DME ANALYSIS AND ENHANCED COOLING PERFORMANCE

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The benefits of undertaking computational fluid dynamic analysis prior to mold cooling design and manufacture

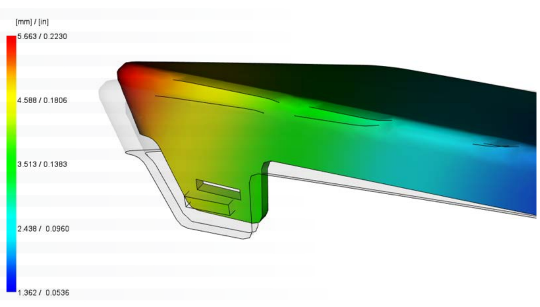
Optimized cooling is crucial to an injection mold's performance and much light has been shed on the matter in recent years. With the addition of conformal cooling and advanced strategic design, we are able to greatly improve the productivity of a molding process, the quality of the manufactured part, and life expectancy of the mold.

Today, too often cooling projects are initiated without the necessary data that is generated through analysis. The result is suboptimal processing performance and part quality.

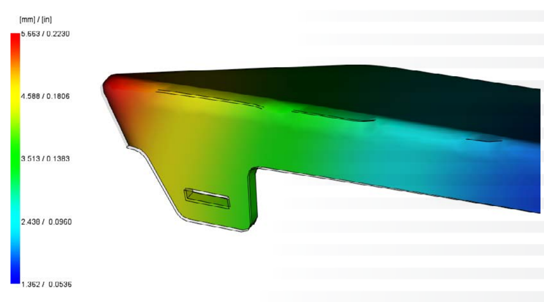
The undertaking of upfront computerized analysis allows for the identification of thermal management challenges and guides the user towards different forms of technology. As the cooling of the plastic part is most often the longest portion of the molding cycle the benefits of analysis and the resulting addition of conformal cooling can have significant economic benefits.

Introduction

The efficiency of cooling and producing a high-quality plastic part is significantly impacted by the difference in temperature across the geometry. This variation in temperature is measured by the Delta T. A lower Delta T will result in a better balanced and more efficient cooling of the plastic part. Cooling is a critical step in the molding process and its efficiency determines cycle time and overall part quality. Insufficient cooling, together with poor part design, improper pressures, gate type or even resin properties can all greatly influence the part warpage after the ejection of the resin part from the mold.



Excessive Warpage



Minimal Warp

For generations the Molding Industry has relied almost solely on the machining of straight drilled channels into the mold in order to cool the plastic part. The addition of cross channels to reach into contoured shapes whilst offering an improvement still presents major limitations. Specialized cooling components such as bubblers and baffles can greatly enhance the versatility of the cooling channels by delivering much needed circuitry and turbulent flow into harder to reach locations.

However, despite all of these advancements, there is still room for improvement when trying to address uneven temperature delta across the part geometry.

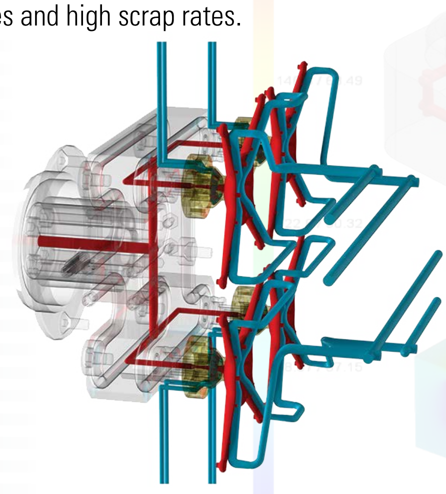
Conformal Cooling is the ability to replicate the cooling channel closely to the part geometry. The concept of conformal cooling is not new, but it has only been with the relatively recent advancements in new manufacturing technologies that has enabled this form of cooling to become mainstream in the molding industry.

Conventional approaches to conformal cooling, such as 2-piece brazing or diffusion bonding, create an inner core containing cooling groves milled into the surface, which are then bonded with an outer shell. These technologies allow for the generation of conformal cooling but are limited to the confines of conventional machining.

It has been the advancements in **3D metal printing technologies** that has enabled the manufacture of conformal cooling channels that truly contour the geometry of the part and generate quantum improvement to the Delta T. The technology allows for the use of metal powder, which is welded, most often via laser, to create a fully 3D built mold or mold insert. With the advancements in the precision welding technology it is possible to create more intricate cooling channel designs that even closer comply with part geometry.

However, even with these advances in conformal cooling technologies, without a thorough analysis at the beginning of a mold design, the cooling performance will still be sub-optimized, and designers will still be guessing where the water channels need to be placed within a mold.

Until now, the location of cooling channels has been one of the last steps of the mold design process and, as a result, the cooling performance of the mold is typically not optimal. Trying to navigate straight drilled channels through the maze of mold componentry and part geometry usually renders cooling vastly inadequate and mold performance generally is less than ideal. The result is unnecessary long cooling times and high scrap rates.



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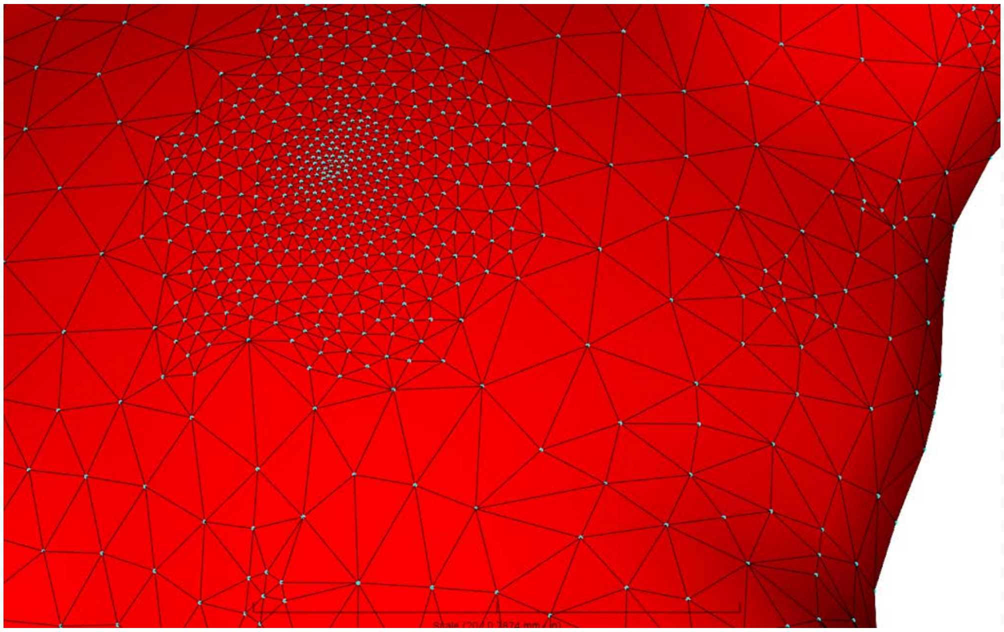
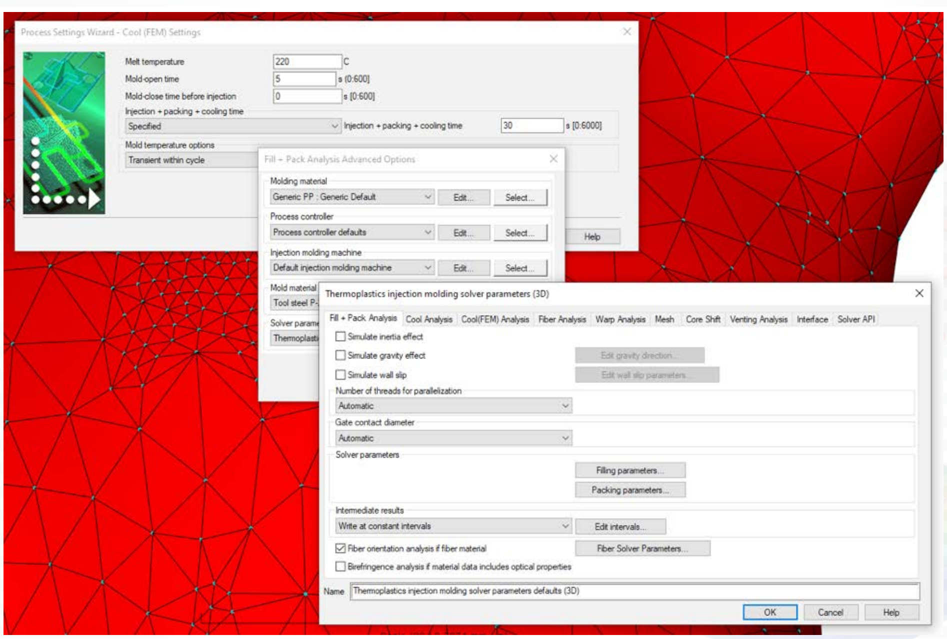
The Process

The mold analysis process begins with the CAD model of the end part design. Analysis software such as **Moldflow®** and **Moldex3D®** breaks this model up into "nodes" or points that can vary in number, depending on how intricate and detailed you wish the results to be. This, as a result, forms small "tetras" or triangles that are all connected, allowing the software to measure the time and flow of resin between each connected node.



Nodes and Tetras for calculations

Parameters that are input into the software advise on how the injection press would operate. A broad range of parameters are available and the more of them used the more accurate the analysis will become.



Entering press parameters

Once set up, the software calculates how the resin will flow throughout the mold and into the cavity. Specifically, it models each stage of the process from the **melt entrance point (MEP)** through the manifold system, into the runners, and the mold cavity. The hold pressure for packing of the part is also assessed. The software analyzes the cooling impact on the plastic part and the surrounding mold. Once the analysis is complete it is possible to determine precisely what is happening to the resin and mold during operations.

Resin flow and direction, weld lines, gas traps, melt front temperature are all part of the fill analysis process.

Mold clamping tonnage is a very useful also useful information of the packing analysis.

Through analysis the temperature delta is measured across the resin part which in turn determines the optimal allowable cycle time. The same analysis also identifies area of potential warpage of the part depending on the cooling pattern, fill, gate conditions and even fiber orientation and shrinkage within the resin, Reconfiguring the cooling channels to lower the Delta T and improve flow allows for faster cycles and superior part quality.

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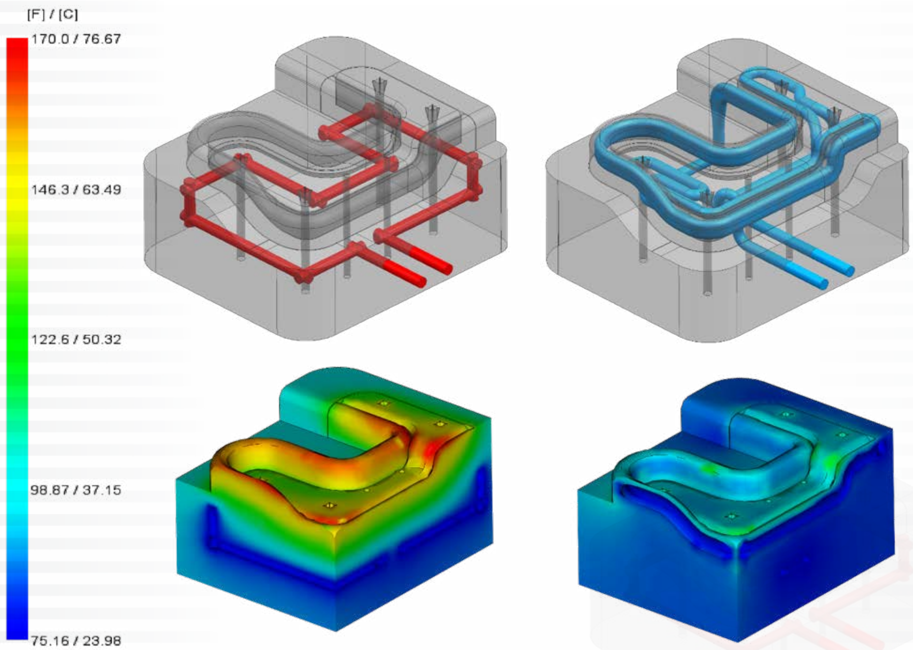


Analysis showing cooling results and temperature delta of mold insert; Conventional cooling vs Conformal Cooling

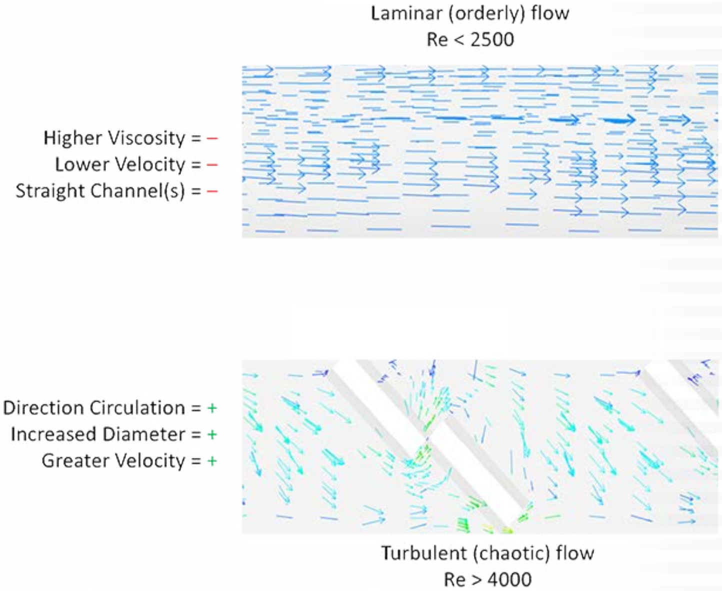
Computation Fluid Analysis

Optimal cooling of a part relies on proximity of the cooling and the efficiency of transfer the heat from the molten resin. This is most impacted by the transfer of the heat out of the mold through the coolant media, typically water. The efficiency by which the water removes the heat is measured through a system called the Reynolds value. The necessary range for a Reynolds value is between 4000 and 6000. If a system is performing with a value that is too low, laminar flow is the yield and if the value is above 6000, the energy level to push the medium exponentially increases thus increasing energy consumption.

Reynolds Calculation:

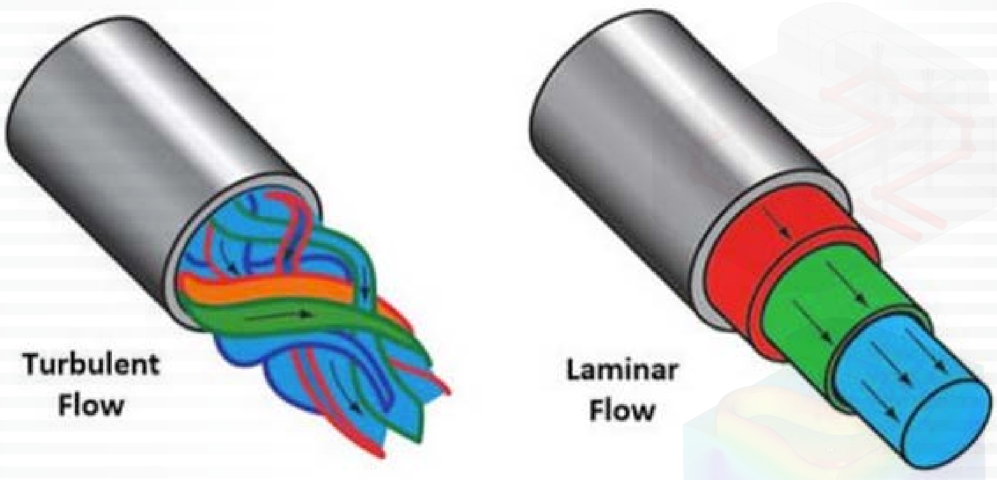
$$\mathrm{Re} = \frac{p \cdot V \cdot D}{\mu}$$

Re – Reynolds Value
p – Density
V – Velocity
D – Diameter
μ – Viscosity



The Reynolds calculation and example of laminar vs turbulent flow.

Laminar water flow is very inefficient as the outer surface become hot reducing the cooling efficiency. The preferred state is that or turbulence where water continually exchanging heat from the surface of the channel to the core.



Turbulent and Laminar flow

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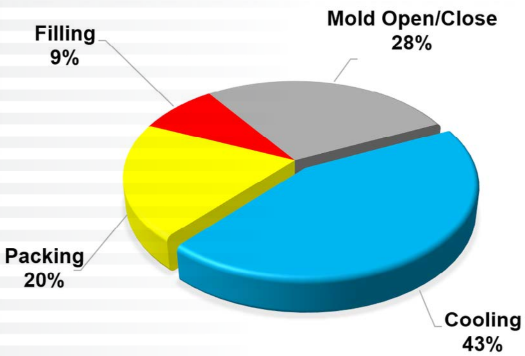
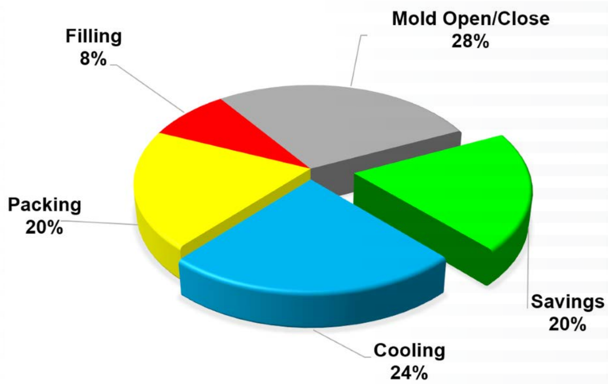
The Results

Upfront analysis enables the understanding of a mold's performance in advance of it being placed in the press. By predicting the cycle time and how much can be saved the optimum number and type of presses and tools can be calculated. Likewise, comparison of different cooling technologies can be assessed.

Typical example of conventional versus conformed cooled tooling



Conventional cycle time



Optimized cycle time; improved cooling

The financial gain by adding conformal cooling to a mold can be significant. In a recent case study, a molder of soup bowls who was manufacturing 131 million parts per year per using three presses was confronted with the challenge of increasing annual output to meet its customers demand. Two alternative investment thesis were explored:

1. The addition of two injection molding presses and two new tools and
2. The modification of the existing three tools with the addition of conformal cooling inserts.

The results of the evaluation showed that despite the higher overall tooling costs the savings from the use of the conformal cooling inserts were significant and the return on investment (ROI) was less than 3 months as illustrated below

Return on investment of analysis and optimized cooling

Operating Parameters	Old Conventional	New DME Conformal	Improvement	Annual Financial Savings
Tools in operation	5	3	2	
Cycle Time	6.7 seconds	4.2 seconds	2.5 seconds (33%)	
Annual Yield	214,129,000 pieces/yr	197,316,000 pieces/yr	65,772,000 pieces/yr	$375,000
Scrap Rate	3%	1%	2%	$235,000
Press Hours	Running 120hrs over a 6 day week (2X 10 hr shifts/day)	Running 96hrs over a 6 day week (2X 8 hr shifts/day)	24 hours per week	$250,000
Presses Required	5	3	2 (33%)	$1,248,000
Tooling Cost	2 additional tools $215,000	$453,600 ($5400/insert)		($238,600)
			Total Difference	$1,869,400
			Conformal ROI (Payback)	< 3 months

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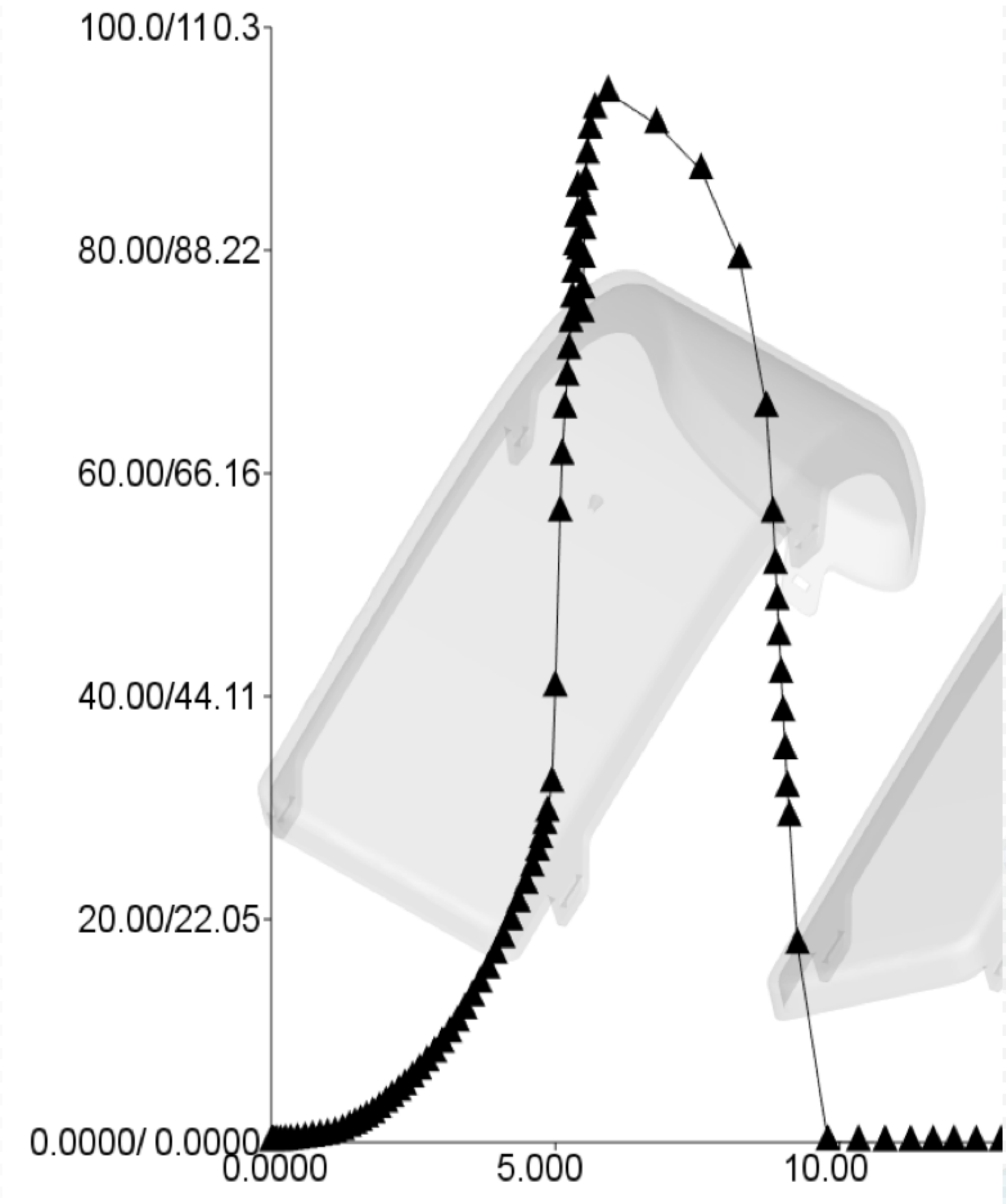
Using the mold analysis data, it is possible to determine the **preferred gating locations** which will allow ideal filling patterns and/or weld lines in the part. It will also allow the determination of how ribs will fill and if there would be any short shot parts based on the capabilities of the press planned to be used.

When calculating the packing conditions, clamp tonnage is a very valuable result. You can determine if your planned press can even handle the pressures for the injection process and clamping force. There are times where this information is not fully considered and the pains of finding out a press can't handle the required pressures negatively impacts production and causes undue stress.



Clamp Force XY plot

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The analysis identifies high Delta T locations in the mold. Actions can be taken either to relocate cooling or additional cooling can be added by using advanced componentry such as conformal cooling inserts.

The use of analysis prior to mold design improves the ability to predict, with great accuracy, the final part and its quality, along with the operating conditions required, all prior to the building of the mold. The molder is able to use this data to run ideal press parameters to quickly achieve the desirable shot weights. At the same time, the mold designer can design the mold to achieve optimum cooling and filling of the geometry. Ultimately analysis allows the OEM to provide its customers a quality product at the lowest possible cost.

Example of greater financial return over investment

By investing time in analysis at the beginning of the process, you can avoid extensive modifications needed in the mold after tryouts. Opening ribs up or adding draft, modifying the gating to allow sufficient fill, enlarging vents to prevent gas traps or even modifying cooling to reduce warpage and allow proper cycle times can all be related to inadequate mold design. The greater return over the investment into a mold can be felt much quicker by adding analysis up front.

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Conclusion

Today's digital technology allows us to predict and prepare for almost any and all circumstances that will take place within the injection molding world. Analysis software can save an unforeseen amount of money by allowing us to plan out, with great detail, a plastic injection mold and the press conditions needed to operate that press. Test running a mold and then pulling, disassembling and modifying things to improve operation is a thing of the past. Most molders that utilize analysis process can hit quality parts within very few shots. Given a basis to start, the molder may only have to fine tune the process to the specific press in use.

The mold can now be strategically planned and optimized without the need for any post build modification or cooling channel improvement.

DME provides a series of different mold analysis services including computational fluid dynamics. See DME.net/cooling-solutions for further information on optimizing your mold's cooling performance.

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