MICROSCOPIC STUDY ON THE NATURAL RUBBER WITH DIFFERENT CARBON LOADINGS UNDER COMPRESSION: SMR CV-60 AND ENR 25

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ABSTRACT: This study presents the microscopic investigation related to the effects of compression on the local natural rubber (NR): the standard Malaysian rubber constant viscosity-60 (SMR CV-60) and the epoxidized natural rubber 25% mole (ENR 25) at four different carbon loadings (0, 20, 40 and 60 pphr). The surface morphology of both NR was studied by using scanning electron microscope (SEM). The results showed that a packed and folded surface was observed on the SMR CV-60 while a crumpled surface was observed on the ENR 25. However, the packed and folded and the crumpled surfaces were decreased as the carbon loading in NR compound was increased. It also showed that the applied compression does not exhibit any significant effects on both compound since the damages only found on the outer layer of rubber surface. The experimental value shows that the NR deflection in response to the compression is reduced as the carbon loading increase. The SMRCV60/0 and ENR25/0 have recorded the highest deflection due to the compression. Meanwhile, the SMRCV60/60 and the ENR25/60 has recorded the lowest deflection under the compression. Through this study, it is found that the compression force does not contribute to the NR compound failure.

KEYWORDS: *Microstructure; SMR CV-60; ENR 25; Carbon Black*

1.0 INTRODUCTION

Recently in Malaysia, the development of laminated rubber-metal spring by using the standard Malaysian rubber constant viscosity–60 (SMR-CV60) is actively done [1-4]. The natural rubber (NR) was often chosen as the main material in various applications due to its excellent properties such as high elasticity, possesses inherent damping, low

heat buildup in dynamic force and has the ability to instantly recover when distorted at room temperature. Additionally, NR can be bonded with other materials such as metal in order to increase its strength. It also requires minimum maintenance as the NR is capable of maintaining itself for a long period.

Uniquely, the properties of the rubber product are highly depended on the applications and the manufacturers: which can be achieved through compounding and rubber processing. Rubbers product properties and processing behaviors are often influenced by its formulation [5]. A proper formulation for rubber compounding should have at least the following materials; elastomer, fillers, plasticizer, protective agents, and vulcanization additives. Each of the materials played important roles in the rubber compounding, especially for the fillers.

Normally, the occurrences of fractures and failures in NR resulting from compression are very rare. However, due to over compression, poor product design, swelling, and thermal expansion, the compressive fracture might occur. Accordingly, in this paper, the microscopic studies on the effects of different carbon loadings in two types of local natural rubber were presented. The microscopic structures of the rubbers under compression were studied. The influences of carbon black as the NR fillers were literally reviewed in the sub-section 1.1. The rubbers' compression properties and the methodology were presented in section 2.0. Lastly, the microscopic results for both rubbers were presented and discussed in section 3.0 and summarized in section 4.0.

1.1 Influence of Carbon Black in NR Compound

Nowadays, most of the rubber products that are used by customers especially in the anti-vibrating applications are reinforced with fillers. There are plenty of fillers available in the market, however, only two types of fillers are known to reinforce rubber effectively which are the carbon black and silica [6-7]. Both fillers are easily available and inexpensive, and known to excellently improve the mechanical properties of NR in terms of tensile strength, elastic modulus, hardness, and hysteresis [8]. With that, the focus of this paper is only on the application of carbon black in the vulcanized NR.

Practically, the NR is reinforced with carbon black with the purpose of providing extra strength for both raw and vulcanized rubbers at low manufacturing cost [9]. Carbon black is frequently used as filler in industrial applications as it is easily available and produced. It is proven to successfully reduce the materials cost, and improve the rubber manufacturing process.

Generally, the properties of the NR compound are highly depended on the carbon black particle sizes [10]. The reinforcing effects become more efficient as the particle size decreases; which the effective carbon particle sizes range from 20 nm to 50 nm [11-12]. Smaller carbon particle also disperses evenly in rubber and agglomerates at a moderate size. It is an additional factor for great rubber performance. Rattanasom and Prasertsri observed the effect of partial replacement of clay with three different grades of carbon black (N330, N550, and N774) on the vulcanized NR at similar hardness level [13]. The authors found that the vulcanized NR with N330 exhibited the highest edge-cut tensile strength, highest tensile and tear strength, and possessed the lowest resilient compared to the others. Notably, this occurred due to the great interaction between the filler and the rubber matrix which resulting from the good filler dispersion. The rubber chain will strongly link on the carbon black surface, providing a good orientation of the NR chain along with the applied force, thus gave more strength to the vulcanized NR.

On the other hand, the properties of the NR also can be influenced by the carbon loading. The high-performance polymer composites usually contain 50 to 80 % reinforcement by volume [13]. In addition, many researchers had studied the effects of increasing carbon filler percentage (0, 20, 45 %) in four types of rubbers [14]. The authors reported that the rubbers with the highest percentage of carbon yielded the best results for the tensile, compression, hardness and static stiffness. However, excessive carbon content would affect the processing characteristics and also, the rubber compound crosslinking properties [5].

2.0 METHODOLGY

2.1 Materials and Sample Preparation

The compounded SMR CV-60 and the 25% mole epoxidized natural rubber (ENR 25), supplied and processed by the Malaysian Rubber Board (MRB) were used in this study. The ingredients compositions that had been used were based on the par per hundreds of rubber (pphr)are as follows: 5 pphr of Zinc Oxide, 2 pphr of stearic acid, 3 pphr of santoflex 13, 2 pphr of paraffin wax, 0.8 pphr of N-Cyclohexyl-2-benzothiazole sulfonamide (CBS), 3.25 pphr of sulphur, and variety mass (0, 20, 40, 60 pphr) of N330 carbon black. The ingredients were mixed and vulcanized at 150˚C.

A simple compression test was conducted on the specimens. A cylindrical disk cut specimens (Figure 1) was prepared following the dimension from ASTM D395 and the compression test was conducted according to the ASTM 575. The test was performed on the Universal Testing Machine (UTM) under the room temperature. A 2kN compression force was applied to the specimen for three seconds and left to be static for another three seconds before releasing the compression plate. The compression properties were presented in Table 1.

2.2 Scanning Electron Microscopy (SEM)

A Zeiss Supra-35VP Emission Scanning Electron Microscope (SEM) was used to study the surface of the SMR CV-60 and ENR 25 rubbers before and after the compression test was conducted. The specimens were coated with a thin platinum layer to avoid any electrostatic charge during the analysis. The analysis was conducted at 400x magnification with the accelerating voltage of 12 kV.

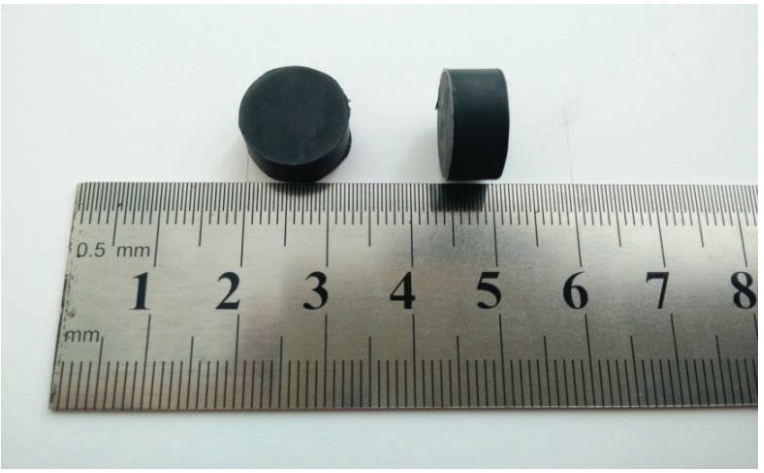

Figure 1: The compression test specimen

Table 1: Compression data for SMR CV-60 and ENR 25 filled various loading of CB samples as taken from [15]

Natural rubber	Compression properties	Carbon loadings			
		0	20	40	60
SMR CV-60	Maximum compressive stress, Mpa	15.38	15.33	15.28	15.27
	Standard deviation, Sstress	0.02	0.015	0.005	0.01
	Maximum deflection, mm	4.38	4.19	4.00	3.60
	Standard deviation, Sdeflection	0.23	0.13	0.09	0.07
	Compressive Modulus, MPa	90.36	80.81	81.07	83.04
	Standard deviation, Smodulus	8.42	2.72	4.51	1.81
ENR 25	Maximum compressive stress, Mpa	15.35	15.31	15.27	15.27
	Standard deviation, Sstress	0.02	0.005	0.01	0.01
	Maximum deflection, mm	4.56	4.32	4.09	3.60
	Standard deviation, Sdeflection	0.06	0.02	0.09	0.10
	Compressive Modulus, MPa	81.48	78.99	78.19	79.97
	Standard deviation, Smodulus	0.15	3.72	0.88	5.90

3.0 RESULTS AND DISCUSSION

Figures 2 and 3 illustrate the microscopic observation on the normal sample of SMR CV-60 and ENR 25 surface, respectively. Based on Figure 2a and Figure 3a, a rough surface was observed on the SMR/CB-0 surface; meanwhile, a flat surface was observed on the ENR/CB-0. On the SMR CV-60 rubber, it is found that the surface roughness was increased as the carbon loading increased; forming a packed and folded surface on the SMR/CB-40 and SMR/CV-60. A lump surface, resulting from the agglutination of the matrix and the fillers, could also be observed on the compound.

In contrast to the ENR 25, the surface roughness was decreased as the carbon loading increased; causing the surface became less packed and folded and formed a crumpled surface. The packed and folded surface was only observed in ENR/CB-20 while a crumpled surface was observed in ENR/CB-40 and ENR/CB-60. Yet, the crumple surfaces were faded as the NR compound contains more carbon. Besides that, there is no lump surface was observed in ENR 25 as found in the SMR CV-60 compounds.

Figures 4 and 5 demonstrate the SEM micrograph of the compressed sample of the SMR CV-60 and ENR 25 surface. Based on Figure 4, the outer layer of SMR/CB-0, SMR/CB-20, SMR/CB-40 and SMR/CB-60 were damaged due to compression, exposing a surface with the porosity which is formed during the rubber processing. It was found that the porosity was diminished as the carbon loadings increased. The absence of porosity is undesirable in rubber fabrication since it may lead to materials failure and can be avoided by filler addition and good filler dispersion [16-17]. Anyhow, the porosity wills not affecting the performance of rubber under the compression load, but in the other test such as the tensile test and tearing test.

Aside from that, in Figure 5a), a cracked surface was observed in the sample of ENR/CB-0. While on the other samples (ENR/CB-20, 40, and 60), the compressed ENR 25 compound exhibited similar behavior as the compressed SMR CV-60, where a damage layer was displayed. However, no porosity was observed on the ENR 25 surface. Based on the morphology analysis conducted on both NR compounds, it shows that the rubbers will exhibit different surface morphology when reinforced with different carbon loadings.

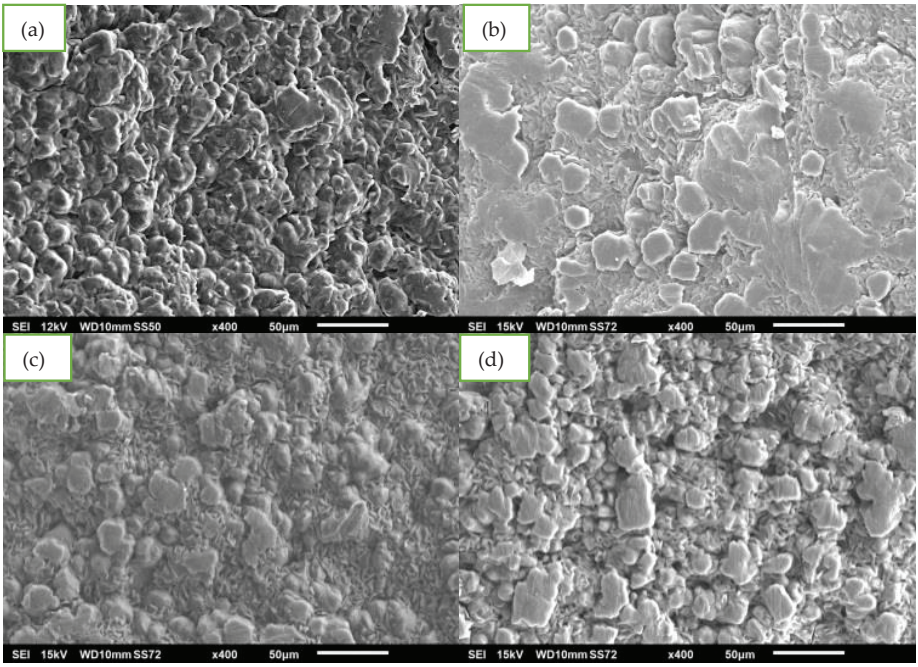

Figure 2: SEM micrograph for normal (a)SMR/CB-0, (b)SMR/CB-20, (c)SMR/CB-40 and (d)SMR/CB-60

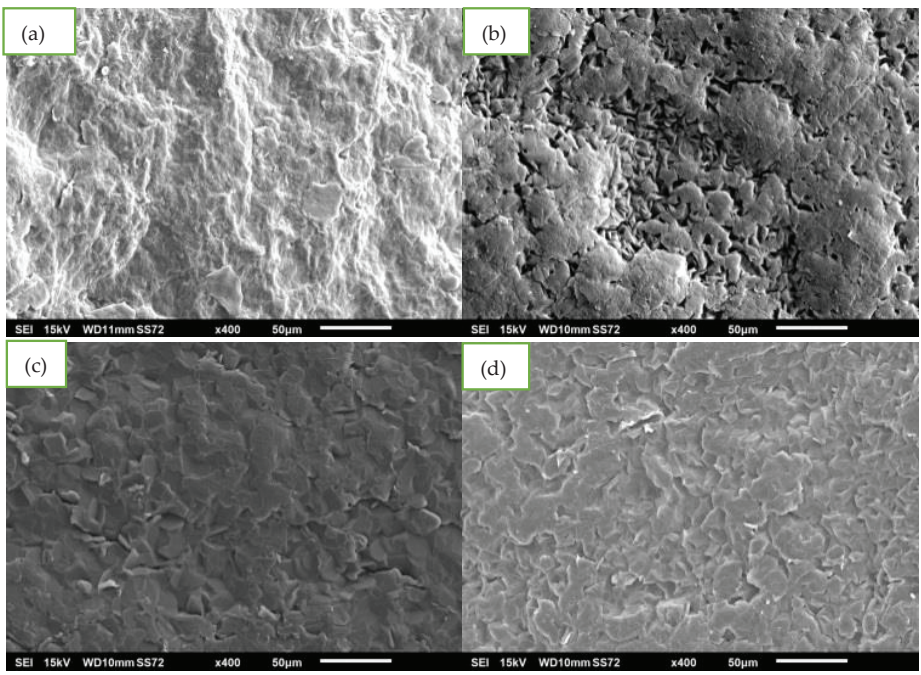

Figure 3: SEM micrograph for normal (a)ENR/CB-0, (b) ENR /CB-20, (c) ENR /CB-40 and (d) ENR /CB-60

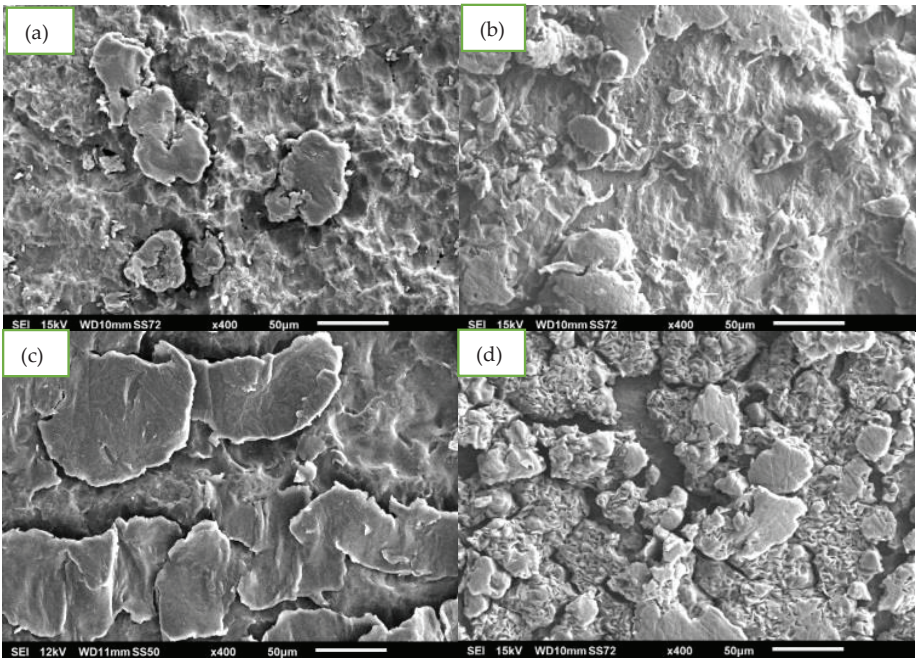

Figure 4: SEM micrograph for compressed (a)SMR/CB-0, (b)SMR/CB-20, (c)SMR/CB-40 and (d)SMR/CB-60

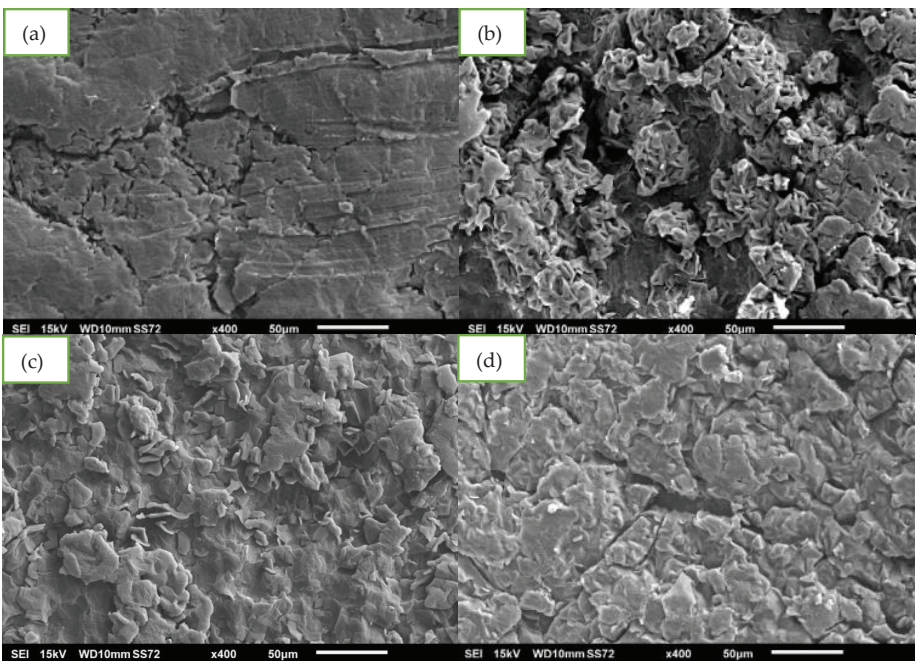

Figure 5: SEM micrograph for compressed (a) ENR /CB-0, (b) ENR /CB-20, (c) ENR /CB-40 and (d) ENR /CB-60

Based on the microscopic observation, the rubber surface morphology has shown that the damages on the surface layer due to the compression were reduced as the carbon loading increase. The additions of carbon black have increase the rubber stiffness and reduce its elasticity, thus require large stress to compress the NR. The stiffness of rubber will restrain the exerted compressive force and reduce the damages from occurred [18]. The effects of carbon reinforcement on the rubber compound also can be found through the experimental data from Table 1, the highest compressive stress value was recorded by both of control sample (SMR/CB-0 and ENR/CB-0 with value of 15.37 MPa and 15.34 MPa), followed by the compound with 20 pphr of carbon loading (SMR/CB-20 and ENR/CB-20 with value of 15.32 MPa and 15.31 MPa) and the compound with 40 phr of carbon loading (SMR/CB-40 and ENR/CB-40 with value of 15.28 MPa and 15.28 MPa). The smallest compressive stress value was recorded by the compound with 60 pphr of carbon loading (SMR/CB-60 and ENR/CB-60 with the value of 15.28 MPa and 15.27 MPa).

Both rubber compounds also show the similar pattern of deflection against the compressive load, where the deflection value was decreased as the carbon loading in compound increased. Highest deflection was recorded by the control samples with the value of 4.31 mm for the SMRCV60/0 and 4.51 mm for the ENR25/0. The lowest deflection has been recorded by the compound with the highest carbon loading which is the SMRCV60/60 and the ENR25/60, with the value of 3.53 mm and 3.64 mm, respectively. From the experimental data, it shows that the addition of carbon has increased the stiffness of the NR and restrains the compressive load acted on the compound. Thus, more stress is needed to compress the sample to the similar deflection levels. Other than that, it is found that the compression force does not contributes to any failure towards the NR compounds since there is no significant failure were observed in the samples.

4.0 CONCLUSION

This paper presented results of the microscopic study on the effects of compression on two types of natural rubber (NR); standard Malaysian rubber constant viscosity-60 (SMR CV-60) and the epoxidized natural rubber 25% mole (ENR 25). The surface observation was conducted on

the normal and the compressed samples of both NR by using scanning electron microscope (SEM). The results of this study showed that the surface appearance was highly affected by the types of NR and carbon loading. A packed and folded surface was observed in SMR CV-60 while a crumpled surface was found on the ENR 25. The lumpy surface was also found on the SMR CV-60 surface. The addition of carbon also helps to reduce the porosity in SMR CV- 60. This study also proves that the carbon black has improved the stiffness of the NR and helps to restrain the applied compressive force, thus reduce the damages due to the compression. It is also found that the compression load does not contribute to the NR compounds failure.

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