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Utilization of Paddy Husk Carbon Black as an Alternative Filler Material in the Rubber Industry

The Global Resource Challenge

The constant growth of the global population and rising consumption levels have made natural resource depletion a prominent international concern. The limited supply of fossil fuels t=which is the source of conventional carbon black, necessitates the development of sustainable consumption patterns and the utilization of waste materials as alternative raw materials. Annually, millions of tons of waste are produced worldwide, often without proper management options.

In the Sri Lankan context, rice production generates substantial agricultural waste across different lifecycle stages. Approximately 895,000 metric tons of rice husk waste are generated during the milling process each year. While a portion is utilized as an energy source for brick production or steam generation, the high silica content and carbon potential of rice husk remain under-exploited in high-value industrial applications.

The Industrial Requirement for Sustainable Fillers

Elastomers are vital in applications ranging from household items to automotive and industrial components. For over a century, the reinforcement of rubber by carbon black has been essential for enhancing the strength and durability of vulcanized products. Modern reinforcing fillers can increase the strength of vulcanized rubber tenfold. However, petroleum-based carbon black is entirely imported to Sri Lanka, creating a constant industrial demand for locally available, cost-effective alternative materials.

This study investigates the feasibility of utilizing Paddy Husk Carbon Black (PHCB) as a partial replacement for conventional carbon black (N330) in tire applications. By characterizing PHCB and optimizing its composition within rubber compounds, the research seeks a sustainable solution for both waste management and industrial cost reduction.

Transforming Waste into Nano-Filler

The preparation of PHCB involves a specialized two-stage process. Initially, dried paddy husk undergoes pyrolysis in a muffle furnace at 850°C in a nitrogen-saturated environment for ten minutes. It is important that nitrogen purging has to happen at the beginning of the heating and the rate of was 200°C/hr. This carbonization process converts the organic waste into a carbon-rich material. The second stage involves mechanical size reduction. After initial grinding, the carbonized powder undergoes 16 hours of intensive ball milling to achieve sub-micron scale particles.

The resulting PHCB particles possess an average size of 200 nm and a surface area of 20.4m^2/g. Scanning Electron Microscopy (SEM) analysis provides a visual confirmation of the particle distribution and the successful reduction of larger carbon aggregates into finer particles, as illustrated in Figure 1.

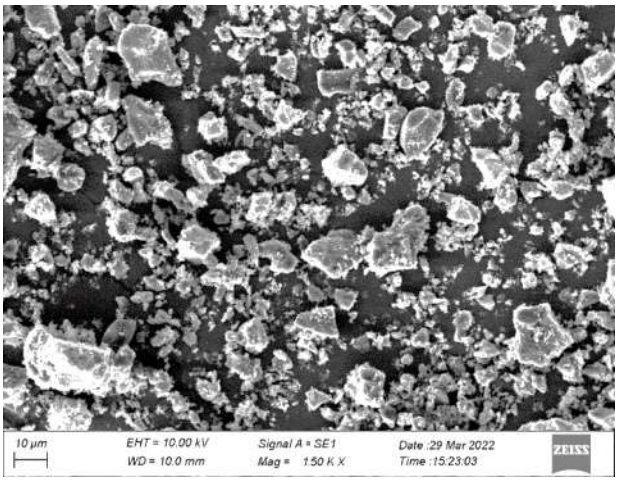


Figure. 1. A sample of PHCB visualising the particle size distribution

Performance Analysis and Optimization

Based on the achieved particle size, the research focused on a bias-ply tube-type tire inner liner compound. Seven distinct samples were prepared using a 200 ml laboratory Banbury mill, varying the ratios of PHCB and industrial N330 carbon black from 0% to 100% replacement. The performance was measured against established industrial specifications, which require a minimum tensile strength of 7.85 MPa and an elongation beyond 300%.

The rheological analysis using an oscillating disk rheometer indicated that the Sample, containing a 40% PHCB and 60% N330 ratio, demonstrated optimal cure characteristics. While tensile strength generally decreases as the percentage of PHCB increases (as shown in Figure 2), the 40% blend successfully maintained the necessary mechanical properties without deteriorating elongation, tear resistance, or bonding strength.

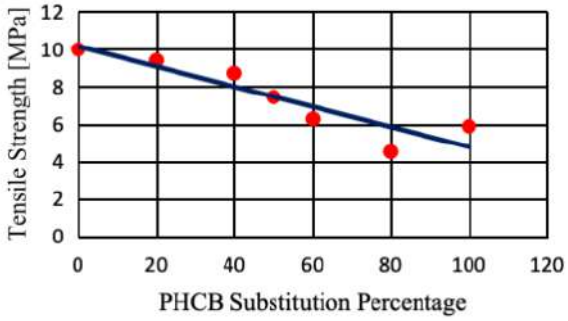


Figure. 2. Variation of Tensile Strength with PHCB substitution

Specifically, the bonding strength of the 40% PHCB sample was recorded at 4.16 N/mm, exceeding the industry requirement of 2.75 N/mm and even outperforming the 100% N330 control sample. This suggests that the inclusion of PHCB provides superior adhesion between the tire's first ply and the inner liner.

Economic and Environmental Impact



Figure 3. Illustrated process of PHCB production

From an economic feasibility standpoint, scaling up PHCB production offers a compelling case for commercial viability within Sri Lanka's rubber sec-

tor. Because paddy husk is an abundant, low-value agricultural byproduct with approximately 895,000 metric tons generated annually, raw material acquisition costs are minimal. The primary operational expenditures (OPEX) at an industrial scale would stem from energy consumption during the 850°C pyrolysis and the 16-hour mechanical milling phases. However, these processing costs are substantially offset by the high-value import substitution achieved. By successfully replacing 40% of conventional, fully-imported N330 carbon black in bias-ply tire inner liners without compromising mandatory mechanical standards, manufacturers can significantly insulate themselves from fluctuating global petroleum prices and foreign exchange vulnerabilities. Consequently, the initial capital investment required for industrial-scale kilns and milling infrastructure presents a highly favourable payback period when measured against long-term material cost savings.

Reference

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Article by

Sampath Weragoda, Bandu Samarasekara, Dinesh Attygalle, Shantha Amarasinghe
Department of Materials Science and Engineering, Faculty of Engineering, University of Moratuwa, Sri Lanka