Texas Tech University
Department of Chemical Engineering
Seminar Series

The Discovery of Carbon Black / Natural Rubber Vulcanizates for Automobile and Truck Tires and the Mechanism for the Exceptionally High Tear Strength of these Nanocomposites

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Abstract

Natural rubber vulcanizates containing 0-50 phr of a fine carbon black (N115, d ≈ 27 nm) were prepared and tensile strengths of normal (no pre-cut) and edge pre-cut specimens were determined. Normal tensile strengths of all vulcanizates were similar. At the relatively slow strain rate experienced wholesale by normal uncut specimens, all vulcanizates, prior to crack initiation, strain-crystallized sufficiently to be strong. However, pre-cut specimens experience increased strain rate at a cut tip. Magnification of the strain rate increases as cut depth **c** increases. Fracture in the gum NR and vulcanizates with up to 14 phr of black occurred by simple forward crack growth from a cut tip, and all exhibited a critical cut size $\mathbf{c}_{cr}$, above which strength dropped abruptly. Furthermore, for these lightly filled samples, strength and $\mathbf{c}_{cr}$ ***decreased*** with increased black content. This indicates less strain-crystallization before rupture of pre-cut specimens when levels of black are low. This effect is attributed to rapid straining at a cut tip and hindering of the chain mobility necessary for crystallization. When black content was increased to 15 phr, with 1 mm < c < 2 mm, about 50% of specimens retained simple lateral fracture and were weak, but, the other 50% developed deviated cracks (knotty tearing) and were much stronger. With 50 phr of black, all pre-cut specimens exhibited knotty tearing and were significantly stronger than corresponding pre-cut gum specimens, especially at large **c**. High strengths with sufficient black levels are attributed to increased strain-crystallization and super-blunting (multiple cracks) at a cut tip. These inhibit forward crack growth. For carbon black to enhance strain-crystallization relative to the gum, it appears there must be enough of it to form a bound rubber/black network. If the black concentration is less than this percolation threshold, strain-crystallization is hindered at a cut tip.

Bio

Gary R. Hamed received B.S. and M.S. degrees in Chemical Engineering from Cornell University, and, under the guidance of Dr. Alan Gent, a PhD in Polymer Science from the University of Akron. He spent four years at the Central Research Laboratory of the Firestone Tire and Rubber Company, before returning in 1980 to the University's Polymer Science Department. In 1987, he was selected as the Outstanding Researcher at the University of Akron. His primary research has focused on the physical properties of rubbers, especially their adhesion, viscoelasticity, and fracture. Professor Hamed is a Fellow of the Adhesion Society and recipient of the Sparks-Thomas and G. Stafford Whitby Awards from the Rubber Division of the American Chemical Society.

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