OPTIMIZATION OF COOLING SYSTEM USING SIMULATION SOFTWARE IN INJECTION MOULDING

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

by

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2022

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

BORANG PENGESAHAN STATUS LAPORAN PROJEK SARJANA MUDA

Tajuk: **OPTIMIZATION OF COOLING SYSTEM USING SIMULATION SOFTWARE IN INJECTION MOULDING**

Sesi Pengajian: **2021/2022 Semester 2**

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I hereby, declared this report entitled "Optimization of Cooling System Using Simulation Software in Injection Moulding" is the result 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 Universiti Teknikal Malaysia Melaka as a partial fulfilment of the requirement for Degree of Manufacturing Engineering (Hons). The member of the supervisory committee is as follow:

……………………………………………………

(PROFESOR MADYA IR. DR. MOHD AMRAN BIN MD ALI)

ABSTRAK

Projek ini memfokuskan pada aplikasi simulasi sistem penyejukan dalam proses membentuk suntikan. Pengoptimuman sistem penyejukan memainkan peranan penting dalam kualiti, kecekapan, dan pembuatan yang menjimatkan. Kesan sistem penyejukan seperti suhu acuan dan masa penyejukan sebagai faktor terpenting dalam pengoptimuman pengacuan suntikan plastik. Suhu acuan akan dibahagikan kepada suhu plat teras dan rongga. Reka bentuk eksperimen (DOE) menggunakan kaedah permukaan tindak balas (RSM) Box Behnken sebagai alat statistik akan digunakan sebagai reka bentuk eksperimen dan analisis varians sebagai alat yang akan digunakan untuk mencari signifikan pemboleh ubah bebas terhadap tindak balas. Pengoptimuman pemboleh ubah bebas (parameter input) terhadap tindak balas dianalisis menggunakan wawasan plastik moldflow (MPI). Dengan gabungan pendekatan simulasi analitik dan numerik adalah salah satu pilihan cerdas yang diterapkan pada pendekatan sistem penyejukan acuan moden. Berdasarkan analisis keputusan varians, suhu teras dan rongga adalah faktor paling ketara yang mempengaruhi tindak balas pesongan, pengecutan dan berat bahagian. Walau bagaimanapun, faktor masa penyejukan adalah tidak signifikan untuk ketiga-tiga tindak balas berdasarkan simulasi dan keputusan analisis statistik. Secara keseluruhannya, nilai optimum yang sesuai boleh disahkan melalui objektif tunggal dan pelbagai objektif menggunakan kaedah permukaan tindak balas (RSM) dalam kajian ini.

ABSTRACT

This project focuses on the application of the simulation of cooling system in the injection moulding process. Optimization of cooling system plays a significant role in the quality, efficiency, and the cost-effective manufacturing. The effect of cooling systems such as mould temperature and cooling time as the most important factors in optimization of plastic injection moulding. The mould temperature has been divided into core and cavity plate temperature. The design of experiment (DOE) using response surface method (RSM) of Box Behnken as statistical tool was used as experimental design and analysis of variance as tool to be used for finding the significant of independent variable to the responses. The independent variables (input parameters) optimization towards the responses were analysed using the moldflow plastic insight (MPI). By combination of analytical and numerical simulation approach is one of the intelligent choices applied to modern mould cooling system approach. Based on analysis of variance results, the core and cavity temperature are the most significant factor that influence the deflection, shrinkage and part weight of the responses. However, the cooling time factor is not significant for all the three responses based on the simulations and statistical analysis results. Overall, the appropriate optimum value can be verified through the single-objective and multi-objectives using response surface method (RSM) in this study.

DEDICATION

Only

my beloved father, Zainudin Bin Che Sab

my appreciated mother, Zana Binti Mulup

my adored brother and sister, Muhammad Deenni Hakkim Bin Zainudin,

Deenna Raihanah Binti Zainudin and Deenna Rainisa Binti Zainudin,

for giving me moral support, cooperation, encouragement and also understandings

Thank You So Much & Love You All Forever

ACKNOWLEDGEMENT

I would want to express my gratitude to Allah, the most Gracious and Merciful, for allowing me to complete this Final Year Project. First and foremost, I would like to convey my gratitude to Universiti Teknikal Malaysia Melaka (UTeM) for providing me with the opportunity to pursue my bachelor's degree in Manufacturing Engineering.

Furthermore, I would like to convey my heartfelt gratitude to Professor Madya Ir. Dr. Mohd Amran Bin Md Ali, my final year project supervisor, for his guidance, counsel, encouragement, and personal attention provided throughout my journey in completing this final year project. All the cooperation, assistance, support, and knowledge provided is very valuable and will be utilized for the long term.

Finally, I would like to express my gratitude to all the teaching staff at the Faculty of Manufacturing Engineering who also imparted a lot of useful knowledge to be implemented in my final year project. Last but not least, I would like to thank my colleagues who also helped in completing this final year project. All ideas, information, and assistance provided either directly or indirectly are greatly appreciated. May all your generosity and goodwill be rewarded.

TABLE OF CONTENTS

CHAPTER 3: METHODOLOGY

APPENDICES

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

ANOVA	-	Analysis of Variance
ASTM	-	American Society for Testing and Materials
CCD	-	Central Composite Design
BBD	-	Box-Behnken Design
DOE	-	Design of Experimental
MFA	-	Moldflow Analysis
MPA	-	Moldflow Plastic Insight
MPI	-	Moldflow Plastic Advisor
RSM	-	Response Surface Methodology
PE	-	Polyethylene
PP	-	Polypropylene

LIST OF SYMBOLS

°C	-	Degree Celsius
k	-	Number of Factors
K	-	Kelvin
Psi	-	Pounds per Square Inch
mm	-	Millimetre
MPa	-	Mega Pascal
GPa	-	Giga Pascal
%	-	Percent
s	-	Seconds
t	-	Tonne
°F	-	Degree Fahrenheit

CHAPTER 1
INTRODUCTION

In this chapter, there are various sub-titles that describe about this optimization of cooling system in injection moulding research including research background, problem statement, research objectives, scope of the research, rational of research, research methodology and thesis organization.

1.1 Research Background

Injection moulding is a method of producing a wide range of components and products from plastic. Even though the technique was created in the nineteenth century, it is still one of the finest ways to make complicated components while keeping costs under control. As already specified by Ye (2020), since injection moulding is the most widely used method for producing plastic components on the globe, it is no surprise that the global market for the process was valued at almost 260 million dollars in 2016, with forecasts for further development in the near future.

Basically, the injection moulding machine utilizes custom-made moulds to fill them out according to specific requirements and constructing identical copies that can be customized in a range of ways. In addition, this injection moulding is a robust process that allows for a wide range of materials and finishes, that making it an ideal choice in a variety of sectors with varying aims and needs.

Cooling system in injection moulding is used to rapidly and consistently disperse the heat generated by the moulding process. Fast cooling is essential for cost-effective manufacturing, while uniform cooling is required for product quality. For consistent moulding, proper mould temperature control is required. According to Masoumi *et al.* (2016), the cooling and freezing phases in injection moulding process take up more than half of the cycle time, thus optimizing the injection moulding cooling system is essential for quality, efficiency, and cost-effective manufacturing.

According to Losek (2021), the cooling system in injection molding starts with water or oil is injected through the mould and cooled in an exterior heat exchanger before re-entering the cooling channels. Usually, a combination of ethylene glycol and water is the most common cooling fluid, which helps to prevent corrosion inside the mould. The liquid is pumped at a high enough rate to create turbulent flow within the mould, which is more effective than laminar flow at removing heat from the mould.

The intention of optimizing the cooling system in injection moulding is typically to produce consistent cooling in relation to the cavity of the component. This involves maintaining consistent temperature control across all cavities in multi-cavity moulds. Losek (2021) explained that temperature monitoring is necessary to maintain components within tolerance since temperature and resin characteristics such as viscosity and molecular weight are linked. In order to optimize the injection molding cooling system, the computer aided cooling analysis and simulation software need to be used as an efficient statistical tool to analyze the experimental design and for finding the significant of independent variable to the responses.

Therefore, this project purposes on optimization of cooling system in plastic injection moulding process. Selected cooling parameters are mold temperature, cavity temperature and cooling time. The responses of this project are fill time, warpage defection and shrinkage all effect. The response surface method will be used to analyze and optimized the data from the simulation process.

1.2 Problem Statement

In the process involving injection molding, there are some problems that can arise especially on the final result of the part to be made. Commonly, the non-uniform cooling system causes a variety of problems, including residual stresses, shrinkage, warping, deflection, and affecting the part weight. These defects have an impact on the final part's appearance and quality.

According to Losek (2021), insufficient cooling before ejection from the mould might cause part shrinkage. Stress fractures in components can occur when shrinking occurs in opposite directions. Moreover, the warping defect can be generated by ejecting the part from the cavity before it has properly cooled, in relation to non-uniform cooling. It can also be caused by an overly cold cooling system.

Martowibowo *et al.* (2017) has indicated that some techniques have been used in several research to optimise plastic injection moulding process parameters and increase the product quality. According to the findings, Martowibowo *et al.* (2017) also specified that melting temperature, cooling time and injection pressure were the most important parameters in optimising shrinkage, tensile strength, and cycle time of the part to be made.

Thus, based on the research above, the cooling system optimization approach in injection moulding is essential to overcome the constraints occurred in the processing machine and to improvise the system so that it can secure a better quality, efficiency, and the cost-effective manufacturing. It is vital to conduct a more in-depth study of the cooling system parameters in injection moulding in order to determine the right range of control variables and hence decrease the consequences of part defects.

1.3 Objectives

The objectives are as follows:

(a) To find the most significant injection moulding parameters (mould temperature: core and cavity temperature and cooling time) that effect the responses of deflection, shrinkage and part weight.

(b) To identify the interaction parameters to the responses.

(c) To validate the result of simulation using single and multi-responses.

1.4 Scopes of the Research

The scopes of research are as follows:

(a) Design experimental matrix of cooling system using response surface methodology through Minitab software.

(b) Perform melt flow simulation using moldflow plastic insight (MPI) for collecting data.

(c) Perform statistical analysis through Response Surface Methodology (RSM) and Analysis of Variance (ANOVA) using Minitab software.

1.5 Rational of Research

The rational of research as follows:

(a) The issue in the injection moulding cooling system, such as non-uniform cooling, may cause some defects. These defects have an impact on the design and quality of the finished part. This research is developed to optimize the cooling system in injection moulding as it plays a significant role in the quality, efficiency, and the cost-effective manufacturing.

(b) Generate scientific information and deep understanding on parameters of the injection mold cooling system that affect component defects based on various variables such as mold temperature, cooling time and injection time. Gather the useful information on technical data of the injection moulding cooling system after performing numerical and analytical simulation approach.

(c) To discover new knowledge behind the experimental research by implementing the statistical analysis through Response Surface Methodology (RSM) and Analysis of Variance (ANOVA) using Minitab software since it is the intelligent approach applied in the advanced mould cooling system. Develop a new idea by control the variable parameters to enhance a better cooling system in injection moulding process.

1.6 Project Report Organization

The organization of this thesis is as following. Chapter 1 is begun with research background, problem statement, objectives, and scope of the research and rational of research that are delineated in order to optimize the cooling system using software in injection moulding process in this thesis.

Chapter 2 literature review comprises previous study or research about the theory of cooling system in injection moulding, operational and functional of cooling system in injection moulding, and the information about the parameters that affecting the response in injection moulding cooling system. In addition, this Chapter 2 also comprises the information of the statistical tool and computer aided simulation software to be used in analyzing the parameters that affecting the cooling system responses.

Next, the Chapter 3 is about the methodology that describes the approaches used in completing this research including design experimental matrix of cooling system using response surface methodology through Minitab software, perform melt flow simulation using moldflow plastic insight (MPI) for collecting data and perform statistical analysis through Response Surface Methodology (RSM) and Analysis of Variance (ANOVA) using Minitab software.

Besides, the Chapter 4 is about the analyzing of information collected based on the results of statistical tools and simulation software that will be performed. All the data and results obtained will be discussed and interpreted accordingly in this chapter. In Chapter 5, conclusion and recommendation about this research are examined.