UNIVERSITI TEKNIKAL MALAYSIA MELAKA

OPTIMIZATION OF FLEXURAL STRENGTH FOR ABS PLASTIC VIA OPTIMAL PROCESSING PARAMETERS USING TAGUCHI METHOD

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

by

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DECLARATION

I hereby, declared this report entitled "Optimization of Flexural Strength for ABS Plastic via Optimal Processing Parameters Using Taguchi Method" is the results of my own research except as cited in references.

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APPROVAL

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

………………………………

(Project Supervisor)

ABSTRAK

Kekuatan lenturan memainkan peranan yang penting dalam pelbagai bidang dan ianya juga satu faktor yang amat penting dalam penilaian prestasi produk plastik. Matlamat utama projek ini adalah untuk menentukan faktor yang paling berkesan dan keadaan parameter yang optimum menganalisis kesan parameter terhadap kekuatan lenturan produk plastik ABS dalam proses injeksi molding plastik. Kaedah taguchi membantu dalam pemilihan atau menentukan keadaan molding yang optimum untuk eksperimen. Jajaran ortogonal, isyarat-kepada-hingar nisbah dan varians analisis (ANOVA) diaplikasikan untuk mangaji ciri-ciri prestasi molding operasi bagi ABS. Dalam kajian ini, kaedah Taguchi telah digunakan untuk mengaji kesan-kesan proses dengan molding parameter yang berbeza dimana parameter tersebut adalah tekanan injeksi, tekanan tahan, kelajuan injeksi dan waktu tahan. Isyarat-kepada-hingar nisbah untuk kekuatan lenturan adalah semakin besar semakin baik kerana kekuatan lenturan perlu di maximumkan. 16 percubaan telah dijalankan pada keadaan proses molding yang berbeza menggunakan mesin Zhafir injeksi molding. Kekuatan lenturan spesimen akan dikenalpasti mengunakan mesin universal testing (INSTRON). Kajian ini penting bagi syarikat industri pembuatan plastik untuk memilih gabungan parameter molding proses yang optimum demi mendapatkan kekuatan lenturan yang tinggi dalam produk plastik ABS. Kajian ini telah menunjukkan bahawa kelajuan injeksi merupakan pengaruh yang paling tinggi terhadap kekuatan lenturan. Keputusan percubaan telah disediakan untuk mengilustrasikan keberkesanan pendekatan ini lalu mendapati bahawa parameter pemesinan yang paling penting mengikut urutan adalah kelajuan injeksi, tekanan injeksi, tekanan tahan, dan waktu tahan. Keadaan proses parameter yang optimum dalam kajian ini adalah tekanan injeksi 110 Mpa, tekanan tahan 15.0 Mpa, kelajuan injeksi 130 mm/s dan waktu tahan 14 s.

ABSTRACT

Flexural strength plays an important role in many areas and it is a great important factor in the evaluation of plastic product performance because it has significant impact on the mechanical property. The main goal of this project is to find out the most significant factor and optimum parameters condition for flexural strength of ABS plastic in injection molding process. Taguchi method and analysis of variance (ANOVA) help to select or to determine the optimum molding conditions under this experiments evaluation. The orthogonal array, signal-to-noise ratio (S/N ratio), and ANOVA were employed to study the performance characteristics in molding operations of ABS. In this study, the Taguchi method was used to study the effects of different molding parameters of the process which are injection pressure, holding pressure, injection speed and holding time. The S/N ratio for larger-the-better was considered to determine for flexural strength because it needs to be maximized. 16 trials were conducted at different molding process conditions by using Zhafir injection molding machine. The flexural strength of the specimens were measured by using universal testing machine (INSTRON). This study is important to plastic manufacturing industry company in the selection of optimum combinations of molding process parameters for obtaining the high flexural strength in ABS plastic product. The result was shown that injection speed was given the highest influence of flexural strength. Experimental results were provided to illustrate the effectiveness of this study and reveal that the most significant molding process parameter for flexural strength is injection speed followed by injection pressure, holding pressure and holding time. The optimum process parameters in this study are 110 Mpa injection pressure, 15.0 Mpa holding pressure, 130 mm/s injection speed and 14 s holding time.

DEDICATION

To my beloved parents, Chong Ngan Fatt and Lim Bee Kuan

My supervisor, Mr. Salleh Bin Aboo Hassan,

And all my friends.

For their love, care, advises and supports.

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TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS, SYMBOLS AND NOMENCLATURE

ºC	-	Degree Celsius
ABS	-	Acrylonitrile–Butadiene-Styrene
ANOVA	-	Analysis of Variance
DOE	-	Design Of Experiment
DWV	-	Drain-Waste-Vent
HDPE	-	High-Density Polyethylene
IR	-	Infrared
LDPE	-	Low-density polyethylene
min	-	Minute
mm	-	Millimetre
MPa	-	Mega Pascal
OTHER	-	Other plastics
OA	-	Orthogonal Array
PETE	-	Polyethylene Terephthalate
PP	-	Polypropylene
PS	-	Polystyrene
PSM	-	Projek Sarjana Muda
PVC	-	Polyvinyl Chloride
QC	-	Quality Control
QFD	-	Quality Function Deployment
S/N	-	Signal to Noise
US	-	United States
UTeM	-	Universiti Teknikal Malaysia Melaka
UTM	-	Universal Testing Machine
σ	-	Stress

CHAPTER 1

INTRODUCTION

1.0 Introduction

This chapter is intended to provide background information of the study and general idea of the project. There are four sections cover in the chapter which are background of project, problem statement, objectives and also the project scopes.

1.1 Background of Project

In competition industry, all manufacturing company wants to manufacture low cost but high-quality product in a short period to meet customer requirement. Due to multitude of different types of customers, injection molding plays an important role on mass-producing plastic components to meet the demand of rapidly rising market. The injection-molded plastic parts can be different types of existing products including electronics, medical, furniture, and automobile products. Plastic injection molding is important in plastic production methods because it has highest efficiency and highest dimensional accuracy among all the processing methods. There is a data show that more than half of all polymer processing equipment are used for injection molding and more than a third of all thermoplastic materials are produce by the injection molded manufacturing process (Fei, N.C. et al, 2013). However, it required many delicate adjustments become more complex processes in manufacturing. There are also some defects correlative with current plastic injection molding. Hence, the complexity of injection molding process bring effort to maintain the quality characteristics under control.

Nowadays, manufacturers and customers concern about the product quality while high production rate and high product quality consistency can achieve the industry's goal. The significant task is to select process parameter for achieving high performance in a molding operation. During the production, the lead of defects that affect the quality of injection-molded parts depends on many factors including material selection, mold design, and process parameter settings. Inappropriate combination processing parameters can cause a number of production problems, such as product defects, high production costs much scrap, long lead time, etc., lead to reduce the competitive price advantage, and decrease significant phases which are plasticization, injection, packing, and cooling (Xu, G. et al, 2012). As noted, many process parameters, such as the mold temperature, melting temperature, injection velocity, injection time, injection pressure, packing time, packing pressure, cooling temperature, and cooling time, as the factors influence product quality (Chen, W.C. et al, 2008). Four basic group categories of processing parameters are temperature, pressure, time, and distance involved in injection molding. Usually, the ideal process parameters are determined by use of handbook and based on previous experience. Process parameters are affected on flexural strength of the product. Flexural strength is an estimate of the technological quality of a product and a cause of influences on manufacturing cost.

In this study, an alternative approach is used to determine the desired process parameter based on the Taguchi method. Genichi Taguchi develop a statistical method to improve the quality of manufactured products named Taguchi methods. Recently, it also brings benefits on engineering, biotechnology, marketing and advertising applications (Karna, S.K. et al, 2015).

1.2 Problem Statement

Nowadays, many industries manufacturers are widely use ABS because it is a low-cost engineering plastic that is easy to machine and fabricate. Reduction in cost of products is desirable to maximize the strength of manufactured plastic product. As the use of ABS has increased over the years, the main concern for major organization is to enhance the flexural strength of plastic products by using design of experiments. Unfortunately, no process conditions are currently known for effectively and efficiently optimize the mechanical property of ABS plastic. Even though many researcher studies about ABS, but they're not totally focus on mechanical properties. Therefore, this project was initiated with the main purpose to find out the most significant factor that affect mechanical property in term of flexural strength in ABS plastic product via Taguchi method. The standardized approach Taguchi method can determine the best process to produce high strength products. It analyzes the relationship between controlled parameter and outcome of the product. It also provides a method for quantitatively identifying just the optimal process to make high quality product in the plastic manufacturing industry.

1.3 Objective

There are several objectives which have been identified. Those several objectives are listed as below:

- To identify the most significant factor that affect mechanical property in term of flexural strength in ABS plastic product.
- To optimize the processing conditions by adopting the Taguchi Optimization Method.

1.4 Project Scope

In order to get the best result, this project must be scoped narrower. From the background of this study:

- The material use for injection molding is Acrylonitrile butadiene styrene (ABS).
- The injection experiment is carry out on an injection molding machine.
- The material injects into injection molding with the shape that use is dog-bone shape.
- The mechanical property selected is flexural strength as the quality target for this study.
- The result will be studied for experimental testing using three-point flexural test.
- The Taguchi method and ANOVA is used to define the most significant factor which affect the flexural strength result.
- The orthogonal array and the signal-to-noise are employed to study the performance mechanical characteristics in injection molding process.
- An orthogonal array as reference to setup the experiment by using four-level array L_{16} .
- The value of measured data and desired value is expected to be as large as possible which is larger the better to achieve the maximum strength.
- The experimental parameters factor included are injection pressure, holding pressure, injection speed and holding time.

CHAPTER 2

LITERATURE REVIEW

2.0 Introduction

This chapter describes fully referenced review from the relevant literature. It covers main sections which are plastic, flexural strength, Taguchi method and injection molding.

2.1 Plastic

Plastics transformed everyday life and become a part of our daily lives for a century of history. Plastics use in many aspects of daily life involve and it makes life more convenient. Malleable synthetic or semi-synthetic organic compounds is the main elements in plastic material and it can be molded to make solid objects. They are usually high molecular mass of organic polymers, but they often involve other essences (Lavallee, D., 2016). Many of the plastic are usually synthetic of renewable materials, most commonly derived from petrochemicals. One of the common property of all materials is plasticity that are able to irreversibly deform without breaking, but this happens to such a degree with this class of moldable polymers.

Plastics involved in a tremendous and expanding range of products, from spaceships to paper clips due to its relatively low cost, imperviousness to water, ease of manufacture, and versatility (Mazumdar, S., 2001). Plastics is replaced most of the traditional materials, such as wood, metal, stone, leather, horn and bone, ceramic and glass in many of former applications. About 1/3 of plastic is apply for each in packaging and buildings such as piping used in vinyl siding or plumbing in developed countries. Plastics also bring many benefits on public health. They enable medical devices ranging through surgical equipment, drips, aseptic medical packaging and blister packs for pills and promote clean drinking water supplies. (Andrady, A.L. and Neal, M.A., 2009). However, the field of plastic surgery is more generic meaning of the word plasticity in regard to the reshaping of flesh but not named for use of plastic material. Other uses include automobiles, furniture and toys.

Bakelite is the world's first fully synthetic plastic and called 'the material of thousand uses', invented in New York by Leo Baekeland in 1907 (Meikle, J.L., 1995). The materials science of plastics is contributed by many chemists, including Herman Mark who has been called "the father of polymer physics" and Nobel laureate Hermann Staudinger known as "the father of polymer chemistry" (Teegarden, D.M., 2004). Regarding its slow decomposition rate, the success and dominance of plastics starting in the early 20th century due to its composition of very large molecules led to environmental concerns after being discarded as trash. One way to solve this problem was met with vast efforts toward recycling, toward the end of the century.

2.1.1 Identification of Plastics

Identification of plastics is complex as separating the base resin from the filler, reinforcements, and colorants to analyze via infrared (IR) spectroscopy. Resin identification code (typically on the bottom of the component) can solve and make it become simple. In 1998, the resin identification codes developed by the Society of Plastics Industry are shown in table.

Table 2.1: Classification of Plastic Resin

(Gerdeen, J.C. and Rorrer, R.A., 2011)

Resin	Symbol	Uses
Polyethylene terephthalate (PETE / PET)		Polyester fibers, carpet, furniture, tote bags, bottles, thermoformed sheet, panelling.
High-density polyethylene (HDPE / PE-HD)		Bottles, car stops, grocery bags, base cups, agricultural pipe, milk jugs, recycling bins, plastic lumber and playground equipment.
Polyvinyl chloride (PVC / V)		Lawn chairs, Pipe, fencing, Window profile, Siding, flooring, non-food bottles, shower curtains, and toys.
Low-density polyethylene (LDPE / PE-LD)		6 pack rings, plastic bags, wash bottles, various containers, tubing, dispensing bottles, and various molded laboratory equipment.
Polypropylene (PP)		Auto parts, industrial fibers, dishware and food containers.
Polystyrene (PS)		Desk accessories, cafeteria trays, clamshell containers, packaging peanuts, video cassettes and cases, toys, and insulation board and polystyrene products
Other plastics (OTHER / O)		Headlight, lenses, bottles, plastic lumber applications, and safety shields/glasses.

2.2 Thermoplastics

We can make good decisions when choosing materials by understanding of why various polymers react the way. Thermoplastics, thermosets, and elastomers is the most common three group of classified polymers. The main distinctions between material types is thermoset and thermoplastic. The thermoplastic materials is term usually refers rather than thermosetting. The prefix, “thermo” is relates to how both material types respond to heat. The relatively weak Van der Waals forces held very long chain-like molecules together in a thermoplastic material. The plastic softens to be processed when heated and liquefies as additional heat to reach the temperature above its melt point of the plastic. When cooling and the temperature drops below its melt point of the plastic, it solidifies like a glass solid (Crawford, R.J., 2013). The plastic melting and solidifying process can be repeated as the plastic temperature increases above and decreases without serve damage, allowing reprocessing and recycling.

During the curing process, the difference between thermosetting and thermoplastics polymers is form irreversible chemical bonds. Thermosets decompose which do not melt or reform upon cooling. Thermoset is remain in a permanent solid state once achieved the final state, it would lead to charring on any additional heat (Biron, M., 2012). The glass transition temperature influence the physical properties of a thermoplastic change, when above and below its melting point without a related phase transform. Below the glass transition temperature some thermoplastics do not fully crystallize but retaining amorphous characteristics (Crawford, R.J., 2013). The addition of plasticizers can be decreased the characteristic brittleness and enhances the mobility of amorphous chain sections to lowers the glass transition temperature effectively. Copolymerization or add in non-reactive side chains to monomers able modifies the polymer before polymerization. The problem of plastic automobile parts would frequently flaw when exposed to low temperatures were solved by these techniques. It capable of repeatedly liquidity on heating and solidify on cooling because consists of the linear or slightly branched long chain molecules.

2.2.1 Engineering Plastics

As a comparison, engineering plastics are a type of plastic materials which better than commodity plastics (e.g. polypropylene and polyethylene) in term of mechanical and thermal (Mittal, V., 2011). Engineering plastics include most of thermoplastics as engineering materials. Many traditional engineering materials such as glass and wood have gradually replaced by engineering plastics in many applications.

Engineering plastics are equaling or surpassing due to their light weight and strong strength and other properties. For produce complicated shapes, they also easier to manufacture in simple process step. Every type engineering plastic has a special combination of properties that may make the difference selection material in difference application. Heat resistance, chemical stability, mechanical strength, self-lubrication, rigidity and fire safety are the properties exhibited by various grades of engineering plastics.

2.2.2 Commodity Plastics

Most of the thermoplastics are commodity plastics. Examples of commodity plastics included polyethylene, polypropylene, polystyrene, polyvinyl chloride, polymethyl methacrylate and other. It is use widely and beneficial in a lot of typical applications, such as film for clothing, packaging, beverage and trash containers, photographic and magnetic tape, and many types of household products where mechanical properties and service environments are not critical. The consumer goods can be made by commodity plastic are cups, plates, containers, carrying trays, seeding trays, medical trays, printed material and other disposable things. This plastic are high production volume, low cost and relatively low mechanical properties.

2.3 Acrylonitrile Butadiene Styrene (ABS)

Acrylonitrile butadiene styrene (ABS) is a terpolymer (three-way polymer), chemical formula $(C_8H_8)_x \cdot (C_4H_6)_y \cdot (C_3H_3N)_z$. ABS also is an examples of engineering plastics. Styrene Acrylonitrile copolymers were available since 1940's, but introduction of a Butadiene as a third component in the 1950s created a range of ABS plastics.

In the presence of polybutadiene, it made with combination of polymerizing styrene and acrylonitrile. The usual ratio of materials of ABS is around 15 to 35% acrylonitrile, 5 to 30% butadiene and 40 to 60% styrene (Kumar et al., 2010). The resulting polymer is consisting of short chains of polystyrene-co-acrylonitrile mixed with a long chain of polybutadiene. ABS glass transition temperature is about 105 °C (221 °F). It is amorphous and therefore has no accurate melting point. For the majority of applications, mechanical properties of ABS used vary with temperature in the range of −20 to 80 °C (−4 to 176 °F).

It is stronger than polystyrene due to the short chains bond by nitrile monomers. The reason of ABS stronger than pure polystyrene is the nitrile groups being polar attract each other and link the chains together from nearest chains. The Acrylonitrile imparts chemical resistance and surface hardness, Butadiene conduces the impact strength and over all toughness, and Styrene helps in processing. ABS integrate the strength and rigidity of acrylonitrile and styrene polymers with the toughness of poly-butadiene rubber (La Mantia, F., 2002). As a result, ABS are tough, lightweight and rigid thermoplastic that has great in term of impact and mechanical strength.

The rubber toughening was produce the properties, where meticulous particles of elastomer are distributed throughout the rigid matrix. ABS plastics are self-extinguishing, but flammable at high temperatures. It melts and boils, when its vapours may burst into flames. On burning ABS does not produce any organic pollutants except carbon monoxide and hydrogen cyanide.