TMG News

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Is Conformal Cooling Right for You?

Matt Dachel

A key benefit of injection molding is the ability to economically mass-produce dimensionally stable parts. The injection molding cycle can be split up into four main stages: filling, packing, cooling and ejection. In general, the cooling stage can comprise around 50-80% of the cycle time, Figure 1. [1] In addition to having a significant influence on the cycle time, the cooling stage can also have a drastic influence on the part performance. The part surface appearance, chemical resistance and dimensional stability can all be influenced by the cooling stage. The cooling time is most often dictated by the thickness of the part and feed system, as well as the mold temperatures. As shown in Figure 2, both the part thickness and mold surface temperature can impact the cycle time. However, the part thickness typically will have a much larger influence on the cycle time than the mold temperature, when the part is processed within the recommended mold temperatures.

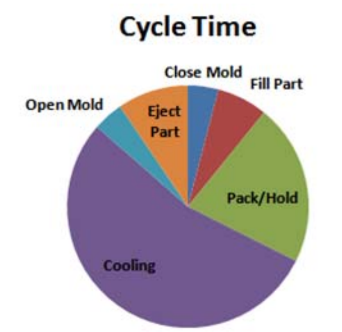

Figure 1 – Pie chart representing a typical injection molding cycle.

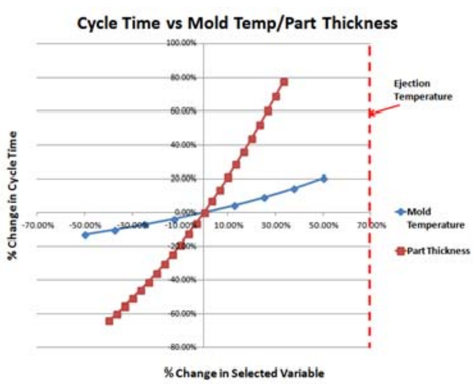

Figure 2 – Graph displaying the percentage change in cycle time versus the percentage change in mold temperature and part thickness.

In some cases, wide mold temperature variations and high mold temperatures can develop. This is particularly true with tall, slender cores, where it can be difficult to get cooling close to the part surface. As the mold temperature approaches the ejection temperature of the material, the influence of the mold temperature on the cycle time sharply increases, Figure 3. The hot surfaces of the part will also take longer to solidify and thus, shrink more than the colder regions of the part. This effect can result in the buildup of stresses in the part. These internal stresses can manifest as part warpage (Figure 4), but can also remain as residual stresses, if the part is rigid enough to resist the warpage. [2]

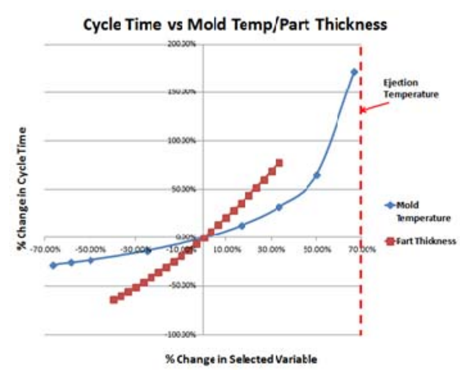

Figure 3 - Graph displaying the percentage change in cycle time versus the percentage change in mold temperature and part thickness.

While it is well-known that cooling the part uniformly is important for the performance of the part, the design of the cooling system is often left toward the end of the mold design process. Therefore, the design

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[1] Subramanian, M. N. (2011) Plastics Processing, in Basics of Troubleshooting in Plastics Processing: An Introductory Practical Guide, John Wiley & Sons, Inc., Hoboken, NJ, USA.
[2] Fischer, Jerry. (2013). Handbook of Molded Part Shrinkage and Warpage (2nd Edition). Elsevier.

freedom of the cooling system is often limited. Additionally, the cooling channels must avoid the already-designed features of the mold, such as slides and ejector pins, and also must maintain the structural integrity of the mold. The cooling channels are typically drilled into the mold, which most often requires that the cooling channels are designed as straight lines. Combine these limitations with complex part designs and uniform cooling of the part, may be difficult to achieve with traditional methods.

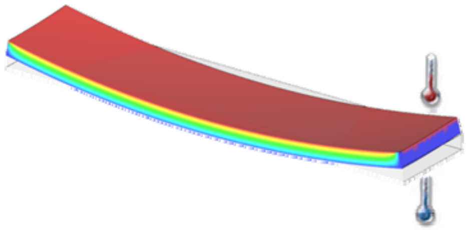

Figure 4 - Temperature differences, from one side of the mold to the other, can lead to layers freezing and shrinking at different times and generating internal stresses.

One solution to this problem is utilizing conformal cooling channels. Molds and mold inserts with conformal cooling channels are typically built utilizing additive manufacturing, such as direct metal laser sintering (DMLS), which builds the tool in thin layers from the bottom up. Building tools in this way allows the cooling channels to be created without drilling through the mold, and allow a much greater freedom when designing the cooling system, as shown in Figure 5. Conformal channels allow the cooling system to follow the curvature and design of the part. The cross-sectional shape of the channel can also be modified to allow the conformal channel to fit into many tight areas, where traditional channels may not be able to reach. At this time, high-conductivity materials, such as beryllium copper (BeCu), are not readily available for 3D printed tools.

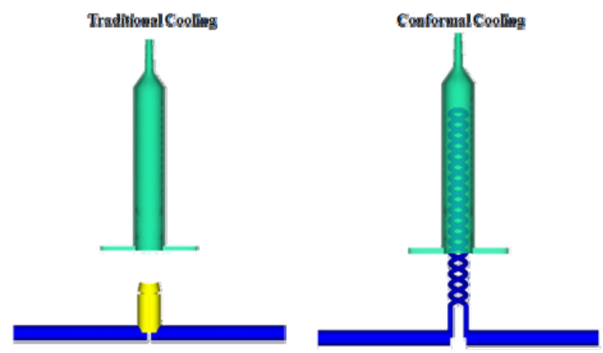

Figure 5 – Traditional cooling channel layout (left) and conformal cooling channel layout (right).

Injection molding simulation software, such as Moldflow, can be utilized in order to simulate the injection molding process and calculate the mold temperatures, as they fluctuate through the injection molding cycle. Carlson Tool provided the mold layout for a quart-sized container. Figure 6 shows the cooling line layout from the container mold that was used to manufacture the container. The mold was designed and manufactured using traditional machining methods. In order to achieve this cooling channel configuration, several inserts needed to be machined and assembled together. This cooling configuration was modeled with both steel and a high-conductivity (BeCu) material for the Moldflow analysis. A steel core insert with conformal cooling channels (Figure 7), was designed in order to compare cooling to the traditional inserts. The channel near the inner corner of the quart can was designed with a triangular cross-section in order to reach closer to the inner corner of the tool, where the highest heat load was expected.

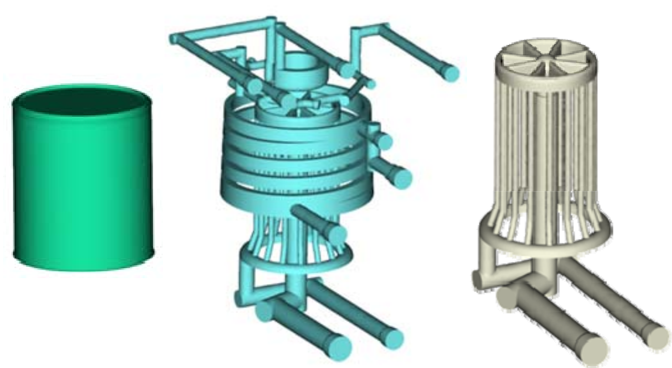

Figure 6 –Quart container (left), cooling channels (middle), core cooling channels (right).

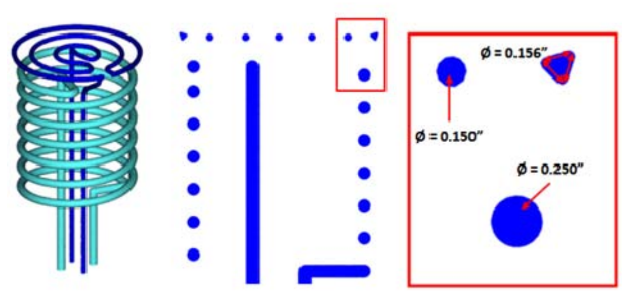

Figure 7 – Core conformal cooling channels (left), cross-section of the conformal cooling channels (middle and right).

The predicted mold surface temperatures are shown for each of the mold inserts in Figures 8-10. The high -conductivity insert and conformal cooling insert (Figures 9 and 10), were predicted to run approximately 17 °F cooler at the hot inner corner of the mold than the traditional steel insert (Figure 8). Both the conformal cooling insert and the high-conductivity insert showed a similar improvement of the mold temperature distribution, when compared to the traditional, steel insert (Figure 8). In this case, the part design allowed enough flexibility to design a core cap insert that achieved relatively uniform mold temperatures using traditional machining methods. However, the traditional channel design needed to utilize a high-conductivity material in order to uniformly cool the inner corner of the mold. The conformal cooling insert displayed uniform mold temperatures without the need of high-conductivity materials.

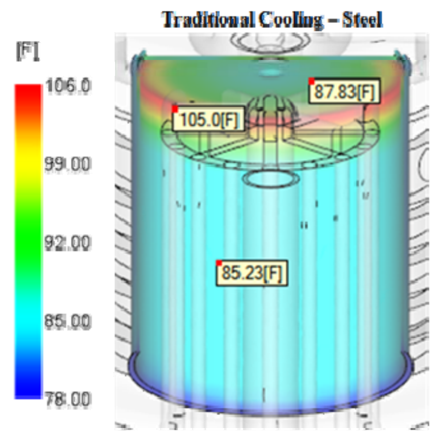

Figure 8 –Mold surface temperature of the steel mold insert with traditional cooling channels.

Summary

This article displays one example in which conformal cooling channels were used in injection molding to promote uniform cooling of the mold. In general, conformal cooling channels can improve the mold temperature distribution and may reduce the cycle time, when compared directly with traditional cooling channels. Conformal cooling lines typically show the most benefit when the limitations of traditional cooling lines are the limiting factor in uniformly cooling the mold. Examples of this type of scenario are parts with deep pockets and confined spaces that may not allow for cooling channels to be drilled into these locations. Conformal cooling channels allow greater mold design flexibility, and can allow cooling channels to cover more of the part than traditional cooling lines would allow. However, for parts that allow plenty of space for traditional cooling lines to uniformly cover the part, such as with a flat plate, conformal cooling lines may not yield a significant benefit over traditional lines. Injection molding simulation can be very useful when deciding if conformal cooling channels should be used for a given mold. These tools can help predict the hot spots in the tool, and quickly evaluate the effects of different cooling system designs.

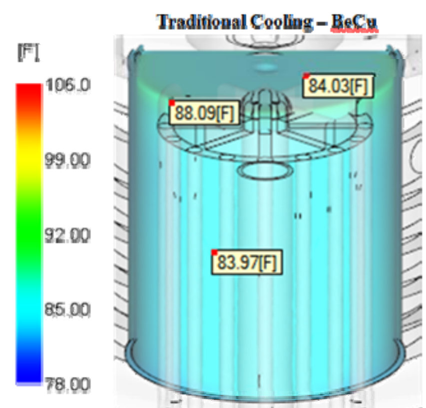

Figure 9 - Mold surface temperature of the high-conductivity (BeCu) mold insert with traditional cooling channels.

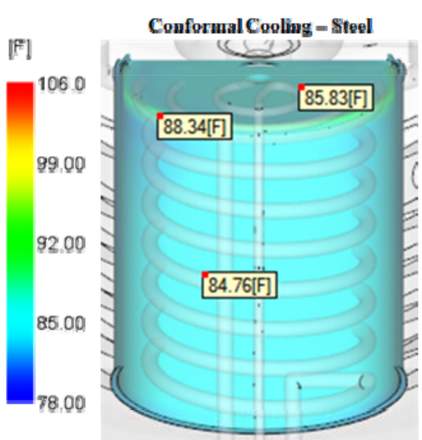

Figure 10 - Mold surface temperature of the steel mold insert with conformal cooling channels.

For more information, please contact
Matt Dachel at 608-231-1907 or matt.dachel@madisongroup.com, or refer to the following article:

Simulate Your Way to a Better Mold
http://madisongroup.com/publications/Simulate-Your-Way-To-A-Better-Mold.pdf

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Upcoming Educational Webinar

Understanding Fatigue of Plastics—*Jeffrey A. Jansen*
Thursday, December 8, 2016
Time: 10:00 AM CST

Society of Plastics Engineers

The exposure of plastic materials to dynamic stress can produce several different responses, and will certainly alter the mechanical properties of the material. Fatigue is a very important failure mechanism for plastic components, and a clear understanding of its implications is essential. Topics covered will include fatigue failure mechanisms for plastics, factors effecting fatigue resistance, and fatigue testing. The effects of fatigue loading will be reviewed, and a case study will be used to illustrate failure resulting from dynamic stress loading.

For more information, please contact Scott Marko at 203.740.5442

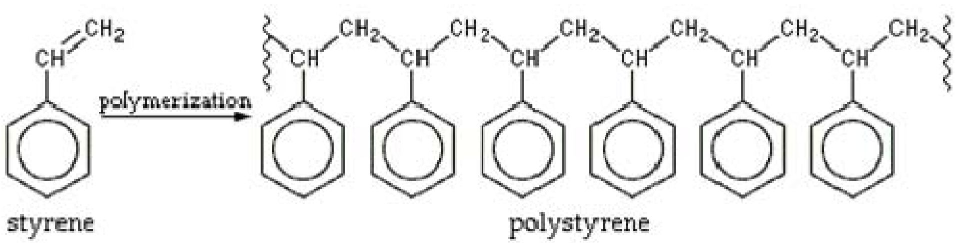
Information regarding upcoming educational opportunities can also be found at: http://www.madisongroup.com/events.html

Addition Versus Condensation Polymerization

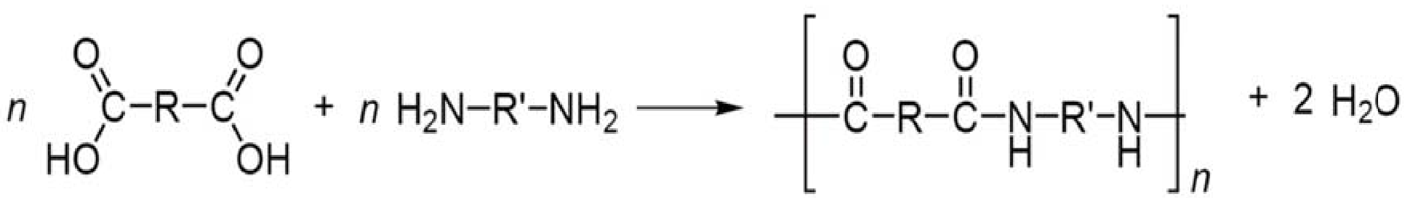
Jeffrey A. Jansen

Polymers are macromolecules that are based on a structure built up, chiefly or completely, from a large number of similar structural units bonded together. Often called chains, the polymer consists of repeating units, similar to links. Polymers are formed through a process known as polymerization, in which monomer molecules are bonded together through a chemical reaction that results in a three-dimensional network of long individual polymer chains consisting of smaller repeated units.

There are two basic types of polymerization reactions: addition and condensation. Addition polymerization is the formation of polymers from monomers containing a carbon-carbon double bond through an exothermic addition reaction. Significantly, this reaction proceeds without the loss of any atoms or molecules from the reacting monomers. Common materials produced through addition polymerization include polyethylene, polypropylene, poly(vinyl chloride), and polystyrene as represented below:



In contrast, condensation polymers are formed by a stepwise reaction of molecules with different functional groups. The reaction is endothermic and produces water, or other small molecules such as methanol, as a byproduct. Common polymers produced through condensation reactions include thermoplastic polyesters, polyacetal, polycarbonate, and polyamides as represented below:



Addition polymers form high molecular weight chains rapidly, and tend to be higher in molecular weight than condensation polymers. Comparing polymers produced via the two different mechanisms, addition polymers are generally chemically inert due to the relatively strong carbon-carbon bonds that are formed. Condensation polymers tend to be susceptible to hydrolytic molecular degradation through exposure to water at elevated temperatures, through a mechanism that resembles the reversion of the initial liberalization reaction.

Polymers produced through these two different types of polymerization mechanisms exhibit inherently different characteristics, including mechanical, thermal, and chemical resistance properties. As such, it is important to understand the type of polymer being considered in an application.