EFFECT OF CARBON BLACK REINFORCEMENT ON THE MECHANICAL PROPERTIES MALAYSIA RUBBER COMPOUND

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A thesis submitted
in fulfillment of the requirements for the degree of Master of Science
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DECLARATION

I declare that this thesis entitled “Effect of Carbon Black Reinforcement on the Mechanical Properties Malaysia Rubber Compound” 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 : Intan Raihan Asni binti Rosszainily

Date : ……..

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 Mechanical Engineering.

Signature	:	……
Supervisor Name	:	Assoc. Prof. Dr Musthafah bin Mohd Tahir
Date	:	……

DEDICATION

To my beloved parents, siblings, and my lectures who always give support and encouragement.

ABSTRACT

Practically, the natural rubber (NR) is reinforced with carbon black (CB) with the purpose of providing extra strength for both raw and vulcanized NR. The aims of this study, first is to investigate the mechanical properties of the Standard Malaysian Rubber with Constant Viscosity 60 (SMR CV-60) and 25 mol % Epoxidized Natural Rubber (ENR 25) compounds, reinforced with different CB loading through mechanical testing. Second is to evaluate the properties of SMR CV-60 and ENR 25 compounds with different CB loading using the nano-scale testing. Third is to determine the optimal and effective CB loadings in both NR compound for future application. Both the SMR CV-60 and ENR 25 were reinforced with 0, 20, 40 and 60 part per hundred (phr) of CB. Four test which are the tensile, compression, microscopic and nanoindentation were conducted according to the ASTM D412, D395, D575, and E2546 to determine the mechanical properties. In tensile test, both NR compounds were stretched up to 450 % of elongation. The results show that the SMR CV-60 and ENR 25 with 60 phr of CB loading exhibit the highest tensile strength and Young's Modulus values. However, both compounds had become less elastic as compared to other compounds since the specimens broke at 353% and 352% of elongation for SMR CV-60 and ENR 25, respectively. Higher CB loading reduce the elasticity of NR and increase the stiffness, resulting for higher strength and low elongation at break. For the axial compression test, a constant 2kN load with 3 sec holding time was applied on the specimens. Results showed that the deflection decreased and the Young's Modulus was increased at the increasing CB loadings. The increased of CB loadings enhances the stiffness of NR compound, increased the resistance of NR compounds toward the compressive force, resulting for lower deflection value. The microscopic studies were also done to investigate the surface morphology of both NR. A pack and folded surface was observed on ENR 25 while lumpy surface was observed on SMR CV-60. Nanoindentation test was carried out by using Berkovich tips with a constant load of 2mN at various holding time of 0, 5, 10, 15, and 20 s. Results shows that SMR CV-60 and ENR 25 compounds with 60 phr exhibit the highest hardness, highest elastic modulus, and lowest penetration depth. This study also showed that the nanoindentation properties were slightly affected by holding time where a fluctuated value was recorded at different holding time. This is due to the reduction of creep effect on the unloading curve, which eventually affects the hardness and elastic modulus readings. Based on the results obtained, it was found that the CB loading highly affects the tensile, compression and nanoindentation properties of both NR compounds. The SMR CV-60 shows better mechanical properties without CB loading while ENR shows better mechanical properties with addition of CB. This is due to ENR 25 have better matrix-filler interaction compared to SMR CV. These studies also revealed that the SMR CV-60 and ENR 25 at 60 phr exhibit highest properties in the tensile strength, compression strength, and the nanoindentation hardness. However, both compounds are not recommended for the application under high strain as the tensile test has recorded the lowest elongation at break compared to other compounds.

ABSTRAK

Secara amnya, kekuatan getah asli (NR) boleh diperkuatkan dengan campuran karbon (CB) sama ada dalam keadaan asal atau tervulkan. Tujuan kajian ini, pertama untuk menyiasat sifat mekanikal bagi sebatian NR berkelikatan 60 (SMRCV-60) dan 25 mol % terekposida (ENR25) yang diperkuat dengan kandungan CB yang berbeza. Kedua untuk menilai sifat sebatian SMR CV-60 dan ENR 25 dengan kandungan CB berbeza menggunakan ujian skala-nano. Ketiga untuk menentukan kadar kandungan CB yang paling optimum dan berkesan bersama sebatian NR bagi kegunaan lain. Dua NR berbeza iaitu SMR CV-60 dan ENR 25 telah diperkuat dengan CB pada kadar 0, 20, 40, dan 60 phr. Empat ujian iaitu ujian ketegangan, mampatan, miksroskopik, telah dijalankan berpandukan standard antarabangsa ASTM D412, D395, D575, and E2546. Ujian regangan dijalankan dengan menarik spesimen sehingga ke 450% pemanjangan. Hasil kajian menunjukkan SMR CV-60 dan ENR 25 dengan 60 phr memperoleh kekuatan regangn dan modulus paling tinggi. Namun begitu, sebatian NR mengalami penurunan kadar elastik berbanding sebatian yang lain apabila spesimen putus pada pemanjangan 353% bagi SMR CV-60 dan 352% bagi ENR 25. Ujian mampatan pula dijalankan dengan mengenakan bebanan tetap sebanyak 2kN ke atas spesimen selama 3 saat. Didapati kadar mampatan berkurang dan kadar modulus meningkat apabila kandungan CB meningkat. Penambahan CB mengakibatkan kekakuan NR meningkat dan menghasilkan rintangan yang tinggi ke arah daya mampatan, menjurus kepada nilai mampatan yang rendah. Ujian mikroskopi dijalankan bagi mengkaji morfologi permukaan bagi kedua-dua sebatian NR. Hasil pemerhatian mendapati terdapat permukaan kasar pada sebatian ENR 25 dan permukaan berbonggol pada sebatian SMR CV-60. Ujian nanoindentatsi dijalankan menggunakan mata uji jenis Berkovich dengan bebanan tetap 2mN dan julat masa tahanan berbeza iaitu 0, 5, 10, 15, dan 20 saat. Kajian mendapati sebatian SMR CV-60 dan ENR 25 dengan 60 phr CB menunjukkan kadar kekakuan dan modulus elastik yang tinggi serta kedalaman lekukan yang paling rendah. Kajian juga menunjukkan bahawa ciri-ciri nanoindentation sedikit terjejas dengan julat masa tahanan berbeza di mana nilai berubah-ubah telah direkodkan. Ini berpunca dari kesan rayapan yang mempengaruhi kekakuan dan modulus elastik. Bedasarkan hasil kajian, didapati penambahan CB kedalam sebatian SMR CV-60 dan ENR 25 amat mempengaruhi sifat regangan, mampatan dan nanoindentasi. Sebatian SMR CV-60 menunjukkan sifat mekanikal yang baik tanpa kehadiran CB manakala sebatian ENR 25 menunjukkan sifat mekanikal yang baik dengan kehadiran CB. Ini disebabkan ENR 25 mempunyai interaksi matrik-pengisi yang lebih baik berbanding SMR CV-60. Didapati juga sebatian SMR CV-60 dan ENR 25 dengan kadar CB sebanyak 60 phr menunjukkan sifat mekanikal paling baik pada ujian regangan, mampatan, serta, nanoindentasi berbanding sebatian lain. Namun begitu, kedua-dua sebatian didapati tidak sesuai digunakan pada aplikasi dengan ketegangan tinggi kerana kedua-duanya telah mencatatkan kadar pemanjangan yang paling rendah berbanding sebatian lain.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF ABBREVIATIONS

AFM	-	Atomic force microscope
ASTM	-	American Society for Testing and Materials
BR	-	Butadiene rubber
CB	-	Carbon black
CBS	-	N-cyclohexylbenzothiazole-2-sulphenamide
CTAB	-	Cetyltrimethyl ammonium bromide
DBPA	-	Dibutylphathalate absorption number
DETC	-	Sodium diethyl dithiocarbamate
DSI	-	Depth sensing indentation
ECF	-	Extra conductive furnace
ENR	-	Epoxidized Natural Rubber
ENR 25	-	25 mol % Epoxidized Natural Rubber
ENR 50	-	50 mol % Epoxidized Natural Rubber
EPDM	-	Ethylene propylene diene monomer rubber
FTIR	-	Fourier-transform infrared spectroscopy
HAF	-	High-abrasion furnace
HDNR	-	High damping natural rubber
LR-MS	-	Laminated rubber-metal spring
MBS	-	N-oxydiethylenebenzothiazole-2-sulphenamide

MRB	-	Malaysian Rubber Board
N	-	Normal curing
NOBS	-	Morpholino thio benzothiazole
NR	-	Natural rubber
PAL	-	Palygorskite
PDMS	-	Polydimethylsiloxane
PP	-	Polypropylene
RRP	-	Recycle rubber
SBR	-	Styrene-butadiene rubber
SIC	-	Strain-induced crystallization
SMR	-	Standard Malaysian Rubber
SMR CV-60	-	Standard Malaysian Rubber Constant Viscosity-60
SR	-	Synthetic rubber
SRM	-	Standard reference rubber
TARRC	-	Tun Abdul Razak Research Center
TBBS	-	T-butyl benzothiazoleyl sulphenamide
TBTD	-	Tetrabutylthiuram disulphide
TMTD	-	Tetramethylthiuram disulphide

LIST OF SYMBOLS

%	-	Percentage
°C	-	Celcius
σ	-	Stress
ε	-	Strain
α	-	Specific angle
ζ	-	Damping ratio
A	-	Area
a	-	Indenter radius
c	-	Viscous damping
dB	-	Decibels unit
E_{it}	-	Indentation elastic modulus/ Young's Modulus
E_r	-	Reduced elastic modulus
F	-	Force
F_t	-	Transmitted force
H_c	-	Tip and material in contact displacement
H_{it}	-	Indentation hardness
h_{max}	-	Maximum displacement
h_p	-	Permanent recovered displacement
H_u	-	Marten hardness/ Universal hardness

k	-	Spring
l	-	Length
Min	-	Time
phr	-	Part per hundred rubber
r	-	Frequency ratio
S	-	Stiffness
sec	-	Time
T_g	-	Glass transition temperature
TR	-	Transmissibility
μ_{in}	-	Indentation work ratio
υ_i	-	Indentation Poisson ratio
Wt.%	-	Weight percentage
W_{total}	-	Total indentation work

LIST OF PUBLICATIONS

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