

Evaluation of Mechanical Characteristics of Polypropylene Hybrid Composites

Hari B.S., Gokul M., Janarthanam V.

Department of Mechanical Engineering, Kongu Engineering College, Erode India

Abstract

The study examines the Impact of Wood Grain, bentonite, talc mixture characteristics on The mechanical specifications of polypropylene complexes (PP). The study compares composites loaded with hybrid filler with those consolidated with coated wood cellulose. The results show that increased aspect ratio corresponds to optimized tensile and bending strength and modulus of wood grain composites. Four types of mineral fillers were compounded with polypropylene (PP) and examined for their result in physical, flow, and thermos traits. The idea was to examine their characteristics and determine potential filler mixtures for hybrid PP integrated. The study found that Talc with polypropylene, Bentonite, and Talc with hybrid composite showed higher mechanical properties compared to pure polypropylene. The study aims to determine the best filler combinations for hybrid PP composites and their potential applications in thermoplastics.

Keywords: Polypropylene, Bentonite, Talc, Wood Fillers, Tensile Strength, Flexural and Impact Test.

1. Introduction

Composite materials are solid multiphase materials with varying chemical, structural, and physical properties used in transportation, construction, and consumer goods. They combine unique features like weight, strength, vibration, stiffness, permeability, electrical, biodegradability, and optical characteristics. Custom composite materials are available to meet specific requirements. Polymers, lightweight, ductile, and easy to manufacture, outperform other materials like metals and ceramics. Composite technology enhances polymer characteristics while remaining lightweight and ductile.

Researchers working on innovative formulations and manufacturing procedures have made major contributions to the field of composites. Recent literature has seen an increase in studies focused on novel techniques to improving the characteristics of polypropylene (PP) composites through the use of hybrid filler systems. Alwekar et al. [1] investigated the influence of processing techniques on long fibre thermoplastic composites and found that well aligned fibre composites outperformed their equivalents. Andrzejewski et al. [2] investigated a cork-wood mix padding method for PP and poly (lactic acid) composites and reported significant improvements in mechanical characteristics. Balakrishna et al. [3] examined

polypropylene/rattan powder/kaolin hybrid composites, which showed improved thermal stability and mechanical strength. Bledzki and Faruk [4] investigated wood fiber-reinforced polypropylene composites, emphasising the significance of processing processes in determining their mechanical properties. Chan et al. [5] shared polypropylene bio composites reinforced with boron nitride and nanohydroxyapatite, with the goal of achieving higher mechanical qualities while being biocompatible. Essabir et al. [6] conducted a correlation of bio- and mineral calcium carbonate fillers in polypropylene composites, emphasising snail shell particles' environmental benefits. Guo and Kethineni [7] investigated direct injection moulding of hybrid polypropylene/wood-fiber integrated and found significant improvements in mechanical performance using glass and carbon fibre reinforcements. Klapiszewski et al. [8] investigated polypropylene composites reinforced with functional ZnO/lignin hybrid materials, gaining insights into their chemical and mechanical characteristics. Leong et al. [9] and Hari BS et al. [11] studied talc, kaolin, and calcium carbonate-filled polypropylene composites and discovered subtle differences in mechanical, flow, and thermal characteristics. Furthermore, Mukhopadhyay and Srikanta [10] Under consideration the implications of ageing on sisal fiber-reinforced polypropylene

composites, providing insight into the material's mechanical properties under various situations.

2. Materials and Methodology

This research aims to enhance the mechanical properties of pure polypropylene (PP) by using innovative filler elements like bentonite and wood powder. Bentonite, a layered aluminum silicate with exchangeable cations, is used as a novel filler in PP, and a hybrid composite using wood powder is investigated. The goal is to determine and compare the mechanical characteristics of these hybrid filler materials to those of pure PP. The materials used include talc-filled grades and wood-derived fillers, which offer advantages like increased stiffness, better surface aesthetics, and sustainability. Specimens are constructed using melt-mixing processes and mechanical tests using advanced equipment like the Universal Tensile Machine, Universal Testing Machine, and Izod and Charpy Tester Machine. The examines seek to offer an in-depth understanding of the complex interplay between hybrid fillers and polypropylene, contributing to the evolution of composite material science and improving their utility in various industrial applications.

2.1 Materials

Bentonite (BEN), a mineral with layered aluminum silicate, is used as a filler in polypropylene to increase thermoplastic strength, stiffness, durability, and hardness with the density of 1.0 to 2.0 g/cm³. Talc-filled grades provide increased rigidity and surface attractiveness with density of 2.58 to 2.83 g/cm³, while wood-derived (WD) fillers offer reduced density, increased deformability, reduced expense and less roughness to the equipment. Hybrid composites: thermoplastic matrices filled with wood flour or wood fiber, can improve the mechanical properties of wood flour/polypropylene materials. These composites have gained low-cost in recent years, high-volume applications, as they can manage or avoid losses in strength, sudden energy, and flow-related processing aspects while preserving other characteristics. Wood-based fillers are a sustainable resource and can be used in hybrid composites for low-cost, high-volume applications. The examples were painstakingly manufactured, with weight percentages shared by polypropylene

and filler components. Table 1 provides specific facts about the composition.

Table 1 Compositions of Materials

S.No	Sample Name	Polypropylene (PP)(WT%)	Filler Material (WT%)
1	PP1	100%PP	NIL
2	PP2	95%PP	2.5% BEN + 2.5% WP
3	PP3	90%PP	5% BEN + 5% WP
4	PP4	85%PP	7.5% BEN + 7.5% WP
5	PP5	95%PP	2.5% TALC + 2.5% WP
6	PP6	90%PP	5% TALC + 5% WP
7	PP7	85%PP	7.5% TALC + 7.5% WP
8	PP8	95%PP	5% BEN + PP
9	PP9	90%PP	10% BEN + PP
10	PP10	85%PP	15% BEN + PP
11	PP11	95%PP	5% TALC + PP
12	PP12	90%PP	10% TALC + PP

13	PP13	85%PP	15% TALC + PP
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Based on research findings, varied quantities of filler materials were introduced into pure polypropylene, including 5%, 10%, 15%, and 20%. The selected approach is a systematic melt-mixing or melt-compounding procedure that uses injection moulding or compression moulding techniques. This systematic method guarantees that filler components are well integrated with polypropylene, creating a solid foundation for future mechanical testing and extensive evaluations.

2.2 Methods

The mechanical properties of the specimens will be thoroughly investigated, including tensile, flexural, and izod tests. The Universal Tensile Machine will be executed to test a wide field of materials, including fabric, tape, yarn, and HDPE pipe samples that require flattening, ring stiffness, compression, and flexural testing. The tensile test, which follows ASTM standards for polymer, plastic, and rubber materials, uses specimens formed in a dog-bone pattern. Careful handling is required, especially for delicate or brittle materials, with the tester's knowledge and proper grips playing an important role. Throughout the test, the specimen gradually elongates, and the stress-strain curve changes, eventually resulting in breaking. Measured characteristics include tensile strength, yield strength, and strain. The flexural test, performed on the Universal Testing Machine, uses ASTM standards for three-point bending to determine a material's flexural modulus or strength. Unlike the tensile test, the flexure test uses horizontal positioning across two points of contact and applies force until the sample fails. The longitudinal strength and flexural modulus are determined using the stress-strain deflection curve. The izod strength test, an ASTM D256 standard, uses the Izod and Charpy Tester Machines to measure material resistance. The test comprises a pivoting arm impacting a notched sample, and the resulting energy absorption is calculated using the arm's post-impact swing height at 3.46 m/s. A notched sample is used to test impact energy and notch sensitivity in a cantilevered beam design. Both the

Izod and Charpy tests give useful information, and the results are easily shown on the tester computer.

2.3 Specimens Preparation

Materials were selected and weighed in accordance with their composition. The mould has dimensions of 170*85*3 mm. In this experiment, the filler components were melt mixed into pp and the specimen was made by injection moulding. The temperature is adjusted to approximately 250°C, and the preparation period for a single specimen is 10 minutes. The specimen was sculpted using the shaping machine. The specimens were formed in guidance with the ASTM D638 standards. For the tensile test, the specimen is fashioned in the ASTM d638 dog-bone shape. The sample size for the flexural test is 49*13*3 mm, whereas the specimen size for the impact test is 49*13*3 mm. Totally 13 specimens were made including pure polypropylene.

3. Results And Discussion

Mechanical testing was conducted on a sample prepared using a melt mixing method at 250°C. The stress strain curves showed the maximum yield load, breaking load, and elongation with respect to the load applied. Mechanical testing assesses materials physical properties and behavior under stress. It includes tensile, flexural, and impact tests. Tensile tests measure strength and elasticity, flexural tests assess bending properties, and impact tests measure energy absorption. These tests help engineers and manufacturers ensure materials meet real-world performance requirements.

3.1 Process

The tensile strength results showed that the PP7 composite had the highest Young's Modulus value increased by 78.78%. Filler material with a greater aspect ratio was used to improve the integrity of polypropylene composites. The PP4 composite had the highest Young's modulus value compared to the same proportion of 5% and PP12. The least Young's modulus was 14.85% for PP11 combination. The highest Tensile Yield Strength percentage was 14.61% MPa for the PP5 combination. The study found agglomerates form flaws, leading to poor filler wetting and voids among filler and matrix. This results in lower yield stress in composites compared to talc composites [13]. Talc, a powerful reinforcing filler, can contribute to polymer flow during

processing due to its thin platy or flaky character. The least Tensile Yield Strength was 2.546154 MPa for the PP4 combination. The graphs showed that the PP7 and PP5 combination had the highest Young's modulus and tensile strength compared to pure polypropylene.

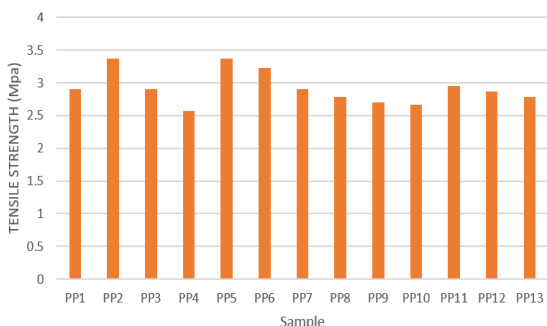
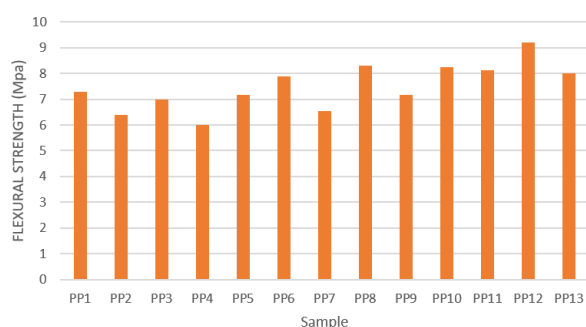


Figure 1: Tensile integrity of Prepared specimen

Flexural integrity obtained during the flexural testing is shown in the figure 2. The study found that PP12 has the highest flexural strength percentage of 25.49%, while 10% of filler materials have the highest value. The dispersion medium of filler materials with PP has more flexural strength. The least flexural strength was found in the prepared composites with PP4, with a value of 6.030 MPa. Talc's high aspect ratio enhances wettability with the polymer matrix, resulting in fewer microvoids and better interaction among the filler and matrix. The addition of filler materials reduced the mechanical properties of flexural strength, as the denser medium of the filler materials combined with PP reduced strength compared to other proportions and pure PP.



Additionally, the originality of the polymer was lost with more filler material ratios [14].

Figure 2: Flexural Strength of Prepared Samples

The Impact tests (izod method) for various polymer composites. Impact strength obtained during the Impact izod testing is shown in the figure 3. Filler

materials with a greater aspect ratio are used to increase the strength of the composites. The dispersion medium specimen with less filler materials has the highest impact strength. The least impact strength is found in the PP11 combination, with a value of 0.000939 (N/mm²). The strength of the composites increases with the increasing filler ratio [9].

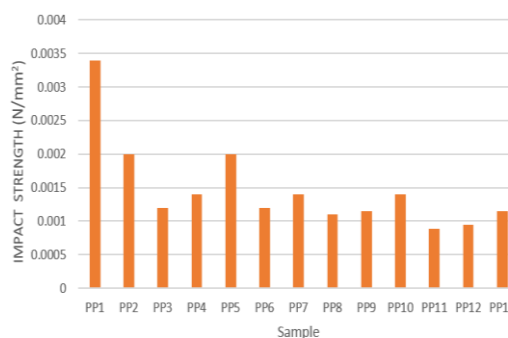


Figure 3: Impact Test of Prepared Samples

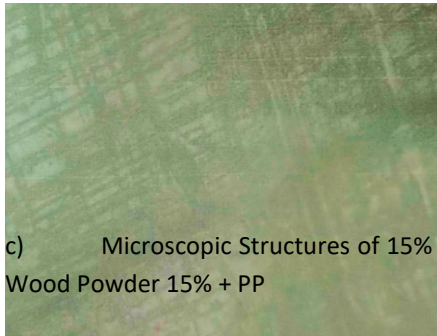
3.2 Microscopic Structure

Microscopic study is required to understand the physical, chemical, and mechanical characteristics of composite materials. Figures 4 show microscopic structures of several materials. The study focused on composites with PP3 and 5% Bentonite + 10% Wood powder, which demonstrated a dispersed medium with polypropylene (PP) and increased mechanical strength. However, a high volume in filler content evolved in a decrease in mechanical properties. The mixture of 15% Bentonite, 15% Wood Powder, and PP produced a denser medium with a greater PP content but poorer mechanical strength than pure PP. The tiny pictures clearly show that the mechanical characteristics decrease when additional filler materials are added.

a) PP3 Microscopic Structure



b) Microscopic Structures of 10% Bentonite+
10% Wood Powder + PP



c) Microscopic Structures of 15% Bentonite+
Wood Powder 15% + PP

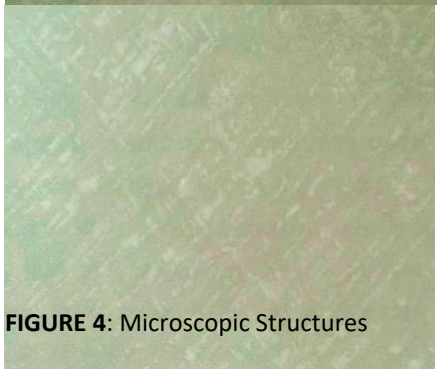


FIGURE 4: Microscopic Structures

4. Conclusion

Finally, the mechanical characteristics of polypropylene composites produced via solution and melt mixing were studied. The study found that the PP5 combination had a higher tensile strength than other specimens, emphasizing the importance of filler content in mechanical qualities. Mechanical strength decreased with increasing filler concentration, but less filler ratios produced a dispersion medium with PP, resulting in stronger strength. The Young's Modulus and flexural strength also varied amongst filler combinations, with the PP7 combination having a greater Young's Modulus. The combination of 2.5% Bentonite, 2.5% Wood Powder, and PP performed best in terms of impact strength. Overall, the study emphasizes the potential of polypropylene composites reinforced with hybrid fillers in applications that need high accuracy and rigidity.

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