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A Review on Design of Plastic Injection Mould

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Abstract: *Injection molding is one of the most preferred manufacturing process used by plastic industries due to its ability to easily manufacture complicated shapes. Plastic products nowadays are used everywhere from household utensils to industrial purpose because of its high strength with low weight characteristic and plastic products can be produced at low cost as per customer requirements. In injection mold design, several important factors are to be considered including material for mold, injection pressure, gate and runner location and size, type of mold, cooling channels,etc. This paper aims to provide an insight of literatures about recent research in design of injection mold for plastic molding.*

Keywords: *Mold Design, Injection molding Process, Plastic, Gate and Runner*

I. Introduction

Plastic has been a god's gift to humans due to its wide range of properties such as hardness, tensile strength, durability, electrical resistance, light weight, availability, low cost, formability, corrosion resistant etc. Due to increasing demand of plastic products in day to day life, many processes has been adopted by industries for manufacturing of plastic components. Processes include extrusion, blow molding, injection molding, thermoforming, etc. Out of all these processes, injection molding has proved to be the most versatile and widely accepted process for manufacturing of plastic products.

Injection molding, is a manufacturing process for producing parts by injecting material into a mould. In this process, plastic material is forced to flow at high pressure in a highly softened state through a nozzle into the mold cavity. The plastic solidifies in the die and ejected by opening the die. The shape of the component is almost in its final form and can be produced at an extremely faster rate. Injection molding pressure usually range from 70 Mpa to 200 Mpa.

Design of injection mold considers several factors. Material of the mold is first selected based on the application. One of the most important factor is type of mold, whether the mold is to be two plate or three plate mold. Next is whether the mold is single cavity type or multiple cavity type. Dimensions of mold are selected based on the dimensions of cavity. Number of gates and runners along with their size and shape are to be defined. Cooling system and venting arrangement is to be provided. Maximum pressure that the mold can sustain while in use is to be defined.

II. Literature Review

We study Literature Survey and classified them according to the following two Categories:

2.1Based on Design Parameters:

J.G. Kovacs, B. Siklo concluded that in this study the temperature distribution ruling in injection molds, especially at corners was analyzed with Autodesk Mold flow Insight 2011 injection molding simulation software. The analysis showed that significant temperature difference appeared between the two sides of the mold. Moreover the cooling of the injected part became asymmetrical. This uneven cooling caused anisotropic shrinkage in the part which is the main cause of corner deformation.

Pankaj Shakkarwal and Lipin Yadav in their research concluded that design with the CAD tools and mould flow analysis is the most important requirement for injection moulding components. The study resulted in reduction of wastages and save valuable man hours, that will be great loss in terms of money that occurs during production phase. Thus mould flow software is a preventive and corrective tool, which can help an engineer to analyse the process to decrease the cycle time and to improve quality of product.

A.J. Giacomin, A.J. Hade, L.M. Johnson, A.W. Mix , Yi-Chang Chen , Hui-Chen Liao ,Shi-Chang Tseng concluded that Core deflection is governed by a single dimensionless group, Q, named core deflectability.This fifth order nonlinear theory predicts measured core deflection accurately. Future work shall employ higher injection rates to explore the role of melt nonlinearity (We > 1) or melt elasticity (De > 1) in core deflection. Future work shall also explore the effect of polymer solidification on the frozen core shape.

Tong-Hong Wang, Wen-Bin Young concluded that the layer removal method was used to measure the residual stresses at a flat thin-walled test sample. Moldings under different conditions were investigated to study the effects of the process conditions on the residual stresses of a thin-walled product. The mold temperature was only the factor to affect the size of the core region as well as residual stress on the surface layer of a thin-walled part . The packing pressure was found to be insensitive to the residual stresses in the studied high-pressure range. The predicted stress level and trend are close to the experimental measurement in viscoelastic model. The layer removal method was also found to be adequate for a thin-walled part.

Josef Gabor Kovacs,Ferenc Szabo,Norbert Krisztian Kovacs,Andras Suplicz,Bela Zink,Tamas Tabi,Hajnalka Hargitai in their research they concluded new method which was developed for rapid tool insert tests. with the help of this technique, all types of rapid tooling technology can be tested, including cooling systems. With the application of this method,FDM and polyjet technologies were studied and the parameters for the simulation programs were determined.It was concluded that simulation software can be used to determine the thermal and other parameters of rapid tooled mold inserts. A special mold insert was designed and produced by different rapid prototyping methods for comparison. Measurements of the inner and surface temperature of the inserts showed that the Polyjet insert has a remarkable advantage over the FDM insert for rapid tooling applications considering surface finish, the density of the models and their heat removal capability. The heat transfer coefficient, thermal conductivity and specific heat of the Polyjet material were determined, and the results were verified with hot plate thermal conductivity and DSC-based specific heat measurements. These results can be used for further simulations to make the calculations even more accurate.

D.M. Yakovleva, G.F. Mukhametzyanova, L.R. Kharisov is concluded in their research, that analysis of the data shows that the maximum level of stress occurs at the contact surfaces during the filling and the subsequent brief exposure of the melt in the mold. At the same time it is noted that within one cycle the stress mark in the surface volumes in transient mode of operation of the mold changes from compressive to tensile.

P.Hernandez, S Taboada, L.Suarez, M D.Marrero, F.Ortega, and A.Benitez is concluded that Interactive Learning Tool project has achieved an internal collaboration pulse inside of group of educational innovation, involving resources and people to take advantage of the research experience in generating a useful and versatile teaching material. It has opened a new line of work of developing interactive training materials with institutional recognition, which allows you to make profitable the effort that goes into this work in the academic field. These projects are forced to maintain operating some laboratory equipment that otherwise, because of its sporadic use, may deteriorate easily. The collaboration of students allows the development of works with great interest that the academic activity, research and management of the Faculty could not achieve them in reasonable time periods. It is very gratifying to see how the students develop their abilities with own materials, which consult independently, and then show you a high interest in deepening the content covered in the courses that you teach.

Patrick Guerrier, Guido Tosello and Jesper Henri Hattel concluded in their research that use of a glass mold is an effective method of performing a direct visual comparison of injection molded parts with simulations. This was achieved in the present study in terms of visual filling pattern and also in terms of actual timing of the melt front during filling and packing. The mold design with a perpendicular injection plane to the mold opening direction presented in this work provided a convenient camera positioning. Thermocouples and pressure sensors were installed and helped getting the overall filling times correct, that are not captured by the high speed camera, and obtaining valuable information regarding the velocity- to pressure-control switch-over, since this is not visible in the video recordings. Simulations have been conducted using the machine inputs and compared with timings from the high speed video and pressure sensors.

Beomkeun Kim,Juwon Min is Concluded in their research that Experiments on stress lattice specimens revealed significant deformation in the thinnest column only. The Experiments and analysis showed that deformation of the injection molded part during post manufacturing thermal cycling was due to the residual stresses that formed during cooling of injection molded parts. Post manufacturing thermal cycling led to the release of this residual stress ,and hence to the elongation of the thinnest columns. Therefore further studies into the injection molding conditions are required, and careful selection of the material properties.

Jack B. Tranter, Paul Refalo,and Arif Rochman concluded that largest consumer of energy was the TCU and the chiller pumps at approximately 50% of the total, followed by the machine at approximately 30% and the chiller at 20%. It is important to select the size of the pumps properly in order not to have excessive power consumption that will not add value to the injection molding process. Concerning the energy consumption of the injection molding machine during a molding cycle, it was determined that the cooling stage consumed the largest energy percentage at 41% of the cycle energy, followed by plasticizing at 21% and holding time at 14%.

Hamyd Hassan , Nicolas Regnier, Guy Defaye in their research concluded that the effect of the injection gate position on the cooling process of injection molding is studied for polymer product having the form of cuboids with two different thicknesses. Three gate locations are assumed, normal to small thickness, normal to the surface cavity, and normal to the large thickness of the cavity. A finite volume method is used for the solution of the mathematical model. The validation of the numerical model shows a good agreement between the numerical and analytical solution. The results indicate that for gate position normal to the small thickness of the cavity, the injection molding process has the minimum time required to solidify the product, the minimum solidification percent during the filling stage and the minimum temperature difference through the product after demolding. They also show that the gate position has a great effect on the temperature distribution of the injected molded product. With this thermal analysis of the gate position effect and a supplementary analysis on his effect on the residual stresses and warpage of the final product and the stability of injection molding machine, an optimum gate location could be determined.

2.2 Based on Optimization Parameters:

A. H. Ahmad Z. Leman , M. A. Azmir , K. F. Muhamad , W.S.W. Harun , A. Juliawati , A.B.S. Alias is concluded that the warpage for ABS material show the different values when the parameter settings were changed. The used of Taguchi's OAs simplified the experiment runs and ANOVA shows the influenced factor that contributed to the warpage defect. The optimum parameters for the ABS material are packing pressure at level 2(375MPa), mould temperature at level 1(400 C), melt temperature at level 1(2000 C) and packing time at level 3(1s). However among these factors, packing pressure is not a significant factor. Meanwhile for the processing factors, it shows the warpage value for mould temperature and melt temperature was increased if the parameter settings factor increased but in versus warpage values for packing time and packing pressure decrease if the parameter settings increased.

Rishi Pareek, Jaiprakash Bhamniya is concluded in their research that In injection molding process of Polycarbonate, for tensile strength melt temperature is found to be the most significant factor. The results show that, for polycarbonate the best combination of processing parameters in terms of tensile strength are 260^0C melting temperature, 150 bar injection pressure and 7.5 seconds cooling time. The influence of all factors has been identified and believed can be a key factor in helping mould designers in determining optimum process conditions injection molding parameters.

Suchana A. Jahan and Hazim El-Mounayri concluded that a design procedure to introduce conformal cooling channels in traditional dies has been developed and demonstrated. Parameters for conformal cooling channel have been optimized for the injection molds for producing 1.5mm thick plastic part. Redesigned 6mm diameter conformal cooling channel with the pitch distance of 8mm and channel wall being 4mm from the mold wall is expected to be the best result. Furthermore, effect of channel cross section on the cooling performance has been analyzed and a rectangular channel proved to be most effective. The optimum design is going to be incorporated into existing injection molding dies by using additive manufacturing technology to improve process performance in industry.

Hamdy Hassan , Nicolas Regnier, Cedric Lebot, Cyril Pujos, Guy Defaye is concluded that the variation of the temperature of the mould through a number of molding cycles is carried out. The simulated results are in good agreement with the transient characteristic of the cyclic mold temperature variations described in and It is found that there is a slightly difference in temperatures values between the simulated results and those described in. The effect of cooling channels form and the effect of its position on the temperatures distribution throughout the polymer and the solidification of the product are studied. The results indicate that as the cooling channels take the form of the product, the cooling rate is improved. The position of cooling channels has a great effect on the cooling process and temperature distribution through the mould and the polymer. The results show that the cooling system layout which performs minimum cooling time not necessary achieves optimum temperature distribution throughout the product, and the system layout must be optimized to achieve the both goals.

Shaikh Mohamed Mohamed Yusoff, Jafri Mohd Rohani, Wan Harun Wan Hamid & Edly Ramly in their research have found that defects in injection molding process were mainly due to improper handling of material, material flow and quality of material. They selected appropriate working range for input and output parameters and level for it. The analysis was made on cavity location. After analysis, they made a final optimal setting, and found that there were no more defects.

Egon Muller, Rainer Schillig, Timo Stock and Miriam Schmeiler concluded that the subject of energy efficiency gets more and more into the focus of attention as the prices to be paid for energy rise. Increasing the energy efficiency requires transparency with regard to the energy and time requirements of machinery and plants. By means of the dual energy signatures the energy and time inputs can be differentiated into value-adding and non value-adding elements. In injection moulding processes this can be done by means of ‘air filling’ or ‘idealised process’.While in ‘air filling’ the process sequences take place without material, the ‘ideal process’ contrasts the time and energy inputs of an actual process with those of an idealised process. Here the value-adding element of energy is calculated theoretically. Optimising in terms of time and energy has been derived from the analyses and show potentials up to 50 %.

Ryosuke Nakao , Hiroyuki Inoya, Hiroyuki Hamada concluded that for their research, different reinforcement forms were adopted and used to make Carbon fiber reinforced polymer by Direct Fiber Feeding Injection Molding to investigate their mechanical properties. To observe changes in physical properties due to the fiber content, the resin supply amount was adjusted with Hungry feeder in 20rpm, 40rpm, and 60 rpm. It was confirmed that the tensile strength is measured to be greater for commingle yarn molded by DFFIM. In the case of commingle yarn, the strain at the maximum tensile stress is beyond the influence of fiber content. On the contrary, the strain at the maximum stress became greater as the content of fiber decreases. The fact is that the fiber is uniformly dispersed, and also, the interface between fiber and resin is more adhesive. For carbon fibers, the surface treatment agent is added, so it is considered as one effect on interfacial adhesion.

Mehdi Moayyediana, Kazem Abharya, Romeo Mariana in their study concluded that the main reason of scrap in cold runner system of injection molding is the feeding system which consists of sprue, runner and gate system. Runner has different cross sections for different applications. In this study, new geometry of runner system with elliptical cross section in comparison with round cross section was successfully developed for injecting two circular plates with thickness 1mm. filling time, melt temperature; mold temperature; pressure holding time and pure cooling time are evaluated as process parameters. Elliptical cross section in comparison with round cross section which has the highest efficiency among current geometries of cross section has 25% reduction in scrap and 2.5% in cooling time for injected parts. The result from simulation demonstrates that the elliptical cross sectional shape of runner is an effective geometry to reduce the scrap and total cycle time and also the easy ejection of molded part out of the cavity. It demonstrates the robustness of new geometry of runner system. Further than our anticipation, remarkable phenomena was detected which is related to process parameters and new geometry of runner system that will be discussed in another paper. The experimental set up will be conducted to justify the simulation result.

Manmit Salunke, Rushikesh Kate, Vishwas Lomate, Gajanan Sopal in their research concluded that the filling time and the cooling time of a four cavity design does not increase to four times longer than having a single cavity. So the cycle time for four cavities design is the most optimum and efficient to be used in the production process. The analysis showed the parameters such as fill time, weld line, air traps, sink marks etc. which will affects the quality of the finished product. Plastic Flow Simulation Simulate the flow of melted plastic to help optimize part and mold designs, reduce potential part defects, and improve the molding process and decrease the cycle time and to improve the quality of the product.

III. Conclusion

During the extensive literature survey of twenty research articles, we can conclude that backpressure, manifold temperature, holding pressure and screw rotation speed are the most important process parameters. To reduce the plastic component rejection, scientists have optimize these process parameters by Taguchi and Anova etc. Some of the scientists use FEA simulation tools to reduce the plastic component rejection.

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