Iranian Polymer Journal (2018) 27:555–561
https://doi.org/10.1007/s13726-018-0632-7

ORIGINAL RESEARCH

Reducing of heat loss of rubber compound using natural zeolite filler: effect of partially substitution of fillers on compound properties

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Received: 31 July 2017 / Accepted: 19 May 2018 / Published online: 18 June 2018

Abstract
The main objective of this work was reducing the heat loss of styrene butadiene rubber by partial substitution of carbon black with natural zeolite as a filler. Reducing the usage of carbon black in the rubber industry is a good strategy to decrease fossil fuel usage and global warming. There are different mineral fillers like silica and clay to be used instead of carbon black. Effect of application of natural zeolite on reducing the heat loss of rubber compound based on SBR was investigated by melt mixing of natural zeolite in rubber matrix in an internal mixer. Natural zeolite was selected as 5, 10, 15, and 20 phr. Carbon black was partially substituted with zeolite and the effect of natural zeolite content and structure on different aspects of the compound including heat buildup, hardness, elongation, and modulus were evaluated. It was shown that although cross-link density and mechanical properties of the compounds decreased a little, but a significant improvement was observed in the fatigue resistance of the compounds beside a favorable decrease in the heat buildup and abrasion loss with an increase in the natural zeolite loading. The rate of improvement in properties was slowed down at zeolite contents higher than 5 phr.

Keywords Zeolite · Fatigue resistance · Heat build up · Mechanical properties · Abrasion loss

Introduction

The highest priority in the rubber industry is production of high-quality products in accordance with environmentally friendly rubber compounds [1, 2]. Therefore, substitution of some problematic ingredients with their ecological counterparts is the main object [3]. One of the most important additives in rubber compounds is reinforcing agent, and carbon black is the most common material amongst all [1–3]. The negative impact of carbon black on the environment and health of workers have forced the scientists to find the proper substituents to neglect it from rubber compounds. Therefore, many studies have been performed to substitute carbon black with other mineral fillers [4–6], specially with natural additives that seems to be the best way to solve this problem. In fact, this substitution is desirable, because the rubber compounds filled with mineral filler show more compatibility of with the environment [7–9]. Zeolite is one of the potential mineral fillers which can be studied as rubber filler.

Zeolites are a group of hydrated alumina silicates with the microporous crystalline structure. Its special porous structure is based on a three-dimensional framework which imparts a high surface-to-volume ratio [10]. Therefore, zeolites have found many useful applications such as reinforcement filler, ion exchange, filtering, and chemical sieves [11, 12]. Zeolite is formed in different geological environments and crystallized in the mountainous regions. The natural zeolite crystals have honeycomb structure with the gross chemical formula as follows:

$$(\mathrm{Li, Na, K})_p(\mathrm{Mg, Ca, Sr, Ba})_q\left[\mathrm{Al}_{(p+2q)}\mathrm{Si}_{n-(p+2q)}\mathrm{O}_{2n}\right]\cdot m_0\mathrm{H}_2\mathrm{O},$$

where p and q are monovalent and divalent content of the metal ions, respectively. In addition, $2n$ and m_0 indicate content of oxygen atoms and water molecules, respectively. This mineral has properties such as high capacity of hydration, stable crystals in dehydrated form, uniform channels in dehydrated crystals, cation exchange properties, and gas absorption ability.

Zeolite has attracted the attention of rubber researchers, in these years [13–15]. Substitution of conventional reinforcing fillers such as carbon black with natural zeolite

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