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BORANG PENGESAHAN STATUS TESIS*

JUDUL: **A study on the Impact of injection Molding Parameters on The Plastic Product Dimensional Stability.**

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UNIVERSITI TEKNIKAL MALAYSIA MELAKA

A STUDY ON THE IMPACT OF INJECTION MOLDING PARAMETERS ON THE PROCESSED PLASTIC PRODUCT DIMENSIONAL STABILITY

This report submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Manufacturing Engineering (Manufacturing Process) with Honours.

By

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2010

DECLARATION

I hereby, declared this report entitled "PSM Title" is the results of my own research except as cited in references.

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APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of UTeM as a partial fulfillment of the requirements for the degree of Bachelor of Manufacturing Engineering (Manufacturing Process) with Honours. The members of the supervisory committee are as follow:

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ABSTRACT

Nowadays, the manufacturing industry demands better product quality. The quality of molded product is crucial to make sure the product can fulfill the customer requirement. This project specifically studies the shrinkage problem in plastic injection molding process where three significant parameters that can affect product dimensional stability have been determined from the literature review. These three parameters are holding pressure, injection pressure and melting temperature which are classified as variables in the experiment while other parameters are fixed. In this study, Polypropylene is selected as the raw material to produce the plastic product. The output response of the experiments is percent of shrinkage on the molded product. Response surface methodology (RSM) is used for experimental design analysis in the project in order to study the factor that can affect product dimensional stability, the effect of interaction factors and the most suitable molding parameters to minimize dimensional variation. From the analysis using Design Expert 7.1.6 Software, it is found that the main factor affect is injection pressure, the strong interaction factors is between injection pressure and cooling time. Finally the best parameters to minimize the shrinkage determined by RSM analysis are 80 bar for Injection Pressure, 190^{o}C for Melting Temperature, 10.68 seconds for Cooling Time. This setting should resulted in shrinkage of 6.05767 for percentage.

ABSTRAK

Kini, industri pembuatan mementingkan kualiti produk yang lebih baik. Kualiti produk berasaskan acuan adalah sangat penting bagi memastikan kehendak pelanggan dapat dipenuhi. Projek ini mempelajari dengan lebih mendalam berkenaan masalah pengecutan yang berlaku dalam proses acuan suntikan plastik di mana tiga parameter penting yang boleh mempengaruhi kestabilan dimensi produk telah dikenal pasti melalui kajian literatur. Dalam proses acuan suntikan, tiga parameter yang telah dikenal pasti tersebut seperti tekanan menahan, tekanan suntikan dan suhu cairan adalah berubah manakala parameter lain adalah tetap. Dalam projek ini, Polypropylene telah dipilih sebagai bahan asas untuk menghasilkan produk plastik. Prosedur eksperimen dan eksperimen matrik telah dihasilkan di mana ia telah digunakan untuk membuat eksperimen-eksperimen bagi mendapatkan peratus pengecutan pada produk-produk acuan platik. Tambahan lagi, ‘response surface methodology’ telah digunakan di dalam projek ini untuk menyelidiki faktor yang mempengaruhi kestabilan dimensi produk, menyelidiki kesan terhadap interaksi faktor-faktor dan mengenalpasti parameter yang paling sesuai untuk meminimumkan perbezaan dimensi pada produk. Semasa analisis menggunakan perisian komputer Design Expert 7.1.6, ia telah mengenalpasti factor utama dan interaksi antara faktor malahan juga tetapan terbaik bagi mendapatkan nilai pengecutan yang minimum telah di hasilkan.

DEDICATION

This thesis is gratefully dedicated to my family, Dr. Lok Yian Yian, Dr. Md Nizam Abd Rahman and my friends for all their advice and encouragement. Thank you very much for your continuous support and effort towards the publication of this thesis.

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LIST OF ABBREVIATIONS

2FI	-	Two Factor Interaction
ABS	-	Acrylonitrile Butadiene Styrene
ANOVA	-	Analysis of Variance
CMM	-	Coordinate Measuring Machine
DOE	-	Design of Experiment
ID	-	Inner Diameter
MFR	-	Melt Flow Rate
OD	-	Outer Diameter
PE	-	Polyethylene
PP	-	Polypropylene
PS	-	Polystyrene
PSM	-	Projek Sarjana Muda
PVC	-	Polyvinylchloride
RPM	-	Rate per Minute
RSM	-	Response Surface Methodology

CHAPTER 1

INTRODUCTION

1.1 Background

Injection molding is the most commonly used manufacturing process for the fabrication of plastic parts. A wide variety of products are manufactured using injection molding, which vary greatly in their size, complexity, and application. The injection molding process requires the use of an injection molding machine, raw plastic material, and a mold. The plastic is melted in the injection molding machine and then injected into the mold, where it cools and solidifies into the final part.

Plastic injection is one of the most preferred molding processes thanks to some significant reasons. The main reason is that the use of plastic parts in daily life has tremendously increased in the last decades. For instance, most of the communication, electronic, kitchen, and daily consumer products are made of plastic materials. Another remarkable reason is that plastic injection molding is capable of producing products which have complicated shapes (Mustafa and Yususf, 2009). Therefore, the benefits of this process is noticeable. Other advantages of injection molding process such as accuracy in weight of articles, choice of desired surface finish and colors, choice of ultimate strength of articles, faster production and lower rejection rates, faster start-up and shut down procedures, minimum wastage, versatility in processing with different raw materials, and option in article sizes by changing the mould.

In a plastic injection molding process, one of the important tasks is to select initial molding parameters for producing high-quality products. Generally, the desired molding parameters are determined based on experience or by using handbook. Yet, these selection methods do not ensure that the determined parameters to result in optimal molding performance that produce parts with minimal defects (Mustafa and Yusuf, 2009). As a result, many studies have been conducted in order to determine the relationship between molding conditions and the quality.

This project specifically studies shrinkage problem in plastic injection molding process. Shrinkage deteriorates the dimensional stability and quality of produced parts. To control and reduce this defect, molding parameters such as injection pressure, holding pressure, injection time, injection speed, barrel temperatures, and ejecting pressure need to be optimized. If the shrinkage problem is not well tackled, the produced parts will be categorized as scraps resulting in increase of wasted resources.

1.2 Problem statement

The molded parts dimensional stability is one of critical product quality attributes and hence a great deal of attention should be directed towards maintaining consistent tolerances and overall dimensions. Any minor defects such as shrinkage, warping, short shot and sink mark are considered serious quality issues especially for the semi-finished part that are subjected to subsequent process assembly. As the demand for high quality final parts continues to increase, molding parameters need to be optimized in order to get the best product dimensional stability.

1.3 Objectives

The main objective of the research is to optimize the injection molding parameters with respect to the stability and accuracy on product dimension. Specific sub-objectives include the following:

- To study the factor that can affect product dimensional stability.
- To study the effect of interaction between process parameters on the product dimensional stability.
- To determine the most suitable molding parameters to minimize dimensional variation.

1.4 Scope of Study

The scope of this study is limited to investigate the most suitable molding parameters within the safe operating range of the moldy process. Only one material is used during experiment that is polypropylene (PP). A 100 tone of Demag Ergotech 100-400 viva injection molding machine is used to produce 'container' products by manipulating the three critical molding parameters such as injection pressure, melting temperature and cooling time. This study only focused on shrinkage defect that can effects product dimensional stability. Other than that, Response Surface Methodology (RSM) in Design Expert 7.1.6 software is used to analyze the experimental data and Coordinate Measuring Machine (CMM) is used as the measuring equipment.

1.5 Report Structure

This report is organized into five chapters. Details of each chapter are described as follows.

Chapter 1 gives an introduction to the research.

Chapter 2 provides a literature review of the injection molding machine, process of injection molding, material and the process selection, possible defect, factors that affect product dimensional stability (shrinkage), and design of experiment.

Chapter 3 describes the experimental methods such as experimental matrix, injection molding process, measuring method and Response Surface Methodology (RSM) for this study.

Chapter 4 analyzes in detail the results from Design Expert 7.1.6 software and discusses about the ANOVA, main factor analysis, interaction analysis and optimization.

Chapter 5 concludes in detail about the study and recommends other things that might improve the study.

CHAPTER 2

LITERATURE REVIEW

In this chapter, the definition of injection molding, the description of machine parts and its process are discussed in detail. A summary of previous studies on injection molding parameters and material properties on the product dimensional stability is provided. Some characteristics to determine the dimensional stability are introduced. Then, the factors that affect molding parameters are reviewed. In this part, key molding process parameters are identified. Finally the experimented methods that had been used by previous researches on how to determine the most suitable injection molding parameters are also presented.

2.1 Injection Molding

Injection molding is the most commonly used method for plastic processing. It is also one of the oldest methods of processing to product such as spoons, cups and saucers. The major advantages of the injection molding process include (Azora *et al*, 2004):

- Its versatility in molding a wide range of products.
- The ease with which automation can be introduced.
- The possibility of high production rates and the manufacture of articles with close tolerances.
- Accuracy in weight of articles.
- Choice of desired surface finish and colors.

2.2 Injection Molding Machine

The first injection molding machine was introduced for compression molding patterned in United States of America in 1872. A few modifications have been made with the usage of pneumatic and hydraulic technique where both thermoplastic and thermosetting resins could be processed (Azora *et al*, 2004).

The first injection molding machine was the plunger type. Due the certain disadvantages such as slow production rate, pre-plastication machines have been introduced. The pre-plastic machine has two cylinders. The purpose of the first cylinder is to melt the plastic pallet using a plunger. The second cylinder is to mix the plastic melt and force it through the nozzle in the mould using another plunger. However, this machine is rarely used due to the cost and complexity in handling. Latest technology has introduced the reciprocating screw machine type, which is very simple and easy (Azora *et al*, 2004). There are two basic units to an injection molding machine:

- Injecting the heated plastic
- Opening and closing the mould.

The first unit includes a feed hopper, a heated injection cylinder and an injection plunger or screw system. The second unit comprises a hydraulic operated moving platen and a stationary platen on which the halves of the mould area are mounted. Injection molding machines have many components and are available in different configurations, including a horizontal configuration and a vertical configuration (Azora *et al*, 2004). Figure 2.1 shows the injection molding machine made from Europe type Demag ergotech 100-400 viva. This machine has been used in this study to produce product ‘container’.

Figure 2.1: Injection Molding Machine type Demag ergotech 100-400 viva.

2.2.1 Injection Unit

The injection unit is responsible for both heating and injecting the material into the mold. The first part of this unit is the hopper, a large container into which the raw plastic is poured. The hopper has an open bottom, which allows the material to feed into the barrel. The barrel contains the mechanism for heating and injecting the material into the mold. This mechanism is usually a ram injector or a reciprocating screw. A ram injector forces the material forward through a heated section with a ram or plunger that is usually hydraulically powered. Today, the more common technique is the use of a reciprocating screw. A reciprocating screw moves the material forward by both rotating and sliding axially, being powered by either a hydraulic or electric motor. The material enters the grooves of the screw from the hopper and is advanced towards the mold as the screw rotates. While it is advanced, the material is melted by pressure, friction, and additional heaters that surround the reciprocating screw. The molten plastic is then injected very quickly into the mold through the nozzle at the end of the barrel by the buildup of pressure and the forward action of the screw. This increasing pressure allows the material to be packed and forcibly held in the mold. Once the material has solidified inside the mold, the screw can retract and fill with more material for the next shot (Azora *et al*, 2004).

2.2.1.1 Screw

The primary purpose for using a screw is to take advantage of its mixing action. Theoretically, the motion of the screw should keep any difference in melt temperature to a minimum. It should also permit materials and colors to be blended better, with the result that a more uniform melt is delivered to the mould. The design of the screw is important for obtaining the desired mixing and melts properties as well as output rate and temperature tolerance in the melt. Generally most machines use a single, constant –pitch, metering type screw for handling the majority of plastic materials. A straight compression type screw or metering screw with special tips (heads) are used to process heat sensitive thermoplastics, etc. As shown in Figure 2.2, the screw is designed into 3 sections: Metering, compression, and feed (Azora *et al*, 2004).

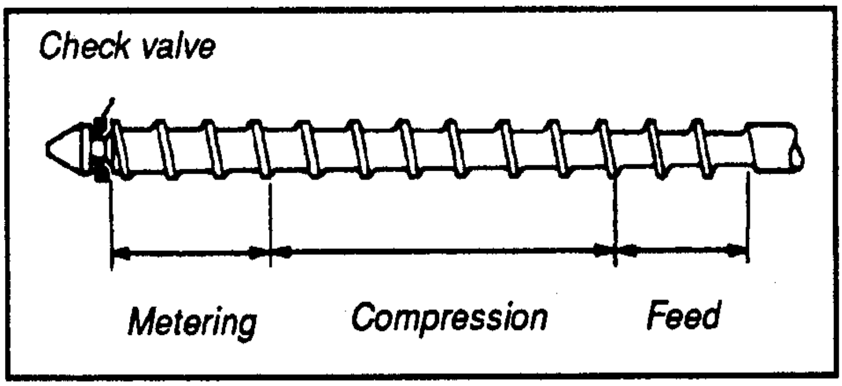

Figure 2.2: Screw design (Azora *et al*, 2004).

(a) Metering

In the metering section, the plastic is smeared and sheared to give a melt having a uniform composition and temperature for delivery to the mould. As high shear action will tend to increase the melt's temperature, the length of the metering section is dependent upon the resin's heat sensitivity and the amount of mixing required. For heat sensitive materials, practically no metering section can be tolerated. Both the feed and the metering sections have a constant cross section. However, the depth of the flight for the feed section is greater than that in the metering section (Azora *et a*., 2004).

(b) Compression (melting)

The compression (melting) section is the area where the softened plastic is transformed into a continuous melt. It can occupy anywhere from 5 to 50 percent of the screw length. This compression section has to be sufficiently long to make sure that all the plastic is melted. A straight compression type screw is one having no feed or metering sections (Azora *et al*, 2004).

(c) Feed

The feed section, which is at the back end of the screw, can occupy from 0 to 75 percent of the screw length. Its length essentially depends on how much heat has to be applied to the plastic in order to melt it (Azora *et al*, 2004).

2.2.1.2 Barrels and Heater

The barrel, which houses the screw, has heater bands surrounding it which heat the barrel and the plastic inside based on temperature controls which take readings from the thermocouples positioned in the barrel wall. The temperature controls are set for a specified temperature and the thermocouples tell the controls whether the requested temperature has been reached (Bernie and Martin, 2001).

2.2.1.3 Nozzle

The nozzle is interconnect between the mould and the injection unit. It is fitted to the front end of the barrel. When the molten plastic material is pushed forward by the screw, the molten plastic will rush out through the small hole in the nozzle and then into the mould. The nozzle is aligned to the mould by the nozzle radius. Improper alignment of the nozzle to the mould (sprue radius) will cause the plastic material leakage during injecting the plastic into the mould (Azora *et al*, 2004).

2.2.2 Clamping Unit

The clamp unit of an injection molding machine performs the following essential functions: (1) holds the mold; (2) closes the mold; (3) keeps the mold closed under pressure during injection (4) opens the mold to allow the parts to be ejected; and (5) accommodates the ejector system which ejects the parts out of the mold. The clamping mechanism provides the force to keep the mold closed during the injection and holding-pressure stages of the machine cycle (Bernie and Martin, 2001).

2.2.2.1 Fixed Platen

This platen does not move, the fixed side of the mould called the cavity side (nozzle side) is fitted onto the fixed platen. In the centre of this platen there is a round hole called the locating hole which accommodates the locating ring which is fitted on the mould. This will centre the mould onto this platen and also aligning the nozzle radius with the mold (Joseph, 1987).