The effect of modified cellulose on the selected mechanical properties and morphology of elastomer compounds

Study deals with the preparation and characterization of elastomeric compounds based on natural rubber filled with biopolymer filler. Pure cellulose (CEL) and surface silanized cellulose (CEL_{sil}) were used as fillers in the natural rubber (NR) matrix in content of 0; 30; 40 and 55 phr. The prepared blends were studied for hardness, tensile strength and elongation at break. Elastomer compounds were prepared by two-stage mixing. The first stage was mixed at a temperature of 115 °C, the second at 90 °C. Tensile properties were determined using a Universal Tensile Testing Machine, while hardness was measured with an IRHD hardness tester. The morphology and interfacial adhesion of the elastomer compounds and fillers were analysed using scanning electron microscopy (SEM).

From the results of hardness values, with increasing filler content in compound, the values increased due to the stiffening effect of fillers. Compounds containing pure cellulose exhibited slightly higher hardness values compared to those containing silanized cellulose, particularly at higher filler concentrations. However, the differences between the samples were relatively small, suggesting that the silanization surface treatment of cellulose did not have a significant effect on the hardness of the material.

The tensile strength graph of the blends shows a linear decrease with increasing filler content for both types of filler, indicating that higher filler loading negatively affects the mechanical integrity of the rubber matrix. Compounds containing pure cellulose exhibited slightly higher tensile strength compared to those with silanized cellulose, particularly at medium filler concentrations. This trend may be related to different interactions between the filler and the polymer matrix following cellulose surface modification.

The filler content and type significantly influenced the elongation at break. With increasing filler content, a pronounced decrease was observed for both types of cellulose, indicating reduced elasticity and flexibility due to the higher proportion of rigid filler in the matrix. Composites containing silanized cellulose showed lower elongation, especially at higher concentrations, suggesting increased stiffness and improved interfacial adhesion, which leads to restricted mobility of polymer chains and reduced deformability.

SEM scans (Fig. 4) show the morphology of pure and silanized cellulose. Pure cellulose exhibits a smooth fibrous surface, while silanized cellulose shows flake-like structures on the fibres. Fig. 5a presents the fracture surface of a compound with a minimal amount of pure cellulose, where a frayed fibre can be observed, likely caused by tensile loading. The detailed cross-section (5b) reveals voids, probably formed during sample preparation, and a relatively uniform filler dispersion. Fig. 6a shows the fracture surface of a blend containing silanized cellulose with fewer voids, which is attributed to reduced absorbency and improved crosslinking with the rubber matrix. The detailed scan confirms better filler incorporation, which is also consistent with the lower hardness of this compound.

The results of the study showed that an increasing content of cellulose filler led to an increase in the hardness of the compounds, confirming the reinforcing effect of the filler in the rubber matrix. At the same time, a decrease in tensile strength and elongation at break was observed, indicating reduced elasticity and deformability of the material. Compounds containing silanized cellulose exhibited lower elongation at break, which is related to improved interfacial adhesion between the filler and the matrix. SEM analysis confirmed better incorporation of silanized fibres into the rubber matrix and a lower occurrence of voids in the blend structure. The results highlight the significant influence of both filler content and surface treatment of cellulose on the mechanical and morphological properties of the prepared compounds.

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