Silica-loaded styrene-butadiene rubber in the incorporation of stearamide: The torque properties

R Dhoni¹, M Ginting¹ and I Surya*¹,
¹Universitas Sumatera Utara, Medan, Indonesia

*E-mail: indradanas@yahoo.com isurya@usu.ac.id ramadhoni318@yahoo.com

Abstract. This research-study investigated the effects of stearamide on the torque properties of silica-loaded styrene-butadiene rubber (SBR). The SBR was loaded with silica at a settled dose (thirty phr) and the stearamide was mixed into the silica-loaded SBR compounds with varied doses from two to eight phr. The effects of stearamide additions on the maximal torque, minimal torque and torque change of silica-loaded SBR were investigated. It was observed that the stearamide caused some affection in torque properties of the silica-loaded SBR. The stearamide diminished the minimal torque but raised the maximal torque and torque change. The bigger the stearamide doses caused in the lower was the minimal torque but caused in the higher was the torque change. The enhancement in torque was attributed to the role of stearamide as the supplementary plasticizing agent for the silica-loaded SBR compounds. The oily property of stearamide decreased the viscosity and enhanced rubber to filler interaction or crosslinks level, respectively.

1. Introduction
The reinforcing fillers are always used in gaining the rubber articles/products with some satisfactory grade of applications [1-2]. One of the reinforcing fillers is silica and it is the most famous reinforcing filler in rubber industry. The silica is used in producing of non-black-colored rubber products.

The silica is relatively non compatible for any rubber when they are utilized. To enhance the processing aspect, this research-study utilizing stearamide as rubber additive to enhance the homogeneity of silica dispersion, as well as enhancing the rubber to filler interactions of silica-loaded styrene-butadiene rubber (SBR) compounds. Therefore, this research-study investigated the influences of stearamide incorporation on torque properties i.e. maximal torque, minimal torque and torque change of the silica-loaded SBR compounds. The stearamide was produced by reacting stearic acid with urea.

2. Methods
2.1. SBR and rubber additives
SBR was used as the raw rubber. The precipitate silica was used as the reinforcing filler. Other rubber additives i.e. sulphur/S, zinc oxide/ZnO, stearic acid, antioxidant/IPPD and accelerator/MBTS were used. The stearamide was produced using urea and stearic acid.
2.2. **SBR compounding**
A typical vulcanization formulation (Semi Efficient) was used for the compounding of silica-loaded SBR plus stearamide that was executed on a 2-roll mill (Model XK-160). Table 1 shows the system of the silica-loaded SBR in the existence of stearamide.

| Rubber/ingredients | Phr |
|--------------------|-----|
| SBR                | 100 |
| ZnO                | 5   |
| S                  | 1.5 |
| MBTS               | 1.5 |
| CB                 | 30  |
| IPPD               | 2   |
| Stearic acid       | 2   |
| Stearamide         | 2 to 8 |

2.3. **Torque properties**
The torque properties i.e. maximal torque (Mx), minimal torque (Mn) and change in torque (Mx – Mn) 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. **Minimal torque**
The minimal torque of the silica-loaded SBR compounds with/with no stearamide is shown in Fig. 1. The incorporation of one phr of stearamide reduced the minimal torque. Increasing the stearamide loading caused in further reducing the minimal torque. In vulcanization theory, the minimal torque indicates relative viscosity of a rubber system and it also indicates the filler to filler agglomeration [3-5]. The lower the minimal torque, the lower the viscosity and also the lower the filler to filler agglomeration.

The reduction of minimal torque was due to the action of stearamide as an extra plasticizing agent/additive which further diminished the viscosity of the SBR systems and enhanced the degree of filler dispersion, respectively. Any rubber additive that could reduce the viscosity of a rubber compound is classified into plasticizing agent [5-7].

![Figure 1. The minimal torque vs stearamide loading.](image-url)
3.2. Maximal torque
The minimal (M<sub>L</sub>) and difference torques of the silica-loaded SBR with/with no stearamide is shown in Figure 3. The incorporation of one phr of stearamide decreased the minimal torque but increased torque difference. The increases the stearamide loading caused in further decrease the minimal torque.

Since the minimal torque is the relative viscosity of a rubber compound and it also indicates the filler to filler agglomeration [8-10]. The lower the minimal torque, the lower the viscosity and also the lower the filler to filler agglomeration. It was connected to the additional usage of stearamide as an internal plasticizer that reduced viscosity of the SBR and improved the homogeneity of the silica dispersion, respectively.

![Figure 2](image1)

**Figure 2.** The maximal torque vs stearamide loading.

3.3. Torque change
The torque change the silica-loaded SBR with/with no stearamide addition is shown in Figure. 3. The one phr of stearamide increased torque change and farther increases the stearamide dose further diminished the torque change. Since the torque change is the level of crosslinks of a rubber system [11-12], a greater torque change means a higher level of crosslinks. The stearamide increased the crosslinks level of the SBR. It was due to the plasticizing effect of stearamide which enhanced the filler dispersion within the SBR compounds. The improvement in degree of filler dispersion improved the supplementary physical crosslinks of the loaded SBR vulcanizates. Thus, increased torque difference could be contributed by the formation of additional crosslinks.

![Figure 3](image2)

**Figure 3.** The torque change vs stearamide loading.
The decreases in the torque change after the six phr of stearamide dose assumable was connected to the dilution affection of the more stearamide that bounded the silica and curatives within its rubber molecule.

4. Conclusion
The stearamide was a curative rubber chemical for silica-loaded styrene-butadiene. The stearamide diminished the minimal torque but increased the maximal torque as well as the torque difference up to a six phr of stearamide additions. The decreasing of minimal torque was due to the plasticizing effect of the stearamide. The increasing of maximal torque and torque difference was due to the intercalation process was enhanced because of the acting of stearamide as practicing agent that improved the silica dispersion.

Acknowledgements
Authors acknowledge the rubber lab of P.T. Industri Karet Deli, Medan Office, Indonesia for performing research-work activities. The authors also acknowledge the financial support from Deputi Bidang Penguatan Riset dan Pengembangan, Kementerian Riset dan Teknologi/Badan Riset dan Inovasi Nasional Tahun Anggaran 2020 (grant no. 11/AMD/E1/KP.PTNBH/2020, tanggal 11 Mei 2020).

References
[1] Boonstra B 1979 Polymer 20 (6) 691-704
[2] Barlow F W 1993 Rubber Compounding: Principles, Materials, And Techniques CRC Press 10.1201/9780203740385
[3] Surya I and Edwin 2020 IOP Conference Series: Materials Science and Engineering 801 (1) 012095
[4] Surya I, Edwin and Anto J 2020 AIP Conference Proceedings 2221 (1) 030035
[5] Surya I and Hafni K N 2020 IOP Conference Series: Materials Science and Engineering 725 (1) 012046
[6] Surya I, Ginting M, Anto J 2018 AIP Conference Proceedings 2024 (1) 020061
[7] Sianturi RW and Surya I 2018 Journal of Physics: Conference Series 1116 (4) 042033
[8] Surya I, Sukeksi L, Hayeemasae N 2018 Mater. Sci. Eng 309 1-6
[9] Surya I and Khosman H 2020 AIP Conference Proceedings 2237 (1), 020076
[10] Surya I, Hayeemasae N and Ginting M 2018 IOP Conf Ser Mater Sci Eng 343 012009
[11] Andriani F and Surya I 2018 J Phys Conf Ser 1116 (4) 042005
[12] Surya I, Ginting M and Anto J 2018 AIP Conf Proc 2024 (1) 020061