Faculty of Manufacturing Engineering

OPTIMIZATION OF INJECTION MOULDING PARAMETERS USING MOLDFLOW SIMULATION SOFTWARE ANALYZE BY RESPONSE SURFACE METHOD

MUHAMMAD HIDAYAT BIN SULAIMAN

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MUHAMMAD HIDAYAT BIN SULAIMAN

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DECLARATION

I declare that this thesis entitled “Optimization of injection moulding using moldflow simulation software analyse by response surface method” is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : ....

Name : ....

Date : ....

APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality as a partial fulfillment of Master in Manufacturing Engineering (Quality System).

Signature	:………………………………………………………..
Supervisor Name	:Assoc. Prof. Ir. Dr. Mohd Amran Bin Md Ali.
Date	:………………………………………………………..

DEDICATION

To my parents Sulaiman Bin Ali and Saemah Binti Badiuzzaman

ABSTRACT

The purpose of this study is to optimize injection moulding parameters moldflow simulation software analyze by Response Surface Method(RSM). The process parameters selected for this study are melting temperature, mold temperature, injection time and number of gate. In this study, the RSM using Box – Behnken is used to determine the most significant parameters toward the responses and determine the optimum parameters values. Based on the design of experiment, 27 numbers of experimental data are collected and analyse using RSM modelling. The result collected was optimized using RSM meanwhile P-value and R-squared were calculated using analysis of variance (ANOVA). From the result analysis, the injection time is the most significant among the rest of factors toward the fill time response with 99% For volumetric shrinkage and deflection responses, melt temperature and number of gate contribute 58.58% and 60.32% respectively. Then, the interaction between process parameters toward responses are investigated. For response of fill time as the injection time is the only major factor that affect the fill time. As for volumetric shrinkage, the interaction between melt temperature and injection time made a quadratic shape as the increasing in melt temperature increases the shrinkage while the injection time increases the shrinkage up to 2.1s and after that the shrinkage decreases. As for deflection responses, the increasing melt temperature increase the deflection but the interaction from multiple number of gate decreases the deflection Finally, for the multi – response optimization, the optimization are 280^{o}C melt temperature, 120^{o}C mold temperature, 4.0s injection time and one gate. For the desirability of multi – response, it resulted 0.9593 while the predicted value resulted are 0.3593 deflection, 4.2441s fill time and 5.9209 volumetric shrinkage respectively.

ABSTRAK

. Tujuan kajian ini adalah untuk mengoptimumkan parameter pengacuan suntikan menggunakan aplikasi simulasi aliran dalam acuan dengan dianalisa oleh teknik tindak balas permukaan. Proses parameter yang dipilih untuk kajian ini adalah suhu cairan, suhu acuan, masa suntikan dan bilangan pagar. Di dalam kajian ini teknik tindak balas permukaan. digunakan adalah "Box Behnken" dimana ianya digunakan untuk mengkaji parameter yang paling penting untuk respon serta untuk mengkaji nilai parameter yang optimum. Berdasarkan reka bentuk eksperimen, 27 eksperimen dijalan dan semua data akan dikumpul serta dikaji menggunakan model teknik tindak balas permukaan. Keputusan yang diperolehi dioptimumkan dengan menggunakan RSM manakala nilai P and "R square dikira menggunakan variasi analisa (ANOVA). Daripada keputusan analisis, masa suntikan adalah yang paling mempengaruhi masa mengisi manakala untuk kekecutan dan kelendingan, suhu cair dan bilangan pagar masing – masing menyumbang sebanyak 58.58% dan 60.32%.Kemudian, hubungan antara parameter terhadap respon disiasat. Untuk tindak balas masa mengisi, interaksi antara suhu acuan dan suntikan sepenuhnya bergantung kepada pencetakan suntikan kerana masa suntikan adalah satu-satunya faktor utama yang memberi kesan kepada masa mengisi. Bagi pengecutan isipadu, interaksi antara suhu cair dan masa suntikan membuat bentuk kuadratik sebagai peningkatan dalam suhu cair meningkatkan pengecutan sementara masa suntikan meningkatkan pengecutan sehingga 2.1s dan selepas itu pengecutan berkurangan. Bagi tindak balas kelendingan, suhu leburan yang semakin meningkat juga meningkatkan lendingan tetapi interaksi dari bilangan pagar mengurangkan lendingan Akhirnya, untuk pengoptimuman pelbagai tindak balas, sasaran pengoptimuman ialah suhu mencairkan sebanyak 280^{o}C, suhu acuan sebanyak 120^{o}C, masa suntikan selama 4.0 saat Untuk kegunaan pelbagai tindak balas, ia menghasilkan 0.9593 manakala nilai ramalan yang dihasilkan adalah 0.3593 untuk kelendingan, 4.2441s untuk masa mengisi dan pengecutan volumetrik untuk 5.9209.

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LIST OF SYMBOLS

y	-	Response
k	-	Number of independent
b	-	Regression coefficient
x	-	Independent factors
ε	-	Error

LIST OF ABBREVIATIONS

RSM	-	Response Surface Method
PP	-	Polypropylene
HDPE	-	High Density Polyethylene
LDPE	-	Low Density Polyethylene
PE	-	Polyethylene
ABS	-	Acrylonitrile Butadiene Styrene

CHAPTER 1

INTRODUCTION

This chapter discusses on the introduction of the project. It also further explains on the problem statement, objectives and scopes of the research project

1.1 Background of Study

Injection moulding is a manufacturing process for producing parts by method of injection molten material into a mould. This process is commonly used for producing plastic part as a means to make a product. The plastic injection moulding is extremely versatile method and one of preferred methods for manufacturing parts because it has multiple advantages over other methods of plastic moulding. Some of the advantages are the injection moulding capable of producing detail features and complex geometry. The injection moulding also possessed high efficiency as it has high production output rate as well as being more cost effective. Other major advantages of injection moulding also includes the ability to use multiple plastic types simultaneously as with the assistance of co - injection moulding helps with the filling other type of plastic materials.

Moldflow simulation software is to simulate the detailed and complete injection moulding as well as to optimize the design whether it is part of the design or entire design. It is also used to optimize the mold design and manufacturing processes. This is essential in order to predict the potential product as well as reduce the resources and cost as well as bring innovation to the market For the purpose of this study,

In order to achieve the optimization of injection moulding parameters, a systematic method is needed to determine the relationship between factors affecting the process and the output of the process. The application of response surface methodology (RSM) in the optimization largely depended on the experimental design chosen in order to fit the adequate mathematical function and to evaluate the quality of the fitted model as well as accuracy to make previsions in relation to the data gathered. Box-Behnken and Doehlert designs gave out more efficient matrices and have increased numbers of published works (Bezerra et al. 2008). In research study on Taguchi design and RSM, both showed promising results in developing mathematical modelling however, RSM is shown to be more accurate or optimize due to the data that results very low average error toward modelling and experimental validation (Sivaraos et al. 2014). In this study, the response surface methodology is used as it gives more global optimization compared to the Taguchi design.

1.2 Problem Statement

Wastage of material and increases in cost for prototype in injection moulding industries. These is due to improper parameter used as many researches have proved that process parameters are the most efficient ways to reduce the cost and resources.

In any industries, the quality control aspect is the most sought and problems faced in manufacturing process. The idea of maintaining the quality of product while preventing and reducing the defects are especially the most important factor in injection moulding industries (Singh et al. 2015)

In realities, the selecting values of injection moulding parameters are based on pure experience or manual and instruction from the book and thus causing inconsistencies in quality. This leads to existence of defects such as shrinkage and deflection. In every parameters changed, there will be always changes and inconsistencies in quality of the plastic part in term of material characteristic. Parameters such as injection time, melt temperature, mould temperature and number of gate are often studied and researched by many researchers. This is due to their effect on the defects. Besides that, the filling time of injection moulding need to be considered as such they determine how much time it takes to fill the mould and as related to pressure and leads to inconsistencies in qualities. Due to many influence of many parameters, there are needs to investigate the relationship between the injection moulding parameters such as melt temperature, mold temperature, number of gates and injection time in order to understand in depth on their effect on selected responses.

1.3 Objectives

The main objective of this project is to study the process optimization of injection moulding parameter using Moldflow simulation software analyse Response Surface Method. The sub – objectives of the project are as follow:

i. To determine the most significant parameters such as melting temperature, mold temperature, injection time and number of gate that affected the responses
ii. To investigate the interaction between process parameters toward the response
iii. To optimize the parameters by using single and multi-response using Box Behnken of RSM and Anova method

1.4 Scope of Study

The scope of this research focuses on the simulation analysis using Moldflow software. The setting parameters such as melting temperature, mold temperature, injection time and number of gate are selected as purposes of responses such as fill time, volumetric shrinkage and deflection all effect. Design of experiment used in this study will be Box Behnken of Response Surface Modelling (RSM) as means to provide more accurate data on modelling and optimizing the parameters.

1.5 Report Structure

This report of consists five chapter in which the Chapter 1 focuses on background of the project, problem statement, objectives as well as scopes of study. On Chapter 2, it discusses on review of which relevant to the previous and current study of optimizing the performance of injection moulding using Moldflow software. After that, Chapter 3 explains on the experimental setup as well as experimental parameters. Chapter 4 shows the analyzation of result and discussion on the study. Lastly, Chapter 5 summarizes on finding of project and reccomendation for future studies.

CHAPTER 2

INTRODUCTION

This chapter explains about the all researches and information related to this study. This study discussed on injection moulding, process and cycle, injection moulding parameters, plastic materials, moldflow simulation and lastly, the optimization of process using experimental matrix using Box – Benhken of Response Surface Methodology (RSM).

2.1 Injection Moulding Machine

Injection moulding is a manufacturing process of shaping of plastic by injecting heated material into mould. In another perspective, Chen et al. (2005) states that injection moulding is one of the most versatile and important manufacturing processes capable of mass-producing complicated plastic parts in net shape with excellent dimensional tolerance. Kitayama et al. (2017) states that the injection moulding is of the important technologies used to produce plastic product with high productivity.

Injection moulding operation involves the usage of melt plastic into the cavity where the mould is heated. The melt plastic is then filled into the cavity with injection pressure and is packed with high packing pressure for the desirable shape. Finally, the melt plastic is cooled down for solidification, and the solid plastic product is ejected (Kitayama et al. 2017). Figure 2.1 shows the basic operation of the injection moulding.

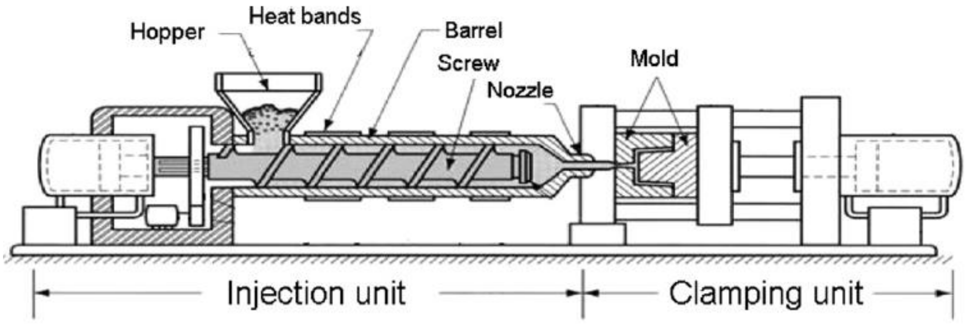

Figure 2.1: Basic operation of the injection moulding (Elsheikhi, 2017)

2.1.1 Injection Unit

In injection unit, it served two functions which are to feed, prepare and dose material consistently as well as accurately and also to inject the set of volume if material at the high pressure into mould tool. It consist of several sections which are the hopper and feed throat section, screw section and injection nozzle section. (Goodship, 2016)

2.1.1.1 Hopper and feed throat

The feed throat and the feed hopper units are important as it ensure the plastics are properly plasticized. The feed throat is the section where the plastic is directed into the screw channel. It is fitted around the first few flights of the screw (Rosato, 2000)

2.1.1.2 Barrel and Screw

The barrel, also called a cylinder or a plasticator barrel, is a cylinder that contains a screw or a plunger. Together with a screw, it provides the bearing surface where shear is imparted to the plastic materials. Heating media and sometimes cooling media are housed around it to keep the barrel (and thus the melt) at the desired temperature profile. The barrel's size is specified by its inside diameter. The barrel of the injection molding machine supports the reciprocating plasticizing screw. It is heated by the electric heater bands. The reciprocating screw is used to compress, melt, and convey the material. The reciprocating screw consists of three zones which are feeding zone, compressing zone and metering zone. Figure 2.2 shows the three zones in reciprocating screw (Rosato, 2000).

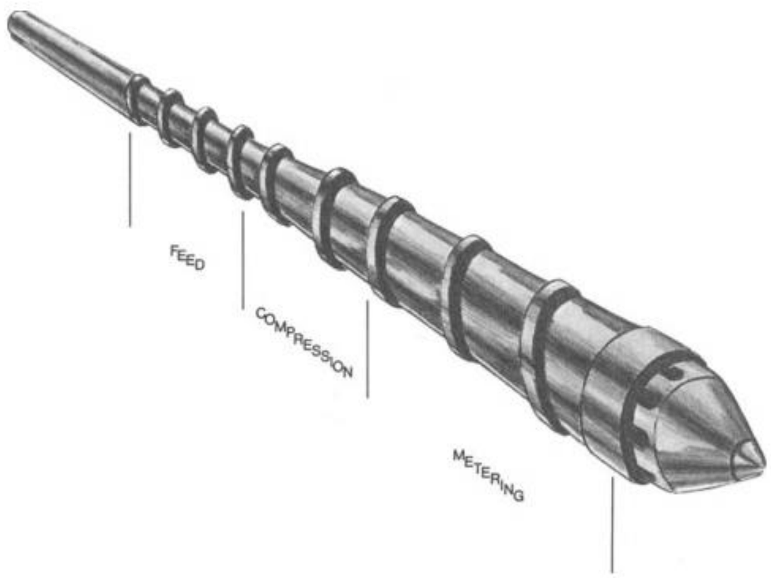

Figure 2.2: Three zones in reciprocating screw (Rosato, 2000)

Based on Figure 2.2, the outside diameter of the screw remains constant while the depth of the flights on the reciprocating screw decreases from the feed zone to the beginning of the metering zone. These flights compress the material against the inside diameter of the barrel,