Increased productivity, New options to high thermal conductivity?

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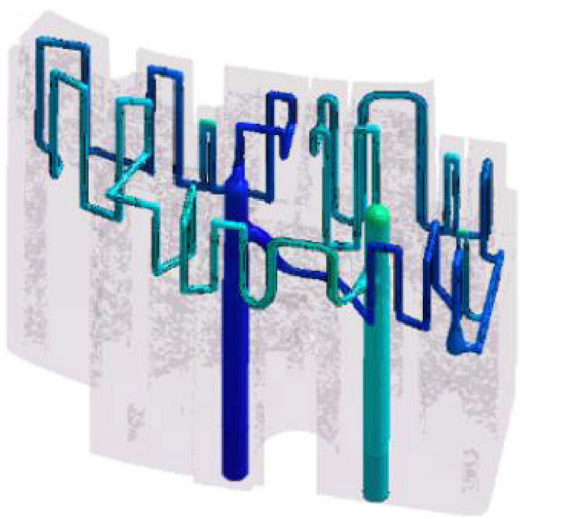
The quest for higher quality and more efficient production is a continued struggle for most industries but for the plastic injection molding process that requires big investments, both in molding equipment and in tools, so it is crucial to have high productivity to bear the costs for these investments.
The limiting factor for the productivity is often the cooling time for the molded parts before ejection from the mold, and that sets the cycle time to produce the part and the productivity.

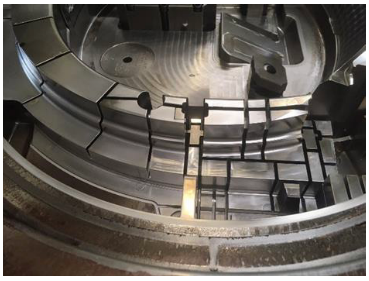
A lot of effort is put to reduce the cycle time and one popular way is to use mold materials with high thermal conductivity to speed up the heat transfer and cool the molded parts quicker. So injection molders turn to for instance aluminium or beryllium copper for the molds and dies instead of the traditional tool steel to benefit from the up to 10 times better thermal conductivity of these materials to decrease the cycle time and increase productivity.
Using these materials with high thermal conductivity has proven an efficient way to lower the cycle time but these materials also have some disadvantages compared to the traditional tool steel. The hardness and strength of the aluminium mold materials are lower than for tool steel, which leads to wear of the tool, or even worse cracking, that can limit the lifetime of the tool.
When using beryllium copper can the strength and hardness often be sufficient for the tools but there are environmental and especially health issues with the beryllium copper so that it during die manufacturing or processing can be harmful for the operators and persons in contact with the mold. The health issues caused by the beryllium copper can and should avoided but that also leads to more complex and costly mold manufacturing.

New opportunities with additive manufacturing

But there is now new options to reduce the cycle time in plastic injection molding by making tools and dies by additive manufacturing. This technology gives new possibilities when it comes to producing complex geometries and for plastic injection molders that is especially interesting when designing the cooling system of your molds. In traditional moldmaking the design of a cooling system was limited to where you could drill the cooling channels, not where you needed your cooling, which lead to inefficient cooling that gave a more general temperature decrease of the die than cooling of any problem areas. And often it was a cooling circuit with a lot of losses that made the die expensive to run.
But with additive manufacturing you can get the cooling where you need it and by that make more efficient molds which eliminates the need for high thermal conductivity since the better designed so call conformal cooling channels is at least as efficient as a material with high thermal conductivity.



One company that has discovered these new opportunities is Miele technika s.r.o., that in their plant in Uničov in the Czech Republic is molding parts for household appliances. The need for high quality and competitive products is pushing them to keep improving the production process and that is of course also valid for the molds for plastic injection molding.



One example are inserts for a mold to produce parts for a dryer which is running in a highly optimized and automated production line that produces almost a 1000 pieces per day. It was needed to increase the productivity and reduce the cycle time so some new ideas was tried instead of the conventionally manufacturing die made in conventional tool steel. These ideas included changing the material in the insert to aluminium and beryllium copper but also an insert made in tool steel by additive manufacturing.

All three options improved the cooling of the parts and reduced the cycle time with about 10 seconds or about 15%, which for this part this means a saving of four production days every month, which is a huge productivity improvement.
As the full molding process had other limitations for the cycle time was the target to reach these 15% cycle time reduction and that was what the inserts were designed for and all met.
It is noticeable that the plastic parts produced with the additively manufactured insert have a lower temperature after ejection, which makes the further processing of the plastic part easier and gives an additional savings as well as a quality improvement.

Even though it worked well and gave a cycle time reduction, the aluminium insert had issues with cracks in the insert quite early in the production and had just half of the lifetime of the other options, and even though it could be repaired, was this option ruled out due to the short life and extra maintenance stops.
The beryllium copper and the additively manufactured inserts have so far produced more than 200 000 plastic parts which is comparable with a conventionally manufactured insert so there are no issue from a tool life or maintenance perspective.

Productivity at a cost?

Normally there is no such thing as a free lunch and this is the case also for these inserts, so all the tested options were more expensive than a conventionally manufactured insert. The additively manufactured inserts were 75% more expensive than the conventionally manufactured inserts so the shorter cycle time had a price but for this part was the increase in productivity well worth this extra cost.
However, the price of the both the aluminium and the beryllium copper inserts were then even more expensive than the additively manufactured part. They were about 70% more expensive than the additively manufactured insert, which makes them about 3 times more expensive than the conventional tool steel insert. This is due to expensive material and complex manufacturing processes with complicated EDM operations, adding to the issues with short lifetime for the aluminium insert and the health and environmental issues for the beryllium copper.

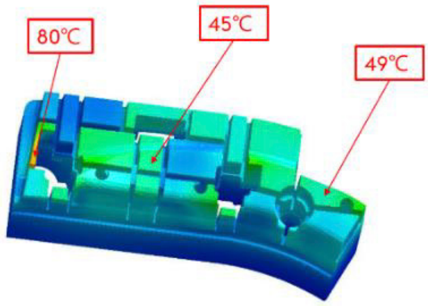
Overall, it shows that additive manufacturing is a very good option, all from productivity, cost and sustainability reasons for plastic injection molds and that high thermal conductivity can be replaced by conformal cooling.

Complicated novel technology or ready to go solution?

To reach the performance of an additively manufactured insert it is of course important to take advantage of the possibilities that the technology gives, with regards to design

of complex structures. The insert for this specific case was designed and manufactured by voestalpine Technology Institute in Nantou, Taiwan, using experience and different simulation software to come up with the best design to get the cooling needed for the plastic part produced, as well as an insert that is easy to produce and uses the properties of the tool steel used for the insert.

Taking advantage of possibilities of the additive technology and the virtual verification in software did not only enable the saving in cooling time but as the technology is so predictable the targeted cycle time was reached at the first shots in the molding machine. As the target was to match the other material options and the full production cycle was the additively manufactured insert designed to reduce the cycle time with 15% but with further optimization of both the design and the process there are opportunities for further improvements in productivity and quality.



Since it is now clear that the benefits from the design possibilities of additive manufacturing technology can solve thermal problems better than high thermal conductivity materials is the low thermal conductivity of a tool steel not an issue anymore and inserts with excellent cooling efficiency can be made by this technology.
The tool steel used for the additive manufactured insert was Corrax® from Uddeholm, Sweden, which is a steel developed for inserts for plastic molding and the specific needs for the molding process. With its optimized chemistry and excellent powder properties, it is a material grade that is easily processed by additive manufacturing and gets the properties needed for molding inserts. Corrax reaches a hardness of 50 HRC and by that handles with the wear from most plastics and its excellent corrosion resistance makes it cope with both aggressive plastics and corrosion issues within the cooling channels. It can also be polished to A1 level, which has been an issue for additive manufactured inserts but with an excellent powder size distribution and morphology this is now possible with Corrax.

So additive manufacturing is a technology that is ready to solve your thermal issues, either it is for better quality or increased productivity, and it is both an economical and sustainable solution to cope with the high investments in plastic injection molding industry.

Miele technika s.r.o. in Uničov, manufactures tumble dryers for domestic and semi-commercial use, entry line dishwashers and toploader washing machines. This production plant with approx. 1,670 employees was founded in 2004, has grown to become the third largest production plant in the Miele Group's international production network, and makes an important contribution towards securing a competitive edge and maintaining quality standards

The voestalpine Technology Institute in Taiwan hosts world-leading facilities for machining, heat treatment, PVD coating, and HIP. With further assistance from local universities and research institutes, vTI focuses on testing the properties of powder/AM parts, simulation of injection processes and analysis of thermal/mechanical stress.

voestalpine High Performance Metals CZ s.r.o is a sales company of the voestalpine group with operations in the Czech Republic focusing on technologically demanding product segments and is a world leader in the field of tool steel, other special steels, welding materials, special forgings and services such as heat treatment or coating

Uddeholm AB is a tool steel supplier from Sweden producing all kinds of tool steel for your every need, whether it is for plastic molding, hot or cold work applications.