The presence of stearamide as a rubber chemical in silica loaded-styrene butadiene rubber: The curing properties

R Dhoni¹, M Ginting² and I Surya*¹
¹Department of Chemical Engineering, Universitas Sumatera Utara, Medan, Indonesia
²Department of Chemistry, Universitas Sumatera Utara, Medan, Indonesia

E-mail: indradanas@yahoo.com isurya@usu.ac.id

Abstract. This research-study investigated the influences of stearamide on the curing properties of silica-loaded styrene-butadiene rubber (SBR). The SBR was loaded with silica at a fixed loading (thirty phr) and the stearamide was added into the silica-loaded SBR compounds with varied doses from two to eight phr. The influences of stearamide additions on the scorch time, optimum curing time and cure rate index (CRI) of silica-loaded SBR were investigated. It was observed that the stearamide caused an enhancement in the rate of the curing process on the SBR compounds. The stearamide decreased both the times to scorch and optimum curing times but increased the CRI. The bigger the stearamide doses caused in the lower were the scorch time, curing time and CRI. The decreases in CRI was attributed to the role of a reactant that interacted chemically inside the silica-loaded SBR compounds. The amine content of stearamide presumably triggered the chemical reaction between the SBR, silica filler and amine itself.

1. Introduction
As a sulphur reaction, vulcanization is used to crosslink the raw rubbers at a certain condition. At the end of the reaction, some elastic products are achieved. The raw rubbers are natural or synthetic typed of rubber. They can be processed individually or as a rubber blend. The rubber products have some satisfactory level of usages i.e. good mechanical properties i.e. tensile strength, hardness and tensile moduli.

The mechanical properties of the rubber products can be further improved by using reinforcing fillers [1, 2]. One of the most popular reinforcing fillers is silica. The silica filler is used in producing of non-black colored rubber products and it relatively less suitable for any type of rubber when they are compounded or processed. Improving the processing aspect, this study applied stearamide as rubber ingredient to improve the processing properties of silica-filled styrene-butadiene rubber (SBR) compounds. Therefore, this study investigated the influences of stearamide additions on curing properties i.e. scorch time, cure time and cure rate index of the silica-filled SBR compounds. The stearamide was produced by reacting stearic acid with urea.

2. Experimental
2.1. SBR and rubber ingredients
SBR was used as the raw rubber. The precipitated silica was used as the reinforcing filler. Other rubber ingredients i.e. N-isopropyl-N'-phenyl-p-phenylenediamine (IPPD), sulphur, stearic acid, zinc oxide,
and benzothiazyl disulfide (MBTS) were applied in rubber compounding. The stearamide was produced using stearic acid and urea. The equation the reaction as follows,

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

Table 1. Silica-loaded SBR in the existence of stearamide

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

2.3. Curing properties
The curing specification of the silica-loaded SBR were studied applying a Monsanto Moving Die Rheometer (MDR 2000) that was operated to specify the scorch and cure times and cure rate index based on ISO 3417. The silica-loaded SBR compounds were vulcanized and tested at 150 °C. The cure rate index (CRI) is a cure rate estimation based on the data of scorch and cure times. The Equation of CRI as follows;

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

(1)

3. Results and Discussion

3.1. Scorch time
The scorch times of silica-loaded SBR without/with stearamide are shown in Fig. 1. The two phr of stearamide decreased the scorch time of the SBR reference-compound (SBR compound with no stearamide). Increasing the stearamide dose up till eight phr further decreased the scorch time. It was attributed to the affection of the amine content of the stearamide. The substance of Amine can enhance the cure rate of a rubber compound [3-6].

3.2. Cure time
The cure time of silica-loaded SBR with/withno stearamide is shown in Fig. 2. The two phr of stearamide decreased the cure time of the SBR reference-compound. It means the stearamide enhanced the cure rate of the compounds. Similar to the trend of scorch time; the greater the dose of stearamide, the lesser was the cure time. It was because of the role of stearamide as a curative ingredient which influenced the scorch and cure times. Any rubber additive that would provide some affections on cure properties of a rubber compound can be classified into curative rubber ingredient [7-10].
Figure 1. The scorch time vs stearamide loading.

Figure 2. The cure time vs stearamide loading.

3.3. Cure rate index
The silica-loaded SBR’s cure rate index (CRI) with/without no stearamide is shown in Fig. 3. The CRI is a measurement of a cure rate of changing a rubber compound into a rubber vulcanizate [11 - 12]. A higher of CRI means a higher rate of cure process. The stearamide increased the CRI of silica-loaded SBR. It was due to the role of stearamide as a supplementary accelerator for the silica-loaded SBR. The amine content of stearamide enhanced the CRI. Higher of stearamide dose caused in a more notable the rate of cure. It was simply because of the higher number was of stearamide in the silica-loaded SBR.
4. Conclusion
The stearamide was a curative rubber ingredient for silica-loaded styrene-butadiene rubber compounds. It decreased the scorch time, cure time and cure rate index of the silica-loaded styrene-butadiene rubber compounds.

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References
[1] Boonstra B 1979 *Polymer* 20 (6) pp 691-704
[2] Barlow F W 1993 *Rubber compounding: principles, materials, and techniques* (New York: CRC Press)
[3] Surya I and Edwin 2020 *IOP Conference Series: Materials Science and Engineering* 801 (1) p 012095
[4] Surya I, Edwin and Anto J 2020 *AIP Conference Proceedings* 2221 (1) p 030035.
[5] Surya I and Hafnim K N 2020 *IOP Conference Series: Materials Science and Engineering* 725 (1) p 012046
[6] Surya I, Ginting M, Anto J 2018 *AIP Conference Proceedings* 2024 (1) p 020061
[7] Sianturi RW and Surya I 2018 *Journal of Physics: Conference Series* 1116 (4) p 042033
[8] Surya I, Sukeksi L, Hayeemasae N 2018 *Mater. Sci. Eng* 309 pp 1-6
[9] Surya I and Khosman H 2020 *AIP Conference Proceedings* 2237 (1) p 020076
[10] Surya I, Hayeemasae N and Ginting M 2018 *IOP Conf Ser Mater Sci Eng* 343 p 012009
[11] Andriani F and Surya I 2018 *J Phys Conf Ser* 1116 (4) p 042005
[12] Surya I, Ginting M and Anto J 2018 *AIP Conf Proc* 2024 (1) p 020061

![Figure 3. The cure rate index vs stearamide loading.](image-url)