The Carbon Black-Loaded Styrene-Butadiene Rubber in The Addition of Palmitamide: The Cure Characterization

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Abstract: This study investigated the influences of palmitamide on the cure characterization of carbon black (CB)-loaded styrene-butadiene rubber (SBR). The SBR was loaded with CB at a fixed loading (thirty phr) and the palmitamide was loaded into the CB-loaded SBR compounds with varied doses from two to eight phr. The palmitamide was prepared from the chemical reaction between urea and palmitic acid at an appropriate condition of reaction. The influences of palmitamide additions on the scorch time, cure time and cure rate index/CRI of CB-loaded SBR were investigated. It was examined that the palmitamide caused an enhancement in the rate of the cure process on the SBR compounds. The palmitamide decreased both the times to scorch and cure times but increased the CRI. The bigger the palmitamide doses caused in the lower were the scorch and cure times but caused in the higher was the CRI. The enhancement in CRI was attributed to the role of palmitamide as the supplementary accelerator for the CB-loaded SBR compounds. The amine content of palmitamide enhanced the CRI.

1. Introduction

Vulcanization process is performed in order to achieve some elastic products from the raw rubbers. A raw rubber or rubber blend, together with the rubber chemicals are compounded to achieve a rubber compound and then the rubber compound is vulcanized with a certain temperature for some minutes and hence, the rubber compound is converted into a rubber vulcanizate. As a summary, through the vulcanization process the rubbers compounds are heated and converted into rubbers vulcanizates. These rubbers vulcanizates or rubbers products have some satisfactory level of usages such as good mechanical/physical properties i.e. tensile strength, tensile moduli and high elasticity. This high elasticity makes the rubbers vulcanizates to become one non-replaceable material and find utilize in one multitude of applications [1].

As mention at the above paragraph, the mechanical properties of the rubber vulcanizates can be further enhanced by utilizing reinforcing fillers [2, 3]. One of the most popular reinforcing fillers 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 processed. 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) compounds. Therefore, this study investigated the influences of palmitamide additions on cure properties i.e. cure time, scorch time and cure rate index of the CB-filled SBR compounds. The palmitamide was produced by chemically-reaction between palmitic acid with urea [4-6]. The palmitic acid comes from palm oil and hence, as the product of the chemical interaction between
palmitic acid and urea; the palmitamide has the oily properties. Any oily material has the potential to be utilize as one plasticizing agent for rubbers compounds or rubbers vulcanizates.

2. Experiment

2.1. SBR and rubber chemicals
SBR 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, antioxidant/IPPD, stearic acid and accelerator/MBTS were used. The palmitamide was prepared by chemically-reaction between 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 and rubber ingredients were mixed on a two-roll mill (Model XK-160). Table 1 shows the system of the CB-loaded SBR in the existence of palmitamide.

| SBR/ingredients | (parts per hundred rubber/phr) |
|-----------------|--------------------------------|
| SBR             | 100                            |
| ZnO             | 5                              |
| S               | 1.5                            |
| MBTS            | 1.5                            |
| CB              | 30                             |
| Stearic acid    | 2                              |
| IPPD            | 2                              |
| Palmitamide     | 2 to 8                         |

2.3. Cure properties
The cure properties of the CB-loaded SBR were studied with one Monsanto Moving Die Rheometer/MDR 2000 that was operated to find the data of scorch and cure times and cure rate index/CRI based on ISO 3417. The SBR compounds were heated/vulcanized and tested at 150 °C. The CRI is a cure rate measurement based on the data of scorch and cure times. The Equation of CRI as follows;

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

3. Results and Discussion

3.1. Scorch time
The scorch times of CB-loaded SBR with/with no palmitamide are visualized in Fig. 1. The two phr of palmitamide decreased the scorch time of the SBR reference-compound (SBR compound with has no palmitamide). Increasing the palmitamide dose up till eight phr further decreased the scorch time.
3.2. Cure time

The cure time of CB-loaded SBR with/without palmitamide is shown in Fig. 2. The two phr of palmitamide reduced the cure time of the SBR reference-compound. It means the palmitamide enhanced the cure rate of the compounds. Similar to the trend of scorch time; the higher the dose of palmitamide, the lower time was the cure. It was because of the role of palmitamide as one curative rubber chemical which influenced the needed-times to scorch and cure. Any rubber chemical that would provide some affections on cure properties of a rubber compound can be classified into curative rubber chemical [7-10].

3.3. Cure rate index

The cure rate index (CRI) of CB-loaded SBR with/without palmitamide is shown in Fig. 3. The CRI is a measurement of a cure rate of converting a rubber compound into a rubber vulcanizate [11-12]. A higher of CRI means a higher rate of cure process. The palmitamide enhanced the CRI of CB-loaded SBR. It was due to the role of palmitamide as a supplementary accelerator for the CB-loaded SBR. The amine content of palmitamide enhanced the CRI. Higher of palmitamide dose caused in a faster cure rate. It was fundamentally because of the higher amount was of palmitamide in the CB-loaded SBR.
Figure 3. The cure rate index vs palmitamide loading.

4. Conclusion
The palmitamide was one rubber ingredient that acted as curative rubber chemical for carbon black-loaded styrene-butadiene compounds. It reduced the needed-times to scorch and cure but increased the cure rate index of the carbon black-loaded styrene butadiene rubber systems/compounds. Presumably, the amine part of the palmitamide contributed positively during the curing process of the carbon black-loaded styrene-butadiene systems/compounds.

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