ANALYSIS AND PREDICTION OF AN INJECTED PARTS USING MOULD FILLING SIMULATION SOFTWARE

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Report submitted in partial fulfillment of the requirements
for the award of Bachelor of Manufacturing Engineering

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JUNE 2013

ABSTRACT

Nowadays, plastic products play an important role in human daily life and injection molding was one of the methods that can produce plastic products. By using the simulation software, the best solution to overcome problems and defects occur in plastic injection molding process can be determined. Previously, the engineers need to use the traditional method to setup new mold which is 'trial and error method'. This method need the maximum time consumption for mold setup but it was applied to make sure the outcome of the product is the best and fulfill their products requirement. Therefore, this project was conducted to analyze the melt flow behavior of injection molding process using Moldflow software and to compare the prediction outcome from Mold Flow software and actual injection molding process in term of molding defects and injection molding parameters. Then, the project was continued with the fabrication of mold until the injection of the product is produced by using NISSEI injection molding machine. After that, the actual injected part was compared with the part from the simulation. From the project result, the filling pattern of the material from both of the simulation and actual injected product is similar and the result for molding defect such as sink marks also shows similarities. As the conclusion, the utilization of the simulation software is helpful in industries because engineers and designers can predict the possibilities of the defects before the mold is built.

ABSTRAK

Pada masa kini, produk plastik memainkan peranan yang penting dalam kehidupan seharian manusia dan pengacuan suntikan adalah salah satu kaedah yang boleh menghasilkan produk plastik. Dengan menggunakan perisian simulasi, penyelesaian yang terbaik untuk mengatasi masalah dan kecacatan yang berlaku didalam proses suntikan acuan plastik boleh ditentukan. Sebelum ini, para jurutera perlu menggunakan kaedah tradisional untuk persediaan acuan baru iaitu 'kaedah cuba jaya'. Kaedah ini memerlukan masa penggunaan yang maksimum untuk persediaan acuan tetapi digunakan untuk memastikan hasil produk adalah yang terbaik dan memenuhi kehendak produk mereka. Oleh itu, projek ini dilakukan untuk menganalisa kelakuan aliran cairan proses pengacuan plastik dengan menggunakan perisian 'Moldflow' dan untuk membandingkan hasil ramalan daripada perisian 'Moldflow' dan proses suntikan acuan plastik yang sebenar dalam bentuk kecacatan pengacuan dan parameter pengacuan suntikan. Kemudian, projek ini telah diteruskan dengan fabrikasi acuan sehingga suntikan produk dihasilkan dengan menggunakan mesin pengacuan plastik NISSEI. Selepas itu, suntikan bahagian sebenar dibandingkan dengan bahagian daripada simulasi. Dari hasil projek, corak pengisian bahan daripada kedua- dua simulasi dan suntikan sebenar produk adalah sama dan keputusan untuk kecacatan pangacuan seperti kesan tenggelam juga menunjukkan persamaan. Sebagai kesimpulan, penggunaan perisian simulasi adalah membantu didalam industri kerana para jurutera dan pereka boleh meramal kemungkinan kecacatan sebelum acuan dibina.

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LIST OF SYMBOLS

%	Percent
°C	Degree Celsius
°F	Degree Fahrenheit
R	Rockwell
+	Positive
-	Negative

LIST OF ABBREVIATIONS

ASTM	American Standard for Testing and Materials
CAD	Computer-Aided Design
CAE	Computer-Aided Engineering
CAM	Computer-Aided Manufacturing
CATIA	Computer Aided Three- dimensional Interactive Application
CNC	Computer Numerical Control
FEA	Finite Element Analysis
HD	High Density
Hz	Hertz
IGES	Initial Graphics Exchanges Specification
MPI	Moldflow Plastic Insight
Mpa	Mega Pascal
N	Newton
PE	Poly-Ethylene
PP	Polypropylene
R	Rockwell
RIM	Reaction Injection Molding
STL	Stereo-lithography
3D	Three Dimensional
2D	Two Dimensional
1D	One Dimensional
2.5D	Two Half Dimensional

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

In this 21^{st} century era, plastic products play an important role in human daily life and injection molding was one of the methods that which can produce plastic products. Furthermore, the injection molding process is a process for the plastic granules will be melted with the presence of high temperature to make sure the melt plastic filling the mold cavity to form the required shape by Hamdy Hassan (2010).

The purpose of the project is to predict the outcomes of the injected parts by several analysis using MoldFlow software to make sure the good final injected parts was produced without any defects occur. Several types of common molding defects in injection molding process including the air traps, blemish, sink marks, warping, flashing and much more. Nowadays, product life cycle had been shortened due to the challenging current market competition which is the plastic product always been renewed from time to time.

Furthermore, to prevent any waste presence while operation especially the waste of time, the utilization of the software simulation of the products has implemented worldwide to make sure the injection molding process run smoothly without any presence of problems during operation. To perform the simulation, they were using the most recommended simulation software which is MoldFlow that can simulate the filling time process from beginning until the end of the injection process. In addition, proper interpretation results of the simulation can help the evaluation of the manufacturability early stage of the product without fabricating prototypes, minimizing the experimental tests Behrooz Farshi (2011), minimizing the cycle time and costs on mold alteration Babur Ozcelik (2012).

Most researchers are using Mold-Flow simulation in order to investigate the parameters that influence defects such as shrinkage and warping of the product and according Ching-Piao Chen (2007) discussed that simulation by Mold-Flow software has been extensively compared with experiments in 'sandwich injection molding'* process and they have indicates that the Mold-Flow software program can be used as a valuable tool for the prediction of melt-flow behavior during the sandwich injection process Babur Ozcelik (2012).

*or known as co-injection molding process which two materials are sequentially injected into mold cavity, typically through same gate

1.2 PROJECT TITLE

Analysis and prediction of an injected parts using mould filling simulation software.

1.3 PROBLEM STATEMENT

In producing any of the plastic products, the manufacturer will face various kinds of problems according the aspect of production quality. There are two types of the common problems that related with the production of the plastic product especially for the new and complicated part which are failure and defects. Therefore, many companies have decided to reduce the product defects by improving technology of the machine like changing the mold design, redesign the products and others.

The next problem is the fast marketing of the plastic product has been increased parallel with our modern technologies era such as the kitchen utensils can be bought by customers at the night market which the function and the appearance is look alike with lower prices compared with the original supplier. Therefore, most of the manufacturers have to compete and make sure that their products have to presence at the market and satisfying their customers with the well functioning product, affordable prices and good appearances in order to attract customer's attention. In addition, the manufacturer did not have long time to produce more new products and they have no times to make any mistakes in their design.

As before the presence of technology like simulation software, the fabrication of the product or mold will take long time to complete. This is because the companies need to consider about their man power, cost estimation and others. But, with the presence of simulation software like MoldFlow, the fabrication of the mold and product just need minimum time to fabricate. To prevent those kinds of problems from happening, most of the plastic companies have chosen their alternative such as using the fundamentals way which is doing simulation at the early stage of product fabrication and the main reasons they need to use the simulation method is it is a time consuming method supported by several researchers and this method can help them to identify possibility of defects occur at the critical design. That experiment was proven by performing the comparison between the simulation and actual injected product which can be seen as below:

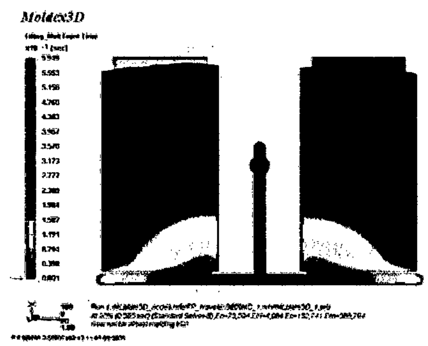

Figure 1.1:
Filling Pattern (Simulation Software)

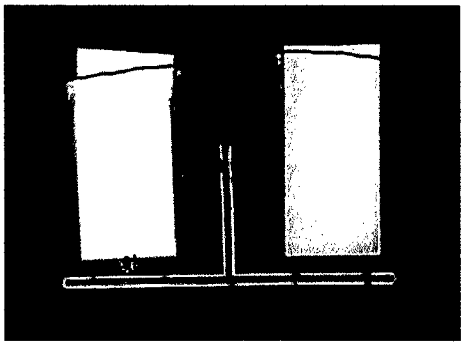

Figure 1.2:
Filling Pattern (Injection Molding Process)

Source: Patcharee (2009)

1.4 PROJECT OBJECTIVES

a) To analyze the melt flow behavior of injection molding process using Mold Flow Software.

b) To compare the prediction outcome from Mold Flow software and actual injection molding process in term of molding defects and injection molding parameters.

1.5 PROJECT SCOPES

The scopes for the project generally focusing on analyzing product design by using Moldflow Plastic Insight 5.0 software with several analyses which are window analysis, gate location analysis, fill time analysis and flow analysis. In addition, the actual product was produced to make the comparison with the previous simulation analysis data. The product design was conducted by using 3-Dimensional (3-D) software which is CATIA and further the file format of 3D drawing will be converted into STL format for importation of the product design into simulation software.

The fabrication of the mold was using the Computer Numerical Control (CNC) Milling Machine and the injection of the product will be using the NISSEI injection molding machine. The actual injection was conducted after all the analyses completed and all the parameters such as melt temperature, injection pressure and clamping force was setting up into the machine according the parameter setting as in the simulation.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

Injection molding is one of the popular processes compared with others involving with plastic materials and the most common products include cups, containers, housings, toys, telephone receivers and electrical and communication-equipment component by Serope Kalpakjian (2006). In addition, Behrooz Farshi (2011) state that; having special features like capability to produce complex products, light weight, resistance to corrosion, ease of producing compared to conventional materials, are the main reasons for injection molding's popularity. Moreover, high quality and precision can be achieved using this method (injection molding) for manufacturing plastic parts.

In injection molding, the consideration of product design is important and considered as the preventive action due to any defects. There are several types of defects that usually occur during injection process such as weld-lines, short shot, flash, warp and etc. Behrooz Farshi (2011) state that; according to a researcher, the achievement of high quality parts requires information processing from several sources necessary to define respect and improve product and mould features linked to design and manufacturing requirements.

Most of the machines and operations will have their own specifications and process parameters in order to achieve their optimum accuracy of shapes and act as preventive way from forming any defects. This fact has been proven by several researchers and one of the statements is; the product quality produced by the injection molding is always affected by the process parameters stated by Babur Ozcelik (2012) and has been stated by L.M Galantucci (2003); the quality of the final products, which may be characterized in terms of dimensional stability, appearance and mechanical properties, directly depends on these factors (process variables) by Behrooz Farshi (2011).

2.2 FINITE ELEMENT ANALYSIS (FEA)

Finite Element Analysis (FEA) is first developed in 1943 by R. Courant, who utilized the Ritz Method of numerical analysis and minimization of variation calculus to obtain approximate solution to vibration systems. Early 70's, FEA was limited to expensive mainframe computers generally owned by aeronautics, automotive, defense and nuclear industries. FEA uses a complex system of points called nodes which make a grid called a mesh stated by R.A Tatara (2006).

Many researchers have used Mold- Flow for their numerical experiments and have shown that it can adequately simulate analysis of injection molding process with a good precision and accuracy stated by Babur Ozcelik (2010). Recently, computer aided engineering (CAE) has been successfully used in the simulation of the injection molding process, since it provides designers/engineers with visual and numerical feedback of the part behavior and eliminates the traditional trial and error approach optimization stated by Babur Ozcelik (2012). Furthermore, the time consuming for the mold designers can be minimize by using the simulation software before producing the actual mold for the new product.

According L.M. Galantucci (2003), design by numerical simulations represents a powerful alternative to speed-up the product development cycle, reducing activities linked to experimental tests and mould fabrication. On the other hands, this type of analysis is mainly connected to the need for physical prototypes to test different process condition. In addition, the numerical models of part and mould designs give accurate solutions and reliable predictions for a specific set of process parameters because they include the physical law formulation of the process itself.

This is because it will reduce the effort and costs connected to the experimental activity stated by Behrooz Farshi (2011).

In conclusion, FEA has become a solution to the task of predicting failure due to unknown stresses by continuing problem areas in a material and allowing designers to see all of the theoretical stress within. Furthermore, the process did not using highest cost of testing and fabricating which is stated by Peter Widas (1997). Figure 2.1 shows the fill time analysis of the product by using the MoldFlow Plastic Insight (MPI) software.

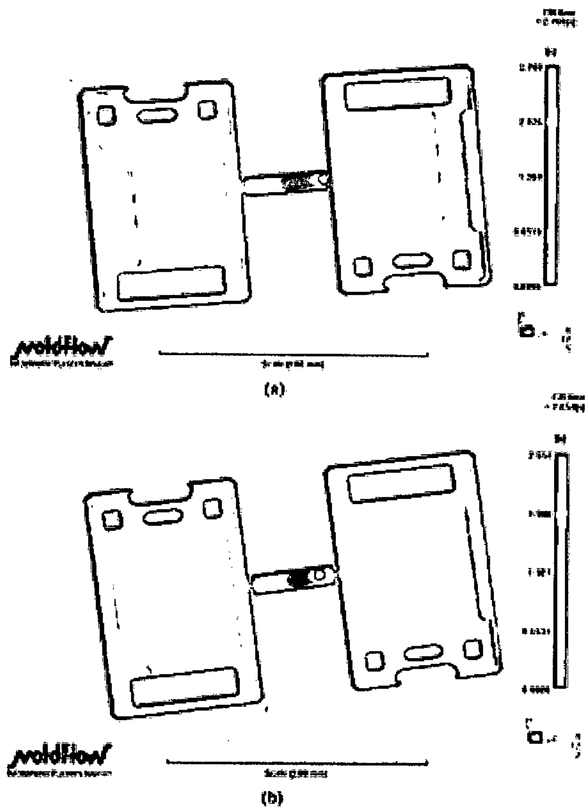

Figure 2.1: Fill Analysis

Source: Lee (2012)

2.3 MOLDFLOW PLASTIC INSIGHT (MPI)

MPI analysis modules are able to simulate the most comprehensive range of manufacturing processes encountered in thermoplastics and thermoset injection molding. With MPI, several of process such as filling, packing, and cooling stages of the thermoplastics injection molding process can be simulated and also can predict post-molding phenomena such as part warpage. It is even possible to analyze the flow of fiber-filled materials, predict the resultant fiber orientation, and take that into account when predicting part warpage. More exotic thermoplastics molding processes also can be simulated, such as gas-assisted injection molding, co-injection and injection compression processes with MPI, as well as reactive molding processes including thermoset injection molding, reaction injection molding (RIM), and microchip encapsulation. Quite simply, MPI software offers the greatest range of molding process simulation tools in the plastics industry, Moldflow Corporation (2001).

2.4 MESHES IN MOLDFLOW ANALYSIS

Finite element mesh or simply known as mesh are elements divide the geometry (domain) of the part or tool component into a small number of domain. These small domains are defines by nodes (coordinates in space) and are used for the calculations inside the Moldflow. The main categories of elements are three and they are beam, triangle and tetrahedron. For further description, beam is the two-node element and usually to represent melt delivery systems which were cold and hot runner and cooling lines while triangle and tetrahedron is three-node element and four-node element respectively, Jay (2006). Figure 2.2 shows the three element types in Moldflow.

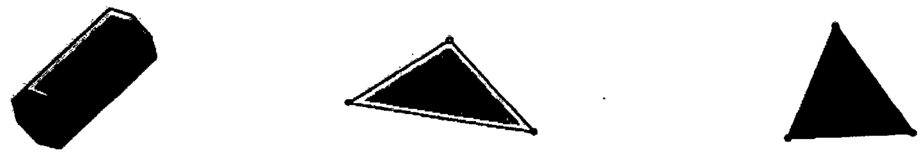

Figure 2.2: Types of Element in Moldflow

Source: Jay (2006)

2.5 TYPES OF MESH

In order to analyze the part model, basically MoldFlow used four mesh types to represent the different geometry component and these meshes are the combination of the element types as described above.

2.5.1 Beams

This type of mesh sometimes referred as 1D element this is because it has an assigned cross-sectional size and shape. In beam elements, flow is assumed to be symmetrical about the axis. The length of a beam element should be two to three times its diameter. Also, a gate should have at least three elements defining its length, Jay (2006).

2.5.2 Midplane

The mesh is defined on the midplane or centerline of the plastic cross section and the triangular elements are primarily used to define the part. The triangles that always been used in midplane mesh are often referred to as 2.5D elements or shell elements. This mesh simulates a 3D part with a two- dimensional plane surface at the center of the thickness. A thickness property is assigned to this planar surface, hence the terminology 2.5 D, Jay (2006).

2.5.3 Fusion

This type of mesh also referred as Dual Domain analysis method and sometimes called a modified 2.5D mesh, represents a three-dimensional part with a boundary or skin mesh on the outside surfaces of the part obtained from a common CAD translation model such as STL or IGES format. This mesh simulates a 3D part with a boundary or skin mesh on the outside surfaces of the part. In this type of meshes, elements across the thickness are aligned and matched while the distance between elements on the opposite sides of the wall defines the part thickness. Furthermore, the mesh density is an important factor in determining the accuracy of the thickness representation, in particular on tapered features such as ribs and the percentage of matched elements in the Fusion mesh is a key factor in determining the quality of the mesh (at least 85%), Jay (2006).

2.5.4 Three Dimensional (3D)

Tetrahedral elements meshed through the volume and usually create a true 3D represent the part. Several rows of elements are used to define the cross section. 3D mesh can be used with thin-wall geometry but particularly works well with "thick and chunky" parts such as electrical connectors or thick structural components that violate the thin-wall thickness limitations described previously. This is because 3D analyses use the full 3D Navier-Stokes equations, rather than the Hele-Shaw approximations that apply specifically to thin-wall parts, Jay (2006).

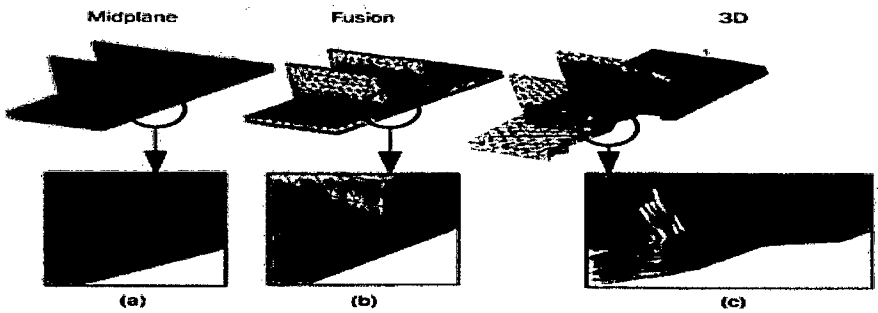

Figure 2.3: Mesh types

Source: Jay (2006)

2.6 INJECTION MOLDING

Among other processes, injection molding is one of the new develop process regarding plastic materials. Modern machines are of the reciprocating or plasticizing screw type act as the tool for injection molding, Hamdy Hassan (2010).

2.6.1 Injection Molding Machine

In 1868, John Wesley Hyatt became the first person that performs the injection of hot celluloid into a mold and producing billiard ball. While in 1872, John and his brother Isaiah patented an injection molding machine that used a plunger and the process remained more or less the same until 1946. At the same year, the first screw plastic injection molding machine was built by James Henry. In addition, majority of plastic injection molding machines now are using the screw to efficiently heat, mix and inject into the molds by Elite Machinery System (2010).

Injection molding machine as shown in Figure 2.4 have two basic parts which are an injection unit and a clamping unit. Several manufactures are offering the hydraulic clamps, toggle clamps or electric driven machines Elite Machinery System (2010). The function of the clamp is to make sure that the molten plastic can be injected into the mold cavity smoothly and make sure the mold can be clamp properly.

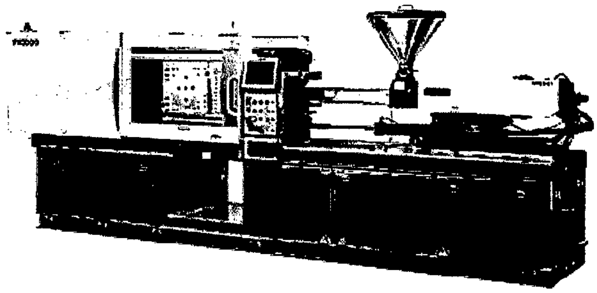

Figure 2.4 : Injection Molding Machine; NISSEI MODEL

Source: Nissei (2012)

2.6.1.1 Injection Unit

The injection unit is much like an extruder. It consists of a barrel that is fed from one end by a hopper containing a supply of plastic pellets. Inside the barrel is a screw whose operation surpasses that of an extruder screw in the following respect: in addition to turning for mixing and heating the polymer, it also acts as a ram which rapidly moves forward to inject molten plastic into the mold, Sinotech (2012).

A non-return valve mounted near the tip of the screw prevents the melt from flowing backward along the screw threads. Later in the molding cycle the ram retracts to its former position. Because of its dual action, it is called a reciprocating screw, which name also identifies the machine type. Older injection molding machines used a simple ram (without screw flights), but the superiority of the reciprocating screw design has led to its widespread adoption in today's molding plants. To summarize, the functions of the injection unit are to melt and homogenize the polymer, and then inject it into the mold cavity, Sinotech (2012).

2.6.1.2 Clamping Unit

The clamping unit is concerned with the operation of the mold. Its functions are to:

(1) Hold the two halves of the mold in proper alignment with each other.
(2) Keep the mold closed during injection by applying a clamping force sufficient to resist the injection force.
(3) Open and close the mold at the appropriate times in the molding cycle.

The clamping unit consists of two platens, a fixed platen and a movable platen, and a mechanism for translating the latter. The mechanism is basically a power press that is operated by hydraulic piston or mechanical toggle devices of various types. Clamping forces of several thousand tons are available on large machines, Sinotech (2012). Figure 2.5 shows the units that consist in injection molding machine.