Review on Injection Moulding Process & its Die Development Using CAD/CAM/CAE

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Abstract – The aim of this review paper is to represent a study on the injection moulding process & injection moulding die development. Injection moulding is a manufacturing process. It produces parts from thermoplastic and thermosetting plastic. Material is fed into a heated barrel, mixed & forced into the cavity of a mould. There it solidifies during cooling. It takes shape of cavity. Once a product is designed mold makers prepare mould from metals like steel, aluminium. Molds are manufactured either by standard machining or Electrical Discharge Machining. Now a days CNC machines are used for machining of these moulds. This paper presents study of injection moulding process & its die development process based on experiments. Experiments were carried to find better mould designs, optimum process parameters, to understand complex relations between process parameters, change of composition of product material etc.

Keywords- Injection Moulding, Experiments, Process Parameters, CAD/CAM/CAE.

I. INTRODUCTION

Since 1940 due to World War II injection moulding process got high demand. It gives a very wide range of products like buttons, combs, automotives, toys, packagings, one piece chairs, mechanical parts like gears etc. This is suitable process for producing high volume of products. Other benefits are repeatable high tolerances, ability to use wide range of materials, less labour costs, lesser scrape, lesser finishing work. Disadvantages are costly equipments, higher running costs etc. For die developments using Cad/Cam tools steps are to prepare 3D model of product component, then develop die cavities, then die blocks, then other parts of die assembly in 3D model form. Data of this 3D model helps to do Cam operations. To get final product component with good finish & close tolerances. Design of mould & process parameters are important. So study of these factors is made here which has experimental base.

Marco Sortino, Giovanni Totis, Elso Kuljanic [1] this paper presented study on innovative moulding technologies such as Injection Compression Molding – ICM or Vacuum Injection
Moulding – VIM. Injection molding is a complex process. It is regulated by many factors like injection speed, injection pressure, melt temperature, mold temperature etc.Though process control and parameter optimization is done it is often difficult to achieve for thermoplastic
components, sufficient dimensional accuracy, especially in the case of geometries with high aspect ratios. For these reason innovative moulding technologies such as Injection Compression Molding – ICM or Vacuum Injection Moulding – VIM is recommended. In this paper conventional injection molding – IM is compared to ICM and VIM for the optical thermoplastic microscale prism patterns typical of Fresnel lenses. A full Design of Experiments was performed including several micro structured prism geometries, injection molding technologies and specific process parameters for a total of 288 tests. Data analysis prooved the greater quality of workpieces observe by ICM, whereas VIM was a minor process improvement. The dimensional accuracy expected in optical components is high and it is often difficult to achieve the required quality standards. For such reasons there is a strong need for innovative instrumentation and manufacturing methodologies. In general, the accuracy obtained by ICM is higher than regular molding. ICM can be recognized as the most precise and repeatable of the three injection molding methodologies.The average transcription ratio of the VIM methodology is lower than ICM but higher than IM for all prism geometries. The application of – Injection Compression Molding (ICM) and Vacuum Injection Molding (VIM) – for the mass production of optical miscroscale plastic components was compared to conventional injection

molding. Injection compression moulding process can be performed only on dedicated machines. Whereas vacuum injection moulding process can be applied to conventional injection moulding machine with minor set-up and mould changes. Vacuum injection molding implies an increase in cycle time
due to the time needed to reach the vacuum condition inside the cavity.

Shohei Kajikawa, Takashi Iizuka[2] in this paper injection molding of steamed bamboo powder was attempted. Process was controlled by the metal mold temperature. Injection molding was conducted when the injection temperature was 180 or 200 ºC and the metal mold temperature was 80-160 ºC. Bamboo powder was steamed at 200 ºC for 20 min in a small pressure vessel. A thermal flow test of the steamed powder was conducted in order to investigate the flowability of the powder. The powder flowed at 160-220 ºC, and shown good flowability at 180 and 200 ºC. It proved possible to obtain products through such trials. Products with a gloss surface similar to plastic were obtained with the metal mold temperature 140 or 160 ºC. Injection pressure found affected by temperature; the material flowed inside the metal mold under low pressure when the injection and the metal mold temperatures were high. But the flowability inside the metal mold showed no effect on the surface texture of the product. The utilization of woody biomass materials as industrial materials is expected to be effective but conventional processing methods of woody biomass, such as machining or plastic forming, have several problems. E.g. workability and productivity is poor. Productivity of woody biomass in particular should be improved because for the use as an industrial material considering mass production. In addition, arbitrary shaped products need to be processed using woody biomass more effectively.

The authors have developed an injection molding method for woody biomass in order to resolve these problems.The flowability of the material is an important factor in injection molding. Under heat and pressure, woody biomass that contains water flows due to the softening and composition of lignin and hemicelluloses. Miki et al. (2004) fabricated a complexly shaped product by injection molding wood powder saturated with water. However, water inside the material has negative effects on molding. because much water vapor and pyrolysis gas are produced when heated. In addition, it was reported that injection molding of wood powder
saturated with water was impossible when a conventional electric injection mold for thermoplastic polymers was used (Miki et al., 2005). In this study, injection molding was attempted using steamed bamboo powder in an oven-dry state. It was preferable that the injection temperature be high for fluidization of the material. On the other hand, the metal mold temperature should be low so the molded product is cooled effectively. However, the material does not flow adequately inside the metal mold when the metal mold temperature is too low. For this reason, injection molding was attempted while controlling the metal mold temperature. In the experiment, the flowability of the steamed bamboo powder was investigated by thermal flow test. The influence of the metal mold temperature on the appearance of the molded product and the pressure variation during molding was evaluated. In particular, the flowability was good at 180 and 200 ºC. In cases when the injection temperature was 180 ºC, products that completely filled the mold were obtained under the condition that the metal mold temperature was 140 or 160 ºC. Moreover, these products were obtained at a metal mold temperature of 100-160 ºC when the injection site temperature was 200 ºC. However, products with a gloss surface similar to plastic were obtained at metal mold temperatures of 140 and 160 ºC regardless of injection site temperature. Regarding injection pressure variation, the injection pressure in cases when material could flow inside the metal mold decreased with the increase in the temperature of the injection site and the metal mold. However, the flowability inside the metal mold did not have an effect on the surface texture of the product.

Egon Müllera, Rainer Schilligb, Timo Stock, Miriam Schmeilerb[3] this paper presents two methods of dualising the time and energy consumption in the plastic injection moulding process. Potentials for improving the process, from the viewpoints of energy and time, are highlighted. Based on the dual process analysis, improvement concepts are brought forward. In polymer processing the plasticizing phase (melting energy) as well as the injection and the holding pressure phase (forming energy) are considered value-adding.The changeover point from the injection phase to the holding phase is at 95% fill of the mould. This means only 5% of the
injection volume are left in the barrel at the changeover from the injection to the holding phase . In other words 95% of the theoretical forming energy is assigned to the injection phase and 5% to the holding phase. The dual signatures show a high value-adding efficiency in terms of time, which is achieved due to the fact that the cooling phase and the plasticising phase (for the next

component) process sequences run in parallel.The low value adding efficiency in terms of energy shows, however, up to now the energy efficiency of the processes obviously has not been in the focus of interest. Possibilities for improving the process in terms of energy as well as in terms of time are identified as follows.1. *Optimization in terms of time - Reducing the process time* In addition to an increase in productivity, a reduction of the process time leads to energy savings, too. In practice, the setting of the process parameters, holding pressure time and cooling time, are adjusted on the basis of experience. In most cases there is no continuous improvement of these times. The lower the minimum wall thickness of the part, the shorter the holding pressure and cooling times. For this thickness, recommended values from the relevant literature indicate significant lower values for the holding pressure and cooling phases than those set on the machine under investigation. 2.Optimisation of the holding pressure time. The holding pressure phase serves to compensate the shrinkage of the cooling component by the feeding of melted mass. The sealing point limits the holding pressure time. At this point the polymer has cooled down to such an extent that the runner has solidified completely. No more melted mass can enter the mould or leak from it. By means of the dual energy signatures the energy and time inputs can be differentiated into value-adding and non value-adding elements.Here the value-adding element of energy is calculated theoretically. Optimising in terms of time and energy can be derived from the analyses and show potentials up to 50 %.

Hong Seok Park and Trung Thanh Nguyen[4] this paper presents the car fender-based injection mold-ing process optimization that aims to resolve the trade-off between energy consumption and product quality at the same time in which process parameters are optimized variables.The engineering analysis that may be employed to conduct holistic optimization of the injection molding process in order to increase energy efficiency and product quality is also mentioned in this paper.In the injection molding process of car fender, energy is taken by plasticization, heating, molten-plastic injection, clamping forces, auxiliary device-operation, and mold movements part-ejection.

According to the analysis of energy consumption, except the plasticization and heating process, clamping force can be considered as the great influence factor for energy saving. Focus on the minimizing clamping force which gives rise to clamping energy based on the optimization of process parameters. Additionally, due to thin-shell characteristic, the warpage values that should be minimized to improve molded product quality are employed as the optimization criteria. To save the time and costs, the simulation-based optimization is employed instead of expensive physical experiments. The commercial software, namely Autodesk Molflow Insight 2012 that can guarantee reliable results is used to simulate the molding process. In this study, warpage values acted as inequality constraints. Based on those results, holistic optimization of injection molding process can be implemented to minimize energy consumption and defects in future work.

Wei Guoa, Huajie Maoa,, Bei Lia, Xiangyu Guoa[5] this paper given that in order to reduce weight and for better dimensional accuracy of plastic products, microcellular injection molding technology is applied more and more in automotive. There are several defects paid special attention by vehicle manufacturers, such as warpage and cell radius. The effect of processing parameters in microcellular injection molding is studied. The study investigated the influence of two kinds of gas foamers (CO_2 and N_2) on microcellular injection molding process, and the following processing parameters such as temperature, time, pressure and gas controlling were considered to research. Design of experiments was employed . According to experimental analysis, not only the significant processing parameters to warpage were found out, but also the interactions between each factor were stidied. This study could provide microcellular injection molding process design with theoretical basis and practical guidance.The automotive plastic products demand both lightweight and high dimensional accuracy. The microcellular injection molding is used to reduce the products weight, because the presence of foam cells in the polymer decreases the density of the material, which ensures using less raw material. Furthermore, the morphological structure of foam cells can be arranged via controlling the porosity ratio in polymer, so different microcellular foam polymer with varying properties can be generated by using microcellular injection molding, which are proper to be used in different industrial area. In this study, the standard tensile sample was selected as a research object. The 3D model and FE model of the sample and mold were established in Unigraphics and MoldFlow in order to investigate the influence of foaming agent and processing parameters on microcellular injection molding process. The variations of warpage, bubble radius and techanical property of the sample under different foamers were revealed by using CAE analysis.

M.A. Sellésa, S. Sanchez-Caballeroa, E. Perez-Bernabeua[6] this paper tells that this work is done to make a small review of computer-aided software based mainly on the calculation of the injection molding cost. An injection molding machine can produce thousands of pieces per day. That depends on many factors. A small improvement in the cost per piece can have a significant impact on the industry. These factors have to be carefully considered by the software in order to make accurate estimations. A total of 5 programs are fully analyzed in this contribution, and this is useful to achieve good cost estimation for the injection molding process. Despite the low number of programs described above, results indicate that the paid software options are more accurate and offer more options for make decisions on which is going to be the final cost of manufacture an specific piece using an injection molding machine. The free software options are more restrictive in considered variables. ProMax-One™ can be a good choice, since it makes calculations on several parameters, such as the cavity data and project information.

II. CONCLUSION

Injection moulding is a mass production process. To achieve reduction in unit price of a plastic product one need to find out best alternatives. On die design part, there is scope to find best die design always. This reduces cycle time, lesser scrape, minimum trials, lesser set up time of die on machine, more die life, lesser maintenance, lesser lead time to develop die set etc. For this CAD softwares help a lot. Processing parameters, holding pressure time and cooling time, are adjusted on the basis of experience. Experiments help to set them close to optimum values thereby reducing time & energy involved & hence cost. Also degree of automation is more as Cad/Cam/CAE are used helping in reduction of fatigue, human skill, lead time, rejection etc. The automotive plastic products demand both lightweight and high dimensional accuracy. The microcellular injection molding is used to reduce the products weight saving material cost without sacrificing quality.

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