Assessment of Mechanical Properties of Biocomposite Material by using Sawdust and Rice Husk

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Abstract: *This paper presents an experimental study on the development of biocomposite material by using sawdust (SD) and rice husk (RH). The use of composite in the present production has increased dramatically since the 1970's. Traditional material like aluminum, steel, iron and copper etc. may be easily replaced by using this classical biocomposites. The tensile test, hardness and tear resistance test were conducted in a Universal testing machine as per ASTM D638, ASTM D2240 and ASTM D1004 standard, respectively. Although commercial industries have increasingly been concerned with the low cost, light weight and eco-friendly material, the biocomposite material has also a great potential for reduced production cost and low maintenance which have proven to be a main factor in a push towards recycled biocomposites. In this paper we have fabricated a biocomposite model from materials like sawdust, rice husk. The main reason to use biocomposites is that they are more economical and have high strength to weight ratio compared to glass fibers. Hence fabricated material can be used for various applications.*

Key Words: *Sawdust, Rice Husk, natural fibers, recycled bio composites, mechanical properties*

1. INTRODUCTION

Over the recent years there has been a significant incurrence in the use of composite materials due to their high performance in aerospace industry. Generally, composites are a combination of two or more distinct materials blended as separate phase and confined to form the desired structure. Rice husk (RH) particles are one of the major agriculture waste stuff and sawdust (SD: Indian elm wood) [1] particles are left to degrade in many woods cutting industries.

The use of biocomposite materials in commercial carrier aircraft is attractive because it reduces the airframe weight and enables to settle fuel economy. Due to the previous success in the application of biocomposite, it is found that, it has its application even in primary structure of the aircraft like wings and fuselage. Taking this into account eco-friendly materials are fabricated using recycled waste materials like sawdust, rice husk and bagasse.

Biocomposite derived from recycled waste materials like sawdust, rice husk and straw has a better strength to weight ratio than steel and is also significantly cheaper to fabricate. Natural fiber composites are also emerging as an alternative to glass reinforced composites. While they can deliver the same performance for lower weight, they can also be 25-30%

stronger for the same weight moreover they exhibit a favorable non-brittle fracture on impact, which is another important requirement in the passenger compartment. The main advantage of using recycled waste materials [2] like sawdust, rice husk, straw and bagasse is their low cost, low density, acceptable specific strength properties of energy recovery.

Nowadays biocomposites have been the subjects of extensive researches, due to their advantages such as lower manufacturing cost and lower weight. The process which is used to make the biocomposites permits an economic and efficient production in which the natural fibers are uniformly dispersed. The model fabricated will be tested for its bio-degradability, hardness, tension and GSM. Such types of composites are moderately more environment friendly [3] and has a wide range of applications in the aerospace sector, railway and other automobile industries.

Raw Materials Description

The raw material which we use in this research is restricted to only the waste recycled materials. We use them mainly because of their bio-degradability, strength to weight ratio and also their flexible nature.
All the materials which we use are as follows:

- Sawdust (Indian elm wood),
- Rice Husk (RH),
- Polyvinyl Alcohol.

Sawdust

Sawdust is a natural waste coming from mechanical processing or preparing of timber (Indian elm wood) into different shapes and sizes. These are the waste materials that are obtained after the carpenter finishes with his wood. We collected the materials from a nearby carpenter.

Sawdust is a material that binds very hard to its matrix phase and we had to powder it to avoid any lumps in it. Sawdust is a result of cutting timber with a saw, made out of fine particles of wood.

Rice Husk

Rice husk is the outer covering of the paddy. Rice husk has also been obtained from a paddy field cultivating rice. We have to first harvest the rice and then extract the husk alone. Rice husk was brittle and also bio-degradable. Rice structures (or rice husks) are the hard coating of grains of rice [2].

Notwithstanding ensuring rice amid the developing season, rice bodies can be put to use as structure material, manure, protection material, or fuel [6].

Polyvinyl Alcohol

Polyvinyl alcohols have outstanding film forming, emulsifying and adhesive properties. It is also opposed to solvents, oil and grease [4].

It is odorless and harmless. It has high tensile flexibility as well as elevated oxygen and aroma barrier characteristics.

However these characteristics are dependent relative on humidity, namely with higher humidity more water is wrapped up.

PVA is completely degradable and breaks up rapidly. PVA has a dissolving point of 230°C and 180– 190°C (356-374 degrees Fahrenheit) for the completely hydrolyzed and halfway hydrolyzed evaluations, individually.

2. SAMPLE PREPARATION

Even after the raw materials were prepared, we had to prepare samples that we fit for being given for the various tests. The composite materials mainly have the two phases involved in it which are matrix the phase and the reinforcement phase. The reinforcement phase used here in the biocomposite refers to the natural fibers and the matrix phase used is the polyvinyl alcohol. The sample is prepared in the form of sheet of 3mm thickness. There are various steps involved in the production of biocomposites by recycling materials.
Sample preparation mainly involved the

a) Mould preparation.
b) Fabrication of materials.

Mould Preparation

For the preparation mould we mostly used a wood sheet and foam board. But at first we used the glass plate of 2mm thickness with a border of around 5mm. When the sample is prepared and dried in glass plate, due to excessive stress during drying the glass plate broke and it became hard to remove the final dried sample from the mould. So we opted to use the sheet made of steel.

The saw dust particles were dried in air and used after the cleaning process. Figs. 1(a) and (b), present the Rice husk (RH) and Sawdust (Indian elm wood dust).

Fig. 1 (a) Rice Husk

Fig. 1 (b) Saw Dust

The main reason we used a steel sheet was that it can bear more stresses than the glass and it will not crack as the glass do. And for the steel plate the border which will not allow the molten PVA to flow out was constructed by using the Foam board. The thickness of the border is of around 6mm. So that 3mm sheet of biocomposite using the recycling materials is formed if the raw molten sample is filled over 6mm thickness mould. Foam board is being used because it does not absorb the resin and it also does not allow the resin to flow outside and it will not wet out.

Fabrication Process

The method of fabrication we used for the developed of the biocomposite sheet is the hand layup method. There are many methods of fabrication [4] available for the production of composites such as open mould process, closed mould process, compression moulding, injection, injection moulding, etc. But those methods are expensive. Hence we opted out for the hand layup process of fabrication. We had used the same fabrication technique for all of the samples. There involves a various procedure to be followed. The detailed description of those steps as given below. Fibers are grown and processed very reasonably and at competitive prices, as compared to artificial fibers produced by modern industries. Therefore the first handing out stage has to take place in the vicinity of the farms.

The various steps involved in the fabrication process are:

(a) Arranging the required chemicals,
(b) Preparation of the resin,
(c) Addition of waste recycling materials,
(d) Casting of sheets,
(e) Drying,
(f) Extraction of sheets.

Fig. 2 Layout and setup of moulding

Fig. 3 Setting the mould

Fig. 4 Drying in sunlight

Arranging the required chemicals

First step of the fabrication process is the collection of the required chemicals that is raw materials that are used for this process [5]. The various materials that are required for this process are polyvinyl alcohol which is the resin material, Glycerol, Urea, Sodium hydroxide, various natural recycling materials such as rice husk, sawdust, sugarcane bagasse, and straw.

Polyvinyl alcohol is a chemical that is used as the resin matrix and it will be usually in the form of powder or granules form which will be converted to hot liquid during fabrication by the addition of hot water. Polyvinyl alcohol is the synthetic material but it is fully biodegradable.

Next glycerol is added to the hot molten PVA. Glycerol is used as a binding agent which ensures the strong binding of the fiber and the matrix phases. Urea and Glycerol is obtained from the chemical suppliers and which is available easily.

Preparation of the resin

A vessel containing about 500ml of water is taken and then it is boiled to the temperature of 100°C. Then the polyvinyl alcohol of about 70g which is usually in the granules form is added to the boiling water and then it is stirred constantly using the metal stirrer. Then after the polyvinyl alcohol dissolves completely in water then another 140g of PVA is added and if water is required it is poured and stirred at a constant speed. The PVA will get completely dissolved and form into the molten gel form of polyvinyl alcohol.

Addition of waste recycling materials

As we mentioned in the previous sections, we fabricated the biocomposite sheet made of four recycling material fibers such as Rice husk, Sawdust, Bagasse and Straw. Out of these four fibers straw is the fiber which is used as the long continuous arrangement of fibers [9]. Then all the three fibers are grinded to powder and then it is mixed with the molten PVA gel. Hence all the three fibers will be in the discontinuous form of arrangement. Sawdust will be already in the grinded powder form, hence it is added directly without any further grinding.

Casting of sheets

The mould for the casting of the sheets of about 3mm thickness was already prepared as presented in figure 2.

In case of Rice husk and Sawdust: Then the prepared resins along with the powdered fibers are poured over the mould which is lubricated [9] properly that ensures easiness of removing or extraction.

Thus the mould is filled with the resin and the matrix. Usually the mould is of 6mm thickness and it is fully filled. And then it is let under the open atmosphere under the sunlight to dry.

Drying

Then the mould is led to dry under the sunlight as presented in figure 4. It is dried for the period of two days. Care should be taken so that there should not be any extensive drying due to which the mould may fix to the surface and will became hard to eliminate from the mould after drying. Also extensive drying leads to the formation of the voids. Hence care should be taken in case of drying.

Extraction of sheets

After the mould is dried under the sunlight the biocomposite sheet made of recycling materials is removed from the mould. During drying process the thickness of the resin and fiber mixture will gets reduced.

This is due to the evaporation of the water from the mixture. Roughly there will be about 50% reduction in the thickness.

The sheet is first sliced in the border and then removed slowly with care so that there will not be any wear and tear on the sheet. Thus the biocomposite sheet is removed from the mould and it is packed for testing.

3. TESTING OF MATERIALS

After the biocomposite sheet is manufactured, it is ready for testing. For the testing of the materials 3mm thickness sheet is recommended. For the purpose of understanding the material structure and its characterization various test [8] such as Tensile strength, Hardness, Tear Resistance and GSM tests are performed. The description and the procedure of various tests are as follows.

Tensile Strength test

Tensile tests determine the force required to break a specimen and the amount to which the specimen stretches or elongates to that breaking point. For ASTM D638 the test speed is determined by the material specification. For ISO 527 the test speed is typically 5 or 50mm/min for measuring strength and elongation and 1mm/min for measuring modulus. An extensometer is used to determine elongation and tensile modulus.

Hardness test

Hardness test is performed on the material according to the ASTM D2240 standards for the testing of materials and used to establish the relative hardness of soft materials, generally plastic or rubber. The test measures the penetration of a specified inventor into the material under specified conditions of force and time. The test procedure involves first the placing of specimen on a hard flat surface. The indenter is then pressed into the specimen making sure that it is parallel to the surface.

Tear Resistance test

Tear Resistance test is performed on the material according to the ASTM D1004 standards for the testing of materials. The tear resistance [10] measures the ultimate force essential to tear film or sheet. It is frequently used for superiority control checks or for material assessment where tear failures are promising. The procedure of testing involves the following steps. The standard thickness of the specimen is measured. The sample is then placed in the grips of the testing machine and pulled at a rate of 2 inch per minute until rupture.

GSM test

Concerned with the composite materials the main factor is the strength-to-weight ratio. GSM test of such materials allows us to know about the weight of the materials. Usually the GSM test is performed cutting of sheet of cross section of 100cm × 100cm and then measuring the weight of the sheet by using an electronic weight measuring device for accurate results. Also the scaling method can also be used. Thus the GSM test is performed.

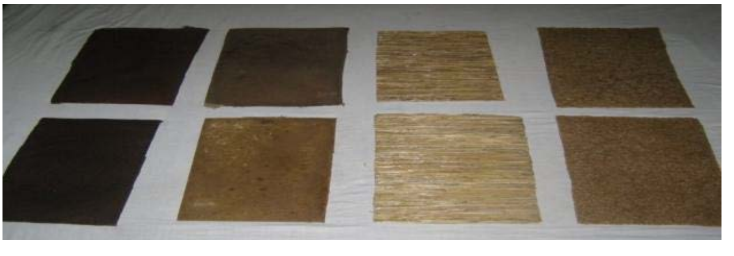

Fig. 5 Bio-Composite Sheet with Different Types of Fibers

Biocomposite Sheet with different types of fibers is presented in figure 5. The specimen thickness of all ASTM standards (ASTM D638, ASTM D2240 and ASTM D1004) during testing is usually machined from smooth cured panels. Preferably, the panels should be lies between 0.040 inches and 0.200 inches depending on the layup.

4. RESULTS AND DISCUSSIONS

Various tests are performed on the biocomposite material and the results are obtained tabulated. For the duration of the tensile test, the ASTM standard D3039 specimens were striped at two fixtures of the machine and load is applied as per the ASTM standard recommends tilling the sample was fooled into two segments. The test result for rice husk (RH) and sawdust (SD) fiber samples is shown in table 1 and table 2 shows the various test results of rice husk fiber, and the corresponding table shows the corresponding fibers test results. Figure 6(a) and fig (b) present the photograph of the polyester composite laminates. The composites fabricated were cut into essential measurement using a saw cutter and the edges refined by using emery paper for mechanical testing.

a) Resin: Rice Husk 90:10 b) Resin: Saw Dust 90:10

Fig. 6 Photograph of laminates: a) PR+RH and b) PR+SD

The tensile test, tear resistance and hardness test were conducted in a Universal testing machine as per ASTM D638, ASTM D2240 and ASTM D1004 standard respectively

Table 1. Various test results of Rice husk fiber sample

Properties	**Sample 1**	**Sample 2**	**Sample 3**	**Sample 4**	**Sample 5**	**Average**
Tensile Strength (MPa)	3.32	3.94	4.27	3.55	3.62	3.32
Hardness (Shore A)	57	69	59	69	61	57
Tear Resistance (N/cm^2)	367.71	390.87	371.29	381.22	392.31	367.71
GSM (g/m^2)	1671	1913	2066	1785	1845	1671

To determine the suitable material there are number of mechanical tests conducted, which are necessary; the following important tests have been performed in the present study.

Table 2. Various test results of Saw dust fiber sample

Properties	**Sample 1**	**Sample 2**	**Sample 3**	**Sample 4**	**Sample 5**	**Average**
Tensile Strength (MPa)	13.5	14.7	10.4	12	15.9	13.5
Hardness(Shore A)	68	80	70	80	72	68
Tear Resistance (N/cm^2)	1107	1367	1224	1091	1041	1107
GSM (g/m^2)	1830	2090	1947	1814	1764	1830

The entire above separate test results are compared and the average values are found out and shown in the comparison table below.

Table 3. Comparison table of various fibers

S. No.	**Properties**	**Rice Husk**	**Saw dust (Indian Ilm wood)**
1.	Tensile Strength (MPa)	3.74	13.3
2.	Hardness (Shore A)	63	74

3.	Tear Resistance (N/cm)	380.68	1166
4.	GSM (g/m^2)	1856	1889

Then the above results are compared. For the comparison purpose graphs are made which eases the analysis step.

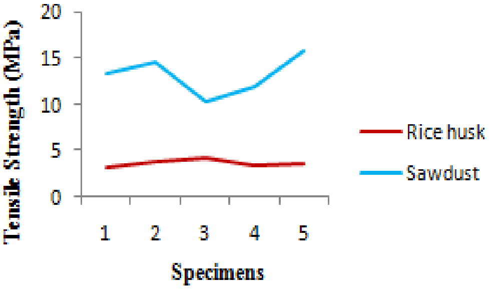

Fig. 7 Comparison of Tensile strength of different fiber sheets for different samples

The graph presented in figure 7 shows the variation of various waste recycled materials tensile strength. The entire value is shown at a unit of mega pascal. From this graph it is clearly shown that the sawdust leads other natural fibers like ricehusk,straw and bagasse. But the increase in the tensile strength is not stable ,it keeps on varying. The saw dust sheet shows more tensile strength of 12-16 Mpa than sheets fabricated with the help of other fibers. This graph has been plotted by taking the results of five samples each of all the waste recycled fibers.

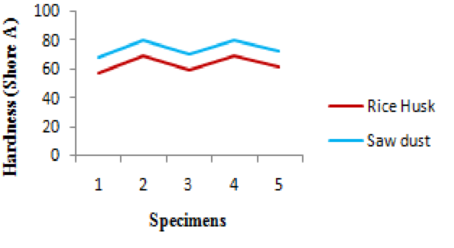

Fig. 8 Comparison of Hardness of different fiber sheets for different samples

This graph has been plotted with the help of testing five samples presented in figure 8 each of rice husk and sawdust. The X-axis depicts the number of samples whereas Y-axis represents the hardness .The sheet fabricated with the help of sawdust shows more hardness of 74 Durometerthan anyother fiber. Next hardness is shown by the sheet fabricated with the help of rice husk by63 Durameter. But the hardnesses imposed by sawdust and ricehusk are overlapping to each other.

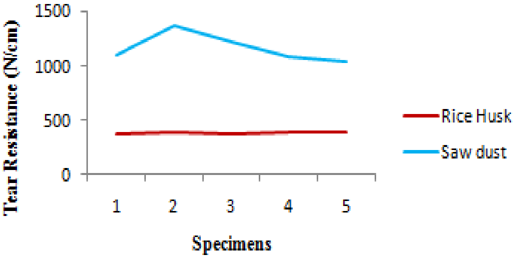

Fig. 9 Comparison of Tear Resistance of different fiber sheets for different samples

This graph presented in figure 9 depicts the tear resistance of various recycled materials like ricehusk and sawdust; the tear resistance is denoted by the unit N/cm. The tear resistance is the highest for sawdust 1166 N/cm followed by rice husk. The least tear resistance is for rice husk at a value of 380N/cm.

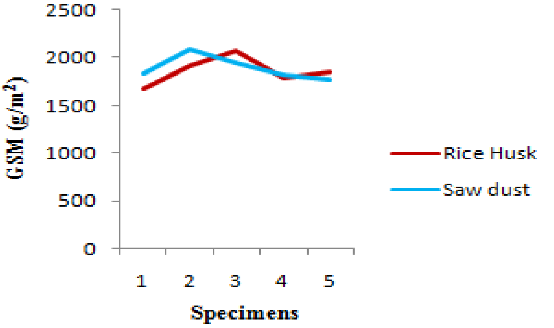

Fig. 10 Comparison of GSM of different fiber sheets for different samples

The graph presented in figure 10 depicts the GSM of waste recycled materials like saw dust and Rice husk. GSM denotes the gram per square meter of various waste recycled materials.The highest GSM is for sawdust of 1889 g/m^2,but the value is constantly varying. The least GSM is for the sheet fabricated with the help of rice husk and saw dust.

5. CONCLUSIONS

In the presnt work the different ASTM standard samples were tested and this methodology is an immense selection for polymer matrix composites testing because of its usability across a wide range of industries. A series of mechanical tests were performed to investigate the tensile strength, hardness testing, tear resistance and GSm testing of different types of bio-composite materials by filling the mixed solution consisting of polyester resin with rice husk (RH) and sawdust (SD) filler into a mould. It has been concluded from the results that:

1. Rice husk reduces the mechanical strength of the epoxy and diminish the tensile strenght. Tensile strength of rice husk fiber varies linearly with load. However this variation for the sawdust has not significant effect over the strength. It has been observed that the average tensile strength for sawdust fibre is higher than that of the rice husk.
2. Sawdust shows more hardness than anyother fiber. But the hardnesses imposed by sawdust and ricehusk are overlapping to each other.
3. The sawdust fiber has shown an excellent tearing resistance over the rice husk. As the loading is increased in each test the tearing resistance also increasing for the sawdust fiber composite.
4. The value of GSM testing is constantly varying. The least GSM is for the sheet fabricated with the help of rice husk and sawdust.

REFERENCES

[1] R. Arulkumar, H. Kanagasabapathy and I. N. Manickam, Combination of Agricultural Waste and Saw Dust into Biomass Material for Briqutte, *Indian Journal of Ecology*, Vol. **46**, pp. 188-191, 2019.

[2] K. S. Paithankar, V. B. Deshmukh, U. N. Shelke, S. B. Iyyer, S. T. More and V. K. Gade, Creatinine Biosensor Based on Graphite PasteElectrode Modified with Dibenzo-30-crown-10 and Rice Husk, *Asian Journal of Chemistry*, Vol. **29**, pp. 1401-1404, 2017.

[3] K. Rohit and S. Dixit, A Review-Future Aspect of Natural Fiber Reinforced Composite, *Polymers from Renewable Resources Sage Journal*, Vol. **7**, pp. 43-59, 2016.

[4] A. K. Rout, A. Satapathy, Study on mechanical and tribo-performance of rice-husk filled glass- epoxy hybrid composites, *Materials & Design*, Vol. **44**, pp. 131-141, 2012.

[5] A. J. F. Carvalho, A. A. S. Curvelo and A. Gandini, Surface chemical modification of thermoplastic starch: reactions with isocyanates epoxy functions and stearoyl chloride, *Industrial Crops and Products*, Vol. **21,** pp. 331–336, 2005.

[6] B. S. Chang, C. K. Lee, K. S. Hong, H. J. Youn, H. S. Ryu, S. S. Chung, K. W. Park, Osteoconduction of porous hydroxyapatite with various pore configurations, *Biomaterials*, Vol. **21**, pp.1291-98, 2000.

[7] S. Kalia, A. Dufresne, B. M. Cherian, B. S. Kaith, L. Avérous, J. Njuguna and E. Nassiopoulos, Cellulose-Based Bio- and Nanocomposites: A Review, *International Journal of Polymer Science*, 2011.

[8] E. Fidančevska, G. Ruseska, S. Zafirovski, B. Pavlovski, Thermal – expansion and mechanical properties of the $Ca_{10}(PO_4)_6(OH)_2$ – TiO_2 composite, *Science of Sintering*, Vol. **34**, pp.241–246, 2002.

[9] V. I. E. Ajiwe, C. A. Okeke, S. C. Ekwuozorand I. C. Uba, A pilot plant for production of ceilling boards from Rice Husks, *Bioresource Technology,* Vol. **66**, pp. 44-45, 1998.

[10] G. George, K. Joseph, E. R. Nagarajan, Jute yarn as reinforcement for polypropylene based commingled eco composites: Effect of fiber content and chemical modifications on accelerated ageing and tear properties, Fibers and Polymers, *Fibers and Polymers*, Vol. **18**, pp. 948-956, 2017.