Mold inserts

Fusionlänk

https://a360.co/3smGSgJ

Bilder

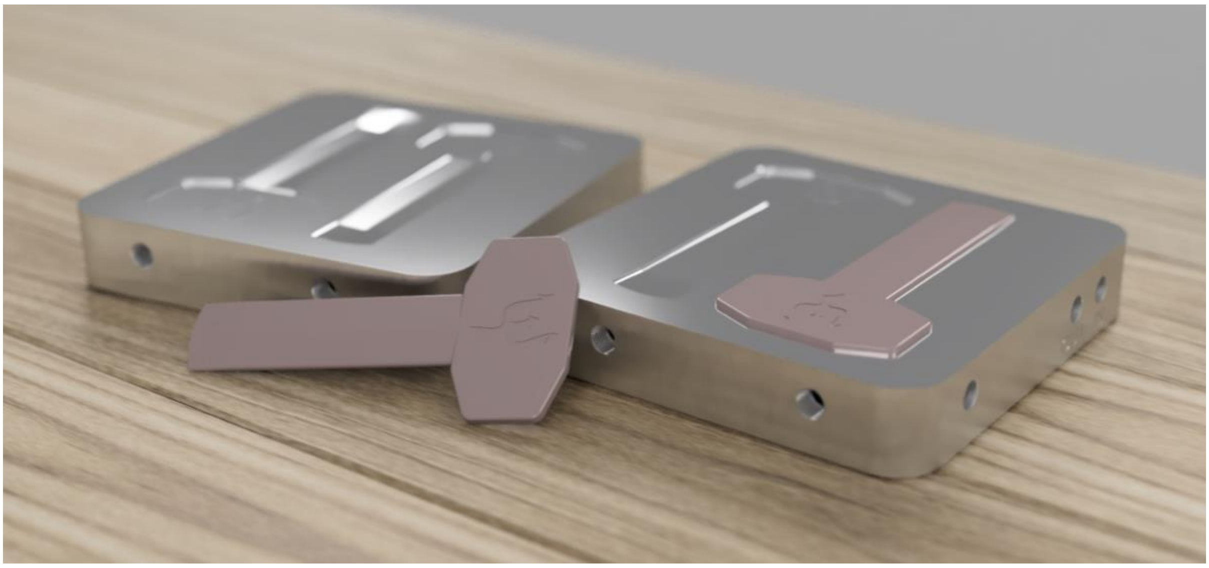

Fig 1 - Injection mold insert machined in aluminum with ABS polymer part, Own Work. Rendered in Fusion 360.

Avancerad Inlämning (VG)

Overview

Here we are working with the concept of polymer injection molding. We create a mold using CAD with traditional machining in mind to understand the concept and analyze the result against our knowledge of additive manufacturing. Specifically, we analyze the pros and cons of machined injection mold inserts, and the potential that additive manufacturing brings to this discipline.

Injection molding

Injection molding is the process of injecting a molten material, in our case a polymer, into a mold to form a part which takes the shape of the cavity inside of the mold *(fig 2)*. The injected material must be at a high temperature, at which the plastic flows as a liquid, when injected. This has the consequence of heating the mold. When the temperature of the polymer is reduced to a point where the polymer becomes solid it can then be ejected from the mold. This transition time from injection of polymer to ejection of part will be important to consider later as we compare traditional and additively manufactured mold inserts.

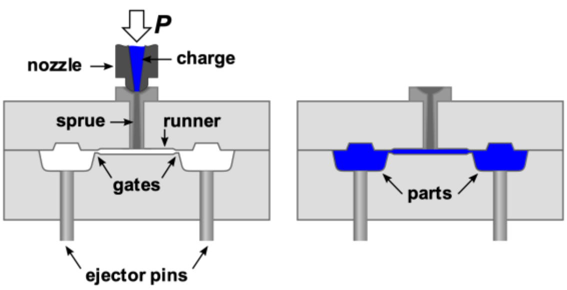

Fig 2 - Simplified diagram of injection molding process. Note the cooling channels are not present in this image.

By Ariel Cornejo, CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=39782900

The mold – Traditional manufacture

We have watched two videos by Lars Christensen, one that creates the model to be injection molded[1], and one that creates the insert for the injection molding machine[2]. By following the videos as guidance, we have created a simplified version of an injection mold insert *(fig 1)*. The mold is simplified as it does not contain all of the passages and hardware required to inject the molten plastic and eject the part after molding, as shown in figure 2 for example, the sprue, gates, runners and ejection pins.

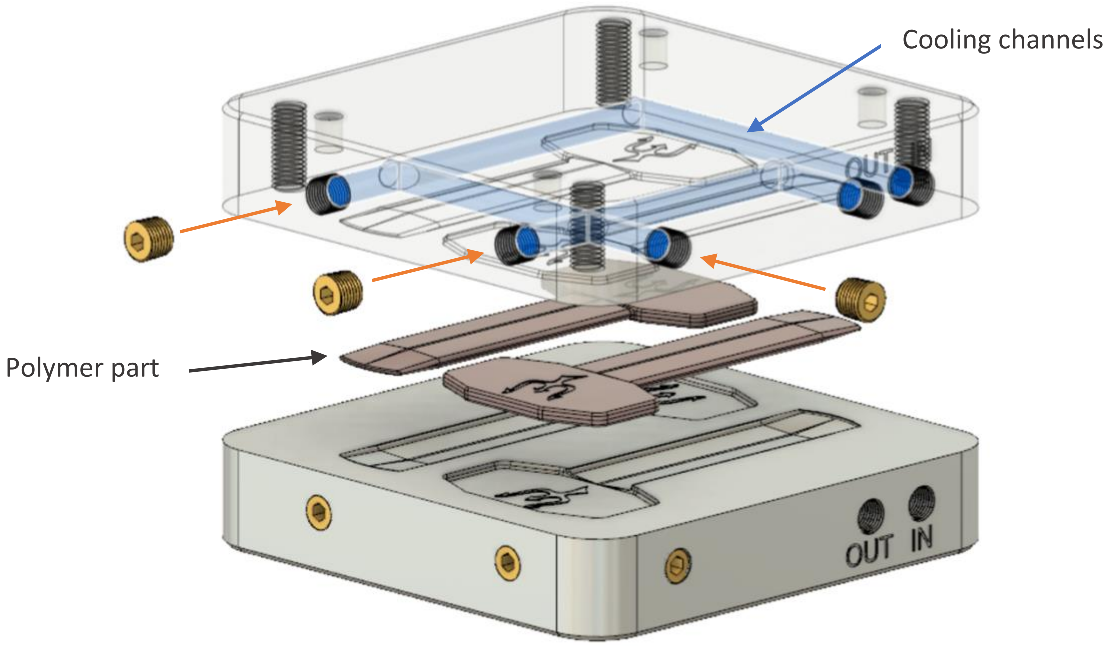

Fig 3 - Injection mold insert modelled for traditional manufacturing, Own work. Note the straight cooling channels and required plugs. Screenshot from Autodesk Fusion 360 modeling workspace.

We take a traditional manufacturing approach to creating this mold insert. The mold cavity is to be machined, typically out of aluminum or steel[3], and the coolant channels are to be drilled. The traditional manufacturing method requires the coolant channels to be drilled in straight lines from two sides because of the limitations of the drilling process *(fig 3)*. We can see how this process of creating coolant channels could be somewhat limiting as we compare to a more conformal style of cooling as can be achieved when using an additive manufacturing design approach.

The mold – Additive Manufacture

Additive manufacturing can be simply explained as the process of building up a part over time by an additive process. This is opposite to the approach of machining, where process begins with a hunk of material that is then chipped away at by some tool until the final piece remains. The traditional injection mold can be greatly improved by using an additive manufacturing (AM) design approach, however there are also limitations to consider.

[1] Fusion 360 Tutorial — Beginner To Advanced — How To Create a Mold— Part 1
https://youtu.be/_hgmwhde1So
[2] Fusion 360 Tutorial — Beginner To Advanced — How To Create a Mold— Part 2
https://youtu.be/h3uTnNPhgzY
[3] As stated in the K7UPG03 assignment literature.

Advantages of AM

Alternate materials

The traditional approach to mold making is via CNC machining, therefore, molds are typically created out of aluminum because due to its ease of cutting with machine tools. The AM approach is not limited by the cutting tool which means other materials can be utilized. For example, tool steel or other extremely hard material could be used to additively create the mold allowing for a much longer mold insert life cycle when compared to aluminum. A long life of the mold tooling means more uptime for the injection molding machine, leading to cost savings by producing more parts because of more uptime and savings on mold tooling by needing to have fewer mold inserts for the lifetime of the machine.

Conformal cooling and cycle time

The time between injecting the molten polymer and ejecting the frozen polymer from the mold is known as the cycle time. This cycle time is a limiting factor for how many parts can be produced per unit time. As we have mentioned and can see above *(fig 3)*, due to the process of drilling, cooling channels made by the machine shop are limited. There are complexity gains that can only be achieved by additive manufacturing. Conformal cooling is arguably one of the largest benefits of applying AM to tooling.

Because we are dealing with the transition between molten and frozen polymers, our cycle time can be reduced by specifically engineered conformal cooling. Conformal cooling is the discipline of creating cooling channels that follow a mold volume to optimize the thermal transfer efficiency of heat away from the part. AM really shines here as it is not limited by straight line tool paths as with the traditional machining approach and can take almost unrestricted size and shape as it travels through the part.

A disadvantage with injection molded parts can be seen when sections of the molded part cool at different rates, leading to warping or even non-functional parts. Conformal cooling has an added benefit of equalizing cooling across the part where needed, directing different sections of the part to cool as rapidly as desired. This produces the highest quality part at the end of the injection molding process.

Light-weighting and short runs

Molds can be produced out of resin. While less durable than its metal counterpart, the resin mold can still function as a prototype or for short runs. Since the price of resin printing scales per cured volume, the price can be significantly reduced by creating internal lattice structures in the mold like seen in figure 4.[4]

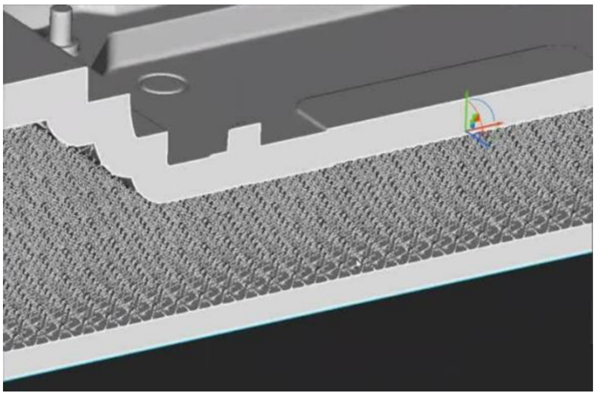

Fig 4 - View of internal lattice structure for light-weighting a resin-based injection mold insert. Screen capture from a live video by nTopology. See reference 3.

[4] nTop Live: Designing 3D Printed Molds for Industrial Injection Molding. https://ntopology.com/videos/video/ntop-live-designing-3d-printed-molds-for-industrial-injection-molding/?utm_source=linkedin&utm_medium=organic-social&utm_campaign=ntl+injection+molding+q2+21&utm_term=&utm_content=linkedin+post+apr+15+2021&source=organic+linkedin. retrieved April 2021.

Disadvantages of AM

Poor surface finish

Compared to machining, the surface finish of a metal additively manufactured part is quite rough. This is an important consideration when creating a mold insert for injection molding. Anything less than smooth within the mold volume will appear on the surface of the molded part. Furthermore, a mold half needs to sit tightly and cleanly against the other half to prevent defects like from forming. The relatively surface of Metal AM parts is too rough for this kind of tight tolerance fit. Metal AM molds currently require post process machining to make the surface smooth enough to solve these problems.

Expensive

It has been quite expensive in the past to create large metal pieces with additive manufacturing. As the AM process becomes more common and materials become more readily available, this price is sure to decrease. This price can potentially be further reduced by blending traditional and additive manufacture.

Not well suited for certain shapes

Many AM technologies are very slow at adding volume to a part, sometimes even taking days to complete large print jobs. Some AM technologies, especially metal, have difficulty managing the thermal loads on the parts being printed which can lead to part warping or failure. Thus, large solid blocks are the least efficient to produce additively and are still best suited to traditional manufacturing.

Blend of Additive and traditional manufacturing

We can take the strengths of AM's complexity and materials advantage and blend it with traditional machining surface quality and get the best of both worlds.

The Future

New materials for AM, like Ceramic resin printing, gives the opportunity for faster and cheaper printing. New or yet developed AM methods or post processing techniques could produce finer surface details eliminating the need for traditional manufacturing for complex injection molding tooling. Some polymer AM, like continuous resin printing, and metal AM, like single pass jetting, are reaching such fast print speeds that they are beginning to seriously compete for some of the traditional injection molding market. The future is surely full of new budding technologies, and that is exciting.