The utilization of palmitamide as palm oil-based plasticizer in SBR/carbon black composites: An observation on degree of carbon-black dispersion

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Abstract. Degree of carbon black (CB) dispersion in the composites of styrene-butadiene rubber (SBR)/CB/palmitamide was observed. The palmitamide is a variety of amides ingredients. It was formed by the chemical reaction of urea and palmitic acid at a locked condition. The palmitic acid is derived from palm oil. The palmitamide was mixed with SBR/CB compounds with varied doses i.e., from two till eight phr, whilst the CB was mixed with the SBR at a settled dose (thirty phr). The impact of palmitamide doses on the degree of CB dispersion in the SBR/CB composites was observed. Based on the torque behaviours of the SBR/CB/palmitamide systems; the degree of CB dispersion was observed. The palmitamide behaved as curative ingredient and plasticizer for the SBR/CB systems. The palmitamide cut down the minimal torque but enlarged maximal torque and torque changes of the systems of SBR/CB. The bigger the palmitamide dose, the lower the minimal. As a plasticizer, the palmitamide cut down the minimal torque causing in better the degree of CB dispersion in SBR. The bigger the palmitamide dose, the better was the CB dispersion.

1. Introduction
The process of mixing of raw rubbers with appointed rubber ingredients is interpreted as compounding. At the final stage of mixing process; output as the rubber compounds/systems are accomplished. The rubber systems can immediately to be processed/heated/vulcanized to gain rubbers vulcanizates with excellent physical/tensile/mechanical properties and great elasticity. Consequently, rubbers vulcanizates are not able to be changed by any other types of materials [1].

The raw rubbers can be natural or synthetic ones. Styrene-butadiene rubber (SBR), as a favoured synthetic raw rubber, usually its vulcanizates has relatively weaker properties compared to the natural rubber (NR) vulcanizates with no filler or gum also [2].

This detriment of the SBR vulcanizates is cleared up by the incorporation of one type of reinforcing fillers into the SBR systems in the middle of the mixing process. A particular filler of those reinforcing fillers is carbon black (CB). The CB is a black-coloured reinforcing filler that relatively applicable to any types of raw rubbers. Because of it has a very small size of particles and has to applicate at relatively bigger doses; the CB particles are possible to forming some agglomerations and turn to a poor degree of CB dispersion that can ruin the properties of the CB-loaded SBR systems/vulcanizates. To settle this trouble; one particular rubber ingredient is involved in the middle of the rubber mixing process. In this observation, palmitamide as one type of amides ingredients that is derived from palm oil, was applied to settling the poor degree dispersion of the CB. The palmitamide has the oily nature
and hence, it has the opportunity to be applied as one type of plasticizing ingredient to raising the degree of CB dispersion. Accordingly, this observation examined the effect of palmitamide dosage on the degree of CB dispersion in the composites of SBR/CB.

2. Experiments

2.1. SBR and rubber additives
SBR was used as the raw rubber. The N330 of CB was used as the particular reinforcing filler. Other rubber ingredients namely stearic acid, sulphur/S, zinc oxide/ZnO, antioxidant/IPPD and accelerator/MBTS were needed. The palmitamide, \( \text{CH}_3\text{(CH}_2\text{)}_{14}\text{CONH}_2 \), was developed applying the urea-stearic acid reaction.

2.2. SBR compounding
A particular vulcanization formulation (Semi Efficient) was needed for the process of compounding of SBR/CB/palmitamide composites was executed on a 2-roll mill (Model XK-160). Table 1 shows the system of the SBR/CB/palmitamide composites.

| Rubber/ingredients       | Parts per hundred rubber |
|--------------------------|--------------------------|
| SBR                      | 100                      |
| Stearic acid             | 2                        |
| ZnO                      | 5                        |
| S                        | 1.5                      |
| MBTS                     | 1.5                      |
| CB                       | 30                       |
| IPPD                     | 2                        |
| Palmitamide              | 2 to 8                   |

2.3. Torque behaviour
The torque behaviours namely maximal torque (Tx), minimal torque (Tn) and change in torque (Tx – Tn) were figured out based on ISO 3417 applying one Rheometer/MDR 2000. The vulcanization temperature was at 150 °C.

3. Results and discussion

3.1. Torque behaviours

3.1.1. Minimal torque. The minimal torque of the SBR/CB composites with/with no palmitamide is shown in Fig. 1. The inclusion of one phr of palmitamide declined the minimal torque. Increasing the palmitamide dosage caused in further declining the minimal torque. In curing of rubber compounds theory, the minimal torque is the indication of viscosity of a rubber system and it is also the indication of aggregation between the particles of the filler [3-5]. The low the minimal torque, the low the viscosity and also the low the tendency of filler to form the agglomeration.

The declining of minimal torque was connected to the behaviour of palmitamide as an extra plasticizing agent/ingredient which further declined the viscosity of the SBR systems and boosted the degree of filler dispersion, jointly. Each rubber ingredient that could decline the viscosity of a rubber compound is labelled into plasticizing ingredient [5-7].
3.1.2. Maximal torque. The maximal torque of the SBR/CB composites with/with no the palmitamide is visualised in Fig. 2. The inclusion of two phr of palmitamide raised the maximal torque. Raising the palmitamide dosage that incorporated into the SBR/CB composites caused in farther raising the maximal torque.

Because maximal torque announces the measurement of stock modulus raised in this observation; the increase in maximal torque was connected to the nature of filler to rubber interaction namely intercalation and exfoliation [7-10]. The raise in maximal torque got more significant if the palmitamide dosage was higher. In this observation, the palmitamide behaviour as plasticizing ingredient that boosted the degree of filler to rubber interaction.

3.1.3. Torque change. The torque changes the SBR/CB composites with/with no palmitamide inclusion is shown in Fig. 3. The one phr of palmitamide raised up torque change and farther increasing the palmitamide dosage farther declined the torque change. The torque change announces
the level of crosslinks of a composite system [11,12], a low torque change means a low level of crosslinks. The palmitamide raised the crosslinks level of the SBR. It was related to the plasticizing behaviour of palmitamide which boosted the filler dispersion degree within the SBR systems. The increase in degree of filler dispersion raised the extra physical crosslinks of the SBR/CB composites. Thus, increased torque change was contributed by the formation of supplementary crosslinks.

![Figure 3. The torque change of SBR/CB/palmitamide composites](image)

The decreases in the torque change after the two phr of palmitamide dose presumably was connected to the dilution behaviour of the over dosage of palmitamide that covered the CB and curatives and hence, declined crosslinks level.

3.2. Observation on degree of CB dispersion

![Figure 4. The L values of SBR/CB/palmitamide composites](image)
The degree of CB dispersion SBR systems (based on torque behaviours) was calculated according to the Equation (2) [13, 14].

\[ L = \eta_r - m_r \quad (1) \]

In which: \( \eta_r \) is \( [T_{Nf}/T_{Ng}] \), and \( m_r \) is \( [T_{Xf}/T_{Xg}] \); in which \( T_{Nf} \) and \( T_{Xf} \) are the minimal and maximal torques of the SBR systems and \( T_{Ng} \) and \( T_{Xg} \) are the minimal and maximal torques of the SBR system with no filler (gum). A low \( L \) value is a low degree of filler dispersion. The minimal and maximal torques of gum SBR were 0.72 and 6.18, jointly [3-4].

Fig. 4 shows the degree of CB dispersion in SBR systems at various palmitamide dosage. As observed, the \( L \) values of SBR/CB systems with palmitamide were lower than that of SBR/CB system with no palmitamide. A high the palmitamide dosage provided a low \( L \) value. It was connected to the plasticizing behaviour of palmitamide that declined viscosity, a better degree of CB dispersion, jointly.

4. Conclusions
The palmitamide was a rubber ingredient that roles as curative ingredient and palm oil based-plasticizing ingredient for the styrene-butadiene/carbon black composites, caused declining in minimal torque but raising in maximal torque, torque change and degree of carbon black dispersion. The bigger the palmitamide dosage, the better the degree of the carbon black dispersion. It was related directly to the plasticizing behaviour of palmitamide that has the ability to reducing the viscosity of the styrene-butadiene/carbon black composites. It was assumable that the oily nature of the palmitamide could decline the viscosity.

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