop equation as its foundation (Figure 2).

$$\Delta P = \frac{8Q l \eta}{\pi r^4}$$

Figure 2

To better understand how this works, consider that all filling and part quality variations are a result of a pressure drop difference experienced by the plastic as it flows to and within the mold's melt delivery system and part cavities.



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The pressure drop equation breaks down the possible causes of these differences into mold steel (l = flow length, r = radius of the flow channel) versus rheological (n = material viscosity) variations. Common steel variations include such things as core/cavity steel dimensions, gate size/gate land variations and venting, in addition to outside variables such as molding machine inconsistencies, heater band functionality, cold slugs and so on. These variations are defined as those that exist within a given flow group.

The variations that exist between flow groups are a result of different material viscosity characteristics within each of the flow groups. The viscosity variations are caused by non-uninform shear history of the material as it travels through the mold.

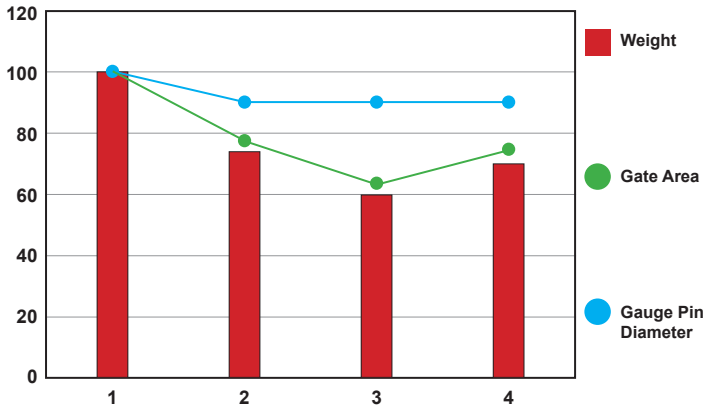

Figure 3

Diagnosing molds systematically

When diagnosing mold debug issues using flow groups and regions, the mold builder first must come to grips with the science behind the procedure so he can build trust in what the data is telling him. The second concept to grasp is that small differences in steel amount to large differences in plastic flow. This is shown by the 'r' value in the pressure drop equation being raised exponentially to the fourth power. This is such an important variable that tolerances (yes, standard machining and part print tolerances) have been shown to cause too much variation in plastic flow that it directly affected the quality of the molded parts. And these differences are often masked based on how the steel is measured.

As an example, Figure 3 shows the short shot weight taken during mold start-up. As can be seen, there is nearly a 40-percent steel variation within Flow Group 1. The part was gated with a standard tunnel gate with a gate size specification of 0.020" +/- 0.001". The gates were measured using pin gauges and all gates were recorded to be within spec; therefore, it was believed that the variation could not possibly be within the gate sizes.

However, most tunnel gates result in an oval opening on the part. Thus, the standard practice of measuring tunnel gates results in measuring oval shapes using a round pin. This results in a measurement in the minor axis only, not the major axis of the oval. Figure 3 also shows the short shot data overlaid with the gate size measurements using a pin gauge versus the actual cross-sectional area of the gate.

The cross-sectional area measurements correspond directly with the short shot data. In this case, the actual variation in steel was larger than the measured values, mainly due to the measurement method. However, it demonstrates that a tolerance of +/-0.001" on a gate size of 0.020" diameter is enough to create larger variations in plastic flow. Simply stated… trust the data.

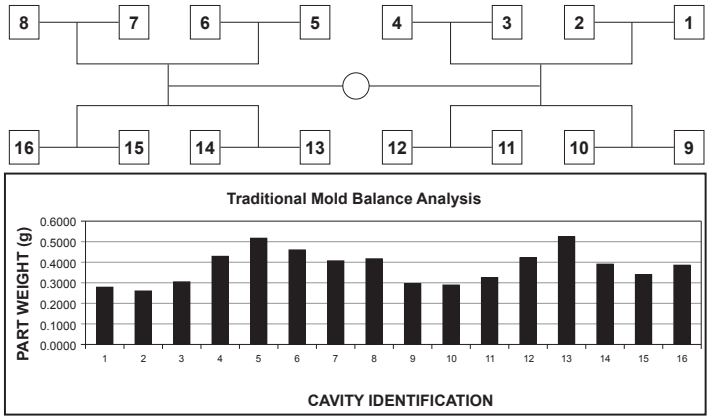

Figure 4

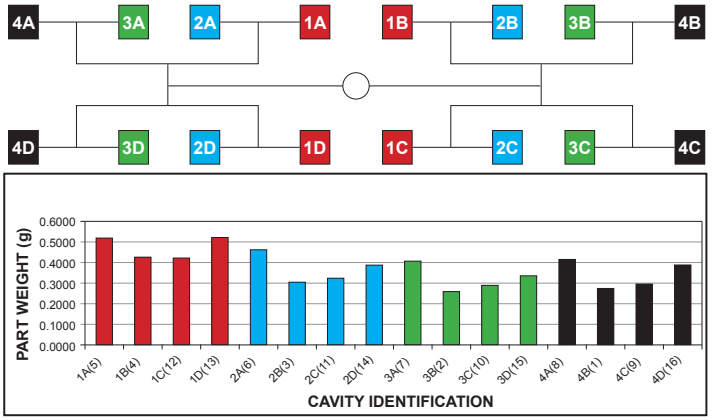

Figure 5

Figure 4 is an example of a 16-cavity mold showing the conventional way of looking at mold data which resulted in a calculated variation of 51 percent. From here, a great deal of variation can be seen, but no rhyme or reason as to what is causing the variation.

Figure 5 is the same data but rearranged according to flow group and regions. By looking at the data in this fashion, steel variations can be calculated within each flow group and viscosity variations between each of the flow groups. In addition, a pattern that existed in the data can be identified easily. Further analysis revealed a trend in which the cavities in the A & D regions were the heaviest cavities in all flow groups. Therefore, root cause analysis efforts could be focused on measuring cavity spacing, runner diameters, runner lengths, etc., which ultimately led to identifying a variation of .006" (.152 mm) in one half of the primary runner. The larger primary runner was on the left side of the sprue (regions A & D), which correlates with the data according to the pressure drop equation. The larger diameter means less of a pressure drop and an easier flow path for the plastic. In contrast, when evaluating the data using conventional methods and through processes, there is little possibility of identifying the trend and ultimately the root cause of the variation.

Summary

Many of the recurring defects and mold debug issues can be diagnosed easier and faster using flow groups and regions. In order to do this, it is just as important for a moldmaker to understand plastic flow as well as he understands CNC programming. This understanding and type of diagnostic procedure are critical to the advancement of the moldmaking industry. After all, whether admitted or not, a moldmaker's perceived quality of work is directly affected by plastic flow and how it affects the molded part. As such, wouldn't it be advantageous to understand it a little more? ■

David Hoffman is the senior instructor and training development manager at Beaumont Technologies, Inc. in Erie, PA., where he co-invented the MeltFlipper Multi-Axis rheological control technology. He is a 20-year industry veteran with experience in part design, processing and mold design/manufacturing. For more information, call 814.899.6390; email dhoffman@beaumontinc.com or visit beaumontinc.com.