Research Article

Investigation of Mechanical Properties of Hemp Hurd/PP Composites for the Application of Water Irrigation Pipes

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Abstract

In this study, for the first time, a new generation hemp hurd/PP composite material coupling sleeve prototype production was performed for the water irrigation pipes. Within the scope of experiments, at first hemp hurds were prepared by using cyclic grinding machine. Later, the compounds of hemp hurds (0 wt%, 10 wt%, 20 wt% and 30 wt%) and polypropylene (PP) were prepared using double screw extruder machine at Ondokuz Mayıs University. After that, the specimens of 0 wt%, 10 wt%, 20 wt% and 30 wt% hemp hurd reinforced polypropylene (PP) composites were fabricated using injection molding machine. Three points bending tests were performed on the fabricated specimens with INSTRON 5982 100 KN universal test device at Ondokuz Mayıs University (OMU) KITAM Central laboratory. Prototyping of hemp hurd/PP

composite material coupling sleeves were produced using plastic injection machines of Poelsan Plastik Sanayi ve Ticaret A.Ş. Long-term tightness test under internal pressure was conducted on the fabricated coupling sleeves in Poelsan Plastik Sanayi ve Ticaret A.Ş. According to the bending test results, the bending modulus of specimens were increased by increasing hemp hurd content. The highest bending strength was obtained by 10 wt% hemp hurd powder reinforced PP composites (46.5 MPa). The findings showed that the coupling sleeves manufactured from hemp hurd/PP composite material can be successfully used as an alternative to %100 PP material coupling sleeve under similar service conditions in water irritation systems.

Keywords: Hemp hurd, Hemp hurd/PP thermoplastic composite materials, Bending properties, Coupling sleeve for the water irrigation pipes

1. Introduction

The importance of water supply networks is huge for humanity. Obtaining simple but effective solutions for engineering practice, at an acceptable cost price, is an important target for the companies. The use of pipes is widespread in the transport of liquids, especially for that of oil and gas, but also water needed by human communities. Various shapes and sizes of pipes and made of different materials, have been used by many people. The most suitable and current plastic material used to produce the pipes needed for water transport in modern water-supply networks has been proven to be polypropylene [1]. Several studies have been done on plastic pipes for water irrigation system [2-7].

The use of renewable plant fiber reinforcements instead of synthetic reinforcement elements such as glass fiber and carbon fiber in polymeric composite materials, has gradually increased in the last decade. The strength values of plant fiber composites are lower compared to composite structures consisting of high-performance fibers (glass fiber and carbon fiber, etc.). For this reason, simpler usage areas of plant fiber products such as tables, shelves, automobile parts, irrigation system materials are recommended instead of areas requiring high mechanical performance [8-11]. Plant fibers make it possible to produce composite materials with lower weight (up to 15% reduction) than glass fiber and better mechanical properties than pure polymer [12].

Some properties of natural fibers and E-Glass fibers are given in Table 1.

Table 1. Comparison of natural fibers and E-Glass fiber properties [13].

Characteristics	Natural Fiber	Glass Fiber
Density	Lower density, contributing to lightweight materials.	Higher density, leading to heavier materials.
Sustainability	More sustainable with renewable sources and biodegradability.	Less sustainable, with energy-intensive manufacturing.
Mechanical Properties	Lower tensile strength and modulus, suitable for many applications.	Superior strength and stiffness, ideal for high-performance.
Chemical Resistance	Limited resistance, may require treatments for durability.	Excellent resistance, suitable for corrosive environments.
Thermal Properties	Moderate insulation, adequate for thermal stability.	Excellent thermal resistance, retaining properties at high temperatures.

Until now several studies have been done on plastic pipes for water irrigation system. However, it was found no research on hemp hurd powder reinforced PP material coupling sleeve pipes. Hemp hurd powder reinforced PP material coupling sleeve was developed in this study. This is a new and environmentally friendly alternative to existing coupling sleeves. In this research, hemp hurd reinforced polypropylene (PP) composites were fabricated using extruder and injection molding machine. Three points bending tests were performed on the fabricated composites. Long-term tightness test under internal pressure was conducted on the fabricated coupling sleeve of prototypes.

2. Materials and Methods

Polypropylene (PP) (Tecolen PP HP) was obtained from Safic Alcan, Türkiye. Hemp hurd materials were supplied from OMU Hemp Institute) (Figure 1).

Figure 1: Hurd Form from The Hemp

2.1. Production of Hemp Powders

Hemp hurd powders were preperad in the Ring Mill Grinder Machine (Unal Machines, Izmir) OMU Metallurgy and Materials Engineering Ceramic Production Laboratory. In this step, the hemp sample in hurd form was ground into powder using a "Ring Mill Grinder" The hemp hurd powder particle size was smaller 200 μm (Figure 2).

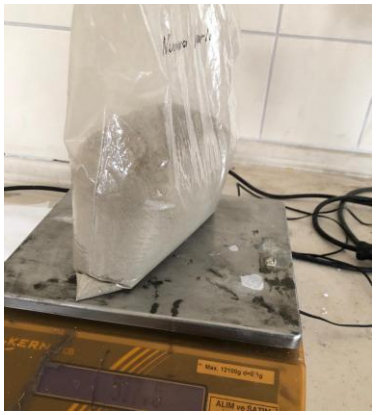

Figure 2: Crushed Hemp Hurd Powder

2.2. Production of Composite Granules

The grinded hemp powder and PP polymers were mixed in a cup. The mixture of hemp hurd powder and PP polymers were converted into granules of hemp/PP by using the twin screws Extruder machine (Kokbir, Türkiye) (Figure 3A). Later, the production of test samples of hemp hurd powder/PP composites were done in order to conduct the mechanical and other tests using the plastic injection device (Permak Makina, Türkiye) at OMU (Figure 3B).

A) B)

Figure 3: A) Granules of Hemp/PP from Extruder and B) Specimens of Hemp/PP from Plastic Injection Machines

2.3. Characterization

The INSTRON 5982 100KN Instrument with bending tests apparatus at OMU Central Laboratory (KITAM) were used to perform three points bending tests. According to the ISO 178 three points bending test standard three specimens were tested. Test span lengths for bending tests were 48 mm (Figure 4A and B).

A) B)

Figure 4: Bending Test Device and Tested Sample, A) Before Test, B) After Test

Long-term tightness test under internal pressure was conducted on the fabricated coupling sleeves in Poelsan Plastik Sanayi ve Ticaret A.Ş.. Scanning electron microscope (SEM) images were attained in a JSM-7001 F.

3. Results

3.1. Mechanical Test Results

Figure 5 and Table 1 shows bending test results. According to the bending test results, the bending modulus of specimens were increased by increasing hemp powder content. The highest bending modulus was obtained by 30 wt% hemp hurd powder reinforced PP composites (1.80 GPa). The lowest bending modulus was obtained by pure PP polymer (1.16 GPa). The highest bending strength was obtained by 10 wt% hemp hurd powder reinforced PP composites (46.5 MPa). The bending modulus of 10 wt% hemp powder reinforced PP composites was 1.48 GPa. The bending strength of pure PP polymer was 44.2 MPa.

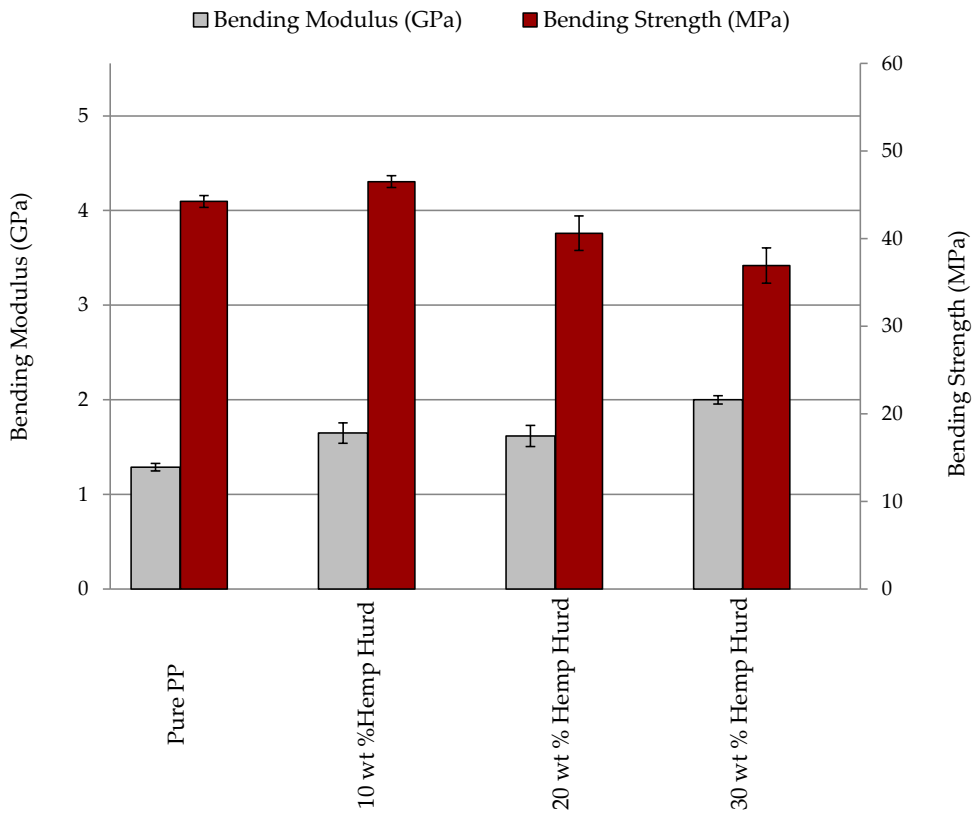

Figure 5. Results of Bending Strength and Modulus

The bending modulus and strength of 10 wt% hemp powder reinforced PP composites was 27.5 % and 5% higher than that was pure PP. Because of the highest bending strength, the 10 wt% hemp powder ratio was the optimum rate for the hemp hurd powder reinforced PP composites.

Table 1. Results of Three Point Bending Tests

Sample Name	Average Modulus (GPa)	Standard Deviation of Modulus	Average Strength (MPa)	Standard Deviation of Strength
Pure PP	1.160	0.025	44.25	0.67
10 wt %Hemp Hurd	1.485	0.035	46.51	0.67
20 wt % Hemp Hurd	1.457	0.097	40.61	1.97
30 wt % Hemp Hurd	1.801	0.100	36.93	2.00

Figure 6 presents photographs from SEM analysis. Figure 6A shows hemp hurd powders, whereas Figure 6B shows SEM photograph of 10 wt% hemp powder reinforced PP composite samples from three points bending tests.

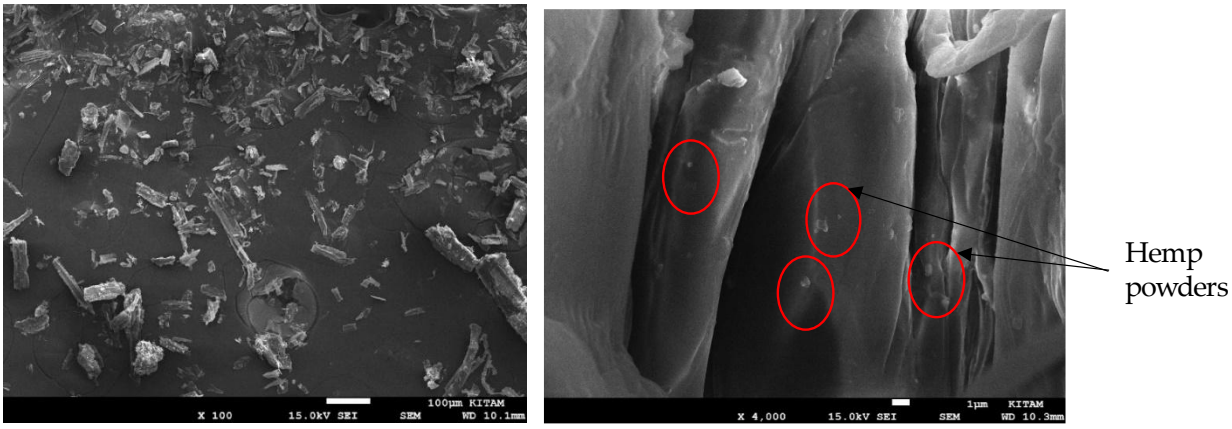

Figure 6. Photographs from SEM analysis, A) Hemp hurd powders, B) 10 wt% hemp powder reinforced PP composites

Due to have a bonding of hemp powder into the PP polymers, the mechanical properties of composites were improved.

3.2. Production and Testing of Hemp hurd/PP Composite Material Coupling Sleeves

According to the obtained bending test results of the thermoplastic composites, it was decided to fabricate coupling sleeve prototype by using 10 wt% hemp hurd powder 90 wt% polypropylene (PP) granule composites. Prototyping of hemp hurd/PP composite material coupling sleeves were produced using plastic injection machines of Poelsan Plastik Sanayi ve Ticaret A.Ş. (Figure 7).

Figure 7. Fabricated Prototype of Hemp Hurd/PP Composite Material Coupling Sleeve

Table 2 shows the results of long-term tightness test under internal pressure of prototypes of coupling sleeve. Long-term tightness test under internal pressure of prototypes was done at 20±3 ºC Temperature (ºC), 19.2 bar pressure, 1000 hours time according to ISO 3458 test method. Figure 8 shows the photograph from the long-term tightness test of prototype under internal pressure. The tested prototype was approved from the test which means the tested sleeve can resist long-term tightness test without any damage.

Table 2. Test results of Long-term tightness test under internal pressure prototypes of coupling sleeve

Name of The Test	Temperature (ºC)	Pressure (bar)	Time (Hours)	Method of the Test	Result
Long-term tightness test under internal pressure	20±3	19.2	1000	ISO 3458	Approved

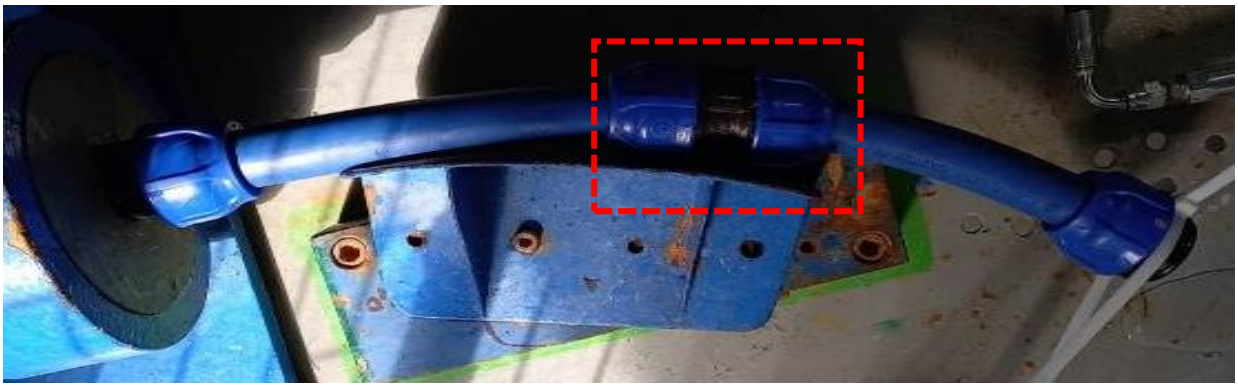

Figure 8. Long-term tightness test of prototype under internal pressure

4. Discussion and Conclusion

Our bending results demonstrated good agreement with the results of Kılıc et al. [14], Mekonnen et al. [15] and Wang et al. [16]. Kılıc et al. investigated mechanical characteristics of hemp stalks reinforced composites [14]. In their study, increasing the amount of HS filler increased the flexural strength, flexural modulus of PP. In our study, we obtained higher modulus by increasing powder weight fraction. Mekonnen et al. investigated Hemp hurd filled PLA-PBAT blend biocomposites [15]. They found that the hemp filled composites demonstrated enhanced mechanical properties. Wang et al. reported glycidyl methacrylate-compatibilized poly(lactic acid)/hemp hurd biocomposites [16]. They found that flexural modulus of the composites increased as the fiber content increased.

The purpose of this research is to develop thermoplastic matrix polymeric composite materials reinforced with hemp natural powders. Hemp powder reinforced PP matrix composites were prepared using ring mill grinder, extrusion and plastic injection machines. Three points bending tests were applied on the samples. The bending test results showed that the bending modulus of specimens were increased by increasing hemp powder content. The bending strength of specimens were decreased by increasing hemp powder content. Long-term tightness test under internal pressure was conducted on the fabricated coupling sleeves in Poelsan Plastik Sanayi ve Ticaret A.Ş.. The tested prototype was approved from the test.

The highest bending modulus was obtained by 30 wt% hemp powder reinforced PP composites (1.8 GPa). The bending strength of 10 wt% hemp powder reinforced PP composites was highest and it was 46.5 MPa. The bending modulus and strength of pure

PP polymer was 1.16 GPa and 44.2 MPa. This study showed that nationally valued hemp powder can be used as a reinforcement in a polymer matrix composites without losing any significant modulus and strength of polymers.

Our study showed that 10 wt% hemp powder ratio was the optimum rate for the hemp powder reinforced PP composites. Furthermore, coupling sleeve prototypes can be fabricated by 10 wt% hemp powder ratio. The mechanical test results of coupling sleeves were positive which means the tested sleeve can resist long-term tightness test without any damage.

5. Acknowledge

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