DEVELOPEMENT OF ULTRASONIC ASSISTED COMPRESSION MOULDING MOULD

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

(Manufacturing Process) (Hons.)

By

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DECLARATION

I hereby, declared this report entitled "Developement of Ultrasonic Assisted Compression Moulding (UACM) Mould" is the results of my own research except as cited in references.

Signature : .....

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Date : 19 June 2017

APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of Universiti Teknikal Malaysia Melaka as a partial fulfillment of the requirements for the degree of Bachelor of Manufacturing Engineering (Manufacturing Process) (Hons.). The members of the supervisory committee are as follow :

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(Principal Supervisor)

ABSTRAK

Secara umum, kebanyakan barang getah yang dihasilkan melalui pengacuan, satu proses di mana getah belum diawet akan diawet di bawah tekanan dalam acuan. Terdapat tiga teknik pengacuan yang umumnya digunakan iaitu mampatan, pemindahan dan acuan suntikan. Dari ketiga-tiga teknik, pengacuan mampatan adalah lebih baik dari segi kebolehpercayaan dan produktiviti. Dalam pengacuan mampatan, pra-ditimbang, pada umumnya bentukkan terlebih dahulu sekeping diletakkan di dalam acuan; acuan ditutup, dengan getah di bawah tekanan, kerana ia perihal memanaskan getah dengan sulfur supaya keras. Walau bagaimanapun, proses pengacuan mampatan boleh diganggu oleh proses pengawetan yang menyebabkan pengecutan, gelembung, kurang kekuatan dan sambung silang. Oleh itu, meningkatkan keupayaan proses pengacuan mampatan adalah matlamat utama untuk meningkatkan getah dari segi prestasi. Salah satu teknik yang mungkin dengan menggunakan getaran ultrasonik pada acuan yang dikenali sebagai UACM semasa pengawetan peringkat matlamat untuk meningkatkan kepekatan tekanan dan keseragaman pada getah. Ini tesis dengan pembangunan dibantu proses pengacuan mampatan ultrasonik untuk / etilena propilena diene monomer (NR / EPDM) bahan Getah asli. Keberkesanan teknik UACM sedang dinilai berdasarkan sebahagian kekuatan dan ketumpatan silang faktor. Di samping itu, Metodologi Respon Permukaan statistik diambil khidmat sebagai reka bentuk eksperimen untuk menilai kepentingan mampatan membentuk parameter iaitu suhu, tekanan, masa dan kuasa ultrasonik pada jawapan. Dari siasatan yang dijalankan, ia menunjukkan bahawa UACM mampu untuk meningkat bahagian prestasi berbanding acuan konvensional. Kehadiran getaran ultrasonik dipertingkatkan kepekatan tekanan dan keseragaman kepada getah pada peringkat pengawetan yang bertambah baik dengan ketara bahagian getah. Di samping itu, dari hasil statistik menunjukkan bahawa tekanan dan masa

ketara memberi kesan kepada bahagian persembahan. Multi-objektif pengoptimuman dilakukan melalui pengoptimuman berangka dan hasil yang diramalkan disahkan dengan perjanjian 90%.

ABSTRACT

In general, most of the rubber articles are produced by moulding, a process in which uncured rubber is cured under pressure in a mold. There are three moulding techniques that are generally employed namely compression, transfer and injection moulding. From those three techniques, compression moulding are preferable in terms of reliability and productivity. In compression moulding, a pre-weighed, generally preformed piece is placed in the mould; the mould is closed, with the rubber under pressure, as it vulcanizes. However, the compression moulding process can be disturbed by the curing process that cause shrinkage, bubble, poor strength and crosslink. Thus, enhancing the capability of the compression moulding process are necessary aim to increase the rubber part performances. One of the possible technique are by employing the ultrasonic vibration at the mould known as UACM during the curing stage aim to enhanced the pressure concentration and uniformity on the rubber. This thesis deals with the development of ultrasonic assisted compression moulding process for Natural rubber/ethylene propylene diene monomer (NR/EPDM) material. The effectiveness of theUACM technique are evaluate based on the part strength and crosslinking density factor. In addition, a statistical Response Surface Methodology are employed as the design of experiment to assess the significance of the compression moulding parameter i.e. temperature, pressure, time and ultrasonic power on the responses. From the conducted investigation, it shows that UACM are capable to increased the part performances compared to the conventional mould. The presence of the ultrasonic vibration enhanced the pressure concentration and uniformity on the rubber during the curing stage which significantly improved the rubber part. In addition, from the statistical results indicated that pressure and time significantly affect the part performances. Multi-objectives optimisation

is performed through numerical optimisation and the predicted result are validated with 90% agreements.

DEDICATION

To my father, Jamaludin Bin Jantan, my mother, Hazlina Binti Ismail, my siblings and friends. Your love is my driving force.

To my supervisor Dr. Raja Izamshah Bin Raja Abdullah and all staffs in UTeM.

Thank you for your supports, guidance, helps and cooperation whether directly and indirectly

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LIST OF ABBREVIATIONS, SYMBOLS AND NOMENCLATURE

UACM	-	Ultrasonic Assisted Compression Moulding
ANOVA	-	Analysis of Variance
ASTM	-	American Society for Testing and Materials
DoE	-	Design of Experiment
F	-	F Test (ANOVA)
P	-	P-test (ANOVA)
UTS	-	Ultimate Tensile Strength
CD	-	Crosslinking Density

CHAPTER 1
INTRODUCTION

1.1 Background of Project

Compression moulding is one of the rubber moulding technique in which the moulding material, are formed in a closed cavity. The mould is closed with a top pressure, weight is associated to drive the material into contact with all shape, while warmth and pressure are still sustain until the trim material has cured. Compression moulding is a process that can form large and it is very complicated parts because using heat and pressure. Mostly, compression moulding requires consistent pressure from any surface to form the part. The material need to preheated first and placed mould cavity that already heated, which frequently is heated through heated platens in a press, and may be cooled at a certain rate depending on the requirement. The mould is closed when the material is put inside cavity of mould, pressure is given to force the material inside the mould to combine, and heat and pressure are constant until the moulded material has cured. Because of compression moulding uses heat and pressure to change the material properties inside the mould, it is suitable for forming the difficult form, high-strength, adhesive compounds for customized applications.

EPDM Rubber means that it is as ethylene propylene rubber, appropriately referred to in synthetic terms as ethylene propylene diene monomer. EPDM is the quickest developing elastomer among the manufactured rubbers since its presentation in 1963 it speaks to 7% of the world elastic utilization and it is the most generally utilized non-tire elastic (Hussain et al., 2010). EPDM rubber was one of the succeed manufactured advancements of the

twentieth century. The rubber had been a backbone of the world economy. Such a large number of items utilized normal elastic that it was outlandish not to go over one on any given day. Nowadays, an expanding number of enterprises utilize EPDM sheet rubber in items that need both flexibility and UV and ozone resistances. EPDM obstacle to weathering is the material's characterizing highlight that separates it from most different elastomers. Like most rubbers, ethylene propylene rubber is easy delivered and can be fabricated in many structures, including EPDM sheet rubber and adhesives. In this manner, to pick the suitable rubber it depends less on shape and more on the rubbers qualities or characteristics.

Natural rubber rules as the most physically solid elastomer. It has an amazingly low pressure set, high rigidity, staggering lengthening, and a high resistances to scraped areas. Most elastomers cannot measure up to normal elastic in such classes. While EPDM has not too bad physical properties, they can not be distinguished level from natural rubber. In any case, EPDM elastic can boast about its resistances to UV and ozone.

Mechanical longitudinal waves that accomplish disfigurement in plastic materials and cause grinding between atoms means for ultrasonic vibrations. The subsequent grating warmth produces a liquefy that bonds the joining accomplices inside the particles. Friction happens because of impedances in the material and impression of the mechanical vibration is inward rubbing in the atom bond which is dissipative work. Furthermore, outside erosion between joining accomplices for surface grinding.

Ultrasound have been used in various place like ultrasonic welding to combine the plastic components, hot embossing to emboss geometry or feature on a polymer or to enhance the cooling time in compression moulding and injection moulding. Ultrasonic moulding with a good results despite polymer degradation was found under certain merger of parameters. Function of ultrasound in ultrasonic moulding process is to melt the material inside the cavity of mould. The sonotrode will go to downward into the plasticizing chamber and the vibration from ultrasonic frequency which is 30kHz will melting the material when the sonotrode is contact with the material. The sonotrode pushes the melted material into the mould cavity and gives the pressure. There have several phases with specific process. Firstly, the material that contact with sonotrode will starts to melt and move to the material that in a solid form.

Second, phase that the material completely melted and it will fill in mould cavity. Third phase, the material fill inside the mould cavity and cooling stage will cover and starts. At the cooling time, the location of the sonotrode still same in its lowest location and produces a compaction pressure the material and mould. Lastly, the sonotrode move back to the initial position and when the mould is opened, the plunger rises and push up the part to extract it. Ultrasonic moulding has a some advantages. It can melt the small things using minimum pressures and make a parts just in a short time or second, which means a very short process time compared with conventional compression moulding. The required amount of material to fill inside the mould cavity is just the required for the part, because the material is directly introduced inside this cavity

The compression moulding parameters such as heating time, pressure, mould temperature, amplitude, and frequency are optimized on the reducing the output of the response such as shrinkage, ozone cracking, residual stress and filling time. The DoE method using Taguchi and ANOVA are implemented to design the experimental matrix and to optimize the level of input parameter. Meanwhile, ANOVA is needed to find the most significant parameter affected the responses.

1.2 Problem Statement

Compression molding is a high-volume and high-pressure manufacturing method; especially for irregular-shaped products made of high strength fiber reinforced composites. Compression molding are widely used for producing automotive parts, such as rubber mounting, bumpers, engine covers, spoilers and other complex and tiny parts. The process of compress molding begins with placing preheated material on the cavity and then compressed by the core side of the mold to deform and occupy the cavity as shown in Figure 1. Comparing with resin transfer molding or injection molding, the advantage of compressive molding is low in cost especially for huge and complex products due to the least wasted material.

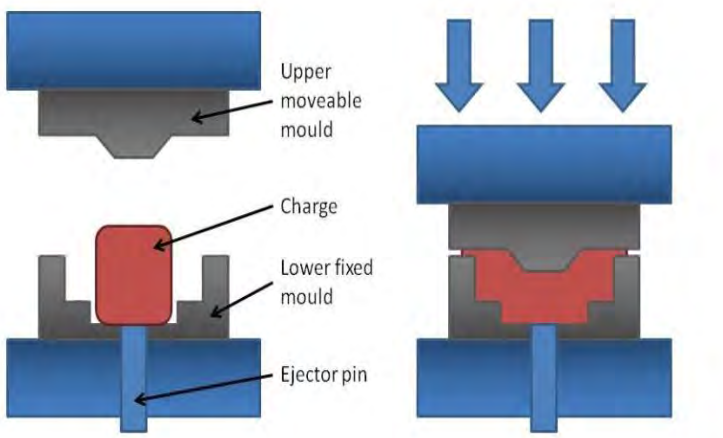

Figure 1. 1 Compression molding technique

However, the main disadvantages of this process are the part inconsistency which is directly related with the process parameter that makes this method less sustainable. Two major problems that are associated with compression of elastomer material are distortion and shrinkage. Due to the flexible nature of rubber material, and the fact that it is affected by temperature, it is possible for distortion to occur when the rubber part is removed from the mold through the process of stretching it over a core. Shrinkage is the measurement of difference between two corresponding linear dimensions of both the rubber mold and the molded rubber part at room temperature. All rubber materials will display some level of shrinkage after the rubber part is molded and subsequently exposed to cooler temperatures.

Shrinkage rates in individual compounds, however, will depend the rubber compound itself and will be affected by variables like cure time, rubber batch variance, temperature, post cure, pressure and the presence of inserts.

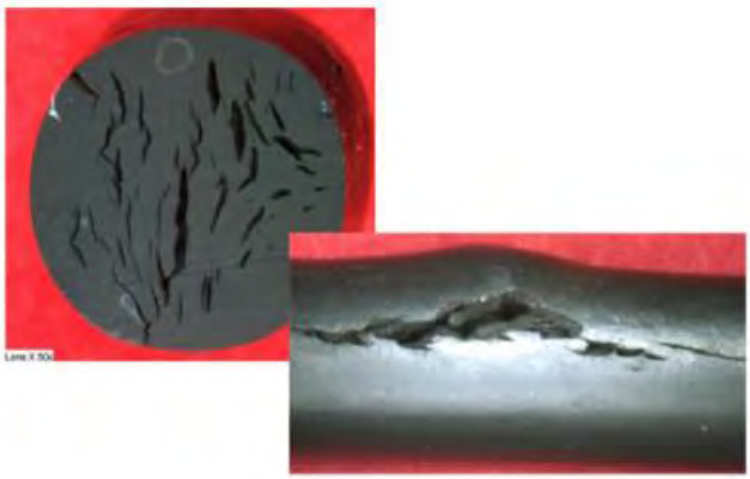

Figure 1. 2 Distortion and shrinkage on rubber component due to insufficient pressure and temperature

The controlling parameters in compression molding method to develop superior and desired properties of the composite are shown in Figure 3. All the three dimensions of the model (pressure, temperature and time of application) are critical and have to be optimized effectively to achieve sustainable tailored composite product as every dimension of the model is equally important to other one. If applied pressure is not sufficient, it will lead to poor interfacial adhesion of fiber and matrix. If pressure is too high, it may cause fiber breakage, expulsion of enough resin from the composite system. If temperature is too high, properties of fibers and matrix may get changed. If temperature is low than desired, fibers may not get properly wetted due to different viscosity. If time of application of these factors (pressure and temperature) is not sufficient (high or low), it may cause any of defects associated with insufficient pressure or temperature. The other manufacturing factors such as mold wall heating, closing rate of two matched plates of the plates and de-molding time also affect the production process.

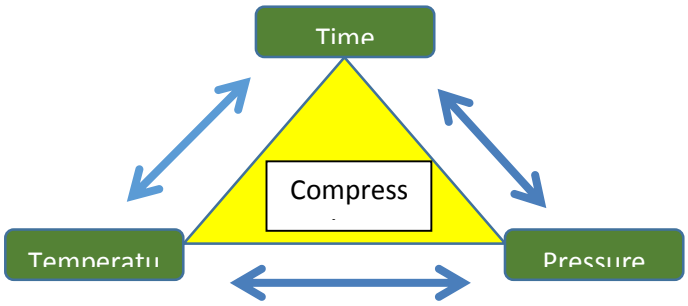

Figure 1. 3 Critical process parameter of compression molding method

Thus, enhancing the capability of the compression moulding process are necessary aim to increase the rubber part performances. One of the possible technique are by employing the ultrasonic vibration at the mould known as UACM during the curing stage aim to enhanced the pressure concentration and uniformity on the rubber.

1.3 Objective of Project

The objective of this study are:

1. To design and fabricate an ultrasonic assisted compression moulding mould (UACM)
2. To study on the effectiveness of the UACM technique on the NR/EPDM part in terms of tensile strength and crosslinking density.
3. To optimize the processing parameters by using Response Surface Methodology (RSM) and validate the effectiveness of the optimized value.

1.4 Scope of Project

The project studies for final project to design and fabricate Ultrasonic Assisted Compression Moulding for part of vehicle that make it good quality of product. The experimental matrix and optimization input level of this experiment used Design Expert and Analysis of Variance (ANOVA). For the design of mould, Computer Aided Design (CAD) software is used. Data are analysed using Box-Behnken design in order to determine the significant parameter to the output responses. Will do some tensile process to reviewing whether the durability is good or not. In addition, will measure the mass of NR/EPDM and study the effect of crosslinking density.

1.5 Outline of Project

There are five chapters for PSM 1 covered of introduction, literature review and methodology. Chapter 1 is contain of introduction, problem statement, objectives, and scope of the project

Chapter 2 is covered of the literature review based on the gathered of references like journals, books, website and so on. It will discuss about the information that needed for this project.

Chapter 3 is will discussing about of research methodology review.

Chapter 4 is about analyse and discuss the result that got from the experiment.

Chapter 5 is about conclusions and future work.

CHAPTER 2
LITERATURE REVIEW

2.1 Introduction

This chapter include of the literature review that give some information of the project which is follow the objectives and scope of the project. In this chapter will study about a material like natural rubber (NR), ethylene propylene diene monomer (EPDM), and NR/EPDM. In addition, in this chapter will study about the type of compression moulding, hot press machine, ultrasonic mechanism, and so on.

2.2 Rubbers

Rubber is a polymer that has the ability to get back its original shape after being change or deformed. The materials recognized as rubber, natural rubber, and various synthetic compounds are amorphous solids composed of long polymers. Nowadays, the natural rubber and synthetic rubber are two type of rubber that used until now. Natural rubber is actually from original rubber tree and synthetic rubber are a rubber that created from the various petroleum-based monomers.