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A REVIEW ON OPTIMIZATION OF WARPAGE IN INJECTION MOLDED PLASTIC PART USING DIFFERENT OPTIMIZATION TECHNIQUES

Rahul Chaudhari.[1], H. G. Patil[2]

Abstract—The main objective of writing review on warpage optimization of injection molded plastic part is to investigate the optimization techniques used for minimization of warpage by optimizing process parameters during injection molding. Highly complex design of plastic products now a days demands dimensional accuracy and good surface finish. As the injection molded part cools, uneven distribution of stresses is set up due to uneven cooling. These stresses warp the part and affect the dimensional accuracy of the part. So as to keep the warpage minimum, accurate prediction of optimum process parameters is very important. This review paper considers warpage as a main defect in the injection molded part. This paper presents an idea about research undertaken or completed on optimization of process parameters to minimize warpage, optimization techniques used, role of Finite Element Analysis (FEA) and most significant process parameters affecting the warpage.

***Index Terms*—Design of experiment, Optimization, Plastic injection molding, Process parameters, Warpage**

I. INTRODUCTION

Injection molding is the most common method of producing parts made of plastic. The process includes the injection or forcing of heated molten plastic into a mold which is in the form of the part to be made. Upon cooling and solidification, the part is ejected and the process continues. The injection molding process is capable of producing an infinite variety of part designs containing an equally infinite variety of details such as threads, springs, and hinges, and all in a single molding operation. A plastic is defined as any natural or synthetic polymer that has a high molecular weight. There are two types of plastics, thermoplastics and thermoset. Thermosets will undergo a chemical reaction when heated and once formed cannot be resoftened. The thermoplastics, once cooled, can be ground up and reheated repeatedly. Thus, the thermoplastics are used primarily in injection molding.

There are four major elements that influence the process. They are- molder, material, injection machine and mold. Of these four, the injection machine and the mold are the most varied and mechanically diverse. Most injection machines have three platens. Newer models use just two platens and may be electrically operated as opposed to the traditional hydraulic models. They can range in size from table top models to some the size of a small house. Most function horizontally, but there are vertical models in use. All injection machines are built around an injection system and a clamping system. Injection molding is a process of forming an article by forcing molten plastic material under pressure into a mould where it is cooled, solidified and subsequently released by opening the two halves of the mould. Injection molding is used for the formation of intricate plastic parts with excellent dimensional accuracy. A large number of items associated with our daily life are produced by way of injection molding. Typical product categories include house wares, toys, automotive parts, furniture, rigid packaging items, appliances and medical disposable syringes.

The molding may cause defects and its processing offers a challenge during its development phase. The cost of the mold is high and any process that is not optimized renders heavy overheads during its development cycle and production. So designing the mold which ensures best suitability for the features on the component with smooth flow of molten plastic is very important part of development process. The successful launch of any plastic product depends on knowing the true costs and profitability before the job is started. Injection molding typically involves large volumes of parts. Small cost overheads per part can be compounded to large cost differences over the life span of the part. Major cost components considered here are material, re-grind and machine costs. Scrap, rejections and regrind costs are also accounted in the cost.

In the present literature the emphasis will be on studying and understanding the warpage optimization in the injection molding process. Warpage is largely depends on processing parameters like melt temperature, mold temperature, packing pressure, packing time etc. A lot of research has been done in the area of modeling polymer processing processes in closed mathematical/physical models. Mold filling simulation is the most common type of process modeling. Commercial Computer Aided Engineering (CAE) software has been available since eighties. Over the years, the scope of such software has expanded beyond filling analysis to include cooling analysis, part gate location, runner sizing, weld line prediction, gas-trap prediction, warpage and residual stress analysis.

II. LITERATURE REVIEW

Xiaoxin Wang et al. worked on reduction of sink mark and warpage of the molded part in rapid heat cycle molding process. To solve the problem of sink mark, they developed a new ‘‘bench form’’ structure for the screw stud on the product coupling with a lifter structure for the injection mold. To solve the problem of warpage, design of experiments via Taguchi methods were performed to systematically investigate the effect of processing parameters including melt temperature, injection time, packing pressure, packing time and also cooling time on the warpage. Injection molding simulations based on Moldflow were conducted to acquire the warpage of the plastic parts produced under different processing conditions.

Ozcelik and Sonat have done warpage and structural analysis of thin shell plastic in the plastic injection molding. They used a thin cell phone cover. They observed the effects of the injection parameters on warpage for different thickness values using Taguchi method. They used Moldflow software to find warpage values. Then they determined the forces that cause the plastic part to fail at the points determined over the top surface of the cell phone cover using CATIA V5R12 (general structural analysis).

Yi-Min Deng et al. used a hybrid of mode-pursuing sampling method and genetic algorithm for minimization of injection molding warpage. During optimization, Kriging surrogate modeling strategy is also exploited to substitute the computationally intensive Computer-Aided Engineering (CAE) simulation of injection molding process. By integrating the two algorithms, a new sampling guidance function is proposed, which can divert the search process towards the relatively unexplored region resulting in less likelihood of being trapped at the local minima. A case study of a food tray plastic part is presented, with the injection time, mold temperature, melt temperature and packing pressure selected as the design variables.

Behrooz Farshi et al. optimized injection molding process parameters using sequential simplex algorithm. They used warpage and shrinkage as defects in injection molding of plastic parts. Moldflow software package has been used to simulate the molding experiments numerically. Plastic part used is an automotive ventiduct grid. They used mold temperature, melt temperature, pressure switch-over, pack/holding pressure, packing time, and coolant inlet temperature as process design parameters.

Fei Yin et al. have done research on warpage prediction and optimization of plastic products during injection molding using back propagation neural network modeling. They developed a Back Propagation (BP) neural-network model for warpage prediction and optimization of injected plastic parts based on key process variables including mold temperature, melt temperature, packing pressure, packing time and cooling time during PIM. They used a approach of BP neural network trained by the input and output data obtained from the Finite Element (FE) simulations which are performed on Moldflow software platform. A kind of automobile glove compartment cap was utilized by them in this study. They proved that the prediction system has the ability to predict the warpage of the plastic within an error range of 2%.

Eghbal Hakimian et al. studied warpage and shrinkage properties of injection-molded micro gears polymer composites using numerical simulations assisted by the Taguchi method. Micro gears containing four cavities and consisting of three different types of thermoplastic filled with glass fibers were analyzed. The effects of the injection parameters on warpage and shrinkage at different fiberglass percentages and cooling temperatures were analyzed according to the Taguchi method.

Ozcelik and Erzurumlu determined effecting dimensional parameters on warpage of thin shell plastic parts using integrated response surface method and genetic algorithm. They investigated about efficient minimization of warpage on thin shell plastic parts by integrating finite element analyses, statistical design of experiment method, response surface methodology and genetic algorithm. For this experimentation, they used thin shell plastic part. They created a predictive model for warpage using response surface methodology exploiting finite element analysis results. Then they interfaced response surface model with an effective genetic algorithm to find the optimum process parameter values.

B. Sidda Reddy et al. Studied the application of soft computing for the prediction of warpage of plastic injection molded parts. They develop a accurate warpage prediction model for plastic injection molded parts using soft computing tools namely, artificial neural networks and support vector machines. For training, validating and testing of the warpage model, a number of Moldflow (FE) analyses have been carried out using Taguchi’s orthogonal array in the design of experimental technique by considering the process parameters such as mold temperature, melt temperature, packing pressure, packing time and cooling time. Comparison between these models is done.

Mohammad Aashiq M et al. have done investigation of process parameters for an injection molding component for warpage and shrinkage. They explored the influence of different mold temperatures on the warpage & shrinkage of the injection molded component. They used simulation software MOLDEX 3D for this study, the simulations were done by varying different mold temperatures and their corresponding warpage & shrinkage were collected. They found that the different mold wall temperature causes the asymmetrical polymer flow in the cross-section due to which the asymmetrical structure in the parts cross-section occurs and this was observed using the flow analysis software

S. Taghizadeh et al. worked on warpage prediction in plastic injection molded part using artificial neural network. They used different parameters for prediction of warpage. They developed an artificial neural network (ANN) model which is capable of warpage prediction of injection molded plastic parts based on variable process parameters. Under different settings, the process was simulated by Moldflow and the warpage of the part was obtained.

A. Riaz Ahamed et al. designed and optimized the parameters which affect the molding process using design of experiment. They took a plastic product made of polycarbonate plastic material was taken for the experiment with optimal injection molding conditions and its tensile stress test was conducted in order to minimize defects and increase its strength. Design of Experiment (DOE) is applied with an attempt to optimize these parameters and to achieve good results using.

III. CONCLUSION

Dimensional stability is of prime importance in injection molded part. Too much variation in dimension can lead to rejection of the part. An extensive research in the past clearly indicates that there is always a scope for improvement. The finite element simulation is the most popular and commonly found approach for warpage prediction. There are many commercial packages are available for use in warpage prediction, such as, MPI, C-Mold, Moldex 3-D. These are equipped with several good techniques and methodologies to optimize the parameters in injection molding and consequently minimize the warpage. The results yielded by these techniques are in close agreement with the simulation results.

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