Applied Tropical Agriculture
Volume 22, No. 1, 1-4, 2017.
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Evaluation of Thermal Conductivity Property of Selected Wood Species in the Steculiacea Family

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ABSTRACT

Thermal conductivity of Pterigota macrocarpa, Triplochiton schleroxylon and Nesogodonia papaverifera, all in the Steculiacea family was investigated. Samples of 50 mm by 50 mm were collected from the sawmill and turned into cylindrical form using the wood turning lathe machine with each sample having a radius of 20 mm and a thickness of 5 mm. The samples were placed between discs A and B of the modified Lee disc machine one after the other while the electrical plate was placed between disc B and C of the apparatus respectively and the thermal conductivity values for each sample taken while the temperature was monitored. The results showed that Nesogodonia papaverifera exhibited the lowest thermal conductivity with a mean of 0.22 Wm-1k-1followed by Pterigota macrocarpa and Triplochiton schleroxylon having a mean conductivity of 0.25 Wm-1k-1 and 0.27 Wm-1k-1 respectively. Also at hot rising and falling temperatures, Pterigota macrocarpa and Nesogodonia papaverifera exhibited highest and lowest thermal agitations at 0.32Wm-1k-1.The selected wood samples in the Steculiacea family possessed good thermal conductivity when compared with other wood species that their conductivity has been studied.

Key words: Thermal conductivity, Steculiacea, temperature, lathe machine, wood samples

INTRODUCTION

Wood is one of the major materials used by man for constructional purposes which include production of prefabricated wood houses and furniture. Although wood expands and contracts with varying temperature, these dimensional changes are small compared with shrinkage and swelling caused by varying moisture content (Daniel, 2010). In most cases, such temperature-related expansion and contraction are negligible and are without practical importance. The significant presence of wood and wood products in buildings, the energy requirement of wood frame buildings and the evaluation of their energy performance depend in part on thermal properties of wood used. Thermal conductivity is a critical attribute when offering energy conserving building products. This is due to the fact that wood has excellent heat insulation properties. According to Daniel (2010), Ajibola and Onabanjo (1995), lower thermal conductivity values equates to greater heat insulating properties. However, field experience suggests that fire performance of engineered wood products is inferior to traditional timber (Mahmood, 2008). Wood plastic composites (WPC) are known to have drawn increasing attention over the years. To this end, wood materials had been preferred to inorganic materials like talcum or fibre due to the density of the composite which is considerably lower and therefore of interest for transportation applications, as well as the renewability and enhanced recyclability of the wood plastic composites (Burgstaller, 2006; 2007). Increasing demand for wood for use as industrial thermal insulator coupled with inherent high cost and health implication of other materials calls for the search for appropriate wood materials with suitable thermal insulating properties. Since there is not enough information on the thermal conductivity of some species in Sterculiaceae family, the study was focused on thermal conductivity of some species in this family.

MATERIALS AND METHODS

Wood materials for this study were selected from three species in the Sterculiaceae family: *Pterygota macrocarpa*, *Triplochiton scleroxylon* and Nesogordonia *papaverifera*. Other materials used were liquid and glass thermometer, Modified Lee disc machine and Electrical plate heater.

Sample Preparation

Wood of the selected species were purchased at the dimension of 50 mm by 50 mm from sawmills in Akure, Ondo State. The weights of all the samples were determined using the weighing balance and later oven dried at a temperature of 103±3 °C for 15 hours in the laboratory. The samples were re-weighed to determine the moisture content. The wood samples were turned using a lathe machine in the workshop, Department of Forestry and Wood Technology Akure into a cylindrical form to the radius of 40 mm. Three samples of 0.5cm thickness were cut from each species were using the circular sawing machine. The surface of the samples was smoothened to enhance good thermal contacts.

Apparatus set-up and Method of Test

The basic apparatus used was a modified Lee disc machine for the measurement of thermal conductivity by the absolute plane parallel plate technique (Griffin and George, (2002); Duncan, (2000). This equipment consists of three brass discs A, B, and C drilled to accept liquid-in-glass thermometers and a 6W electrical plate heater of the same diameter as the discs (Plate 1).

Plate 1: Picture of the setup

Each sample was placed between discs A and B one after the other. The heaters were sandwiched between discs B and C and also tighten the clamp screw to hold all the discs together. The set-up was connected to a DC power supply as shown in Plate 1. The whole assembly was placed in an enclosure to minimize the effects of draughts. A thermometer was placed close to the apparatus, to measure the ambient temperature. At the beginning of each determination, the voltage from the stabilized Direct Current supply was set to about 6.0V while the temperatures of the discs (i.e. the temperatures of plates A, B and C) was monitored until the temperature of disc A attained a desire value of 50 °C. This took several hours. Readings were taken at 5 minutes intervals during this period. At this stage, the Voltage supply has reduced and temperature readings of the discs was monitored at every 5 minutes interval.

In order to effectively analyze the thermal agitation in the samples, the thermal conductivity were estimated at every 15 minutes interval up to a point at which the temperatures of the discs had stabilized to within ±0.1°C for at least 30 minutes. The value for the thermal conductivity (λ) of each sample of thickness d and radius r were estimated from the relationship (ISO, 1991):

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

Where e is given by

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

And

$$a_A = a_C = \pi r^2 + 2\pi \mathrm{rl_d} \qquad (3)$$
$$a_B = 2\pi \mathrm{rl_d}$$
$$a_S = 2\pi \mathrm{rl_s}$$

Where: $\mathrm{l_d}$ and $\mathrm{l_s}$ were the thickness of the disc samples.

a_A, a_B, a_C and a_S were the exposed surface area of disc A, B, C.. $\mathrm{T_A}$, $\mathrm{T_B}$ and T_C were the temperatures of the discs A, B and C above ambient temperature (i.e. the thermal equilibrium temperature of the disc minus the ambient temperature) while V is the potential difference across the heater and I was the current which flows through it.

Experimental design

The experiment was laid out in a completely randomized design with the wood species constituting the treatment. The experimental model is given as:

$$\sum y_{ij} = T_i + \mu_j \ldots\ldots\ldots\ldots\ldots\ldots\ldots(4)$$

Where $\sum y_{ij}$ = individual observation, $\mathrm{T_i}$ = Wood species (treatment) and μ_j = experimental error

RESULTS AND DISCUSSION

The results presented in Tables 1 and 2 showed the level of significance of the thermal conductivity for the three wood species. The thermal agitation of the samples was found to be significant among the species of the

Sterculiaceae family. *Nesogordonia papaverifera* exhibited lowest thermal conductivity while there was no significant difference in the thermal conductivities of *Pterygota macrocarpa and Triplochiton scleroxylon* wood although it was higher with *Triplochiton scleroxylon* wood. Figure 1 showed the comparative variations of the rising temperatures thermal conductivities of the three wood samples with time.

Table 1: Mean thermal conductivities of selected species in the Sterculiaceae family

Species	**Thermal Conductivity (Wm^{-1}k^{-1})**
Triplochiton scleroxylon	0.26972700 ± 0.027^{a}
Pterigota macrocarpa	0.25231800 ± 0.045^{a}
Nesogordonia papaverifera	0.22253200 ± 0.014^{b}

Table 2: Analysis of Variance for the thermal conductivities of the species

Source	***Sum of Squares***	***Df***	***Mean Square***	***F***	***Sig.***
Species	0.011	2	0.006	5.789	0.008
Error	0.027	27	0.001		
Total	0.038	29			

The *Pterygota macrocarpa* sample exhibited the highest thermal agitation at 0.31986Wm-^{1}k-^{1} followed by *Triplochiton scleroxylon* while *Nesogordonia papaverifera* exhibited the lowest thermal agitation. Figure 2 showed the comparative variations of the falling temperatures and thermal conductivity of the three wood samples with time. The *Pterygota macrocarpa* also exhibited the highest thermal agitation and with the lowest thermal conductivity followed by *Triplochiton scleroxylon* and *Nesogordonia papaverifera* exhibited the lowest thermal agitation. This effect could be attributed to the fact that initially, enough energy is required to break the bonds of the particles in the samples and on reaching their maximum excited positions, and as the thermalenergy reduces, the particles tend to return to their mean position according to Oluyamo *et al,* (2012), Ogunleye Awogbemi (2007). Hence withdrawal of heat from the system would cause the particles to return back to their mean position faster and more regular than when the temperature was rising. It was evident that as the temperature of the samples increased the particles received thermal agitation and thereby are scattered away from their equilibrium position. This is more prominent at the rising temperature. The comparative variations of the rising temperatures and thermal conductivities of the three wood samples with time (Figure 1) showed that *Pterygota macrocarpa* wood exhibited the highest thermal agitation at 0.31986Wm-^{1}k-^{1} followed by *Triplochiton scleroxylon* while *Nesogordonia papaverifera* exhibited the lowest thermal agitation. Figure 2 showed the comparative variations of the falling temperatures and thermal conductivity of the three wood samples with time. The *Pterygota macrocarpa* also exhibited the highest thermal agitation and with the lowest thermal conductivity followed by *Triplochitons cleroxylon* and *Nesogordonia* papaverifera exhibited the lowest thermal agitation.

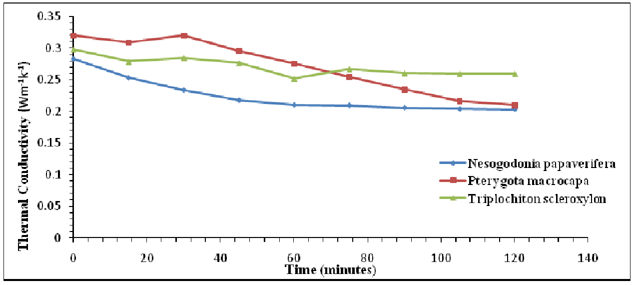

Figure 1: Thermal Conductivity of the species with time at rising temperatures

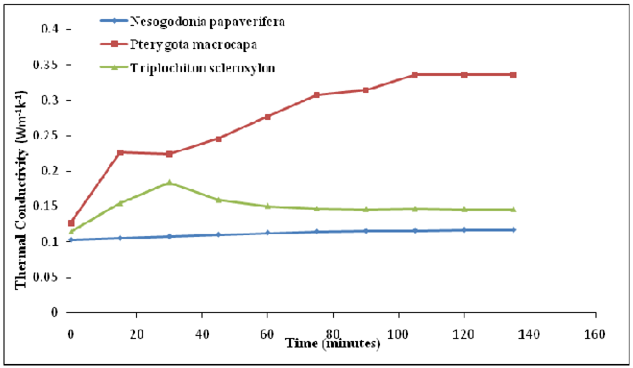

Figure 2: Variations in thermal conductivity of the wood species with time at falling temperatures

According to Mahmood (2008), the thermal properties of wood vary with species type with conductivity values generally in the range of 0.1-0.8Wm^{-1}k^{-1}. The values of the thermal conductivity obtained in this study conform to this result. Oluyamo *et al.* (2012), Simpson and Tenwolde (1999), also found out that most wood species experience average thermal agitation between the thermal conductivity values which range of 0.2Wm^{-1}k^{-1} and 0.3Wm-^{1}k-^{1}, and the results in this study also was within the range. They are also found to possess good thermal behaviour. However, the *Pterygota macrocarpa and Triplochiton scleroxylon* wood samples have both higher thermal agitation and conductivities than the *Nesogordonia papaverifera*. This suggests that *Pterygota macrocarpa* and *Triplochiton schleroxylon* can easily transmit heat energy in service; they could be good wood species in heat sink applications.

CONCLUSION

The results of this study revealed that the wood species in the Sterculiaceae family possessed good thermal conductivity. The thermal conductivity values for the samples were found to conform to the general range of conductivity for wood materials. *Pterygota macrocarpa* exhibited the highest thermal agitation and with the lowest thermal conductivity followed by *Triplochiton scleroxylon* and lowest in *Nesogordonia papaverifera*. Thus, wood species with low thermal agitation will possess high thermal conductivity. Therefore, *Nesogordonia papaverifera* showing a lower thermal agitation at both falling and rising temperature is more suitable for constructional purposes and can be used in prefabricated wood houses even in hot climate while relying on its low thermal conductivity compared to other species investigated.

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