Influences of Modified Palm Stearin on Vulcanization Properties of Carbon Black-Loaded Epoxidized Natural Rubber

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Abstract. The present research-study investigated the influences of modified palm stearin (MPS) on the vulcanization properties of carbon black (CB)-loaded Epoxidized Natural Rubber with 25% mole (ENR 25). The ENR 25 was loaded by CB at a fixed loading (thirty phr) and the MPS was added into the CB-loaded ENR 25 compounds with varied doses from one to seven phr. The influences of MPS additions on the optimum vulcanization and scorch times and also cure rate index (CRI) of CB-loaded ENR 25 were investigated. It was observed that the MPS caused an enhancement in the rate of the vulcanization process on the ENR 25 compounds. The MPS decreased both the times to scorch and optimum vulcanization time but increased the CRI. The bigger the MPS doses caused in the lower were the scorch and optimum vulcanization times but caused in the higher was the CRI. The enhancement in CRI was attributed to the role of MPS as the supplementary accelerator for the CB-loaded ENR 25 compounds. The amine content of MPS enhanced the CRI.

1. Introduction
Several reinforcing fillers are very usual to be applied in providing rubber articles/products with some satisfactory grades of usages [1, 2]. They are added into the rubbers compounds at the middle of the mixing process. Therefore, they can be classified as rubber additive materials. One of the reinforcing fillers is carbon black (CB) and it is the most well-known reinforcing filler in industry. The CB is used in making of black-colored rubber products.

The CB is relatively suitable for any rubber when they are processed. In order to enhance the processing aspect, this research-study using modified palm stearin (MPS) as rubber additive to improve the homogeneity of CB dispersion, as well as the processing properties of CB-loaded epoxidized natural rubber (ENR) compounds. Therefore, this research-study investigated the influences of MPS additions on vulcanization properties i.e. scorch time, optimum vulcanization time and cure rate index of the CB-filled ENR compounds. The MPS was produced by reacting palm stearin with ethanolamine [3, 4]. The palm stearin is the solid waste of cooking oil production. As a waste, the palm stearin is cheap and because the material comes from palm oil; the palm stearin has the potential whenever the material is used as a plasticizing agent. It is usual for using plasticizer to improve the degree of any type of fillers.
2. Experimental

2.1. ENR 25 and rubber additives
An ENR 25 was used as the raw rubber. The N330-typed CB was used as the reinforcing filler. Other rubber additives i.e. sulphur/S, zinc oxide/ZnO, stearic acid, Antioxidant/IPPD and Accelerator/MBTS were used. Known also as alkanolamide, the MPS - CH₃(CH₂)₁₄CON(CH₂CH₂OH)₂ - was produced using Refined Bleached Deodorized Palm Stearin/RBDPS and diethanolamine. The RBDPS is a solid waste of the cooking oil production. The reaction stages and the performance of MPS were previously reported [5, 6].

2.2. ENR 25 compounding
A typical vulcanization formulation (Semi Efficient) was used for the ENR 25 compounding. The mixing process was performed on a two-roll mill (Model XK-160). Table 1 shows the system of the CB-loaded ENR 25 in the existence of MPS.

| Ingredients     | Amount (parts per hundred rubber/phr) |
|-----------------|---------------------------------------|
| ENR 25          | 100                                   |
| ZnO             | 5                                     |
| S               | 1.6                                   |
| MBTS            | 1.6                                   |
| CB              | 30                                    |
| IPPD            | 2                                     |
| Stearic acid    | 2                                     |
| MPS             | 1 to 7                                |

2.3. Vulcanization properties
The vulcanization properties of the CB-loaded ENR 25 were studied using a typical Monsanto Moving Die Rheometer/MDR 2000 that was operated to measure the scorch and optimum vulcanization times and cure rate index based on ISO 3417. The ENR 25 compounds were vulcanized and tested at 150°C. The cure rate index/CRI is a cure rate measurement based on the data of scorch and optimum vulcanization times. The equation of CRI as follows;

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CRI = \frac{100}{(\text{Optimum vulcanization time} - \text{Scorch time})}
\]

3. Results and Discussion

3.1. Scorch time
The scorch times of CB-filled ENR 25 without/with MPS are shown in Fig. 1. The one phr of MPS decreased the scorch time of the ENR 25 reference-compound (ENR 25 compound with no MPS). Increasing the MPS dose up till seven phr further decreased the scorch time.
3.2. Optimum vulcanization time
The optimum vulcanization time of CB-loaded ENR 25 with/with no MPS is shown in Fig. 2. The one phr of MPS decreased the optimum vulcanization time of the ENR 25 reference-compound. It means the MPS enhanced the vulcanization rate of the compounds. Similar to the trend of scorch time; the higher the dose of MPS, the lower was the optimum vulcanization time. It was because of the role of MPS as a curative additive which influenced the scorch and vulcanization times. Any rubber additive that would provide some affections on vulcanization properties of a rubber compound can be classified into curative additive [7, 8]. Therefore, MPS was considered as one rubber curative additive for the CB-loaded ENR 25.

**Figure 1.** The scorch times vs MPS loading.

**Figure 2.** The cure times vs MPS loading.
3.3. Cure rate index
The cure rate index/CRI of CB-loaded ENR 25 with/with no MPS is shown in Fig. 3. The CRI is a measurement of a vulcanization rate of converting a rubber compound into a rubber vulcanizate [9, 10]. A higher of CRI means a higher rate of vulcanization process. The MPS enhanced the CRI of CB-loaded ENR 25. It was due to the role of MPS as a supplementary accelerator for the CB-loaded ENR 25. The amine content of MPS enhanced the CRI. Higher of MPS dose caused in a more pronounced the rate of vulcanization. It was simply because of the higher amount was of MPS in the CB-loaded ENR 25.

![Figure 3. The Cure Rate Index vs MPS Loading.](image)

4. Conclusions
The modified palm stearin was a rubber curative additive for carbon black-loaded ENR 25 compounds. It increased the scorch time, optimum cure time as well as the cure rate index of the carbon black-loaded ENR 25 compounds. Presumably, the amine part of the modified palm stearin contributed positively during the cure process of the carbon black-loaded ENR 25 compounds.

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