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Investigation of Slurry Erosion Wear Behaviour on Coir-Filled Polypropylene Composites

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Abstract

Naturally occurring fibres are better and more advantageous than metals because they are lightweight, low-cost, biodegradable, recyclable, etc. Natural fiber-reinforced composite materials are becoming more and more important in engineering and technology because they have excellent qualities and properties, such as being lighter, cheaper, and more resistant to corrosion. Because of this, most industries use these composites in today's unsustainable environmental state. Slurry erosion is the degradation of material caused by the impacts of solid particles suspended in a liquid. This is influenced by many factors. The primary objective of this study is to make Polypropylene (PP) composites using coconut coir as a natural filler and then study how these composites react to slurry erosion wear. Polypropylene (PP) composites were loaded with untreated and treated coconut Coir Fibre (CF). PP composites were made with treated and untreated coconut CFs and filler materials that made up 10%, 20%, and 30% of the total weight. Maleic anhydride (2 wt.%) was used as a coupling agent to help the coconut coir fibres stick to the PP better. The slurry erosion was conducted American Society for Testing and Materials (ASTM) G73 standards. Pure PP and composites made of coconut coir in the slurry media that had been worn down were tested. The test was done on these composites to see how they wear down at 500 rpm, 1000 rpm and 1500 rpm with 50% slurry and at 1000 rpm for an hour with 25%, 50%, and 75% slurry. The silica sand used had a grain size of 41µm. It was found that treated coconut coir fibre-reinforced composites exhibit better resistance to wear properties compared to their untreated counterparts.

Keywords: Biodegradable, Coir, Natural Fibre, Polypropylene, Slurry Erosion

1.0 Introduction

Composite materials are replacing conventional materials in many engineering applications due to their cost efficiency, corrosion resistance and high strength. The main requirements for several applications are the

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composite's mechanical behaviour and erosion properties[1]. Rapid growth in the population, increasing awareness of environmental issues, and faster degradation of fossil fuels were reviving interest in biopolymers derived from renewable resources. Bio-renewable polymers are found abundantly in polysaccharides, and natural fibres are one type of polysaccharide that is widely used in reinforcing composites to strengthen them for several applications. Natural fibers have many advantages when used in composite fabrication, like their abundant availability, sustainability, low weight, superior mechanical, thermal, and acoustic insulation qualities, and CO_2 neutrality. They possess neutrality and non-abrasiveness, do not cause adverse health effects, are biodegradable, and are environmentally friendly[2]. For their superior engineering characteristics and applications, research in polymer-based composites has gained significant momentum in the research arena. Some benefits of composite materials include their increased strength, longevity, ease of production, and cost-effectiveness[3]. More and more advanced polymer composites with filler particles are being used in engineering projects for things like satellites, spacecraft, medical devices, structures, and other places that need to dissipate heat well, not expand too much, and be light[4,5]. Subsequently, there have been significant efforts to use agricultural by-products as reinforcing fillers with thermoplastics. Natural fibre-reinforced polymer composites are becoming increasingly popular from an economic perspective because they are affordable, lightweight, comparatively low in processing temperatures, and have minimal wear and tear on processing equipment. The main objective of adding fillers to thermoplastic matrix polymers is to improve the distinct mechanical and physical characteristics of the composites. The mechanical strength and physical properties of composites are affected by things like the amount of filler loading, the shape and size of the fillers, and how well they stick to the matrix[6].

Sustainable materials have been in high demand recently due to growing environmental concerns and the need to lessen dependence on synthetic polymers. Fibre-Reinforced Polymer (FRP) composites are a promising alternative because they have excellent mechanical properties, are durable, and are lightweight. These composites, which are typically made with synthetic fibres and polymer matrices, have been thoroughly investigated for a variety of applications, such as aerospace, automotive, and structural industries. On the other hand, their non-biodegradable nature presents considerable environmental difficulties, which has prompted researchers to investigate biodegradable composites as a more sustainable alternative[7].

Biodegradable composites are made from natural fibres, such as coir, abaca, and Pineapple Leaf Fibre (PALF), and are reinforced with biodegradable polymer matrices, such as Polylactic Acid (PLA). These materials are an environmentally friendly option that still has the mechanical and thermal properties that are desired. In addition, chemical treatments are frequently used on natural fibres to improve their compatibility with polymer matrices, which enhances interfacial adhesion and overall performance. Several studies have looked into the mechanical, thermal, and erosion resistance properties of biodegradable composites, demonstrating that they could be a viable alternative to traditional FRPs[8,9].

Coir is the predominant natural fibre utilised because it is readily available, affordable, low-density, simple to produce and environmentally friendly[10,11]. Chemically treating the coir fibre has enhanced interfacial adhesion and minimised microvoids at the fibre-matrix interface, These changes have made treated coir-polypropylene composites stronger and less likely to absorb water than untreated coir composites. This is due to the favourable interaction between the PP matrix and the treated coir, which results in a significant reduction in agglomerates and microvoids and demonstrates better fibre dispersion within the matrix[12,13]. However, the use of natural fibres in engineering applications has been limited because of their high moisture absorption, low strength, and poor compatibility. Through chemical treatments on fibres, these problems can be eliminated before they are used as reinforcements in the fabrication of composites. Alkalisation, acetylation, silane, acrylation, maleic acid and benzoylation are commonly used chemical treatments for fibre treatment[14]. Santosh Kumar[15] looked into what happens when you treat PP composites with treated and untreated coconut CF at different amounts (10%, 20%, 30%, and 40%). The samples were fabricated using injection moulding techniques; a coupling agent was employed to increase the bonding between the fibre and PP. In this case, 2% maleic anhydride is used as the coupling agent. The results showed that coconut

coir fibre-reinforced composites had better mechanical properties and higher fracture toughness values than pure polypropylene. Chemically treated CF-loaded composites have better resistance to wear properties in comparison to untreated CF-loaded composites. Isiaka Oluwole Oladele[16] looked at what happened to coconut coir-filled PP composites when sodium hydroxide and Potassium Hydroxide (KOH) were used as chemicals to treat them and produced the composites using the compression moulding method, it was seen that treating samples with NaOH improves their tensile properties, and treating samples with KOH improves their flexural and water-repellent properties compared to samples that were not treated[17,18].

Owing to the rapid negative environmental impact of the consumption of petroleum-based products and the increase in environmental awareness when it comes to sustainable materials and products. Natural fibres and biodegradable polymers are eco-friendly and also there is a scope to develop and analyse biodegradable composites. CF PP composites offer a mechanically feasible, economical, and environmentally friendly substitute for conventional materials. They are a desirable option for sectors trying to strike a balance between sustainability and performance because of their potential for enhanced toughness, wear resistance and lightweight qualities[19-21]. This study's primary goal was to examine PP composites that were stronger with coconut CF that had not been treated with chemicals and fibre that had been treated with 2% NaOH. The 2% maleic anhydride was used as a coupling agent to study how these PP composites react to slurry erosion wear.

2.0 Materials and Methods

2.1 Materials

(a) Polypropylene: Polypropylene (PP) is a polyolefin type, slightly more rigid than polyethylene. It is regularly used as a matrix material. Polypropylene is a rigid, semi-crystalline thermoplastic available in various grades. It is a common plastic with good heat resistance, low cost, low density, better chemical resistance, fatigue resistance, improved tensile strength, and good stiffness. It has a melting temperature around 170°C.

(b) Coconut Coir Fibre: These are major natural fibres belonging to the Arecaceae (palm) plant family obtained from the outer husk of coconut. Coconut coir is a fibrous material found between a coconut's hard outer covering and its inner shell. It is used as a reinforcing filler in the creation of composites.

(c) Maleic Anhydride (Compatibiliser): It is an organic compound with the chemical formula C4H2O3. It is a colourless or white solid with an acrid odour. Maleic anhydride is used to improve the bonding between the coconut CF and PP.

(d) Sodium Hydroxide (NaOH): It is commonly known as caustic soda. It is a colourless, odorless, highly soluble substance that melts at a temperature of 318°C and boils at 1,388°C. It is used to chemically treat coconut CF, facilitating surface modifications and the removal of impurities.

2.2 Coconut Coir Fiber Preparation and Chemical Treatment

(a) Water Washing (Untreated Coconut Coir): The coconut CF were rinsed with clean water to eliminate dust, plant debris, and other unwanted foreign particles. After the pure water wash, the coconut CF were dried in the sunlight to eliminate their moisture content. We cut these dried fibres into small fibres, each measuring approximately 5 to 10mm in length.

(b) Chemical Treatment with NaOH (Treated Coconut Coir): The coconut CF were dipped in sodium hydroxide solution for 24 hours at atmospheric temperature for the chemical treatment. A chemical solution of NaOH was developed by dissolving 250 grams of NaOH in 12.5 litres of water. After the chemical treatment, coconut CF were washed with clean water to eliminate dust, plant debris, and other unwanted foreign particles.

2.3 Fabrication of Composites

Fabrication of composite materials followed the same process as in the earlier article by Santosh Kumar[22].

3.0 Characterisation of Fabricated Composites

3.1 Slurry Erosion Wear

The purpose of this wear test is to find out the slurry erosion wear behaviours of a material. The cooling tank made of

Table 1. The formulation of the fabricated PP composite materials

Specimen Name	Weight Percentage(%)		Coupling Agent Maleic Anhydride (wt.%)	Sodium Hydroxide(wt.%)
	Poly propylene	Coconut CoirFibre		
PURE PP	100	-	-	-
U10	90	10	2	-
U20	80	20	2	-
U30	70	30	2	-
T10	90	10	2	2
T20	80	20	2	2
T30	70	30	2	2

stainless steel material is a rectangular, hollow vessel filled with cooling water to remove the heat generated during the erosion test. It has six openings on the top face to accommodate slurry vessels, as well as water inlet and outlet ports. A motorised screw jack mounted below the cooling tank raises and lowers the tank vertically. The specimen holder is connected to a revolving shaft. We fill a pot with slurry and immerse the entire assembly in it. To prepare the slurry medium, silica sand of grain size 412µm is dissolved in pure water, and the slurry erosion wear loss of the specimens was determined as a function of weight loss by taking the sample's weight before the test (initial weight) and after the test (final weight). The difference in weight determines the quantity of weight loss. As per ASTM G73 standards, Figure 1 shows the test specimen, which is 76mm long, 25mm wide, and has a hole of 8mm in the middle. Figure 2 shows the slurry erosion test rig.

3.2 Slurry Erosion Wears Test Variables

- Slurry Composition (25%, 50% and 75%).
- Test speed (500 rpm, 1000 rpm and 1500 rpm).
- Type of sample (Pure PP, U10, U20, U30, T10, T20 and T30).
- Test duration (1 Hour).
- Silica sand of grain size 412µ.

The tests are conducted using a slurry erosion tester. It consists of a specimen holder connected to a revolving shaft. The entire assembly immerses the slurry in a pot. To prepare the slurry medium, silica sand of grain size 412µm is dissolved in pure water in varying proportions of 25%, 50% and 75%. Each time, fresh water was used to prepare the slurry medium, and the experiment was carried out at room temperature.

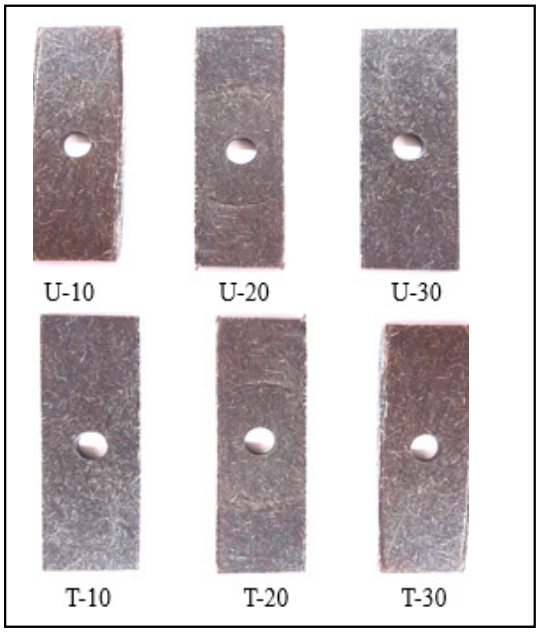


Figure 1. Test specimens as per ASTMG73 standard.



Figure 2. Slurry erosion test rig.

The specimen holders in the slurry pot hold samples of known weights. After putting the specimens in the slurry, they are spun at a constant 1000 rpm for one hour at room temperature with slurry weights of 25%, 50% and 75%. They are also spun at 500 rpm, 1000 rpm, and 1500 rpm for 50 wt. % of slurry (50 wt. % pure water and 50 wt % sand). The sample wear was determined as a function of weight loss.

4.0 Results and Discussions

4.1

Slurry erosion weight loss of pure PP and PP composites filled with untreated and treated CF at a constant speed of 1000 rpm for varying slurry wt. percentages.

The wear resistance of the treated PP composites is compared with that of pure PP and untreated PP composites to evaluate the effect of treating coir fibre reinforcement with sodium hydroxide (NaOH). Figures 3 to 5 compare the weight loss values of pure PP, untreated PP composites, and treated PP composites for 10%, 20%, and 30 wt.% fibres at a constant speed of 1000 rpm for varying slurry weight percentages of 25%, 50% and 75%.

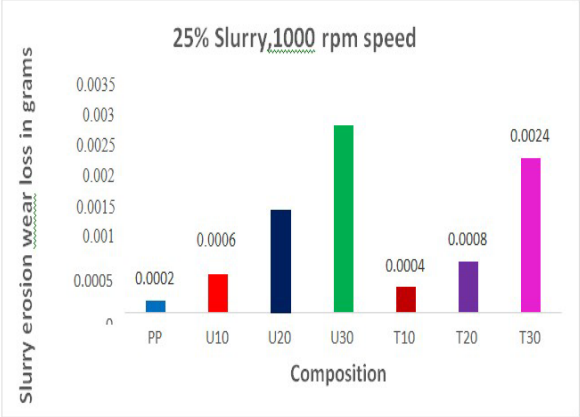


Figure 3. Slurry erosion wear loss of composition in 25% slurry at 1000rpm.

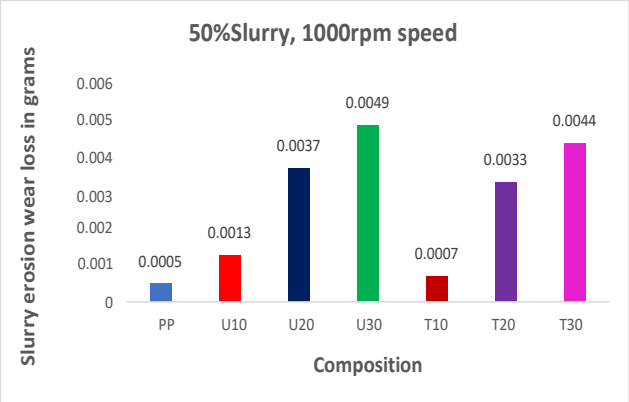


Figure 4. Slurry erosion wear loss of composition in 50% slurry at 1000rpm.

The weight loss values of PP composites filled with untreated coir and treated coconut CF increase in direct proportion to the percentage of fibre loading. When the quantity of fibre content in the composites increased, the weight loss values also increased. The wear resistance values of treated CF composites are better than those of untreated coconut CF composites. When compared to coconut coir composites that have been chemically treated, untreated coconut coir composites lose the most weight at all weight percentages of slurry. There is a lot more weight loss in composites with 30% wt.% CF than with 10% and 20% wt.% CF. This is true for both untreated and treated composites. Both the treated and untreated composites have considerably greater weight loss values

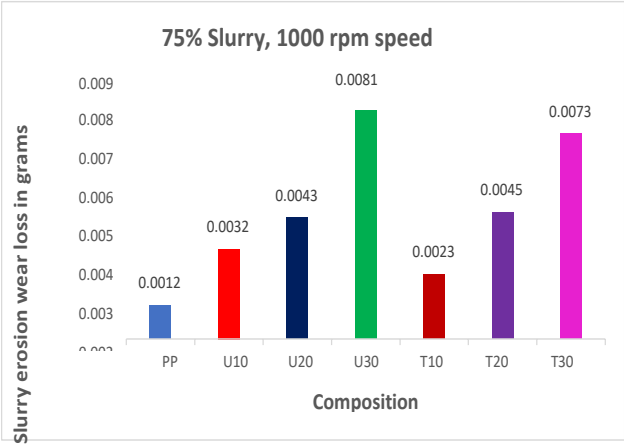


Figure 5. Slurry erosion wear loss of composition in 75% slurry at 1000rpm.

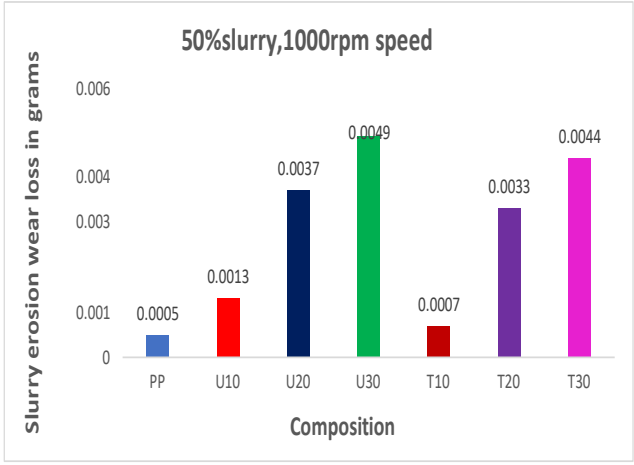


Figure 7. Slurry erosion wear loss of composition in 50% slurry at 1000rpm.

compared to pure PP. So the sand proportion is one of the significant factors that influence weight loss values.

4.2 Slurry Erosion Weight Loss of Pure Polypropylene and PP Composites Filled with Untreated and Treated Coir Fiber at Varying Speed for 50 wt.% of Slurry

The wear resistance of the treated PP composites is compared with that of pure PP and untreated PP composites to evaluate the impact of sodium hydroxide (NaOH) chemical treatment on coconut CF. Figures 6 to 8 compare the weight loss values of pure PP, untreated PP

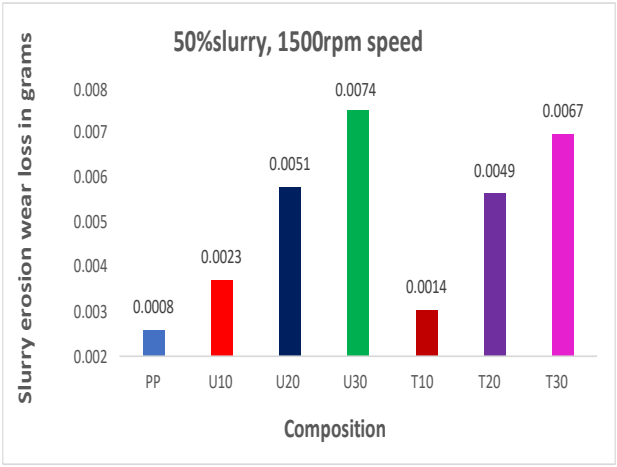


Figure 8. Slurry erosion wear loss of composition in 50% slurry at 1500rpm.

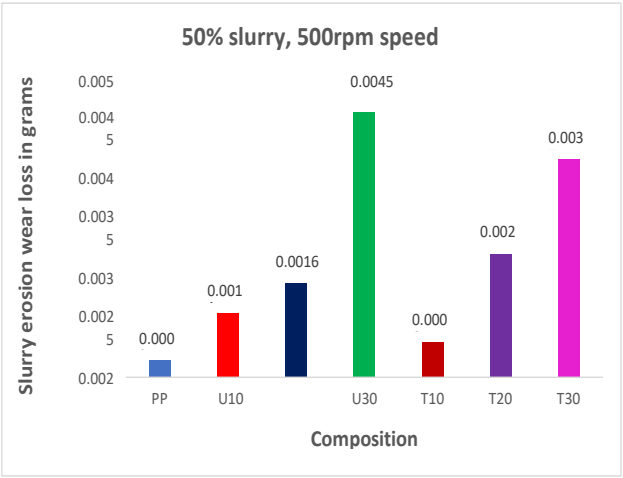


Figure 6. Slurry erosion wear loss of composition in 50% slurry at 500rpm.

composites, and treated PP composites for a fibre loading of 10, 20 and 30 wt.% at different speeds of 500 rpm, 1000 rpm, and 1500 rpm for 50 wt.% of slurry.

The weight loss values of PP composites filled with untreated coir and treated coconut CF increase in direct proportion with an increase in speed. When the speed is increased, the weight loss values also increase. The wear resistance values of treated CF composites are better than those of untreated coconut CF composites. Compared to chemically treated coconut coir composites, untreated coconut coir composites have maximum weight loss values for the same percentage of fibre loading at all ranges of speeds. In untreated and treated coconut coir-

filled composites, the weight loss value in 30 wt.% CF content is considerably greater than 10 wt.% and 20 wt.% of CF content. Both the treated and untreated composites have considerably greater weight loss values compared to pure polypropylene. So speed is one of the important factors that influence weight loss values.

5.0 Conclusion

This work investigates the effects on the slurry erosion wear behaviours of PP composites by adding different percentages of fibre loading of 10%, 20%, and 30% with chemically treated and untreated coconut coir fillers, different slurry weight percentages of 25%, 50%, and 75%, as well as varying speeds of 500 rpm, 1000 rpm, and 1500 rpm. In PP composites reinforced with varying weight percentages of both treated and untreated coconut coir, the slurry erosion wear behaviour increases in direct proportion to the percentages of fibre loading. The weight loss values of untreated and treated PP composites are noticeably higher than the values of pure PP for any percentage of fibre loading. For the same fibre loading proportions of 10%, 20%, and 30%, untreated coconut coir-filled PP composites exhibit higher wear loss values than chemically treated coconut coir-filled PP composites. Compared to untreated coconut CF composites, chemically treated coconut CF and PP composites have improved wear resistance values. In both chemically treated and untreated coconut CF PP composites, the weight loss values at 30 wt. % of coconut coir composition are considerably greater than those at 10 wt.% and 20 wt.% of the coconut CF composition. The weight loss values of the treated and untreated composites are significantly higher than those of pure PP. CF PP composites are attracting interest for their ability to improve slurry erosion wear resistance. These composites utilise the inherent features of coir fibres to enhance mechanical properties and erosion resistance, rendering them appropriate for diverse applications in sectors such as marine and construction.

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