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Mechanical Behaviour of Agricultural Residue Reinforced Composites

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Abstract: The increasing awareness and the quest for newer materials have given renewed interest to the development of green composites. This article focuses on the potential use of abundantly available waste agricultural residue for the preparation of composites. The mechanical properties of Rice straw fibers reinforced with Polyester resin, Vinyl ester resin and Isophthalic polyester resin are studied and compared. Hand Layup technique is used to prepare the samples on which flexural and impact studies are made. Samples are made using different volumetric compositions of fiber and resin. The results show that the Vinyl ester resin and Isophthalic resin offer good mechanical properties when compared to the polyester resin. Both these resins show similar behavior with respect fiber loading. The flexural strength decreases with increasing fiber loading for polyester resin and increasing trend is observed for both vinyl ester and isophthalic resin. Impact strength increases for the increase in fiber loading up to a certain limit and then decreases. It can be concluded from this study that the agro-waste materials are attractive reinforcements from the standpoint of their mechanical properties.
Keywords: Rice straw fiber; Polyester; Vinyl ester; Isophthalic resin; Mechanical properties.

1. Introduction

The usage of natural fibers in making composite materials is increased due to their light weight , non-abrasiveness, non-irritating, non-toxic, bio-degradable properties, low carbondioxide emission during burning, availability and renewability. Polymer composites are easier to manufacture than metal-matrix, carbon matrix and ceramic matrix composites due to the good bonding capability between fibers and matrix and thus adding strength. Many researches are conducted using short fiber reinforcement. The use of natural fibers is improved remarkably due to the fact that the field of application is improved day by day. Natural fibers are now at par with the synthetic fibers which are quite costlier and expensive to manufacture. Natural fibers are now found abundant and they need pre-processing before making them as a composite material.

Rice (Oryza sativa L.) is one of the oldest cultivated crops Zareiforoush, *et al.* [1] and ranks as the most widely grown food grain crop that serves as the most staple food for more than 60% of the Indian population. According to International Rice Research Institute, Manila, India‘s rice production crossed 100 million metric tons, which implies its importance as a basic food crop. The crop leaves several million tons of straw annually and which of them are mainly used for burning purposes and as cattle feed. These are considered as agricultural waste. But, there is growing interests on agricultural waste as a substitute for wood-based raw materials and recently many studies and researches are going on to tap the potential uses of the rice straw as they prove to exhibit appreciable mechanical properties [2]. The rice straw can be easily crushed into chips or particles, which are very similar to wood particles or fibers. The hydrophilic character of the rice straw is one of the reasons for relatively high moisture content, approximately 60% on a wet base, or 10-12% on a dry base. The ash content of up to 22% and low protein content result in a material decomposing not as readily as other straws [3]. The rice straw resistance to bacterial decomposition makes this material suitable as filler in building composite materials. On the other hand, high content of silica (up to 20%) represents an additional potential benefit in building industry. Rice straw has been studied as potential filler in various thermoplastic matrices. Recently, Yang, *et al.* [4] reported improved mechanical properties, i.e. increased flexural modulus and impact modulus of the Polypropylene / Rice Straw composites with the increase of filler content. In this study, Mechanical properties such as flexural strength and impact strength are studied using rice straw reinforced composites in polyester resin, Isopthalic resin and vinyl ester resin. The studies are done using

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different resin and matrix composition. The studies revealed an increase in the flexural and impact modulus of the fiber composites, applied in building structures, manufacturing of toys, automotive parts etc.

2. Materials and Methods

In this present work, Rice straw is taken as the principal raw material i.e fiber. Initially, the rice straw fibers are cut into small pieces manually for a length of about 20mm. Then they are dried under the sun light for 72 hours to reduce the moisture content. The other constituent of composites is Matrix such as Polyester resin, Isopthalic resin and Vinyl ester resin. Polyester resins are a family of polymers used to produce a broad range of products. Thermoset polyesters are known as unsaturated polyester resins. They are available in a number of formulations for specific applications. Isophthalic polyester resins are a broad class of resins formulated from isophthalic acid, glycols, and maleic anhydride. The specific resin specification is selected to impart desired properties and corrosion resistance. These resins can be used for moderate corrosion resistance applications to a temperature range around 180° F. Isophthalic resins exhibit good resistance to water, acids, weak bases, and hydrocarbons such as gasoline and oil. Technically vinyl ester resins are a polyester resin, however they are normally classified separately from polyesters due to their enhanced mechanical properties and corrosion resistance. Vinyl esters offer enhanced strength and generally better impact and thermal shock resistance than polyester resins. While the standard epoxy vinyl ester resins are limited to 220 – 250° F in most applications, other versions with higher-density cross linking are suitable for temperatures above 250° F. These resins exhibit excellent resistance to acids, alkalis, hypochlorites, and many solvents. The composite fabrication is done by hand lay up method, the simplest and oldest open molding method [5]. It is a low volume, labor intensive method suited especially for large components, such as boat hulls. A wooden mould of size 150 x 150 x 3mm is first prepared for making the samples. A thin film of polyvinyl acetate was coated on the inner surface of the mold which aided in the easy removal of the sample from the mold after curing. Resin was poured along with fibers of definite proportion in the mold. Entrapped air was removed manually with rollers. These air molecules may affect the mechanical property of the composite samples. Curing was initiated by a catalyst namely methyl ethyl ketone peroxide and cobalt as an accelerator in the resin system, which hardened the fiber reinforced resin composite without external heat. The composites were prepared with different fiber loadings (10, 20, 30, 40 and 50%) by volume proportion. The mechanical properties of the fibers were determined in accordance with ASTM D790 and ASTM D 256 [6].

3. Results and Discussion

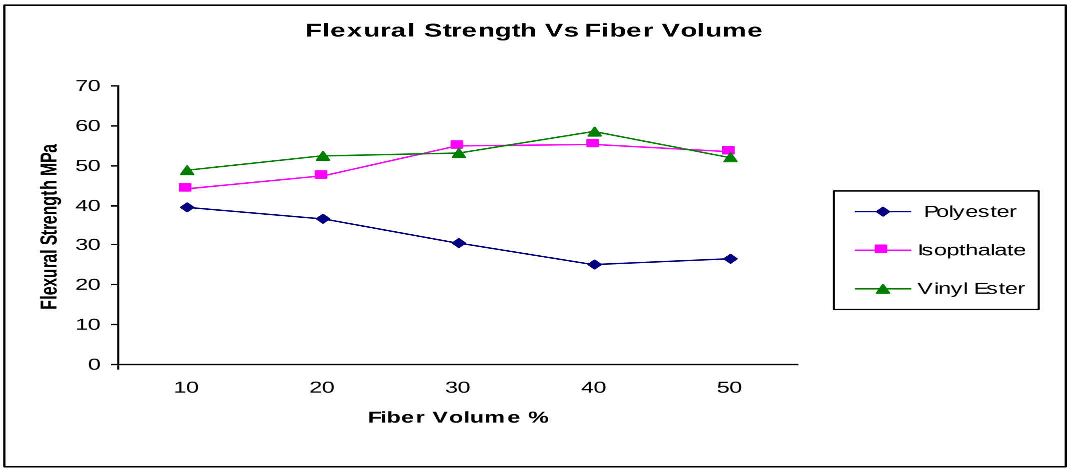
The mechanical properties such as Flexural and impact were analyzed and its results are discussed below.

3.1. Flexural Strength

This strength determines the maximum stress induced in the outer most fiber. Tests are performed on three samples for consistency. Studies show linear relationship between fiber loading and resin [7].

The rice straw fibers are fabricated with unsaturated polyester resin, Isopthalic resin and Vinyl ester resin and their flexural properties were determined according to ASTM D790 with different fiber loadings 10,20,30,40 and 50%.

Fig-1. Variation of Flexural Strength with Volume Proportion

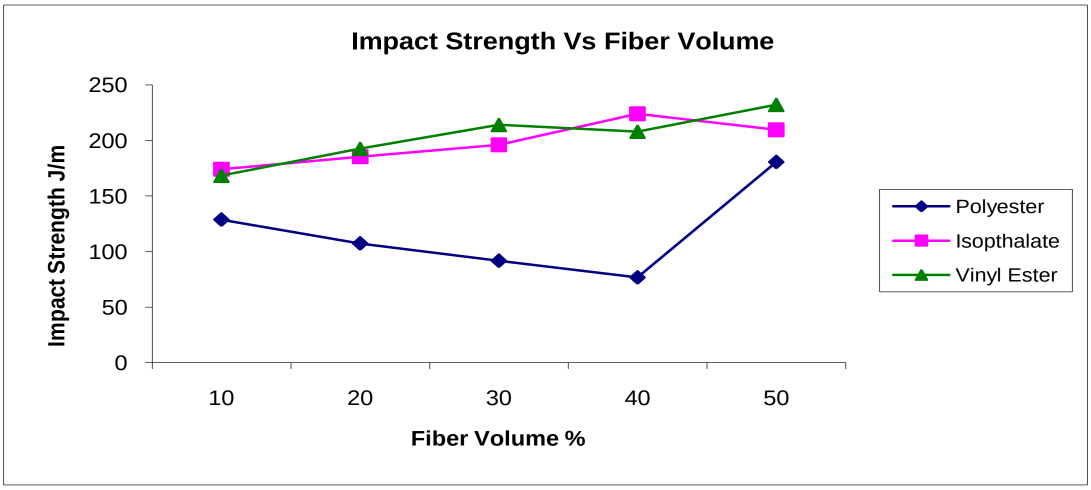


The randomly oriented coir fibers in a polyester matrix were shown to exhibit a flexural strength lower than that of the resin at all fiber loading [8]. The above graph shows that the polyester resin composites show a decreasing trend with increasing volume proportion of fiber. But the isopthalate and vinyl ester reinforced composites show an increasing trend on fiber loading. But when the fiber loading reaches around 40% volume proportion there is an increasing trend of flexural strength in the case of polyester resin whereas decreasing trend in the case of both isopthalic and vinly ester resin. The highest flexural strenth obtained is 58.36 MPa for vinyl ester resin and 55.45 MPa for Isopthalic resin. The polyester composites show a least flexural strength of 24.96 MPa.

3.2. Impact Strength

The impact strength of rice straw fibers fabricated with unsaturated polyester resin, Isopthalic resin and Vinyl ester resin were determined according to ASTM D256 with different fiber loadings 10,20,30,40 and 50%. The experimental results indicated that, the impact strength values of the rice straw fiber reinforced composites decreases continuously till a fiber volume of 35% and then increases rapidly when the fiber loading is greater than 40%. The impact strength of Isopthalic resin reinforced rice straw fiber composites increase for increase in fiber volume from 10% to 40% after which there is a slight decrease in impact strength. The Maximum impact strength observed is 224.2 J/m. The Vinyl ester reinforced rice straw composites showed increased impact strength behavior from 10% to 30% followed by a slight decrease and then increases to a maximum impact strength of 232.4 J/m. This value agrees with the previously reported value of rice straw polyester composites i.e 284 J/m at fiber volume of 46% [6]. It is well known that the impact response of fiber composites is highly influenced by the interfacial bond strength, the matrix and fiber properties.

Fig-2. Variation Of Impact Strength with Volume Proportion



The above graph shows that the polyester resin composites show a decreasing trend with increasing volume proportion of fiber till 40 % and a sudden increase of impact strength after 40%. But, both the isopthalate resin and Vinyl ester resin composites show an increasing trend of Impact strength for incresing volume proportion till a volume proportion of 30% . Then , there is an marginal change of impact strength in the case of vinyl ester composites but an increasing trend is observed in the case of vinyl ester resins. After 40% fiber loading there is a decresing trend of impact strength in the case of isopthalic resin but incresing trend in the case of vinyl ester resins.

4. Conclusion

The composites show better mechanical properties on addition of fibers. The mechanical properties were found to be better for a optimum resin fiber combination of 60/40. The flexural properties of isopthalic resin reinforced composites and vinyl ester reinforced composites show 2.22 and 2.34 times improved values when compared to the polyester resin for a combination of 60/40 resin fiber volumetric composition. Similarly the impact strengths too show increased values for isopthalic resin and vinyl ester reinforced composites. The natural fiber composites have the great potential in making light weight sustainable components in automotive industry that could reduce energy consumption. Moreover, the molded parts made of these agro waste bio-composites can be burnt without leaving any carbon imprint thereby reducing land and water pollution [9]. Chemical modifications may be employed to improve the interfacial matrix-fiber bonding resulting in the enhancement of tensile properties of the composites [10].

5. References

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