

LEMBAR
HASIL PENILAIAN SEJAWAT SEBIDANG ATAU PEER REVIEW
KARYA ILMIAH : PROSIDING

Judul Artikel : Thermal and Electrical Properties on Three Planes of Mangium Wood (*Acacia mangium Willd*) with Different Trunk Position
 Nama Pengusul : Aminullah, S.TP., M.Si
 Jumlah Penulis : 19 Orang
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Bogor, 29 Maret 2022

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 Pendidikan Terakhir : S3

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Komponen Yang Dinilai	Nilai Maksimal <i>Prosiding</i> (isi kolom yang sesuai)			Nilai Akhir Yang Diperoleh
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Bogor, 16 Maret 2022

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Pendidikan Terakhir : S2

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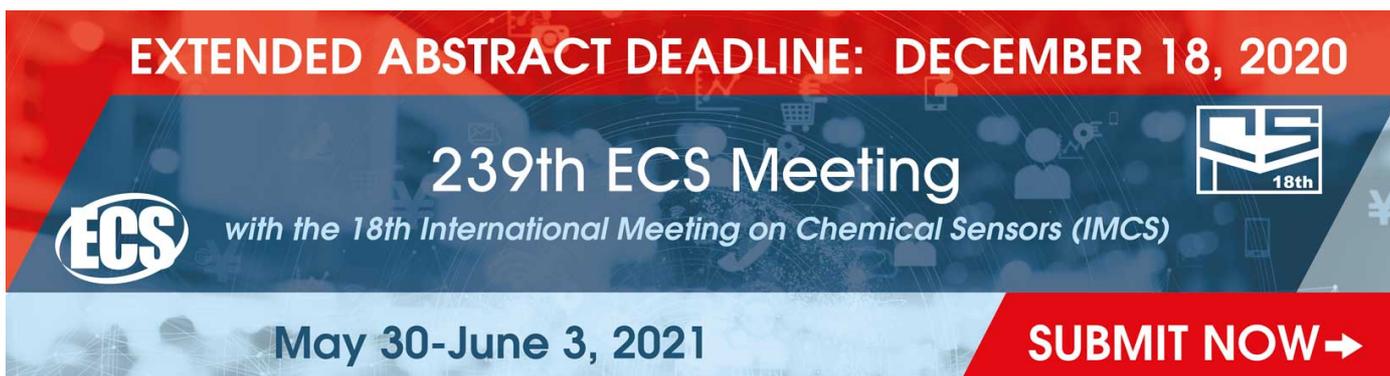
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Thermal and electrical properties on three basic planes of Mangium wood (*Acacia mangium* Willd) with different trunk position

Irzaman¹, A S R D Lestari², S Sadiyo³, N Nugroho³, I Wahyudi³, D R Nugraha³, N A Ohorela³, N Putri³, M Mubarak³, N S M³, M Y S Nababan³, P S Sejati³, A T Lestari³, M Efendi³, A Solikhin³, J Hendrik³, A A A Aziz³, Hadyan³, and Aminullah³

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Abstract. Wood was very complex lignocellulose materials due to its anisotropic property. In this work, the objective was to analyze and determine the effect of wood orientation of *Acacia mangium* wood on thermal and electrical conductivities, dielectrical constant and impedance property by using Stefan Boltzman method. The results showed the relationships between thermal and electrical conductivities in *Acacia mangium*. The highest thermal conductivity value was in the cross section plane at the bottom of the tree. In contrary, the highest electrical conductivity value was in tangential plane. These differences were expected due to anisotropic property of wood which is influence thermal and electrical properties.

1. Introduction

Wood is lignocelluloses materials which could be used as structural and non-structural materials. There are differences in physical and mechanical properties due to its genetic source, environmental factors and anisotropy. These properties substantially affect the quality of wood product and the utilization of wood in building construction or in other applications [1].

Acacia mangium is one of the hardwood species from plantation forest, well known as fast growing tree species, native of Australia, Papua New Guinea, and Indonesia [2]. In Indonesia, Mangium is widely spread in many provinces especially in Eastern Regions. Mangium has received highly attention in recent years because the chemical, physical and mechanical properties which are suitable for erosion control, plantation and community forestry, production of fuel wood, pulp for papermaking, construction and furniture timber as well as tannin for leather making [3,4]. Those potentials have prompted many



researchers in order to understand in detail the properties. Yet, the mechanical properties of mangium wood, notably for thermal and electrical properties have been not researched.

Thermal conductivity is one of the important properties that characterize thermal behavior of woods [5,6]. This property is needed in many applications such as fuel conversion, building construction, and other areas of industry [7], thermal treatment, steaming, kiln-drying operations, preservation impregnation, hot pressing of wood based composites, and wood thermal degradation [8].

For practical purposes, the influences of the anisotropy of wood and the fiber orientation in related to the electric field must be also considered [9]. The optimum field orientation, higher for the field orientation which is parallel to the grain, in an application may be deduced from the 'ε' eff versus moisture content curves as losses which is the characteristic of wood and paper products [10]. So, it is required specific comprehension particularly as electrical material purposed. Several basic properties which have to be known in whole materials are dielectric property and ability to storage the electrical energy. Wood is considered as solid materials which has plenty of benefit to be an electrical material.

In this research, the objective is to analyze and determine the effect of basic planes of Acacia mangium wood on thermal and electrical properties in this case which are thermal conductivity, electrical conductivity, dielectric constant and impedance.

2. Material and method

2.1. Thermal conductivity measurement

The 3 (tangential, radial and cross-section) x 3 (bottom, middle, and, upper) samples with size of 4 cm x 5 cm x 0,5 cm for each sample were used in this measurement by using Stefan Blotzman method (voltage of 9 Volt). These samples were divided into 3 sections namely 7.5 m for upper sample, half of total height for middle sample and diameter at breast height (DBH) for bottom sample. Then, the samples were dried in order to reach the desired moisture contents of 10 to 15%. Three basic planes in wood [11] was shown in figure 1.

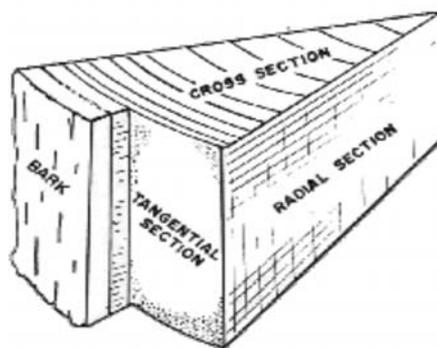


Figure 1. Three basic planes in wood

2.2. Electrical properties measurement

The 3 (tangential, radial and cross-section) samples with size of 2 cm x 1 cm x 0,5 cm for each sample were used by using capacitance capacitor method. Electrical properties (conductivity, dielectric and impedance) were measured by using 3532-50 LCR HiSTER (Hioki), ranging from 42 Hz to 5 MHz. The measurement was conducted in room temperature (26-27°C) with various frequencies of 10; 100; 103; 2,104; 4,104; 6,104; 8,104 and 105 Hz. In addition, the conductance was measured in nano Siemens (nS)

[11]. To support the electrical conductivity data, the bottom of the *Acacia mangium* sample was used in this measurement.

3. Results and Discussion

3.1. Thermal Conductivity of Wood

Thermal conductivity of common structural woods is much less than that of metals, where woods are often mated with metals in construction. Increasing in thermal conductivity could be affected by several factors such as density, moisture content, temperature, or extractive content of the wood [7], [12], [13]. Moisture content above 30 % will significantly influence wood properties which has impact to decrease thermal conductivity [14]. In addition, extractive content, grain direction, structural irregularities such as checks and knots, fibril angle, and temperature also can be affected it. For example, the conductivities of structural softwood lumber at moisture content of 12% in the range of 0.1 - 1.4 W/(m×K) (0.7 to 1.0 Btu×in./(h×ft²×oF)), compared to 216 (1,500) for aluminum, 45 (310) for steel, 0.9 (6) for concrete, 1 (7) for glass, 0.7 (5) for plaster, and 0.036 (0.25) for mineral wool. Several researches state that thermal conductivity in the radial plane is slightly higher than that in tangential plane [12]. Figure 2 shows the powers, which are used in this research, ranging from 16.28 to 16.47 watt.

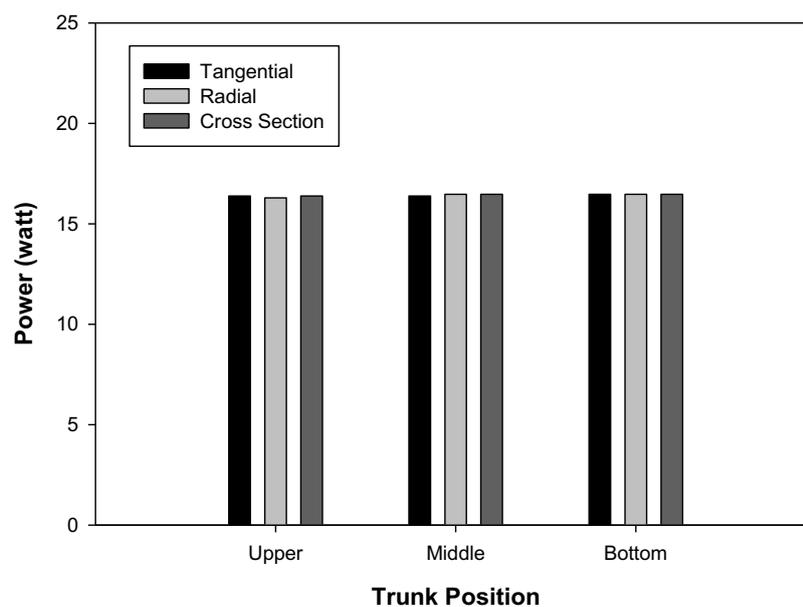


Figure 2. The relationship between power (H) and trunk position in different basic planes.

The results show that all samples which are obtained from upper, middle, and bottom parts in different basic planes are displayed in Figure 3 and the average of thermal conductivity of each basic plane can be seen in Figure 4. The parts of the tree trunk influenced to thermal conductivity of wood. The average of thermal conductivity of bottom part (1,3581 watt/m^oC) is higher than that of middle (0.8205 watt/m^oC) and upper (0.7406 watt/m^oC) parts.

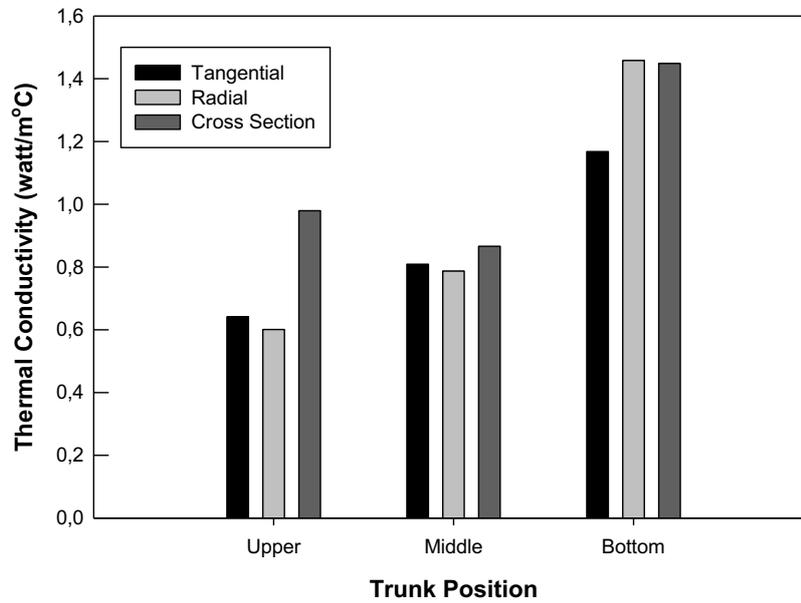


Figure. 3. The relationship between thermal conductivity and trunk position in different basic planes.

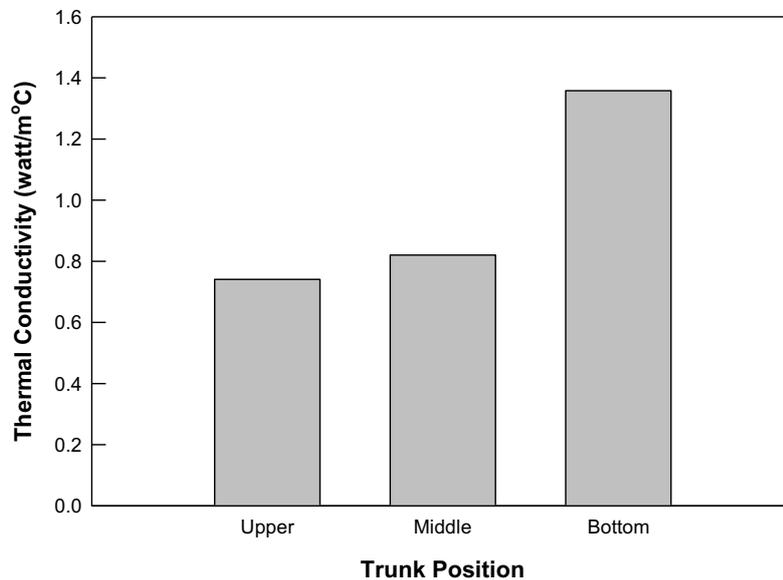


Figure. 4. The relationship between thermal conductivity and trunk position.

The results of statistically Tukey test with confidence interval of 0.5 % show that the average of thermal conductivity of the bottom trunk is significantly different with that of the upper and middle trunks. While, thermal conductivity of the upper trunk is no different with that of the middle trunk. These differences are generated by high variability of wood, although these parts are taken from the same tree,

due to its different specific gravity. Thermal conductivity is influenced by moisture content and specific gravity [15]. Specific gravity of the upper section tends to be lower than that of the bottom. The higher specific gravity leads to the higher thermal conductivity of wood.

In addition, specific gravity is also influenced by the juvenile wood. Heat transfer processing is affected by the ratio of growth rings, so that heat transfer will be easier in the mature wood than in juvenile wood [16]. The upper part of mangium wood has higher juvenile portions than the bottom and middle parts, therefore thermal conductivity of the upper part is lower than that of bottom and middle parts.

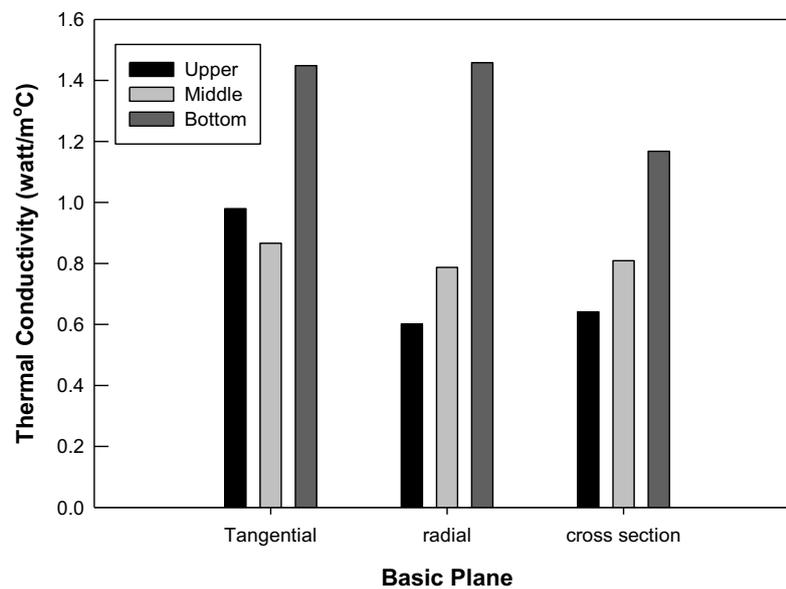


Figure 5. The relationship between thermal conductivity and basic planes in different trunk position.

Thermal conductivity measurement of mangium wood is conducted on axial (parallel to the grain) and transversal (radial and longitudinal) planes. Figure 5. shows thermal conductivity of three basic planes with different trunk position. Thermal conductivity on these planes is significantly different. In Figure 6, thermal conductivity of one sample to another samples is no significantly different. Axial plane or cross section has the highest thermal conductivity (1.09), followed by radial (0.94) and tangential (0.87) planes. This result is similar with [14],[15] which state that axial section has the highest value due to the morphological wood and fibers position which was in the line of axial plane of most of cell walls. There is no significant difference between thermal conductivity in radial and tangential planes, however, there is a high thermal conductivity due to ray cells. The part of wood which plays role to tangential plane is different proportion between early wood and late wood.

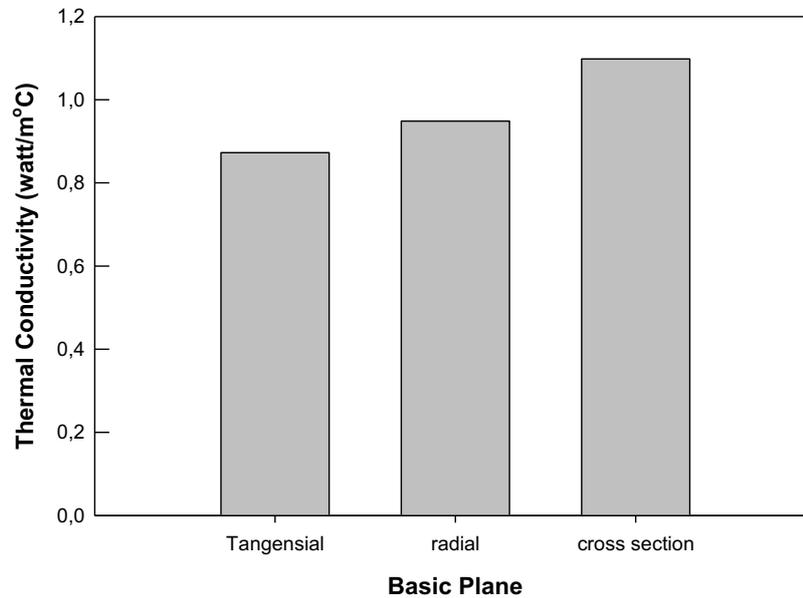


Figure 6. The relationship between thermal conductivity and basic planes.

Thermal conductivity in the radial is similar with that in tangential plane with respect to the growth rings. Conductivity along the grain has been reported as 1.5 to 2.8 times greater than conductivity across the grain, with an average of 1.8. Diffusivity is defined as the ratio of conductivity to the product of heat capacity and density. Thermal diffusivity is a measure of how quickly a material can absorb heat from its surroundings. Therefore, the conclusion regarding its variation with temperature and density are often based on calculating the effect of these variables on heat capacity and conductivity. Low thermal conductivity and moderate density and heat capacity of wood give impact to the thermal diffusivity of wood which is much lower than that of other structural materials, such as metal, brick, and stone. Thermal diffusivity of wood is $0.161 \times 10^{-6} \text{ m}^2/\text{s}$ ($0.00025 \text{ in}^2/\text{s}$) compared to $12.9 \times 10^{-6} \text{ m}^2/\text{s}$ ($0.02 \text{ in}^2/\text{s}$) for steel and $0.645 \times 10^{-6} \text{ m}^2/\text{s}$ ($0.001 \text{ in}^2/\text{s}$) for mineral wool. For this reason, wood does not feel extremely hot or cold to the touch as do some other materials [12].

3.2. Electrical conductivity of wood

Electrical conductivity is the ability of material to conduct the electrical current which is shown by the magnitude [17]. Electrical conductivity is strongly influenced by moisture content, density, and structure of the wood [18]. In wood, the electrical conductivity rate depends on the direction of heat transfer in the grain orientation, that is have a relation with wood properties as an anisotropic material. Electrical conductivity which is obtained from that three types of wood on the radial section in the range of $0.35 - 1141 \times 10^{-8} \text{ S/cm}$.

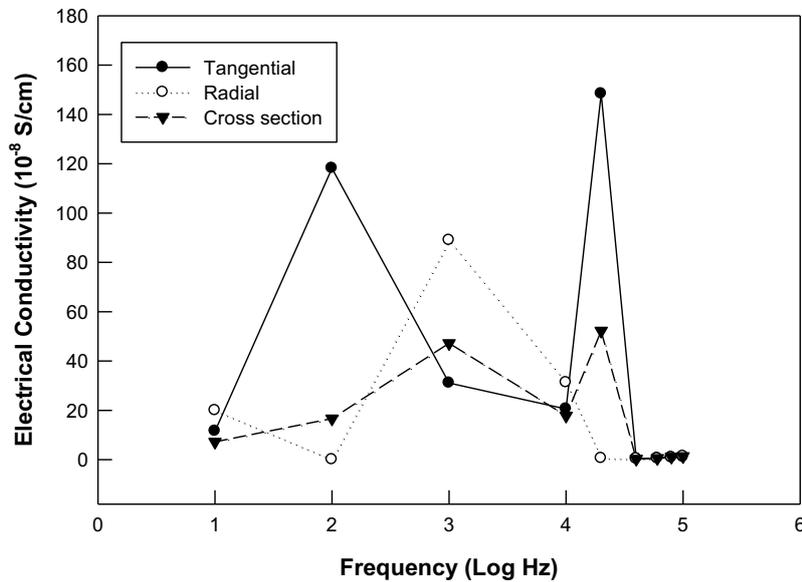


Figure 7. The Relationship between frequency and electrical conductivity of *Acacia mangium* in different basic planes from bottom trunk.

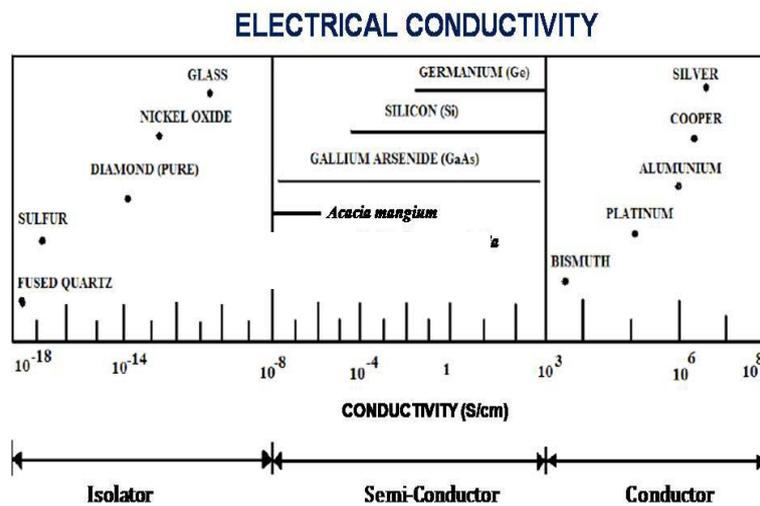


Figure 8. Electrical conductivity of *Acacia mangium*.

Figure 7. shows the electrical conductivity of mangium wood varies on the radial, tangential and cross sectional plane. The highest electrical conductivity is in tangential plane with value of $148.37 \times 10^{-8} \text{S/cm}$ and followed by radial and cross section respectively $88.95 \times 10^{-8} \text{S/cm}$ and $52.24 \times 10^{-8} \text{S/cm}$. Electrical

conductivity value was influenced by variation of anatomical structure among species [9]. Result in Figure 8 shows that *Acacia mangium* is a semiconductor.

3.3. Dielectrical constant of wood

Dielectrical properties of a material describe the interaction between material and electric field. The interaction of primary interest are the absorption and storage of electric potential energy (dielectric constant) [19], [20]. Dielectric properties of material are influenced by frequency, temperature, water content, density, composition and material structure [17].

Wood is a very complex material, which has anisotropy, unsymmetric molecule, and heterogeneous structure that is composed of fibers, rays, vessels, air, imbedded water, and free water [19], [20]. Therefore, the dielectric properties of wood especially dielectrical constant, are different in various plane.

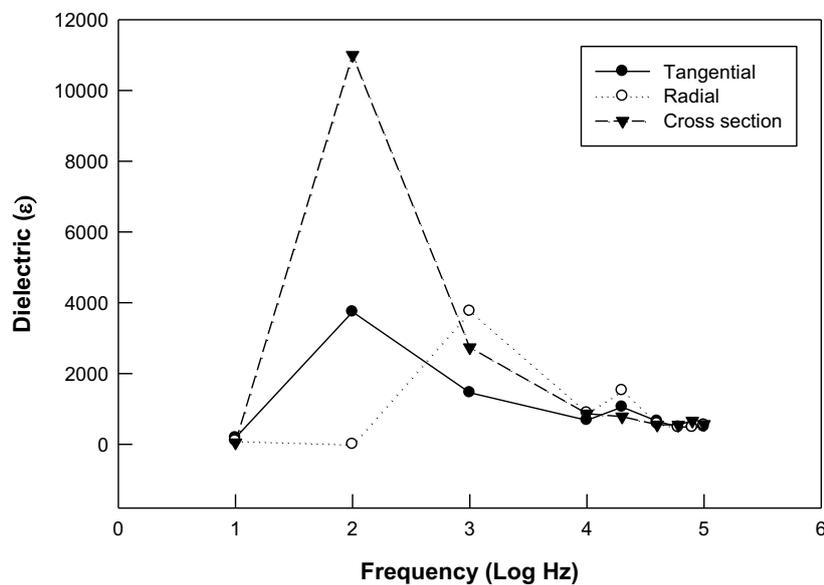


Figure 9. The Relationship between frequency and dielectric of *Acacia mangium* in different basic planes from bottom trunk.

Figure 9. shows that the dielectric constant in cross section of *Acacia mangium* (10995.78) has the highest value, then tangential (3741.53) and radial plane (1520.29) tend to have similar value. According to [20] about the comparison of the measured and theoretically predicted dielectrical properties for a given moisture content, showed that the variation of the dielectric constant is affected by structural directions of wood. The highest value is reached when parallel to the wood fiber, and the smallest value when parallel with the tangential wood structure direction. This was determined by direction vector of electrical field in cross section higher than radial and tangential section.

3.4. Impedance properties of wood

According to Figure 10, impedance value of mangium wood is in ranging 0.01 to 685.75 Ω . The impedance value decreases on the higher frequency of above 10 Hz. The impedance value varies on radial, tangential and cross section plane of mangium wood. The highest impedance value is on tangential plane about 685.75 Ω with frequency 10 Hz. However, the impedance value of tangential and radial direction is similar.

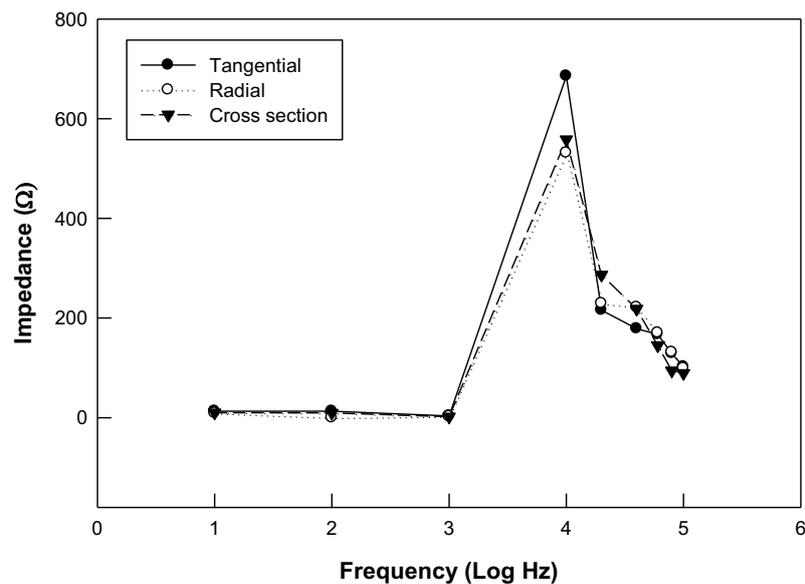


Figure 10. The Relationship between frequency and impedance of *Acacia mangium* in different basic plane from bottom trunk.

There were the relationships between thermal properties and electrical properties of *Acacia mangium*. The thermal conductivity value in cross section was higher than in tangential and radial plane. But, in contrast, the electrical conductivity value in tangential direction was higher than radial and cross section planes. This differences can be caused by the anisotropic properties of *Acacia mangium* wood. The higher value of thermal conductivity in cross section plane was expected by the lot of porous content, therefore the thermal radiation could be easily passed the thickness of wood. Whereas, the highest value of electrical conductivity was in tangential plane, which was expected by the little porous content in this plain.

4. Conclusion

Based on the data obtained, there were the relationships between thermal and electrical conductivity in *Acacia mangium*. The highest thermal conductivity value was at the bottom of the tree and in cross section plane, whereas the smallest was at the top. In contrary, the highest electrical conductivity value was in tangential plane. This differences was expected by the anisotropic of wood which influence thermal and electrical properties.

Acknowledgements

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