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Investigation of using diatomaceous earth variants as fillers in rubber composites: cure characteristics and tensile properties

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Diatomaceous earth (DE) generally made of fossilized diatom exoskeletons, is well-known for its high porosity and potential usage as a rubber filler alongside silica. This study characterizes various grades of DE such as amorphous, crystalline, crystalline brewery waste, and ground brewery waste to reduce the particle size, compared to silica. This research aims to identify their morphological properties and impact on the cure characteristics and tensile properties of natural rubber vulcanizates. First, rubber formulation was optimized to provide a baseline for the cure characteristic tests. The ground waste DE was thus prepared by ball-milling crystalline waste DE for 3 hours at 300 rpm in a laboratory scale ball mill. The fillers were then characterized extensively using established techniques such as Scanning Electron Microscopy (SEM), Dynamic Light Scattering (DLS), X-ray diffraction (XRD), X-ray fluorescence Spectroscopy (XRF), and Fourier-Transform Infrared Spectroscopy (FTIR). Rubber composites were formulated with 55 phr of each filler. As the next step, amorphous and crystalline waste DE was mixed with silica in proportions of 25%, 50%, and 75% of DE-based filler to silica by weight to prepare rubber composites. Cure characteristics were obtained using a Moving Die Rheometer (MDR) at 150 °C for 30 minutes, and ultimate tensile strength was measured with a Universal Testing Machine according to ASTM D412 standards (die cut-C) at a strain rate of 500 mm/min. The results revealed that ball milling was ineffective in reducing the particle size of crystalline waste DE at the given conditions. 100% Amorphous DE-filled composite showed inferior cure characteristics, with a low cure rate index and low cross-link density. Nevertheless, composites with 25% amorphous DE blended with silica demonstrated higher ultimate tensile strength compared to composites with 100% silica, explained by the positive synergistic effect from particle size and increased surface area of amorphous DE. However, loadings of more than 25% of amorphous DE to silica caused reduced tensile properties due to lower filler density. Waste DE-loaded composites showed reduced tensile properties due to both larger particle size and agglomeration. In conclusion, amorphous DE exhibited positive synergism with silica when used as a rubber filler, enhancing tensile properties due to higher cross-link density facilitated by smaller particles and increased filler-matrix interactions due to the nano-roughness of DE. Composites loaded with waste DE showed significantly reduced tensile properties due to pronounced agglomeration. The optimal loading of amorphous DE as a filler was determined to be 25% of DE with silica, providing a balance between improved tensile properties with higher reinforcement. This study emphasized the potential of using amorphous DE as a bio-based filler in rubber composites, highlighting the need for optimization of filler loading to mitigate agglomeration and optimize the material performance. These findings could contribute to innovating sustainable materials in polymer composites.

Keywords: Rheology, Tensile strength, Natural rubber, Filler, Cross-link density

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