Faculty of Manufacturing Engineering

OPTIMIZATION OF COMPRESSION MOLDING PROCESS FOR MIXING NATURAL RUBBER WITH SYNTHETIC RUBBER

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OPTIMIZATION OF COMPRESSION MOLDING PROCESS FOR MIXING NATURAL RUBBER WITH SYNTHETIC RUBBER

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DECLARATION

I declare that this thesis entitled "Optimization of Compression Molding Process for Mixing Natural Rubber with Synthetic Rubber" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : .....

Name : Muhammad Zaki Bin Kasman

Date : 12 July, 2021

APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Master of Science in Manufacturing Engineering.

Signature : 

Supervisor Name : Associate Professor Dr. Mohd Shahir Bin Kasim

Date : 12 July, 2021

DEDICATION

My beloved father, mother, family, supervisor, and supportive friends accompany me along the problematic pathway in my university life.

ABSTRACT

NR/EPDM mixed development has continuously grown due to its superior physical characteristics and good weathering resistance, especially zoning. EPDM offers improved chemical resistance and oxidation, whereas NR has great strength and excellent dynamic characteristics. Through different procedures, such as latex dippers and extruding and calendaring, compression moldings, these rubber-based goods may be produced. For economic reasons, compression molding is an important method. The major problem of this procedure is that portion of the discrepancy is directly linked to the process parameter, which makes this technique less sustainable. Distortion and shrinking are two main issues related to elastomer compression. Because of the flexibility of the rubber material and the temperature that affects the material, it may become distorted by removing the rubber portion from the mold by deepening it. Furthermore, the reduction is the result of a restricted period for solidified material. Micro-fractures developed beneath the optical microscopic images on the rubber surface. This work focuses in this field on the investigation of the parameters of compression molding (i.e., temperature, pressure, heating time, and pressure time) and their impact on the mechanical characteristics of NR/EPDM elastomers (i.e., ultimate tensile strength (UTS), cross-lines and exenteration errors). The aim of the research is to determine optimal settings for processing compression molding. The optimization is accomplished using RSM and the Box Behnken technique as experimental design for a total of 29 runs. A mathematical model for each response is developed to access the relationship between the parameters. Furthermore, in the measurement of important input variables and potential interactions, the suitability of the models is statistically evaluated using an analysis of variance (ANOVA). Finally, numerical optimization is used to optimize several objective outcomes and verify anticipated results. Between 93% and 96%, there is a strong agreement between the experimental combinations and the chosen parameter combinations, confirming the solution as an optimum running condition. The results show that temperature and heating are the major components that affect ultimate tensile strength, while there is just one important temperature parameter for cross-link density. The temperature of UTS and link density decreases with the deterioration of the heat (the temperature is too high for NR/EPDM). Therefore, the procedure under the NR/EPDM degrading point is suggested to prevent scissoring rubber to improve the mechanical characteristics afterward.

PENGOPTIMUMAN PROSES PEMAMPATAN ACUAN UNTUK GETAH CAMPURAN GETAH ASLI DENGAN GETAH SINTETIK

ABSTRAK

Perkembangan campuran NR / EPDM terus berkembang kerana ciri fizikalnya yang unggul dan ketahanan cuaca yang baik, terutamanya pengezonan. EPDM menawarkan ketahanan dan pengoksidaan kimia yang lebih baik, sedangkan NR mempunyai kekuatan hebat dan ciri-ciri dinamik yang sangat baik. Melalui prosedur yang berbeza, seperti pencelup lateks dan penyemperitan dan penentukuran, pengacuan pemampatan, barang-barang berasaskan getah ini dapat dihasilkan. Atas sebab ekonomi, pengacuan pemampatan adalah kaedah penting. Masalah utama prosedur ini adalah bahawa bahagian perbezaan berkaitan dengan parameter proses, yang menjadikan teknik ini kurang mapan. Herotan dan pengecutan adalah dua masalah utama yang berkaitan dengan pemampatan elastomer. Oleh kerana kelenturan bahan getah dan suhu yang mempengaruhi bahan, bahan tersebut boleh menjadi herot dengan mengeluarkan bahagian getah dari acuan dengan memperdalamnya. Tambahan pula, pengurangan tersebut adalah hasil jangka masa terhad untuk bahan pepejal. Retakan mikro berkembang di bawah gambar mikroskopik optik pada permukaan getah. Karya ini memberi tumpuan pada penyiasatan parameter pengacuan pemampatan (iaitu suhu, tekanan, masa pemanasan, dan masa tekanan) dan kesannya terhadap ciri mekanikal elastomer NR / EPDM (iaitu, kekuatan tegangan muktamad (UTS) , garis silang dan kesalahan eksentasi). Tujuan penyelidikan adalah untuk menentukan tetapan optimum untuk memproses pengacuan pemampatan. Pengoptimuman itu dilakukan dengan menggunakan RSM dan teknik Box Behnken sebagai reka bentuk eksperimen untuk keseluruhan 29 larian. Model matematik untuk setiap tindak balas dikembangkan untuk mengakses hubungan antara parameter. Selanjutnya, dalam pengukuran pemboleh ubah input penting dan interaksi yang berpotensi, kesesuaian model dinilai secara statistik menggunakan analisis varians (ANOVA). Akhirnya, pengoptimuman berangka digunakan untuk mengoptimumkan beberapa hasil objektif dan mengesahkan hasil yang dijangkakan. Di antara 93% dan 96%, ada kesepakatan yang kuat antara kombinasi eksperimen dan kombinasi parameter yang dipilih, yang mengesahkan penyelesaiannya sebagai keadaan berjalan yang optimum. Hasilnya menunjukkan bahawa suhu dan pemanasan adalah komponen utama yang mempengaruhi kekuatan tegangan utama, sementara hanya ada satu parameter suhu penting untuk ketumpatan pautan silang. Suhu UTS dan ketumpatan pautan berkurang dengan kemerosotan haba (suhu terlalu tinggi untuk NR / EPDM). Oleh itu, prosedur di bawah titik penurunan NR / EPDM disarankan untuk mengelakkan gunting getah untuk memperbaiki ciri-ciri mekanikal getah tersebut.

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Muhammad Zaki Bin Kasman,

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LIST OF ABBREVIATIONS

ANOVA	-	Analysis of Variance
ASTM	-	American Society for Testing and Materials
BIIR	-	Bromobutyl Rubber
CIIR	-	Chlorobutyl Rubber
CM	-	Compression Molding
CR	-	Chloropene Rubber
DOE	-	Design of Experiment
DRC	-	Dry Rubber Content
EPDM	-	Ethylene Propylene Diene Monomer
EPM	-	Ethylene Propylene Monomer
HT	-	Heating Time
IR	-	Isoprene Rubber
IIR	-	Butyl Rubber
ISO	-	International Standard Organization
Max	-	Maximum
Mc	-	Crosslink Molecular Weight
NBR	-	Nitrile Rubber
NR	-	Natural Rubber
NR/EPDM	-	Natural Rubber/Ethylene Propylene Diene Monomer

PT	-	Pressure Time
Q	-	Silicone Rubber
Qm	-	Weight of NR/EPDM Blends
R	-	Residual
RSM	-	Response Surface Methodology
SBR	-	Styrene Butadiene Rubber
T	-	Temperature
UTS	-	Ultimate Tensile Strength
Vc	-	Crosslink Density
Vs	-	Gasoline (Solvent) Molar Volume
Vr	-	Swollen Rubber Volume Fraction

LIST OF SYMBOLS

°F	-	Fahrenheit
%	-	Percentage
°C	-	Degree celsius
Cal/cc	-	Calories/cubic centimeter
cm	-	Centimeter
g	-	Gram
m	-	Millimeter
MPa	-	Mega Pascal

LIST OF PUBLICATIONS

Journal article:

1. Izamshah, R., Kasman, M.Z., Kasim, M.S., Rafiq, M., and Aziz, M.S.A., 2020. Optimisation of Compression Moulding Parameter for NR/EPDM Material. *International Journal of Recent Technology and Engineering*, 9(1), pp. 1-6.

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Conference proceedings:

1. Kasman, M.Z., Abdullah, R.I.R., and Kasim, M.S., 2018. Optimization of Compression Molding Process for NR/EPDM Elastomeric Material. *Proceeding of Innovative Research and Industrial Dialogue, Melaka*, pp. 250-251.

CHAPTER 1

INTRODUCTION

1.1 Research Background

Natural rubber/ethylene propylene diene monomer (NR/EPDM) is widely used in the automotive industry (>40%), construction application (>5%), and lubricant additive applications (>4%), and the demand keep increasing up to the year of 2024 (Appendix A). It consists of two types of rubber, namely natural rubber (NR), which comprises the blending of ethylene propylene diene monomer (EPDM) to enhance physical properties.

NR has high strength, reasonable competitive price, and excellent dynamic properties (Botros, 2002), whereas EPDM has excellent chemical and weather resistance, in particular ozone attacks (Sahakaro et al., 2009). Thus, the blending between NR and EPDM has given combined advantages of both materials.

Various forming processes such as injection molding, vacuum forming, compression molding, and extrusion blow molding are involved in producing rubber material products. Each process has its distinct advantages. For example, the compression molding process can produce high-volume products with high accuracy and repeatability (Collyer, 2016).

The compression molding process, a traditional and straightforward process, has already been introduced since the twentieth century. Surprisingly, its application is still relevant in today's automotive manufacturing. The process begins by placing the billet raw material into the mold. While the billet is pressed, the heat is applied to form the product as per the designed mold.

In the compression molding process, the parameters that control the process are critical to ensure the rubber products meet the requirement. Based on the literature, four main dominating parameters, namely; mold temperature, clamping pressure applied heating time, and holding heating time (Roze and Zhigun, 1973; Dixit et al., 2015; Gabrion et al., 2016; Ding et al., 2017; Xie et al., 2019), affect the mechanical characteristics of the compression molding products.

This thesis focuses on observing the effect of process parameters on the physical quality of NR/EPDM parts. The factors that have been identified for optimized parameters as well as for composing desired objectives. In order to perform the experimental study, Kandar and Akil (2016) found that a suitable strategic approach can minimize experiment time and waste of material used. Hence, the Design of Experiment (DOE) approach was embedded to perform an experimental design scheme. The Box Behnken DOE of response surface methodology (RSM) type was used by using Design Expert statistical software.

1.2 Problem Statement

Generally, the performances of the elastomeric damping material are closely related to its manufacturing/processing steps. Therefore, various processes exist for manufacturing rubber products, and this has attracted many industries to test and determine the best parameter that should be applied to get a good product in terms of mechanical and physical properties so that service life and cost can be improved. Commonly, for economic reasons, rubber is preferably manufactured by the compression molding technique, in which the process is conducted by forming the rubber, which involves heat and stress in the mold. However, the drawback of this technique is inconsistency in part quality, which is directly related to the process parameters that make this method ineffective.