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Effect of Particle Sizes on Thermal Conductivity of Five Wood Species from the Family of *Sterculiaceae*, *Moraceae*, and *Ulmaceae*

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ABSTRACT: The objective of this paper was to investigate effect of particle sizes on thermal conductivity of five wood species from the family of *Sterculiaceae, Moraceae*, and *Ulmaceae* using Differential Thermal Analyser after pulverizing and sieving wood materials into different maximum particle sizes of 106 µm, 300 µm, 425 µm, 850 µm and 1180 µm respectively with appropriate mesh. The result of the thermal conductivity ranged from 0.0100 to 0.0492 $Wm^{-1} K^{-1}$. It was observed from the result that thermal conductivity of wood materials is dependent of particle sizes. This suggests that the performance of the material could be influenced by particle size. Builders are encouraged to work hand in hand with researchers so as to have a deep understanding of insulating material to be used in building constructions.

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Wood is a hard, fibrous structural tissue found in the stems and roots of trees and other woody plants. Wood is a very important structural material. It has numerous advantages and few disadvantages. In addition to being a biological material that is readily available, it also has an excellent strength/weight ratio and good ductile properties. Due to the significant presence of wood and wood products in buildings, the energy design of wood frame buildings and the evaluation of their energy performance depend in part on thermal properties of wood products (Adekoya *et al.*, 2020). Wood is an anisotropic material whose thermal conductivity is a function of heating direction, temperature, density and moisture (Urszula *et al.*, 2019). The thermal properties of wood-based materials are required in applications such as fuel conversion, building construction and other fields of industry (Zi-Tao *et al.*, 2011). In building construction, wood as a building material is of special concern because of its low thermal conductivity and good strength. The poor heat conductance of wood is due to the paucity of free electrons which are media for energy transmission and due to the porosity of wood (Oluyamo *et al.*, 2017). Thermal insulation can be defined as the reduction to the flow of heat. Factors affecting the insulation performance are- Thermal conductivity, Surface emissivity, Insulation thickness, Density, Specific heat capacity, etc. (Jatin; Shubham, 2015). Over the years, different materials have been used as thermal insulators based on their thermal insulation properties, availability, cost,

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density and environmental friendliness. Hence, material with low value of thermal conductivity comparable with existing industrial insulator is of global interest. Commonly used materials as thermal insulator include calcium silicate, mineral fibre, fibre glass, Polyurethane, polystyrene, plastic foam etc. Thermal conductivity is important in thermal insulation of buildings and related fields such as heat sink applications. It is a critical attribute when offering energy conserving building products because of the significant presence of wood and wood products in buildings. Thermal properties of wood are also needed in applications such as fuel conversion, building construction, and other areas of industry (Smith *et al.*, 2016). Both high and low thermal conductivity materials are crucial, as various applications need to both move heat (in electric vehicles and power electronics) and block heat (in building envelopes, gas turbine and batteries). For example, from solid-state lighting to power transistors for electric infrastructure, high-performance (opto)-electronic devices require materials with high thermal conductivity to efficiently dissipate the heat from localized sources of ever-increasing power density. Low thermal conductivity materials are also widely needed. For example, the thermal barrier coatings (TBCs) on the blades of gas turbine engines increase their efficiency and power output, which demands multifunctional materials with low thermal conductivity and thermomechanical and chemical stability to protect the blade at high temperature (Zheng *et al.*, 2021). Hence, the objective of this paper was to investigate effect of particle sizes on thermal conductivity of five wood species from the family of *Sterculiaceae*, *Moraceae*, and *Ulmaceae*.

MATERIALS AND METHODS

Sample Preparation and Experiment Method: The materials that were used in the study include five 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 and were pulverized. A mechanical test sieve shaker was used to sieve the particle dust using different mesh sizes: 106 μm, 300 μm, 425 μm, 850 μm and 1180 μm respectively. The basic apparatus used was a Differential Thermal Analyzer which was used to measure the temperature, the direction and the magnitude of thermal transitions induced by heating or cooling a material in a controlled manner. DTA measures these properties by comparing the temperature of the sample and that of a reference material, which is inert under similar conditions. This temperature difference is measured as a function of time or temperature under a controlled atmosphere and it provides useful information about the transition temperature and also about its thermodynamics and kinetics. The experimental set-up was placed in a confined area to avoid environmental disturbance. The sample was placed inside a sample holder and was mounted on the set-up. The sample substance and a reference substance were heated in an oven with a continuous increase in temperature. The sample holder and an inert substance were then placed in such a way that there was a connection between them and the thermocouple so as to heat up the sample and the reference material. By using two thermocouples, the temperature difference between the sample and the reference (the inert substance) ΔT was measured as a function of furnace temperature. The value for the thermal conductivity (k) of each sample was estimated using the relation.

$$K = \frac{q\Delta_x}{A\Delta T} \quad (1)$$

Where, q is the heat flow, ΔT is the temperature difference across the crucibles, Δ_x is the sample size and A is the cross-sectional area.

RESULTS AND DISCUSSION

The table 1 showed the results of the thermal conductivity of different wood materials considered with respect to their particle sizes. The thermal conductivities ranged between 0.0492 $Wm^{-1}K^{-1}$-0.0134 $Wm^{-1}K^{-1}$ for *Celtis phillipensis*, 0.0274 $Wm^{-1}K^{-1}$-0.0192 $Wm^{-1}K^{-1}$ for *Milicia excelsa*, 0.0283 $Wm^{-1}K^{-1}$-0.0164 $Wm^{-1}K^{-1}$ for *Pterygota macrocarpa*, 0.0316 $Wm^{-1}K^{-1}$-0.0181$Wm^{-1}K^{-1}$ for *Antiaris africana* and 0.0271 $Wm^{-1}K^{-1}$ -0.0100 $Wm^{-1}K^{-1}$ for *Guarea cedrata*. It could be seen from the table that thermal conductivity (K) values varied according to wood species and particle sizes which is in agreement with previous research (Bader *et al*, 2007; Sonderegger; Niemz, 2009; Kol *et al*, 2008).

The values obtained revealed that almost all the samples have their highest thermal conductivity at 106 μm with *Celtis phllipensis* recording the highest thermal conductivity value of 0.0492 $Wm^{-1}K^{-1}$ and *Guarea cedrata* having the least thermal conductivity value of 0.1210 $Wm^{-1}K^{-1}$. At 1180 μm, *Milicia excelsa* has the highest value of thermal conductivity 0.0192 $Wm^{-1}K^{-1}$ and *Guarea cedrata* has the lowest thermal conductivity value 0.0100 $Wm^{-1}K^{-1}$

The figure 1 showed the values of thermal conductivity of different wood species with respect to particle size. Significant variation in thermal conductivity value of the same wood species as the particle size changed was noticed in the study. Generally, all the samples were noticed to follow the same pattern or trend. Among the particle sizes, 106 μm has the highest thermal conductivity value compared with other particle sizes. This was due to the reduction in the porosity of the sample (Oluyamo and Adekoya, 2015, Oluyamo *et al*., 2017). It has also been observed from the results that the samples do not have the same thermal conductivity, though, they are from the same species.

Table 1: Thermal conductivity of the wood materials as a function of particle size

Sizes	*Milicia excelsa*	*Celtis phillipensis*	*Pterygota macrocarpa*	*Antiaris africana*	*Guarea cedrata*
106 μm	0.0274	0.0492	0.0283	0.0316	0.0271
300 μm	0.0222	0.0417	0.0250	0.0309	0.0247
425 μm	0.0203	0.0271	0.0240	0.0293	0.0190
850 μm	0.0200	0.0249	0.0223	0.0273	0.0121
1180 μm	0.0192	0.0134	0.0164	0.0181	0.0100

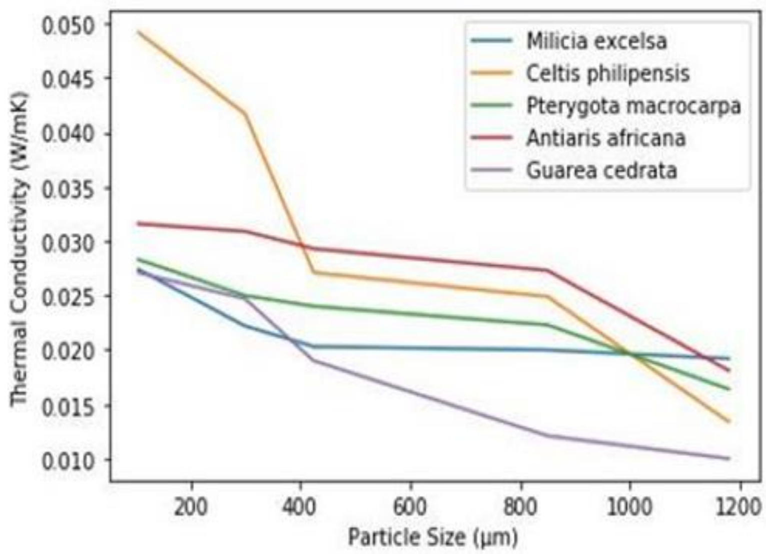

Fig 1: Thermal conductivity of the wood materials as a function of particle size

Conclusion: It was established that the thermal conductivities of wood varied with particle sizes. Within the scope of this research, thermal conductivity of wood is greatly dependent of particle sizes and also wood species. Also, almost all the wood materials fall within the range of insulating materials used in building construction as well as industries for energy conservation purpose.

Declarations of Conflict of Interest: The authors declare no conflict of interest.

Data Availability Statement: Data are available upon request from the first author.

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