IOSR Journal of Applied Physics (IOSR-JAP)
e-ISSN: 2278-4861.Volume 9, Issue 3 Ver. I (May. – Jun. 2017), PP 14-17
www.iosrjournals.org

Variation of Bulk and Particle Thermal Properties of Some Selected Wood Materials for Solar Device Applications

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Abstract: *The study examines the variation of thermal properties of bulk and particle of three different wood species: Pterygota macrocarpa, Milicia excelsa and Celtis philippensis of the families of Sterculiaceae, Moraceae and Ulmaceae. The particle samples were moulded to appropriate disc shape using modified hydraulic press mould while the bulk samples were turn into disc shape using circular saw machine. The results showed that thermal conductivity of the selected wood materials changed with particle sizes. Bulk samples have higher thermal conductivity values than the particles for all the wood species. Among the particle sizes, 300 μm has the highest thermal conductivity value compared with 600 μm and 850 μm respectively. It was established in the research that the thermal conductivity of wood materials in the study ranged between 0.0855 -0.3150 Wm^{-1} $K^{-1}$for particle sizes and 0.2130-0.4298Wm^{-1} K^{-1} for bulk samples. The wood samples for the specific particle sizes exhibit low thermal conductivity that is comparable with materials used as industrial insulators. Within the limit of this research, all the particle sizes considered potent better thermal insulators compared with bulk wood materials.*

Key Words: *Wood materials, thermal conductivity, solar device, Lee's disc.*

I. Introduction

Thermal insulating materials have been found very useful especially in energy storage system to minimize heat loss. The choice of insulating material to be used in an energy storage system is greatly dependent on the thermal properties such as; thermal conductivity, resistivity, diffusivity, absorptivity and specific heat capacity. The cost and availability of the material also need to be considered before selecting an insulating material (Ayugi *et al*. 2011).There are several insulating materials in various forms like calcium silicate, mineral fiber, fiber glass, polyurethane, polystyrene, perlite, rock wool e.t.c.These materials are always in use due to their low thermal conductivity. However, increasing demand for the use of industrial thermal insulators as well as cost and health implication of such materials necessitate the search for alternative thermal insulating materials. Hence, materials with low value of thermal conductivity comparable with the existing industrial insulators are of global interest. Natural products such as cotton wool, clay, sawdust, rice husk among others found to exhibit low thermal conductivity values are also useful as solar device materials (Oluyamo and Bello, 2014).

The use of wood and wooden materials cannot be over emphasized. Various researches had been carried out on these materials at different stages and conditions. Bulk and particle from different wood species had been noted to exhibit varying interesting thermal conductivity values (Ogunleye and Awogbemi, 2007; Oluyamo and Bello, 2014). This suggests that thermal conductivity of wood vary from species to species. Thermal conductivity is an essential attribute when offering energy conserving building products. Thermal properties are strongly influenced by the structure of the material, size, porosity, moisture content, density, presence of defect, temperature and pressure and other factors (Ayugi *et al*. 2011). Until recently, studies in available literature had only focused on the thermal properties of wood bulk materials. However, research on particle properties had shown some major differences from their bulk materials of the same wood. Hitherto, no definite variation had been established between the bulk and particle thermal properties of wood materials. In this study therefore, attention is focused on the variation of bulk and particle thermal properties of some selected wood materials. The device applications of these materials will also be examined.

Sample Preparation and Experimental Method

The materials that were used in the study include three different types of wood species of the families of *Sterculiaceae*, *Moraceae* and *Ulmaceae* found in the rainforest region, South Western Nigeria. The wood samples were collected from different sawmill in Akure South Local Government Area of Ondo State, South Western Nigeria. Some of the wood materials were machined to the same diameter of the lees' disc using circular saw machine and the rest were shaved into particle dust. The samples were oven-dried at 50°C for 40minutesto avoid redistribution of water under the influence of temperature and to have loose particles for proper moulding. A mechanical test sieve shaker was used to sieve the particle dust using different mesh sizes: 300 µm, 600 µm and 850 µm respectively. The surface of the bulk samples were smoothened for good thermal contact and sawdust were also compressed into circular disc's shape using a modified hydraulic press mould.The basic apparatus used was a modification of the standard Lees' disc method for the measurement of thermal conductivity by the absolute plane parallel plate technique. This method, in its classical form, utilizes a steam chest to provide a temperature of 100°C on one side of the sample and subsequently cooling measurements in order to calculate the heat flow through the sample (Duncan and Mark, 2000). However, the equipment used for this research work uses electrical heating without the need of cooling measurement. The details of the experimental procedure can be found in the literature (Griffing and George, 2002). The value for thermal conductivity (λ) of each sample of thickness (*d)* and radius(*r)* given by (Griffing and George, 2002; Oluyamo *et al*. 2012; Oluyamo *et al*. 2016) was estimated using the relation.

$$\lambda = \frac{ed}{2\pi r^2}\left[a_S\left(\frac{T_A + T_B}{2}\right) + 2a_A T_A\right] \qquad 1.$$

where e is given by

$$e = \frac{IV}{\left[a_A T_A + a_S\left(\frac{T_A + T_B}{2}\right) + a_B T_B + a_C T_C\right]} \qquad 2.$$

where a_A, a_B, a_c and a_S are the exposed surface areas of discs A, B, C and the specimen respectively. T_A, T_B and T_C are the temperatures of the discs A, B and C above ambient.

II. Results And Discussion

The results of the analysis are presented in Figure 1-3. The thermal conductivities of the sample for all the wood species considered are plotted against wood samples.The Figures shows the variation of thermal conductivity of bulk and particle of different sizes of wood materials. Significant variation in thermal conductivity value of the same wood species as the particle sizes changed was noticed in the study with *Celtis philippensis* having the highest thermal conductivity value. Although, this is expected since decrease in particle sizes leads to increase in thermal conductivity. In addition, variation could also be due to the fact that *Celtis* families usually have their grains aligned and interlocked (Ken, 2014). Among the particle sizes, 300 µm has the highest thermal conductivity value compared with 600 µm and 850 µm respectively. This could be due to decrease in porosity as the particle size decreases. As sample particle size decreases, thermal conductivities increase as a result of the reduction in the intermolecular distance between the grains in wood materials. This agrees with previous research (Oluyamo and Adekoya, 2015). The result of the analysis revealed that the thermal conductivity of sawdust samples of the same wood material considered is lower compared with their bulk wood materials. This could be due to the fact that bulk wood samples already contain all the particle sizes which might help in filling up the pores, thereby creating opportunity for more contact between the grains in the sample. Table1contains the result of the thermal conductivity of different wood materials considered. It was revealed that almost all the samples have their highest thermal conductivity at 300 µm with *Celtis philippensis* recording the highest thermal conductivity value of 0.3150Wm^{-1} K^{-1}and *Pterygota macrocarpa* having the least thermal conductivity value of 0.1294Wm^{-1}K^{-1}. At 850 µm, *Celtis philippensis* also has the highest value of thermal conductivity 0.2841 Wm^{-1}K^{-1} and *Pterygota macrocarpa* has the lowest thermal conductivity value 0.0855 Wm^{-1}K^{-1}. The values obtained for all the particle sizes for the wood materials fall within the range of thermal conductivities of materials used as thermal insulators in solar cell development and applications.

Comparing the result in this study with the thermal insulation property of some commonly used materials for flat plate solar collector which ranges between 0.0245-0.1202 Wm^{-1}K^{-1},some of the values obtained for the samples considered fall within the range of already established flat plate solar collectors (Young, 1992;Ziman, 1967). Based on the recorded thermal properties in this research, particle wood material is best used as insulator or in solar device applications.

III. Conclusion

It was established in the research that the thermal conductivity of wood materials ranged between 0.0855-0.3150 Wm^{-1} $K^{-1}$for particle sizes and 0.2210 -0.4298Wm^{-1} K^{-1} for bulk samples. The thermal conductivities values for the wood samples were found to conform to the general range of conductivity for wood materials. The thermal conductivity values of the bulk materials were found to be higher than those of the particles. The wood samples considered at specific particle sizes exhibit low thermal conductivity that is comparable with materials used as industrial insulators. Therefore, samples with particle sizes could serve as better thermal insulators compared with bulk wood materials.

Table 1: Thermal Conductivity ($Wm^{-1}K^{-1}$) Values of Wood Samples for Bulk and Different Particle Sizes.

Sample Name	Bulk Samples/ Particle Sizes	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Mean	S.ER.
Celtis philippensis	Bulk	0.3580	0.3126	0.3202	0.3086	0.2958	0.3190	±0.0105
	300 µm	0.3021	0.3011	0.2190	0.2190	0.3150	0.2712	±0.0215
	600 µm	0.1373	0.2199	0.1310	0.3091	0.2234	0.2041	±0.0328
	850 µm	0.2841	0.1474	0.2020	0.2002	0.1364	0.1940	±0.0262
Melicia excelsa	Bulk	0.2861	0.3078	0.2941	0.4637	0.2210	0.3145	±0.0444
	300 µm	0.1365	0.1592	0.2154	0.2796	0.2166	0.2014	±0.0250
	600 µm	0.2429	0.1496	0.2896	0.1202	0.1733	0.1951	±0.0311
	850 µm	0.1983	0.2228	0.1585	0.1457	0.1538	0.1758	±0.0148
Pterygota macrocarpa	Bulk	0.2717	0.4298	0.3882	0.3577	0.3262	0.3547	±0.0702
	300 µm	0.1390	0.1658	0.2075	0.2164	0.1294	0.1716	±0.0176
	600 µm	0.1802	0.1191	0.1503	0.1501	0.1513	0.1502	±0.0097
	850 µm	0.1553	0.1889	0.0940	0.0963	0.0855	0.1240	±0.0204

Key: S.ER. –Standard error

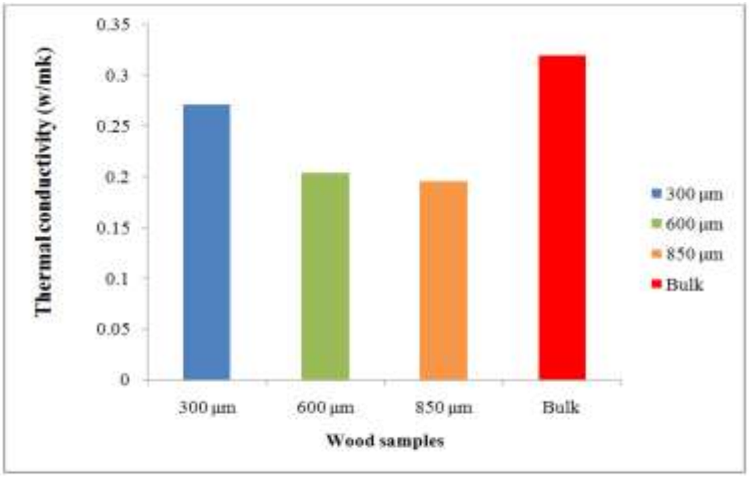

Figure 1: Thermal conductivity as a function of wood sample for *Celtis philippensis* (Ita funfun).

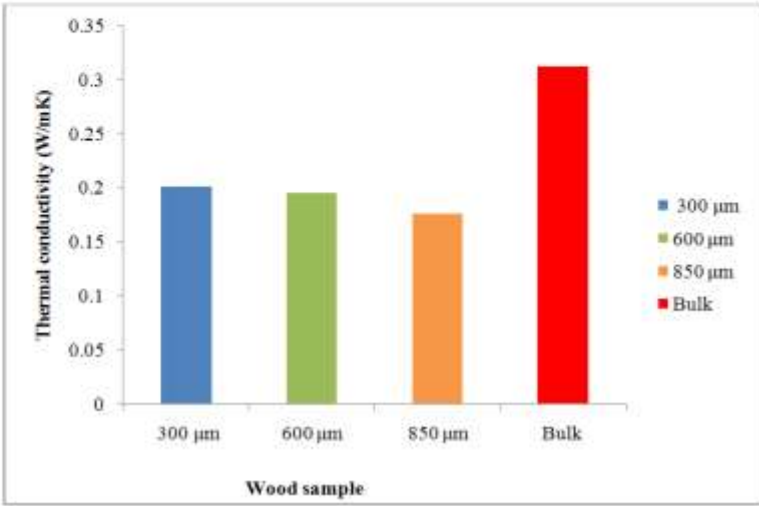

Figure 2: Thermal conductivity as a function of wood sample for *Milicia excelsa* (Iroko).

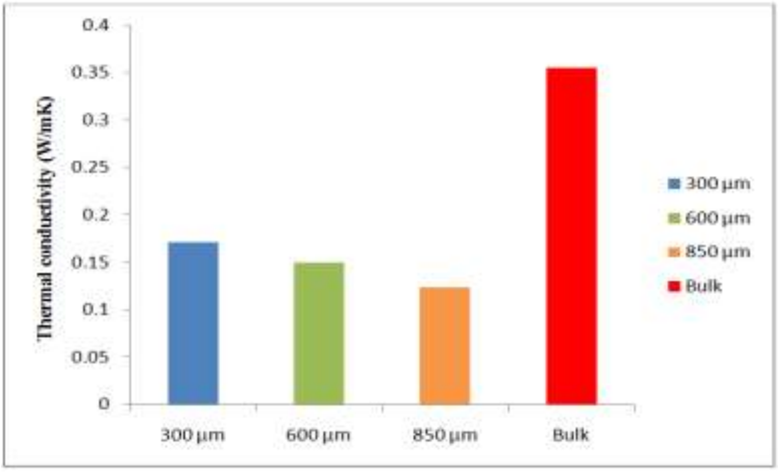

Figure 3: Thermal conductivity as a function of wood sample for *Pterygota macrocarpa* (Oporoporo).

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