Effect of potassium oleate on chemical structure-compression relationship of natural rubber foam

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Abstract. Rubber foam-based products, such as mattresses, pillows, and cushions, are becoming increasingly popular. Rubber foam's formulation is still being developed to improve the properties, because of its wide range of applications. Potassium oleate is a surfactant for producing the rubber foam, although it can be used in different concentrations to prepare the different properties of rubber foam. The Dunlop method was used in this work, due to its simplicity and easy-to-use in the foam preparation. The effect of potassium oleate, which was used as a foaming agent, was investigated in this study by reducing the amount of potassium oleate. The density, compression, and Fourier transform infrared (FTIR) spectroscopy results showed that both density and compression of foam samples with half amounts of potassium oleate are higher than those of control sample with normal amounts of potassium oleate. Moreover, the FTIR result revealed a significant change in spectra with the reductions of potassium oleate contents. Therefore, rubber foam formulations are still developed to provide the optimum properties for suitable applications.

1. Introduction
Rubber foam is utilized in a variety of products, such as mattresses, pillows, cushions and so on [1]. The Dunlop process is the most extensively used, due to its ease of formation, low production costs, and straightforward methodologies [2]. In addition to the production technique, the formulation has been considered very important factor because the foam formulation is a key factor to develop the suitable rubber foam.

In this study, potassium oleate (PO) as a surfactant is a foaming ingredient. PO was used as a comparing concentration because it is a foaming producing material. The technique of preparing the foaming process is the Dunlop process. Furthermore, the Dunlop process has been widely using in manufacturing, and potassium oleate is a foaming chemical that is easy to make [3], as more user-friendly. Supitta et al [3] investigated the relationship between morphology and elasticity of natural rubber foam which related to the concentration of the chemical blowing agent or PO. The results indicated that there are no significant differences in the macroscopic compression stress–strain curves between the control foam and foam with decreasing PO up to 45% samples, attributed to the fact that the rubber foam represented heterogeneous cell size distribution. When the concentration of the chemical blowing agent was decreased, the cell size decreased while the cell density increased. However, the porosity percentage was only slightly different. As a consequence, the mechanical properties of all samples were similar. The objective of this research was initiated to study the relationship between the chemical blowing agent concentration and the chemical structure-compression properties of natural rubber foam, especially at low concentration of PO.
2. Experiment
In the preparation of rubber foam, the chemicals are classified into four groups: the first group is the foaming agent or soap is potassium oleate (PO), the second group is the vulcanizing agent, such as ZDEC (Zinc diethyldithiocarbamate), ZMBT (Zinc-2-Mercaptobenzothiazole), wingstay L, and sulfur, the third group is the initiator and gel stabilize as ZnO and DPG (Diphenylguanidine), and the last group is the gelling agent as SSF (Sodium silicofluoride). All the chemicals were supplied by Thanodom technology company limited, Bangkok, Thailand. The formulation of rubber foam is represented in Table 1.

Before starting the mixing, the concentrated natural latex (CNL) was stirred to reduce ammonia (NH₃) with a blender for 1 min. After that, PO was added and stirred for 10 min. Then, ZDEC, ZMBT, Wingstay L, and sulfur were added and stirred for 1 min. Next, ZnO and DPG were added and stirred for 1 min. Then, SSF was added and stirred for 1 min. After that, foam sample was poured into a mold and left for 45 min before vulcanizing at 90°C for 1.45 h. Finally, the sample was washed and heated to 70°C for 4 h.

Table 1. The formulation of rubber foams in phr (parts per hundred of rubber)

| Formula               | Control sample | Half-soap sample |
|-----------------------|----------------|------------------|
| 60% CNL               | 100            | 100              |
| 10% PO solution       | 3.30           | 1.65             |
| 50% Sulfur dispersion | 2.00           | 2.00             |
| 50% ZDEC dispersion   | 1.00           | 1.00             |
| 50% ZMBT dispersion   | 1.00           | 1.00             |
| 50% Wingstay L dispersion | 1.00     | 1.00             |
| 50% ZnO dispersion    | 2.80           | 2.80             |
| 33% DPG dispersion    | 0.56           | 0.56             |
| 12.5% SSF dispersion  | 1.84           | 1.84             |

The samples were measured for width, length, and height to calculate the volume. Then, the samples were weighed on a balance and calculated the density by using the weight and volume of the samples, calculated as the following [4]:

\[
\text{Density} = \frac{M}{V} \quad (1)
\]

where \(M\) is the rubber foam sample's weight (kg) and \(V\) is the rubber foam sample's volume (m³).

For Compression testing, the samples were determined by a texture analyzer (TA.XT Plus, Stable Micro Systems, Godalming, Surrey, UK). The samples were pressed down to 75% of the sample height at a speed of 0.1 m/s.

Attenuated Total Reflection-Fourier Transform Infrared (ATR-FTIR) spectroscopy (VERTEX 70, Bruker, Billerica, MA, USA) was used to analyse the chemical functional group of rubber foam with Ge crystal probe at 500–4000 cm⁻¹.

3. Results and discussion
First of all, Figure 1 shows the density and compression tests of foam samples. The density test results indicated that both foam samples represent the density almost in the same level, the half-soap sample tends to be higher density than the control sample. Because the number of gas bubbles on the foam rubber surface and the amount of potassium oleate decreased in which resulted in the possibility of an increase in condensate. However, decreasing the PO concentration by more than 50% results in a
material becomes too dense and inappropriate with natural rubber foam products. Meanwhile, when PO was decreased, the compression strength of the half-soap sample was greater than that of the control sample at 17 kPa and 15 kPa, respectively [5].

![Graph showing stress-strain curves for control and half-soap samples](image)

**Figure 1.** Results of the compression test showed the stress ($\sigma$)–strain ($\varepsilon$) curves of foam samples with varied concentrations of the chemical blowing agent (PO), and the densities of rubber foam at varying amounts of potassium oleate were also shown at the end of the line.

The ATR-FTIR results were studied in the chemical functional groups of both samples, as shown in Figure 2. The results of the control sample showed the peak at 3036-2850 cm$^{-1}$ of C-H stretching (CH$_3$ and CH$_2$), the peak at 1663 cm$^{-1}$ of C=C stretching in the double bond of natural rubber molecules [3], the peak at 836 cm$^{-1}$ of C=C wagging and the peak at 1127-928 cm$^{-1}$ of C-H stretching, respectively. We also found a peak at 1562 cm$^{-1}$ which represented the asymmetric stretching modes of the carboxylate ion from potassium oleate [5]. The chemical structure of PO was shown in Figure 3. However, there are no significant differences of FTIR spectra between two samples.

![ATR–FTIR spectra of foam samples in transmittance from 500 to 3500 cm$^{-1}$](image)

**Figure 2.** ATR–FTIR spectra of foam samples in transmittance from 500 to 3500 cm$^{-1}$.
Figure 3. The PO structure with C=O bonds formed in the molecule [6].

4. Conclusions
In this research, effect of potassium oleate on chemical structure-compression relationship of natural rubber foam was studied. We found that foam density and compression increase with the decrease of PO concentration at 50%. When comparing both samples using ATR-FTIR, they exhibited similar results. So, we can adjust the foam density and mechanical properties of rubber foam using different PO concentrations.

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