The Strength and Reinforcement Behaviors of Styrene Butadiene Rubber-Silica Compound with Oleamide as Palm Oil-Based Rubber Additive

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Abstract. In the application of a semi-efficient method for the rubber compounding and vulcanization, the study on the effects of oleamide addition, as a rubber additive, on the strength and reinforcement behaviors of styrene butadiene rubber (SBR)-silica compound was carried out. The oleamide was synthesized in a laboratory via a chemical synthesizing of urea and oleic acid. Since oleic acid is a palm oil-based material, oleamide is considered a palm oil-based material. The lab-synthesized oleamide was added to a silica-filled SBR compound with varying concentrations (2, 4, 6, and 8 parts per hundred SBR, phr). The results observed that oleamide has functioned as a co-curing and plasticizing material for the SBR-silica compound. The additive has decreased the curing time but lifted the curing rate of the compound of SBR-silica. The greater the oleamide concentration, the lower the curing time. The oleamide also lifted the delta torque, tensile strength, moduli, and reinforcement index. The tensile strength was lifted whenever the oleamide was added to a 4 phr.

Keywords: Styrene Butadiene Rubber · Oleamide · Strength · Reinforcement

1 Introduction

Composites of rubbers are defined as the combined material of inorganic materials and organic rubber matrixes which function synergistically in producing some desired mechanical dan processing properties without damaging the properties of the base rubber matrix [1, 2].

Besides rubber inorganic material, inorganic fillers are also compounded into the base rubber [3, 4]. The compounding process can be performed on an opened two-roll mill or internal mixer. Inorganic fillers were added to the rubber compound for some reason. Inorganic non-reinforcing fillers, such as calcium carbonate, kaolin, etc., are used to

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cheapen the cost of rubber composite products. At the same time, the inorganic reinforcing fillers were used to reinforce the base rubber and produce much better mechanical properties, e.g., betterment in tensile and tear strengths, abrasion resistance, and so on.

There are two types of inorganic reinforcing fillers, i.e., silica and carbon black (CB). The silica is chosen whenever to produce light-colored rubber composites, while the CB is used whenever black color is wanted in the rubber composite [5–7]. Rubber composite products filled with CB are good in tensile strength, and rubber composite products filled with silica are good in tear strength. Because of their differences in molecular level, both the reinforcing fillers offer different levels of reinforcing effect on the base rubbers. The silica reinforcing filler is more hydrophilic and polar than CB, so its reinforcement effect is relatively lower than CB. Many factors that affect the reinforcement effect of a reinforcing filler include the nature of rubber-to-filler interaction, filler-to-filler interaction, the sizes of the filler's particles, etc.

Like CB, the particle sizes of silica are very fine, and the particles of these fillers have strong filler-to-filler interaction. At the same time, the rubber-to-filler interaction is relatively not strong, especially when the basic rubbers are non-polar, e.g., natural rubber (NR) and styrene butadiene rubber (SBR). Those natural and synthetic rubbers are also hydrophobic materials. The silica filler particles tend to form silica aggregate or silica agglomeration inside the rubber molecules during the compounding process. This can be considered silica's disadvantage whenever the filler is designed to reinforce base rubbers [8].

Many rubber technologists and researchers have already reported their findings in solving the fillers dispersion problem of silica, including the usage of silane coupling agents [9–11], processing/dispersant aid [12, 13], or compatibilizer agents [14–16]. To our best knowledge, no attempt has been made to solve the poor silica dispersion using oleamide. Oleamide is an amide substance; it can be produced from the oleic acid of palm oil with urea. The substance is a unique molecule; it has two different functional groups: amide and hydrocarbon. The amide group is polar, whilst the hydrocarbon group is non-polar. Therefore, oleamide has the potency to be used as a compatibilizer. The amide group can interact strongly with silica, and the hydrocarbon group will interact with NR or SBR. Those interactions will produce an oleamide-silica-rubber coupling bond, which will handle the silica's low reinforcing effect and dispersion level.

The chemical formula of oleamide is $CH_3\ (CH_2)_7CH = CH\ (CH_2)_7CONH_2$, and its typical FT-IR spectrum is shown in Fig. 1. Therefore, this paper reports the results of the application of oleamide in SBR/silica compounding. The effects of oleamide on strength and the reinforcement behaviors of SBR/silica compound/composite were studied. The oleamide was lab-produced by synthesizing the process of oleic acid and urea. The substance was added into the SBR/silica with varied amounts, i.e., from 2 to 8 parts per hundred parts of SBR (phr). The SBR/silica/oleamide compound was vulcanized with a semi-efficient method at 150 °C.

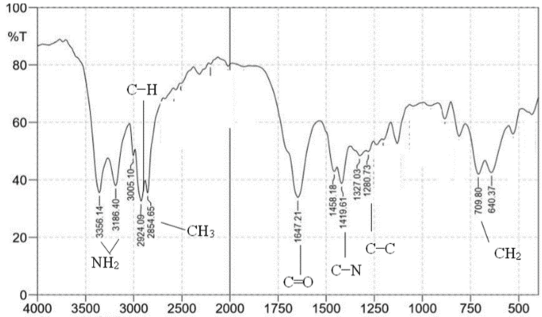

Fig. 1. The typical infrared spectrum of oleamide SBR/silica/oleamide compounding

Table 1. The typical formulation for the SBR/silica/oleamide compounding.

Chemical substances	Amount (phr.)
SBR, basic rubber	100
Sulfur, crosslinker	1.7
IPPD, antioxidant	2.1
Stearic acid, coactivator	2.1
MBTS, accelerator	1.6
Zinc oxide, activator	5.1
Silica, reinforcing filler Oleamide	30 2, 4, 6, 8

2 Method

2.1 Chemical Substances

The 1502-type of SBR and other chemical substances, i.e., silica, sulfur as the crosslinker, zinc oxide, isopropyl-N'-phenyl-p-phenylenediamine (IPPD), mercapto benzothiazole disulfides (MBTS) and stearic acid were utilized. They are prepared by direct buying from local chemical suppliers. The oleamide was a laboratory-synthesized of urea and oleic acid synthesizing, and the typical infrared spectrum of oleamide is shown in Fig. 1.

The base SBR and other chemical substances were mixed or compounded using a semi-efficient curing method. The compounding steps refer to ASTM D3184–80 on a laboratory-sized two-roll mill. The typical formulation for making the rubber compound and the function of each material are tabulated in Table 1.

2.2 Vulcanization Behaviours

The vulcanization behaviors include t90, time of optimum curing; Mx trq, maximum torque; Mn trq minimum torque; Mx trq – Mn trq as delta torque of the

SBR/silica/oleamide composite were studied refer to ISO 3417 with a cure meter (MDR 2000). The SBR/silica/oleamide compounds were cured at 150 oC.

2.3 Reinforcement Index/Tensile Behaviours

The tensile behaviors of SBR/silica/oleamide composite were studied referring to ASTM D-882 with a tensiometer with a 500 mm/minute rate of extension. The reinforcement index or RI was determined by referring to Eq. 1.

$$RI = 100 \times (M300/M100)\% \tag{1}$$

where M300 and M100 are stressed at 300% and 100% elongations.

3 Results and Discussion

3.1 Vulcanization Behaviours

Figures 2, 3, 4 demonstrate the affections of oleamide on t90, Mx try, Mn try, and delta torque of SBR/silica composite. It was seen in Fig. 2; the incorporation of 2 phr of oleamide has lowered the optimum curing time. The bigger the oleamide amount is causing, the less optimum curing time. Therefore, the oleamide has acted as a co-curing substance. This was due to a more and more significant acceleration effect of the oleamide as a secondary accelerator. The amide (NH2) group presumably caused a more significant acceleration effect of the SBR/silica compound. Amide is the one of actual accelerators in the process of vulcanization of rubbers compounds [17].

As seen in Fig. 3, the 2 phr of oleamide addition has shifted the maximum torque, which explains that the stock modulus value has improved. This was accredited to rubber-to-filler interaction behavior, e.g., filler insertion and exfoliation [18, 19]. The shifting of maximum torque was more significant whenever the oleamide amount was further raised to 6 phr. The filler insertion, exfoliation, and rubber-to-filler interaction were shifted furtherly in this case.

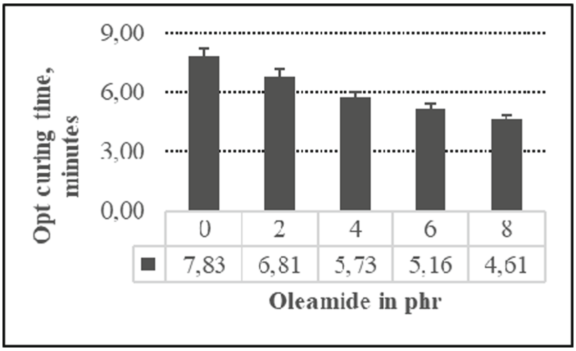

Fig. 2. Optimum curing time vs. oleamide amount

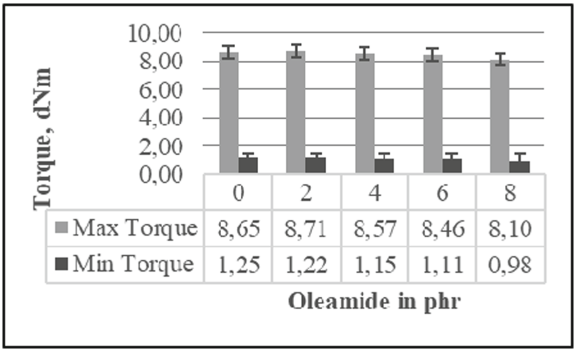

Fig. 3. Torques vs. oleamide amount

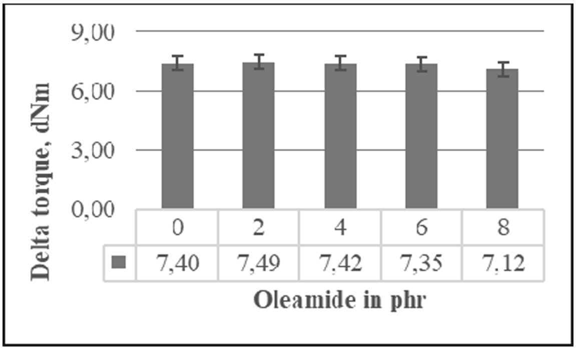

Fig. 4. Delta torques vs. oleamide amount

As seen in Fig. 4, the addition of 2 phr of oleamide to the control compound has yielded an SBR/silica/oleamide compound with a greater delta torque compared to the control compound (SBR/silica/no oleamide). The oleamide additions up to a 6 phr shifted the delta torque value. It is known very well that delta torque corresponds to the crosslinks level of rubbers compounds [18, 20]. The bigger the value, the greater the crosslinks level is formed. These crosslinks include chemical (sulfide) and physical crosslinks [21]. The oleamide incorporations up to a 6 phr shifted the delta torque of the SBR/silica composite. This was due to the physical crosslink shifting that shifted the rubber-to-filler interaction.

3.2 Tensile and Reinforcement Behaviours

Figure 5 shows the RI (Reinforcement Index) and tensile moduli of the SBR/silica/oleamide composite. The tensile moduli, i.e., tensile moduli at 300% and 100% elongations (M300 and M100). Table 2 tabulates EB as elongation at break and TS as tensile strength. The 2 phr of oleamide incorporation has shifted the RI, M300, M100, and TS values of the SBR/silica/no oleamide compound. The composite behaviors shifted due to the crosslinking level enhancement via the shifting of rubber-to-filler

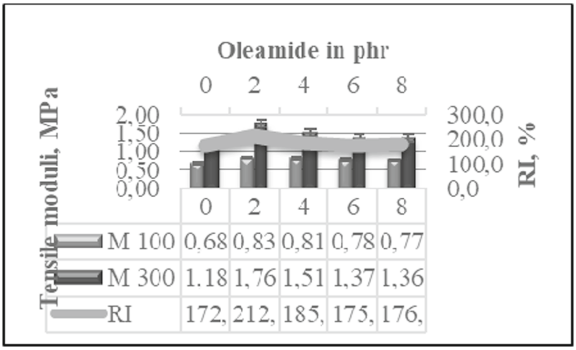

Fig. 5. RI and tensile moduli vs oleamide amount

Table 2. Tensile strength and breaking elongation of SBR/silica/oleamide composite

TS and EB properties	Oleamide amount (phr)				
	0	2	4	6	8
TS, Mpa	17.8	20.4	14.6	14.0	13.7
EB, %	880	690	770	860	900

interaction or physical crosslinks [10]. The EB was increased as oleamide was added and increased if the oleamide increased its amount.

The increase in oleamide amount up to 6 phr further shifted the RI, M300, M100, and TS values. After the 6 phr of oleamide incorporation, the values of those SBR/silica behaviors started to decrease. Enhancement in those properties was because of the shifting of the crosslinking level, and the diminishing of those properties was attributed to the crosslinking level decreasing.

4 Conclusion

Oleamide has the potency to be a compatibilizer for styrene butadiene rubber/silica composite. It functioned as a curative chemical substance. The addition of oleamide into styrene butadiene rubber/silica compound has caused in decreasing trend of optimum curing time but shifted the delta torque. The oleamide also has significantly provided some reinforcement effects to styrene-butadiene rubber/silica compound. The rubber properties such as tensile strength, reinforcement index, and tensile moduli were shifted to a 4 phr of oleamide amount.

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