UNIVERSITI TEKNIKAL MALAYSIA MELAKA

OPTIMIZATION OF INJECTION MOLDING PARAMETERS FOR 80:20 VIRGIN-REGRIND BLENDED ABS PLASTIC MATERIAL

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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DEDICATION

To my beloved mom and dad.

ABSTRAK

Plastik telah digunakan secara meluas sebagai bahan untuk kebanyakan produk dalam kehidupan manusia. Walau bagaimanapun, kadar pengeluaran produk plastik jauh lebih cepat daripada kadar kitar semula plastik, mengakibatkan pencemaran plastik. Kitar semula plastik adalah proses yang biasa dalam industri, untuk pemeliharaan alam sekitar dan yang lebih pentingnya penjimatan kos. ABS adalah sejenis plastik yang biasanya digunakan sebagai batu-bata Lego dan sebagai bahan filamen untuk cetakan 3D, produk rumah tangga seperti perkakas dapur dan paip, kerana ketangguhan dan rintangan hentaman tinggi. Selain itu, pengacuan suntikan adalah pemprosesan plastik yang paling biasa untuk pelbagai jenis termoplastik. Untuk mengoptimumkan parameter pengacuan suntikan bahan plastik ABS dalam nisbah bahan baru kepada bahan dikitar semula 80:20, empat parameter kawalan adalah tekanan suntikan, tekanan memegang, kelajuan suntikan dan masa pegangan dengan setiap empat tahap masing-masing ditabulasikan menggunakan jadual orthogonal array L'16 yang ada dalam kaedah Taguchi. Spesimen jenis I dari ASTM D638-14 dihasilkan dengan menggunakan mesin pengacuan suntikan dengan 16 eksperimen dari jadual OA, diikuti dengan lima ujian uji tegangan untuk mendapatkan kekuatan tegangan muktamad (UTS). Keberertian setiap parameter kepada UTS spesimen sebatian ABS dan kombinasi optimum dari parameter dengan tahap masing-masing dapat ditentukan dengan menggunakan kaedah analisis nisbah S/N dan ANOVA. Selepas proses analisis, objektif kajian ini telah dicapai. Faktor yang paling penting dalam kajian ini adalah tekanan suntikan, dan parameter pengacuan suntikan yang dioptimumkan untuk bahan plastik ABS dalam nisbah bahan baru kepada bahan dikitar semula 80:20 ialah tekanan suntikan pada 110 MPa, tekanan memegang pada 20 MPa, kelajuan suntikan pada 115 mm/s dan masa pegangan pada 10 s.

ABSTRACT

Plastic has been a widely used as the material for most of the products in the human life. However, the rate of producing plastic product is much faster than the rate of the recycling of plastic, resulting the plastic pollution. Plastic recycling is a common process in the industry, for environment preservation and more importantly cost saving. ABS is a type of plastic that commonly used as Lego bricks and as the material of filament for 3D printings, household products such as kitchen appliances and pipes, due to its toughness and high impact resistance. Moreover, injection molding is the most common plastic processing for various type of thermoplastic. To optimize the injection molding parameter for 80:20 virgin-regrind blended ABS plastic material, the four control parameters are injection pressure, holding pressure, injection speed and holding time with each four levels is tabulated with corresponding levels using the L’16 orthogonal array table in Taguchi method. Type I specimen from ASTM D638-14 is produced by using the injection molding machine with 16 experiments from the OA table, followed by five trials of tensile testing to obtain the ultimate tensile strength. The results are analyzed by using the S/N ratio and ANOVA, which the significance of each parameter towards the UTS of the ABS blends specimens and the optimal combination of the parameter with corresponding level can be determined. After the analysis, it can be said that the objectives of the research are achieved. The most significant factor in this research is the injection pressure, and the optimized injection molding parameter for 80:20 virgin-regrind blended ABS plastic specimen is injection pressure at 110 MPa, holding pressure at 20 MPa, injection speed at 115 mm/s and holding time at 10 s.

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LIST OF ABBREVIATIONS, SYMBOLS AND NOMENCLATURES

ABS	- Acrylonitrile-Butadiene-Styrene
PP	- Polypropylene
PS	- Polystyrene
PE	- Polyethylene
PVC	- Polyvinyl Chloride
PC	- Polycarbonate
PET	- Polyethylene Terephthalate
PBT	- Polybutylene Terephthalate
PPO	- Poly (p-phenylene oxide)
SAN	- Styrene-acrylonitrile
EP	- Ethylene-Propylene
OMMT	- Organo-montmorillonite
HIPS	- High Impact Polystyrene
WEEE	- Waste from Electrical and Electronics Equipment
UTS	- Ultimate Tensile Strength

UTM - Universal Testing Machine

OA - Orthogonal Array

ASTM - American Society of Testing and Materials

ANOVA - Analysis of Variance

S/N - Signal to Noise

T_m - Melting Temperature

T_g - Transition Temperature

df - Degree of Freedom

$\overline{x}$ - Mean

s - Standard Deviation

ss - Sum of Squares

ms - Mean of Squares

CHAPTER 1

INTRODUCTION

1.0 Introduction

This chapter describe the background of research, problem statement, objectives of research and scope of research as an overview of this project. The structure of the research is explained briefly to have better conceptual understanding about the study of the project.

1.1 General Background

Polymer are one of the materials that has been widely used in industry. According to Sobotova *et al.*, (2013), plastic products are used in human daily life in almost every activity, due to the expansion in plastic manufacturing technology. There are many types of polymer comes with different grades, includes polyethylene (PE), polypropylene (PP) and Acrylonitrile-Butadiene-Styrene (ABS) in different application such as telecommunication, automotive and household products. Although polymers are light in weight and have low machining temperature, polymers perform considerably high in strength and economical, which brings advantages in different application. For example, ABS is one of the polymers that well-perform in its mechanical properties and high impact strength (Dariuosh and Heidar, 2007)

The properties of polymer that it is recyclable makes it become more preferred material. Thus, recycling of polymer has become a very widespread process. According to Rahimi *at al.* (2014), reuse of materials not only saving the natural resources of the Earth, recycled polymers can be well-performed as the virgin polymers at a lower cost. The polycarbonate (PC) and ABS blends product provide high toughness, rigidity and high impact resistance (Eguiazabal *et al.*, 1990). When the recycled polymer commonly accepted by the industry, improvement on the processing of recycled polymer is done in different way for obtaining a better performance on mechanical properties such as tensile strength, impact strength and hardness of the recycled polymer.

In order to improve the quality of the recycled polymers, the processing of polymer recycling and the material to be recycled itself needed to be monitored. According to Rahimi *et al.* (2014), one of the most common method to process polymers as well as the recycled polymers is by injection molding.

1.2 Problem Statement

ABS exhibit good mechanical properties and high impact resistance. Along with the advance technology, ABS is one of the polymers which been very popularized and mass-oriented material in many industries due to its durability and low cost. The more the usage, the more the production, causing the more the discard. Hence, a proper recycling of ABS is necessary after the product lifespan to minimize waste, preserve natural resources and save cost as a long-term benefit. More importantly, recycling ABS plastic can cut the usage of 100% virgin material and thus lower the unit cost for the production line. This makes recycling of ABS is a very crucial process which gives influence on quality of recycled ABS and directly determine the marketability and acceptability of recycled ABS in the industry.

Clearly, the quality of the recycled ABS on the mechanical properties is the most important aspect to be ensured and improved. Based on previous studies, improving quality of recycle plastic or polymer product are done by optimizing the percentage or ratio of the material blends. Although many studies of this topic have been done, there is still a determinacy on the optimum injection molding parameters for the processing of recycled ABS and the interaction between the parameters and performance to exhibit the best tensile strength of the regrind-virgin blended ABS.

1.3 Research Objectives

In this project, there are two main objectives that to be achieved as shown as the following:

i. To determine the most significant factor that affect the tensile strength of the regrind blended ABS.

ii. To identify the optimum injection molding process parameter in processing regrind blended ABS.

1.4 Scope of Research

The scope and range of this research are:

i. To study on determination of the most significant factor that affect the tensile strength of regrind blended ABS and identification of the optimum injection molding process parameter in processing regrind blended ABS.

ii. The study will only focus on the percentage of 20% regrind material and 80% virgin material of ABS. This composition of virgin-regrind ABS blends will exhibit the best mechanical properties compared to other composition according to the studies by Rahimi, Esfahanian and Moradi (2014).

CHAPTER 2

LITERATURE REVIEW

2.0 Introduction

In this chapter, the study of background, processing, application and performance of virgin-regrind blended plastic will be discussed. Besides, substantive findings of other researcher on recycling thermoplastic materials and the optimizing process parameters of injection molding also will be further discussed and highlighted in this review.

2.1 Thermoplastic

The big family of polymer consists of two group of plastic, which known as the thermoplastics and thermosets.

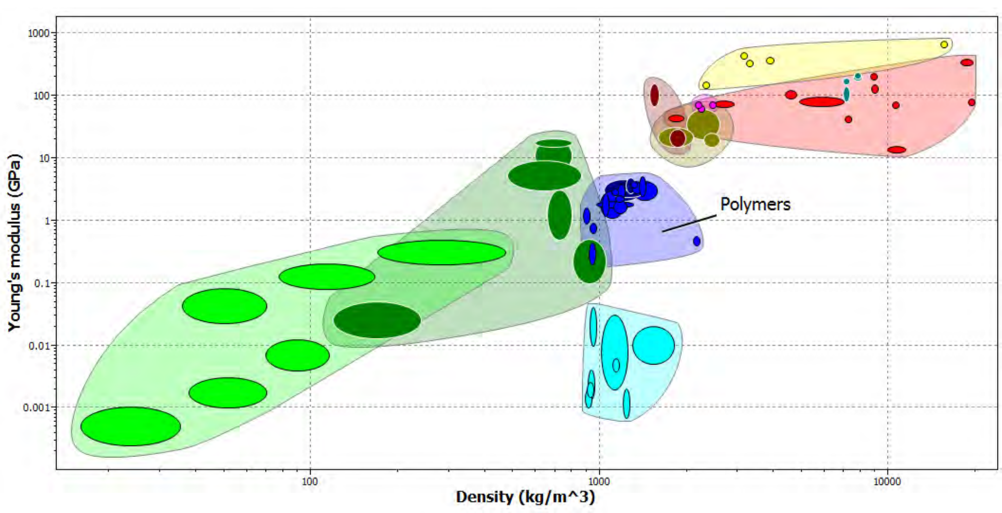

Figure 2.1: Ashby chart on Young's modulus versus density of materials

2.1.1 General properties of Thermoplastic

Thermoplastic is solid at room temperature and can be melted into liquid or become molten state at a higher temperature and back to solid after a cooling process, while the thermoset comes from the same family, but it does not melt (Brent, 2006). This is due to the secondary Van Der Waals force and linear bonding between the particles of the thermoplastic which break easily with the presence of heat, unlike the stronger cross-linked bonds and covalent bonds between the particles of thermosets. The molecular structure of thermoplastic is the key that makes the molecular chain of thermoplastic weaken rapidly when exposed to a high temperature and thus the melting (Liu *et al.,* 2015). As a result, thermoplastics is recyclable, and it can be recycled for times, and vice versa for thermosets.

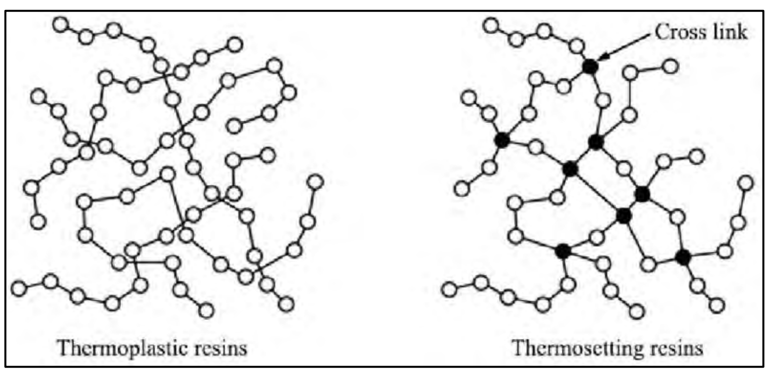

Figure 2.2: Comparison between molecular structure of thermoplastics and thermosets (Liu *et al.,* 2015)

Thermoplastics is also flexible and have rebound properties compared to thermosets, which is normally recover from applied adversity of forces. This property distinguishes the function of the both plastic in different field of usage. Undoubtedly, plastic is not electric and thermal conductive, so is the thermoplastics too. As advantage, thermoplastics have relatively high impact and creep resistance, ideal for a long-term usage for certain purposes. Summary of general properties of thermoplastic is highlighted in the table below.

Table 2.1: General properties of thermoplastic

General Properties	Elaboration
Recyclable and ease of molding	The melt-able properties of thermoplastics enable it to recycle and re-melt and remold for times.
Flexible and high plasticity	Thermoplastics are plastic which is flexible and resilient.
Poor thermal and electrical conductibility	Thermoplastics do not conduct heat and electric and heat, due to their low freedom of electrons movement.
High creep resistance	High entanglement polymer chains and non-freely movement of polymer atoms reduce the formation of creep.
Good Appearance	Ability to provide good surface finish and lustre.
High Impact Strength	Absorbs energy and relatively high impact resistance as a plastic.

2.2 Acrylonitrile-Butadiene-Styrene

In this study, the thermoplastic used is Acrylonitrile-Butadiene-Styrene (ABS). ABS is an amorphous thermoplastic and contains the Poly(styrene-co-acrylonitrile) (SAN) copolymer and the second phase by dispersed butadiene, which makes the ABS belongs in the continuous and rubbery-dispersed phase (Urrutibeascoa *et al.*, 2015).

ABS is widely used as 3D printing filament, due to its affordability to produce prototypes in low cost and comes with variety of colors. In addition, ABS is relatively high in stiffness and impact strength in the group of thermoplastics, and it is commonly used in the industries of manufacturing computer body parts, automobiles components and electronics industry due to its high impact strength and highly moldable properties (Tostar *et al.*, 2014). ABS also known as Lego plastic, because it is the most common material that used to produce the Lego bricks due to its toughness. ABS are normally opaque in appearance; some grades of ABS somehow provide a clear and transparent optical property.

Table 2.2: Properties of monomer in ABS

Monomer	**Properties**
Acrylonitrile	• Chemical resistance • High stability • Tensile strength • Aging resistance
Butadiene	• High Impact Strength • Toughness • Low temperature properties
Styrene	• Moldability and processability • Strength • Rigidity • Lustre/Gloss surface

ABS is known as a terpolymer, which it is synthesized by three monomers, that are Acrylonitrile, Butadiene and Styrene. These three monomers have the following properties that contributes on the physical and mechanical properties of ABS, such as the high impact strength that the ABS usually proud of, and other physical properties such as the gloss surface appearance and ease to mold.

2.2.1 Properties of Acrylonitrile-Butadiene-Styrene

Affiliates with the above table, mechanical properties of ABS are summarized in Figure 2.3. It is shown that the Young's modulus of ABS is at minimum of 1.1 GPa, maximum of 2.9 GPa, and the low thermal and electric conductivity, resulting ABS a good insulator.

General properties				
Density	1.01e3	-	1.21e3	kg/m^3
Price	* 2.84	-	3.13	USD/kg
Mechanical properties				
Young's modulus	1.1	-	2.9	GPa
Yield strength (elastic limit)	18.5	-	51	MPa
Tensile strength	27.6	-	55.2	MPa
Elongation	1.5	-	100	% strain
Hardness - Vickers	5.6	-	15.3	HV
Fatigue strength at 10^7 cycles	11	-	22.1	MPa
Fracture toughness	1.19	-	4.29	MPa.m^0.5
Thermal properties				
Maximum service temperature	61.9	-	76.9	°C
Thermal conductor or insulator?	Good insulator			
Thermal conductivity	0.188	-	0.335	W/m.°C
Specific heat capacity	1.39e3	-	1.92e3	J/kg.°C
Thermal expansion coefficient	84.6	-	234	µstrain/°C
Electrical properties				
Electrical conductor or insulator?	Good insulator			
Optical properties				
Transparency	Opaque			
Eco properties				
Embodied energy, primary production	* 90.3	-	99.9	MJ/kg
CO2 footprint, primary production	* 3.64	-	4.03	kg/kg
Recycle	True			
Recycle mark				

Figure 2.3: Physical and mechanical properties of ABS.

2.2.1.1 Amorphous Thermoplastic

Thermoplastic is divided into two categories: crystalline and amorphous, where the ABS is categorized as amorphous thermoplastic. Amorphous referred to the properties of thermoplastic which does not have a true point for melting temperature, T_m. This is means that the thermoplastic starts to become soft and melt into rubbery state after its glass transition temperature, T_g (Mostofa, 2016). When exposed to heat, amorphous thermoplastic softens by gradient and the molecules absorb heat energy to move more freely. Also, if the T_g of a thermoplastic below room temperature, the appearance of the thermoplastic is flexible, soft and rubbery at room temperature. In contrast, the thermoplastic will be brittle and glassy at room temperature if its T_g is located higher than the room temperature.

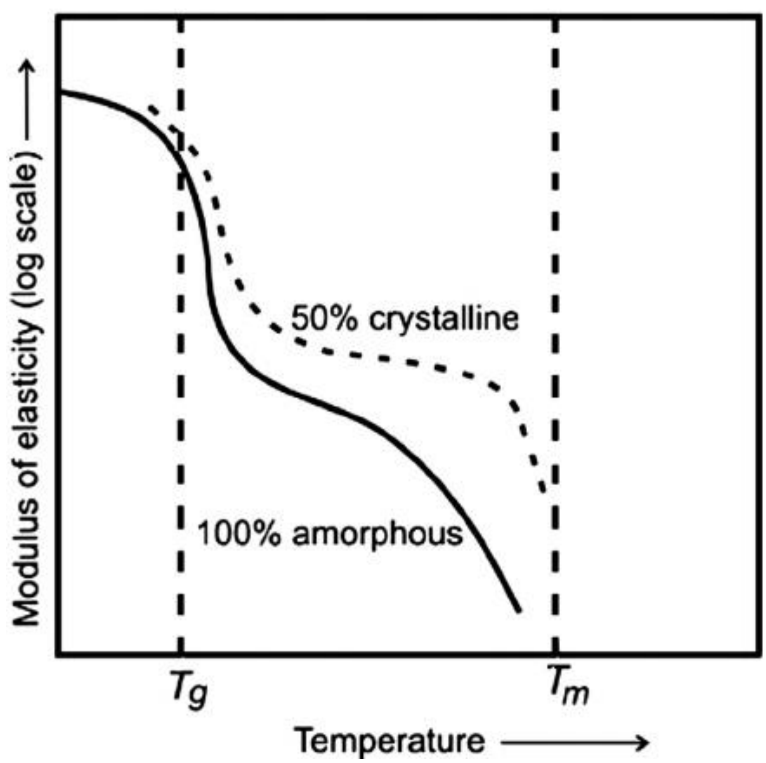

Figure 2.4: Comparison of thermal transition of thermoplastic (Dos Santos *et al.*, 2013)