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Determination of Coefficients of Thermal Conductivity (CTC) of Plastics Using Lee's Disc Method (LDM)

Daniel T. and Gbaorun F.

Department of Physics
Benue State University, Makurdi

Abstract

Coefficients of thermal conductivity of different kinds of plastics were determined using the Lee's Disc Method (LDM). Eight plastics such as Polyethylene Terephathalate (PET), High-Density Polyethylene (HDPE), Polyvinyl Chloride (PVC), Low-Density Polyethylene (LDPE), Polypropylene (PP), Polystyrene (PS), Acroylonitril Butadiene Stryrene (ABS) and Polycarbonate (PC) were sampled at the Wurukum and Modern Markets in Makurdi and their thermal conductivity coefficients were obtained. The coefficient of thermal conductivity of PET was calculated as 0.15±0.01 $Wm^{-1}K^{-1}$, HDPE as 0.42±0.01, PVC as 0.23±0.01, LDPE as 0.31±0.01, PP as 0.10±0.01, PS as 0.03±0.01, ABS as 0.17±0.01 and PC as 0.19±0.01. The results are in good agreement with the experiment. PP has the least coefficient of thermal conductivity and it is recommended for making of utensils handles while PVC recommended for making of ceilings and drain-waste pipes.

Keywords: Coefficients of Thermal Conductivity, Plastics, Wurukum and Modern Markets, Makurdi.

1.0 Introduction

Every material in the world can be classified in terms of how well it conducts heat or electricity [1, 2]. The conductivity of the material depends on the nature. Certain materials such as plastics never conduct heat or electricity and are classified as insulators, while materials such as copper conducts and are said to be good conductors of heat. All materials are made up of ions and electrons. The difference in conduction is due to how the electrons are arranged around the nucleus [3, 4].

The ability or power of a material to conduct or transmit heat is known as the thermal conductivity of the substance (materials) [2, 4, 5, 6] and it is denoted by K.

With the increasing need of using some of these materials, proper measures should be put in place to enhance their effectiveness through adequate technology simulations and applications. This growing need is the motive behind this work and the objective is that the correct materials are used in manufacturing finished products.

The choice of plastic for application depends on the behaviour of the plastic when exposed to cold or heat. The understanding of the maximum temperatures involved and the duration of exposures will dictate plastics selection [7, 8, 9, 10].

Previous works on the heat conduction ability of plastics revealed that plastics have considerably low value of thermal conductivity due to their resistance to the flow of heat [4]. They are therefore classified as good insulating materials [2,5]. Their lower thermal conductivity values have advantages in so many applications such as piping, building, insulation etc. The usage of plastics is increasing due to advantage of low cost, high durability and easy availability [11]. This paper is segmented as follows: Section 2.0 discusses the Materials and the Mathematical Formulations of the method used, Section 3.0 details the Numerical Results of both Experiment and our Calculation while Section 4.0 is the Brief Discussion of the Results.

Corresponding author: ***Daniel T.,*** E-mail: dgemanam@yahoo.com, Tel. +2348062165349

2.0 Materials and Mathematical Formulation

The method used in this work is the Lee's Disc Method (LDM) which is generally used for the determination of the coefficient of thermal conductivity of poor conductors of heat [2,3]. Thermoplastics which include HSPE, PS, PVC, PP, PET, LDPE, PC and ABS were collected with different thickness from Wurukum and Modern Markets in Benue State with different densities, and were later shaped in circular disc of the desired diameter. Using the Lee's Dics Method, (LDM), the samples were mounted one after the other and the total amount of heat emitted from the apparatus is [3, 4, 7]

$$H = Ea_A T_A + Ea_s\left(\frac{T_A + T_B}{2}\right) + Ea_B T_B + Ea_c T_c \quad (2.1)$$

where a_A, a_B, a_c and a_s are the exposed surface areas in square meter, respectively, of disc A, B, C and Sample, (S), while T_A, T_B and T_c are the corresponding temperatures of the disc and E is the heat energy. Since heat flows through bad conductors with great difficulty [3] and from the relation,

$$H = \frac{KA(T_1 - T_2)t}{d} \quad (2.2)$$

it is advantageous to use a substance with very small thickness and large cross sectional area. In equation (2.2), H is the quantity of heat flow, A is the cross sectional area of the sample and d is the thickness measured in meters. Heat is supplied by heating the coil, and thus,

$$H = VI \quad (2.3)$$

with V as the potential difference across the element in volts and I is the current in amperes. From equations (2.1) and (2.3), the heat energy E can be written as

$$E = \frac{VI}{a_A T_A + a_s\left(\frac{T_A + T_B}{2}\right) + a_B T_B + a_c T_c} \quad (2.4)$$

But the heat flowing through the specimen S is given by equation (2.2) and can be rewritten as [3, 4] in terms of the radius of the specimen sample and K.

$$H_s = \frac{K\pi r^2 (T_B - T_A)}{d} \quad (2.5)$$

Assuming the heat flowing through the sample S is the mean of the heat entering S from B and leaving S for A, then the heat entering S from B is that which is emitted by S and A together. Thus,

$$H_{BS} = \left[E_{as}\left(\frac{T_A + T_B}{2}\right) + Ea_A T_A\right] \quad (2.6)$$

The heat leaving S for A is that which is emitted by A alone and

$$H_{BA} = Ea_A T_A \quad (2.7)$$

The mean of equations (2.6) and (2.7) is therefore given as

$$H_s = \frac{E}{2}\left[a_s\left(\frac{T_A + T_B}{2}\right) + 2a_A T_A \right] \qquad (2.8)$$

Hence,

$$K\pi r^2\left(\frac{T_B - T_A}{d}\right) = \frac{E}{2}\left[a_s\left(\frac{T_A + T_B}{2}\right) + 2a_A T_A \right]$$

and

$$K = Ed\left[\frac{\frac{1}{2} a_s (T_B + T_A) + 2a_A T_A}{2\pi r^2 (T_B - T_A)}\right] \qquad (2.9)$$

which is the expression used in the determination of the coefficient of thermal conductivity,(CTC), of the samples.

This heat was allowed to run through the disc's and specimens for current of 0.3A, 0.35A and 0.4A depending on the sample ability to withstand heat and was constant through the period of observation.

3.0 Numerical Results

The CTC of the samples is calculated using equation (2.9) for parameters corresponding to the equation where temperature, current and the voltages were measured parameters from the instruments respectively.

Table 1.0: The calculated K – values of the selected plastics.

Plastics	*Experimental K-values ($W_m^{-1}K^{-1}$) [4].*	Calculated K – values ($W_m^{-1}K^{-1}$)
PET	*0.15 – 0.24*	0.15
HDPE	*0.42 – 0.51*	0.42
PVC	*0.14 – 0.28*	0.23
LDPE	*0.30 – 0.34*	0.31
PP	*0.10 – 0.22*	0.10
PS	*0.03*	0.03
ABS	*0.17*	0.17
PC	*0.17 – 0.22*	0.19

4.0 Discussion

The numerical results of the calculated K-values of the selected plastics are given in Table 1.0. Comparing the Calculated K-values with the Experimental K-values the results of our calculation are in a very close agreement of Column 2 of Table 1.0 [4].

It has showed that the PP is a good plastic material for making of cooking utensils handles since the K-value is very minimal and considering the shortest possible distance between the plastic handle and the metal part (good conductor of heat). Thou, the PS whose K-values is $0.03Wm^{-1}K^{-1}$ with a high density component is not good based on it material density component and as such can not play a very vital role in the handles making as the PP. This K-value of PP proved its high resistive nature to heat. For the Drain-Waste Vent (DWV), piping, low thermal conductivity maintains more uniform temperature when transporting fluid and therefore ABS and PVC among others are best plastics for the production of DWV pipes and house hood ceiling insulation.

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