Impact of Cellulose Physical-Mechanical Treatment on Elastomeric Composite Properties

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This study deals with the treatment of cellulose (CEL) as a filler through physical and mechanical methods. The effect of filler treatment on the properties of elastomeric composites based on natural rubber (NR) and cellulose was analyzed. The mechanical treatment involved pressing cellulose at different time intervals (2 - 6 min) at a temperature of 110 °C. For physical treatment, a plasma discharge was applied. The treated cellulose, in an amount of 45 phr, was incorporated into NR-based elastomeric composites. The rheological, mechanical properties and cure characteristics of the prepared NR/CEL composites were examined to assess the impact of filler treatment on these properties. This study aims to determine the optimal combination of physical and mechanical treatment parameters for cellulose as a primary filler in elastomeric composites, comparing the results with composites containing untreated cellulose.

Table 1 Designation of prepared composites

Blend designation	Filler content (phr)	Physical-mechanical treatment of filler
UnF	0	Without filler
CEL-st	45	Standard, without treatment
CEL-p	45	Pressing process
CEL-pp	45	Pressing process, Plasma treatment

Table 1 shows the designation of the prepared composites according to the method of treatment of the filler itself.

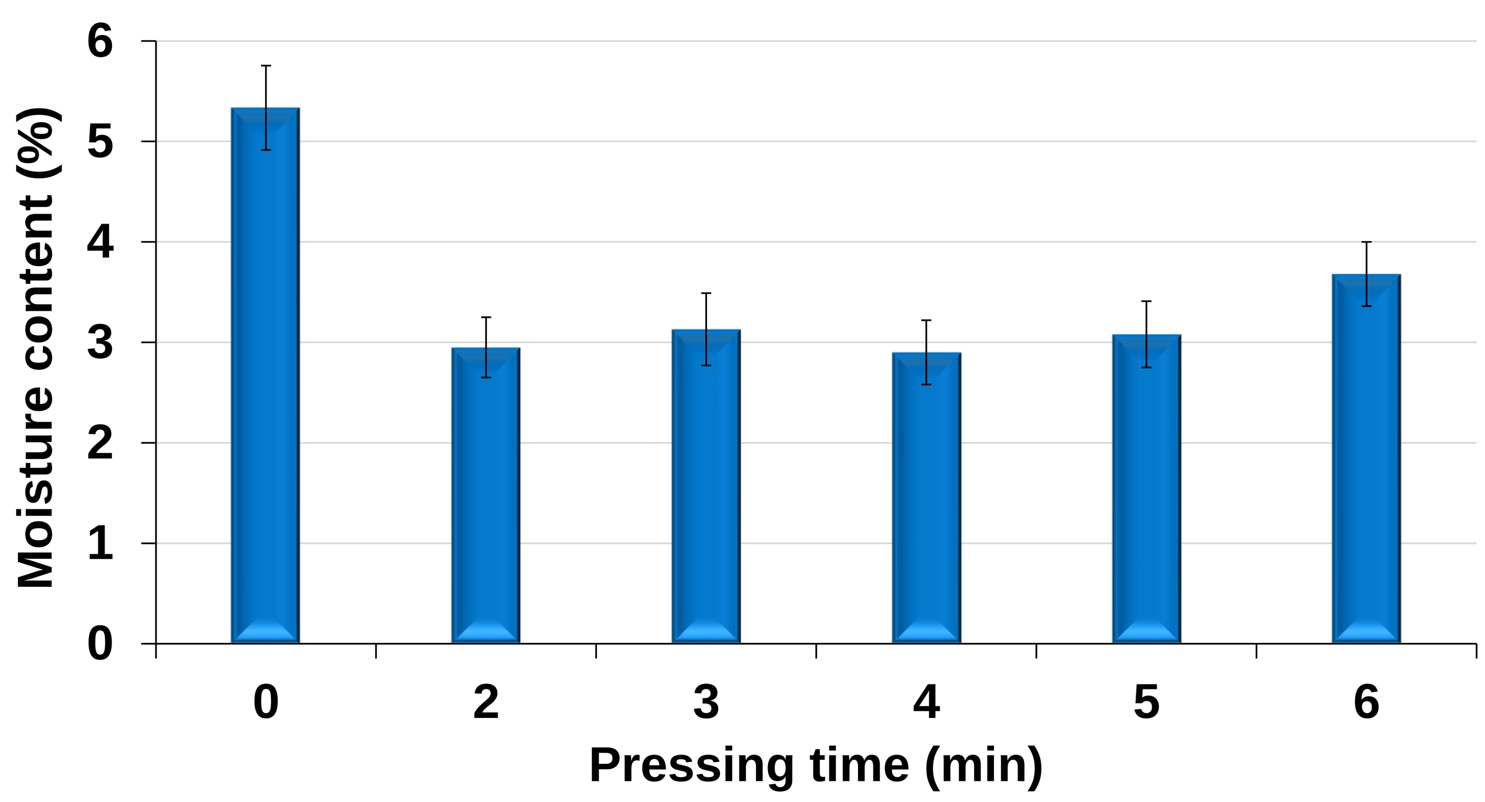

Fig. 1 Effect of pressing time to moisture content of filler

The study examined how pressing time affects the residual moisture of the filler (Fig. 1). Comparing pressed and unpressed samples shows how much moisture is removed. The moisture content of the sample can be viewed from two perspectives, the first is the effect on the plasma process, where it is proven that higher filler moisture supports plasma etching, reduces surface oxidation, and the second is the negative effect on elastomer composites (e.g. air bubbles). A 4-minute pressing time was selected as optimal, minimizing moisture and its negative impact on vulcanizates.

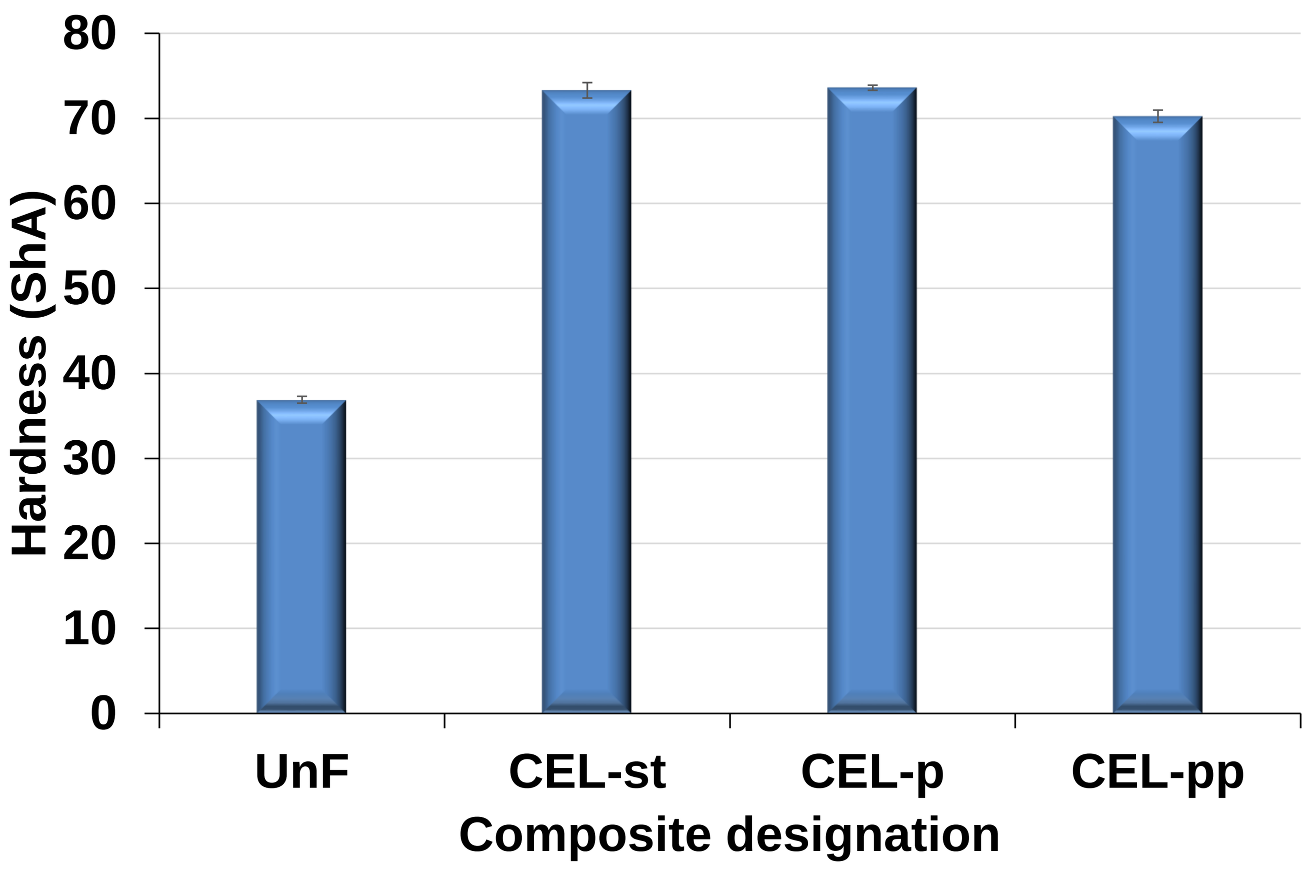

Fig. 2 Hardness of prepared composites

The unfilled composite showed the lowest hardness, as it depends solely on crosslink density (Fig. 2). Adding filler (CEL-st) increased hardness by reducing flexibility and increasing resistance to hardness tester indenter penetration. Pressed filler (CEL-p) had minimal impact on hardness (in comparison with composite CEL-st), indicating the pressing process had no significant effect. A decrease in hardness was observed in the composite with plasma-treated filler (CEL-pp), likely due to fiber shortening, which increased matrix flexibility and reduced restrictions on the movement of crosslinking bridges.

The unfilled composite reached the highest tensile strength (Fig. 3), as its value was determined solely by vulcanization crosslinks. Adding fillers significantly reduced tensile strength. The lowest value was observed for the CEL-st composite, likely due to filler moisture affecting accelerator activity. Composite CEL-p, with reduced moisture, showed improved crosslinking and strength. Plasma-treated filler in composite CEL-pp had a slight drop in tensile strength, likely due to shortened fibers acting as stress concentrators. If the filler was chemically bound into the network, the effect might reverse.

The highest elongation at break (Fig. 3) was also seen in the unfilled composite, due to high matrix flexibility and unrestricted crosslinks. Fillers limited this movement, reducing elongation. Bio-fillers often act as stress concentrators, lowering both elongation and strength—unless modified to crosslink with the matrix.

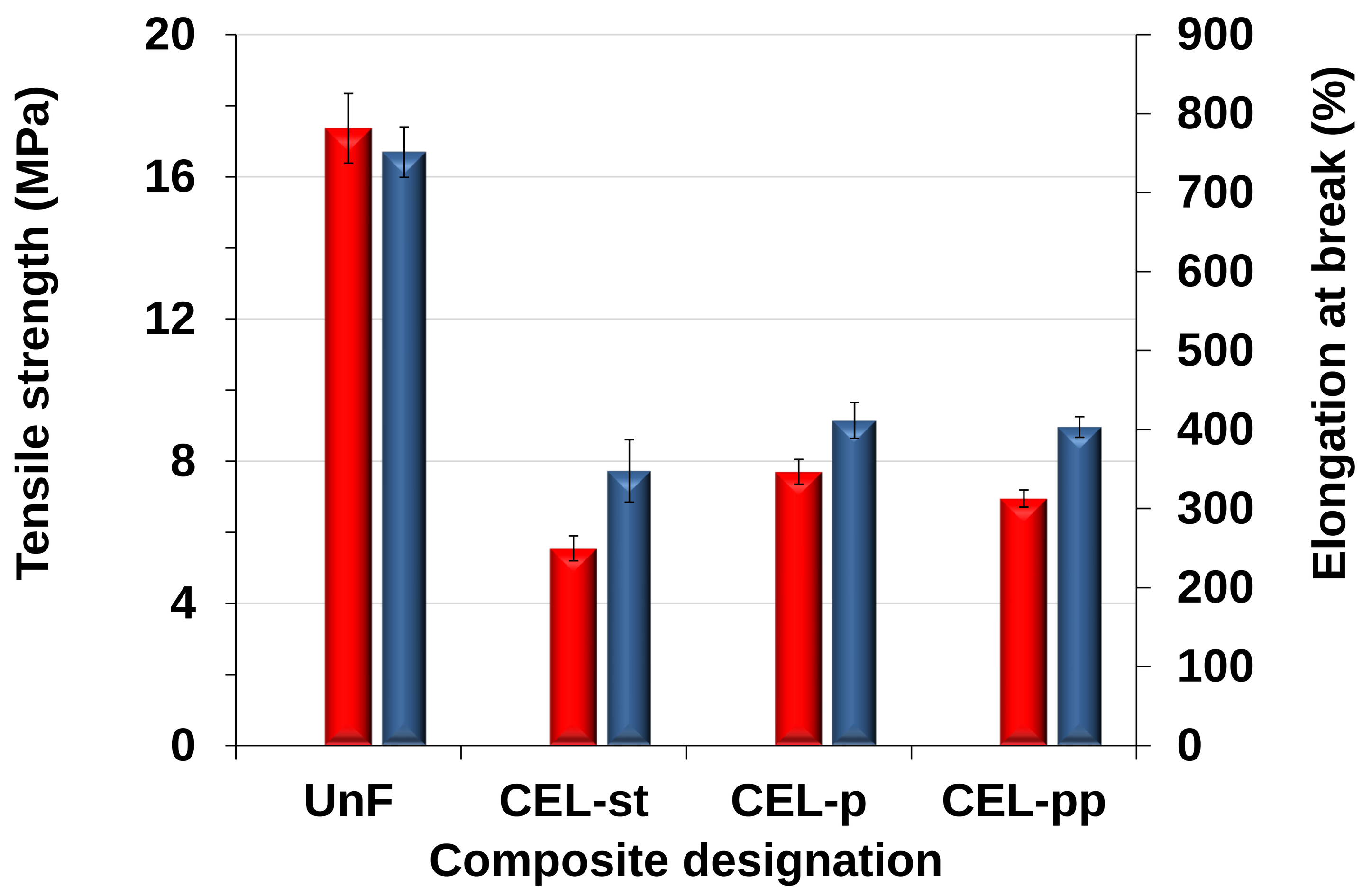

Fig. 3 Tensile properties of prepared composites

- CONCLUSION -

In conclusion, it can be stated that the filler treatment by pressing has a significant effect not only on the moisture content in the filler but also on the rheological properties and vulcanization characteristics. The positive effect of the pressing treatment is also visible on the tensile properties. The pressing of the filler also shortened the time needed to dose the filler to composite during the mixing process. The treatment of the filler by the plasma process partially limited the positive effects of the filler pressing, but the composite with this filler treatment still achieved better properties than the composite with the filler without treatment. Further research will also be focused on describing the possible effect of the absorption of components in the liquid state by the plasma filler by cellulose during the mixing process and its effect on the properties of elastomer composite.

This research work has been supported by the Operational Program Integrated Infrastructure, co-financed by the European Regional Development Fund by the project: Advancement and support of R&D for "Centre for diagnostics and quality testing of materials" in the domains of the RIS3 SK specialization, Acronym: CEDITEK II., ITMS2014+ code 313011W442 and Scientific Grant Agency VEGA 1/0265/24.

NAPLES, ITALY 30 JUNE - 4 JULY
ACEX2025 NAPLES
18th International Conference on Advanced Computational Engineering and Experimenting

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