UNIVERSITI TEKNIKAL MALAYSIA MELAKA

OPTIMISATION OF THE MECHANICAL PROPERTIES OF THE ENGINEERING PLASTICS VIA OPTIMAL PROCESSING PARAMETERS USING TAGUCHI METHOD

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

by

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APPROVAL

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………………………………

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ABSTRAK

Proses pengacuan suntikan plastik ialah satu proses pembuatan polimer di mana bahagian dengan geometri yang rumit dan kompleks boleh direka dengan ketepatan tinggi sambil mengekalkan kekemasan permukaan yang baik. Kelebihan utama acuan suntikan plastik ialah skala ekonomi yang dibawa dalam pengeluaran besar-besaran.Aplikasi plastik yang luas dalam pelbagai bidang membuktikan kelayakan sebagai bahan pilihan kerana sifat yang ringan dan mudah dibentuk. Plastik secara umumnya dikategorikan kepada dua (2) kumpulan utama, iaitu termoplastik dan plastik termoset. Proses pengacuan suntikan plastik menggunakan mesin pengacuan suntikan plastik Zhafir Venus II Siri 900 II / 210 dengan empat (4) parameter pemprosesan dalam projek penyelidikan ini, iaitu tekanan suntikan, tekanan pemegangan,kelajuan suntikan, dan masa pemegangan. Teknik Taguchi digunakan untuk menjalankan pengoptimuman kepada empat (4) parameter pemprosesan tersebut. Spesimen plastik kemudian diuji untuk kekuatan tegangan menggunakan mesin pengujian universal Instron 3360 Dual Column Jenis 50kN. Kekuatan tegangan seterusnya disahkan dengan analisis Taguchi dan Analisis Varians (ANOVA). Keputusan dari analisis Taguchi adalah sepadan dengan hasil dari Analisis Varians (ANOVA). Tekanan puncak suntikan ialah faktor terpenting dalam menentukan kekuatan tegangan spesimen yang dibuat daripada acrylonitrile butadiene styrene (ABS). Masa pemegangan, kelajuan suntikan, dan tekanan pemegangan mempunyai pengaruh yang kecil kepada kekuatan tegangan spesimen. Kombinasi parameter pemprosesan yang dioptimumkan dalam menentukan kekuatan tegangan spesimen ialah A2, B3, C1, D4, yang mencerminkan tekanan puncak

suntikan 110MPa; tekanan pemegangan 17.5MPa; kelajuan suntikan 115mm/s; dan 14 saat masa pemegangan.

ABSTRACT

Plastic injection moulding is a polymer manufacturing process where complicated and complex geometries of parts can be fabricated with high precision and accuracy while retaining good surface finish. The main advantage of plastic injection moulding is the economics of scale brought about in mass production. The vast applicationsof plastic in numerous fields have proven its credential as the material of choice due to its lightweight and malleable properties. Plastic can be generally categorised into two (2) main groups, namely the thermoplastics and thermosetting plastics. The plastic injection moulding process in this research project is carried out using the Zhafir Venus II Series 900 II /210 plastic injection moulding machine with four (4) different processing parameters as the controlled variables in this research project, which are the injection peak pressure, holding pressure, injection speed and holding time. The Taguchi technique is applied to conduct optimisation on these four (4) processing parameters. The plastic parts produced are later being tested for their respective tensile strength using the Instron 3360 Dual Column 50kN Universal Testing Machine (UTM). The tensile strengths are then verified by the Taguchi analysis and the Analysis of Variance (ANOVA). The results from the Taguchi analysis matches the results from the Analysis of Variance (ANOVA). The injection peak pressure is the most significant factor in determining the tensile strength of the specimen made from acrylonitrile butadiene styrene (ABS). The holding time, injection speed and holding pressure have small effects relative to the tensile strength of the specimens. The optimised combination of processing parameters in

determining the tensile strength of the specimen is A2, B3, C1, D4, which is reflective to 110MPa injection peak pressure; 17.5MPa holding pressure; 115mm/s injection speed; and 14 seconds holding time.

DEDICATION

This thesis is dedicated to my beloved parents, supervisor and friends in helping and guiding me throughout the project.

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I would like to thank Mr Salleh bin Aboo Hassan, my project supervisor for his help and guidance throughout the project. The completion of project would not have been possible without his guidance. I have learned a lot from him not only the way to writea thesis in a more organised but also the way he taught me to think about a problem from different perspectives. This does not only allow me to complete the project but also benefit me in future life with a new mind set he taught.

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TABLE OF CONTENT

DECLARATION	**iv**
APPROVAL	**v**
ABSTRAK	**vi**
ABSTRACT	**vii**
DEDICATION	**viii**
ACKNOWLEDGEMENT	**ix**
TABLE OF CONTENT	**x**
LIST OF TABLES	**xiii**
LIST OF FIGURES	**xiv**
LIST OF ABBREVIATIONS, SYMBOLS AND NOMENCLATURE	**xvi**
CHAPTER 1: INTRODUCTION	**1**
1.0 Introduction	1
1.1 Overview	1
1.2 Problem Statement	5
1.3 Objectives	5
1.4 Scopes	6
1.5 Structure of the Research Project	7

CHAPTER 2: LITERATURE REVIEW **8**

2.0 Introduction 8
2.1 Injection Moulding 8
2.2 Plastics 12
2.2.1 Structure of Plastics 13
2.2.2 Mechanical Properties of Plastics 15
2.2.3 Thermoplastics 16
2.2.4 Thermosetting Plastics 19
2.2.5 Engineering Plastics 21
2.2.6 Commodity Plastics 24
2.3 Processing Parameters 27
2.4 Taguchi Technique 28

CHAPTER 3: METHODOLOGY **33**

3.0 Introduction 33
3.1 Overview 33
3.2 Planning of Study 34
3.3 Gantt Chart 39
3.3.1 Bachelor Degree Project (BDP) Gantt Chart 40
3.4 Experimental/Study Design 41
3.4.1 Selection of Test Material 41
3.4.2 Selection of Processing Parameters in Plastic Injection Moulding 43
3.4.3 Identification of Factor Levels and Orthogonal Array 43
3.5 Parameter Studies 50
3.5.1 Analysis of Signal-to-Noise (S/N) Ratio 50
3.5.2 Analysis of Variance (ANOVA) 51

CHAPTER 4: RESULTS AND DISCUSSIONS **52**

4.0 Introduction 52
4.1 Plastic Injection Moulding 52
4.2 Tensile Testing 54
4.3 Results of Tensile Testing 55
4.4 Taguchi Analysis 56
4.5 Analysis of Variance (ANOVA) 58

CHAPTER 5: CONCLUSION AND RECOMMENDATIONS **60**

5.0 Introduction 60
5.1 Conclusion 60
5.2Recommendations 61

REFERENCES **63**

APPENDIX **67**

PHOTOS **67**

LIST OF TABLES

Table 1.1: Structure of the Bachelor Degree Project. 7

Table 2. 1 Table of Comparison between Thermoplastics and Thermosetting Plastics. 20

Flow Chart 2. 1 P-Diagram for Plastic Injection Moulding Process. 30

Flow Chart 2. 2 Steps in Taguchi Parameter Design. 31

Table 3. 1 Table of Physical Properties of Acrylonitrile Butadiene Styrene (ABS). 41

Table 3. 2 Table of Injection Moulding Parameters and Their Respective Levels. 43

Table 3. 3 Table of L16 Orthogonal Array with the Processing Parameters and Their Respective Levels. 44

Table 3. 4 Constant Processing Parameter Settings in Injection Moulding. 46

Table 3. 5 Specifications and Dimensions of ASTM D-638 Type IV. 48

Flow Chart 3. 1 Bachelor Degree Project Phase 1. 35

Flow Chart 3. 2 Bachelor Degree Project Phase 2. 36

Table 4. 1 Experimental Results of Tensile Testing for ABS. 55

Table 4. 2 Response Table of S/N Ratio for ABS. 56

Table 4. 3 Analysis of Variance (ANOVA) for S/N Ratio. 58

LIST OF FIGURES

Figure 2. 1: Graphical Illustration of the Complete Cycle of Plastic Injection Moulding
Process……………………………………………………………………………… 11
Figure 2. 2: Structure of Plastics……………………………………………………12
Figure 2. 3 Linear Structure.………………………………………………………...13
Figure 2. 4 Branched Structure……………………………………………………...13
Figure 2. 5 Cross-Linked Structure…………………………………………………14
Figure 2. 6 Network Structure. ……………………………………………………...14
Figure 2. 7 Stress- Strain Behaviour of Plastic……………………………………... 15
Figure 2. 8 Molecular Structure of Thermoplastics………………………………… 17
Figure 2. 9 Applications of Thermoplastics…………………………………………18
Figure 2. 10 Molecular Structure of Thermosetting Plastics……………………….. 19
Figure 2. 11 Applications of Thermosetting Plastics………………………………..20
Figure 2. 12 Forecast of the Compound Annual Growth Rate (CAGR) of the Engineering Plastics Market by Region from 2016 to 2026………………………...23
Figure 2. 13 Cause-and-Effect Diagram Illustrated Using Fishbone Diagram……...28

Figure 3. 1 Dog-Bone Specimen 34
Figure 3. 2 Bachelor Degree Project (BDP) Gantt Chart.. 40
Figure 3. 3 Table of Typical Properties of Toray Plastics Toyolac® 700 Type 314 General-Purposed Acrylonitrile Butadiene Styrene (ABS) Resins........................... 42
Figure 3. 4 Zhafir Venus II Series 900 II /210 Plastic Injection Moulding Machine. 45
Figure 3. 5 Barrel Heating in Injection Moulding. 46
Figure 3. 6 Charge Settings in Injection Moulding.. 47
Figure 3. 7 Instron 3360 Dual Column 50kN Universal Testing Machine (UTM). .. 47
Figure 3. 8 ASTM D-638 Type IV Specifications and Dimensions. 48
Figure 3. 9 Geometry and Default Dimensions in Tensile Testing........................... 49
Figure 3. 10 Control Parameters in Tensile Testing. 49

Figure 4. 1 Dog-Bone Specimens Produced. 53
Figure 4. 2 Dog-Bone Specimens Produced. 53
Figure 4. 3 Resultant Specimens after the Tensile Testing. 54
Figure 4. 4 Plot of Main Effects for S/N Ratio. 57

Figure 6. 1 Processing Parameter Settings for Run No.1. 68
Figure 6. 2 Processing Parameter Settings for Run No.2. 68
Figure 6. 3 Processing Parameter Settings for Run No.3. 69
Figure 6. 4 Processing Parameter Settings for Run No.4. 69
Figure 6. 5 Processing Parameter Settings for Run No.5. 70
Figure 6. 6 Processing Parameter Settings for Run No.6. 70
Figure 6. 7 Processing Parameter Settings for Run No.7. 71
Figure 6. 8 Processing Parameter Settings for Run No.8. 71
Figure 6. 9 Processing Parameter Settings for Run No.9. 72
Figure 6. 10 Processing Parameter Settings for Run No.10. 72
Figure 6. 11 Processing Parameter Settings for Run No.11. 73
Figure 6. 12 Processing Parameter Settings for Run No.12. 73
Figure 6. 13 Processing Parameter Settings for Run No.13. 74
Figure 6. 14 Processing Parameter Settings for Run No.14. 74
Figure 6. 15 Processing Parameter Settings for Run No.15. 75
Figure 6. 16 Processing Parameter Settings for Run No.16. 75

LIST OF ABBREVIATIONS, SYMBOLS AND NOMENCLATURE

%	-	percent/percentage
∑	-	Sigma/Sum of
℃	-	degree Celcius
℉	-	degree Fahrenheit
ABS	-	Acrylonitrile Butadiene Btyrene
ANOVA	-	Analysis of Variance
ASTM	-	American Society for Testing and Materials
BASF	-	Badische Anilin- und Soda-Fabrik
BDP	-	Bachelor Degree Project
BHN	-	Brinell Hardness Number
CAGR	-	Compound Annual Growth Rate
CF	-	Correction Factor
cm^3	-	centimetre cube
g/cm^3	-	gram per centimetre cube
g/cm^3	-	gram per centimetre cube
g/min	-	gram per minute
HDPE	-	High Density Polyethylene
i	-	Variable (s)
ICI	-	Imperial Chemical Industries
IMM	-	Injection Moulding Machine
kN	-	kiloNewton
LCP	-	Liquid-Crystal Polymer
LDPE	-	Low Density Polyethylene
LLDPE	-	Linear Low-Density Polyethylene
m/s	-	metre per second
MDPE	-	Medium Density Polyethylene
MPa	-	MegaPascal
MSD	-	Mean Square Deviation

MYR	-	Malaysian Ringgit
n	-	Number of variable (s)
N/mm^2	-	Newton per millimetre cube
OA	-	Orthogonal Array
PBT	-	Polybutylene Terephthalate
PC	-	Polycarbonate
PE	-	Polyethylene
PEEK	-	Polyether Ether Ketone
PEK	-	Polyetherketone
PET	-	Polyethylene Terephthalate
PF	-	Phenol Formaldehyde
POM	-	Polyoxymethylene
PP	-	Polypropylene
PPS	-	Polyphenylene Sulfide
PS	-	Polystyrene
PUR	-	Polyurethane
PVC	-	Polyvinyl Chloride
S/N	-	Signal-to-Noise ratio
ST	-	Total sum of square deviation
T_g	-	Glass Transition Temperature
US $	-	United States Dollar
USA	-	United States of America
USD	-	United States dollar
UTM	-	Universal Testing Machine
UV	-	UltraViolet

CHAPTER 1

INTRODUCTION

1.0 Introduction

Chapter 1 provides general insight to the readers on the topic which will be done in the Bachelor Degree Project, which is about altering the processing parameters of the plastic injection moulding process in order to optimise the tensile strength of the dog bone specimen fabricated using acrylonitrile butadiene styrene (ABS) plastic resins via Taguchi methodology. This chapter includes problem statement, objective as well as structure of the project to give a basic idea about the project to the readers. In this chapter, the scope is also set to limit a certain extent of study which is uncontrollable. Moreover, Chapter 1 comprises the structure of project as well in order to clarify how the project goes.

1.1 Overview

Injection moulding fabricates parts by injecting molten material into a mould cavity (Kumar and Vasudevan, 2013). It is a cyclic process beginning with filling the mould cavity followed by cooling and ejecting the completed part from the mould (Pero and Josip, 2014). The material for the part is supplied and heated in an injection barrel to a molten state; the molten material is then mixed comprehensively, prior to being forced under tremendous pressure ranges between 500 bar to 1500 bar into a mould cavity where the temperature of the material drops and the material hardens accordingly to the configuration of the cavity, thus produces the part (Kumar et al., 2013).

A vast range of materials are feasible to perform injection moulding, in the forms of grains or powder, which include metals, elastomers and glasses, with the most commonly utilised materials being thermoplastic and thermosetting polymers (Kumar et al., 2013).

The mould is designed, fabricated and precisely machined to build up the required and desirable specifications by a mould maker, usually using metal such as steel and aluminium (Kumar et al., 2013). Among the common manufacturing processes utilised today, such as casting, joining, forming, machining and additive manufacturing, injection moulding possesses the largest efficiency with largest amount of yield and most precise dimensional accuracy of the parts produced (Ng, Nik and Shahrul, 2013).

Engineering plastics refer to thermoplastics having the higher strength per unit weight than the usual metallic materials, yet having low material cost. Some examplers of engineering plastics include acrylonitrile butadiene styrene (ABS), polyetheretherketone (PEEK), polyetherketone (PEK), polyethylene terephthalate (PET) and polycarbonates (PC). The mechanical and thermal properties are better in comparison with the vastly and extensively utilised commodity plastics such as polystyrene (PS), polypropylene (PP), polyethylene (PE) and polyvinyl chloride (PVC) (Hiroki and Etsuo, 2004).

Engineering plastics are commonly devoted for objects smaller in sizes or applications of small quantities such as the mechanical parts rather than for large aggregate and massive utilisations such as containers and packaging. Today, the advancement attainable in engineering plastics have resulted in the gradual substitute of the conventional engineering materials, for instance wood or metal in various purposes. This is due to the reason that the engineering plastics are much easier and effortless to manufacture and fabricate a part, especially in complicated geometries besides possessing equal or surpassed credentials in terms of weight, strength and other mechanical and thermal properties (Crompton, 2014).

Injection moulding accounts for more than one third of all thermoplastic materials as well as more than 50% of all polymer processing machineries (Ng et al., 2013). Injection moulding is applied extensively in the manufacturing industries due to the capacity of producing parts repetitively with virtually unlimited, complex geometries at high production rates (Kavade and Kadam, 2012).

Hence, injection moulding carries the responsibility of large volume production of plastic components to meet the ever demanding and increasing market demands globally as an array of consumer products in various fields such as medical, electronics and automobile consist of injection-moulded plastic parts (Ng et al., 2013).

The plastic injection moulding process is a broad manufacturing process where the resultant structural shape of the plastic product can be greatly influenced by the possible defects occurred during the injection process. There are a number of processing parameters affecting the plastic injection moulding process, such as the mould temperature, melt temperature, holding pressure, holding time, cooling time, injection velocity, injection time, injection peak pressure, location of the injection gate and the type of the runner of the mould (Guido and Manuel, 2013).

Due to the adverse processing parameters available, the accurate, desirable design and optimisation of the whole injection moulding process is a challenge to be solved before the plastic injection moulding process can take place. The complexity in the interactions among the processing parameters is high and has to be investigated prior to the injection moulding process in order to fine tune the industrial process which will result in fabricating the most number of plastic parts possessing the demanding qualities in tolerance, hence minimising scraps (Guido et al., 2013).

The processing parameters of the plastic injection moulding process do not only affect the final geometrical shape of the plastic part, which has direct relationship with the quality, physical and mechanical properties of the resultant part, but also bringing effects to the yield, lead time and energy efficiency of the whole plastic injection moulding process. The optimum processing parameters of the plastic injection moulding process minimises the cycle time of the process, while at the same time raises the quality and perfection of the plastic part. While the optimisation of the processing parameters is vital in obtaining the desirable plastic product, the optimisation is mostly dependent on the experience of the process engineer, where the optimisation does not guarantee the correct values of the processing parameters at all time (Dang, 2013).

The real challenge lies in the optimisation procedures due to the complicated thermos-viscoelastic property of the plastic. Hence, the optimisation of the processing parameters is always referenced from hand books before adjusting the processing parameters subsequently using trial-and-error method. The main drawbacks of the trial-and-error method are high expenditure and lengthy time spent in order to get to the optimum processing parameters (Dang, 2013).

The Taguchi technique, also known as the Robust design, has been applied extensively in enhancing the engineering productivity. The Taguchi technique is a simple and competent method utilised especially in off-line quality control to construct products of high quality and decide the ideal setting of the manipulated parameters. The best spectrum of designs for quality, performance and enumerated cost can be determined systematically using Taguchi technique (Nik and Shahrul, 2012). The Taguchi technique uses the orthogonal array experiments to optimise the performance characteristics within the integration of design parameters (Kumar et al., 2013).

In the product or process design of Taguchi technique, three (3) steps are concerned, namely the System Design, Parameter Design and Tolerance Design (Kumar et al., 2013). The System Design refers to the utilisation of scientific and engineering proficiencies desired for in producing a product while the Parameter Design is involved in finding ideal process values in order to enhance the quality characteristics. The Tolerance Design is employed in deciding and analysing the tolerances in the ideal settings proposed by the Parameter Design (Wang, Kim and Song, 2014).

The Taguchi technique recommends the application of signal-to-noise (S/N) ratio and Analysis of Variance (ANOVA) in the determination of the quality characteristics and indication of the impact of the processing parameters for optimisation (Wang et al., 2014). The signal-to-noise (S/N) ratio signifies both the average and the diversity of the quality characteristics. It is a measure of performance dedicated at developing products and processes insensitive to noise factors (Kumar et al., 2013).

1.2 Problem Statement

The tensile strength of an acrylonitrile butadiene styrene (ABS - engineering plastic) specimen depends upon the processing parameters such as the injection peak pressure, injection speed, holding pressure and holding time. However, the most significant processing parameter to affect the mechanical properties of the dog bone specimen during tensile testing has to be determined. Moreover, the optimum processing parameters in injection moulding to produce the dog bone specimen with the best tensile strength are to be recognised.

1.3 Objectives

This research project is conducted with the following objectives to be achieved.

a. To determine the most significant processing parameter possessing an effect in the tensile strength ofacrylonitrile butadiene styrene (ABS).
b. To identify the optimum combination of processing parameters in injection moulding using acrylonitrile butadiene styrene (ABS)having the optimum tensile strength.

1.4 Scopes

The project work scope focuses on the optimisation of the processing parameters, namely the injection peak pressure, injection speed, holding pressure and holding time during the injection moulding process of the acrylonitrile butadiene styrene (ABS - engineering plastics) to produce the dog bone specimen possessing the best tensile strength. The processing parameters aside from the four (4) processing parameters mentioned above are kept constant and are not considered. The project work scope does neither involve engineering plastics other than acrylonitrile butadiene styrene (ABS) nor commodity plastics. Besides that, the only mechanical property under study is the tensile strength. Hence, the specimens do only undergo tensile testing as the material testing method. No other material testing method will be assigned to the specimens.

1.5 Structure of the Research Project

Table 1.1: Structure of the Bachelor Degree Project.

Chapter 1	Introduction	The explanation on the study of the main topic which is to optimise the tensile strength of acrylonitrile butadiene styrene (ABS) plastic resins via optimal processing parameters using Taguchi method.
	Problem Statement	The description of the problem existing in determining the optimum processing parameters in plastic injection moulding process in order to obtain the plastic part with the highest tensile strength.
	Objectives	The direction of the study goals to avoid the study from drifting out of topic.
	Scopes	The limitation of the project which defines the content inside and outside the project report. Considerations of the project are made based on the scopes defined.
Chapter 2	Literature Review	The literature review will be conducted to enhance the understanding in the field and ease the establishment of the theoretical framework and methodological focus.
Chapter 3	Methodology	The briefing of the methods and tools used in the project to come out with the final result.
Chapter 4	Results and Discussions	The optimised processing parameters of the plastic injection moulding process which result in the highest tensile strength of the dog bone specimen. The discussions raise and find solutions to the problems arise during the experiments conducted.
Chapter 5	Conclusion and	The description on the goal achieved and