Original Article

Experimental Investigation on Influence of Biochar on the Impact Properties of Novel Jute Fiber Reinforced Epoxy Composite

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Abstract

Aim: Biochar is the sustainable material addition of biochar that could significantly vary the composite strength. Hence biochar is eco friendly it causes no effect to the environment further it increases the chance of developing sustainable composites with increased mechanical strength. The goal of this study is to investigate the impact strength of a novel biochar-added jute fiber composite. **Materials and Methods:** By the utilization of hand lay up technique composites were fabricated into two distinctive groups (Experimental and control group). The sample groups were tested according to the ASTM-D256 protocol. The Izod impact testing was used to find the impact strength of the samples. For experimentation sample size was calculated using the G-power calculator at 80% of G-power value. The independent sample T-test was done using SPSS software for analyzing the impact strength variation. In both the groups 20 samples were tested using the SPSS tool. **Result:** The samples with and without filler were tested and their impact strength was calculated and compared. Sample with the novel biochar filler showed higher impact strength. The mean impact strength was 29 J/m which was 21 % higher than the unfilled composite. The p value noted was 0.043 which was significant ($p<0.05$) at 95% significance level. **Conclusion**: Within the limitations of the study, the result revealed that the hybrid composite with 5% of biochar filler possesses the maximum impact strength than the composite created without filler material. This demonstrates the ability of the novel biochar particle in the composites for the development of impact resistance.

Keywords: Jute Fiber, Novel Biochar, Impact Strength, Material Characterization, Epoxy, Filler.

DOI: 10.47750/pnr.2022.13.S04.074

INTRODUCTION

Composite material are the advanced light weight material system designed by the addition of two or more constituent materials with significantly different physical or chemical properties, the resultant composite properties depend upon the properties of constituent materials (i.e) the fibers and matrix (Singh et al. 2018). The main perform of the matrix is to transfer stress between strong fibers and protect the composite from mechanical damage. Reinforcement within the composite improves the mechanical properties like flexural strength, impact strength, durability and stiffness (Vigneshwaran et al. 2020). Novel Jute fibers are naturally plant fibers and are free of carbon compounds and area units so environmentally friendly where these fibers do not cause any environmental additionally to boot to the good thing about disposal of their residues while not damaging. Novel Jute fibers damage created from compounds of quickly degrading plant materials. These fibers have nice choices and inspiring for engineering uses. The outstanding advantages of natural fibers embrace acceptable specific strength properties, low cost, density, high toughness, smart thermal properties, and therefore on. Low specific weight, that leads to a better specific strength and stiffness than glass could be a profit significantly in parts designed for bending stiffness (Rana et al. 2019). The natural novel jute fiber is an effective material to strengthen composite strength (Swamy 1992). The natural fiber based composites in present days were used in the applications like structural applications.

In the past few years, recently many articles have been published about the Impact Properties in fiber composites. Cumulatively 100 research articles are published in google scholar and 75 articles are published in science directly related to the novel biochar based composites impact absorption. Composites materials have been used in lot of engineering applications. The advanced properties of these materials makes them appropriate for a speed of

applications like part structures, Automotive compounds, and Marine structures. The notable properties of these composites were resilience, creep resistance, high strength and stiffness to weight ratios, corrosion resistance, and sensible damping properties (Choudhary et al. 2019)(Jawaid, Thariq, and Saba 2018). Nowadays Agricultural resources are exploded in Engineering revolution. The interest in using natural fibers like novel Jute fibers and coconut fibers as reinforcement in plastics material has increased dramatically (Chawla and Bastos 1980). The use of natural fiber in the polymer matrix increases the composite strength (Shahinur et al. 2015). However the bonding between the fiber and the matrix is not satisfactory. To overcome this the fillers have been used along with polymer matrix. In recent years various fillers have been identified and used in the preparation of fiber composites.(Choudhary et al. 2019) investigated the marble waste filled glass fiber composite and reported enhanced properties on the glass fiber composite because of the addition of marble dust. To maintain sustainability it is essential to ensure bio based filler reinforcement in. In such a way different bio based fillers have also been identified and used. Biochar is a carbon rich material which has been obtained through the pyrolysis process on biobased materials. Novel biochar is a carbon skeleton material formed after the complete burning of bio substance in the bio materials. Biochar is a highly porous material which has good mechanical properties. The porous nature of bio char would help in increasing the mechanical interlocking between the matrix. The biochar (Matykiewicz 2020) addition could also be helpful in increasing the wear resistance of the polymers (Choudhary et al. 2019)(Richard, Selwin Rajadurai, and Manikandan 2017). (Matykiewicz 2020) fabricated biochar filled epoxy carbon fiber composite. The fabricated composite showed enhanced mechanical performance than the carbon fiber epoxy composites. In another work (Adeniyi et al. 2020) found improved properties on the addition of biochar to the natural fiber composite. It was inferred that the best study was closely related to the present research work on the addition of biochar to filled composite.

Our team has extensive knowledge and research experience that has translate into high quality publications(Bhansali et al. 2021; Jayanth et al. 2021; Sudhakar, Ravel, and Perumal 2021; Sathiyamoorthi et al. 2021; Deepanraj et al. 2021; Raju et al. 2021; Arun Prakash et al. 2020; Kamath et al. 2020; Shanmugam et al. 2021; Rajasekaran et al. 2020; Adhinarayanan et al. 2020; Rajesh et al. 2020; Aurtherson et al. 2021). From the review it has been found that investigation dedicated to impact strength of the biochar composites was rare. This research could expertise the young researchers who are working in the research area of bio based composites for gaining theoretical and experimental knowledge on biochar based composites.The aim of this present research is to investigate the impact strength of the biochar filled composites and the results were analyzed using SPSS software and compared with composites without biochar.

MATERIALS AND METHODS

The composites were fabricated in the Saveetha School of Engineering, Saveetha Institute of Medical and Technical Sciences, Chennai. No ethical issue is needed for this work since the research is related to thermoset based plastics. Hand layup technique was followed for fabricating the composites. The jute hybrid composite samples were prepared in two sets (n=20) for experimentation sample size was calculated using the G-power calculator and G-Power Kept at 80% (Erdfelder, Faul, and Buchner 1996).

The present investigation used thermoset polymer epoxy along with the hardener The epoxy was purchased from Vasavibala resins pvt.ltd chennai. The novel jute fiber used in the work was purchased from Kayal aerospace industry in chennai. The novel jute fiber was in the form of a woven mat.

Using the hand lay-up method the laminated plates were made (with and without filler groups). The first group of composites was fabricated without any biochar. During the fabrication steel mold was used. Over the mold the well mixed epoxy and hardener solution was applied and the first layer of novel Jute fiber was pleasing over it. Then again the Epoxy and hardener solution is applied and the process is repeated for up to six layers. After the final layer the miller film was placed. The rollers were used to remove the air gaps. A load of 25kg was placed above the setup and allowed to cure for 24 hours.

The second group was biochar novel jute fiber composite. For the fabrication similar steps as like group1 were followed. However the matrix solution was prepared with addition of biochar. Initially the matrix solution of 500gms was taken in a beaker and 5% of biochar was added to it. Then the mixture is thoroughly mixed for 10 minutes manually. After that the hardener was mixed in the ratio of 2:1 and the matrix solution used for biochar composite preparation. The fabricated composites are shown in the figure1.

The waste Neem seed peel was collected from agricultural land near Andhra Pradesh. It was dried for 3days to get rid of the moisture content in it. Then the neem seeds were tightly packed and heated at 600 ℃ by using a furnace with limited presence of oxygen for up to 2 hours. After 2 hours the furnace was shut down and allowed to cool.After 24 hours the container was taken out and the biochar particles were collected. The biochar particles were converted into powder by using the Ball milling method . The fine biochar powder obtained from the ball milling operation was then kept in an airtight instrument to avoid contact with the atmosphere.

The izod impact test was used to determine the specimen's impact strength in this case. The izod impact test determines the materials' impact resistance. The impact testing machine was used in conjunction with a digital

activity device to determine the material's impact strength throughout this investigation. The setup arm swings down during testing, positioning the sample for a specific purpose, while a computer management device monitors the stress at which the sample fails. The amount of energy absorbed by the sample during testing is used to determine the impact energy of the test sample, as per standard operating procedure. Figure 1 shows the composites used for impact testing. Figure 2 shows the composites after impact testing.

Statistical Analysis

Statistical software used to analyze damping factor results to study its significance is SPSS. The type of test conducted in the SPSS tool is the Levene's test for equality of variances and t-test for Equality of Means in SPSS software of version 23. During testing, the independent variable used was the biochar addition and the dependent variable considered was impact strength (Gaur and Gaur 2009).

RESULTS

Novel Jute fiber hybrid composites strengthened with 5wt.% biochar was created by using the hand lay-up method. Table 1 shows the experimental value and the analytical mean value are shown in Table 2. Table 3 shows the statistical results obtained using the SPSS software system and the importance of the findings (impact strength) obtained by independent t-test for each sample categories.

DISCUSSION

The variation in the experimental test result can be understood from Fig. 3. Figure 4 illustrates the mean impact strength of the composites fabricated. This study discovered that filler-added hybrid compound composites have higher impact strength than those without Biochar filler. The mean of impact strength calculated for the test group is found to be 28.530. The minimum and maximum value calculated for the test group is found to be 26.64 J/mm and 30.68 J/mm. The mean of impact strength calculated for the control group is found to be 24.090 J/mm. The maximum and minimum value calculated for the control group is found to be 20.48J/mm and 25.98 J/mm. The p value obtained from the t test demonstrated the significance of the experimental investigation. If the p value is less than 0.05, the experimental result is significant. The p value for the current results was 0.043, which proves the significance of the experimentation.

According to the experimental results, the impact strength of the composite with filler is higher than that of the composite without filler. The addition of fillers may cause the polymer strength to vary. Variation in impact strength was also observed in the current study in relation to the filler addition. The addition of filler to composites may aid in improving fibre matrix bonding, resulting in an increase in mechanical strength. The filler has the ability to change the physical properties of the composites. In this study, the addition of biochar filler increased the impact strength of the composites. The increased interfacial bonding was responsible for the increased strength (Deepak Joel Johnson et al. 2021) which was the result of uniform stress distribution (Faruk and Sain 2014). The biochar added increased the bonding. The presence of pores in the biochar structure is the major reason for it. The matrix infiltrated into the biochar pores during manufacturing and created a strong mechanical interlocking (Vigneshwaran et al. 2020). This study evidenced the influence of biochar in the natural fiber composites. Use of fillers in the natural fibers may lead through the enhanced strength (Adeniyi et al. 2020), however the increment depends on the nature and properties of the filler particle used.

The statistical test result demonstrated the experiment's significance. The p value obtained from the t test was 0.043, demonstrating the experiment's significance. The result of the investigation could help in developing new composites which are high strength and at the same time more sustainable. However this research has some limitations, the present investigation only studied the impact properties of the composites, only at 5 wt.% of the biochar content. The future research on the composite could focus on studying the composite's properties at varying biochar content.

CONCLUSION

Within the limitations of this study, impact strength of the Jute hybrid composite with 5% Biochar filler was found to be significantly higher than the impact strength of the composite without any filler. The experiment was found to be significant and the p value obtained is 0.043. The improved strength was the result of the enhanced bonding between the fiber, filler and matrix.

DECLARATIONS

Conflict of Interests

The authors declare that there is no conflict of interest in this manuscript.

Authors Contribution

Author NNR was involved in data collection, data analysis, Manuscript writing. Author RS was involved in conceptualization, data validation, and critical review of the manuscript.

Acknowledgements

The authors would like to express their sincere gratitude towards Saveetha School of Engineering, Saveetha Institute of Medical and Technical Sciences (Formerly known as Saveetha University) for providing the necessary infrastructure to carry out this work successfully.

Funding

We thank the following organizations for providing financial support that enabled us to complete the study.

1. Vasavibala Resins Pvt. Ltd.Chennai.
2. Saveetha University
3. Saveetha Institute of Medical and Technical Sciences.
4. Saveetha School of Engineering

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TABLES AND FIGURES

Table 1. Experimental Impact strength of jute fiber reinforced polyester composite with and without biochar as filler material. Impact strength values of the jute fiber reinforced polyester composite without adding biochar varies from 20.46 J/mm to 25.98 J/mm and 5 % biochar addition varies from 26.64J/mm to 30.68 J/mm.

No.of samples	With biochar	Without biochar
1	28.64	20.46
2	27.53	23.78
3	29.75	25.65
4	28.86	23.89
5	26.64	24.57
6	27.56	21.66
7	28.74	23.89
8	28.45	21.38
9	27.46	25.54
10	27.38	24.27

No.of samples	With biochar	Without biochar
1	28.64	20.46
11	28.28	25.74
12	29.32	21.67
13	29.18	24.29
14	28.69	23.46
15	30.68	24.78
16	29.19	25.18
17	28.44	24.69
18	28.53	25.16
19	29.49	25.98
20	27.79	25.87

Table 2. Mean and Standard Deviation of impact Strength analyzed using SPSS software shown below.

Group Statistics					
	Group	**N**	**Mean**	**Std. Deviation**	**Std. Error Mean**
Impact Strength	**With Filler**	20	28.530	0.954	0.213
	Without Filler	20	24.090	1.628	0.213

Table 3. Details of Independent sample test results are shown below. The significance of the independent sample test is found to be 0.041.

Independent Samples Test

Impact Strength	Levene's Test for Equality of variances		t-test for equality of Means						
	F	Sig.	t	df	Sig. (2 tailed)	Mean Difference	Std. Error Difference	95% confidence interval of the Difference	
								Lower	Upper
Equal variances assumed	4.374	0.043	10.519	38	0.000	4.439	0.422	3.585	5.293
Equal variances not assumed	-	-	10.519	30.679	0.000	4.439	0.422	3.578	5.300

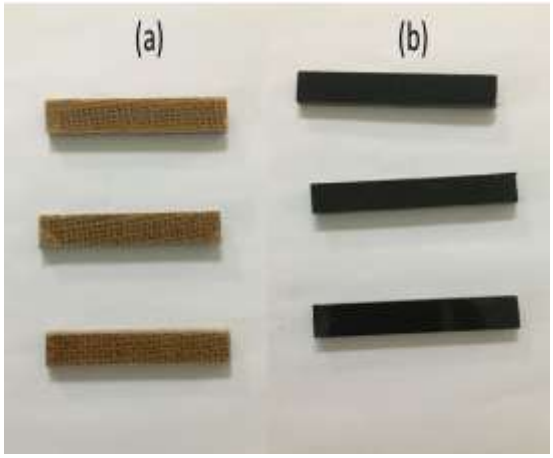

Fig. 1. Composites used for impact testing (a) unfilled composite (b) biochar filled composite.

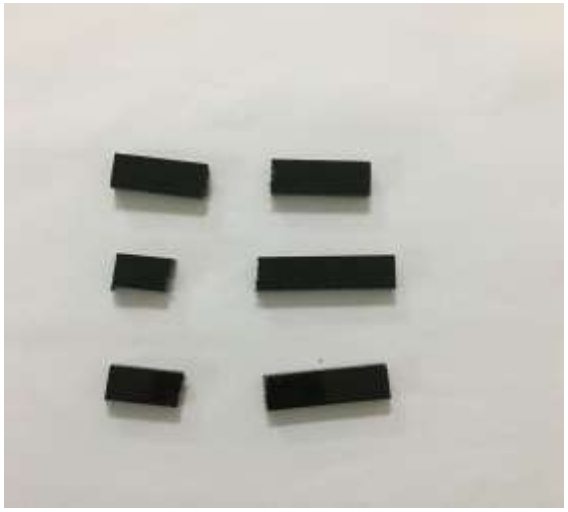

Fig. 2. Biochar composite after impact testing.

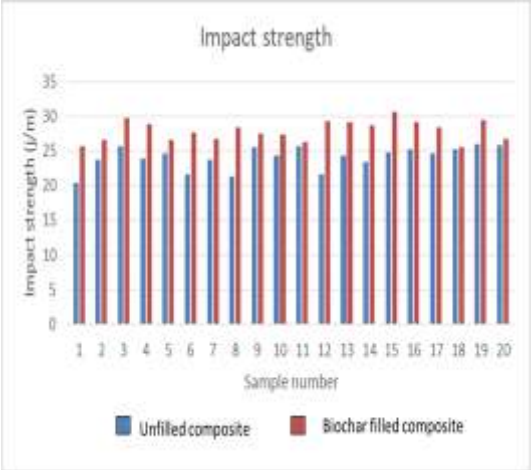

Fig. 3. Impact strength of composites

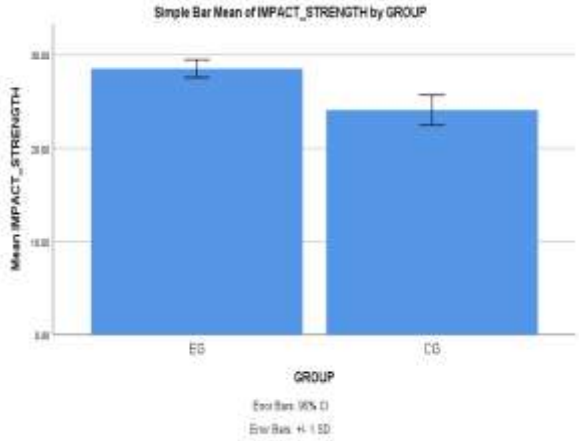

Fig. 4. The impact strength of hybrid composites fabricated with and without filler are compared and represented in the bar graph. The impact strength of the samples fabricated with biochar filler (28.530 J/mm) are found to be high compared to the other samples without biochar filler (24.090J/mm). Mean Impact strength of detection +/- 1 SD.