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Understanding Asbestos Free Brake-Pad: Using Carbon Nanotube Derived from Waste Rice Husk

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Abstract

This paper investigates the development of asbestos-free brake pads utilizing carbon nanotubes derived from waste rice husks. The aim was to replace the hazardous asbestos with an eco-friendly composite. The study implemented an experimental research design approach. The sol-gel method was used in the production of carbon nanotubes (CNTS) from rice husks. The composition of the brake pads was developed by varying the CNTs (0.5–1.5 wt. %). About five (5) weight percent $CaCO_3$ obtained from oyster shells served as a filler. In addition, five-(5) weight percent graphite served as a friction material, which was added to the mixture of epoxy and hardener. Wear, thickness swelling in SEA oil and water, hardness values, and microstructure are among the properties that were examined. The results show that the brake pad from the CNTs formulation at 1.5 wt. percentage was not only effective but also comparable to conventional brake pads in performance. Therefore, the research proposes the use of CNT grade derived from rice husks as a convenient alternative material for the production of asbestos-free brake pads.

Keywords
Rice husk, Microstructure, Brake pad, Wear

1. Introduction
Man and the environment suffer negative effects from the usage of asbestos in the manufacture of vehicle brake linings (Aigbodion et al., 2010; Borawski, 2022). According to reports from the World Health Organization (WHO) and environmental protection organizations, Asbestos releases hazardous gaseous byproducts and has a detrimental effect on human health (Edokpia et al., 2016). Authorities in charge of environmental protection have placed restrictions on the use of asbestos in the production of brake lining (Idris et al. 2015). Recent years have seen an increase in research on how emissions from asbestos brake pads affect the environment and general public health (Singh et al., 2015). Reducing the amount of dangerous materials at the source is crucial. One way of achieving this can be through creating novel material compositions with lower risks to the environment and public health.

Researchers have created innovative brake materials free of asbestos to decrease the negative effects of asbestos (Baklouti et al., 2015). The remarkable new properties and substantial surface area of nanoparticles have recently been exploited in the manufacture of asbestos-free brake lining materials. These studies examine carbon nanotubes (CNTs-RH) manufactured from waste rice husks, which could replace some of the materials now applied to brake pads. Rice husk was selected because it is cheap, environmentally friendly, and easily available as trash. The brake pads were produced using the solution stir-cast technique. This approach was selected because it is often employed to make composites, particularly in laboratory settings. Solution stir casting involves swirling CNTs into a polymer that has been dissolved in a solvent before the polymer is cast in a mould and the solvent is evaporated. The lower viscosity of the polymer in solution (as opposed to a melt) coupled with mechanical stirring or ultrasonication helps the CNTs to disperse easily. The solvent selection is influenced by the polymer's solubility. Before adding pure nanotubes to the polymer solution, a surfactant is normally added to aid in their dispersion (Venkatesh and Murugapoopathiraja, 2019).

2. Materials and Method
The CNTs were produced from sol-gel method. The rice husks (RH) were first cleaned with water to get rid of dirt and other unwanted items. They were subsequently washed in deionized water and dried for eight hours at 90 °C. The RH was further finely crushed and sieved to a 65-m particle size. The mixture was covered with an aluminum sheet. The samples were heated in the center of the quartz tube using the Samsung microwave oven model M539 MAN200405W, which has a 600W power output and a 2.45 GHz frequency (the standard microwave frequency). The quartz tube was evacuated to a base pressure of 1.3 x 103 mbar before microwave plasma irradiation and during a 40-minute deposition period. The brake pad composites were developed using a modified solution stir-casting procedure. The ratio of epoxy resin to hardener was 1:10, and the CNTs-RH content varied from 0.5 to 1.5 wt%. The combination of epoxy and hardener also included 5 weight percent $CaCO_3$ made from oyster shell as a filler and 5 weight percent graphite as a friction ingredient. The mixture was stirred using a magnetic stirrer for 15 minutes. The mold was compressed during manufacture at a pressure of 20 MPa using a compression moulding machine (model: 0577-86365889). A heated wooden mold was used to cast the brake pad material, which was then given four hours to cure at 100 ^{o}C.

The JEM-2100F from Joel was utilized to analyze the CNTs-RH's microstructure. Tests were performed for friction and wear as per ASTM G99 and DIN 50324. The test was conducted using an Anton Paar pin-on-disc tribometer. The wear disc and wear pin were cleaned with acetone to remove any potential remnants of surface impurities. The tribological property ranges were chosen according to the JASO C-406 schedule. The microstructure distribution of the samples was determined using the scanning electron microscope model VEGA 3 TESCAN.

3. Result and Discussion
Figure 1 displays the TEM pictures of the CNTs made from RH. In the TEM photos, the multiple-walled carbon nanostructure can be detected. There was a network that resembled a nanocluster or web and had a length of several nanometers. The TEM picture displays particles with an average size between 45 and 75 nm. This is comparable to the CNT nanostructures that previous researchers reported (Asnawi et al., 2018).

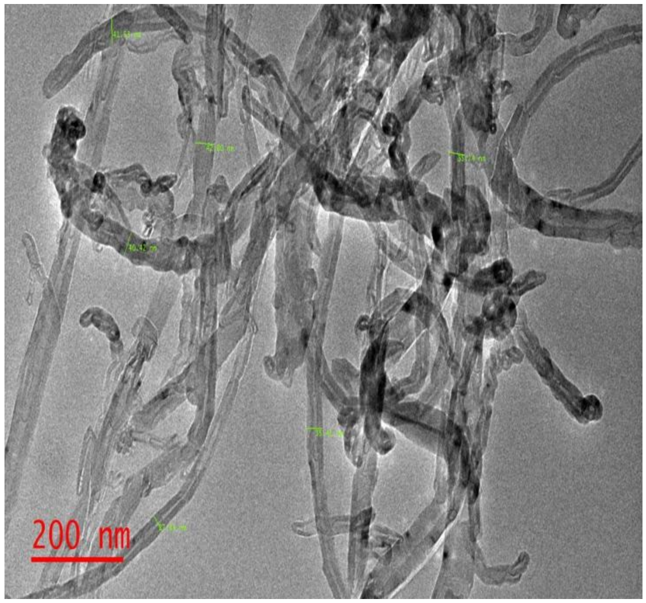

Figure 1: TEM image of the CNTs derived RH

Figure 2 presents the results of the wear rate and COF. The main observation was that as the CNTs-RH increased considerably from 0.5% weight to 1.5% weight there was noticeable reduction in wear rate. The increment in COF was attributed to strong interfacial bonding between the epoxy resin and reinforcement. Past authors (Sigh et al. 2016) reached similar conclusions. The authors discovered that the weight % of silicon dioxide affects a composite's capacity to support weight. As a consequence, COF increased, wear rates reduced, and brake pad quality in cars became better.

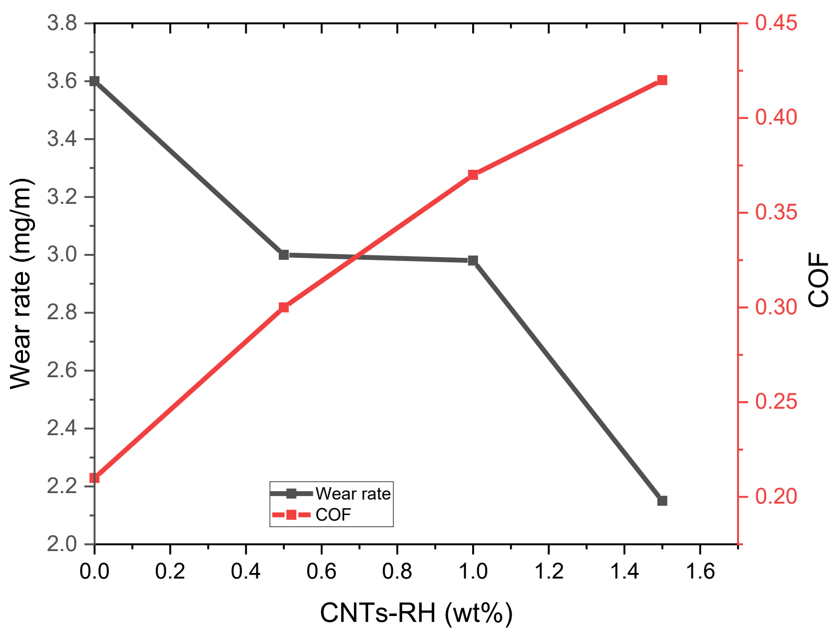

Figure 2: Variation of wear rate, COF with CNTs-RH

SEM was used to analyze the worn surface morphology of the materials employed in making the brake pads. Figure 3 shows the brake pads' SEM micrographs. Figure 3 also capture the epoxy binder in the dark region and the particle dispersion in the white area. The metal matrix in the friction material becomes unstable due to the high applied stress, which leads to the asperities dispersed throughout the contact surface to distort and shatter, thereby creating debris. The main wear processes encountered during this kind of wear include ploughing of the materials, severe plastic deformation, and spallation of the reinforcing CNTs-RH particles (Figure 3a-c).

The counter-disc part tries to deform the sample material by applying a response force to the worn pin initially (Figure 3 b-c). The formulation's improved interfacial adhesion between the particle and resin and decreased possibility of particle pull-out, which can help to boost wear resistance at 15wt%CNTs. Aigbodion et al. (2010) employed bagasse as a frictional medium and concluded with similar observation.

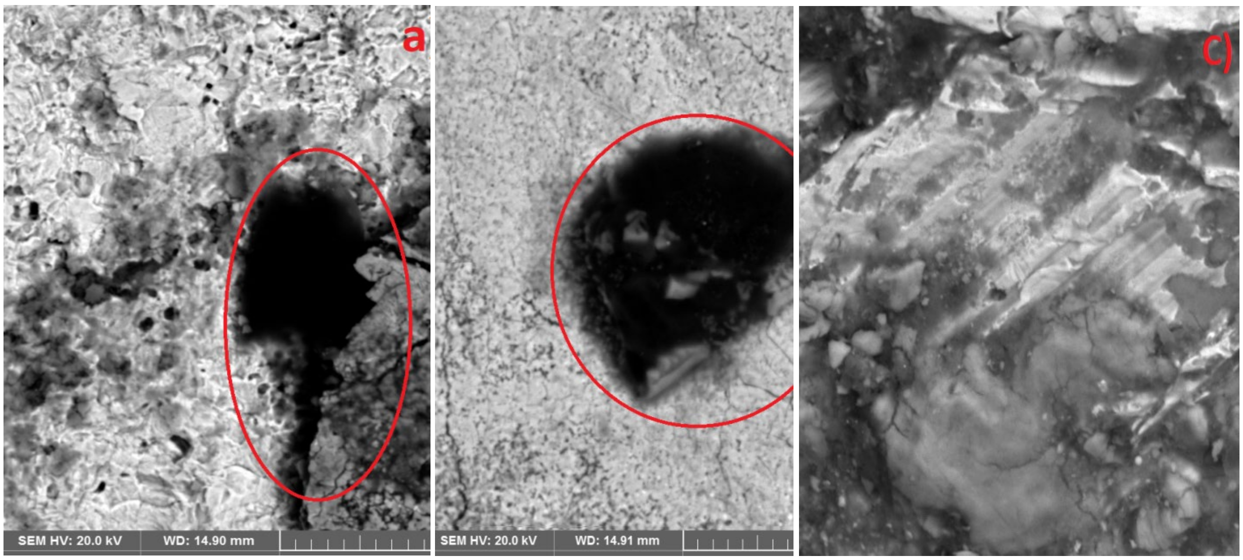

Figure 3: SEM worn surface of a); 0wt% CNTs, b) 0.5wt%CNTs c) 1.5wt%CNTs-RH

The hardness values and physical characteristics were evaluated and compared to those of laboratory brake pads made of asbestos (see Figure 4). Figure 4 displays the results of the testing on the brake pad samples' water and oil absorption. The solubility of brake pad composites may be affected by the reduction in porosity that might be brought-on by the strong interactions between the binder and the CNTs-RH particles. At this situation, a hardness value of 125 HRB was attained. This value is more than that of commercial brake pads. The attributes achieved at 1.5wt%CNTs-RH are within the authorized values for the application of brake pads, as per J3281-202305 and ISO 6312:2010 standards. The investigation's findings show that the developed brake pads are superior to commercial brake pads, which are made with asbestos. As a consequence, these compositions may be used to make asbestos-free brake pads.

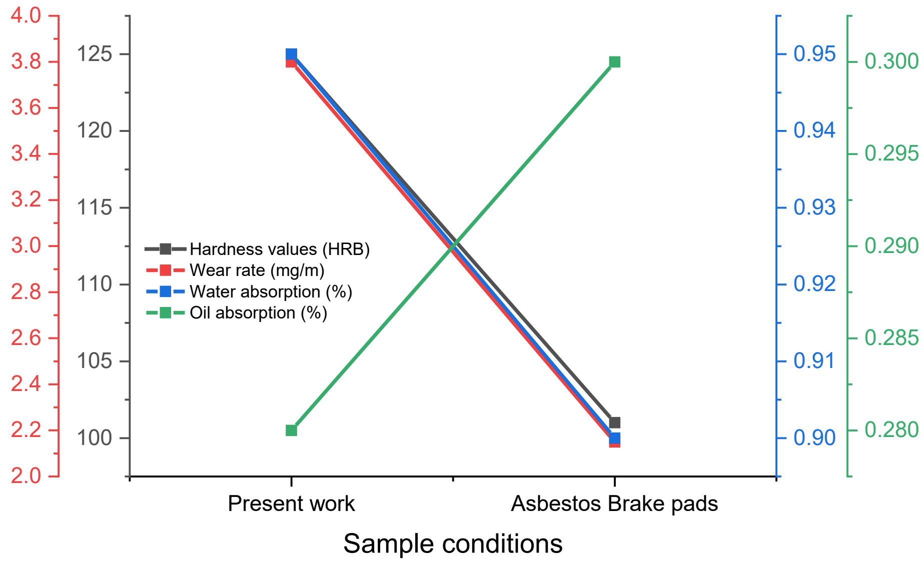

Figure 4: Comparing results with commercial asbestos-based brake pads

4. Conclusions

This research looked at how asbestos brake pads can be replaced using novel friction materials made of carbon nanotubes from rice husk, $CaCO_3$ from oyster shell, and graphite from old batteries. The brake pads were made using the solution-stir-cast method. The optimal conditions were achieved at 1.5 wt% carbon nanotubes manufactured from rice husk. These conditions comprised a wear rate of 2.15 mg/m and a coefficient of friction of 0.42. The values obtained are within the acceptable range for brakes with high friction. As a result of the strong interfacial bonding between the particles and the binder, higher frictional brake pads were attained in this research. The use of these innovative materials will eliminate the primary issue with brake pads made of asbestos.

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Professor Charles Mbohwa is the Pro Vice Chancellor of the University of Zimbabwe, Harare, Zimbabwe. He obtained B. Sc. Honours in Mechanical Engineering in 1986 from Department of Mechanical Engineering of the same University. He later bagged M. Sc. in Operations Management and Manufacturing Systems with a distinction in 1992, from Department of Manufacturing Systems Engineering, University of Nottingham, UK. He obtained PhD in Engineering (Production Systems focusing on Energy and life cycle assessment) from Tokyo Metropolitan Institute of Technology, Tokyo, Japan in 2004. Professor Mbohwa is an NRF-rated established researcher. In January 2012 he was confirmed as an established researcher making significant contribution to the developing fields of sustainability and life cycle assessment. In addition, he has produced high quality body of research work on Southern Africa. He is an active member of the United Nations Environment Programme/Society of Environmental, Toxicology and Chemistry Life Cycle Initiative, where he has served on many taskforce teams. He has published over 600 research articles in leading international Journals and Conference Proceedings. Prof Mbohwa had been keynote speaker in many international conferences and has supervised many local and international postgraduate students while playing host to several international postdoctoral fellows. He is a visiting Professor to the University of Johannesburg, South Africa, where he had served in various capacities; including Dean of Postgraduate Studies and Executive Dean of Faculty of Engineering and the Built Environment.