

## Wood Plastic Composite

Rajiv Raj S, Tarun Subramanian, Shashaank Yogesh\*, V.E Annamalai

Department of Mechanical Engineering, SSN College for Engineering, Chennai – 603 110

\*Corresponding author: E-Mail:shashaank13094@mech.ssn.edu.in

### ABSTRACT

Wood plastic composites (WPC), in a conventional sense, consists of wood elements combined with polymers. In this paper, the composite consists of wood flour, thermoplastics, coupling agent, lubricant and mineral filler. The paper presents a review on the current state-of-the-art in WPC's. This paper further highlights the methodology used in the manufacture of WPCs. The studied WPCs were extruded using a twin-screw extruder and injection moulded using recycled wood flour and polypropylene and mineral filler. The paper studies the effect of variation of composition of the wood plastic on the physical and mechanical properties of WPC. Furthermore, the feasibility of the composite as a 3D Printer Fused Deposition Modelling Material was developed. The composite developed showed lower density, lower water absorption values compared to ABS, Nylon 66 and Durus RGD 430.

**KEY WORDS:** Wood Plastic Composite, Mineral Filler, Talc, Mechanical Properties, 3D Printing, Additive Manufacturing.

### 1. INTRODUCTION

Environmental issues and sustainable development have driven the popularity of Composite materials over the past 15 years. Limited wood resources has led to shortage in supply of wood. Therefore, there is a pressing need to recycle wood waste to a more useful form. WPC materials consists of a thermoplastic matrix reinforced by lignocellulosic component. However, they can contain a variety of additional elements to improve their physical and mechanical properties. Wood is the most common source of the lignocellulosic element in WPCs. Using wood as a filler material poses some disadvantages. The processing temperature must be lesser than 210. (Below thermal degradation point) The incompatibility resulting from hydrophilic wood fillers and hydrophobic polymers. This leads to increased moisture absorption due to the presence of hydrophilic wood fillers. Wood Flour (WF) contains cellulose, hemicellulose and lignin. These contain hydroxyl groups which can form hydrogen bonds with water molecules, which can increase the water absorption. Due to increased water absorption, there is a greater possibility of formation of micro cracks resulting from poor bonding. (Li, Xiang et.al 2014) There are certain methods that can be used to improve the physical and mechanical properties of WPCs. They include heat, sodium hydroxide, Silane and acetylation treatments to the WF. Another method to improve the physical and mechanical properties is through the process of hybridisation. In this process, two or more type of filler materials are used to reinforce the thermoplastic matrix. By hybridisation, one type of filler material can compensate for the disadvantages presented by the other filler material. Careful optimisation of the composition as well as processing techniques can result in a material that can meet economic and practical requirements (Kord, 2011). Mineral fillers such as Talc, Calcium Carbonate, Mica, Kaolin can be used in addition to the wood flour in the manufacture of WPCs. Talc was chosen as the mineral filler as it posed the highest capability of bending strength (Huuhilo, 2010). WPCs have been initially used for decking and non-structural applications in construction such as railings and door frames but in recent times they have been developed for applications including automotive interiors and garden products (Maiju Hietala, 2011). The objective of this study is to investigate the effect of Talc as a mineral filler on the physical and mechanical properties of wood based composite. The secondary objective of this study is to investigate the application of Wood Plastic Composite as an Additive Manufacturing material. The composition of zinc stearate and MAPP were held constant at 1% and 4 % respectively while the wood flour was varied from 10-30% and Talc from 5-20%.

Over the past ten years, the additive manufacturing industry has grown immensely. Presently there is a need for "green" composites to meet the need of recyclability. The secondary objective of this study is to investigate the application of Wood Plastic Composite as an Additive Manufacturing material.

### 2. MATERIALS AND METHODS

**Materials:** Pine wood flour (degradation temperature= 210°C and 120 Mesh Size) sawdust was used as the filler material in the experiment. Pine wood flour form was chosen for this experiment due to the increased commercial availability. Wood flour consists of small wood particles of aspect ratio typically between 1 and 5. Polypropylene in the form of granules (properties of PP) was used as a matrix polymer. Maleic anhydride grafted with polypropylene (MAPP) (Melt Flow Index of 10g/10min (190 °C) and melting point of 167°C) as coupling agent between hydrophilic saw dust and hydrophobic polypropylene, Zinc stearate lubricant to reduce friction and talc were used as mineral filler.

**Preparation and Methodology:** Uniform grain size of sawdust was obtained by meshing it approximately in the range of 120 microns. To establish moisture free content from the meshed saw dust and polypropylene granules, it was heated in an oven at a range of 110-120 °c for about 24 hours, well below the degradation temperature of saw dust. Moisture content in the mixture would account for the loose bonding between sawdust and the polymer, hence

this step was mandatory. The manufacturing of the wood plastic composite was established through three processes namely, profile extrusion using twin screw extruder, grinding of extruded material into pellets and finally injection moulding of the pellets into various test specimens. Right before manufacturing, WPC mixtures were weighed and stored in air tight packets. The table below shows the various proportions of the mixtures:

**Table.1. Composition of prepared samples**

Sample	% of pine sawdust (Wt %)	% of polypropylene granules (Wt %)	% of MAPP (Wt %)	% of Talc (Wt %)	% of Zinc stearate (Wt %)
Sample 1	15	71	3	10	1
Sample 2	20	71	3	5	1
Sample 3	25	71	3	0	1

A co-rotating twin screw extruder (L/D Value=40) from Central Institute of Plastic Engineering and tools (CIPET), Chennai was used as the compounder. The WPC mixture was fed into the hopper of the twin screw extruder to induce the extrusion process and later the rate of feeding was increased for uniform extrusion. The die temperatures in the 5 zones from the hopper to the die were 160 °C, 165 °C, 170 °C, 175 °C, 180 °C respectively. The screw rotation was set at 55 RPM. The compounded wire was then grounded using a metal cutter to form pellets. The pellets were dried at 80 °C for 8 hours to remove any additional moisture. Then the pellets were injection moulded at temperature 180 °C and pressure 4 MPa using an injection moulding at CIPET.

The WPC pellets were moulded into various test specimens namely tensile test specimen, Water absorption test specimen, flexural strength test specimen according to ASTM D 7031 standards. Flexural and tensile strength tests were performed according to ASTM D790 and D638 standards respectively. Scanning Electron Microscope (SEM) pictures were using a Vega3 Tuscan Scanning Electron Microscope operating at 10 kV.

### 3. RESULTS & DISCUSSION

**Mechanical Properties:** In this study, the effect of different concentration of sawdust on the wood-plastic composites was examined. The above table shows the variation of Tensile Strength as a function of varying wood flour composition. It has been observed that the flexural strength remains constant when the composition of wood flour is increased from 15% to 25% and reducing Talc content from 15% to 0% whereas the tensile strength increases. Thus, we observe that a change in the talc content has an effect on the Tensile Strength of the wood polymer composition. The Flexure Strength was calculated using the formula,

$$\sigma = \frac{3PL}{2bd^2}$$

Where,

$\sigma$  = stress in the outer fibres at midpoint, MPa

P = load at a given point on the load-deflection curve, N

L = support span, mm

b = width of beam tested, mm

d = depth of beam tested, mm

From the above table, we can infer that the density of the various compositions of the WPC prepared are lower than the density of the reference materials namely, ABS, Nylon and Resin. These are the most common material that are used for 3D printing.

**Physical Properties:** The density and water absorption of the WPC samples were measured. One of the major issues regarding the application of WPCs is the water absorption. This characteristic can ultimately decide the nature of applications of WPCs. The major reason for water absorption in WPCs is due to presence of hydrogen bonding in the WF and gaps in the matrix and reinforcement material. Fig 3 & Fig 4 shows the variation of water absorption percentage as a variation of increasing WF and decreasing Talc percentage. The water absorption increases from 0.03% to 0.04% when the WF increases from 15 to 20 % and Talc reduces from 10 to 5% respectively.

The sample was dried for 24 hours and it was weighed using a balance meter. Then it was immersed in distilled water at 23 °C for 24 hours and the sample was weighed again. The difference in weight in percentage is expressed as water absorption.

The percentage of water absorption was calculated by

$$\% \text{ of water absorption} = \frac{W_2 - W_1}{W_1} \times 100$$

Where,

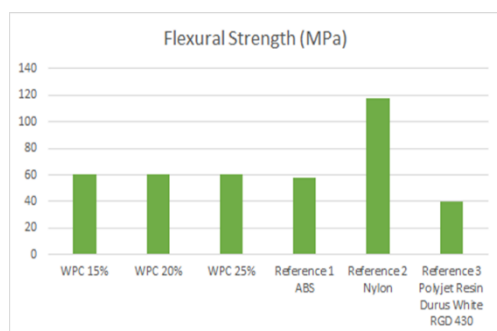
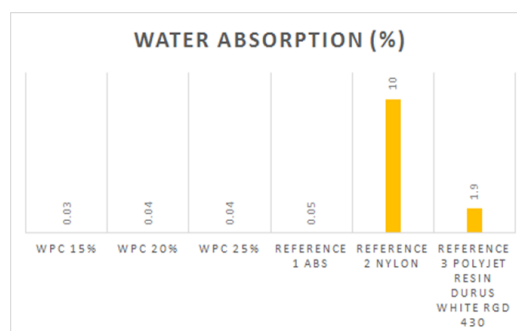
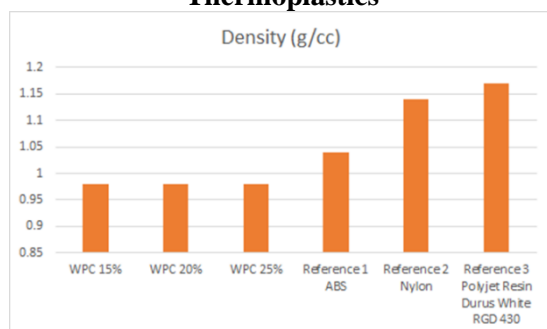
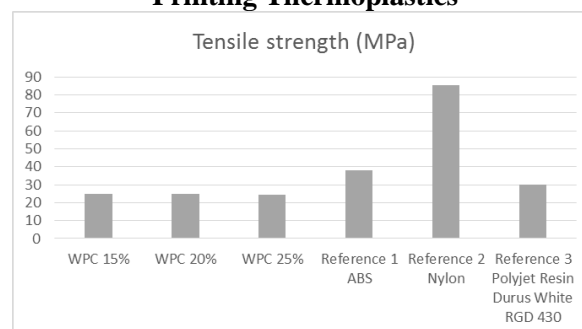
W1 = Weight of the oven dried composite before test being conducted

W2 = Weight of the composite after the water has been absorbed.

The table below shows the results acquired after testing the WPC samples.

**Table.2. Comparison of Physical Properties of prepared samples and reference 3D printing materials**

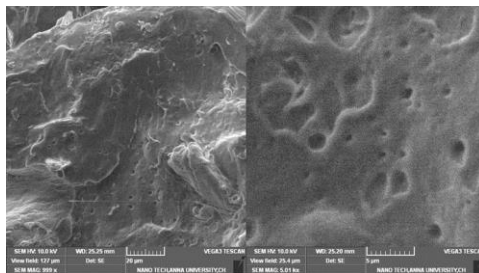
Material	Density (g/cc)	Water Absorption (%)	Flexural Strength (MPa)	Tensile strength (MPa)
Sample 1	0.98	0.03	60	24.99
Sample 2	0.98	0.04	60	24.93
Sample 3	0.98	0.04	60	24.31
Reference 1 ABS	1.04	0.05	58	33
Reference 2 Nylon	1.14	10	118	85.5
Reference 3 Polyjet Resin Durus White RGD 430	1.17	1.9	40	30

**Figure.1.Effect of addition of mineral filler in Flexural strength in WPC and comparison with 3D Printing Thermoplastics****Figure 2: Effect of Addition of mineral filler on Density in WPC's and comparison with 3D Printing Thermoplastics****Figure 3: Effect of Addition of mineral filler on Density in WPC's and comparison with 3D Printing Thermoplastics****Figure 4: Effect of Addition of mineral filler on Tensile Strength in WPC's and comparison with 3D Printing Thermoplastics**

The tables and the graphs below shows the results acquired after testing the WPC samples. The mechanical and physical properties of WPCs change with change in wood flour composition in the composite. It has been observed that the water absorption of WPC test samples is much lesser when compared to other thermoplastic 3D printing materials. Additionally, the density is also less when compared to other reference materials. It is safe to assume that the inclusion of talc as a constituent has reduced the water absorption in the WPCs samples. Maleic anhydride Polypropylene (MAPP) from references has proven to improve the interfacial interaction and bonding in WPCs. The addition of MAPP with an optimal level of 3% and talc, as expected, has produced a combined effect of decreasing the water absorption.

**Interface Morphology:** The SEM images of the prepared samples are presented in the figure below. The SEM images are shown in figure.5. The magnification of the image was varied from 30x- 5000x wherein 1mm to 5µm are visible respectively. In this paper, only one sample is shown due to similarity in images with other samples. Figure.5, shows the SEM image in 999x and 5000x of Sample 3 respectively. It can be noted that sample 3 contains no talc mineral filler.

In figures.5, it can be seen the porosity is very low. The lack of pathways for moisture is indicative of the low water absorption values obtained in the results. Low porosity of the composite results from better interfacial adhesion caused by the coupling agent, MAPP.



**Figure.5. SEM Image of Sample 3 in 999x and 5000x magnification**

#### 4. CONCLUSION

One aim of the study was to develop an environment friendly composite made from Wood, Polypropylene, MAPP, Talc & Zinc Stearate. The physical and mechanical properties was studied and the results showed increase in tensile strength with increase in mineral filler percentage as expected. Another aim of the study was to investigate the feasibility of the wood plastic composite as a 3D Additive Manufacturing material. The study revealed that the composite developed in this paper has lesser density values and greater flexural strength than the conventional ABS thermoplastic used in Fused Deposition Modelling and PolyJet Printers. The composite showed lesser water absorption values than commercially available ABS, Nylon and Durus RGD 430.

**Future Work:** In this study the feasibility of the composite developed as a 3D printer Fused Deposition Modelling material was proved. Further work includes thermal analysis and fabrication of the wood plastic composite filament and subsequent testing in a 3D Printer.

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