THERMAL CONDUCTIVITY OF SOME NATIVE WOOD SPECIES IN NIGERIA

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ABSTRACT
Woods and wood-based materials continue to play important roles in human life. There is therefore a need to continuously update data on the various thermal properties of different wood species. The ability of wood materials to withstand shock and deformation depends on their thermal responses with respect to temperature and time. This study examines the thermal behavior of six wood species (celtis zenkeri, piptadeniastrum africanum, ricinodendron heudelotii, alstonia bonei, terminalia superba, nesogordonia papaverifera) using the lee's disc method. Thermal agitation in the wood samples increase as temperature increases until thermal stability is attained. The thermal conductivities at thermal stability are recorded. The values of thermal conductivity recorded for across and along the grain sections fall into the acceptable range of (0.01 -0.8 Wm-1K-1) for woods. Hence, the selected wood materials can be used as industrial insulators as their thermal conductivity values fall within the range of existing industrial thermal insulators. The materials could also serve as good potential devices for heat resistance.

Keywords: *Wood species, Lee's Disc Method, Thermal Conductivity, Thermal Insulators*

INTRODUCTION

Wood is a natural organic composite material which consists of cellulosic fibers and lignin. Wood has a long history of use as a solid fuel and construction material. Wood exhibits low thermal conductivity (high heat insulating capacity) compared with materials such as metals, marble, glass, and concrete. Wood is one of the most useful materials to man in the provision of shelter, tools, weapons, furniture, packaging, artworks, and paper (Ahn et al., 2009)

The thermal state of wood in terms of conductivity, absorptivity, emissivity and diffusivity of heat should be investigated. The knowledge of thermal properties and other physical properties like density of wood samples is significant in the choice of its suitability and thermally friendliness for different building designs. The energy design and energy performance evaluation of wood-frame buildings partly rely on the thermal properties of wood and wood products (Ten Wolde et al. 1988). The analysis of combustion and pyrolysis of wood exposed to fire also demands the knowledge of their thermal properties (Thunman and Leckner, 2002). As building materials evolve, there is a need for continuous updating of the information on various thermal properties of wood products.

There are two methods for determining the thermal conductivity of a sample: steady state and non-steady-state (or transient) methods. Steady state methods require that the experimental setup must reach equilibrium before calculation or measurement is made. Transient methods on the other hand do not require that equilibrium is reached before calculation or measurement is made. Steady-state methods include Searle's bar for good heat conductors and the Lee's disc for poor conductors of heat. The advantage of transient techniques is that measurements can be made relatively quickly while their disadvantage is that mathematical analysis of data is general more difficult.

MATERIALS AND METHOD

The instruments used for the Lee's disc experiment include Voltmeter (0-12volts), Ammeter (0-3amps), Rheostat (0-12 Ohms to carry 3Amps), Plug key, Steady supply of D.C 0.12volts, Three thermometers calibrated 0-50oC and a thermometer for recording the temperature of the environment. A constant heat source is sandwiched between two identical metal cylinders. The test specimen is sandwiched between the second cylinder and a third identical metal cylinder so that all the cylinders and the test specimen are concentrically aligned. When the heat source is switched on, the temperatures of the three discs are allowed to reach equilibrium and measured. The experimental set up is shown diagrammatically in Figure 1 where X, Y and Z are brass discs of 50mm diameter and thickness 13mm with holes drilled to take thermometers. Figure 2 shows how the various apparatus were set up in the laboratory during the experiment.

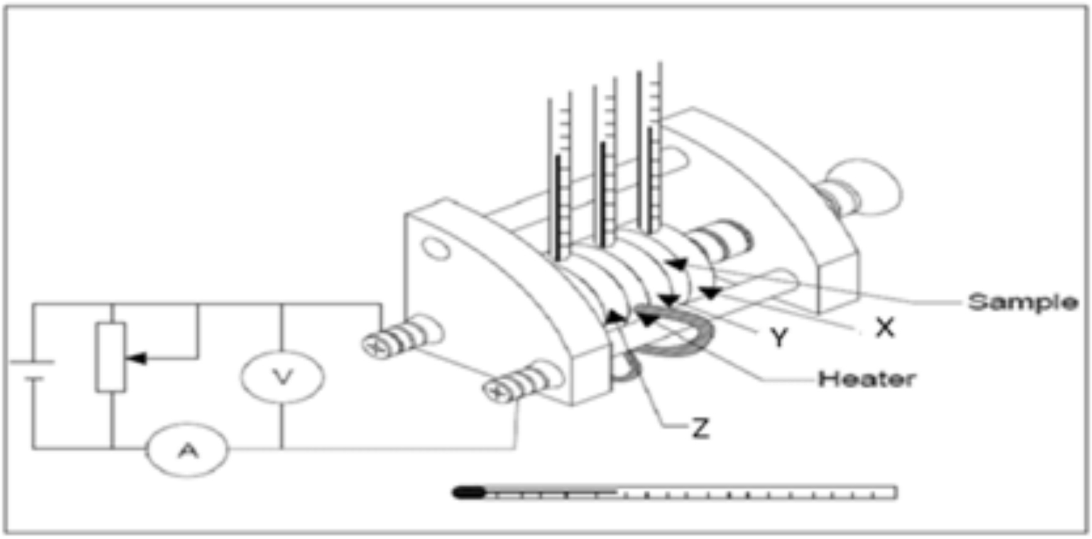

Fig 1: *Schematic set-up of lee's disc experiment (Oluyamo et al., 2012).*

Fig 2: *Experimental set up of the Lee's disc method*

Fourier's law which states that the rate of heat flow in a specimen is directly proportional to its cross sectional area and the temperature difference between its ends but inversely proportional to its thickness is employed as the basic equation (Equation 1)

$$\frac{Q}{t} = KA\frac{dT}{dX} \quad (1)$$

where K is a constant of proportionality called the coefficient of thermal conductivity.

The relationship between heat supplied by the heating element of the Lee's disc method and the total heat emitted per second from the discs and the specimen is shown in equation (2)

$$VI = ea_x\theta_x + ea_s\frac{(\theta_y+\theta_x)}{2} + ea_y\theta_y + ea_z\theta_z \quad (2)$$

Where V is the potential drop; I is the current; θ_x, θ_y, and θ_z are the excess temperature in the brass discs; and e is the rate of emission of heat; a_x, a_y, a_z and a_s are the areas of brass discs and the specimen exposed to the surroundings obtained using (3a) - (3c).

$$a_x = a_z = \pi r^2 + 2\pi r l_d \quad (3a)$$

$$a_y = 2\pi r l_d \quad (3b)$$

$$a_s = 2t_s(l+b) \quad (3b)$$

The thermal conductivity is then obtained by equation (4)

$$KA\frac{(\theta_y-\theta_x)}{d} = \frac{e(\theta_y+\theta_x)}{2} + a_x\theta_x \quad (4)$$

RESULTS AND DISCUSSION

The time for each experiment to reach equilibrium, the values of ambient temperature (T_{amb}), temperature of the discs θ_x, θ_y, and θ_z, heat emitted (e) and thermal conductivity (K) of Piptadenia-strumAfricanum (Ekhiwmin), Alstonia Boonei (Astonia), Terminalia Superba (White Afara), Nesogordonia Papaverifera (Aye Danta) and Ricinodendron Heudelotii (Okhuen) are tabulated along the grains in Table 1 and across the grains in Table 2.

Table 1. Values obtained for each wood samples along the grains.

Local Name	Time (min)	θ_x (^oC)	θ_y (^oC)	θ_z (^oC)	T_{amb} (^oC)	Voltage (v)	e ($W/m^{2o}C$)	K (W/m^oC)
Ekhiwmin	55	45	80.5	85.5	26.5	4.1	18.8992	0.088178
Danta	60	44.5	74.5	76	26.5	3.9	19.9306	0.083885
Astonia	65	53.0	81.5	67.5	28.0	4.4	23.3022	0.087609
Okhuen	65	51.5	83.5	69.0	28.5	4.4	23.3740	0.072231
White Afara	55	56.5	87.5	70.0	28	4.5	21.6878	0.085325
Ohia	60	54	64.5	81	27.5	4.2	20.5188	0.33604

Table 2: *Values obtained for each wood samples across the grains.*

Local Name	**Time (min)**	**θ_x (^oC)**	**θ_y (^oC)**	**θ_z (^oC)**	**T_{amb} (^oC)**	**Voltage (v)**	**e ($W/m^2.^oC$)**	**K (W/m^oC)**
Ekhiwmin	65	56.0	83	72.5	27.5	4.6	21.7107	0.1501
Danta	60	50.0	80.2	86.0	27.0	4.5	19.8820	0.0993
Astonia	60	52.5	77.5	69.0	26.5	4.4	22.3807	0.1525
Okhuen	60	52.5	85.0	72.0	27.5	4.6	22.0499	0.1533
White Afara	60	52.0	76.5	69.5	26.0	4.5	22.6965	0.15811
Ohia	40	55.0	73.0	67.0	28	4.5	24.2697	0.2379

The results showed that generally thermal conductivities of woods cut across the grain are about two times or more of those cut along the grain except for *celtis zenkeri* (ohia). The values obtained in this study are in agreement with Oluyamo et al., (2014) and Udeozo et al., (2014) who estimated thermal conductivity of woods to be between 0.045 and 0.8 W/m0C. The conductivity of *Alstonia boonei* (astonia) 0.0876 W/m0C agrees with Oluyamo et al., (2014) who obtained 0.086 W/m0C. The thermal conductivities of *Ekhiwmin, Danta* and *Okhuen* which were obtained in this study were not found in literature.

CONCLUSION

The thermal conductivities of six native Nigerian wood species were obtained. The results showed that these woods are suitable for use as industrial insulators and heat resistant devices for engineering purposes.

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