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Impact of carbon black substitution with nanoclay on microstructure and tribological properties of ternary elastomeric composites

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ABSTRACT

Various particulate composites based on epoxidised natural rubber (ENR), carbon black (CB), and nanoclay (NC) were prepared keeping the total filler content constant at 35 phr (parts per 100 g rubber). Tribology and hysteretic (stress–strain) properties of the composites were analyzed. Morphology of these composites were also characterized by small angle X-ray scattering (SAXS), transmission electron microscopy (TEM), scanning electron microscopy (SEM) to establish the structure–property correlations. SAXS results reveal enhancement in overall interfacial roughness (*ds*) with the increased substitution of CB by NC. Increased CB–NC interface causes enhancement in *ds*, leading to reduction in wear resistance of ternary composites. Reduction of wear resistance for NC populated samples is attributed to lower dispersion parameter ($D_{0,1}$) values of NC in the matrix, realized through image analysis of TEM photomicrographs. Thus, for ternary particulate samples, a definite interrelation among the extent of wear, *ds* and $D_{0,1}$ is realized. Frictional force (F_T) and its adhesive component (F_A) increase when CB is substituted by NC up to 15 phr. When NC fraction exceeds 15 phr, both F_T and F_A decrease substantially. This is attributed to the lubricity offered by the modified NC at higher NC concentration, which is explained using a predictive mechanism.

1. Introduction

The epoxidised natural rubber (ENR), a chemically modified variety of natural rubber (NR), possesses remarkable characteristics like good oil resistance, air impermeability, adhesive strength, tensile modulus, wet grip, etc. Numerous particulate nanocomposites were reported in which ENR was used as a component [1–3]. Ternary ENR blends comprising of fillers like ISAF (intermediate super abrasion furnace), SRF (semi-reinforcing furnace) black, and silica were investigated by De et al. This study revealed the role of ENR and fillers in changing the miscibility of the components of the blends [4]. Various ENR composites with interesting mechanical properties, e.g., wear characteristics and adhesion, were described in the literature [5,6].

Carbon black (CB) is generally used as a reinforcing filler in rubber composites to enhance tensile strength, tear strength, and abrasion resistance of the composites. The recent trend is to partially replace CB in reinforced rubber composite with nanoclay (NC) [7]. NC offers the following advantages: (1) reduction in specific gravity of the composite, (2) increase in component life, (3) low pollution, since it substitutes CB which is a product of incomplete combustion of petroleum, if its production can be decreased, the environmental pollution and the global warming can be prevented, (4) substitution of petroleum product resulting in less petroleum consumption and (5) such composites can have colors other than black. One typical application of such material is an automobile tire [7].

A composite, made up of the matrix and two different particulate phases, is known as ternary particulate composite. Microstructures of these composites are known as hybrid microstructure since they contain two different reinforcing particulate fillers. Such nanocomposites exhibit certain microstructural features like 'nanounit' formation [8], haloing effect [9], etc. A 'nanounit' is a kind of morphology or unit structure that comprises of two different types of fillers (in nanodimensions), and shows behavior like a unit structure. It is composed of stacked NC platelets that deform to wrap partially around one or two primary CB aggregates [8]. The possibility of 'nanounit' formation increases depending upon the increased availability of partially intercalated and exfoliated NC platelets since such isolated particles are often thin (<5 nm thickness) and can bend around a CB particle. On the other hand, 'haloing effect'

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