Characterization and Analysis of Natural Fibre-Rice Husk with Wood Plastic Composites

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Abstract:Natural fibers are renewable materials and have the ability to recycle. But, they are hydrophilic in nature and exhibit poor resistance to moisture. The main associated in developing new composite is adhesion property existing between fiber and matrix which can be enhanced by chemical variation which result in reducing hydrophilic nature. The powder with small particles was preferred since when the size of the particle decreases the intermolecular force adhesion increases. In this research work, matrix involving polyester resin possessing 62.07 of molecular weight (M_w) combined with rice husk (RH) to create an Hybridized Wood-Plastic Composite (HWPC). The impact of contribution of RH, wood powder by both contribution percent and its particle size are evaluated by investing its flexural, tensile and impact properties of HWPC. The investigation infers that by analyzing the percent of RH, wood powder, polyester resin matrix by weight ratio, it is inferred that the wood powder proportion increment increases the tensile property. Meanwhile, after reaching its maximum bar limit, it causes the impact and tensile property to get minimized rate. From mechanical properties analysis it results that high flexural strength can be obtained by smaller RH size utilization where it increases the interaction between RH and wood powder due to reduced voids and cavities which are obtained from the analysis of a scanning electron microscope (SEM) analysis.

Keywords: Natural Fiber, Hybridized Wood-Plastic Composite (HWPC), Rice husk and wood powder.

1. Introduction
Composites have become an integral part of day-to-day life and they can be exploited everywhere. The advanced composite materials based on wood flour gets increased due to its better physical and chemical characterization. Making more inspiration towards the concern of natural fiber rather than carbon fiber to serve as a better reinforcement for developing composite polymers. The wood composites plays vital role in the industrial application for its impacts towards the environment due to its non-abrasive, minimum cost, biodegradability and renewability. Major analysis of wood plastic composite characterization in terms of mechanical and physical behaviour by incrementing the amount of filler in the composition to find out the variation and size nature [1]. The wood composite manufactured with bark materials possess lower water absorbing tendency on comparing with other composite regarding wood [2]. The development of wood plastic composite by incorporating using recycled polypropylene (RPP) plastics along with wood flour through extruded moulding. The analysis study points are comprised about wood flour particle size, mass ratio and further the evaluation concentrating on lubricant and coupling agent adding ratio [3]. The final result revealed that wood-polypropylene composite gets minimized swelling during water absorption by its reduced particle size of 125 µm. The wood flour content added for developing composite gives more impact in mechanical and physical properties such as by 50% it maximizes the mechanical influence but when it exceeds 50% it drastically demotivates the effect of physical and mechanical properties [4]. Examining the recent research trend concentrating on natural fiber and wood plastic composite by predominant motivation of analyzing representation of mechanical filler. By comparing with natural fibre category of glass and carbon fiber, implicates higher value of strength rather than natural and plastic composite.
In modulus, the kenaf along with hemp shows considerable exhibits the same values of glass fiber composite varieties with concontributing factor term of 3 [5].

Conducting experimentation for analyzing the entire properties the composite manufactured using single-wall carbon nanotube (SWCNT) through further addition of wood flour by polymer panel of injection moulding. Further the investigation is made by addition of maleic anhydride grafterd polyethylene (MAPE) material in the case of internal mixer ratio. The composite developed using carbon nanotubes with bondage of anhydride polyethylene exhibits highly improved rate of mechanical properties and panel with rate of 2 results in higher impact strength property. Through Scanning Electron Microscope (SEM) micrographs results infers that the existence of voids are overlapped and also carbon nanotubes with polyethylene provides better reinforcement by higher interaction [6]. Comparative studies between natural plastic and natural fibre with polyester resin composite by testing and understanding the mechanical behaviour variations. In that analysis, the hemp and sisal combined with polyester resin formed composite results in better material properties in the case of fibre weight associated fraction and its combination gives better mechanical properties on comparing with other natural fibre composition combinations[7].The natural fiber composite by reinforcement on regarding tensile strength by considering thermosets and thermoplastics. It exemplifies that the interfacial adhesion gives higher bonding rate when matrix and fibre gets interrelated. The main demerits associated with this is implementing natural fibre as an reinforcement in plastic composite preparation offers reverse flowchart of very low tensile strength rate resulting very poor adhesion when natural fibre and matrix gets correlated. Investigation on composite involving sisal and coir fibre associated with epoxy resin to serves as matrix for this combination and its mechanical along with physical properties are analysed by considering material with variation in length and volume of fire contributed [8]. The hand-lay methodology is implemented and the result confirmed that 20% contribution both sisal and coir fibre with the length of 3mm shows much enriched mechanical behaviour than other composite contribution rate in performance analyses of impact, flexural strength during testing based on ASME standards. And also obtained that specific properties of the composite can further improved by surface treatment in chemical manner [9].

An analysis of plastic composites with different contribution ratio of fiber with filler and further with epoxy resin and analyzed its impact and hardness to estimate its water absorbent extent property. the result finalized that rice husk with untreated coir fiber provides better water absorption resistant that treated coir fiber combining with rice husk [10]. The mechanical properties of plastic composite combined with rice husk by evaluating its different constituents like percentage (%) of RH and its size with RH hydroxyl groups in the preparation composition. The results shows that the RH % AND RH hydroxyl % increases the mechanical properties but after certain limit of reaching target range, it starts to decrease the characterization of the material. When its ratio of RH gets decreased it increases the tendency of cell wall thickness resulting in increasing the water absorbent and swelling nature of the plastic composite [11].Hence in this present work, hybridized wood plastic composites using Hand Layup process with different composition is produced and on comparing with other conventional resin matrix Polyester serves as predominant economical resins. The choice of this resin as the matrix is attributed to its high values of strength, durability, stability, corrosion resistance, and accelerated processing of the composites. The mechanical behavior of hybridized wood plastic composites like tensile, flexural, impact properties and scanning electron microscopy (SEM) images results are analyzed and it is compared withconventional wood plastic products.

2. Methodology of fabricating hybridized wood-plastic composite (HWPC)

Initially, resin, catalyst, and accelerator were procured, raw materials like wood and rice husk powder, polyester resin are collected based on their structural characteristics. The composite material is then fabricated in two steps. In the first stage, the wood powder and rice husk powder were mixed thoroughly for different compositions. In the second stage, the developer mixture is reinforced with polyester resin.

2.1. Selection of rice husk fiber

Rice husk from paddy (Oryzasativa) serves as a great potential upon organic substances categories.
By conducting thermochemical converting technique, numerous fuels and feedstocks containing high lingo-cellulosic compounds obtained majorly from rice husk. Since rice husks are obtained from paddy, during milling technique nearly the weight contribution of 79% by rice and 21% by husk. These 21% of husk further subjected to firing process where 76% of organic volatile substances are extracted from the rick husk along with husk ash contributes 24% from rice husk compounds on following material processing technique of paddy. The most interesting properties of rice husk is that the amorphous silica content is very high of about 83-89% due to its greater moisture nature of around 7.99 to 11.24% with the density of 90 to 112 kg/m³. The other characterization includes it possess enlarged external surface area with high porosity and light weight characterization Rice husk associated with ash serves as excellent insulator and absorbent and strengthening agent in industrial environmental applications.

2.2. Selection of Polyester resin

Generally polyester resin are unsaturated due to the existence of numerous C=C double bonds formed by maleic anhydride chemically reacting with propylene glycol. The thermoset polyester matrix can be formulated from these polyester resin compounds. In order to breakdown these C=C double bonds existence, the curing is conducted by adding t-butyl per benzoate (tBPB) organic peroxide agent as catalyst in small amount in liquid form. This curing is conducted with the temperature range of 1078 ºC–1638 ºC, due to this high heat prevalence the organic peroxide catalyst decomposes at higher speed into fine radicals. The decomposition of the double bond occurs when this radicals combines with the styrene attached single compounds. Styrene reacted with radical’s further form bond with polyester unsaturated compound resulting development of cross-link chain. Based on the adoption rate of cross chain link bond, the characterization of polyester resin gets varied as solid with hard and soft upon brittle and flexible nature. The polyester resin possess higher curing time with low viscosity. Table 1 enumerates the composition of various resin types associated with the different composite formation.

| Table 1. Thermoset polymers properties applied in natural fiber composites |
|---------------------------------------------|
| Properties | Polyester Resin | Vinyl Ester Resin | Epoxy Resin |
| Density (g/cm³) | 1.1–1.38 | 1.5–1.37 | 1.07-1.31 |
| Cure shrinkage (%) | 4-8 | 5.4-10.3 | 1-2 |
| Poisson’s ratio | 0.38 | 0.351 | 0.32-0.35 |
| Elongation (%) | 2 | 4-7 | 1-6 |
| Izod impact strength (J/m) | 0.14-3.1 | 2.3 | 0.2 |

2.3. Preparation of the composites

2.3.1. Incorporation of hardner in polyester resin

The methyl ethyl ketone peroxide (MEKP) of 1.0 percentage of weight is incorporated with polyester resin as hardner agent by using the mechanical stirrer. Besides accelerator is added to accelerate the reaction.

2.3.2. Physical Treatment of fiber

Rice husk fiber is powdered in a mill. The powered rice husk and wood powder are then dried at room temperature for 48 hours. Then both powders are served using sifter of size 100 microns. For the sample preparation, the most essential procedure is to create the desired mold with proper calibrations. In this research work, steel dies are applied to fabricate the developed new composite specimens. The composite plates are designed by following the conventional hand-lay technique. At first, the steel dies are subjected to coating process on male and female side by releasing agent in order to get the composite specimens easily without ruptures during solidification. After that, the taken specimens are allowed for drying process simultaneously string process is done thoroughly by mixing rusk huak and wood flour with required proportion of polyester resin. During the final stage, this stirred mixture is coated and extended smoothly on which closed mold is applied with compressive pressure during curing technique. The corresponding accelerator and catalyst are taken

- Accelerator (Cobalt Naphthenate)
- Catalyst (Methyl Ethyl Ketone Peroxide)
In this fabrication process, in order to nullify polyester resin the hardner syntheisi the formulation attributed by accelerator accompanied with catalyst in the preparation. The accelerator is considered at 1 wt % and the catalyst is engaged at 1.5 wt % based on the estimation of total weight of polyester resin. The complete fabrication process carried out for making hybridized wood-plastic composite is shown in Figure 1 using Hand-layup process. The composite with different composition wood and rice husk powder are enumerated with its particle size and polyester resin rates respectively in Table 2.

![Fabrication of Hybridized wood-plastic composite using compression molding.](image)

**Figure 1.** Fabrication of Hybridized wood-plastic composite using compression molding.

**Table 2.** Prepared specimens with proportion of resin, wood powder and rice husk.

| S.No | Specimen Code | Particle Size (M) | Polyester Resin (G) | Wood Powder % | Rice Husk Powder % |
|------|---------------|-------------------|---------------------|---------------|-------------------|
| 1    | I             | <425              | 150                 | 80            | 20                |
| 2    | II            | <425              | 150                 | 70            | 30                |
| 3    | III           | <425              | 150                 | 75            | 25                |
| 4    | IV            | <106              | 150                 | 80            | 20                |
| 5    | V             | <106              | 150                 | 85            | 15                |
| 6    | VI            | <106              | 150                 | 90            | 10                |

From Table 2, the hybridized wood–plastic composite is prepared with a particle size less than 425 microns and less than 106 microns with polyester resin matrix of 150 grams. Six specimens of HWPC materials are fabricated with wood as a major dominant component ratio with 70-90 % incorporated with rice husk powder inhibiting lesser amount with a ratio of 10-30% in the entire composite materials formulations.

3. Experimental investigation and analysis

3.1. Evaluation of mechanical characterization

The samples of six different compositions of HWPC incorporating wood powder and rice husk powder varying ineach particle size taken as detailed in Table 2, of eighteen test pieces were subjected to tensile, flexural and Izod impact test in order to analyze the characterization mechanical behavior of the prepared composite. The obtained results regarding the hybridized wood plastic composite are then compared with some of the present wood-plastic products. The properties of present wood-plastic products are shown in Table 3.
Table 3. Mechanical properties of Present wood-plastic products

| Composite                                      | Specific gravity | Tensile Representation | Flexural Representation | Izod Impact energy (J/m) |
|-----------------------------------------------|------------------|------------------------|-------------------------|--------------------------|
|                                               |                  | Strength               | Modulus                 | Strength                  |
|                                               |                  | MPa (lb/in$^2$)        | GPa ($10^6$ lb/in$^2$)  | MPa (lb/in$^2$)           | GPa ($10^6$ lb/in$^2$)   |
| Polypropylene (PP)                            | 0.90             | 28.5                   | 1.53                    | 0.22                      | 38.30                   | 5555                      | 1.19                      | 0.17                      | 20.9                      | 656                       |
| PP with composition of 40% wood flour         | 1.05             | 25.4                   | 3.87                    | 0.56                      | 44.20                   | 6411                      | 3.03                      | 0.44                      | 22.2                      | 73                        |
| PP with added 40% wood flour and 3% coupling agent | 1.05             | 32.3                   | 4.10                    | 0.59                      | 53.10                   | 7702                      | 3.08                      | 0.45                      | 21.2                      | 78                        |
| PP with the added 40% wood fiber              | 1.03             | 28.2                   | 4.20                    | 0.61                      | 47.90                   | 6947                      | 3.25                      | 0.47                      | 23.2                      | 91                        |

3.1.1 Tensile test
The tensile properties of the prepared hybridized wood-plastic composite specimens are determined by the Universal tensile strength testing machine as per the ASTM D638 standards specification with speed of 50mm/min at normal environmental condition is visualized in Figure 3. The HWPC specimens contain thickness of 3mm and length of 165mm with having sufficient width of 13mm when subjected to testing as shown in Figure 2.

The test results reveals that tensile strength of specimen I is increased by 18.2 %, 32.7 %, 4%, 19.5% whereas for II is increased by 14.2 %, 28.1%, 0.7%, 15.4 % and specimen VI tensile strength is increased by 15.3%, 29.3%, 1.7%, 16.5% when compared with values of respective conventional plastic wood composites given in Table 3.So, significant improvement in tensile strength is observed due to dual reinforcement (wood powder and rice husk). Further the tensile strength of specimen IV and III, V are found to decrease by (22.57%) and (6%) due to reduced reinforcing effect of rice husk. This trend is attributed to higher fiber content since the percent of rice husk added is not at an optimum level.

![Figure 2. Tensile specimen](image)

![Figure 3. Specimen subjected to a tensile test in universal loading machine.](image)
Henceforth that the HWP composite exhibits improved tensile strength nature because of the reduction in particle size of wood and rice husk. The surface gets clean and surface roughness is increased which indeed enriches strong adhesion bonding between fiber and matrix. The highest value of tensile strength was obtained for the specimen I (33.70 MPa) as elaborated in Figure 4.

3.1.2. Flexural test
The specimens are put forth for flexural ASTM D790 standard testing of three point method possessing length of 75 mm with the width of 13 mm and finally thickness of about 3 mm correspondingly for evaluation as shown in Figure 5.

From the testing results, it is inferred that the flexural strength of specimen IV is increased by 209 % and specimen V is increased by 171 % than specimen I and II which are increased by 148 % and 138 % in average respectively on comparing with conventional wood-plastic composite flexural values. Specimen IV is found to be increased (by 209%) with flexure of (140.83 MPa) due to incorporation of rice husk with reduced particle size to 100 microns when compared with specimens I, II and III as shown in Figure 6 as Young’s modulus increases with fiber content with strong interaction between surface matrix and accelerator of Cobalt Naphthenate on wood and rice husk.

![Figure 4](image1.png)

**Figure 4.** Tested each HWPC specimens obtained tensile strength values.

![Figure 5](image2.png)

**Figure 5.** Testing specimens with Flexural testing machine setup.

![Figure 6](image3.png)

**Figure 6.** Tested each HWPC specimens obtained tensile strength values.
3.1.3 Izod impact test

The developed composite specimens with dimension of 65 mm x 13 mm x 3 mm as shown in Figure 7 are subjected to Izod impact ASTM D256 standard testing. The Izod impact testing exploits the 25 Joule capacity in which each specimen inhibits desired range of energy during testing. In the standard testing machine, a pivoted arm is enlarged to acquire sufficient constant potential strength and then unconfined from that fixed height elongation. The specimens are subjected to break into little samples by arm striking down which travels with high velocity. The evaluation is done by computing the energy utilized by each specimen from the height where the arms are started to swing in order to hit the specimen. The obtained results are calibrated as energy exploited for every unit of thickness (J/m) and also oer unit area of cross section(J/m²) at the notch. The evaluated results describes that the evaluated specimens IV and V possess same Izod impact strength, in which specimen I is increased by 60% in average, and specimen II is increased by 66.1% when compared with Izod impact strength of last three composites of conventional wood-plastic composites taken in Table 3. So, improvement in Izod Impact strength is due to physical treatment of fiber. Because mercerizing is implemented to enrich the adhesion characterization of fibers into the matrix of the composite.

![Figure 7. Testing specimens with Izod impact testing machine setup.](image)

Figure 7. Testing specimens with Izod impact testing machine setup.

![Figure 8. Test specimens with obtained Izod impact strength values.](image)

Figure 8. Test specimens with obtained Izod impact strength values.

The highest value of Izod Impact strength is obtained for the specimen II (134 J/m) due to the incorporation of rice husk and specimens IV and V Izod impact strength are found to slightly decreasing (14.7 %) due to increase in hardness as shown in Figure 8.

3.1.4 Surface morphology analysis

The SEM analysis has been carried out on the fracture zone of the tensile test specimen for rice husk with hybridized wood composites to study the fiber pull-out and voids. A fiber organization structure with the composite are analyzed at the surface by evaluating Electronic micrographs were taken at the surface of the conventional wood-plastic composites WPC samples as shown in Figure 9.

![Image](image)
Figure 9. Scanning Electron Microscope Image of Polypropylene Wood-Plastic Composite
(A) 100 µm (B) 500 µm

The porous structure of hybridized wood-plastic composite is prevalent due to the presence of rice husk and pectin. The fibers and matrix bonding adhesion is reduced by these impurities. The aggregates establishing tendency evolves due to the mismatch property of hydrophilic nature present in both natural fibers and applied polyester resin matrix. Natural fiber reinforced composites offers poor tensile strength by its more water absorbing tendency. It is because of very less resistant towards moisture due to the existence of hydrophilic fibers. These fiber pull out phenomena are observed in the SEM image exemplifies that the mechanical properties are not improved and its range lies in poor rate.

Figure 10. Scanning Electron Microscope Image of Hybridized wood-plastic composite
(A) 10 µm (B) 50 µm (C) 500 µm

The scanning electron micrograph of the specimen regarding hybridized wood-plastic composite is often not possible to see individual rice husk particles mixed in the polymer matrix. However, the surface properties observed in specimens is an indication of the uniformity of the rice husk and wood powder dispersion. The rough fracture surface exists by the presence of clay particles. The fibers and
matrix correlating adhesion behavior is upgraded and this gives better tensile properties, minimum fiber pull out and voids as shown in Figure 10. The morphological characteristics of the HWPC composite are studied by comparing with the SEM image of the polypropylene wood-plastic composite shown in Figure 9. The inference from SEM images of hybridized wood-plastic composites of tested specimens:

- The wood-plastic composite with rice husk added i.e HWPC has no voids and cavities as revealed in Figure 10(A) compared to wood-plastic composite shown in Figure 9(A).
- The hybridized wood-plastic composite displays smooth morphology at the scale 500 microns as given in Figure 10(C) compared to conventional wood plastic composite shown in Figure 9(B) which displays rough morphology.
- The void and cavities occur in the Hybridized wood-plastic composite only at the scale of 10 microns as displayed in SEM images of Figure 10(B).

4. Conclusions and Future scope

The hybridized wood composites have been prepared at various compositions incorporating wood as a major dominant component ratio with 70-90 % with rice husk as additional constituents of 10-30% ratio possessing particle size of 425 microns and also with 106 microns. The mechanical characterization regarding the hybridized wood-plastic composite of six different specimens are analyzed as per ASTM standards D638, D790, D256. The following inferences are acquired by carrying out experimentation.

- The tensile strength of specimen I have been obtained the maximum value (33.7 MPa) compared to the tensile strength of conventional wood-plastic composites as given in Table 3. By incorporating rice husk in the polyester resin matrix increases the tensile strength to considerable extent.
- By adding rusk husk at the optimum point through hybridization technique, the flexural strength increased by further 12%. Hence, developed composite yields more strength by hybridization than associated with single fiber loading.
- The impact strength of specimen III is obtained maximum (134 J/m) compared to impact strength of conventional wood-plastic composites. The improvement in characterization about the composite properties due to the presence of rice husk in the composite specimen.
- The SEM images of hybridized wood-plastic composite revealed that the addition of rice husk with wood powder reduced the voids and cavities and also the surface roughness get decreased. The main areas of application where this hybridized wood-plastic composites can be used are partitioning and pallets manufacturing.

In future, the fibers of hybridized wood-plastic composites can be subjected to various surface treatment methods other than chemical behavior handling process. The mechanical properties of the hybridized wood plastic composites with rice husk proportion can be improved by adding extra filler materials like coir pith and corn cob.

References

[1] Renard, C.: Injection molding WPC, bachelor thesis, KTH Industrial technology and management, Stockholm, 2011.

[2] Haider, A, Eder, A: Markets, Applications, and Processes for Wood Polymer Composites (WPC) in Europe, Presented at 1st International Conference on Processing Technologies for the Forest and Bio-based Products Industries (2010), http://conference.fhsalzburg.ac.at/fileadmin/files/documents/presentations/4B_Haider.pdf [accessed 11. April 2011].
[3] Haider, A.: The market for injection moulded and extruded WPC products, URL: http://www.plastics.gl/consumer/the-right-mix/ [15. August 2015].

[4] Shoemaker, J.: Moldflow design guide, Moldflow Corporation, Framingham, 2006.

[5] Funke, C., Albring, E., Moritzer, E.: WPC has different filling behaviour, Kunststoffe international 8 (2010), 53 - 56.

[6] Thienel, P., Hoster, B., Bayerl, H., Braun, U.: A mould with a window allows development of the filling pattern for thermosetting molding compound, Kunststoffe 80 (1990) 12, 1346-1350.

[7] Restrepo, J., López, I.D.: Implementation of highly efficient meshless method for the thermal analysis of fountain flow during filling in injection molding, 4SPE ANTEC 2012, Orlando, 2012.

[8] Duretek, I., Friesenbichler, W., Holzer, C.: New insights into characterization of flow properties of PP based wood plastic composites, 26th International Conference of the Polymer Processing Society (PPS 26), Banff, 2010.

[9] Hristov, V., Takacs, E., Vlachopoulos, J.: Surface tearing and wall slip phenomena in extrusion of highly filled HDPE/Wood flour composites, Polymer Engineering and Science, 46 (2006) 9, 1204 - 1214.

[10] Sina, L.T., Rahmanb, W.A.W.A., Rahmatb, A.R., Teea, T.T., Beea, S.B., Yua, and L.C.: Computer aided injection moulding process analysis of polyvinyl alcohol–starch green biodegradable polymer compound, Journal of Manufacturing Processes 14 (2012), 8–19.

[11] Bociaga, E., Jaruga, T., Experimental investigation of polymer flow in injection mould, Archives of Materials Science and Engineering 28 (2007) 3, 165 - 172.