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Characterization of Rice Straw Fiber Filled Polylactic Acid Composites

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Abstract

The natural fibre strengthened composite materials; they are playing a larger role in engineering and technology. When compared to the bulk of businesses' use of metals, natural fibres serve as preferable materials due to their light weight, low cost and resistance to corrosion in the current unsustainable environmental situation. The primary goal of this research is to examine the mechanical characteristics and fracture toughness behaviour ofPLA composites filled with rice straw fibres. The composite specimen was created using injection moulding and both untreated and treated rice straw fibres in various weight fractions. According to ASTM standards, testing for mechanical,thermal Properties (such as tensile, flexural, XRD, and TGA) and fracture toughness were conducted. According to the findings, treated and untreated fiber-reinforced composites exhibit greater values for fracture toughness when compared to pure polylactic acid composites. The fibre reinforcement increases the composite's fabrication's ability to withstand fracture. For untreated fibre reinforced composites, the values for fracture toughness increased as the amount of fibre content did. The fracture toughness ratings for treated fibre reinforced composites declined as the fibre content increased. In comparison to pure PLA samples, untreated fibre samples with up to 20% weight of rice straw fibre shown good mechanical properties. However, they failed to display good impact and hardness qualities. Treated fibre samples with 10 wt% of fibre showed good tensile and flexural capabilities. The fibres didn't hold up to the load for chemically treated samples, hence they displayed poor mechanical qualities in comparison to samples of untreated fibre. Following chemical treatment, the fibres grew brittle and were unable to sustenance the load.

Key words: Rice straw, treated, fracture toughness

1. Introduction

Material composites are shaped of additional different materials that, when blended, make another material with credits that are not the same as the constituent materials. These materials should have extensively unique synthetic or actual properties. Regular filaments acquired from horticultural waste have as of late acquired importance in the development of new kinds of composite materials. At the point when these composite materials give a few benefits over manufactured strands.

Supporting parts like strands, particles, chips, as well as fillers are integrated into the grid material (polymers) to make material composites. The network material keeps up with the filaments in the suitable shapes and conveys the load among the strands, while the support material controls the composite's solidarity. The requirement for materials with prevalent execution in designing has expanded as of late, which has ignited the making of new kinds of composites. Most of the composite materials made lately have tracked down many purposes in the auto business. [1] Erosion obstruction, a high solidarity to weight proportion, minimal expense, and light weight are only a couple of the advantages of normal fiber supported composites. Composites offer a great many applications due to these beneficial qualities. The characteristics of the developed composite are improved by the support of the filaments into the network material. Normal strands, which are promptly accessible in nature, act as better supporting materials in the ongoing impractical ecological circumstance. Subsequently, they have arisen as a critical and helpful asset for the production of composites.

Rural based inexhaustible materials have acquired significance as of late as supporting materials due to their reasonableness, light weight, eco-kind disposition, openness, and natural awareness. Models incorporate rice straw waste, sugar stick bagasse, rice and wheat husk, rice straw, and so on. Scientists are progressively searching for new materials that are gainful to human wellbeing and the climate because of expanded natural worries, an unnatural weather change; squander the board difficulties, and rising oil costs. Regular fiber composites have been utilized in different modern areas throughout recent years, especially in the car business for entryway boards, seat backs, head liners, bundle plate, run sheets, and inside parts.

Fracture Toughness Characterization

Jute/glass fibre hybrid composites' mode 1 fracture behaviour was examined by Harikrishnan KR et al. in their study published [2]. The fracture behaviour was discovered using a SENB test. Fibreglass and jute Compression moulding was used to create composites made of epoxy resin and fibre reinforcement. The findings demonstrated that composites reinforced entirely with glass fibre had the highest fracture toughness. The composites made with 75% glass fibre and 25% fibre and 50% glass fibre and 50% jute fibre have fracture toughness values that are the closest to those of glass fibre composites. For the same, finite element analysis was used. Nikita Agarwal and co-workers, [3] Hand-layup technique was used to create epoxy composites with carbon fibre reinforcement. The composite samples' carbon fibre content ranged from 20, 30, 40, and 50% by weight. The composite plates' mechanical and fracture toughness characteristics were looked at. Higher fracture toughness values were found in the composite sample with 50 weight percent carbon fibre. The 50weight percent carbon fibre composite samples demonstrated good hardness, flexural strength, and impact strength. The composite sample with 40 weight percent carbon fibre displayed strong tensile properties.

Malleable attributes and break durability of coconut shell fiber epoxy composites were surveyed by Abdul Hakim Abdulla ct, et al[4]. The strands were first treated with a basic, silane arrangement that included both a soluble and a silane part. The examples of hand-layup composite development were in fact sound. Elasticity of strands treated with silane. Maximunfiber supported composite showed more prominent break in untreated examples. Break sturdiness conduct of sisal supported epoxy composites was researched by Araya AberaBetelie strength, et al., [5]. The Hardener (HY-951) and the lattice (AY-105) are both utilized. By utilizing the hand-layup approach, composite examples with different weight parts of fiber (15, 25, 30, 35, and wt%) were made. More noteworthy Break Sturdiness was exhibited by the composite example with 30 wt% of fiber. BasappaHulugappa and partners [6] By utilizing the hand-layup process and a hot press, glass texture supported epoxy composites with a few fillers, including silicon carbide and graphite, were made. We took a gander at the materials' malleable, flexural, effect, and break strength. The composite example's glass fiber piece was set at 55 weight percent. The filler part went from 5 to 10 weight percent. Great pliable and flexural capacities were shown by the composite example with 10 weight percent graphite filler. The composites that weren't loaded up with filler had more prominent effect opposition. Expanded graphite filler stacking expanded the composites' cracking strength. M Kullayappa and associates [7] Vinylester stick was utilized to build up groundnut shell and silicon carbide particles, and composite plates were made utilizing the hand-layup strategy. powdered groundnut shell saturated with a malic corrosive.

V. Santhnam and others, [8] Hand-layup technique was used to create polyester resin composites reinforced with banana and glass fibre. The composite samples' varying fibre contents 13.17 to 20.0% of the volume. Methyl ethyl ketone (2%), Department of I & P Engineering, NIE, Mysuru, utilised as an accelerator and PEST. Catalyst made with 1% cobalt. Composites with banana fibre reinforcement displayed tracture toughness values that were more similar to those of composites with glass fibre reinforcement. Thus, in some applications, composites reinforced with banana fibre can take the place of composites reinforced with glass fibre. PS Shivakumar Gouda and coworkers [9] Mode 1 Glass-carbon fibre reinforced hybrid polymer composite's fracture behaviour was studied. Along and across the specimen's fibre orientation, the specimen's fracture toughness was assessed.

Z Khan et al., [10] Review of the Literature the study of bamboo fibre reinforced epoxy composites' fracture behaviour was panned. Initially, 24 hours were spent treating fibres with 2, 6, and 10% NaOH solutions. The composite samples were created using fibres that were 10, 20, and 25 mm in length. The hand-layup approach was used to create the composite specimens. The findings demonstrated that fracture toughness values were higher in composite samples with fibres of 25 mm length and lower in composite samples with fibres of 10 mm length. JC Man-made cellulose fibres that have been strengthened by Zarges et al[11]. Composites made of polypropylene were created using the injection moulding process. On the fracture toughness, the effects of fibre content and coupling agent were investigated.

Mechanical Properties Characterization

The water absorption, mechanical properties, and electrical properties of the coconut fibre reinforced polypropylene composites were studied by Maria Virginia Gelfuso et al. Coconut fibres were first mechanically (using an ultrasonic shockwave) and chemically (using an alkalization process) treated, and then they were dried using UV light. By using injection moulding, composite samples with 5, 10, 15, and 20 vol% of treated and untreated coconut fibres were created. In comparison to untreated and chemically treated composite samples, composite samples containing 5 vol% of mechanically treated fibres exhibit higher tensile strength values. Electrical tracking test and electrical resistivity results are best for composite samples having 10% mechanically treated fibres. The findings demonstrate that composite samples made with fibres that have undergone mechanical treatment are appropriate for electrical applications.

Isiaka O and others, [13] Chemically treated coir fibre reinforced polypropylene composites' tensile and flexural characteristics were studied. Coconut coir fibres undergo chemical processing. using Potassium and Sodium hydroxides. The composite samples' fibre content ranges from 2, 4, 6, 8, and 10 wt%. Compression moulding is used to create the composite samples. Better tensile and flexural properties were seen in samples that had been treated with KOH and NaOH, respectively. Nadir A and others, [14] Polypropylene composite panels reinforced with coconut fibre were created using the hot press process. The composite sample has varying amounts of fibre (40, 50, 60, and 70 wt%). As a coupling agent, maleic anhydride grafted polypropylene (MAPP) powder (3 wt%) is utilised.

Md. Nazrul Islam and others [15] The physico-mechanical characteristics of the polypropylene composite with coir fibre reinforcement were assessed. O-hydroxybenzene diazonium salt is used to cure coir fibres. The composite sample's fibre content ranges from 10, 15, 20, and 25 weight percent. By using the injection moulding technique, the composite samples are made from both untreated and treated coir fibres. Chemically altered samples displayed improved mechanical qualities. Anshu A S and others, [16] Polypropylene composites reinforced with coconut fibre were created using the injection moulding technique and 2% maleic anhydride as the coupling agent. The composite has varying amounts of fibre (5–10 wt%). Investigated were the composites' tensile characteristics. The findings revealed that as compared to pure PP, the composite made with 2% maiele anhydride had better tensile characteristics.

The malleable, flexural, effect, hardness, and water retention properties of coconut coir built up polypropylene composites were inspected by Md. Mominul Haque et al. in their writing survey from [17]. Crude coir fiber was synthetically treated exclusively in basic, acidic, and unbiased circumstances with benzene diazonium salt. By using the injection moulding technique, composite samples made of both treated and untreated coir fibres were produced. The composite samples' fibre content ranges from 10, 15, 20, 25, 30, and 35 weight percent. In comparison to other samples, those made from alkali-treated coir fibre shown superior mechanical qualities. investigated the properties of coconut coir reinforced polypropylene composites in terms of tensile, flexural, impact, hardness, and water absorption. Raw coir fibre was chemically treated individually in alkaline, acidic, and neutral conditions with benzene diazonium salt. By using the injection moulding technique, composite samples made of both treated and untreated coir fibres were created. The composite samples' fibre content ranges from 10, 15, 20, 25, 30, and 35 weight percent. In comparison to other samples, those made from alkali-treated coir fibre shown superior mechanical qualities. Padmaraj NH and others, [18] Short, randomly oriented Areca husk and coir fibres were reinforced with unsaturated polyester resin to create composite samples. To strengthen the binding between the fibre and matrix, the fibres were first given a NaOH pre-treatment.

S. V. Alagarsamy et al., [19] By employing the hand lay-up method and reinforcing chicken feather and coconut coir fibre in polyester resin, hybrid composite samples were created. The fabricated samples were subjected to tensile, flexural, and impact tests. The samples' total fibre content was set at 30 weight percent. Chicken feather content varies from 10, 8, 6, and 4 weight percent whereas the coir fibre content ranges from 20, 22, and 24 weight percent. The composite samples using 26 weight percent coir fibre and 4 weight percent chicken feather performed better in the tensile and impact tests. In terms of flexural strength, the composite sample with 20 weight percent coir fibre and 10 weight percent chicken feather performed best. CY Lai and others, [20] Compression moulding was used to create polypropylene composites reinforced with coconut fibre. In addition to alkali, stearic acid, acetone, and potassium permanganate, the coir fibres underwent a new treatment. The composite sample's fibre content ranged between 10, 20, and 30 weight percent. The composite samples' tensile strength, flexural strength, and hardness were evaluated. In comparison to treated fibres, samples of untreated coir fibre had better mechanical qualities. The tensile, flexural, impact, hardness, and water absorption characteristics of the coconut coir reinforced polypropylene composites were examined by Md. Mominul Haque et al. in their literature review from [21]. Using an injection moulding machine and a single screw extruder, the composite samples were created. Initial benzene diazonium salt treatment was applied to coir fibres.

Girisha C. and others, [22] Hand lay-up technique was used to create epoxy composites with sisal and coir fibre reinforcement. To investigate the effects of water absorption on the mechanical properties, composite samples were put through water immersion tests. The composite sample's fibre content ranged between 20, 30, and 40% by weight. Increases in moisture content percentage resulted in a decrease in tensile and flexural characteristics. By using composite samples epoxy resin to reinforce carbon coconut shell, Salleh Z et al., [23] created their creation. The fillers consist of polypropylene and naturally occurring activated carbon. Silicon rubber moulds were used to create composite samples. The composite sample's filler content alternates between polypropylene (4, 6 and 8 wt.%) and activated carbon (6, 4 and 2 wt.%).

The mechanical characteristics of red mud filled coir fibre reinforced polymer composites were evaluated by iren J. Saradava et. al. in [24]. The hand layup technique was used to create the composite samples, which contain 60 vol% polyester resin, 0, 10, 20, 30, and 40 vol% coir fibre, and 10 vol% red mud. Superior Tensile and Flexural qualities were displayed by composite samples made composed of 60% resin, 40% coir fibre, and 0% red mud. Density values were higher in composite samples containing 30 vol% red mud, 60 vol% resin, and 10 vol% coir fibre. Satender Kumar and colleagues [25] Research Review the resin transfer mould method was used to create composite materials reinforced with coir fibre and epoxy resin

2. Objectives

The main objective of the present research paper is to investigate the fracture toughness of natural fibre reinforced polylactic acid composites with the scope being,

a) Fabrication of rice straw fibres reinforced PLA composites with varying filler weight fraction.

b)Characterization of mechanical, thermal Properties and fracture toughness propertyas per the ASTM standards.

3. Materials And Methods

3.1 Materials

Polylactic acid granules

The building blocks of lactic acid are used to create polylactic acid, also known as polyactide (PLA), a biodegradable and bioactive polyester. A lot of literature has been written about polylactic acid (PLA), one of the most promising biodegradable polymers (biopolymers), over the past ten years. PLA is commercially accessible (produced on a big scale) in a variety of grades and may be treated using a wide range of processes. It is useful for a variety of applications due to its outstanding qualities and affordable price.

Fig. 3.1. Polylactic acid granules.

Rice straw fibres

Similar to linen fibres, rice straw fibres are composed of 64% cellulose and 63% crystalline cellulose, with a strength of 3.5 g/denier (450 MPa), an elongation of 2.2%, and a modulus of 200 g/denier (26 GPa). Compared to other naturally occurring cellulose fibres derived from agricultural byproducts, the rice straw fibres described here have superior characteristics. Rice straw is a readily available, abundant, and reasonably priced source of natural cellulose fibres, with an annual global availability of 580 million tonnes. In addition to helping to increase the value of rice harvests and provide a sustainable source of fibres, using rice straw for high-value fibrous applications will also be good for the environment.

Sodium Hydroxide

Natural fibre is chemically treated using sodium hydroxide. Sodium Hydroxide's chemical name is NaOH. It is frequently referred to as Caustic soda. The sodium hydroxide flakes used to chemically treat the fibre are depicted in Figure 3.5. It is a Na and OH-containing white solid ionic compound. Its density is 2.13 gcm, and its melting and boiling points are 318 and 1388 °C, respectively. It dissolves quite well in water. The industries use the majority of the sodium hydroxide that is produced.

Fibepreparation and treatment

Washing with water

The fibres that were removed are cleaned with water to remove any remaining dust and plant material. Fibers are dried in the sunlight after washing with the water to remove their moisture content. These dried fibers have cut to an approximate length of 5 to 10 mm.

Chemical treatment of fibre with NaOH (Sodium hydroxide)

250 grammes of NaOH is dissolved in 12.5 litres of water for the purpose of chemically treating fibers. Natural fibers are then immersed in the chemical solution for 24 hours later washed inwater to remove excess NaOH solution, next to remove the moisture from the fibres, they are dried under the sun light.

Composites Fabrication

Composite material's composition

Using the injection moulding process, composite material samples with varied weight percentages of treated and untreated natural are created. The conformation the composite materials fabricated are shown in the table below.

Table 1: Composition of composite material

Composite name	**PLA weight%**	**Straw Fibre weight%**	**Total weight%**
PURE PLA	100	00	100
U-10-S	90	10	100
U-20-S	80	20	100
U-30-S	70	30	100
T-10-S	90	10	100
T-20-S	80	20	100
T-30-S	70	30	100

Extruding procedure of Composite specimen pellets

The first petite natural fiber and polylactic acid are blended in a ZV-20, aTwin Screw Extruder Machine, located at the (CPET) Kochi located Kerala. When combining the mixture of natural fiber and polylactic acid. The motor speed was being set to 90 RPM, and melting temperature was set at 210°C. There were 5 to 14 bars of melt pressure.

Specific Twin Screw Extruder Machine Specifications

- Screw Diameter: 21 mm
- Output: 10 Kg/hr (wt. %)
- Motor: 5.5 KW 10 (untreated)
- LD ratio: 40:1 20 (untreated)
- Heating load: 5 KW

The twin extruder machine produces strands of the composite material made of polypropylene and rice straw fibre.These extruded strands passed through the water bath because they were heated. To make composite pellets, these extruded strands are sent into the grinder machine.The extruded strands take a small quantity of water content with them as they pass through the water bath. To minimize the moisture content, these composite pellets were dried in the sunlight.

Fabrication of composite plate

In an injection moulding machine, the composite specimen is created using the extruded pellets. The temperature at which extruded pellets are dried in an oven isof 70°C for three hours before beingcsupplied into the injection moulding machine's hopper to eliminate any residual moisture. The installation moulding machine, JIT 80, is used to create composite materials. This equipment is offered at the CIPET in Mysore, Karnataka state. The machine of injection moulding is depicted in figure 3. The different requirements for the injection moulding machine include- 32mm screw diameter; 129 grammes of shot capacity: Power capacity is 13.5Kw at 1810 kg/cm of injection pressure.

The injection moulding machine has four distinct heating zones. The injection moulding machine's temperature zones are kept at 1stZone -180°C, 2nd Zone -190°C, 3rdZone -200°C, and 4thZone -210°C so that the plastic materials fed from the hopper melt in each zone and flow freely into the die cavity. The pressure is kept at 60, 50, 47, and 45 bars in each of the different zones, correspondingly. The injection moulding process is used to create composite plates with dimensions of 100 X 90 x 5 mm. According to ASTM guidelines, test specimens are received from these composite material plates that are manufactured.

Fig.3.2 Injection moulding machine

3.4 Material Characterization

Fracture Toughness

To ascertain the 1st mode fracture toughness, a SENB examination was performed. Fracturetoughness of plastics are found using this testing procedure in terms of the critical stress intensity tactor. By cutting a notch, the test specimen is already pre-cracked. To spread the initial crack, a tensile load is provided to specimen. As seen in the picture, tests for fracture toughness (SENB) are performed using a UTM in accordance with ASTM D-5045. At room temperature.

Using a knife, a 0.5 mm initial crack was created in the specimen. The greatest load that the material could withstand was noted, and the same is true for fracture toughness. The FT of the specimen is expressed using the K_{IC}. The equation can be used to get the critical stress intensity factor for the 1st mode fracture toughness test.

$$K_{IC} = \frac{P}{B\sqrt{W}} f(x)$$

$$f(x) = \frac{6\sqrt{x}\,[1.99 - x(1-x)(2.15 - 3.93x + 2.7x^2)]}{(1+2x)(1-x)^{3/2}}$$

Where

B= Specimen thickness,

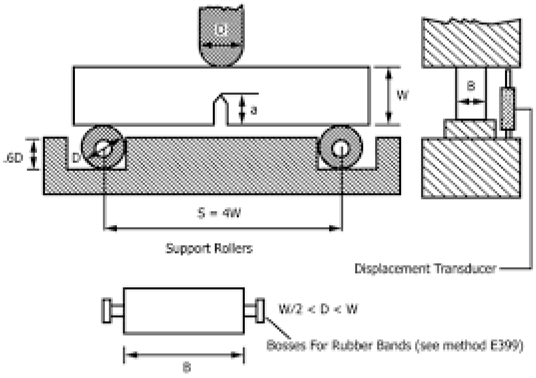
W= Specimen width,

a = Crack length,

P= Extreme load supported by Specimen,

(a/w) = Geometric factor

Trial specimen dimensions are accordingthe American Society of Testing Materials standard. The constructed SENB test specimen is depicted fig 4 and 5.



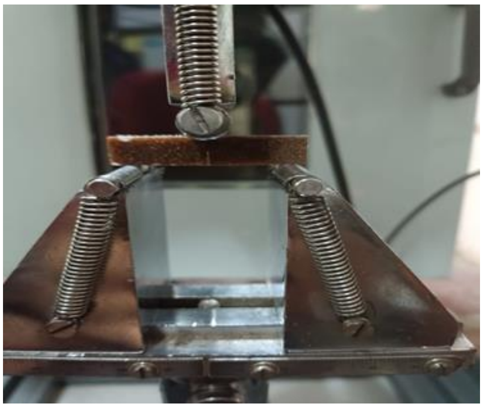


Fig 4 ASTM standard specimen for SENB **Fig 5 SENB Test**

The table 2 shows the f(a/w) values for above Test for different values of a/w.

Table 2: the f(a/w) values for SENB Test

a/w	**f(a/w) for SENB test**
0.450	2.286
0.460	2.354
0.470	2.426
0.480	2.501
0.490	2.580
0.500	2.663
0.510	2.749
0.520	2.840
0.530	2.936
0.540	3.036
0.550	3.142

Tensile Strength test

The best malleable pressure that a material can support without fizzling is known as the substance's elasticity. The test is led to decide the example's limit, otherwise called the ASTM D-638 limit, and the power important to break it. [19). Elasticity tests are performed on the General Testing Machine (UTM) as per the norm, as found in the figure. At room temperature, the test is run with a cross head speed of 1 mm/min and a measure length of 60 mm. Malleable test example aspects as per ASTM D-638 are displayed in figure 3.17. The made elastic test is portrayed in figure 3.18. The exploratory test arrangement for the elastictrial of composites is displayed on the example in figure 3.19

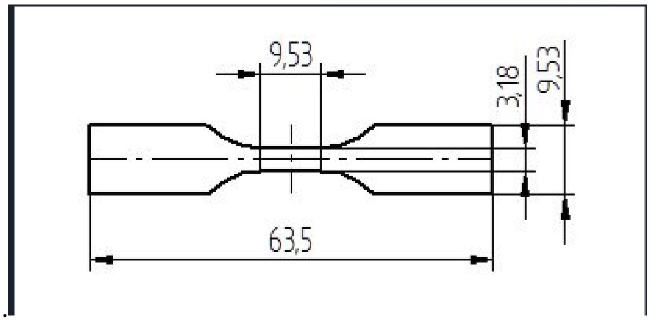


Fig 3.3 Tensile Test Specimen Dimensions as per ASTM standards

Fig 3.4 Tensile test set up

Flexural strength test

Flexural tests are conducted to ascertain the amount of force necessary to bend a bcam under three-point loading circumstances. Materials for the project are chosen based on the findings of the flexural test. parts or sections that can sustain loads without bending. (39), Flexural Strength Tests are conducted using the UTM-Kalpak Universal Testing Machine in accordance with ASTM D-790 standard. At room temperature, the test is run at a crosshead speed of Smm/min and a span length of 75 mm. The test specimen was set up on the two parallel roller supports, and a load was applied using a loading nose at the specimen's midpoint. [30). The dimensions of the Flexural Test Specimen are shown in Figure 3.23 in accordance with ASTM D-790.

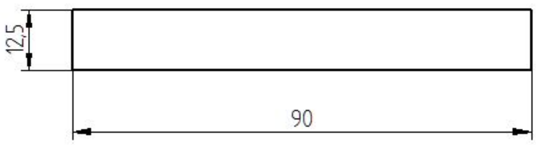


Fig 3.23 Flexural strength specimen

TGA (Thermal Gravimetric Analysis) Analysis

The composite specimens were subjected to a controlled temperature rise while the accompanying weight loss was measured using Thermal Gravimetric Analysis (TGA). Important information on the heat stability and decomposition behaviour of the composites was provided by the TGA data. The results of the investigation showed that the breakdown of organic components such natural fibres and polylactic acid (PLA) might be the cause of the weight loss seen in the composite materials as the temperature rose. Understanding the thermal performance of the composites was made easier by the quantitative information the TGA data offered on the temperature ranges connected to these components' breakdown.Furthermore, the TGA study provided insightful information for maximising processing settings and choosing appropriate uses for the composite materials according to their thermal properties. The TGA study results enhance our understanding of the PLA and rice straw fiber-reinforced composites' thermal behaviour, which helps us make wise decisions about their possible industrial uses.

XRD (X-ray diffraction) Analysis

The composite specimens consisting of rice straw fibres, natural fibres treated with sodium hydroxide, and polyactic acid (PLA) are subjected to X-ray diffraction (XRD) examination, which offers important insights into the crystalline structure and phase composition of the materials. Different diffraction peaks that correspond to the crystalline areas in the composites are visible in the XRD patterns. There are peaks that are exclusive to PLA and other peaks that are linked to the inclusion of rice straw fibres. The altered crystallinity of the treated natural fibres shows how well the chemical treatment with sodium hydroxide modified the fibre structure.The composite materials may experience changes in their crystalline organisation, which might affect their mechanical capabilities, according to the XRD data. The determination and measurement of crystalline phases by X-ray diffraction (XRD) help in the assessment of the composites' appropriateness for various applications by providing a thorough understanding of their structural properties.

4. Results and Discussions

4.1 Fracture Toughness (SENB) test:

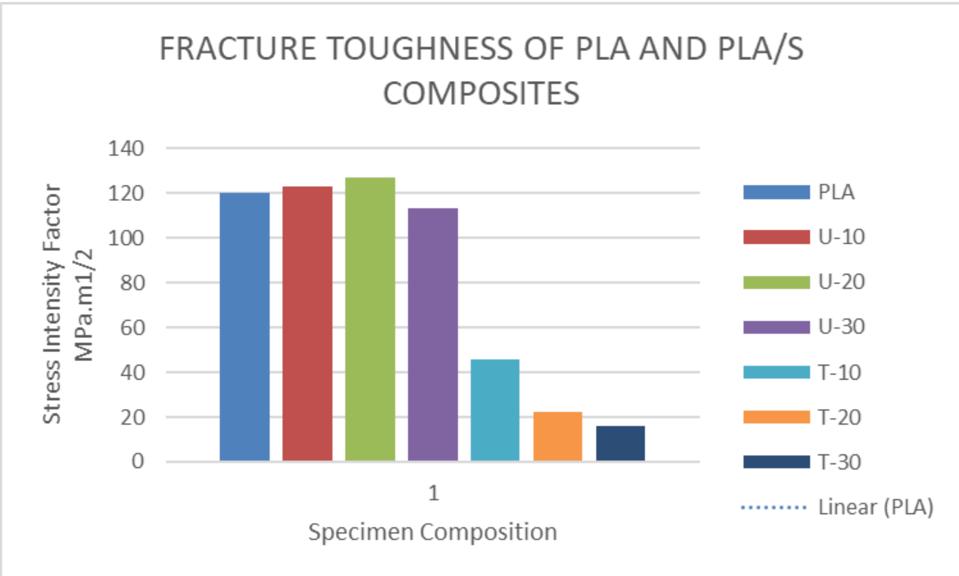


Fig.4.1. Fracture Toughness of PLA and PLA/S Composites

Fig.4.1 shows the pressure power factor values for unadulterated PLA and rice straw fiber built up PLA composites. The above chart, it is seen that for untreated 10 wt% and 20 wt% fiber built up PLA composites the Break Durability values, i.e Stress Power Variable qualities are higher when contrasted with that of unadulterated PLA composites. Yet, untreated 30 wt% rice straw fiber built up PLA composites exhibits lesser worth of Break Durability or Stress Force Component when contrasted with that of unadulterated PLA. Comparatively the above chart, it is seen that for treated 10 wt%, 20 wt% and 30 wt% rice straw fiber supported PLA composites shows decremental upsides of Break Sturdiness or Stress Power Element when contrasted with that of unadulterated PLA.

By Fig.4.1 we can likewise infer that when contrasted with treated fiber example untreated one shows better upsides of Crack Strength thus great burden bearing limit. By looking at untreated 10,20 and 30 wt% fiber supported PLA composites among themselves they shows climbing example of Break Durability lined up with expanding weight part with slight decrements in 30 wt% composites. Likewise, by contrasting treated 10,20 and

30 wt% fiber supported PLA composites among themselves they shows decending example of Break Durability lined up with expanding weight part. By this we can reason that synthetic treatment of the fiber influences the strength of the fiber and makes the fiber fragile; subsequently expansion in fiber content in treated fiber supported composites neglects to convey the heap.

The table 4.1 indicates the maximum load carried by each type of the specimen and Stress Intensity Factor values for the different composite samples.

Table 3 Experimental results of Fracture Toughness (CT) test.

Specimen Name	Load (N)	K_{IC} (MPa.m$^{1/2}$)
PURE PLA	178.45	120.19
U10	182.41	122.86
U20	188.71	127.1
U30	168.49	113.48
T10	67.96	45.77
T20	33.09	22.28
T30	23.9	16.09

4.2. Tensile Test:

Figure below represents the results of Tensile strength test

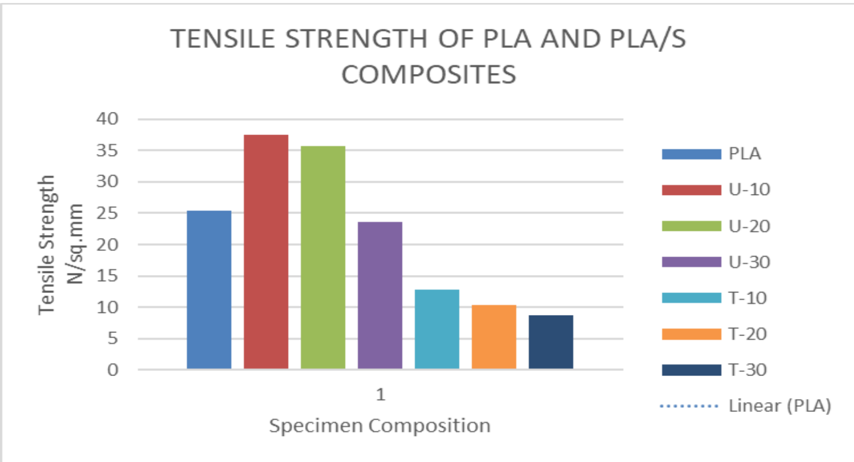


Fig.4.2 Tensile Strength of PLA and PLA/S composites

The Fig.4.2 shows the Rigidity values for unadulterated PLA and rice straw fiber built up PLA composites. The above chart, it is seen that for untreated 10 wt% and 20 wt% fiber supported PLA composites the Elasticity values are higher when contrasted with that of unadulterated PLA composites. In any case, untreated 30 wt% rice straw fiber supported PLA composites shows lesser worth of Rigidity when contrasted with that of unadulterated PLA. Additionally, the above diagram, it is seen that for treated 10 wt%, 20 wt% and 30 wt% rice straw fiber built up PLA composites shows decremental upsides of Rigidity than that of unadulterated PLA.

By Fig.4.2 we can likewise infer that when contrasted with treated fiber example untreated one shows better upsides of Rigidity consequently great burden bearing limit. By contrasting untreated 10,20 and 30 wt% fiber built up PLA composites among themselves they shows rising example of Rigidity lined up with expanding weight division with slight decrements in 30 wt% composites. Likewise, by contrasting treated 10,20 and 30 wt% fiber supported PLA composites among themselves they shows decending design for Elasticity lined up with expanding weight portion.

4.3. Flexural Strength:

Figure below represents the results of Flexural strength test

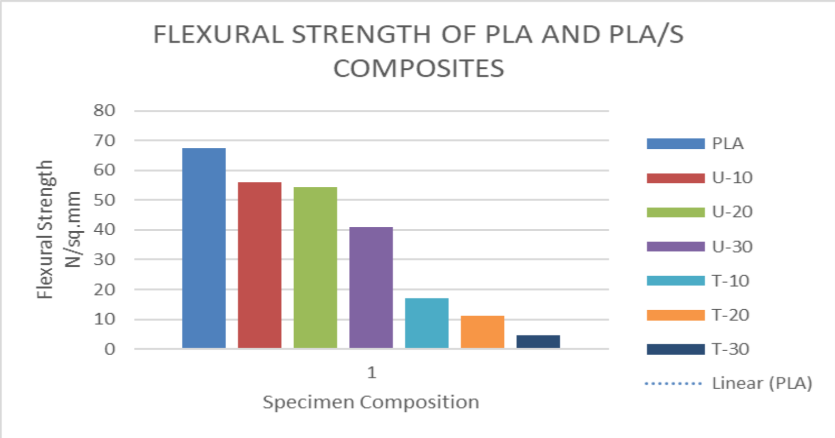


Fig.4.3. Flexural Strength of PLA and PLA/S composites

Fig.4.4 shows Flexural Strength for pure PLA and rice straw fiber reinforced PLA composites. The above graph, it is observed that Flexural strength of untreated 10,20 and 30 wt% fiber reinforced PLA composites drops as increase in weight fraction as compared to that of pure PLA.Similarly, the above graph, it is observed that for treated 10 wt%, 20 wt% and 30 wt% rice straw fiber reinforced PLA composites shows decremental values of FlexuralStrength than that of pure PLA.

By Fig.4.4 we can also derive that as compared to treated fiber specimen untreated one shows better values of Flexural Strength hence good load bearing capacity. But, comparing untreated 10,20 and 30 wt% fiber reinforced PLA composites among themselves they shows decending pattern of Flexural Strength parallel to increasing weight fraction. Similarly, by comparing treated 10,20 and 30 wt% fiber reinforced PLA composites among themselves they shows decending pattern for Flexural Strength parallel to increasing weight fraction.

4.4TGA Analysis

Thermogravimetric Analysis (TGA) was used to examine the thermal degradation behaviour of the four specimens, which included pure polylactic acid (PLA) and PLA composites (U-10-S, U-20-S, and U-30-S) reinforced with rice straw fibre. The degradation temperature gives information about the materials' initial thermal stability, and the successive weight loss stages reveal the properties of their breakdown. With a comparatively modest beginning weight loss of 0.569% up to 200°C and a large weight loss of 99.431% from 200°C to 450°C—with no residual ash at 450°C—pure PLA showed the maximum degradation start at 310.83°C.The heat degradation characteristics of the reinforced composites, U-10-S, U-20-S, and U-30-S, varied. U-30-S demonstrated a deterioration that began at 267.65°C and three discrete weight loss phases at varying temperature intervals: -2.681%, 75.069%, and -13.421%. At the different temperature ranges, U-20-S showed weight losses of 1.881%, 82.084%, and 11.073%, with an onset temperature of 265.88°C. At the designated temperature intervals, U-10-S showed weight losses of -1.299%, -93.819%, and -3.380%. Its greatest onset temperature was 273.06°C.

By contrasting the reinforced specimens with pure PLA, it is possible to observe how the inclusion of rice straw fibres affected the behaviour of heat deterioration. When compared to pure PLA, the reinforced composites usually showed lower onset temperatures and unique weight loss patterns. Furthermore, comparing the reinforced specimens shows that the weight loss percentages varied at different temperature intervals and that the commencement of degradation temperatures dropped as the rice straw fibre content rose (U-10-S to U-30-S).According to the TGA data, the PLA composites' thermal stability is impacted by the addition of rice straw fibres, to varying degrees depending on the fibre quantity. These results are essential for comprehending the

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composites' thermal properties and offer insightful information about their possible uses in various temperature-dependent settings.

Figure below represents the results of TGA Analysis

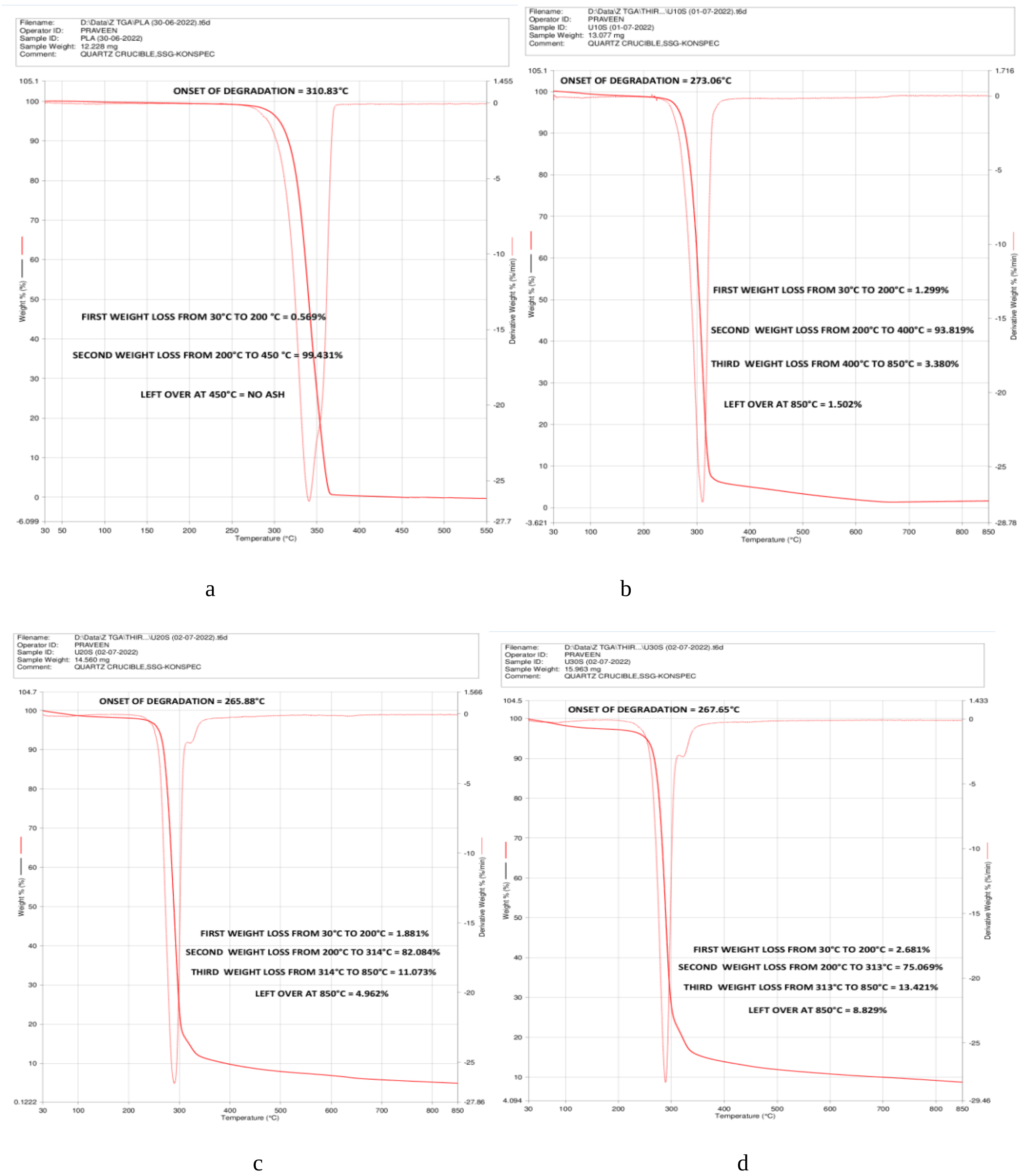

Fig 4.4 represents TGA analysis results of a. PLA b. U-10-S c. U-20-S d. U-30-S

4.5 XRD Analysis

The maximum intensity and 2θ values of the four specimens—pure polylactic acid (PLA) and PLA composites reinforced with rice straw fibre (U-10-S, U-20-S, and U-30-S)—show different patterns according to X-ray diffraction (XRD) examination. When comparing the reinforced specimens to pure PLA, it becomes clear that the XRD patterns are affected by the inclusion of rice straw fibres. At 2θ = 17°, U-10-S reaches its maximum intensity of 1800 a.u., U-20-S reaches its highest intensity of 300 a.u., and U-30-S reaches its maximum intensity of 700 a.u. By comparison, the highest intensity of pure PLA is 350 a.u. at 2θ = 17°.

The comparison of the reinforced specimens reveals differences in the diffraction peak intensity, indicating that the presence of rice straw fibres has altered the crystalline structure. Compared to U-20-S and U-30-S, U-10-S exhibits a more noticeable impact on the crystalline arrangement and has the maximum intensity at 2θ = 17°. Moreover, the variations in peak intensity between the reinforced specimens imply that the PLA matrix's crystalline structure is influenced by the quantity of rice straw fibre reinforcement.

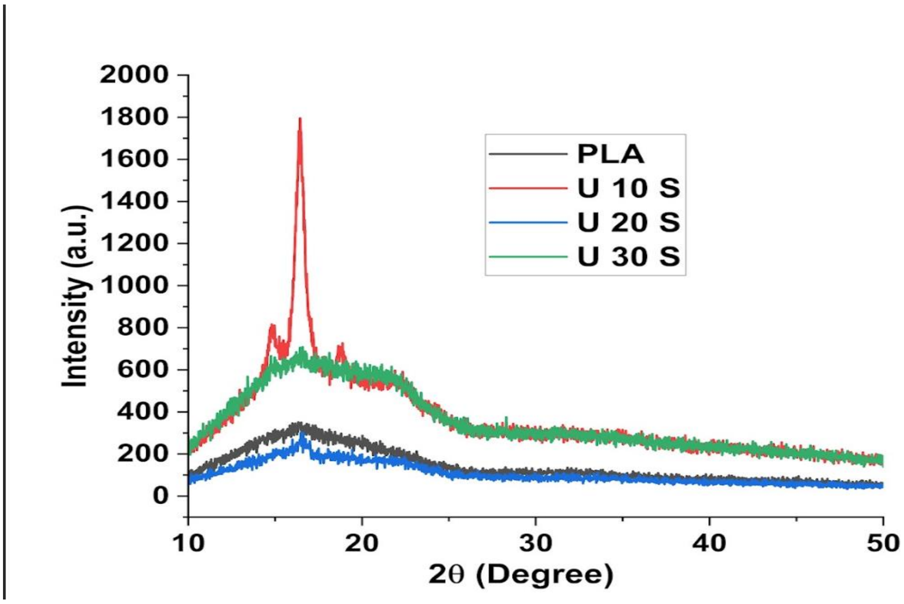

Fig.4.5 XRD plot

5. Conclusion

In summary, the purpose of this learning was to examine the behaviour of mechanical and fracture toughness properties of polylactic acid (PLA) composites reinforced with rice straw fibres. Using injection moulding, composite specimens with unlike weight percentages of treated and untreated rice straw fibres were created throughout the manufacturing process. The mechanical attributes, such as fracture toughness and flexural and tensile strengths, were assessed in compliance with ASTM guidelines. In contrast to pure PLA composites, the results showed that fiber-reinforced composites, whether treated or not, had greater fracture toughness values. This implies that adding rice straw fibres to the composite improves its resistance to fracture, as untreated fibre composites exhibit increasing the amount of fibre while maintaining fracture toughness.The creation of PLA composites filled with rice straw fibre and the evaluation of their mechanical characteristics effectively met the study's goals. Natural fibres, especially rice straw, have shown to be a viable and sustainable substitute for conventional metal reinforcements. Additionally, the fibres were chemically treated with sodium hydroxide as part of the experiment to improve their compatibility with the PLA matrix. On the other hand, it was noted that when the fibre content rose, the treated fiber-reinforced composites' fracture toughness decreased. This emphasises how crucial it is to give careful thought to natural fibre treatment techniques in order to maximise their mechanical qualities in composite materials.

The composition of the composite materials, the extrusion procedure, and the injection moulding technique used to create composite plates were all covered in the materials and methods section. The characterization methods, which included XRD, TGA, and tensile and flexural strength testing, gave detailed insights into the crystalline structure, mechanical, and thermal characteristics of the composites. The TGA results showed that the inclusion of rice straw fibres affected the PLA composites' thermal stability, with different effects depending on the amount of fibre added. Similarly, XRD examination highlighted the influence of rice straw fibre reinforcement on the PLA matrix by revealing alterations in crystalline structure.

To sum up, our research contributes significant knowledgeto the expanding field of composite materials reinforced with natural fibres. The results highlight the potential of rice straw fibres as useful PLA composite reinforcements, however careful treatment technique selection is still necessary. Our understanding of these composites is improved by the thorough characterization of their mechanical and thermal characteristics, which serves as a foundation for deliberations about their possible industrial uses in ecologically friendly engineering and technology.

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