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Design and Analysis of Die Casting Die With Conformal Cooling Channel

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Abstract:
Pressure Die Casting Die is a process for producing metal parts by forcing molten metal under high pressure into reusable steel mould. The process cycle time in Pressure Die Casting moulding process depends greatly on the cooling time of the Metal parts, which is facilitated by the cooling channels in the Pressure Die Casting Die mould. Effective cooling channel design in the mould is important because it not only affects cycle time but also the part quality. Traditional cooling channels are normally made of straight drilled holes in the mould, which have limitations in geometric complexity as well as cooling fluid mobility within the Pressure Die Casting Die mould. Over the years, conformal cooling techniques are being introduced as effective alternative to conventional cooling. The main objective of this study is to determine an optimum design for conformal cooling channel of Pressure Die Casting Die moulded Metal part using finite element analysis and thermal heat transfer analysis. Die casting dies with conformal cooling channel fabricated by rapid prototyping techniques. Rapid prototyping used to fabricate an impression block with conformal cooling channels. Different combinations of process parameters were tested to exploit the improved performance of the cooling system. Test results show that conformal cooling improves the surface finish of castings due to a reduced need of spray cooling, which is allowed by a higher and more uniform cooling rate.

Key words: Die casting, Conformal cooling, Conventional cooling, Analysis, temperature.

I. INTRODUCTION

Die Casting is a metal casting process. It is a manufacturing process for producing sharply, defined, smooth or textured-surface metal parts. Moulded metal is forced and injected under high pressure into a mould cavity which then is held under pressure during solidification.

In principle, the process is very similar to the injection moulding with another class of materials. Most die casting parts are made of non-ferrous metals such as zinc, copper, aluminium, magnesium and depending on the type of metal that is being cast, a hot- or a cold-chamber is used.

The die casting process allows products to be made with high degree of accuracy and also produce fine details such as textured surfaces or names without requiring further processing.

The die casting process is a suitable choice for mass produced products because of its ability of producing highly detailed parts. Almost every product or a part of a product one uses in daily life is produced using this process.

II. COOLING CHANNEL

Mould cooling process accounts for more than two-thirds of the total cycle time in the production of Die Casting die parts. An efficient cooling circuit design reduces the cooling time, and in turn, increases overall productivity of the moulding process. Moreover, uniform cooling improves part's quality by reducing residual stresses and maintaining dimensional accuracy and stability

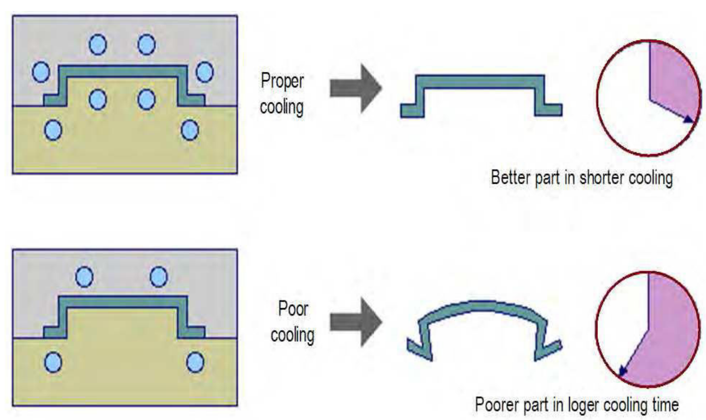

Figure.1.Proper Cooling Design Versus Poor Cooling Design

A mould cooling system typically consists of the following items:

- Temperature controlling unit
- Pump
- Hoses
- Supply and collection manifolds
- Cooling channels in the mould

The mould itself can be considered as a heat exchanger, in which the heat from the hot polymer melt is taken away by the circulating coolant.

III. CONFORMAL COOLING CHANNELS

To obtain a uniform cooling, the cooling channels should conform to the surface of the mould cavity that is called conformal cooling channels. The implementation of this new kind of cooling channels for the plastic parts with curved surfaces or free-form surfaces is based on the development of solid free-form fabrication (SFF) technology. On the other hand, conformal cooing channels can also be made by U-shape milled groove using CNC milling machine.

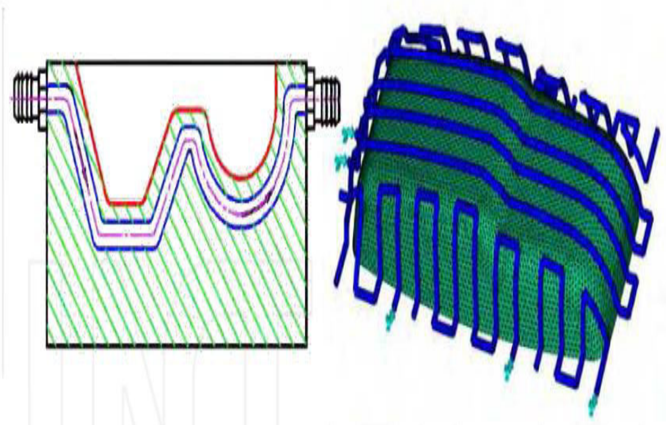

Figure.2. A Layout Of Conformal Cooling Channels

The conformal cooling channels are different from straight-drilled conventional cooling channels. In conventional cooling channels, the free-form surface of mould cavity is surrounded by straight cooling lines machined by drilling method. It is clear that the distance from the cooling lines and mould cavity surface varies and results in uneven cooling in moulded part. On the contrary, for the conformal cooling channels, the cooling paths match the mould cavity surface well by keeping a nearly constant distance between cooling paths and mould cavity surface (see Fig.). It was reported that this kind of cooling channels gives better even temperature distribution in the moulded part than the conventional one.Figure shows an example of moulds with conformal cooling channels made by direct metal laser sintering method. It was said that this cooling channels not only ensure the high quality of the product but also increase the productivity by 20 %.

A. ***A new C-space method to automate the layout design of injection mould cooling system***

The main function of the C-space is to capture all of the feasible geometry of the layout design so that a genetic algorithm (GA) can be used to explore the design space. This paper reports a further extension of the C-space method in two respects. The new method overcomes the previous limitation of the non-variability of the design topology. C-Mould analysis has been applied to confirm that the layout designs generated by the proposed method provide a cooling function similar to that of the preliminary design. The analysis results for the preliminary design and Layout-1 are shown in Fig. 15(a) and (b). With a cooling time of 15 s, it can be seen from both figures that the maximum mould-wall temperature is about 46–47 °C and the maximum temperature difference is less than 10 °C in both cases. These results indicate that the cooling functionprovided by Layout-1 is satisfactory, and is similar to that of the preliminary design. The other layout designs have been analysed and similar results obtained.

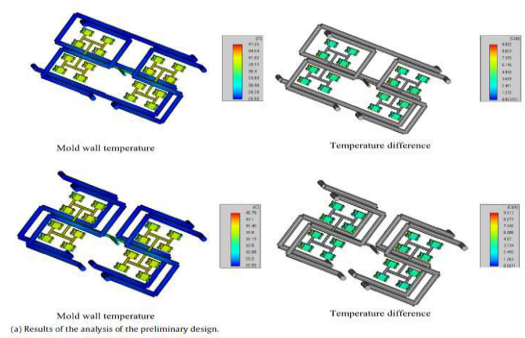

Figure.3. Results of the C-Mould Cooling Analysis of the Preliminary Design

B. ***Design and optimization of conformal cooling channels in injection moulding tools.***

With increasingly short life span on consumer electronic products such as mobile phones becoming more fashionable, injection moulding remains the most popular method for producing the associated plastic parts. The process requires a molten polymer being injected into a cavity inside a mould, which is cooed and the part ejected. The main phases in an injection moulding process therefore involve filling, cooling and ejection. The cost-efficiency of the process is dependent on the time spent in the mouldingcycle. 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 moulding tool using FEA and thermal heat transfer analysis . An optimum shape of a 3D CAD model of a typical component suitable for injection moulding was designed and the core and cavity tooling required to mould the part then generated. These halves were used in the FEA and thermal analyses, first determining the best location for the gate andlater the cooling channels. These two factors contribute the most in the cycle time and if there is to be a significant reduction in the cycle time, then these factors have to be optimised and minimised. Analysis of virtual models showed that those with conformal cooling channels predicted a significantly reduced cycle time as well as marked improvement in the general quality of the surface finish when compared to a conventionally cooled mould.

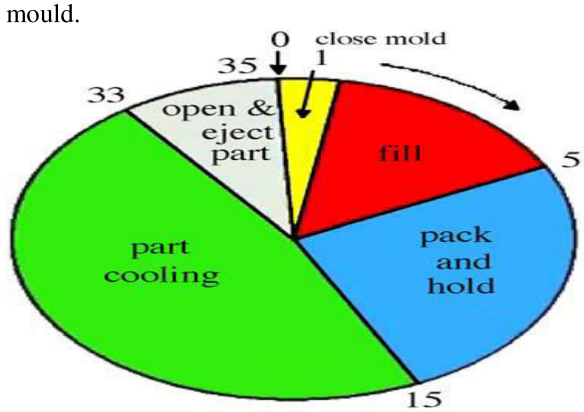

Figure.4. Cycle Time In Injection Moulding

C. ***Design of conformal cooling layers with self-supporting lattices for additively manufactured tooling***

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 vorticity 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 moulding 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. The results show the conformal layers reduce cooling time by 26.34% over conventional cooling channels.

D. *A Simulation Study of Conformal Cooling Channels in Plastic Injection Molding*

In order to reduce the cycle time, and control the uniform distribution of temperature, it is necessary to create conformal cooling channels, which conform to the shape of the mold cavity and core. This paper presents a simulation study of different types of cooling channels in an injection molded plastic part and compares the performance in terms of time to ejection temperature, shrinkage, temperature profile, and part warpage to determine which configuration is more appropriate to provide uniform cooling with minimum cycle time. Autodesk Moldflow Insight (AMI) simulation software is used to examine the results of the cooling channels performance.

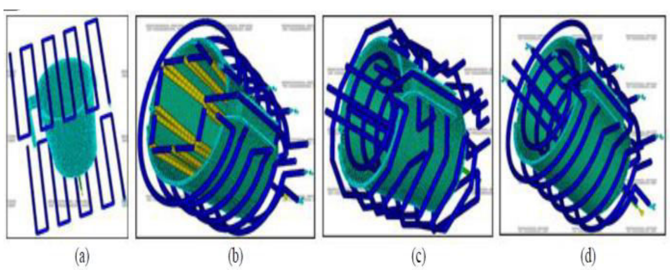

Figure.5. CoolingChannel Types:(A) Normal, (B) Conformal Combination With Baffle, (C) Conventional Combination With Conformal And (D) Conformal

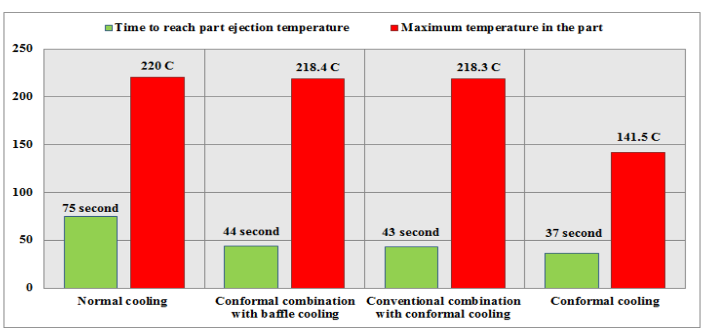

Figure.6.Comparison of Time Reach Ejection Temperature and Maximum Temperature

IV. CONCLUSION

After the reviewing Research paper related to design and analysis of conformal cooling channel concluded that. Conformal cooling channel have continues cooling compared to the convention cooling channel. Cooling time reduced and increase productivity.

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