Optimization Design of Cooling Channel

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Abstract. The design of cooling channel in injection mould has a direct impact on injection molding products quality and production efficiency. With the help of Moldflow, a filling analysis of 3D model of the four cavities mould under Pro/E was made. The meshing and repairing on injection molding products in Moldflow have been finished, and the matching rate reached 86.7%. A preliminary design of size, layout of cooling channel and cooling process parameters were made. On the basis of products average temperature, cavity temperature, critical temperature of mould surface and products, further modification of cooling channel was made. The method, positioning cooling channel according to the feature of injection products, was obtained. The analysis was distributed into the optimization of cooling channel. As the results show, by improving cooling channel, cavity surface can have consistent color, well distributed temperature and small temperature difference. Mould temperature is in required range, and the cooling time meets the requirement as well. The goal of improving cooling channel designing efficiency is achieved; moreover, circulation time of cooling becomes shorter, and the injection molding products have rapid and uniform cooling.

Introduction

Today, encouraging achievements in cooling channel design have been obtained, both home and abroad. C. L. Li, et al. used a separate automatic layout system, which can heuristically search the advantages and disadvantages of cooling channel, and save the mould designer plenty of time [1]. C. G. Li , et al. combined a simple genetic algorithm and C-space, came up with a automatic layout system in mould design, and gave an emphasis on feasibility of cooling channel geometric design [2]. Based on several geometric models, C. L. Li described a thickness-adjustment method, and put forward a cavity temperature balancing optimization program. Using the method, through the combination of Fortran and commercial software Moldflow, good effect was obtained [3]. B. Ozcelik, et al. associated Moldflow with orthogonal experiment, analyzed the injection molding of thin-walled plastic products, found the weakness in the plastic products, and reduced the rejects in practical manufacture [4]. D. E. Dimla, et al. regarded a mobile phone model as the research object, by finite element analysis and thermal heat transfer analysis, designed the shape and layout of cooling channel. Compared with cooling channel designed with conventional method, the cooling time decreases, and surface quality has notable improvement [5]. All the examples mentioned above, applied Moldflow to analyze injection molding products. From aided engineering analysis in molding field, as parting line in most injection moulds is plain, flat stripper plates and other flat stripping mechanism are widely used in injection mould. For injection molding products with streamlined open end, parting line is curved, and stripper plate is designed according to the special shape of open end. Utilizing Moldflow, through the analysis from the CAE software we can obtain reasonable process parameters and cooling channel.

The Designs of Parting Line and the Beginning Cooling Channel

The shape of the part is a cylindrical shell (Fig. 1). The wall thickness is 2 mm. The side of the part has a certain of radian and the top is convex-concave arc. The part is made of polyethylene (PE) which is the polymerization of ethylene and belongs to alkene polymer. PE is the most productive in plastics industry. It is odourless and ivory and its density is 0.91~0.96 g/cm^3. PE has excellent insulating properties, chemical resistance, low temperature tolerance and water resistance. It can keep its properties unchanged in spite of being in water for a long time. This material is easy to be processed into various shapes (barrel, pipe, bag, basin and so on) of plastic product, which is widely used in electrical industry, chemical industry food industry, mechanical manufacturing industry, agriculture and so on. PE is soft and easy to demould. Plastic product can do forced to demould from mould. The injection mould was chosen one module and four cavities according to delivery time， curved parting line and medial spoke gate.

One of the difficult points in the design of mould is the plan of parting line. We used the mould design module of Pro/E software to complete parting design, And decided to choose the parting line shown in Fig. 2 considering the shape and structure of the mould, the arrangement of cavity and the gate location.

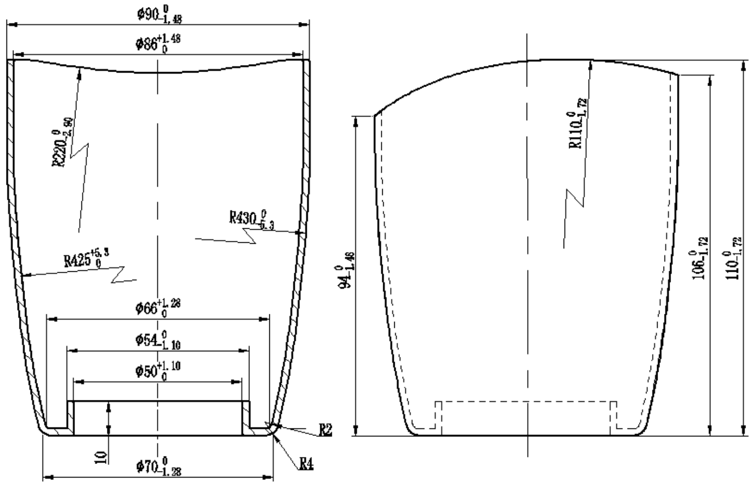

Fig. 1 Plastic parts

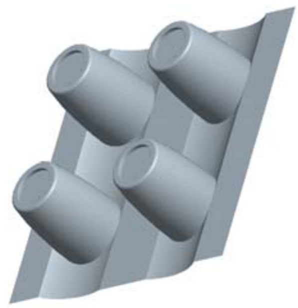

Fig. 2 Curved parting line

Three-plate mould, the frozen material of it is usually taken out by manpower or manipulator. But it is low production efficiency and high labor intensity. In order to meet the requirement of automatic control production, the way using side concave to break frozen material in gate was taken to let frozen material of feed system drop off. The results show, the three-plate injection mould is used side concave to break frozen material of second sprue when splitting mould first and take it out of intermediate plate. When position limiting leader pin works, major parting line is parted, core and sprue puller move towards movable mould. Plastic parts are also taken towards movable mould. Feed system breaks away from sprue puller and then falls off automatically.

In the injecting molding process, the temperature of the mould affects the molding quality and production efficiency of plastic parts directly. In order to minimize molding cycle, it is desirable to keep the temperature of the mould the lowest possible level. But if the temperature of the mould is too low, some problems will occur, such as flow mark, weld lines, low strength and so on. If it is too high, large sink mark and shrinkage cavity will occur and molding cycle will be prolonged even though the liquidity of plastic melt is good and the surface roughness of the plastic parts is low. Therefore, from the point of molding and operating requirements, the temperature of the mould should be kept balance. The beginning cooling time can be calculated by experiential formula.

Save the solid model made by Pro/E in the format of STL, then lead it into Moldflow to fill and analyze. The model will be firstly plotted into grid in the Moldflow. If the match scores of grid reach to 85%, it will be up to the basic demand. In this article, the molding was plotted into grid and repaired, and the most aspect ratio is 11.5 and the match scores is 86.7%. Considering the structure and feature of plastic parts and the design principle of cooling channel, the setup of the initial cooling channel of the mould is shown in fig. 3.

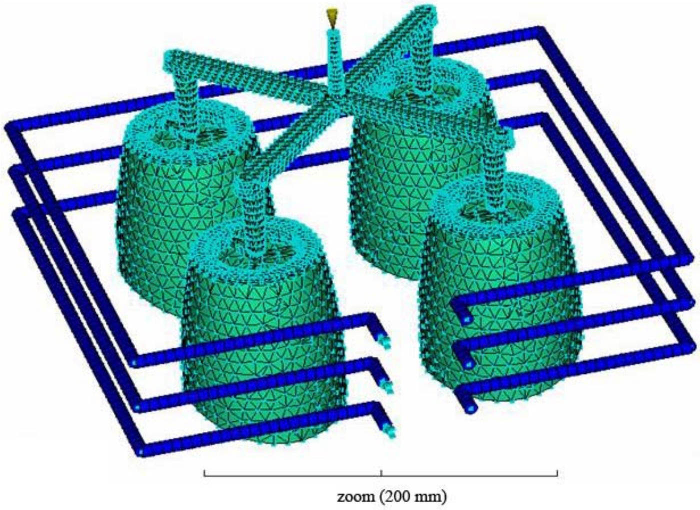

Fig. 3 The initial cooling channel of the mould

Adoption the cooling channel above in cooling, core and cavity in more than 40℃ temperature difference, far beyond 20℃, this is within the scope of recommended value under such circumstances. It will be most likely to place the plastic parts distortion. In addition, the maximum mould temperature also exceeds 100℃, which is limit temperature of dragging out the plastic parts. The internal temperature is high, indicating that core does not have enough cooling, which is the main reason for high temperature products. Therefore, for the intentions of reducing the temperature and the temperature difference, better cooling channel arrangement should be designed.

Cooling Channel Improvements

In order to lower the internal temperature of products, clapboard cooling channel was added to core, and reset cooling channel as shown in Fig. 4.

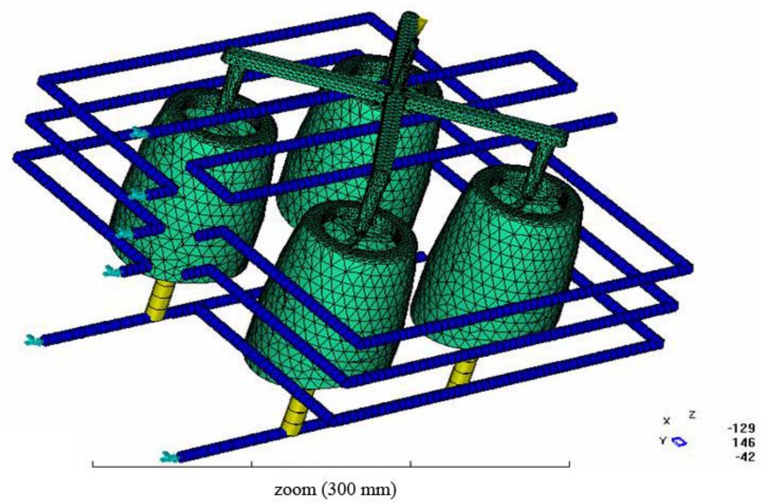

Fig. 4 Clapboard cooling channel

The cooling effect is shown: after the completion of the product cooling, the minimum average temperature in thickness direction fell from 53.93℃ to 39.81℃. The highest mould temperature is below the limit temperature of dragging out the plastic parts. But the surface temperature of products distribution uneven and the difference in temperature is relatively large. This may be due to the toroidal cooling channel can't cool the inner of products which contributes to that the inside surface is hotter than the outside. What's more, it's diseconomy for the temperature of cooling is lower than that of dragging out the plastic parts. It's economical to reduce the number of cooling channels. Therefore, further improvement is necessary for the cooling project.

The temperature around the outside of the products should be well distributed and not too low.

The modified cooling channel was designed to solve this problem (Fig. 5). The unanimous color of cavity surface and well-distributed temperature are shown in Fig. 6. It takes prearranged time for the mould to cool down in the range of required temperature. Above all, the results show that the cooling channel is feasible.

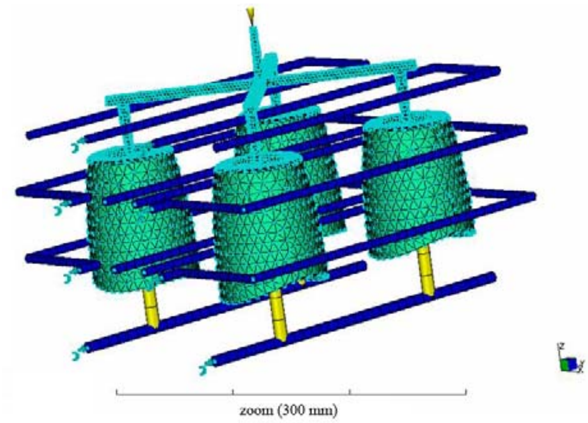

Fig. 5 The improved cooling channel

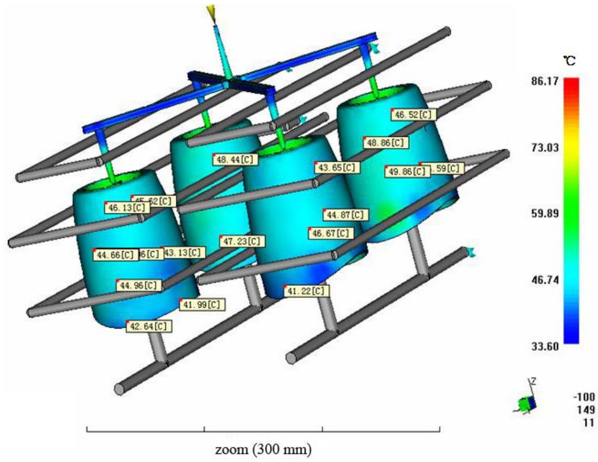

Fig. 6 The temperature of products

Conclusions

(1) The initial design of cooling channel is created by empirical formula; it is needed for being corrected further. Better results can be achieved by revising the cooling channel according to the average temperature of products, temperature of cavity and the critical temperature of the surface of plastic as well as the mould.

(2) The toroidal cooling plan can't make the inner of products cool which contributes to that the inside surface is hotter than the outside. Cooling channels should be set between cavities for four-cavity mould.

(3) Not only the cooling capacity as the range of temperature after cooling down but also the distribution of heat should be considered for the cooling channel.

(4) The efficiency is obvious when Moldflow is applied to the design of cooling channel with better quality of plastic parts.

Acknowledgements

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