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Manufacturing and Evaluation of Mechanical Properties for Rice Husk Particle Board Using IoT

Tanya Buddi[a*], Susmitha Valli Gogula[b], Kuldeep K Saxena[c]

[a]Department of Mechanical Engineering, GRIET, Bachupally, Hyderabad, 500 090, India
[b]Department of Computer Science Engineering, GRIET, Hyderabad, 500 090, India
[c]Department of Mechanical Engineering, GLA University, Mathura, 281 406 India

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In recent times, different types of particleboards are being preferred in the construction of houses, partitions, furniture etc. The production of such materials can be manufactured using rice husk, which has been obtained as waste produced in rice millers. Adhesive such as formaldehyde, when exposed to fire, causes toxic flames which are fatal in nature. The basic condition for production of particleboards is to check the temperature and humidity content in the rice husk which has been done by using DHT 11 sensors i.e., application of Internet of Thing (IoT) erected method. This identification helps in finding the suitable temperature through which bio-based adhesives have been prepared. In present study, two different types of bio-adhesives namely tamarind with formalin and tamarind with boric acid has been used in manufacturing process. The application of IoT erected method follows a complex preparation method but will partially fulfil the job and reduces human involvement. Finally, when the proper temperature and moisture level has been measured, the preparation becomes easy. After manufacturing the particleboard, the strength has been tested by a three-point bend test and have been compared with commercially available boards with formaldehyde base adhesive.

Keywords: Particleboard, Bio-based adhesive, DHT 11, Sensor, Moisture, Temperature

1 Introduction

The manufacturing of particleboards involves mixing of wood flakes, jute-stick or any sustainable material with a suitable binder or resin[1]. The characteristics such as light weight, density, and cheaper cost make particleboards best substitute over plywood and conventional wood where strength of the material has been compromised.

Rice Husk is a by-product of rice milling process[2,3], which includes fine particles of rice, dust, and ash of husk. The main components include cellulose (25-35%), lignin (26-31%), silica (15-17%), and some moisture (7-8%)[4]. The rice husk collected has been dried and weighed after continuous subjection to testing until the sample contains no moisture content[5]. In agricultural countries, lots of agriculture residues or biomass wastes, such as rice husk and woods, are produced every year. The world annual production of rice has more than 540 million metric tons[6,7].

The key aspect has the utilisation of rice husk and rice straw has an important source of renewable energy[8] where agricultural countries like India have a lot of rice and its wastes.

Adhesives play a major role in production of wood-based composites. Formaldehyde, urea-formaldehyde, and melamine-modified urea-formaldehyde resins are the preferred adhesives for producing panels for exterior grade[9]. Emissions of formaldehyde, a volatile, colourless gas with strong odour usually employed in manufacturing of building materials[10,11] are known to cause throat and nasal congestions, burning eyes, headaches, and badly effecting upper respiratory system. long term exposure leads to the increasing risk of developing cancer[12-15]. Formaldehyde was reclassified as a known carcinogen from a group 2A suspected carcinogen by the international agency of research on cancer, a division in World Health Organisation[12] By increasing the usage of 'Green' materials, the intense exploitation of resources can be reduced, the amount of formaldehyde content releasing into the atmosphere can be controlled, such that the resources can be utilized in a sustainable manner.

Tamarind *(Tamarindus indica)* otherwise called "Indian date," is a large tree belonging to Fabaceae family having the ability to grow in poor soils due to

*Corresponding author
(E-mail: tanyab@griet.ac.in)

its Nitrogen fixing capability and endurance through long periods of dry season makes them ideal for low input, high yielding trees[16]. Tamarind kernel powder (TKP) is a crude extract of tamarind seeds. The seeds are rich in polysaccharide (~65-72%), glucose, xylose, and galactose units[17,18] The substance forms viscous solutions when dissolved in water due to the presence of polysaccharide gums extracted from plant materials. The other properties of TKP which make it a suitable adhesive are high thermal stability, anti-microbial, anti-inflammatory, and fire retardance.

The DHT11 is an inexpensive temperature and moisture detecting sensor which uses a capacitive sensor and a thermistor resistor to test the moisture content and temperature in the air. It is a simple sensor which do not require any analog pins, shows the results as a digital signal on data pin[19,20].

2 Materials and Methods

2.1 Materials

Rice Husk: Rice husk was collected from the by-product produced in the milling of rice from the millers. This must be carefully filtered, and this filtered husk should be sent for further processing. Before processing it was necessary to find the moisture level in the husk. The temperature was noted, and repeatedly tested till the husk was available in a dry condition. Rice Husk can be dried naturally, but it was time consuming and hence hot blowers can be used to reduce the moisture levels in the husk. After the husk was dried and its weight was measured using weighing scales, it was sent for processing. The initially collected husk was subjected to repetitive testing until the sample contains no moisture.

Tamarind adhesive 1 (TA1): TKP powder was boiled and continuously stirred in water at 80-100°C to form a soft dough. Addition of cold water makes the TKP to swell. Substances like glucose, sodium carbonate are introduced as additives for improving the bond strength and to alter the viscosity, which directly effects the strength and weight of the board. A little amount of formalin was added to inflate the strength like that of a formaldehyde adhesive board. Formalin also helps defend termite attacks as it acts as a disinfectant.

Tamarind adhesive 2 (TA2): In this method, boric acid and phenol were used as additives. The borates improve the adhesives by improving the fire retardancy and viscosity. But the limit of boric acid addition should be monitored since the excessive amounts causes piles to slip over one other. Phenol on the other hand acts as a preservative and results in exterior grades of the boards as shown in below Fig 1.

DHT11 Sensor: DHT11 was a commonly used temperature and humidity sensor. The sensor comes with a dedicated NTC to measure temperature and an 8-bit microcontroller to output the values of temperature and humidity as serial data. The sensor was also factory calibrated and hence easy to interface with other microcontrollers. The sensor can measure temperature from 0–50°C and humidity from 20-90% with an accuracy of ±1°C and ±1%.

2.2 Methodology

Rice husk preparation for processing undergoes the following steps.

Step 1: Initially, large amounts of rice husk was collected from millers.

Step 2: The rice husk was repeatedly tested for moisture and temperature.

Step3: While finding these parameters, lot of strain was taken to put rice husk into proper temperature.

Step 4: If the required temperature was not observed, hot blowers are employed to remove the excess moisture and then retested.

Step 5: DHT 11 Sensor was used for checking temperature and moisture in the husk.

Rice husk will be broadly classified into 3 broader categories based on the temperature and humidity we find results like partially dry, partially wet, and completely wet. While calculating temperature and humidity there will be multiple values for them by taking the average of all the values which we got we can finally conclude that this husk can be used in plywood preparation or not. The demonstration of connections using the sensor and Arduino can be seen in Figs 2 & 3.

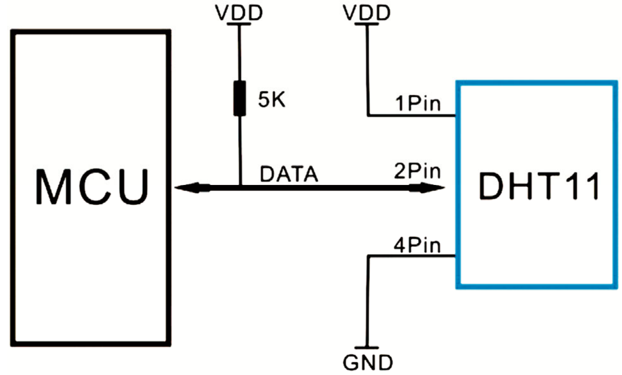

Fig. 1 — DHT11 Sensor pin and setup.

Manufacturing of Particle boards were carried with drying the particles in oven until uniformity in moisture content was observed to be in the range of 6-8%. Prepared adhesive was then manually mixed with the rice husk particles and put into a mould of 29.8cm x 15cm x 1.5cm, hand pressed into the form of a mat. It was later hot-pressed with a warm forming test rig at a pressure of 5 MPa and a temperature of 160-170^{o}Cfor 15-20 minutes.

The prepared panels are cooled and conditioned for several days before the tests are carried out. The boards are trimmed to a size of 16t in length and for t > 6mm width is50mm if t < 6mm width will be 25mm where 't' was thickness of board. The average density of the panels was varied from 594-618 kg/m^3.

2.3 Determining dimensional stability:

Thickness swelling (TS), water absorption (WA) test and density test are performed on the particleboard. Replicate specimens from each type of panels are used for T, WA properties but prior to the tests, the specimens are conditioned in a room at 20^{o}C and 65% relative humidity. The reading for weight and thickness are taken before they are soaked in distilled water for WA, TS tests. After 2 hours of immersion values are noted and after1-day, the specimens are removed from water and measured to the nearest thickness and weight as shown in below Fig. 4.

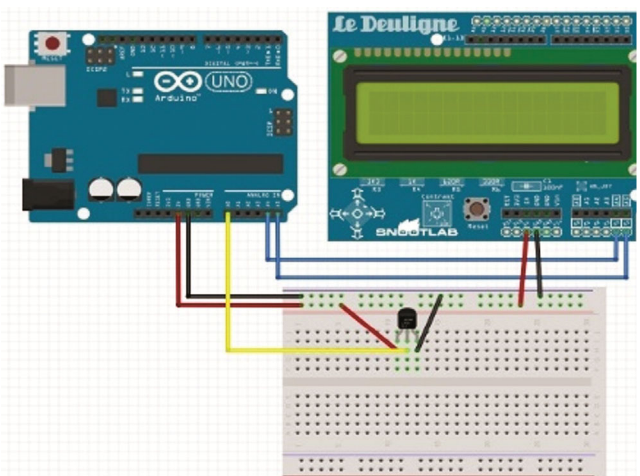

Fig. 2 — Connections with the sensor and Arduino.

2.4 Determining flexural properties:

Modulus of rupture and compression strength are measured in the following tests with three specimens each. MOR was conducted as per the three-point loading method based on the prescribed formula. The specimens are tested at various combinations of temperature and pressures with pressure varying between 10-14bar and temperature ranging from 110-135^{o}C. Employing a UTM, compression test was carried out applying continuous load at the constant rate of 0.5mm per min till failure.

3 Results and Discussion

3.1 Rice husk monitoring

Using DHT 11 Sensor when rice husk samples are partially dry, partially wet, and wet as shown in below Table 1.

The results present show that if the humidity in the rice husk was <20% the this can be further used further in by product preparation.

3.2 Dimensional stability

Particle board's dimensional stability was improved significantly with TKP as core material. TS and WA values of the specimens are less than the values of a formaldehyde resin board, and the reason for lower values was due to the poor bonding between

Fig. 3 — Particleboard prepared with rice husk, TA1, and TA2.

Fig. 4 — Three-point bend test on a particleboard on UTM.

Table 1 — Rice husk results

Partial Dry	Partial Wet	Wet
Temperature: 25.12	Temperature: 25.42	Temperature: 24.92
Humidity: 20%	Humidity: 45%	Humidity: 62%
Temperature: 25.50	Temperature: 25.30	Temperature: 23.58
Humidity: 25%	Humidity: 47%	Humidity: 65%

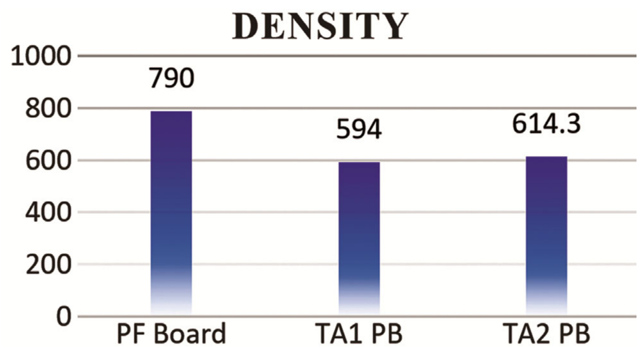

Fig. 5 — Density kg/m^3 for PF board, TA1 PB, TA2 PB.

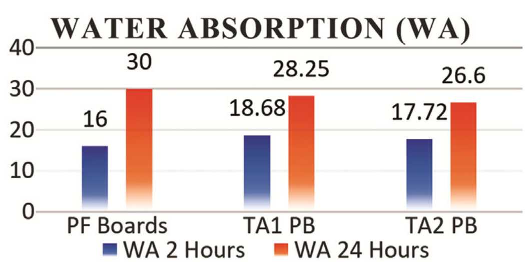

Fig. 6 — Water absorption after 2 hours and 24 hours of immersion of PF Board, TA1 PB, TA2 PB.

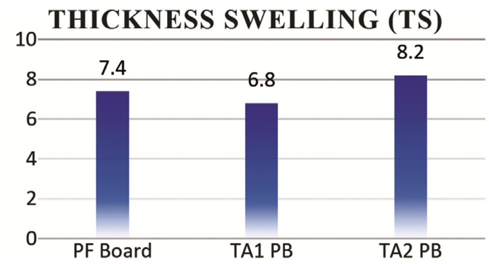

Fig.7 — Thickness swelling for Three kinds of PB.

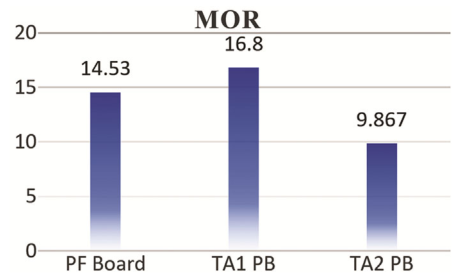

Fig. 8 — MOR N/mm^2 for three types of PB.

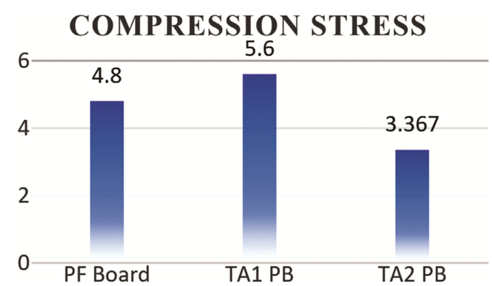

Fig. 9 — Compression strength N/mm^{2}for three types of PB.

the resin and rice husk particles as a result of silica and wax having high buffering capacity[21]. TKP mixed with borates to monitor the viscosity reacts with water repellent cuticle of rice husk and penetrates into the husk forming a few voids[22]. Whereas TKP mixed with formalin showed same results as that of a formaldehyde board but with a few voids in the matrix due to which the results of WA have only slight variation as shown in below Figs 5-9.

3.3 Flexural properties

There was a significant improvement in MOR of the particleboard compared with PF (formaldehyde) adhesive. The PB with TA1 based adhesive showed comparatively better results because of the presence of phenolic groups that enhanced the strength of boards. From, results it can be observed that RH PB's are having lower strength values but are possessing higher values than those of PF PB due to their small length to thickness ratio also called as slenderness ratio. An increase in the ratio results in strong boars with more stiffness. Wax and silica layers reduce interaction between binding materials and particles especially in cases of liquid-based formaldehyde resin boards. The suitable temperature for making boards was observed in 160-170^{o}C range. If the temperature is less than 160, the boards formed are not properly binding, which in turn causes problems with curing of the adhesive. Whilst higher temperatures cause poor finishing of the boards.

4 Conclusion

Based on the findings obtained from the present study, the following conclusions are drawn:

- By using this husk material particleboards have been made but temperature should properly be monitored, and moisture should have been eliminated. The study suggests that these features shown by the materials have been suitable and advantageous for preparation of particleboards.

- Better performance characteristics have been observed from incorporation of TA in particleboards than in PF based boards.
- The drawback of RH particleboards having less commercial acceptance due to low strength and higher requirement for adhesives can be overcome by substituting tamarind kernel-based adhesive.
- An improvement in delamination and wettability properties have been observed when TKP adhesive has been used.
- The particleboard's strength and stiffness can be altered by laminating with laminates which have a sound effect in terms of texture and strength.
- Increased strength of the boards have been suspected with the decrease in viscosity of the resin such that the voids can be filled in gluing surface.
- Resistance to termite and microbial attacks are additional advantages to these strong boards free of carcinogen contents.

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