A STUDY ON EFFECT OF LAMINATED RUBBER – METAL SPRING ON TENSILE AND HARDNESS

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UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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A report submitted in fulfillment of the requirements for the degree of Bachelor of Mechanical Engineering

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DECLARATION

I hereby, declared this report entitled a study on effect of laminated rubber – metal spring on tensile and hardness is the results of my own research except as cited in references.

Signature: ……

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APPROVAL

This report is submitted to the Faculty of Mechanical Engineering of Universiti Teknikal Malaysia Melaka (UTeM) as a partial fulfilment of the requirements for the degree of Bachelor of Mechanical Engineering with Honours.

Signature: ……

Supervisor: Dr. Mohd Azli Bin Salim

Date:

DEDICATION

To my beloved parents

(Mohamed Razak Bin Sheik Hamid and Sofiah Binti Hassan)

My beloved family,

(Mohamad Irfan Bin Mohamed Razak and Mohamad Irwan Bin Mohamed Razak)

My Supervisor,

(Dr. Mohd Azli Bin Salim)

My lectures,

And all my beloved friends

(Azrin Ahmadin, Muthanna Bin Jumadil, Syafiq Firdaus, Mad Haniff bin Mad Rasi, Rais Adham, Azamuddin Nasir, Fakhruddin Mutussin, Ahmad Afiq Amsyar dan Mohd Zairunshah Bin Bernados)

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ABSTRACT

This project is to promote SMR CV-60 as the most important substance in the development of laminated rubber metal spring (LR-MS). In order to investigate the compatibility of SMR CV - 60 as the main substance in LR-MS development, the hardness and the young modulus of SMR CV - 60 at various force (0.1, 0.2, 0.4, 0.6, 0.8, 1.0, 1.2, 1.4 and 1.6) mN are to be investigated. This thesis will describes in details the methodologies that have been used during conducting the nanoindentation testing. In order to achieve this objective, a nanoindentation test was conducted to obtained mechanical properties for NR which is SMR CV-60 in 3 different types of NR conditions which is normal test, tensile test and heat treatment before conducting nanoindentation test. The normal test refer to original condition of rubber without any testing before using nanoindentation test. Tensile test was conducted at room temperature by stretching the specimen at rate of 100, 200 and 300 mm/min before conduction nanoindentation testing. Heat treatment was carried out at temperature of 100 and 200 before conducting nanoindentation testing. The reason to conduct 3 test above was to determine the hardness and young modulus for before and after test. For normal test, the depth penetration increase as the force increase. The hardness/young modulus is unpredictable as the force increase but graph showing an increasing trend for hardness value. For tensile test 100, 200 and 300 mm/min, the depth penetration also increase as the force applied increase where the hardness/young modulus decrease after tensile test have been done to SMR CV-60. Lastly, for heat treatment, the depth penetration also increase as the force applied increase. For sample 9 where heat treatment at 100, the hardness decrease after heat treatment for both sample 9 and 10 but young modulus remain unchanged after heat treatment

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ABSTRAK

Projek ini adalah untuk mengkaji kebolehan SMR CV-60 sebagai bahan yang paling penting dalam pembuatan Laminated Rubber-Metal Spring (LR-MS). Untuk mengkaji keberkesanan SMR CV - 60 sebagai bahan utama dalam pembangunan LR-MS, kekerasan dan young modulus SMR CV-60 pada pelbagai daya (0.1, 0.2, 0.4, 0.6, 0.8, 1.0, 1.2, 1.4 dan 1.6) mN akan dijalankan. Tesis ini akan menerangkan secara terperinci metodologi yang telah digunakan semasa menjalankan ujian nanoindentation. Untuk mencapai matlamat ini, ujian nanoindentation dilakukan untuk mendapatkan sifat mekanikal untuk Natural Rubber (NR) yang merupakan SMR CV-60 dalam 3 jenis keadaan Natural Rubber NR yang berbeza iaitu keadaan normal, ujian tensile dan rawatan haba sebelum menjalankan ujian nanoindentation. Ujian normal merujuk kepada keadaan asal getah tanpa sebarang ujian sebelum menggunakan ujian nanoindentation. Ujian tensile dilakukan pada suhu bilik dengan menarik spesimen pada kadar 100, 200 dan 300 mm / min sebelum pengujian nanoindentation dijalankan. Rawatan haba dilakukan pada suhu 100 ℃ dan 150 ℃ sebelum melakukan ujian nanoindentation. Sebab untuk menjalankan 3 ujian di atas adalah untuk menentukan kekerasan dan young modulus sebelum dan selepas ujian. Bagi ujian biasa, penembusan kedalaman meningkat apabila daya meningkat. Kekerasan / young modulus tidak dapat diprediksi memandangkan peningkatan daya tetapi graf menunjukkan peningkatan trend untuk nilai kekerasan. Untuk ujian tegangan 100, 200 dan 300 mm / min, penembusan kedalaman juga meningkat apabila daya digunakan meningkat di mana kekerasan / young modulus menurun selepas ujian tegangan telah dilakukan ke SMR CV-60. Akhir sekali, untuk rawatan haba, penembusan kedalaman juga meningkat apabila daya digunakan meningkat. Untuk sampel 9 di mana rawatan haba pada 100℃, kekerasan menurun selepas rawatan haba untuk kedua-dua sampel 9 dan 10 tetapi young modulus kekal tidak berubah selepas rawatan haba.

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LIST OF ABBREVIATIONS

mN	-	Micro newton
μN	-	Micro newton
μm	-	Micro meter
h_{max}	-	Maximum depth
P_{max}	-	Maximum force
h_p	-	Penetration depth
h_c	-	Depth of contact
h_e	-	Displacement associated with the elastic recovery during unloading
E_r	-	Converted elastic modulus
E_i	-	Initial elastic modulus
V_i	-	Poisson's ration for indenter
E_{it}	-	Indentation elastic modulus
V_s	-	Poisson's ratio for specimen
r	-	Radius
A_r	-	Area
A_l	-	Aluminium

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CHAPTER 1

INTRODUCTION

1.0 Introduction

This section will explain more about the context of this experiment, a study on the impact of laminated rubber – metal spring on tensile and hardness consisting of natural rubber history in Malaysia and the use of natural rubber in engineering applications that focus on vibration isolator This section will illustrate the mechanical characteristics, material utilization and implementation of the two common natural rubbers, Standard Malaysian Rubber (SMR) and Epoxidized Natural Ruber (ENR).

1.1 Background Study

Nowadays, natural rubber (NR) is a versatile and adaptable material because in 150 years, it was successfully used in many engineering applications. It is a type of sustainable material and very popular in Malaysia as well as around the world for many applications1 such as in the automotive industry, manufacturing, civil, railways, offshore, aerospace, and defense. It becomes an important material due to its ability to withstand large deformations and store more elastic energy per unit volume compared with other elastic materials (Salim, Putra, Mansor, Musthafah, Akop, Abdullah, et al., 2016). It also has characteristic damping in term of vibration resonance. NR also has a unique response which is small compressibility during the application of excitation force. By adding other

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materials inside the NR, it will be known as the composite material (Salim et al., 2016). A rubber bearing was introduced to become isolator to suppress the amount of vibration particularly in building structure for earthquake protection. It is made up from layers of rubber with thin steel plates between them, and a thick plate located at above and bottom of the rubber materials. These rubber bearings are set between the bottom of a building and its foundation by embedding the metal plates that will provides excellent performance in terms of stress and strain level once high load is applied and prevents the bulging impact within the horizontal direction. It's designed to be really stiff and powerful for vertical load, so it able to accommodate the extreme weight of the building strain level once the high load is applied and prevents the bulging impact within the horizontal direction.

Epoxidized Natural Rubber (ENR), the epoxidation method was a major option as it exhibits a simple reaction procedure and effective compounding cost. The epoxidation process involving the addition of oxygen atom into a proportion of carbon-carbon double bonds through the addition or substitution reaction to produce the epoxide ring. This process is more effective when conducted at the latex stage by using several chemicals such as the performic acid, the hydrogen peroxide, and the formic acid. The performic acid is a soluble liquid with strong oxidizing properties. The NR can be epoxidized up to 75 mole % under a controlled condition to produce NR compound with superior properties such as better resistance towards the hydrocarbon oil and high mechanical properties. However, the epoxidation of NR up to 100 mole% will produce hard thermoplastic materials (Baker et al., 2014). The advantages of ENR over the other modified NR are the outstanding damping properties, high resistance to hydrocarbon oils,

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good strength properties, high wet grip and lower air permeability. For this reasons, the ENR has been used in various application such as automotive tire tread, adhesive, bladders, vibration mount, and shoe soles. Besides that, the epoxidation process has supplied the ENR with high glass transition temperature and high polarity. High polarity in ENR makes it suitable to be used with the vulcanized NR with different polarity and bonded with metals (Baker et al., 2014). Currently, only two types of ENR was commercially used which is the ENR 25 and ENR 50. In Malaysia, the ENR was commercialized by Malaysian Rubber Board (MRB) under the name of Ekoprena 25 and Ekoprena 50. The physical properties for ENR 25 and the ENR 50 was summarized and presented in Table 1.1.

Table 1.1: The physical properties for ENR 25 and the ENR 50

Property	**SMR CV-60**	**ENR 50**
Tensile strength (MPa)	22.4	21.0
Elongation at break (%)	497	465
Rebound Resilence, at 23°C (90)	39.7	25.9
Compression set (72hr, RT) (%)	16.5	20.5
Tear strength (N/mm)	94.0	57.0

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Standard Malaysian Rubber Constant Viscosity (SMR CV), variety grade of coagulated NR compound was available and all of them have been technically specified according to the American Society for Testing Materials (ASTM). All coagulated compound were measured based on its physical properties such as the dirt content and the method of production. However, the detailed description of the NR also can be obtained through the respective rubber producing country. As in Malaysia, the basic grades of coagulated NR compound were promoted as Standard Malaysian Rubber (SMR) The SMR 5, SMR 10, SMR 20, SMR GP and SMR L are the examples of NR compound under the SMR scheme. In order to obtain the consistency in viscosity of the NR latex, a specialized grade with a constant viscosity (SMR CV) was introduced. The constant viscosity properties were also available for the SMR grade and the product was labeled as SMR 10CV and SMR 20CV The SMR CV grade contains about 0.15% of hydroxylamine hydrochloride or hydroxylamine neutral sulfate. The main purpose of the chemicals addition is to maintain the viscosity of the raw rubber liquids in order to prevent rubber hardening during the storage period. Rubber hardening could occur due to the reaction of the particle crosslinking process with the low humidity in storage surrounding. The SMR CV-50 and SMR CV-60 are the examples of SMR CV grade that is commercially available. The only differences between both types of constant viscosity NR are their Mooney viscosity values 50 and 60 Mooney unit. The tensile properties of the rubber blend were presented in Table 1.2

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Table 1.2: The tensile properties of the rubber blend

Property	**Blend ratio, MPa (SMR CV-60 to ENR 50)**				
	0/100	**25/75**	**50/50**	**75/25**	**100/0**
Tensile strength (MPa)	10.70	9.50	12.50	14.00	13.20
Elongation at break (%)	700	700	700	700	700
Tensile modulus at 300% of elongation (MPa)	1.65	1.60	1.60	1.70	2.60

1.2 Problem Statement

Before this, it was found that the development of the laminated rubber-metal spring (LR-MS) for the application of automotive mounting is in current trend (Salim et al., 2015). The objective of LR-MS is to reduce the vibrations in some specific portion of the receiver structure. Previously, many engineers failed to choose the appropriate rubber to be used as laminated for the rubber bearing. The rubber used has weak in mechanical properties such as hardness and young modulus. Therefore, this study is conducted to study the application of the Malaysian NR which is the vulcanized standard Malaysian rubber constant viscosity 60 (SMR CV-60) reinforced with carbon black (CB) as the potential main materials to be combined with the metal plate for the development of LR-MS has become the interest. This study focuses on the investigations of the mechanical properties of the vulcanized SMR CV-60 through the nanoindentation testing. The properties of the SMR CV-60 were compared for three types of testing that have been done to the SMR CV-60 which is normal test, tensile test and heat treatment.

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1.3 Objective

The objectives of this project are:

i. To investigate and evaluate the tensile properties of SMR CV – 60

ii. To determine the relationship between tensile properties and hardness of SMR CV - 60

1.4 Scope of Project

Based on the objectives of the study, several scopes covered in this project are listed as below:

i. The experiment only use SMR CV-60 as the main material for mechanical testing.

ii. This study only obtain the mechanical properties (hardness and young modulus) for natural rubber using nanoindentation method

iii. The force applied to the natural rubber (NR) is varied for force (0.1, 0.2, 0.4, 0.6, 0.8, 1.0, 1.2, 1.4 and 1.6) μN

iv. The orientation of SMR CV-60 only in Y-axis for tensile test

1.5 Report Organization

This report is cover by five chapters. The first chapter start with the introduction, problem statement, objective and scope of project. The literature review is discussed in Chapter 2 and project methodology in Chapter 3. The result and collection of data will be discussed in Chapter 4. In Chapter 5 will be the summary of this project with some recommendation. Here are the main chapters for this project

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In chapter 1 will covered the background of the overall operation, the problem statement that happened before this. The aim of the objective of this project is to solve the problem statement. Besides, the scope of work is limitation of project to prevent future problem.

In chapter 2 will covered the research, find and read relevant topics from the sources such as reference book, internet and journal to get deeper knowledge and information for the project. Research on the same system that already in the market to know the characteristics of the system will provide understanding in this project.

In chapter 3 will explains more about the work flow of the development of this project from the beginning of the project until the end of the project. The flow chart is used as to visualize the work flow of this project. The purpose is to have a guideline while conducting this project.

In chapter 4 will focuses on the result and the findings of the study, the results is obtained after following the methodology in the Chapter 3. It will discuss briefly on the project findings in this chapter.

In last chapter which is chapter 5 will summarize for the outcomes of this experiment. Besides, it will discuss several recommendations for future improvements and development.

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CHAPTER 2

LITERATURE REVIEW

2.0 Introduction

As mentioned in the previous chapter, the development of the Laminated Rubber-Metal Spring (LR-MS) for the application in high-frequency protection was in the current research interest. Therefore, the Malaysian Rubber Board (MRB) has taken an initiative to optimize the usage of local grade Natural Rubber (NR) instead of imported rubbers in the development of the Laminated Rubber-Metal Spring (LR-MS), by introducing the SMR CV-60 as the main substance. Thus, in this chapter, the theories and the advantages of the Standard Malaysian Rubber (SMR CV-60). The theories of mechanical testing of the Natural Rubber (NR) were also literally presented in this chapter. In addition, a brief introduction to the nanoindentation theories and studies were included in this chapter. Lastly, the basic concept of the vibration isolation system and the history and recent studies on the laminated rubber bearing were also included to prove the effectiveness of NR as main substance in the LR-MS

2.1 Natural Rubber as the Sustainable Green Materials

The NR has been extensively used in various applications due to its distinctiveness over the other materials like excellent physical properties, renewable sources origins, and economical. The elasticity and the flexibility of the NR are the main reasons for this

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material to be applied in various fields especially in the engineering area. In addition, the ability of NR to withstand for exceptional large stress without permanent deformation or fracture has ensured the survival of the materials itself and makes it suitable to be used in variety environment, except for the environment that exposed to the ozone and chemicals.

Table 2.1: Application and properties of NR

Application	**Properties**
Surgical gloves	Tear resistance, strain induce crystallization
Blow-out preventers, hoses connectors, inner tubes, and bladders	Oil-resistance, gas permeability
Tires	Tear strength, wet-grip, rolling resistance/abrasion
Bearings	Elasticity, low dissipation factor, wear resistance
Shoes	Damping

The basic strength of the NR actually depends on its basic chemical structure. Like the other natural product such as cellulose and silk, the NR was categorized as high polymer materials. The NR, which was classified in the hydrocarbon group is 99% build up from the poly-isoprene arranged in a high cis-1, 4 configurations as shown in Figure 2.1 in below. The presence of such a chemical configuration gives the NR a glass transition temperature of approximately -75 C, which makes NR become extremely elastic and works very well at room temperature (Chandrasekaran, 2010). It also

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