Kylkanal i Formverktyg

Fusionlänk

https://a360.co/2PKzlez

Bilder

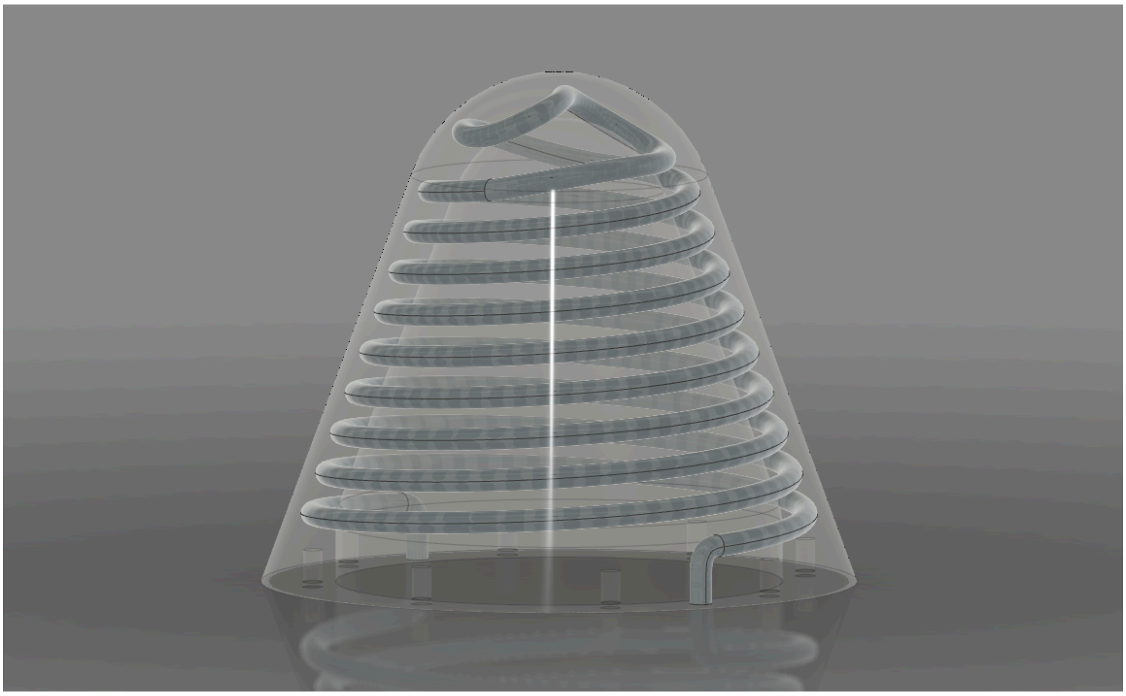

Fig. 1 - Final mold, translucent with coolant channels visible.

Enkel Inlämning (G)

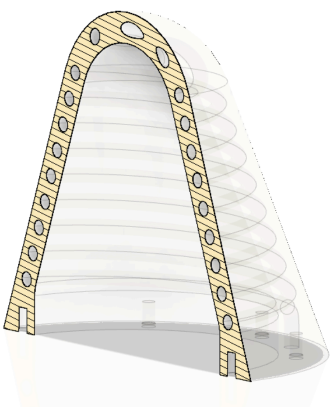

Fig 2 - Cross-section with opacity showing coolant channels.

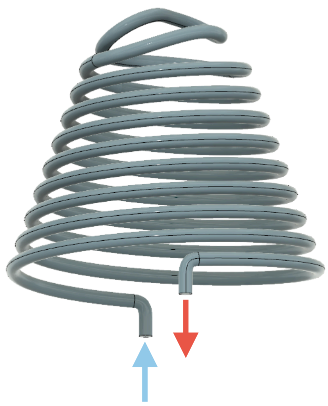

Fig 3 - Modeled coolant volume shown without mold shell. Blue and red arrows represent entrance and exit of coolant.

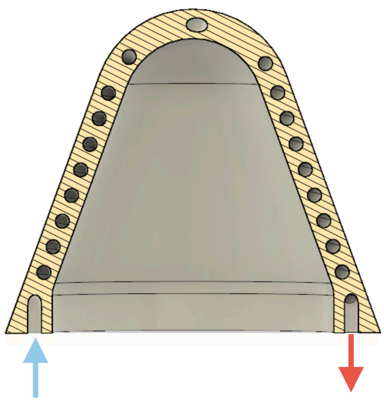

Fig 4 - Cross-section through the center of the mould and coolant inlet and outlet.

Avancerad Inlämning (VG)

Overview

Additive manufacturing allows us the opportunity to easily add complexity to a design that was previously difficult or impossible to manufacture. Here we use the benefits of additive manufacturing to redesign a vacuum forming mold with internal cooling channels with the goal of decreasing cycle time of the vacuum forming process.

A drawing and CAD model are supplied for a vacuum-forming mold. The task is to remodel the mold to include internal coolant channels. The channels could be for air or water. The outer surface and attachment points and size are important, and must not be changed. The completed design must be 3d printable using a resin-based technology such as SLA (stereolithography), DLP (Digital light processing) or 3SP (Envisiontec proprietary Scan, Spin and Selectively Photocure). Below we will consider the design, thought processes, workflow, and consider the benefits of such changes.

Workflow

We take time to understand the design and manufacturing possibilities and restrictions. This allows us to design with respect to the needs of the project and the limitations of the manufacturing method. The next step is to model in CAD. With a good CAD model we will then be able to send our design to be manufactured or for digital CFD and thermal simulations.

Pre-design Considerations

We need to understand a few things before we dive into the design, which are: the process of vacuum forming, required design parameters for the finished mold, and the chosen method of resin-based additive manufacturing.

Understand vacuum forming

According to wikipedia, "Vacuum forming is a simplified version of thermoforming, where a sheet of plastic is heated to a forming temperature, stretched onto a single-surface mold, and forced against the mold by a vacuum... Normally draft angles are present in the design of the mold (a recommended minimum of 3°) to ease removal of the formed plastic part from the mold."[1]

Required design features

We consider the important parts of the mold that must not be changed. These are the fastener size and location and the mold's outer surface and shape. *(Fig 5)*

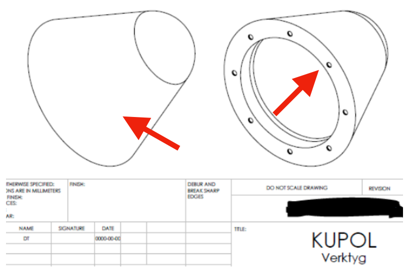

Fig 5 - Portion of supplied part drawing. Red arrows noting required design surface and fastener locations.

Mold manufacturing method

SLA, DLP and 3SP are all photo-curable-resin printing methods. It is important to consider how these print methods accomplish the task of printing for our design to print successfully. Quite simply these print methods submerge a platform into a vat of photosensitive resin, expose a translucent surface of the vat with an ultra-violet light source (laser or projected), and the surface moves and the exposure repeats until the entire shape is realized. The final part must usually be post processed with more UV light exposure.

All typical design considerations from FDM are observed[2]. There are several special design considerations when designing for SLA, DLP and 3SP.

Minimum feature size can be quite small and resolutions quite high[3], both only limited by the laser or pixel resolution size. This is interesting and good for the outer surface finish of the mold, but not so important for us as this part will not have a need for very high resolution otherwise.

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[1] "Vacuum Forming." *Wikipedia,* Wikimedia Foundation, 3 Feb. 2021, https://en.wikipedia.org/wiki/Vacuum_forming

[2] Diegel, Olof. "Designing for Material Extrusion." *A Practical Guide to Design for Additive Manufacturing.* Also by Axel Nordin and Damien Motte, Springer Nature Singapore Pte. Ltd., 2020, e-book pp. 106-110

[3] Diegel, Olof. "Print Orientation." *A Practical Guide to Design for Additive Manufacturing.* Also by Axel Nordin and Damien Motte, Springer Nature Singapore Pte. Ltd., 2020, e-book p. 116

If the vertical cross-sectional area in the XY layer is too large there can be an issue with the force required to remove each layer from the vat.[4] We will consider build orientation of our mold when designing the coolant channels so they print successfully.

Resin can be trapped in areas and the design might require drainage holes.[5] Since the part is a vacuum form, drainage holes might pose a problem for performance, and if on the surface of the mold, might appear as marks on the finished molded part. Proper placement will need to be carefully considered if drainage holes are needed.

A final design consideration with resin based printing are circular hole diameters. These must be larger than 0.5 mm, otherwise they risk being closed off during the resin curing process.[6] In our design this will only be an issue if we are to design suction passage holes for the vacuum process. Any hole through the mold surface will leave some sort of mark on the finished vacuum formed plastic. If the holes are larger they have a greater chance of appearing in the final vacuum formed product.

Thermal properties

The goal is to create a vacuum form that functions better than the original. Since the vacuum forming process is typically hot work, simply adding coolant passages in the mould, even without computational thermal simulation, should reduce cycle time by at least 10 percent. Furthermore, introducing engineering simulations on the design can improve the cycle time reductions to as much as 40 percent.[7]

Design with CAD

Sometimes it is good to start with a sketch before driving into a CAD program. This gives us an overview of the workflow. Since the design is quite basic, we will simply have a mental overview of the steps we will take to accomplish the finished design.

Recreate the mold

We are supplied with a CAD model and a drawing *(fig 5)* to work from. We can take the measurements from the CAD model and model our design to be identical to that. Careful consideration is taken to ensure the outer mold surface and screw mounting points are identical to the design. The interior of the original design is adequate, so that is also reproduced to be identical to the original.

Design the coolant channel

The mold coolant channel is a relatively simple design which can be completed frailly quickly in Autodesk Fusion 360 with the spiral tool. We choose the spiral type[8] as it seems to be the most uniform cooling strategy with one entrance and exit post for the coolant. The channel will enter at the base of the mold, travel up win a helical pattern attach at the top and travel back down in a parallel helical patter to exit at the opposite side of the bottom*(Fig 3)*.

In A Practical Guide to Design for Additive Manufacturing, Diegel recommends some basic starting points for sizing and spacing.[9] As these are simply starting points, I will also use my own experience working with heat exchangers for hydraulics and ending cooling and my own intuition to aid in a draft design. As I have experienced, the more

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[4] Diegel, Olof. “Print Orientation.” *A Practical Guide to Design for Additive Manufacturing.* Also by Axel Nordin and Damien Motte, Springer Nature Singapore Pte. Ltd., 2020, e-book p. 116

[5] Diegel, Olof. “Hollowing Parts and Resin Removal.” *A Practical Guide to Design for Additive Manufacturing.* Also by Axel Nordin and Damien Motte, Springer Nature Singapore Pte. Ltd., 2020, e-book p. 117

[6] Diegel, Olof. “Feature Type: Circular Holes.” *A Practical Guide to Design for Additive Manufacturing.* Also by Axel Nordin and Damien Motte, Springer Nature Singapore Pte. Ltd., 2020, e-book p. 119

[7] Diegel, Olof. “Conformal Cooling.” *A Practical Guide to Design for Additive Manufacturing.* Also by Axel Nordin and Damien Motte, Springer Nature Singapore Pte. Ltd., 2020, e-book p. 86

[8] Diegel, Olof. “Coolant Flow Strategies.” *A Practical Guide to Design for Additive Manufacturing.* Also by Axel Nordin and Damien Motte, Springer Nature Singapore Pte. Ltd., 2020, e-book p. 88

[9] Diegel, Olof. “Coolant Channel Spacing.” *A Practical Guide to Design for Additive Manufacturing.* Also by Axel Nordin and Damien Motte, Springer Nature Singapore Pte. Ltd., 2020, e-book p. 90

fresh coolant flows, the faster the part cools. With this intuition, I choose as large a diameter for the coolant passages as I feel comfortable without reducing the structural integrity of the part. It is definitely worth considering the flow volume, as more volume requires more coolant, which requires larger pumps. Considering this is perhaps outside of the scope of this assignment, but remains an important real world consideration.

Connecting the spirals is achieved using the spline tool in a 3d sketch, ensuring each end of the spline is constrained to the center of the end of both coil profiles, and lofting between the coil profiles using the spline curve as a center rail.

The entrance and exit holes are located directly across from one another at the base of the mold and exactly in-between two screw holes that mount the mold to the vacuum platform. The thinking behind this is that there could be some simple push-fit and watertight connections which seal as the mold is firmly fastened to the vacuum platform making removal or replacement a simple and quick process. It is possible to redirect the openings of the coolant passages to the inside of the mold instead if so desired.

It is important to realize that this design is simply a draft and will probably undergo changes after simulation and testing. With this in mind, the design is robust for changes to the coolant channel. One simply needs to change the profile size and shape of the coil feature and the rest will follow. If the shape is to be changed, for example to increase turbulent flow within the channels, consideration should be taken for the exit and entrance channels to ensure the fitment to the vacuum base is consistent, that the circular press fit will still function. It should be fairly robust, but it might be the weakest link when considering such changes.

Fritext

Simulate and Test

The obvious next step is to simulate this part's thermal properties with some computational engineering simulation software to better understand what design will work the best and exactly how much optimization can be achieved.

Another approach is to simply test the part. Today, additive processes are so inexpensive when the machines are already in-house, that simply printing the part off, installing it, and running several batches of the thermoforming process will also give real world data on many potential gains in cycle time. Various different channel designs can be adapted and printed with very little effort and simply tested to see what works best.

Materials

Composite molds tend to be much less expensive when compared to their machined or cast counterparts and can be quite long lived.[10] The use of additive manufacturing gives the opportunity to reduce cost and increase complexity of the design, especially when comparing to the machined and cast mold counterparts. Today there are even resins mixed with ceramic powders or other additives that could aid in the thermal transfer from the part to the coolant.

Closing remarks

With only being introduced to resin printing theoretically, I realize my knowledge in the nuances of the printing process is somewhat lacking. Being a hands-on kind of person makes it easier for the knowledge and nuance of a procedure to stick when I can experience the technology hands-on. I am interested to know how the resin process would react with placing the bottom flat side to the build platform and printing this. Will there be a suction created that will be detrimental to the print? When the print gets near the area that will close off, how much resin will be trapped inside, and will that cause any difficulties in the process? How will the resin, if any, trapped inside of the cooling channels affect the final print? It will be interesting to find out.

[10] "Vacuum Forming." *Wikipedia*, Wikimedia Foundation, 3 Feb. 2021, https://en.wikipedia.org/wiki/Vacuum_forming