The incorporations of palmitamide as a rubber chemical into carbon black-loaded styrene-butadiene rubber: cure rate index and torque properties

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Abstract. This study studied the effect of palmitamide as a new rubber chemical on the index of healing rate and torsion properties of carbon black (CB) charged styrene-butadiene rubber compounds. SBR was loaded with CB at a fixed load (thirty phr) and palmitamide was added to the CB-loaded SBR compound at doses varying from two to eight phr. The effect of palmitamide addition on the healing rate index and torsional properties of SBR CB loads were investigated. It was revealed that palmitamide caused an increase in the speed of the healing process in SBR containing CB. The greater the palmitamide dose, the higher the CRI. The increase in CRI is associated with the role of palmitamide as an additional accelerator for CB-loading SBR. The amine content of palmitamide increases CRI. It was also revealed that palmitamide lowers the minimum torque but increases the maximum torque as well as the torque difference by up to six palmitamide additions. The minimum torque reduction is due to the plasticizing effect of palmitamide. The increase in maximum torque and difference in torque is due to the increased intercalation process due to the action of palmitamide as an acting agent which increases CB dispersion.

1. Introduction
As the vulcanization process is known as the heating process of a rubber compound in order to gain the elastic rubber vulcanizates/products from the compound of the raw rubber. The raw rubber is mixed with some recommended-rubber chemicals to achieve a rubber compound and subsequently rubber compound is heated/vulcanized with a fixed temperature for several minutes and hence, the rubber compound is transformed into a rubber vulcanizate. The rubber vulcanizate has got several utmost level of applications such as excellent mechanical properties i.e. tensile strength and tensile moduli.

The mechanical properties of the rubber vulcanizates can be further increased by adding reinforcing fillers [1,2], and one of them is carbon black (CB). The CB is used in making of black-colored rubber products and it relatively suitable for any type of rubber when they are compounded. In order to enhance the processing aspect, this study using palmitamide as rubber chemical to improve the processing properties of CB-loaded styrene-butadiene rubber (SBR). Therefore, this study investigated the influences of palmitamide additions on cure properties i.e. cure rate index and torque properties of the CB-loaded SBR. The palmitamide was prepared by reacting palmitic acid with urea [3-5].
2. Experimental

2.1. SBR and rubber additives
SBR was used as the raw rubber. The N330-typed CB was used as the reinforcing filler. Other rubber additives i.e. sulphur, zinc oxide, stearic acid, N-isopropyl-N'-phenyl-p-phenylenediamine (IPPD), and benzothiazolyl disulfide (MBTS) were used. The palmitamide was produced using palmitic acid and urea. The reaction procedures and the performance of palmitamide were reported in the previous papers [3-5].

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

Table 1. CB-loaded SBR in the existence of palmitamide

| Rubber/chemicals                        | Amount (parts per hundred rubber/phr) |
|-----------------------------------------|---------------------------------------|
| SBR                                     | 100                                   |
| Zinc oxide                              | 5                                     |
| Sulphur                                 | 1.5                                   |
| mercaptobenzothiazol disulfide          | 1.5                                   |
| CB                                      | 30                                    |
| IPPD                                    | 2                                     |
| Stearic acid                            | 2                                     |
| Palmitamide                             | 2 to 8                                |

2.3. Cure rate index properties
The cure properties of the CB-loaded SBR were studied using a Monsanto Moving Die Rheometer (MDR 2000) that was operated to determine the scorch and cure times and cure rate index based on ISO 3417. The SBR 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 cure times. The Equation of CRI as follows;

\[
\text{CRI} = \frac{100}{(\text{Cure time} - \text{Scorch time})}
\]

2.4. Torque properties
The optimum cure time \(t_{90}\) and torque properties include maximum torque \((M_x)\), minimum torque \((M_n)\) and change in torque \((M_x - M_n)\) were determined based on ISO 3417 through the use of a Rheometer (MDR 2000). The vulcanization temperature was 150 °C.

3. Results and Discussion

3.1. Cure rate index properties

3.1.1. Cure times and scorch times. The cure times and scorch times of CB-filled SBR with and with no palmitamide are shown in Fig. 1. The incorporation of two phr of palmitamide reduced the scorch time of the SBR control-compound (SBR compound with no palmitamide). Increasing the palmitamide incorporation up till eight phr further reduced the scorch time.

The two phr of palmitamide incorporation reduced the cure time of the SBR control-compound. It indicated that the palmitamide improved the rate of cure of the CB-filled SBR compounds. It was similar with the trend of scorch time; the bigger the loading of palmitamide, the lower was the cure time. It was attributed to the role of palmitamide as a curative additive for the CB-filled SBR which affected
the scorch times and cure times. A rubber additive that would cause some affections in cure properties of a rubber compound is classified into a curative additive [6-7].

![Figure 1](image1.png)

**Figure 1.** The cure time and scorch time vs palmitamide loading.

### 3.1.2. Cure rate index

The cure rate index (CRI) of CB-filled SBR with/without palmitamide is shown in Fig. 2. The CRI is a determination of a rate of cure of transforming a compound into a vulcanizate of rubber [8-9]. A lower of CRI means a lower rate of cure process and vice versa. The palmitamide increased the CRI of CB-filled SBR. It was attributed to the role of palmitamide as extra accelerator for the CB-filled SBR. Presumably, the content of amine of palmitamide increased the CRI. Bigger concentration of palmitamide loading caused in a more pronounced the rate of cure. It was simply attributed to the bigger concentration was of palmitamide in the CB-filled SBR.

![Figure 2](image2.png)

**Figure 2.** The cure rate index vs palmitamide loading.
3.2. Torque properties

Figure 3. The maximum and minimum torques vs palmitamide loading.

Figure 4. Difference in torque vs palmitamide loading.

4. Conclusions
The palmitamide was a curative rubber chemical for carbon black-loaded styrene-butadiene. It decreased the scorch time, cure time but increased the cure rate index of the carbon black-loaded styrene butadiene rubber compounds. The also palmitamide decreased the minimum torque but increased the maximum torque as well as the torque difference up to a six phr of palmitamide additions. The decreasing of minimum torque was due to the plasticizing effect of the palmitamide. The increasing of maximum torque and torque difference was due to the intercalation process was enhanced because of the acting of palmitamide as practicing agent that improved the carbon black dispersion.
Acknowledgement

Many thanks to the rubber lab of P.T. Industri Karet Deli, Medan (Indonesia) for performing research-study activities.

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