

Use of Lignin as a Compatibiliser in Sunn hemp Fibre Reinforced Epoxy Composites

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Abstract— Increasing environmental awareness throughout the world has triggered a paradigm shift towards designing such materials, which are compatible with the environment. The use of natural fibers, provides a positive environmental benefits with respect to disposability and raw material utilization. It has been established that the final mechanical properties of a composite are dependent on the magnitude of the strength of the bond between the fiber and matrix. As such, the poor adhesion that exists between the fibers and resins prevents Natural Fiber Reinforced Composites (NFRCs) from having commercially useful structural properties. This study investigated how lignin as a compatibiliser influences the composites mechanical properties in sunn hemp fiber reinforced epoxy composites. The addition of lignin in composites of epoxy resin and sunn hemp fiber reinforcement seems to be beneficial towards improving the impact, tensile and flexural strength, although the latter two also showed a decrease when excessive lignin was added. This is attributed to the lignin particles preventing complete resin infusion across the sunn hemp mat which subsequently reduces the mechanical properties.

Keywords— Natural Fibers, Sunn Hemp, epoxy, lignin, compatibiliser, composite.

I. INTRODUCTION

One of the main problems with using natural fibers as reinforcement is the poor interface between the hydrophobic fibers and the hydrophilic resins. Experimental and theoretical studies on composites over the past decade have shown that control on fiber-matrix interfacial bond strength is a critical factor to achieve the best mechanical properties of the resultant composite materials.

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There are a wide variety of treatments that can be used to improve the fiber–matrix adhesion in composite. The vast majority of these involve some form of chemical

processing such as mercerization with sodium hydroxide solution and acetylation with acetic anhydride. However, it is desirable to reduce the chemical input and associated wastes with the process. There are some alternative treatments e.g. steam explosion that avoid some of the chemical input to the composite manufacture; however there is a large associated energy cost with generating the steam required. An alternative to chemical treatments is the use of natural materials as compatibilisers in the composite structure.

Lignin is particularly interesting as it is a waste product from the paper industry. It showed that lignin can impart beneficial properties to the structure of a composite by either dissolving the lignin in aqueous sodium hydroxide or chemical modification of the lignin with butyric anhydride to solubilize it in an epoxy resin. However both of these methods still require some additional chemical processing to the lignin before the composite is manufactured.

Lignin has also been utilized in compression moulding techniques to make natural fiber–polypropylene composites although this method uses high temperatures which can be potentially damaging to the natural fiber reinforcement and impair the structural properties of the composite. In this work, it was proposed that even in the solid state, the lignin would improve fiber-to-matrix adherence and structural properties of the resulting composite whilst keeping the number of steps and chemical treatments to a minimum. Sunn hemp fibers were chosen for the reinforcement because of the easy availability and cost effectiveness of this material. Epoxy resin was selected as the matrix as this is used in a variety of high performance applications, and therefore has industrially relevant properties.

II. MATERIALS AND METHODS

The material classified in this project is Sunn hemp fiber non-woven mats as a reinforcement and epoxy resin as a matrix and lignin as a compatibiliser.

The sunnhemp fibers are obtained from local sources. The raw fibers are cut into lengths of 25 mm, opened and form a nonwoven web. Lignin used as a compatibiliser is in solfonated form which is soluble in water and it is biodegradable.

III. COMPOSITE FABRICATION

Compression moulding machine was used to prepare a composite sample. After drying the treated webs were cut as per the V_f ratio. The volume fraction of the fibre (V_f) was kept 0.10, 0.20 and 0.30. The amount of lignin as a compatibiliser (i.e. 1.5%, 2.5%, 5.5% w/w in epoxy) was added in an epoxy for each combination of reinforcement and matrix. The composites were fabricated by using thermoset method of composite manufacturing. The samples were pressed in a hydraulic press at the room temperature for 12 hour with a pressure of 10 ton. After pressing for required duration the composite samples were kept for drying for 24 hours followed by cutting the samples into specified shape & size according to ASTM standard for each different mechanical test.

IV. EXPERIMENTAL DETAILS

In this research work, we have performed three types of mechanical testing on the samples, tensile strength test¹⁰, and flexural modulus test¹² and impact strength test¹³. The entire tests are carried out according to American Standard Testing Material (ASTM).

V. RESULT AND DISCUSSION

1. Effect of Lignin (%) as a Compatibiliser on Tensile properties of Sunn hemp – Epoxy Composites

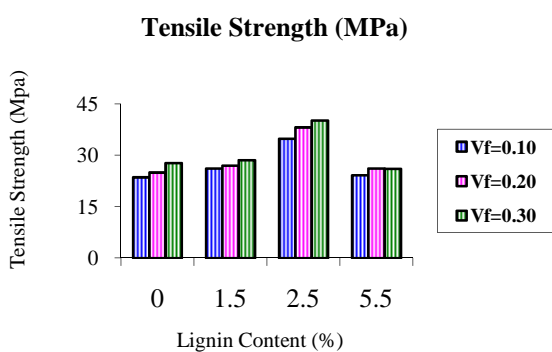


Fig.1 : Tensile Strength of Sunn hemp / Epoxy Composite at varied Lignin Content

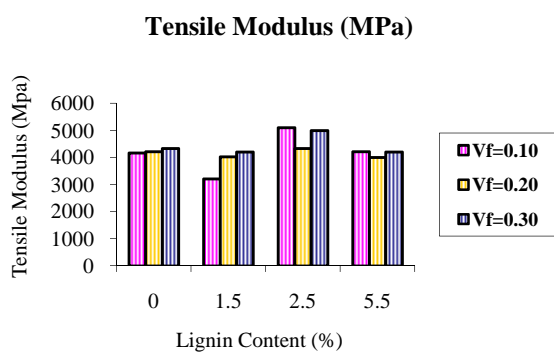


Fig.2 : Tensile Modulus of Sunn hemp / Epoxy Composite at varied Lignin Content

The results for the tensile test show that 2.5% w/w lignin is the optimum amount for improving the properties of the final part. The Tensile modulus increased from 4161.18 MPa at 0% w/w to 5592.39 at 2.5% w/w and the Ultimate Tensile Strength (UTS) increased from 22.63 MPa to 33.71 MPa for the same addition of lignin in case of sunn hemp fiber reinforced composites. A further increase to 5% w/w lignin content caused a reduction in Tensile modulus and Tensile Strength, most likely caused by the large volume of lignin particles preventing complete wetting out of the fiber reinforcement. This would also explain the brittle nature of the composite, given that the strain at failure is on average 27% higher for composites containing 2.5% w/w lignin than 5% w/w lignin.

There are some interesting changes when lignin is added at a 1% w/w level. The ductility of the composite is increased compared with both 0% w/w and 2.5% w/w lignin content. However, the tensile strength is reduced indicating there is a politicizing effect of the lignin at that level. There is an increased in flexibility but reduced strength and stiffness. This can be attributed to a combination of the interfacial effect between the lignin and the sunn hemp fibers and an effect related to the increased viscosity of the resin causing incomplete infusion of the composite part.

2. Effect of Lignin (%) as a Compatibiliser on the Flexural properties of Sunn hemp – Epoxy Composites

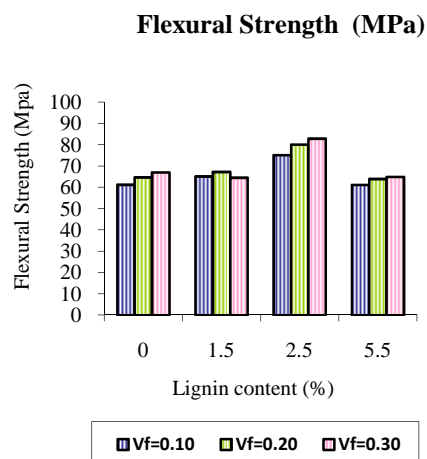


Fig.3 : Flexural Strength of Sunn hemp / Epoxy Composite at varied Lignin Content

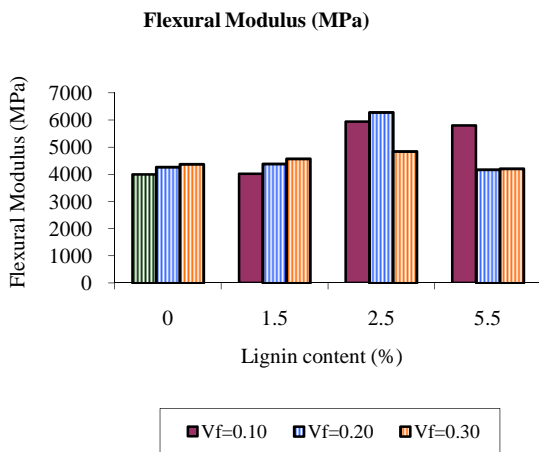


Fig.4 : Flexural Modulus of Sunn hemp / Epoxy Composite at varied Lignin Content

An increase in strength was also observed when the composites were tested for their flexural stress properties. The maximum flexure stress 82.89 MPa was observed at 2.5% w/w lignin content, 66.98 MPa for no lignin content. There is an increase in both strength and ductility for both the 1.5% w/w and the 2.5% w/w lignin content composites, indicating good mixing and infusion. There is no benefit in strength at 5.5% w/w lignin content compared to 0% lignin content in composite.

The flexural modulus showed a similar pattern although the peak was observed at 1.5 % w/w lignin content instead of 2.5% w/w. The flexural modulus of composites with lignin contents of both 1.5 % w/w and 2.5% w/w showed an improvement on the composite made with no lignin added, again highlighting the beneficial properties of lignin in natural fiber composites. The composites containing 5.5% w/w lignin have retained the ductility of the composites as with 0% lignin content for higher fibre volume fraction.

3. Effect of Lignin (%) as a Compatibiliser on the Impact Strength Sunn hemp – Epoxy Composites

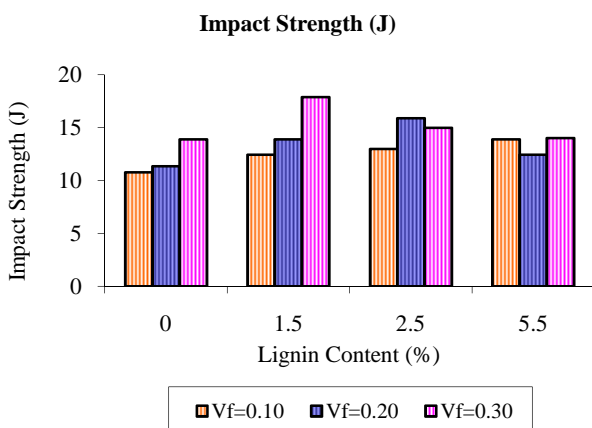


Fig.5 : Impact Strength of Sunn hemp / Epoxy Composite at varied Lignin Content

The Izod impact test showed that there is an increase in toughness as more lignin was added to the part. Izod impact strength for without lignin was 10.78 J, which increased to 13.89 J with 5.5 % w/w lignin content for fibre volume fraction 0.10 ($V_f=0.10$). Similar increase in impact strength trend is observed for $V_f=0.20$ upto lignin content 2.5% w/w. As the volume of fibre increases the impact strength decreases beyond 1.5% lignin content. It is observed that, there is no significant difference in impact strength to all three fibre volume fractions for 5.5.% w/w lignin content.

VI. CONCLUSION

The addition of lignin to sunnhemp reinforced epoxy composite shown to be beneficial towards improving the impact, tensile and flexural strength, although the latter two also showed a decrease when excessive lignin was added. This is attributed to the lignin particles preventing complete resin infusion across the hemp mat, which subsequently reduces the physical properties. Similarly the composite made from an epoxy resin and sunn hemp fiber reinforcement with varying amount of lignin content shows that the addition of lignin above 1.5 % and below 5.5 % is beneficial for the mechanical properties of composite. This method of adding lignin to composites has advantages over previous methods of fiber surface modification for improving fiber matrix interface, as it eliminates the need for costly and wasteful chemical processing, either to the natural fiber mat or the lignin itself to solubilize it in the resin matrix. However, it is desirable to reduce the chemical input and associated wastes with the process and to minimize the environmental pollution by using lignin as a compatibiliser in composite and keep our environment clean and healthy.

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