Effects of Modified Palm Stearin on Torque Properties of Carbon Black-loaded Epoxidized Natural Rubber

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Abstract. This research study investigates the effects of modified palm stearin (MPS) on the torque properties of carbon black (CB)-loaded Epoxidized Natural Rubber with 25% mole (ENR 25). The ENR 25 was loaded with 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 effects of MPS incorporations on the maximal torque, minimal torque and torque change of CB)-loaded ENR 25 were investigated. It was observed that the MPS caused some affection in torque properties of the ENR 25. The MPS lowered the minimal torque but raised the maximal torque and torque change. The bigger the MPS doses caused in the lower was the minimal torque but caused in the higher was the torque change. The enhancement in torque was attributed to the role of MPS as the supplementary plasticizing agent for the CB-loaded ENR 25 compounds. The oily property of MPS decreased the viscosity and enhanced rubber to filler interaction or crosslinks level, respectively.

1. Introduction
The reinforcing fillers are always used in gaining rubber articles/products with some satisfactory grade of applications [1]. One of the reinforcing fillers is carbon black (CB) and it is the very famous reinforcing filler in the field of the rubber industry. The CB is used in producing of black-coloured rubber products.

The CB is relatively suitable for any rubber when they are utilized. To enhance the processing aspect, this research-study utilizing modified palm stearin (MPS) as rubber additive to enhance the degree of CB dispersion, as well as enhancing the rubber to filler interactions of CB-loaded epoxidized natural rubber (ENR 25) compounds and hence, this research-study observed the effects of MPS incorporations on torque properties i.e. maximal torque, minimal torque and torque change of the CB-loaded ENR compounds. The MPS was produced by reacting palm stearin with ethanolamine [2-3].

2. Methods

2.1. ENR 25 and rubber additives
The ENR was used as the raw rubber. The N330-type CB was used as the reinforcing filler. Other rubber ingredients i.e. sulphur/S, zinc oxide/ZnO, stearic acid, antioxidant/IPPD and accelerator/MBTS were used. The MPS - CH₃(CH₂)₁₄CON(CH₂CH₂OH)₂ - was delivered by the reaction between diethanolamine and Refined Bleached Deodorized Palm Stearin/RBDPS. The reaction procedures and the performance of MPS were reported in the previous papers [2-3].
2.2 ENR 25 compounding
A typical vulcanization formulation (Semi Efficient) was used for the ENR 25 compounding. The ENR 25 compounding was performed on a two-roll mill (Model XK-160). Table 1 shows the formulation of the CB-loaded ENR 25 compounds in the existence of MPS.

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

2.3. Torque properties
The maximal torque (Mx), minimal torque (Mn) and changes in torque (Mx – Mn) were determined based on ISO 3417 through the use of a cure meter (MDR 2000). The vulcanization temperature was 150 °C.

3. Results and Discussion

3.1. Minimal torque
The minimal torque (Mn) of the CB-loaded ENR 25 compounds with/with no MPS is shown in Fig. 1. The inclusion of one phr of MPS reduced the minimal torque. Increasing the MPS loading caused in further reducing the minimal torque. In vulcanization theory, the minimal torque indicates relative viscosity of a rubber compound and it also indicates the filler to filler agglomeration [4-6]. The lower the minimal torque, the lower the viscosity and also the lower the filler to filler agglomeration. The reduction of minimal torque was due to the action of MPS as an extra plasticizing agent/additive which further reduced the viscosity of the ENR 25 compounds and enhanced the degree of filler dispersion, respectively. Any rubber additive that could reduce the viscosity of a rubber compound is classified into plasticizing agent [7-8].

3.2. Maximal torque
The maximal (Ms) torque of the CB-loaded ENR-25 compounds without/with the MPS incorporation is shown in Fig. 2. The incorporation of one phr of MPS raised the maximal torque. Increasing the MPS loading that incorporated into the CB-loaded ENR-25 caused in a constant value of maximal torque. Because of maximal torque announces the measurement of stock modulus that raised in this study (for one phr of MPS); the increase in maximal torque was connected to the nature of CB to ENR-25 interaction i.e. intercalation and exfoliation [9-10]. In this study, the MPS acted as plasticizing ingredient that improved the CB to ENR-25 interaction.

3.3. Torque change
The torque changes the CB-loaded ENR 25 with/with no MPS incorporation is shown in Fig. 3. The one phr of MPS raised torque change and further increases the MPS loading further decreased the torque changes. Since the torque change indicates the degree of crosslinks behaviour of a rubber compound [4-6], a greater torque change means a higher level of crosslinks. The MPS increased the crosslinks level of the ENR 25. It was connected to the plasticizing effect of MPS that enhanced the filler dispersion within the ENR 25 compounds. The improvement in the degree of filler dispersion improved the supplementary physical crosslinks of the loaded ENR 25 vulcanizates. As an incorporation explanation,
the ENR 25 is a polar rubber and connected to the presence of several epoxy groups. As expected, the amine utilized the epoxy groups as crosslinks sites. Thus, raised torque change could be contributed by the forming of some amine-epoxy crosslinks. The amine-epoxy typed of crosslinks was considered as a peculiar type of crosslinks and, together with physical and sulphide crosslinks, contributed to the total crosslinks of the CB-loaded ENR 25 compounds.

**Figure 1.** The minimal torque vs MPS loading

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**Figure 2.** The maximal torque vs MPS loading
The decreases in the torque change after the one phr of MPS loading assumable was connected to the dilution effect of the excessive MPS that not only bounded the CB and curatives within its molecule but also facilitated a significant formation of amine-epoxy crosslinks which disrupted the stereoregular structure of ENR 25 causing the compound less elastic and hence, decreased the total crosslinks.

4. Conclusions
The modified palm stearin decreased the minimal torque but increased the maximal torque and torque change. The bigger the modified palm stearin doses caused in the lower was the minimal torque but caused in the higher was the torque change. Presumably, the enhancement in torque was attributed to the role of modified palm stearin as the supplementary plasticizing agent for the carbon black-loaded ENR 25 compounds. The oily property of modified palm stearin decreased the viscosity and enhanced rubber to filler interaction or crosslinks level, respectively.

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