Palm Leaf as a Thermal Insulation Material

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Abstract

This paper presents calculation of thermal conductivity (K) of palm leaf experimentally using Lee's disc method to be used as thermal insulator. The thermal conductivity is found to be equal to (k=0.03 W/mK) indicating that palm leaf is a good thermal insulator compared to the other insulators. The effect of the thermal insulator thickness on temperature difference, heat transfer coefficient, thermal conductance, thermal resistance, thermal insulation are investigated in this paper. It was found that increasing thickness of the good insulator (such as palm leaf) leads to increasing both thermal resistance and insulation while decreasing both heat transfer coefficient and thermal conductance until specific point which after it they are not affected by thickness (they being constant).

Introduction

In metal, thermal conductivity approximately tracks electrical conductivity, as freely moving valence electrons transfer not only electric current but also heat energy. However, the general correlation between electrical and thermal conductance dose not hold for other materials, due to the increased importance of phone carriers for heat in nonmetals. Due to the anharmonicity within the crystal potential, the phonons are known to scatter. There are three main mechanisms for scattering; i- boundary scattering(a phonon hitting the boundary of a system), ii-mass defect scattering(a phonon hitting an impurity within the system an saturating),iii- phonon- phonon saturating(a phonon colliding with another phonon and merging into one higher energy phonon) (1).

It is important to know how heat is transferred in structures. Heat is transferred by conduction, convection or radiation, or by a combination of all three. Heat always moves from warmer to colder areas; it seeks a balance. In simple terms this is a measure of the capacity of a material to conduct heat through its mass (2). Different insulating materials and other types of materials have specific thermal conductivity values that can be used to measure their insulating effectiveness. Thermal conductivity can be defined as the amount of heat (energy) that can be conducted in unit time through unit area of unit thickness of material, when there is a unit temperature difference(3). The primary function of thermal insulation materials used in structures and the storage containers is to reduce the transmission of heat through walls into the place. By reducing the amount of heat leakage, the amount of electric energy requirements for refrigeration systems can be reduced if these are used. A wide range of insulation materials is available; however, the choice of insulation material can be very important. Selection of insulation material should be based on initially cost, effectiveness, durability, the adaptation of its shape to that of the structures and the installation methods available in each particular area. From an economic point of view, it may be better to choose an insulating material with a lower thermal conductivity rather than increase the thickness of the insulation in the structure and hold walls(4). The need for the electric energy in increasing and it will be one of the most expensive products in the future. Consequently the need for saving the electric energy consumed by air conditioning units installed in structures which constitutes a large part of its overall consumption requires using insulating wall, floor ,and roof of the structures to prevent leakage of heat through them(5). Extensive studies and many researchers discovered several new thermal insulators. In 1982 L.B.Mcmillan(6) derived equations for the economy of insulation which necessitated the scientists and engineers to focus their attention on usage of air space in the middle of the wall to reduce the heat transfer. As reported by C.P.Aeora (7), the air space can not completely prevent the heat transfer therefore, exploration for an insulation material available and cheap is very important. In 1983 Hamood(8) used the rice husk as thermal insulating material with (k=0.04W/mK). In 1995 Saqir & Emad(9)used papyrus as a thermal insulation material with (k=0.1218W/mK). Therefore searching for good and economic thermal insulation such as palm leaf will give good reduction to the cooling load . In the south of Iraq there are grate many palm which available and covers wide area and the collection process of palm leaf does not cost much. Therefore, it is possible to use it as an insulation material. In view of the foregoing the aim of this paper is to determine the thermal conductivity value (k) for this material and use it as a thermal insulator.

Experimental

The aim of the work is to study the possibility of using the palm leaf as a thermal insulation material by measuring its thermal conductivity. Best insulation materials should have the lowest thermal conductivity, in order to reduce the coefficient of heat transfer. The experiment to determine the value of (k) was carried out in physics laboratory, college of science, Karbala university, using Lee s disc method. In this instrument, the heat is transferred from the disc A jointed by pipe with water vapor container putting on heater to the followed disc B through testing sample till it reaches the steady state. The temperatures (T_A ,T_B) for the two discs A&B can be specified by using the thermometers inside them respectively. One of the most important influences is to ensure that the surfaces of the copper discs are clean and compatible to obtain the best heat transfer through them . The thermal conductivity is defined as a flux of heat (energy per unit area per unit time) divided by a temperature gradient (temperature difference per unit length).The value of the thermal conductivity(k) can be calculated by the following equation (10),

$$k=\frac{Q}{At}\times\frac{x}{\Delta T} \quad \text{..[1]}$$

Where $\frac{Q}{t}$=mc($\frac{dT}{dt}$)$_{TB}$ represents heat flow rate, m=800g is mass of disc B, c=390 J/kg K is specific capacity of disc B, ($\frac{dT}{dt}$)$_{TB}$ is cooling rate of disc B insulated by testing sample from T_B+10°C to T_B-10°C ;namely ($\frac{dT}{dt}$)$_{TB}$ =slope of curve of cooling rate at steady state point, A is surface area of sample which is compatible with discs = $r^2\pi$ = 50.24cm^2, r represents sample radius =4cm, χ represents sample thickness ,ΔT is temperature difference =T_A-T_B ,T_A is water vapor temperature =99°C.The reciprocal of thermal conductivity is thermal resistivity measured in (K.m/W). For general scientific use, thermal conductance σ measured in (W/K) and its reciprocal; thermal resistance R measured in (K/W), heat transfer coefficient T measured in (W/m^{2}K) and its reciprocal; thermal insulation I measured in (m^2 K/W),can be described as (10):

$$\sigma = \frac{Q}{t\Delta T} \qquad [2]$$

$$R = \frac{t\Delta T}{Q} \qquad [3]$$

$$T = \frac{Q}{tA\Delta T} \qquad [4]$$

$$I = \frac{tA\Delta T}{Q} \qquad [5]$$

The palm leaf have been cut and arranged in such a way as to be similar to the specimen that was already supplied with the equipment to measure the thermal conductivity of insulating materials. They were arranged in the experiment in the same manner that we suggested to be used practically in the wall.

Results and Discussion

The palm leaf that have used in the experiment was dry where they already exposed to dry summer weather. The measurement of the thermal conductivity of the palm leaf requires using a micrometer to measure the thickness of the specimen before putting it between the discs (A&B). The temperature of the disc A which represents water vapor temperature was constant to equal 99°c. After allow sufficient time (20min) to reach steady state condition, we can record the temperature at two discs. The measured value of the thermal conductivity of the palm leaf at thickness x=0.5cm was found to be(k=0.030W/mK).This result indicates that palm leaf is a good insulation material compared to other insulations. To study the influence of the thickness on the temperature difference, heat transfer coefficient, thermal conductance, thermal resistance, and thermal insulation; the same experiment was repeated on the varied thicknesses (x=0.5,1,1.5,2,2.5 cm). It is clear from Fig.(1) the increasing thickness of the thermal insulating material (palm leaf) causes increasing temperature difference $\Delta T = T_A - T_B$; i.e. decreasing T_B , until neglecting this effect at thickness (x=2cm). Such material is known as good thermal insulator. The effect of thermal insulator thickness on cooling rate (slope) has been studied, as shown in Fig.(2), where the increasing thickness causes additional reduction in (slope). The decreasing of heat transfer coefficient and thermal conductance due to increasing thickness of the thermal insulating material exhibits throw Fig.(3) and Fig.(4) respectively. It is clear from Fig.(5) and Fig.(6) the increasing thickness of the thermal insulating material causes increasing in both the thermal insulation and thermal resistance respectively. However this increasing being slight where the thickness exhibits a smaller effect on them with increasing it until neglecting this effect at thickness (x=2cm).

Conclusions

The measured value (k=0.030W/mK) indicates that palm leaf is a good insulation material compared to other insulations. It is clear from the experimental results that increasing thickness of good thermal insulator exhibits initially observed effect on the temperature difference, heat transfer coefficient, thermal conductance, thermal resistance, and thermal insulation. However this effect being slight and then neglecting this effect at specific thickness. The palm leaf which act as thermal insulator is very cheap and economic because of it is a common natural plant which is available in the south of Iraq and covers a wide area. Lastly from an economic point of view, we can observe that palm leaf act as thermal insulator at little thickness(x=0.5cm) where it may be better to choose an insulating material with a lower thermal conductivity rather than increase the thickness of the insulation.

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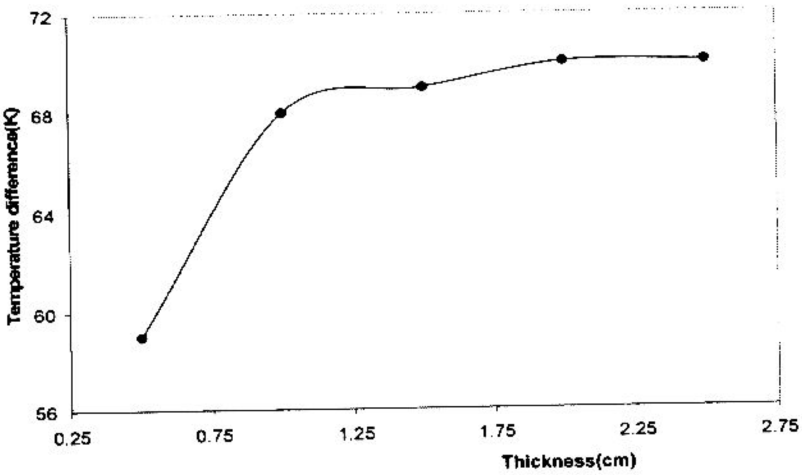

Fig.(1):The effect of thermal insulator thickness on temperature difference

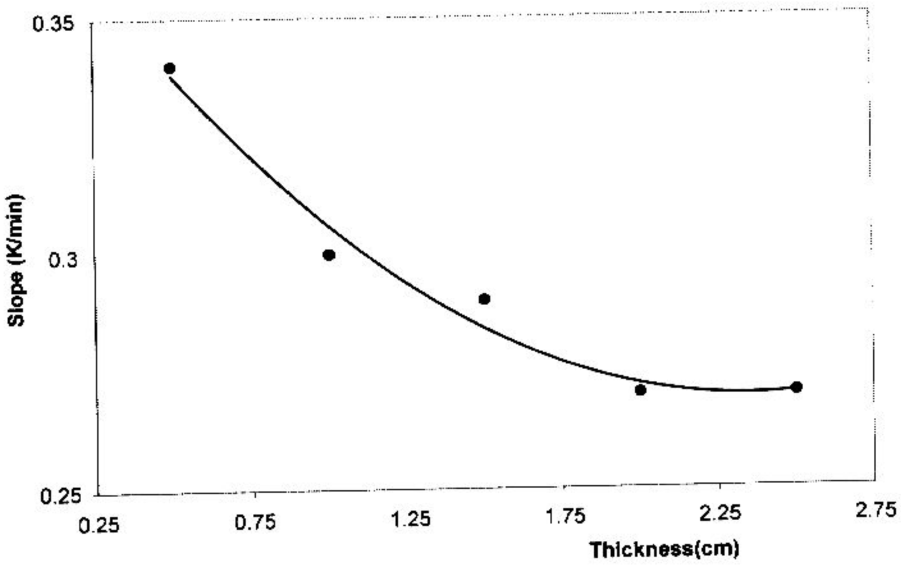

Fig.(2):The effect of thermal insulator thickness on cooling rate (slope)

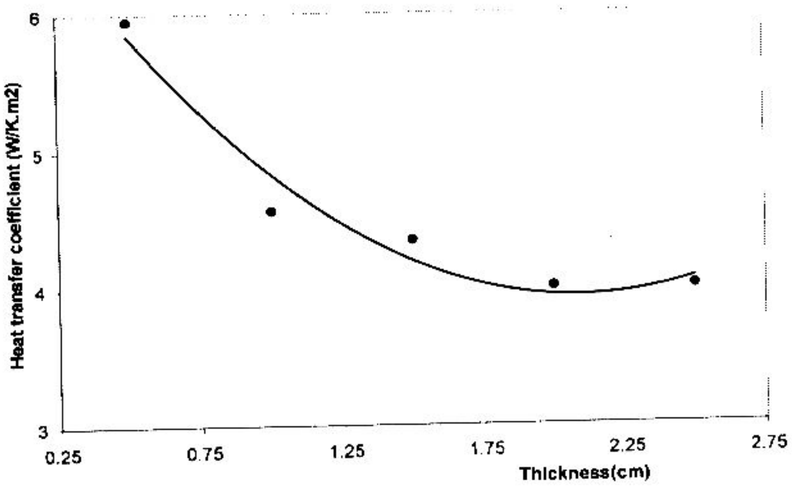

Fig.(3):The effect of thermal insulator thickness on heat transfer coefficient

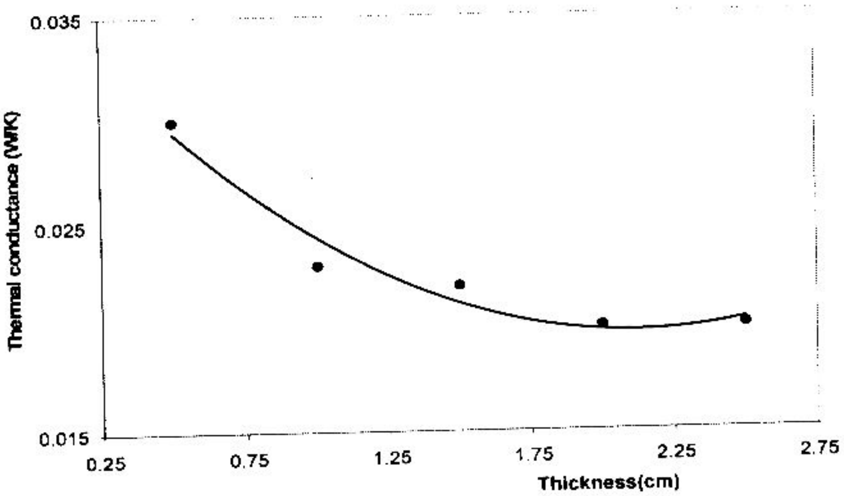

Fig.(4):The effect of thermal insulator thickness on thermal conductance

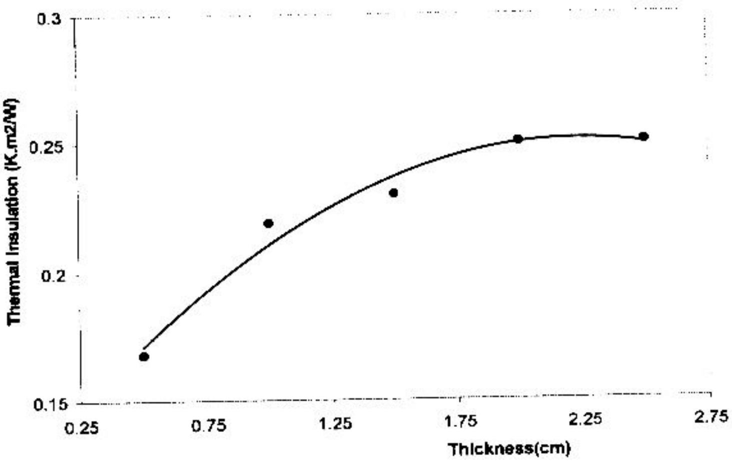

Fig.(5):The effect of thermal insulator thickness on thermal insulation

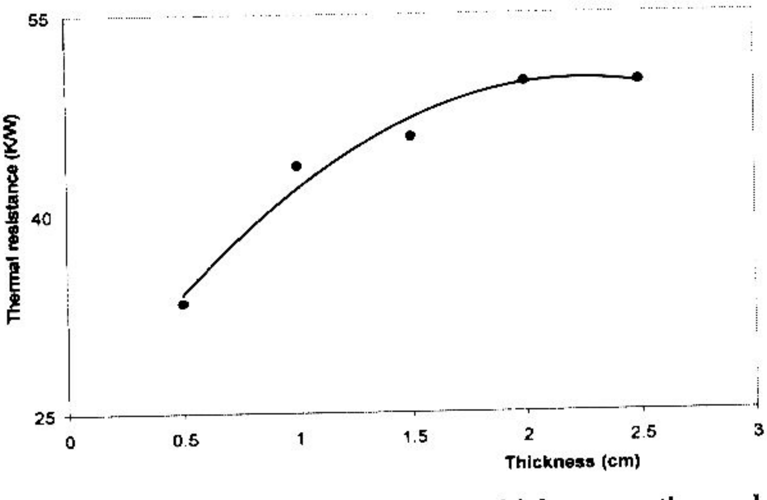

Fig.(6):The effect of thermal insulator thickness on thermal resistance

ورق النخيل كمادة عازلة للحرارة

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الخلاصة

يتضمن هذا البحث حساب التوصيلية الحرارية عمليا لورق النخيل باستخدام طريقة قرص لي لغرض استخدامه كمادة عازلة و قد وجدت مساوية (0.03 W/mK) و التي تشير إلى أن ورق النخيل عازل حراري جيد مقارنة مع العوازل الأخرى. درس أيضا في هذا البحث تأثير سمك العازل الحراري على فرق درجة الحرارة ،عامل الانتقال الحراري، التوصيل الحراري،المقاومة الحرارية،العزل الحراري. فقد وجد أن زيادة سمك العازل الجيد كورق النخيل يؤدي إلى زيادة كل من المقاومة الحرارية و العزل الحراري بينما يقل كل من عامل الانتقال الحراري و التوصيل الحراري حتى نقطة محددة و التي بعدها هذه العوامل لا تتأثر بالسمك .