UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Faculty of Mechanical and Manufacturing Engineering Technology

OPTIMIZATION OF INJECTION MOULDING PARAMETERS TO REDUCE WARPAGE ON ACRYLONITRILE BUTADIENE STYRENE (ABS) DOG BONE PART USING TAGUCHI METHOD

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Bachelor of Manufacturing Engineering Technology (Process and Technology)

2020

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A thesis submitted
in fulfillment of the requirements for the Bachelor of Manufacturing Engineering Technology (Process and Technology) with Honours

Faculty of Mechanical and Manufacturing Engineering Technology

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2020

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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TAJUK: **OPTIMIZATION OF INJECTION MOULDING PARAMETERS TO REDUCE WARPAGE ON ACRYLONITRILE BUTADIENE STYRENE (ABS) DOG BONE PART USING TAGUCHI METHOD**

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

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DEDICATION

Dedicated to

My beloved late father, SABARUDIN BIN YUSOFF

My beloved mother, SALMEY BINTI MOHD SAID

All my beloved siblings, Saifuddin, Sayyid and Sarah, and

All my friends who has supported me, gave their best in providing me the ultimate moral support, cooperation, encouragement and understandings.

Thank you so much, this is for you.

ABSTRAK

Kajian ini bertujuan untuk mencari parameter optimum pengacuan suntikan untuk mengurangkan ledingan dalam produk berbentuk *dog bone* daripada bahan Acrylonitrile Butadiene Styrene (ABS) untuk mesin pengacuan suntikan menggunakan Kaedah Taguchi. Pembuatan suntikan dalam pembuatan produk plastik dianggap sebagai salah satu proses yang paling penting. Proses pembuatan boleh menyebabkan kecacatan seperti ledingan. Ledingan dilihat sebagai salah satu masalah pada spesimen ini yang disebabkan oleh perbezaan dalam pengecutan. Parameter yang difokuskan dalam kajian ini adalah masa penyejukan, masa pemampatan, kelajuan suntikan dan suhu acuan. Oleh itu, penyelidikan ini adalah untuk mengurangkan ledingan dengan mendapatkan parameter yang dioptimumkan menggunakan Kaedah Taguchi. Nisbah isyarat-ke-bunyi untuk bahan ABS dikira menggunakan perisian Minitab dengan ciri-ciri yang lebih kecil adalah lebih baik. Faktor-faktor yang mempengaruhi tindakbalas *dog bone* ABS telah disimpulkan bahawa masa pemampatan dan masa penyejukan menunjukkan kesan yang ketara kepada respons. Parameter yang paling ketara ialah masa pemampatan yang mana kedudukannya sebagai nombor 1 dalam urutan delta S/N. Parameter optimum akhir diperolehi selepas ujian pengesahan yang memampat masa pada 10s, masa penyejukan pada 15s, kelajuan suntikan pada 50mm/s dan suhu acuan pada 40 °C. Tahap masing-masing adalah 3,3,3 dan 2. Tambahan pula, faktor yang mempengaruhi *dog bone*, masa pemampatan, menunjukkan kesan min yang teguh terhadap tindak balas.

ABSTRACT

This study is solely on purpose to find the optimum parameters of injection moulding to reduce warpage in Acrylonitrile Butadiene Styrene (ABS) dogbone manufacturing for injection moulding machine using Taguchi Method. Injection moulding in plastic product manufacturing is considered one of the most important processes. The processes of injection moulding machine can cause defects such as warpage. Warpage is seen as one of the problem on dog bone specimen that is due to differential shrinkage. The parameters focused in this study are cooling time, packing time, injection speed and mould temperature. Hence, this research is to reduce warpage by obtaining optimized parameters using Taguchi Method. The signal-to-noise ratio for ABS material was calculated using the Minitab software with the characteristics of smaller is better. The factors affecting the warpage of ABS dog bone has been concluded that packing time and cooling time shows robust mean effect to the response. The most affecting parameter was packing time where it is ranked as number 1 in delta sequence of S/N ratio. The final optimum parameters were obtained after confirmatory test which are packing time at 10s, cooling time at 15s, injection speed at 50mm/s and mould temperature at 40 °C. The levels are 3,3,3 and 2 respectively. Plus, the factor affecting the warpage of ABS dog bone, packing time, shows a robust mean effect to the response.

ACKNOWLEDGEMENTS

I would like to express my deepest gratitude to my supervisor, Ts Salleh bin Aboo Hassan for his unwavering support, advice and guidance in making this research project a success. Thank you Mummy for keeping me going all these years and never letting me give up. I couldn't have done it without my one and only backbone. To my brothers and sisters for not getting tired of me complaining and grumbling, for giving me the best support that any sister would need to hear.

To all the lecturers and dear friends for the directly and indirectly guidance and knowledge that without them I could not have successfully completed my project. Thank you Nur Atiqah, Nur Fithrah, Hamizah, Farah Izzati, Syuhada Hafiza and Nurul Atikah. Throughout these years, it has been an honour to know all of you. Atiqah, you never stopped giving, I thank you for that.

My deepest gratitude extends to the lab technicians Mr Basri and Mrs Zalipah for their support and acquisition of experimental equipment and materials. Without these people, I would not have survived this project.

To all my friends that have shown love and support in this period of time.
To my brain for withstanding unnecessary temptations from the heart and my eyes for going through countless nights of facing computer screens also to my ears for allowing me to listen to all kinds of comments, sometimes hurtful sometimes harsh.

To my best friend, who never stopped believing in me, pushed me to be the best among the best, Thank you, Nurasyqin.

Most importantly, to my fingers and hands whose tip tapping sounds accompanied my lonely nights. And finally thank you dear self for not getting sick at critical times. For putting up with the amount of coffee and instant noodles that goes into the body system.
Last but not least, to every soul who helped out either directly or indirectly in the completion of this project, thank you, it could not have been done without you.

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LIST OF ABBREVIATIONS

ABS	-	Acrylonitrile Butadiene Styrene
DOE	-	Design of Experiment
CO2	-	Carbon dioxide
ANSI	-	American National Standard Institute
PET	-	Polyethylene terephthalate
PEN	-	Polyethylene naphthalate
PP	-	Polypropylene
FEP	-	Fluorinated ethylene propylene
PTFE	-	Polytetrafluoro ethylene
S/N	-	Signal to Noise

CHAPTER 1

INTRODUCTION

1.0 Introduction

This chapter is envisioned to provide background information of the study and the overall idea of the project. The sections included in this chapter are background study, problem statement, objectives and project scopes.

1.1 Background of Study

Injection moulding is one of the most popular methods of processing polymers especially those with complex geometries. In 1872, an American inventor John Wesley Hyatt has patented the first injection moulding machine. It has processed similarly to a large needle and injected a plastic through a heated cylinder mould. Injection moulding is suitable for processing in high volumes with good dimensional tolerance while maintaining cost effectiveness. Over a third of all plastic products are made using injection moulding while over half of the world's polymer processing equipment is used for injection moulding process (Beaumont, Nagel and Sherman, 2002).

The injection moulding process is basically divided in 5 stages. They are plasticization, injection, packing, cooling and ejection. Though the stages may seem fairly simple, they are actually very complex in nature affected by a countless of parameters (Sivarao, 2013). Hence, part manufacturing defects are common. These defects include

warpage, weld lines, burn marks and short moulds. Warpage is considered as one of the most common problem in injection moulding process (Goodship *et al* 2004).

Injection moulding is common in processing plastic products that one third of all plastic products uses injection moulding (Zhou, 2013). Warpage is the deformation of a moulded component caused by non-uniform changes in internal stress, differential shrinkage and/or orientation effects. Alfreda (2006) stated that when a part is bend or twist out of shape after injection moulding process and changes the dimension it is therefore the warping defect. There are several factors that causes warpage such as mould and melt temperatures, design of the injection moulded part, cooling system, length to thickness ratio, packing pressure and time, gate type, dimension and its location.

Acrylonitrile Butadiene Styrene (ABS) is an engineering plastic that has butadiene part uniformly distributed over the acrylonitrile-styrene matrix. It possesses excellent toughness, good dimensional stability, easy processing ability, chemical resistance, and it is also a low-cost material. Since the process of injection moulding includes melting and forming the plastic, the processes will affect the rheology of the material which resulting this defect.

Recently, a study on injection moulding parameters that caused warpage of Polypropylene (PP) dog bone was conducted by Siti Salmah, (2014). This study focused on the effect of injection moulding parameters on warpage deflection of PP dog bone by using Taguchi Method as the Design of Experiment (DOE). Four factors namely mould temperature, cooling time, melt temperature and cavity temperature were studied. Cavity temperature was found to be the most significant factor that caused warpage followed by mould temperature, cooling time and melt temperature. According to M. Amran (2015), holding pressure was the most significant factor contributing to warpage, followed by

clamping pressure, back pressure and injection pressure. The values of warpage percentage depreciated to 4.6% after the optimum parameters were set.

However, in this study, the effect of injection moulding parameters which are cooling time, packing time, injection speed and mould temperature on dog bone warpage was also investigated by using Taguchi Method. This method possesses the most preferred approach and its capability and reliability is proven in other studies (Kamal, 2016). The statistical software Minitab 17 was used for analysis purpose and to create a robust design for factors and levels. Orthogonal arrays of L9 were designed using Minitab in Taguchi DOE. All the trials was conducted using ABS material. ABS was chosen due to the material's high melting point where it would be a challenge to control the differential shrinkage throughout the part. All the data was analysed mathematically and statistically using Minitab 16 software in order to determine the optimum level of process parameters.

1.2 Problem Statement

Injection moulding is considered as one of the most important process in plastic product productions (Marton, 2015). Mass production of plastic products can be done with injection moulding process. Plastic products such as bottles and dog bone for tensile testing is a type of man-made polymer where it is produced by various processes. Alexander Parkes (2015) stated that the first man-made plastic was in 1892 was an organic material derived from a cellulose that is heated and can be moulded and retain its shape after the cooling process. After decades, the processes have improved and varied. These processes cause defects that can only be adjusted with optimum factors. In injection moulding, defects such as shrinkage, weld lines, warpage and flash are very common due to unstable cooling time and melt temperature. Due to this, the percentage of warpage on plastic products can increase along with production percentage.

UTeM's dog bone is used for tensile and other destructive testing for student's practice. The condition of the dog bone is vital in order to get an accurate result for the tests. Warpage or twisted part of dog bone can affect the calculation of maximum elongation in tensile strength. Warpage can also be a cause of waste in manufacturing. Waste of material is considered as waste when any defected products cannot be used both in mechanical testing and chemical testing. Increasing productivity and reducing the amount of waste that is in and generated through any method is vital. From here it can be seen that warpage needs proper attention to be overcome. Hence, setting up the optimum parameters for a production can reduce the percentage of warpage. By focusing on the intricated parameters such as cooling time, packing time, injection speed and mould temperature, warpage can be minimized. Therefore, the optimization of the parameters of UTeM's ABS dog bone is crucial in order to produce warpage free products.

1.3 Objective

The objectives of this research are;

- To determine the factors affecting warpage of ABS dogbone.
- To optimize the parameters of injection moulding in reducing warpage.
- To validate the result drawn by Taguchi optimization method.

1.4 Scope of Project

The limitations set for this research will affluence the experiment and data collection.

- The material that will be used is Acrylonitrile Butadiene Styrene (ABS).
- This experiment will take place on injection moulding machine in Plastic Laboratory, Faculty of Mechanical and Manufacturing Engineering Technology (FTKMP) in UTeM.
- The parameters that has been congregated are cooling time, packing time, injection speed and mould temperature.
- This project will optimize the parameters to an optimum number to reduce warpage during ABS dog bone part products.
- The shape used for the injection product is dog-bone shape.
- Taguchi method and ANOVA will be used to analyze the optimum parameter in reducing warpage.
- Taguchi and signal-to-noise (S/N) ratio will be employed to determine the controllable factors affecting towards warpage.

1.5 Significant / Importance of Study

The findings of this study will benefit to the manufacturers or operators and to the environment. This experiment will provide the optimum set up of parameters for injection moulding process in ABS dog bone part. With respect of reducing warpage and produce more defect free parts. The cost of producing dog bone parts is high hence is it prominent to reduce the number of defected parts. Next, it is beneficial for the future researchers to improve this study by selecting more parameters to indicate the best set up for injection moulding process in reducing warpage. Thus, more parts can be produced as defect free.

CHAPTER 2

LITERATURE REVIEW

2.0 Introduction

This chapter reviews a referenced review and basic knowledge from related journals and researches. It will cover plastic injection moulding, plastic, thermoplastic, Acrylonitrile Butadiene Styrene (ABS) and Taguchi Method.

2.1 Plastic Injection Moulding Machine

Injection molding is the most commonly used manufacturing process for removing plastic parts. Using injection molding, different types of products are produced, which vary greatly in size, complexity and application. The injection molding process requires an injection molding machine, raw plastic materials and molds to be used (Patil, 2015). In the injection molding machine, the plastic is diluted and then injected into the mold, cooled and strengthened it to the end. Today's injection molding assumes great responsibility in producing plastic components to meet market demands.

In 2015, Tikel stated that the quality of the product depends on the selection of the design material of the mold and process parameters. Types of injection moulding all around the world is usually generally for all types of material. For an example, a picture of an injection moulding machine in one of UTeM's lab is shown in figure 2.1 as reference indicating the machine that will be used for this study.

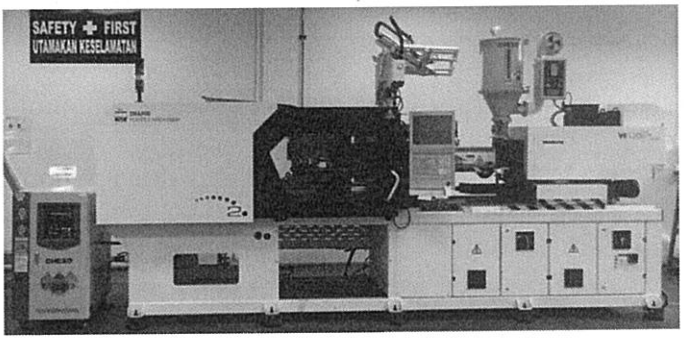

Figure 2. 1: Injection Moulding Machine in UTeM

2.1.1 History of Injection Moulding Machine

The evolution of the process started when John Wesley Hyatt in 1868 developed a plastic celluloid and to process the material into a form that can be used to substitute ivory those days. According to Douglas (2007), the plastic industry was born after the discovery and by 1920, injection moulding industry was well known. The evolution of the machine took place when Hyatt brothers created a large hypodermic needle which contains basic plunger in order to inject a heated plastic through a cylinder and into the mould. The first patent of injection moulding machine is shown in figure 2.2. In 1946, James Henry started to do researching in screw injection machine and patented a design to replace the plunger device created by Hyatt brothers. Nowadays, almost 95% of injection machines uses screw injection.

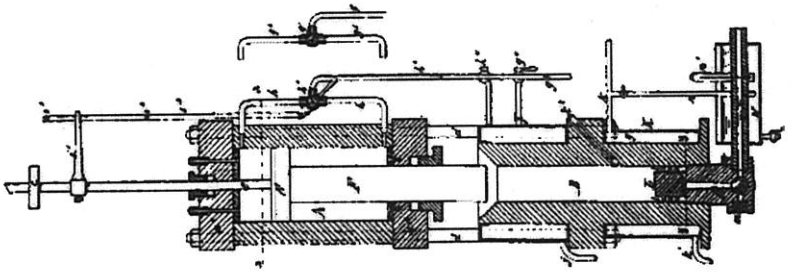

Figure 2. 2: Patent application of Hyatt's injection moulding machine.

(Douglas, 2007)

2.1.2 Application of Injection Moulding

Injection molding is used to create many things like wire spools, packaging, bottle caps, automotive parts and components, toys, pocket combs, some and parts of musical instruments, one-piece chairs and small tables, storage containers, mechanical parts including gears, and most other plastic products available today.

2.1.2.1 Materials used in Injection Moulding

In the injection molding process, there are many types of materials that can be used. Most polymers, including all thermoplastics, certain thermosets, and some elastomers, can be used. When used in the process of injection molding, these materials usually have small pellets or a fine powder in their raw form. In the process, colorants can also be added to control the final part's color. The selection of a material to create molded parts for injection is not based solely on the final part's desired characteristics. While each material has different properties that will affect the strength and function of the final part, the parameters used in processing these materials are also determined by these properties. Numerous studies have attempted to determine the materials that can be used in injection moulding machine. Douglas (2007) traces the development of injection moulding machines in materials that can be used for manufacturing. Studies on the materials are tabulated as below.