Review on Optimizing Cooling Efficiency through Conformal Cooling using Moldex3D CAE Simulation

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Abstract: In today's manufacturing world, time is money. This is especially true in the injection molding industry, where a reduction in the cooling time can help achieve significant savings. Therefore, the importance of the cooling system is unquestionable. In an injection molding process, cooling time usually dominates the whole cycle time. Therefore, decreasing cooling time can help save manufacturing cost. Cooling system design is one of a crucial factor to reduce cooling time. However, by using traditional molding manufacturing method, cooling system layout is restricted. For cavities with greater curvature, the distance between cooling channels and cavity may vary throughout the part. This causes local heat accumulation and hence worse product quality. By using some non-conventional methods such as laser sintering and 3D printing techniques, cooling channels can get closer to the cavity surface than using traditional method.

The current study uses a true three dimensional simulator to predict the injection molding process and product deformation. The results from a conventional and a conformal cooling design were compared. The results also show flow behavior inside cooling channels which provide important indices for cooling efficiency improvement. With a shorter cycle time and better product quality, conformal cooling has a great potential in injection molding industry.

Plastics are known to reduce costs and boost efficiency in a number of industries, with their countless applications and advantages. One of the industries that continues to be aided by the use of plastics and by the consistent innovations is the auto industry. Better, safer vehicles, better energy efficiency, higher employment, and increased exports. It seems the benefits of plastics in automotive industry are truly significant.

We selected two wheeler automobile mudguards for our case study due to its mass manufacturing & curved shaped geometry .This part is manufactured through injection molding having tradition cooling channel, which ultimately lead to higher cycle time, due to domination of cooling cycle itself.

This problem is addressed by using conformal cooling , all three phases analysis has been done to find optimized parameter for best part quality and reduced cooling and cycle time .Part defect & war page analysis also been addressed through this simulation.

We used Moldex3D to optimize the layout design of the conformal cooling system that could improve cooling time, temperature difference, and part deformation.

Key words: conformal cooling, injection molding, mold design, traditional molding, 3D printing techniques, war page analysis, local heat accumulation, cooling efficiency, laser sintering, and Moldex3D simulator.

INTRODUCTION

Whole injection molding cycle, cooling stage usually takes the longest time. Thus, reducing cooling time also means cost saving. Common factors related to cooling time are cooling system design, mold material, coolant type, coolant temperature, and flow rate etc. Among these factors, cooling system design variation is possibly the most difficult part by using traditional molding method. However, by using techniques such as three dimensional printing and laser sintering processes, conformal cooling channel is able to be manufactured and getting popular. Dalgarno and Stewart used indirect selective laser sintering method for conformal cooling channel manufacturing. In the two cases they tested, cooling time was drop up to 50% [1].Three dimensional printing is another technique developed by Sachs et al. in MIT [2].In their experiment, the results with conformal cooling design show better control on mold temperature than those without it. As to the design algorithm of conformal cooling channels, there is a general design rule among distance from cavity to cooling channel, distance between cooling channels and cooling channel diameter [3]. For cooling channel layout, numerous studies have provided different algorithms on building an optimized cooling channel [4-7]. In this research, we use a simple model with numerical simulations to demonstrate the effects of conformal cooling designs on tool temperature and product deformation.

The overall pattern in the infusion shaping industry is to diminish fabricating costs and improve item quality. Infusion forming process duration has an immediate relationship to the expense of assembling. During the whole pattern of infusion forming, cooling stage for the most part takes quite a while. In this manner, lessening the cooling time additionally implies cost reserve funds. General elements identified with the cooling time cooling framework configuration, printed materials, the sort of coolant, coolant temperature, and the pace of stream and so forth. Among these elements, the varieties cooling framework configuration is likely the most hard to utilize customary printing techniques. Nonetheless, utilizing methods, for example, imprinting in three measurements and a laser sintering process, in understanding cooling channels can be created and progressively well known. Dalgarno Stewart and utilizations the particular sintering process for assembling the circuitous laser to the cooling channels conformal. In the two cases they analyzed, the cooling time is an abatement of up to half [1]. The three-dimensional printing is another strategy created by Sachs et al. MIT [2]. In their trials, the outcomes got with the conformal cooling configuration indicated better control of the form temperature than those without. Cooling channel calculation as indicated by the structure, there is an overall plan rule between the good ways from the pit to the cooling channels, the separation between the measurement of the cooling channels and cooling channel [3]. For cooling channel format, various examinations have given various calculations to assemble an improved cooling channel [4-7]. In this investigation, we utilized a basic model with numerical recreations to show the impacts of conformal cooling plan temperature distortion and product instrument.

Infusion forming is where the plastic pellets liquefied and afterward constrained into a shape, where the material to frame the last shape. When the pit is filled, spread coolant through the cooling ways in the shape to bring the base for legitimate release temperature. As per Khan et al. (2014), the cooling area is a significant piece of the procedure to deliver excellent parts, however expends half to 80% of the process duration by development.

Cooling section is a customary machine straight. A cooling liquid moves through the channel at a temperature and weight information, to advance the process duration and part quality. This strategy gives inaccurate outcomes on the grounds that the correct way can't guarantee uniform cooling in the form cavity. Cooling level for a given section of the form depends, to some degree, to its closeness to the cooling channel. Non uniform cooling in the segment prompting longer process durations, lopsided cooling, warpage and notices.

Infusion forming is one of the most abused modern procedures for the creation of plastics. Its prosperity depends an extraordinary ability to create 3D shapes at a more elevated level than, for instance, blow forming. The fundamental standard is that the infusion trim of strong polymer, fluid and infused into the pit in the form; which is then cooled and the evacuated bit of the machine. The principle period of the infusion shaping procedure since it includes the filling, cooling and discharge. Benefit of the procedure relies upon the time spent in the embellishment cycle. Correspondingly, the cooling stage is the most significant advance in the three decides the speed at which the parts are produced. As in most present day businesses, time and expenses are concerned. In addition is the ideal opportunity for the gatherings to deliver more is the expense. Less time spent cooling the past area was distributed fundamentally improve the degree of creation, which decreases costs. In this way, it is essential to comprehend and consequently enhance the warmth move process in an ordinary successful printing process. Before, this has been accomplished by making a few straight gaps in the form (center and hole) and by driving the cooling liquid to stream and coordinating the overabundance heat away with the goal that parts can be effectively evacuated. The procedure used to create these openings depends on traditional machining techniques, for example, boring.

To deliver complex shapes Inability, for example, the track or wave in 3D space. Different strategies that give a cooling framework that is "fitting" to the state of the inward center, hole, or both have been proposed. This strategy utilizes the layouts of such a channel, additionally constructed close as conceivable to the form surface to improve the retention of warmth from liquid plastic. This guarantees the part is cooled consistently and productively.

The initial segment of this examination concentrated on the audit and assessment of the infusion shaping procedure to sort out the information and foundation regarding the matter. Ensuing investigations have proposed techniques for the turn of events and use of conformal channels, distinguish the most practical strategy.

Unique software was used to enhance the plan and development of the form, with an attention on improving the structure device by applying the limited component examination of warmth stream. Along these lines, an investigation of the viability of the cooling channels dependent on a virtual model conformal done utilizing the I-DEASTM programming for prototyping and reproduction. These examinations is going and ideally lead to the proposal of the fundamental ability level to utilize a virtual model for choosing printing determinations for the creation of parts.

LITERATURE REVIEW

[1] Fu-Hung Hsu1, Hung-Chou Wang1, Wei-Da Wang1, Chao-Tsai Huang1, Rong-Yeu Chang2 (2007) [1] - In an injection molding process, cooling time usually dominates the whole cycle time. Therefore, decreasing cooling time can help save manufacturing cost. Cooling system design is one of a crucial factor to reduce cooling time. However,

by using traditional molding manufacturing method, cooling system layout is restricted. For cavities with greater curvature, the distance between cooling channels and cavity may vary throughout the part. This causes local heat accumulation and hence worse product quality. By using some non-conventional methods such as laser sintering and 3D printing techniques, cooling channels can get closer to the cavity surface than using traditional method. The current study uses a true three dimensional simulator to predict the injection molding process and product deformation. The results from a conventional and a conformal cooling design were compared. The results also show flow behavior inside cooling channels which provide important indices for cooling efficiency improvement. With a shorter cycle time and better product quality, conformal cooling has a great potential in injection molding industry.

[2] J.C. Ferreira a, A. Mateus b (2002) [2] - The development and manufacture of injection molds is a well-known complex processing technology for bulky production of plastic parts. An injection mold, when seen as a production tool, is expected to perform well both mechanically and thermally, to replicate the surface finish required for the part and produce moldings accurate to the dimensional specifications. Parts made by rapid prototyping (RP) systems may be used directly in many final applications today. RP generated parts may well offer a direct solution to application problems with material requirements ranging from plastics or ceramics, to steel or titanium. However, even the fastest RP systems are still far too slow and limited in technique. They simply cannot produce parts in a wide enough range of materials; at a fast enough rate, to match the enormous spectrum of requirements of industry. Conventional processing technologies such as molding and casting are still the only means available to do that, but RP is often the starting point for making these processes faster, cheaper and better.

[3] Yu Wang, Kai-Min Yu, Charlie C.L. Wang (2015) [3] - Designing cooling channels for the thermoplastic injection process is a very important step in mold design. A conformal cooling channel can significantly improve the efficiency and the quality of production in plastic injection molding. This paper introduces an approach to generate spiral channels for conformal cooling. The cooling channel designed by our algorithms has very simple connectivity and can achieve effective conformal cooling for the models with complex shapes. The axial curves of cooling channels are constructed on a free-form surface conformal to the mold surface. With the help of boundary-distance maps, algorithms are investigated to generate evenly distributed spiral curves on the surface. The cooling channels derived from these spiral curves are conformal to the plastic part and introduce nearly no reduction at the rate of coolant flow. Therefore, the channels are able to achieve uniform mold cooling. Moreover, by having simple connectivity, these spiral channels can be fabricated by copper duct bending instead of expensive selective laser sintering.

[4] Antonio Armillotta & Raffaello Baraggi & Simone Fasoli (2013) [4] - The paper reports an experimental study of die casting dies with conformal cooling fabricated by direct metal additive techniques. The main objective is to compare the benefits and limitations of the application to what has been widely discussed in literature in the context of plastics injection molding. Selective laser melting was used to fabricate an impression block with conformal cooling channels designed according to part geometry with the aid of process simulation. The tool was used in the manufacture of sample batches of zinc alloy castings after being fitted on an existing die in place of a machined impression block with conventional straightline cooling channels. Different combinations of process parameters were tested to exploit the improved performance of the cooling system.

[5] D.E. Dimla a, M. Camilotto b, F. Miani b (2005) [5] - With increasingly short life span on consumer electronic products such as mobile phones becoming more fashionable, injection molding remains the most popular method for producing the associated plastic parts. The process requires a molten polymer being injected into a cavity inside a mold, which is cooed and the part ejected. The main phases in an injection molding process therefore involve filling, cooling and ejection. The cost-efficiency of the process is dependent on the time spent in the molding cycle. Correspondingly, the cooling phase is the most significant step amongst the three, it determines the rate at which the parts are produced. The main objective of this study was to determine an optimum and efficient design for conformal cooling/heating channels in the configuration of an injection molding tool using FEA and thermal heat transfer analysis. An optimum shape of a 3D CAD model of a typical component suitable for injection molding was designed and the core and cavity tooling required to mold the part then generated. These halves were used in the FEA and thermal analyses, first determining the best location for the gate and later the cooling channels

[6] Hadley Brooksa, Kevin Brigdenb (2006) [6] - Additively manufactured (AM) conformal cooling channels are currently the state of the art for high performing tooling with reduced cycle times. This paper introduces the concept of conformal cooling layers which challenges the status quo in providing higher heat transfer rates that also provide less variation in tooling temperatures. The cooling layers are filled with self-supporting repeatable unit cells that form a lattice throughout the cooling layers. The lattices increase fluid vortices which improves convective heat transfer. Mechanical testing of the lattices shows that the design of the unit cell significantly varies the compression characteristics. A virtual case study of the injection molding of a plastic enclosure is used to compare the

performance of conformal cooling layers with that of conventional (drilled) cooling channels and conformal (AM) cooling channels.

[7] EMA"EL SACHS', EDWARD WYLQMS', SAMUEL ALLEV, MICHAEL CIMA2, and HONGLIN Guo (2000) [7] - injection molding of polymer components faces in-creasing demands for part quality and production rate. Proper thermal management of injection molding tooling is key to achieving simultaneous improvements in rate and quality. Cooling passages placed in the tooling manage the heat flow out of the plastic. Current fabrication methods place severe limitations on the configuration of the cooling channels used for heat withdrawal.The freedom to create internal geometry by the use of the 3D Printing process allows for the fabrication of molds with complex internal cooling passages. These cooling channels can be designed to be conformal to the molding cavity. Conformal passages produced with the 3DP process provide the ability to more accurately control the temperature of the molding cavity throughout the process cycle. Such temperature control has the potential to shorten cycle times and to produce parts with lower residual stresses.

[8] K.M. Au, K.M. Yu, W.K. (2011) [8] -Chiu In plastic injection molding process, cooling channel design is an essential factor that affects the quality of the molded parts and the productivity of the process. Non-uniform cooling or long cooling cycle time would result if a poorly designed cooling channel is adopted. Due to limitations of traditional machining processes, the cooling channel is usually formed from straight-line drilled holes and only simple shapes are allowed, regardless of the shape complexity of the part being molded. With the advent of rapid tooling technology, cooling channels in complex shapes can now be possible. However, there are not many design methodologies for supporting this type of cooling channel. In this paper, a methodology called visibility-based cooling channel generation is proposed for automatic preliminary cooling channel design for rapid tooling.

METHODOLOGY

In this study, the fluids are considered to be incompressible, Newtonian (for water) or generalized Newtonian (for polymer melt). The governing equations for 3D transient non-isothermal motion are:

$$\frac{\partial \rho}{\partial t} + \nabla \cdot \rho u = 0$$

$$\frac{\partial}{\partial t}(\rho u) + \nabla \cdot (\rho u u + \tau) = -\nabla_p + \rho g$$

$$\rho C_P \left(\frac{\partial T}{\partial t} + u \cdot \nabla T\right) = \nabla(k \nabla T) + \eta \dot{\gamma}^2$$

Where **u** is velocity vector, **T**is temperature, **t** is time, **p**is pressure, **τ**is stress tensor, **ρ**is density, **η**is viscosity, **k** is thermal conductivity, and **Cp** is specific heat and **g&** is shear rate. For the polymer melt, the stress tensor can be expressed as:

$$\tau = -\eta(\nabla u + \nabla u^T)$$

The modified-Cross model with Arrhenius temperature dependence is employed to describe the viscosity of polymer melt:

$$\eta(T, \dot{\gamma}) = \frac{\eta_0(T)}{1 + (\eta_0 \dot{\gamma} / \dot{\tau})^{1-n}}$$

$$\eta_0(T) = BExp\left(\frac{T_b}{T}\right)$$

Where n is the power law index, *o* h is the zero shear viscosity, t * is the parameter that describes the transition region between zero shear rate and the power law region of the viscosity curve.

The total element number is from 8.11M to 9.33M. As to the numerical schemes, Moldex3D uses a hybrid finite-difference/control volume/finite element method. Time step selection has an important effect on accuracy and calculating speed. An internal parameter was carefully chosen to have a good balance on accuracy and efficiency.

CONCLUSION

8.1 SHORTEN COOLING TIME

In the subsequent assessment, the outcome indicated that the conformal cooling channel furnished a lot more prominent warm control contrasted and the regular cooling channel and the one without cooling channel and diminished the cooling time.

8.2 QUALITY PREDICTION

Cooling efficiency increased due to uniform cooling, which ultimately give better part quality.

8.3 DEFECT ANALYS

Flatness variation is reduced,Volumetric shrinkage reduced and warpage which greatly influence the part aesthetic and quality concern.

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