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Experimental Investigation of Thermal Properties of Wood Polymer Composites

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Abstract
In the present work, the thermal properties of the waste wood powder filled epoxy composites investigated. The results of various characterization tests are reported here. This includes evaluation of thermal Conductivity, Specific Heat, and water absorption test, co-efficient of thermal expansion, thermo gravimetric analysis and differential scanning calorimetry studied and discussed. The interpretation of the results and the comparison among various composite samples are also presented.
Keywords - Pupae-biodiesel, Mechanical Direct Injection, Piezoelectric Direct Fuel Injection.

1. INTRODUCTION

The wood substance itself is a complex, three-dimensional, polymer composite made up primarily of cellulose, hemicellulose, and lignin. Wood is a natural polymer based on the cellulose chain. It can be also considered as a natural composite material with a hierarchical architecture, where cellulose, hemicellulose, and lignin form cellular microstructures [1-6]. Wood is a lignocellulosic material made up of three major constituents (cellulose: 42–44%, hemicelluloses: 27–28%, and lignin: 24– 28%) with some minor constituents (extractives: 3–4%) [7]. the cellulose forms the frame of the cell wall hemicelluloses and lignin on the other hand, form the surrounding intercellular substance. Cellulose and hemicelluloses are hydrophilic chain polymers that have hydroxyl groups.

The thermal properties of wood plastic composite are equally important as mechanical properties. In turn the mechanical properties of thermoplastic are dependent on the thermal properties. Product designers and material selection of wood plastic composites constantly face the challenge of selecting suitable composition for elevated temperature. Wood Plastic composites are used over a wide range of temperatures, effect of temperature and impact of types of loads over a long service time on the thermal properties should be established before a material can be used for a particular product application. Considering the mechanical and thermal properties of composites, they are anisotropic in nature. This behavior of the material also causes development of huge thermal stresses due to thermal gradient across the section [8-9]. This problem emphasizes the necessity of knowledge to understand the thermal behavior of wood polymer composites. Akpabio et al. [2] studied the thermal properties of some palm fibers and established that oil and raffia palm fibers are good thermal insulators. The present chapter deals with the detailed experimental investigation of thermal properties of wood polymer composites under varied proportion of waste wood flour with epoxy resin.

1. THERMAL PROPERTIES

1.1 THERMAL CONDUCTIVITY TEST

Thermal conductivity test setup is shown in fig.1 used for testing of wood epoxy composites. Fig.2 shows the test specimen. An aluminum plate of ϕ140 mm is placed over a heating plate containing the heating coil. Test specimen is kept on the aluminum plate. The cooling plate which is cooled by water is kept over the test specimen. All these parts are clamped with the help of bolts and nuts to the wooden plate such that air gap is avoided between the specimen, heating and cooling plates. The heating coil is connected through wattmeter to power supply. Input can be controlled by dimmerstat. After proper connections were made the power supply was switched on, then readings T1 and T2 were taken when the steady state was reached.

Fig 1. Pupae Biodiesel

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Fig 2.Thermal conductivity test setup

1.1 SPECIFIC HEAT TEST

The Fig.3 shows the test specimens. Experimental set up for the determination of specific heat is as shown in Fig.4. A thermocouple is placed at the center of sphere during casting. The mould is placed on vibrator and material is compacted for about 4 minutes duration. Hydraulic oil is poured into the stainless steel container placed on electric heater. The leads of the thermocouple are connected to the multimeter and the specimen is immersed in oil then electric heater is switched on and oil temperature is brought to 60oC. This temperature is maintained constant by proper stirring of the oil and controlling the heat input through switching on and off the electric heater. Time elapsed for every 0.2 mV change in multi meter reading is recorded until steady state is reached. Fig.5 Centre line Temperature variation of 30% wood content.

Fig 3. Test Specimens

Fig 4. Specific heat test set up

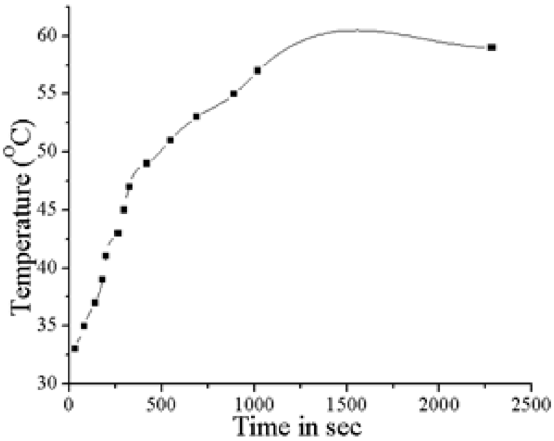

Fig 5. Centre line temperature variation of 30% wood content

1.1 MOISTURE ABSORPTION TEST

Water absorption test is conducted to determine the amount of water absorbed under specified conditions for wood polymer composites. The specimen geometry is shown in Fig.6 (All dimension in mm) .The test is conducted as per ASTM Standard D570-98. The test setup is shown in Fig 7

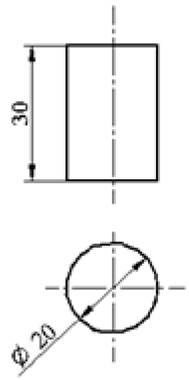

Fig 6. specimen geometry

Fig 7. Test set up

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1.1 HOT BOILING TEST

This test mainly concentrates on the behavior of the wood polymer composite under elevated temperatures. This test determines the sustainability or the usages of the composite material under high temperatures. Wood composite is said to have good service temperature characteristics, due to this the wood powder composite behaves well under elevated temperatures. The specimen was prepared as per the ASTM Standard D1042-06 for the test. The test setup is shown in Fig 8.

Fig 8.Test set up of Hot Boiling Test

1.1 CO-EFFICIENT OF THERMAL EXPANSION TEST

Experimental set up to determine the coefficient of thermal expansion is shown in Fig 9. It consists of a steel vessel to accommodate the specimen. The specimen is supported in the bore which is provided to a circular plate. This circular holder is placed at the bottom of container. It is ensured that it holds the specimen tightly. The specimen is held in such a way that it is absolutely free to expand without any resistance from the top side i.e. free end. Oil is poured in to the vessel and heated to a particular temperature by keeping an electric heater in the vessel. The oil bath temperature is maintained constant by stirring the oil frequently and switching on and off the heater when the temperature exceeds the required value. The temperature of the oil is recorded by the thermometer inserted in to the oil.

Fig 9. Experimental setup

1.1 THERMO GRAVIMETRIC ANALYSIS

The sample holder is rigidly attached to the end of the balance arm in the horizontal configuration and there is no added mass due to a suspension harness. In the top loading arrangement the suspension arm must be rigid with a weight below to keep it vertical. This added mass reduces the total mass range available for the sample. Suspension below the balance may be less rigid and does not require the compensating weight and thus detracts less from the available range. Note that top - and bottom loading instruments have a vertical orientation while the side loading TGA has a horizontal orientation. Fig 10 shows the experimental setup of TGA.

Fig 10. Thermo gravimetric analysis setup

1.1 DIFFERENTIAL SCANNING CALORIMETER

Differential scanning calorimetry is the technique in which the heat flux (power) to the sample is monitored against time or temperature while the temperature of the sample in a specified atmosphere is programmed. In practice the difference in heat flux to a pan containing the sample and an empty pan is monitored. The instrument used is a differential scanning calorimeter or DSC. The DSC is commercially available as a power-compensating DSC or as a heat-flux DSC.

1.1 RESULTS AND DISCUSSION

From the Fig 11 it is evident that with the increase in the wood content there is decrease in the thermal conductivity of the wood epoxy composites. The 30% composition has exhibited the highest thermal conductivity of 0.2183W /m K. The 50% composition shows the lowest thermal conductivity of 0.145 W / m K.

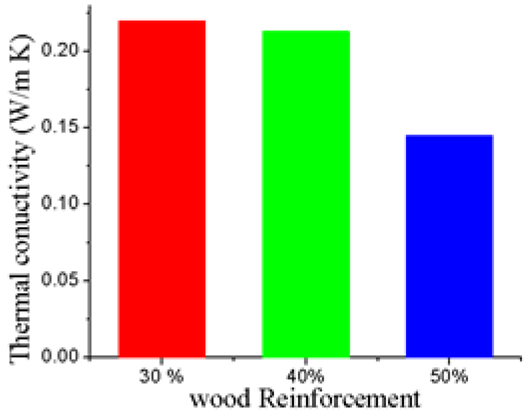

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Fig 11. Variation of thermal conductivity with wood content

The Fig 12 shows that 30% of the wood content has exhibited the highest specific heat; where as 40% have shown slight decrease in the specific heat. As the wood content increases the specific heat decreases gradually.

Fig 12. Specific heat v/s reinforcement percentage

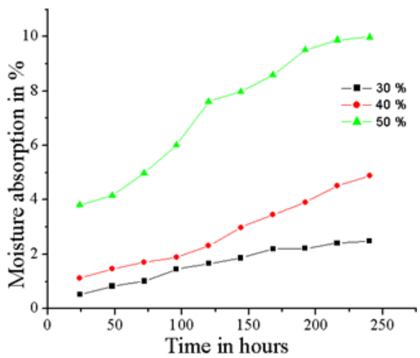

Fig 13. Variation of moisture absorption with time

The graph is plotted showing the moisture absorption of the specimen of various compositions of wood in Fig 13. By seeing the above graphs it is clear that the water absorption capacity increases with wood composition. For all percentage of wood in composite the absorption rate is very high during the first 24 hours and after that it varies in small proportion. So this is highly suitable for application where less water absorption is needed. The graph for 50% wood reinforcement has a steep rise so this shows that as the wood percentage is more the water is absorbed in more capacity. Similarly the graph of 40% WP reinforcement lies in between 30% and 50% graph. From result we can conclude that the material with the higher wood powder content would absorb more moisture.

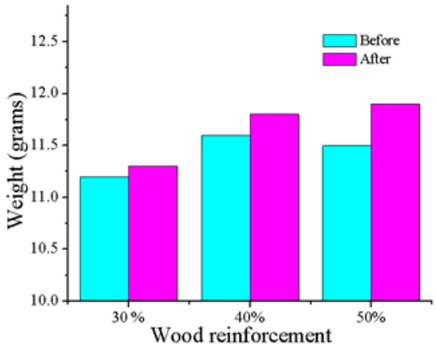

Fig 14. Results of hot boiling test

From this Fig 14. it was observed that the water percentage absorption of 30% and 40% is small as compared to 50%. This shows that the moisture percent absorption is more in case of higher wood powder reinforcement. This test determines the dimensional stability of the composite in water. From this it was concluded that for the applications related to water, lower percentage of wood reinforcement should be used.

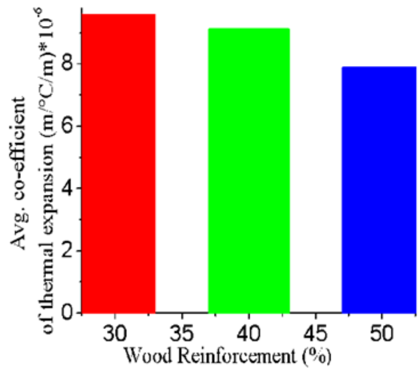

Fig 15. Variation of Average co-efficient of thermal expansion with wood reinforcement

It can be seen from the Fig. 15 that 30% wood filled composite has higher linear expansion as compared to 50%. This is because the linear thermal expansion of the resin is higher than wood. Increase in epoxy content results in the higher thermal expansion of wood polymer composites. From the results it is advisable to prefer 50% of wood polymer composite which yields lower thermal expansion. Thus it can be concluded that less percentage of epoxy resin in composite is preferable in hot condition.

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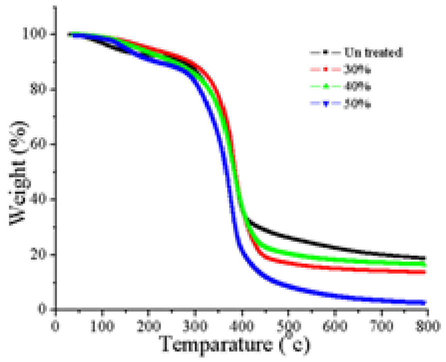

Fig 16. TGA thermographs wood polymer composites

Fig 16. Shows the TGA thermographs of wood polymer composites. It was evident that there is gradually decrease in weight with increase in temperature. There is sudden weight loss from 85% to 20% in the wood polymer composite for variation in temperature from 350 to 400°C. After reaching 500°C the percentage of weight loss remains constant.

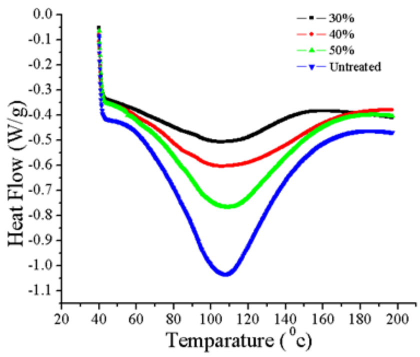

Fig 17. DSC of wood epoxy composites Fig 17 shows the DSC of the samples.

The melting temperature was started from 104.97 °C for 30% and gradually increased from 106.10 °C for 40% to 108.85 °C for 50%. The melt enthalpy was found to be very less around 38 J/g for 30% of wood reinforcement and increases with the increase in wood reinforcement. The melt enthalpy was found to be maximum around 124 J/g for 50% of wood reinforcement.

3. CONCLUSION

The thermal properties of waste wood polymer composite were estimated experimentally. The observation were made and discussed below.

- There is an increase in thermal conductivity, co-efficient of thermal expansion and specific heat with increase in epoxy resin content of waste wood epoxy composition. The 30% of the wood content has shown better thermal properties compared to other composition.
- Wood epoxy has shown very less affinity towards water. The moisture absorption rate increases with the increase in the percentage of wood content. The 30% of the wood content has shown better moisture resistance properties compared to other composition.
- From thermogravimetric analysis it was observed that the degradation of untreated waste wood was started around 210°C. While 30%, 40%, 50% wood polymer composites started at 237.82°C, 230.91°C and 233.87 °C respectively. The weight residue after 500°C in untreated waste wood fiber was found to be 22.05% and has gradually decreased for different wood epoxy composition.
- From differential scanning calorimetry analysis the melt enthalpy increases with the increase in the percentage of wood content. The 50% of wood content has shown better melt enthalpy, compared to the other composition.

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