OPTIMIZATION OF FEED SYSTEM DESIGN IN FAMILY MOULD USING MOULD FLOW SIMULATION SOFTWARE

MOHD U'KASYAH BIN HASHIM

A thesis submitted is fulfillment of the requirements
for the award of the degree of
Bachelor of Manufacturing Engineering

Faculty of Manufacturing Engineering
UNIVERSITI MALAYSIA PAHANG

JUNE 2012

ABSTRACT

Various problems have been found in the plastic injection industry recently. One of the major obstacles is a balancing of gates and runners in a family mold due to lack of clear understanding of the flow behavior of plastic in the mold resulting in overpacking, short shot or any other defects on the parts. The objective of this research is to to compare mould flow simulation software with actual injection molding and predict possibility of injection molding defect before injection. 'The aim of our analysis is to provide a simple experimental model simulation was performed. Different sizes of simple geometric parts were selected as a case study for a family mold with two cavities. Mould flow simulation software was employed to analyze the plastic feeding system such as sprues, runners and gates. The simulation results were obtained as a useful guideline for balancing of gate and runner system for a family mold. Consequently, a numerical tool simulating plastic injection processes can assist mold designers to design molds and to optimize the injection processes in order to avoid any defects such as fill time, pressure, pressure at end of fill, volumetric shrinkage, pressure at V/P switchover, temperature at flow front, sink mark index, weld lines and many more before manufacturing the molds. After get result we chose the best and compare the actual after injection.

ABSTRAK

Pelbagai masalah yang telah dijumpai dalam industri suntikan plastik baru-baru ini. Salah satu halangan utama adalah pengimbangan pintu pagar dan pelari mengikut acuan keluarga yang disebabkan kekurangan kefahaman yang jelas tentang kelakuan aliran plastik mengikut acuan menyebabkan tembakan overpacking, pendek atau mana-mana lain-lain kecacatan pada bahagian. Objektif kajian ini adalah untuk membandingkan perisian simulasi aliran acuan dengan pengacuan suntikan sebenar dan meramalkan kemungkinan kecacatan pengacuan suntikan sebelum suntikan. 'Tujuan analisis kami adalah untuk menyediakan model simulasi eksperimen mudah dilakukan. Saiz yang berlainan bahagian geometri mudah telah dipilih sebagai kajian kes untuk membentuk keluarga dengan dua rongga. Perisian simulasi aliran Acuan telah digunakan untuk menganalisis sistem memberi makan plastik seperti sprues, pelari dan pagar. Keputusan simulasi telah diperolehi sebagai garis panduan yang berguna untuk mengimbangi sistem pintu gerbang dan naib juara untuk membentuk sebuah keluarga. Akibatnya, alat yang berangka simulasi proses suntikan plastik boleh membantu pereka acuan acuan reka bentuk dan mengoptimumkan proses suntikan untuk mengelakkan sebarang kecacatan seperti isi masa, tekanan, tekanan pada akhir pengecutan isi, isipadu, tekanan di V / P peralihan , suhu di bahagian hadapan aliran, tenggelam indeks tanda, garisan kimpalan dan banyak lagi sebelum pembuatan acuan. Selepas keputusan mendapatkan kita memilih yang terbaik dan membandingkan sebenar selepas suntikan.

TABLE OF CONTENT

LIST OF FIGURES

LIST OF TABLES

LIST OF SYMBOLS

V	Velocity
R, r	Radius
r	Density
T	Temperature
η	Shear Viscosity
k	Thermal conductivity
ε	Strain
P	Pressure
α	Modulus of Elasticity
Cp	Specific heat
D, d	Diameter
C	Celsius
V	Volume
t	Time
s	second
v/p	velocity/peresure
MPa	Mega Pascal

LIST OF ABBREAVIATION

MPI	Mouldflow Plastic Insight
CAD	Computer-Aided Design
CAM	Computer-Aided Manufacturing
CAE	Computer Aided Engineering
CNC	Computer Numeric Control
FMLD	Family Mould Layout Design
3D	Three Dimensional
PP	Polypropylene
PS	Polystyrene
PE	Polyethylene
PC	Polycarbonate
PMMA	Poly(methacrylic acid)
PA	Polyacetylene
PVC	Polyvinyl Chloride
PPS	Polyphenylene Sulphide
LDPE	Low-density Polyethylene
HDPE	High-density Polyethylene
ABS	Acrylonitrile Butadiene Styrene
HIPS	High Impact Polystyrene
AS	Acrylonitrile Styrene
PU	Polyurethane
PBT	Polybutylene Terephthalate

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

In an age of globalization, the technology of the tool and die fabrication in plastic injection is one of the world's fastest growing industries. Plastic is now used in almost every application, ranging from household articles to space travel, from transportation to packing, from medicine to toys, from bridge building to sports. Generally, injection moulding is a process that forms the plastic into a desired shape by melting the plastic material and forcing the plastic material under pressure into the mould cavity. The shape of the plastic that is desired is achieved by cooling in thermoplastic or by chemical reaction for thermosetting. (Source by Shamsuddin Sulaiman, Napsiah Ismail & A.M.S. Hamouda, Design and Simulation of Plastic Injection Moulding Process. Department of Mechanical and Manufacturing Engineering Universiti Putra Malaysia).

Mould design and fabrication is a costly and high technology process because it uses science-based as mould flow plastic insight (MPI) software to analyse and simulate the plastic parts, computer-aided design (CAD) software to design the complicated plastic product and computer-aided manufacturing (CAM) to do the programming fabrication to run the computer numerical control (CNC) for milling or latch. Advances in computer technology have led to an increasingly favorable power to cost ratio for computers. So this advantageous and costly technology will improve productivity and process consistency.

Thus, for this fast growing industry, new technologies are vital to ensure that this technology reaches perfection. So mould flow plastic insight (MPI) is the assistant to process and calculate the plastic material flow inside the injection moulding.

1.1 PROBLEM STATEMENT

In the mould manufacturing nowadays, Family mould is still being used by some companies especially when the production volume is low and tooling cost is an issue. One of the above started reason is batch production that becoming common in manufacturing today. Global market competition and customer demand had lead to shorter product lifecycle complicated and quality product with competition price and the essence of right time delivery to market.

Family mould is due to can save money on multiple part types. It consists of a complete mold with a few or many different cavity inserts that runs as a single part each cycle or more parts each cycle. Family molds are often utilized when two or more part designs are similar but not identical, or if mold cost is a driving factor. Two different parts can be produced from a single mold. This can save on time and expenses by sharing common mold components such as the mold base, but also allows for a single mold setup.

Family molds are typically better suited for lower volume applications, and automation may be necessary to separate pieces during or after production. They also have the potential for greater downtime as repairs and modifications to a single part affect all the components within the mold. Some of the benefits of a family mold are lost if the parts in the mold are run in different resins. When designing plastic parts for the injection moulding process, the important element to understand is how the plastic is filling in the mould. In the mould injection filling phase, molten plastic is injected into the cavity until the cavity is just filled. As plastic flows into the cavity, the plastic in contact with the mould wall quickly freezes and this will create a frozen layer of plastic between the mould and the molten plastic. The problem also can detect when use mould flow simulation, example balance flow, clamping force, feed system not balance. In this experiment can know how to compare from data Autodesk mould flow inside with actual while injection molding.

1.2 SIGNIFICANT OF STUDY

There are few significances of this study when objectives have been achieved as follow:

i. We can use simulation software before produce product in injection molding. Comparison in software analysis.
ii. We can study design balance flow analysis in family mould and optimization of feed system design.

1.3 PROJECT OBJECTIVES

The objectives of this study are:

i. To compare mould flow simulation software with actual injection molding
ii. To predict possibility of injection molding defect before injection.
iii. To apply knowledge of machining process into practical way.

1.4 SCOPES OF THE PROJECT

The scopes of this project are limited to:

i. Study on feed system design for the gate and runner modeling-critical to achieving accurate results.
ii. Study on the Optimization of the design to anticipate any molding problems before the tool is constructed.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

In this research, will discuss about the mould flow simulation software Mould flow Plastic Insight (MPI). MPI is used to study the effects of feed system design in family mould. There are a number of factors to consider when designing the feed system, including the gate locations, the number of cavities, the shape of the runner system components, and flow balance.

The first step in designing the feed system is to determine the gate locations for each part in the mold. The rest of the components will fit into place depending upon each gate location. The objective when designing the feed system is to design it with balanced flow so that each part in the mold fills at the same rate. The creation of a well-balanced feed system requires careful consideration the following elements:[1]

- Single-cavity, multi-cavity, or family mold
- Cavity layout
- Location of the sprue
- Runner system layout
- Shape of the sprue, runners, and gates

In general, make runners as short as possible, with the lowest possible shot weight. In the following diagram, the flow length for every part is the same. This is a naturally balanced runner system [1] . Balance runner as shown in the Figure 2.1

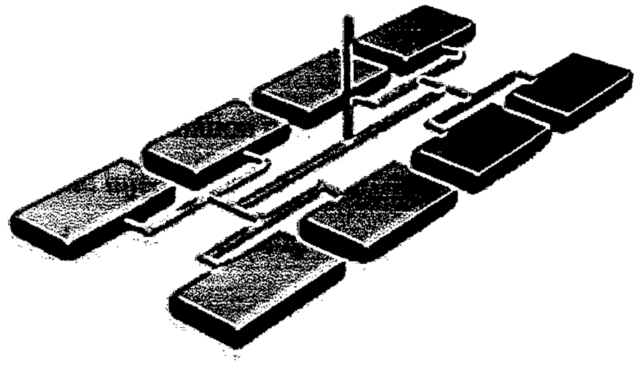

Figure. 2.1: Balance runner

The balancing of the runner system is an iterative, trial-and-error process, relying heavily on the knowledge and experience of the mold designer. It is generally a three phase process comprising filling, packing and cooling phases. Its popularity is typified by the numerous products produced in this way at the present time by L.W. Seow, Y.C. Lam [2]. These analysis programs can be used by a mold designer to simulate and balance the runner system of the mold. The goal during runner balancing is to vary the diameters of the runner segments such that all the cavities fill at the same time and pressure by Ivan W.M. Chan · Martyn Pinfold · C.K. Kwong · W.H. Szeto [3].

2.2 MOLD FLOW PLASTIC INSIGHT SOFTWARE

Moldflow Plastic Insight software was developed by Mold flow. Corporation to aid designers in the plastic industries to:

- reduce product development time and rework, hence decreasing overall costs

- reduce manufacturing cycle time;
- improve product design and foresee any problems related to product manufacturability.
- provide options for various processing parameters and material for both plastic and composite product.

The software provides simulation modules for various processes such as:

- thermoplastic injection molding;
- gas assisted injection molding
- co-injection molding
- injection-compression molding
- reaction injection molding
- microchip encapsulation
- underfill encapsulation (flip chip)

Thermoplastic injection molding simulation involves solving the governing equation of mass, momentum, and energy numerically over the physical domain. The numerical implementation involves discretizing the physical domain into a number of sub domains, or elements. The dependent variables (velocity, pressure and temperature) are approximated within each element.

2.3 PLASTIC SIMULATION

Simulation tools used range from simple, CAD centric filling and gating studies, to product optimization, highly complex warp predictions, and visco elasticity load cases. Presented below are some examples of mold flow projects, many were performed in concert with a design optimization effort prior to tooling release. There are two major benefits to performing a serious mold flow study prior to part release.

Optimization of the design to anticipate any molding problems before the tool is constructed. Capture of the "as-molded" structural properties of the part not as designed, but as manufactured, enabling highly accurate FEA of the part.

The bottom line-these tools and techniques reduce tool validation times, decrease or eliminate unanticipated part failures, and provide indicators for dimensional stability before releasing the part.

Formally the domain of the tool shop, the value of performing these types of studies as a component of the design and part engineering process is well established. Review the examples below and see how your project can benefit from using advanced mold flow simulation.

2.4 MESH ANALYSIS

There are two main prerequisites that must be specified in the model in order to run a flow analysis. They are:

(i) A meshed part model;

(ii) Specifying injection nodes in a boundary condition file.

There are three main types of mesh provided by this software; midplane, surface (fusion) and volume (3D) mesh. The clutch pedal model is drawn using the software attributes and meshed using a midplane mesh. A midplane mesh consists of three nodded triangular elements located at the half thickness of the part surface. By stating the thickness of the part, the two-dimensional midplane mesh represents the solid model during the molding analysis.

2.5 FLOW ANALYSIS

Mould Flow analysis is recommended be performed on this project. This is because it will assist in identifying potential problems in the molding process and allow to vary gate location, process conditions, and/or geometry to predict problems and determine solutions. A filling analysis will allow the make these changes before the tool is cut and will reduce potential costs associated with reworking a tool. The field of flow analysis has gained increasing importance in injection molding. Flow analysis has provided rational solution to many of the hard-to-understand effect that cause problem in he molding process. These effects have including warping, molded-in stress, excessive fill pressure, part flashing and other.

2.5.1 Advantages of Flow Analysis

The CAE simulation provides engineers, designers, moulders with a visual and numerical feedback about what actually happens inside the mould cavity during the injection moulding process.

2.6 FAMILY MOULDS

Cold runner family moulds are widely used in some industries, such as toys and domestic products, because it is an economical method to produce plastic parts of different shapes of the same plastic material with a relatively low-dimensional accuracy requirement for a small-to-medium production volume.

The cost estimation for quotation and themoulding performance of a family mould are highly dependent on a family mould layout design (FMLD) decision made during the early mould design phase. It is because FMLD determines many key design factors such as cavity layout design, runner layout design, mould base selection, cooling system design and so forth by Ivan W.M. Chan · Martyn Pinfold · C.K. Kwong · W.H. Szeto [3]

For example, a simple family mould of four dissimilar parts already involves a number of possible cavity layout and runner layout design alternatives can be see in Figure 8. Design alternative (**a**) seems to be the best one because of its compact and balanced layout, but it requires two individual sliders for part 2 and part 3. Design alternative (**h**) can save cost by combining the two individual sliders into one but at the expense of an unbalanced layout and larger mould base. In some cases, a larger mould base is not preferable or even not allowed due to the insufficient space of the mould platen of a customer's molding machine. Layout possible cavity and runner respectively as shown in the Figure 2.2 by Ivan W.M. Chan · Martyn Pinfold · C.K. Kwong · W.H. Szeto [3].

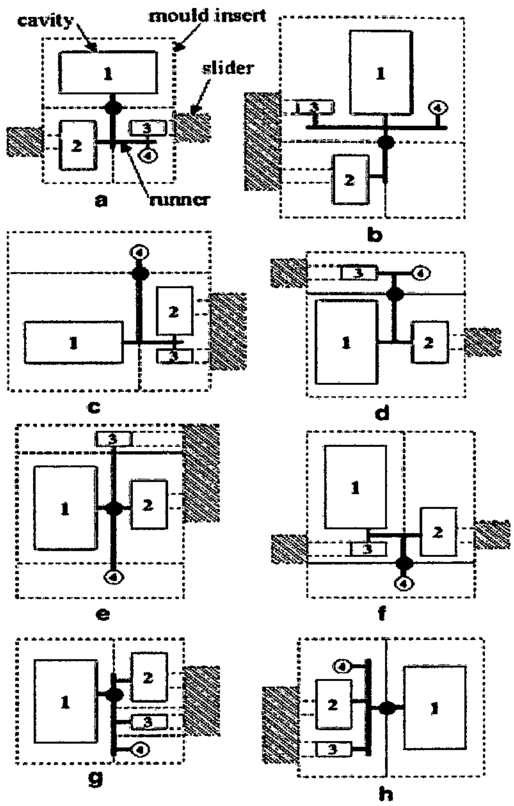

Figure 2.2: Some examples of possible cavity and runner layout design alternatives of a family mould of four dissimilar parts

(Source by Ivan W.M. Chan · Martyn Pinfold · C.K. Kwong · W.H. Szeto, A review of research, commercial software packages and patents on family mould layout design automation and optimisation, Int J Adv Manuf Technol 2011)

Simulation software solves the governing equation of mass, momentum,band energy of injection moulding process numerically. Simulation of filling and packing phase of injection moulding process depends on accurate characterization of the material properties by Iwan Halim Sahputra [7]

2.7 GOVERNING EQUATIONS

Plastic flow in the filling phase is like flow between two plates separated by a small distance. This is well modelled by the Hele-Shaw approximation in general by L.W. Seow, Y.C. Lam [2]. Assuming an incompressible, generalized, non-Newtonian fluid, the equations for the filling phase can be written as:

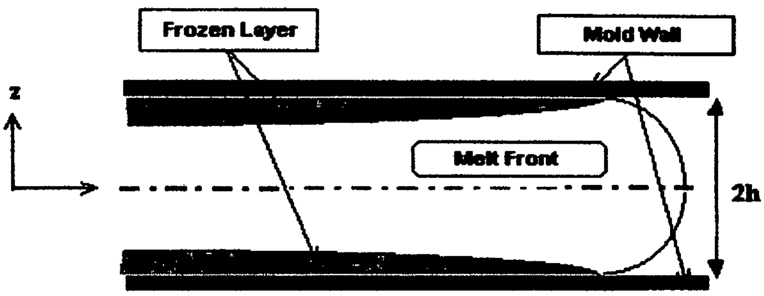

Figure 2.3: Cross-sectional view of the flow front

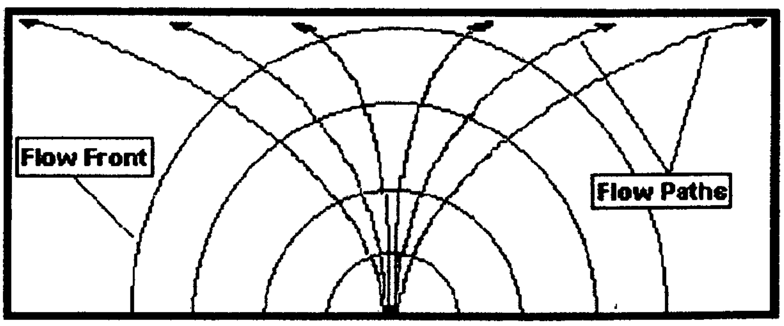

Figure 2.4: Flow paths in unbalanced flow

Continuity equation:

(1)

$$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}+\frac{\partial w}{\partial z}=0$$

Momentum Equation:

(2)

$$\frac{\partial p}{\partial x}=\frac{\partial}{\partial z}\left(\eta\frac{\partial u}{\partial z}\right)$$

$$\frac{\partial p}{\partial y}=\frac{\partial}{\partial z}\left(\eta\frac{\partial v}{\partial z}\right)$$

$$\frac{\partial p}{\partial z}=0$$

Energy Equation:

(3)

$$\rho C_{\mathrm{p}}\left(\frac{\partial T}{\partial t}+u\frac{\partial T}{\partial x}+v\frac{\partial T}{\partial y}\right)=\eta\gamma^2+k\frac{\partial^2 T}{\partial z^2}$$

where (x, y, z) are the Cartesian coordinates and (u, v, w) are the velocity components, respectively. T is the temperature, p the pressure, r is the density, Cp is the specific heat and k is the thermal conductivity of the material whilst η is the shear viscosity where the shear rate y is:

(4)

$$\gamma=\sqrt{\left(\frac{\partial u}{\partial z}\right)^2+\left(\frac{\partial v}{\partial z}\right)^2}$$

Following the treatment by Kennedy [5], the continuity and momentum equations can be combined to yield:

(5)

$$\frac{\partial}{\partial x}\left(S\frac{\partial p}{\partial x}\right)+\frac{\partial}{\partial y}\left(S\frac{\partial p}{\partial y}\right)=0$$

Where

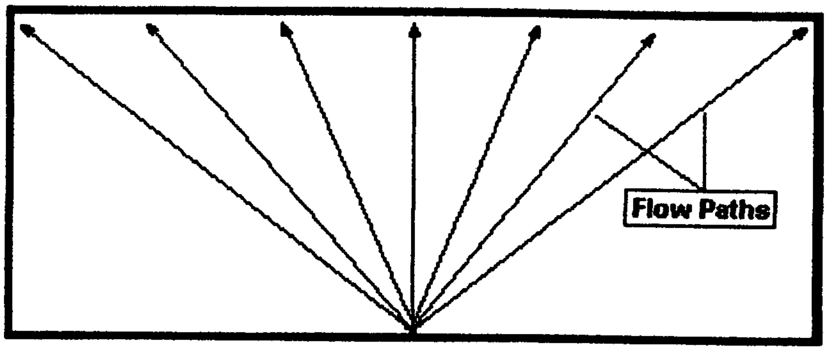

Figure 2.5: Flow paths in balance flow

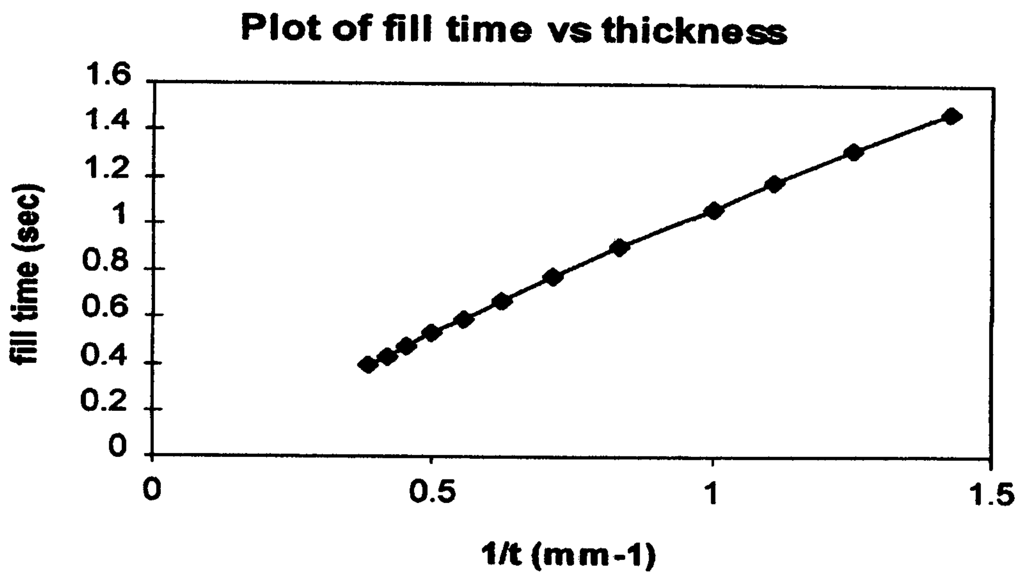

Figure 2.6: Plot of fill times at different thicknesses.

$$S=\int_{0}^{h}\left(\frac{z^{2}}{\eta}\right)\mathrm{d}z \tag{6}$$