CONFORMAL COOLING IN ACTION

New manufacturing techniques set the stage for more efficient cooling systems that reduce cycle time, warpage, and visual defects.

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Conformal Cooling In Action

The right idea for higher efficiency

The faster injection molding machines run, the more profits your company makes. Every second of cycle time you can remove from the process helps. Cooling consumes the majority of cycle time, which is why it is a major target for efficiency improvements.

Conformal cooling is a proven strategy for reducing cycle time, in some cases as much as 70%. Until recently, however, the manufacturing techniques used to create conformal channels offered limited design options and were too expensive to use in most applications. Today, additive manufacturing techniques are bringing down these costs, enabling shops to experiment more freely, use conformal cooling in more applications and discover new ways to enhance efficiency.

Optimize cooling in challenging parts

The concept of conformal cooling is not new. It came about because it solves a difficult problem: removing heat uniformly from parts with complex geometries. In these parts, placing cooling channels near corners and large, cored-out features can be difficult or impossible with conventional milling and drilling. Conformal cooling inserts feature curved channels that wrap around the part in an even distribution, much like the tubes of an old-fashioned radiator. These channels can easily reach the part's most inaccessible regions while easily accommodating ejector pins, attachment screws and other features, and remaining a consistent distance from the surface of the mold.

The big problem with this approach was cost. Creating the molds using vacuum brazing or similar techniques was simply too expensive to justify the benefit. Recently, however, direct metal laser sintering (DMLS), also known as powder bed fusion or laser sintering, has changed the equation.

This additive manufacturing technique fires a laser into a bed of powdered metal, hardening the material, layer by layer, to gradually create a final structure directly from a CAD file. DMLS can build virtually any structure and the process is extremely cost-effective. In other words, DMLS allows you to design conformal cooling inserts without the normal concerns about drillability, making them a much more attractive and attainable option for moldmaking shops.

Conformal Cooling In Action

Conformal cooling in the real world

FADO is one such shop. This tooling and injection molding company, based in Bydgoszcz, Poland, offers a wide range of services for clients in automotive, electronics and consumer goods. Two of the company's special areas of expertise are cooling optimization and additive manufacturing. As a result, conformal cooling was a natural fit.

To quickly review, there are four principles to keep in mind for mold cooling optimization:

1. **Wall thickness.** Cooling time increases exponentially with the wall thickness of the part. With 1mm walls, many materials cool in five seconds. At 5mm, cooling times extend from 40 to 75 seconds.

2. **Thermal diffusivity.** This ratio of thermal conductivity to heat capacity is important because the lower the thermal diffusivity of the material, the longer it will take to extract heat from molten plastic.

3. **Mold temperature.** Higher mold temperatures help reduce pressure during the filling phase and improve surface finish, but they can double or triple cooling time.

4. **Depth and pitch.** The size, depth, and spacing of cooling channels should result in temperature differences across the mold surface of no more than 5° C for semi-crystalline materials and 10° C for amorphous materials. More channels spaced closer together near the surface of the mold accelerate cooling while maintaining surface temperature uniformity.

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Conformal cooling in the real world

Considering all of these factors helps the FADO team analyze and overcome temperature deviations in parts, which can happen due to shrinkage on the core side, or spaces in the part that have very limited space, or channels in the core that are subject to higher temperature exchange.

The conventional ways to address these deviations include using two thermal controllers, selecting a less conductive material for the cavity side, and altering the distances between channels and the cavity. These work well for many applications. But for some parts, the FADO team has seen first-hand why conformal cooling offers a more sensible solution:

- More uniform pressure. Every 90° angle in conventional cooling designs creates a 2% pressure loss. The use of baffles and bubblers can generate additional losses as well.
- Greater freedom. In addition to letting mold designers create smooth transitions and channels with smaller diameters in circular or elliptical cross-sections, conformal cooling creates opportunities to reach areas of parts where conventional channels simply don't fit.
- Lower cycle time. In many instances, the FADO team has seen conformal cooling cut cycle time as much as 70% compared to conventional cooling. This translates directly into customer savings.
- Higher quality. More uniform temperature distribution reduces the risk of introducing stresses that cause deformation and visual defects.

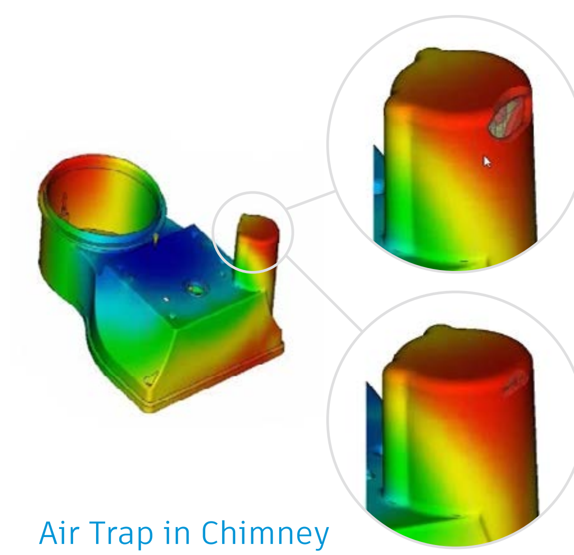
CASE STUDY: WATER METER COVER

In one instance, the FADO team was tasked with designing the mold for a water meter cover. During the initial part geometry optimization, 12 design modifications were made to eliminate hot spots and even out the temperature distribution during cooldown.

Before

After

When it came time to start designing the mold, a filling analysis revealed an air trap in the side wall of the chimney that would potentially lead to burn marks on the molded part. It was impossible to use air vents due to the location of the air trap, so the team implemented flow leaders and deflectors to move the flow front to an area of the part that could be vented. But this created another issue: very limited space for cooling channels due to the number of ejectors and vents involved.



Air Trap in Chimney

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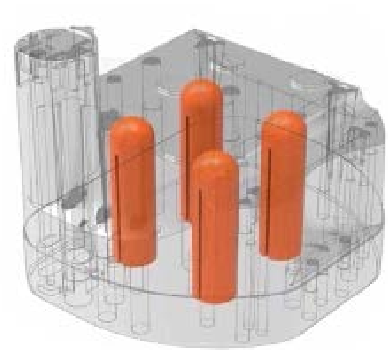
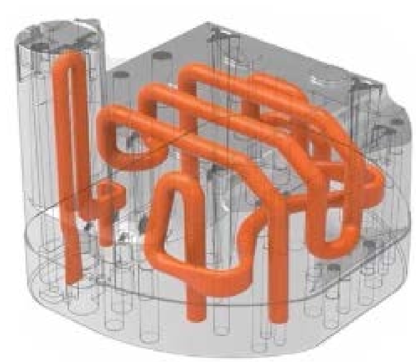
CASE STUDY: WATER METER COVER

A simulation of conventional cooling using four bubblers showed a cycle time of 55 seconds with a temperature differential of 36°C, from 92°C in the meter housing to 128°C in the top of the chimney. The high mold temperature in the core of the chimney area also resulted in a nearly 50°C difference in temperature through the thickness of the part, which could lead to high stresses, deformation, and visual defects. A simulation of conformal cooling demonstrated much more attractive results, with channels that reached all critical areas, a temperature differential of just 5°C across the surface of the mold and through the thickness of the part, and a cycle time of just 33 seconds.



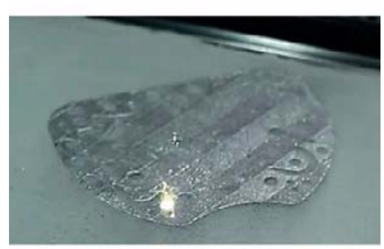
Conventional Cooling



Conformal Cooling

The FADO team then moved on to manufacturing the insert from 1.2709 maraging steel with a post-processing hardness of 54 HRC. It took 30 hours to do this using DMLS with 50-micron layers. Then came the real test: seeing if the simulation matched up with reality. Analysis confirmed that channel pressures matched the simulation exactly. Dimensions of the molded part also matched the analysis results, with two points differing by 0.12mm, well within the tolerance for this application.

Cooling Insert



DMLS Process

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In the end, the choice to use conformal cooling delivered important benefits for FADO's customer. Designing the conformal channels led to part design improvements. Cycle time dropped from 55 seconds to 33 seconds, a difference of 40%. In a production run of 100,000 parts, this saved the customer nearly 14,000€.

Takeaways

1. Conformal cooling works best in complex parts
2. Laser sintering makes the process more affordable
3. Mold shops can achieve cycle time reductions up to 70%

Select the right application

While conformal cooling is not the right choice for every application, it can definitely make a difference in those parts that pose the biggest threat to uniform temperature distribution. The FADO team, for example, estimates that it delivers significant economic benefits to approximately 5% of the projects in their shop and can measurably improve cooling efficiency in another 20%.

To explore more information about mold design, cooling systems, and cycle time reduction, visit our CAE Analyst resource center.

CAE ANALYST RESOURCE CENTER