TENSILE PROPERTIES AND SWELL BEHAVIOURS OF NATURAL RUBBER MODIFIED BY STARCH FOR BIODEGRADABLE RUBBER PRODUCT

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

by

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Date : 22 June 2017

APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of Universiti Teknikal Malaysia Melaka as a partial fulfilment of the requirement for Degree of Manufacturing Engineering (Engineering Materials) (Hons). The member of the supervisory committee are as follow:

…….....

(Prof. Madya Dr. Noraiham binti Mohamad)

ABSTRAK

Vulkanizat getah adalah bahan yang sering digunakan didalam produk berasaskan getah. Masa kini, keperluan terhadap produk getah yang boleh mereput secara semulajadi telah meningkat. Kajian ini mengkaji keupayaan potensi vulkanizat getah asli diubahsuai dengan kanji untuk produk getah yang mesra alam bagi sifat tegangan dan pengampulan dalam larutan. Getah asli dan kanji dicampurkan melalui proses penyebatian untuk menilai masa pematangan vulkanizat getah asli yang mengandungi variasi kanji. Sifat-sifat fizikal dan mekanikal dari segi sifat tegangan dan pengampulan dalam larutan telah ditentukan dengan menggunakan ujian tegangan dan ujian pengampulan untuk kanji yang berbeza yang dimasukkan ke dalam matriks getah. Ujian pengampulan telah dilakukan dengan cara merendam sampel vulkanizat getah asli yang diubahsuai dengan kanji dalam dua jenis pelarut terdiri dari pelarut berkutub (air suling dan natrium klorida) dan pelarut tidak berkutub (toluena dan n-heptana) selama 28 hari. Sampel kemudian dianalisis dengan menggunakan analisis morfologi yang menggunakan mikroskop optik (OM) dan mikroskop elektron pengimbas (SEM) manakala pencirian getah dan serbuk kanji asli mentah telah dilakukan dengan kaedah analisis pembelauan sinar-X (XRD). Ia dapat diperhatikan bahawa, semakin meningkat jumlah kanji didalam vulkanizat getah, masa skorj dapat dikurangkan serta dapat meningkatkan kebolehan pemprosesan. Disamping itu, apabila meningkat jumlah kanji didalam vulkanizat, pengurangan yang tidak ketara sebanyak 11 % dapat dilihat pada kekuatan tegangan pada jumlah kanji 20 phr. Pengurangan ini adalah disebabkan oleh sampel vulkanizat mengalami pengurangan dari segi keupayaan penghabluran. Dari ujian pengampulan, vulkanizat getah yang mengandungi kanji yang direndam didalam pelarut tidak berkutub terdiri daripada toluena dan n-heptana menunjukkan ketinggian peratusan dalam pengampulan iaitu sebanyak 183.33% berbanding dengan pelarut berkutub contohnya natrium klorida dengan 6.71% selepas rendaman selama 28 hari dengan jumlah kanji 60 phr. Pemerhatian ini telah dijangkakan disebabkan oleh sifat hidrophilik pada kanji dan sifat hidrophobik pada getah asli yang semulajadi. Hasil kajian yang diperolehi adalah penting untuk membuktikan bahawa vulkanizat getah yang mengandungi kanji sesuai digunakan sebagai bahan gantian untuk produk getah sedia ada.

ABSTRACT

Rubber vulcanizates is common material that widely used for rubber-based product. Nowadays, the need of biodegradable rubber products have increased. This research aimed to investigate the tensile properties and swell behaviours of natural rubber modified by starch for biodegradable rubber product. The natural rubber filled with starch were compounded through melt compounding process in order to assess cure characteristics of natural rubber vulcanizates which contain variations of starch loading. The physical and mechanical properties in terms of tensile properties and swelling behaviour was determined by using tensile test and swelling test for different loading of starch that was incorporated into the rubber matrix. The swelling test was performed by immersion of the natural rubber vulcanizates modified by starch samples in two types of solvent comprises of polar group solvent (distilled water and sodium chloride) and non-polar group solvent (toluene and n-heptane) for 28 days. The samples then be analysed by using morphological analysis which were optical microscopy (OM) and scanning electron microscopy (SEM) while the characterization of raw natural rubber and starch powder was done by X-ray diffraction method (XRD) analysis. It was observed that, the higher the starch loading in natural rubber vulcanizates, can reduce the scorch time and hence achieving higher processing ability. In addition, as the starch content increase in the vulcanizates, only 11 % decrement was observed in tensile strength at 20 phr of starch loading. The decrement in tensile strength was mainly due to the lower crystallinity exhibit by the vulcanizates samples. From swelling test, rubber vulcanizates filled starch which was immersed in non-polar group of solvent consist of toluene and n-heptane shows higher percentage of swelling which is 183.33% as compared to polar group such as sodium chloride with only 6.71 % after 28 days of immersion period at 60 phr starch loading. This observation was expected due to hydrophilicity of starch and hydrophobicity of natural rubber characteristics in nature. The results are significant which proved that starch modified natural rubber has potential to be used as replacement material for existing rubber product.

DEDICATION

Only
my beloved father, Mahadi Bin Safei
my beloved mother, Norhayati Binti Ismail
my lovely siblings,
for giving me moral support, money, cooperation, encouragement and also understandings
Thank You So Much & Love You All Forever

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

NR	-	Natural rubber
UV	-	Ultraviolet
CB	-	Carbon black
PALF	-	Pineapple leaf fibre
ARI	-	Abrasion resistance index
PSP	-	Peanut shell powder
TGA	-	Thermogravimetric Analysis
SSP	-	Snail shell powder
D	-	Diffusion coefficient
DOE	-	Design of experiment
SMR	-	Standard Malaysian Rubber
RRIM	-	Rubber Research Institute of Malaysia
MDR	-	Moving Die Rheometer
ASTM	-	American Society for Testing and Materials
OM	-	Optical Microscopy
SEM	-	Scanning Electron Microscopy
FTIR	-	Fourier Transform Infrared Spectroscopy
XRD	-	X-ray Diffraction

DSC	-	Differential Scanning Calorimetry
CV	-	Conventional vulcanization
SEV	-	Semi-efficient vulcanization
EV	-	Efficient vulcanization
CED	-	Cohesive energy density

LIST OF SYMBOLS

°C	-	Degree celcius
g cm^{-3}	-	Density
K^{-1}	-	Thermal expansion coefficient
bar^{-1}	-	Atmospheric bar
W m^{-1} K^{-1}	-	Thermal conductivity
J kg^{-1} K^{-1}	-	Specific heat capacity
kHz	-	Kilohertz
S m^{-1}	-	Conductivity
Pa	-	Pascal
Mpa	-	Mega Pascal
Phr	-	part per hundred rubber
χ	-	Interaction parameter for natural rubber in a good solvents
V_s	-	Molar volume of the solvent
V_r	-	volume fraction of rubber in swollen gel
g	-	gram
M_L	-	Minimum torque
M_H	-	maximum torque
T_{S2}	-	scorch time

Kgf	-	kilogram force
2Ө	-	2 theta

CHAPTER 1

INTRODUCTION

This chapter briefly describe the background of study, problem statement, objectives, scope, project significance, organization of report and summary.

1.1 Background of study

Over the years, polymeric materials specifically rubber is widely used in many industrial applications. Rubber can sustain amount of force where it can be stretched up to 200 percent from the original length and able to return back to the original state after force is removed (Lawrence, 2013). There are two types of rubber elastomers which is natural rubber and synthetic rubber (Hertz, 2001).

Natural rubber is latex produced from rubber tree called Hevea Brasiliensis. The physical features of natural rubber are soft and sticky. It tends to be soft when exposed in a room temperature and hardens in cold weather (Thomas, 2014). As compared to synthetic rubber, natural rubber is renewable product with various useful properties such as high green strength, high tensile strength, low heat hysteresis and high damping. Natural rubber latex mainly consists of 30-40% rubber, 50-60% water and 5-6% non-rubber components (Smitthipong et al., 2016). Due to the good characteristic of natural rubber, it has been an important industrial raw material to four key areas which is medical devices, industrial

products, domestic and recreational goods and automobile products (Mohanty, 2005). It is also used in heavy duty task as it is able to crystallize under tensile deformation (Zhao et al., 2016). There are at least 40000 different products made from natural rubber. Despite many synthetic rubber that have been produced which is derived from petroleum to make rubber products, natural rubber seems to be demanded as product that required higher performance need a greater amount of natural rubber component (Shinzo, 2014).

In addition, natural rubber is vulcanized to create a crosslink between the chains with the addition of other materials such as sulphur, fillers and antioxidants as to improve the properties and change the soft and sticky natural rubber into vulcanized natural rubber which is hard, non-sticky, elastic and flexible when stretching as well as do not easily dissolve in organic solvents (Thomas, 2014). Although natural rubber seems to exhibit outstanding properties, fillers are often added to this matrix so as to improve the modulus, hardness, wear resistance as well as reduce the material cost (Yu et al., 2016).

Fillers represent one of the most important additives used in rubber compounding to achieve desired properties and applied in rubber industry to mix with natural rubber (Sridharan & Elangovan, 2013). The addition of fillers will affect the fracture and fatigue of rubber vulcanizes. Meanwhile, size, shape, surface activity, filling fraction and dispersion morphology in rubber matrix will also affect the behaviours of rubber vulcanizes (Liu et al., 2012). Currently, Malaysia, Thailand, Indonesia, India, China, Sri Lanka and Vietnam are the main country that producing natural rubber. There are many types of well-known fillers that is used in natural rubber vulcanizates such as silica and carbon black but it have some disadvantages in which they are non-renewable and high in cost. Thus, natural fillers become a centre of attention in replacing the non-renewable fillers as it is found to be as good as existing fillers. Natural fillers have many benefits such as renewability, high toughness, high abrasion resistance as well as high modulus elasticity (Hanafi et al., 2016).

Natural rubber is considered as an environmentally friendly material. One of the important methods to improve undesirable properties such as low heat and hydrocarbon oil resistances and transforming natural rubber into new polymeric materials is through chemical modification. Chemical modification involves changing of the chemical structure of natural rubber such as by hydrogenation where it can improve the thermal properties of natural rubber. This chemical reaction may facilitate degradation of natural rubber, giving