SIMULATION AND CORRELATION OF THE MELT FLOW CHARACTERISTIC USING POLYSTYRENE IN UNSYMMETRICAL CAVITY INJECTION MOLD

ABDULLA MAHMOUD AHMED

SCHOOL OF MATERIALS ENGINEERING

UNIVERSITI MALAYSIA PERLIS

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by

ABDULLA MAHMOUD AHMED

(1031620001)

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بسم الله الرحمن الرحيم

In the name of Allah, the Beneficent, the Merciful

With blessings and peace be upon the most honorable Prophets and Messengers, Muhammad and his Folk, Companions and those who follow noble way.

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ABDULLA MAHMOUD AHMED

UNIVERSITI MALAYSIA PERLIS

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Author's full name : **ABDULLA MAHMOUD AHMED**..

Date of birth : **15th/07/1973**...

Title : **SIMULATION AND CORRELATION OF THE MELT FLOW CHARACTERISTIC USING POLYSTYRENE IN UNSYMMETRICAL CAVITY INJECTION MOLD**..........

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UNIVERSITI MALAYSIA PERLIS

SIGNATURE **SIGNATURE OF SUPERVISOR**

G 1876363 **DR. DU NGOC UY LAN**

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ABSTRAK

Masalah-masalah yang ditemui dalam peringkat mereka acuan untuk menghasilkan suntikan plastik ialah keupayaan aliran plastik dan penghasilan acuan rongga suntikan yang tak simetri. Perbezaan ketebalan, morfologi dan isipadu ronga akan menyebabkan ciri-ciri aliran rongga dan hasil yang berbeza pada masa suntikan yang berbeza. Penyelidikan ini menggunakan teknologi"Solid-Work" dan "Cad-Mould" sebagai "Computer Aided Engineering"(CAE) untuk analisis corak dan pembinaan acuan rongga suntikan yang tak simetri. Bahan yang digunakan dalam kajian ini adalah untuk mencari kesan-kesan keupayaan aliran plastik, ialah polistirena (PS). Pembolehubah-pembolehubah yang telah digunakan dalam acuan rongga suntikan yang tak simetri ini adalah suhu takat lebur. Acuan suntikan praktikal dilakukan dengan menggunakan acuan suntikan BOY 22M.Parameter-parameter suntikan yang ditetapkan telah direkodkan dan digunakan untuk simulasi.Sampel-sampel PS yang telah disuntik dicirikan pada sifat-sifat ketumpatan dan mekanikal (tegangan dan lenturan). Sifat-sifat mekanikal tertinggi yang dicapai adalah pada pengesetan suhu 210 °C, kadar aliran 116 cm^3/s, dan tekanan maksimum 614 bar. Perilaku reologi polistirena disifatkan melalui Indeks Aliran Leburan and Reometer Rerambut untuk proses simulasi. Hasil yang diperolehi adalah kelikatan kadar ricihan dan faktor anjakan suhu – parameter-parameter jubin. Untuk simulasi, empat pengesan telah disediakan di kedudukan get dan hujung untuk setiap rongga.Keputusan proses simulasi telah dianalisis dengan menggunakan program Cadmold. Korelasi antara praktikal dan simulasi telah dibuat. Daripada situ, pengubahsuaian acuan di get rongga dijalankan untuk mendapatkan aliran dan produk -produk suntikan yang lebih baik. Analisis dan pertimbangan yang dibuat berdasarkan kepada keputusan-keputusan proses simulasi. Hasil kajian menunjukkan pengubahsuaian acuan telah mencapai kelikatan yang lebih tinggi dan kadar ricihan yang lebih rendah untuk rongga dumbel yang boleh menjanjikan sifat-sifat mekanikal lebih baik.

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ABSTRACT

In plastic injection molding, the problems found in the mold design stage are the capability of plastic flow and unsymmetrical cavity of the injection molding. Different thickness, morphology and volume of cavities have causes the different flow characteristic and results in different injection times. This research uses Solid-Work and Cad-Mold as Computer Aided Engineering (CAE) technology for design analysis and construction of unsymmetrical cavity injection molding. The material used in this study in order to find the effects of the capability of plastic flow is polystyrene (PS). The variables used in this unsymmetrical cavity injection mold consist was melt temperature. Practical injection molding is carried by BOY injection molding 22M. The injection setting parameters are recorded and used for simulation. The injected PS samples are characterized on density and mechanical properties (tensile and flexural). Temperature setting at 210 °C, 116 cm^3/s flow rate and maximum pressure of 614 bar achieved the highest mechanical properties. For simulation, the rheology behavior of polystyrene is characterized from melt flow index and capillary rheometer. The obtained results by the rheology testing are viscosity, shear rate and temperature shift factor - carreau parameters. As for simulation, four sensors are setup at the gate and end of each cavity. While simulation results are analyzed by a Cadmold program. The correlation between practical and simulation are made. From there, a modified mold at a cavity gate is carried out in order to get better flow and better injection products. The analysis and judgment is based on simulation results. The result shows that the modified mold achieve higher viscosity and lower shear rate for the dumbbell cavity which could better mechanical properties.

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LIST OF SYMBOLSAND ABBREVIATION

ASTM	American Society for Testing and Materials
°C	Degree Celsius
F	Force
g	Gram
MFI	Melt Flow Index
V	Velocity
Kg	Kilogram
MPa	Mega Pascal
PS	Polystyrene
GPPS	General Purpose Polystyrene
mm	Millimeter
cm	centimeter
min	Minute
s	Second
%	Percentage
rpm	Revolutions per Minute
PIM	Powder Injection Molding
SEM	Scanning Electron Microscope
LCR	Laboratory Capillary Rheometer

UTM	Universal Testing Machine
η	Viscosity
γ	Shear rate
τ	Shear stress
Q	Volumetric Flow Rate
Tg	Glass Transition Temperature
P	Pressure
L	Length of Capillary
r	Radius of barrel
POM	Polymer Optical Microscope
CAE	Computer Aided Engineering
CAD	Computer Aided Design
STL	Stereo lithography
IGES	Initial Graphics Exchange Specification
2-D	Two Damnation
t_{cycle}	Cycle Time
$t_{closing}$	Closing Time
$t_{cooling}$	Cooling Time
$t_{ejection}$	Ejection Time
S_1	The first sensors
S_2	Second sensors

S_3	Sensors third
S_4	Sensors fourth
P_0	Viscosity for shear rate zero
P_1	Reciprocal shear rate
P_2	Value for the gradient in the shear

CHAPTER 1

INTRODUCTION

1.1 Research Background

Plastic product has an important role in our daily life. The process of forming and shaping can be done in many behaviors such as injection moulding, blow molding, and thermal compression. Among these processes, injection moulding is the most generally used process for the production of plastic part. There is approximately 70-80% of worldwide industries used an injection in plastic part production (Sakchai, 2007).

According to the plastic injection process, the most critical step is the flow of melt plastic from nozzle to fill in a narrow shaped mold (Dominick, 1998). It is difficult to control the flow of a melt plastic through the narrow channel or at the far mold end from the nozzle due to the distance, the cross section of channel, mold temperature, and plastic type. Therefore, an investigation of plastic flow behavior and variables effecting an injection of plastic into the mold is needed for a better understanding.

Injection molding is the most common method of part manufacturing. Injection molding is used to create many products such as wire spools, packaging, bottle caps, automotive dashboards, pocket combs, and most other plastic products available today. Some advantages of injection molding are high production rates, repeatable high tolerances, the ability to use a wide range of materials, low labor cost, minimal scrap losses, and little need to finish parts after molding. However, some disadvantages of this process are expensive equipment investment, potentially high running costs, and the need to design moldable parts (Charles, 2006).

Simulation of injection molding is, arguably, the most successful example of simulation for any plastic forming process. The expense associated with creating an injection mold and the likelihood that a problem discovered in production will result in costly retooling and lost time, make molding simulation of high value to industry. This may be contrasted with other polymer forming processes where tooling costs are much lower or where problems may be overcome by varying process conditions (Rong, et al., 2011). Despite the apparent success of injection molding simulation, too few parts are subject to any simulation. Moreover, the prediction of shrinkage and warpage is subject to increasingly higher standards of accuracy.

1.2 Problem statement

1. The geometrically symmetric runner system is required to use when designing a multi-cavity mold. Moreover, the mold cavities are usually needed to be similar volume and morphology. This is to overcome the uneven stretching that occurs during injection, resulting in a variation in wall thickness and to prevent the unfulfilled samples obtained. The originated reason is shear-induced imbalance during injection (Tim, et al., 2008)
2. Imbalance filling for each cavity is strongly depending on the melt rheology of the injected polymer. Imbalance filling causes defective product on shape, dimension and performance properties.
3. A system of unsymmetrical cavities of injection mold is less understood and difficult to control.

1.3 Research Objectives

a) Comprehension of the flow behavior of runner system and unsymmetrical cavity injection mold during injection with polystyrene. (UniMAP injection).
b) Simulation and correlation the melt flow characteristic between practical (UniMAP injection machine) and Theoretical (Cadmold software).
c) Modify to get optimum design for the mold for better injection products by Solid work software and simulate with Cadmold software.

CHAPTER 2

LITERATURE REVIEW

2.1 Injection Molding

Injection molding is a process of forming a product by forcing molten plastic material under pressure into a mold where it is cooled, solidified and subsequently released by opening the two or three halves of the mold. According to (Bryce, 1996) has stated that the 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 contain house wares, toys, automotive parts, furniture, rigid packaging items, appliances and medical disposable syringes.

Plastic injection molding is one of the most important polymer processing operations in the plastic production today. According to (Michael, 2009) has stated that the plastic industry that is injection molding and involving manufacturing has high growth potential caused by the products are made nowadays is from the polymer material.

The most establish method for producing plastic or polymer parts in mass production is plastic injection molding. This is a highly cost-effective, accurate and competent manufacturing method, which can be automated. However, it is very costly tooling and machinery are needed this manufacturing process. This process is also applicable to metals and ceramics by a new technology known as powder injection molding (PIM). The design of a polymer or plastic injection mold is an integral part of plastic injection molding as the quantity of the final plastics part is greatly reliant on the injection mold. A plastic injection mold is a high precision tooling used to mass produce plastic parts and it by itself an assembly of cavities (Vannessa, 2004).

2.1.1 The Molding Machine

Injection molding machines can fasten the molds in either a horizontal or vertical position. The majority of machines are horizontally oriented as shown in Figure 2.1, but vertical machines are used in some niche applications such as insert molding, allowing the machine to take advantage of gravity. As stated in (Tim, et al., 2008) there are many ways to fasten the tools to the platens, the most common being manual clamps (both halves are bolted to the platens); however hydraulic clamps (chocks are used to hold the tool in place) and magnetic clamps are also used.

The injection molding process consists of injecting molten plastic material from a reservoir into a closed mold, allowing the plastic to cool down and solidify, and ejecting the finished product from the mold (Bryce, 1996). Injection molding is the most widely used process for manufacturing thermoplastic products (Mitchell, 1996). The time since the molten plastic is injected until the solidified part is removed is called cycle time, and it is typically in the range of 10 to 30 seconds, although longer cycles are not rare to find with large parts. Injection molding is the most popular method to process thermoplastics and some thermosets. Continuous efforts have been made to increase the productivity of injection machines; these changes are often the replacement of the injection unit for a more efficient one, the re-design of the mold to simultaneously produce more than one part, cooling of the injected parts out of the cavity, etc.

To arrive at high-quality products, the machine settings at the beginning of the injection molding process optimization procedure should be as close as possible to optimal processing conditions. Although an educated guess of the processing conditions for a given material is always at hand, the final conditions are dependent on specific material grades, injection molding machine size, screw wear, part and mold design, and other material independent variables. Each processing condition setting is directly influenced by the following parameters (Tim, et al., 2008):

- Desired Properties of the Finished Product
- Injection Molding Machine
- Injection Mold
- Injection Molding Material
- Part Geometry