

# Study of the Effect of Volume Fraction of Alumina Oxide on the Thermal Conductivity Values of Polyester Resin Particulate Composites

Salem. M. Alburki

Chemical Engineering Department, Faculty of Engineering, El-Mergib University, Al-Khums, Libya

**Abstract** - This work aims to study the change in the thermal conductivity of the polyester resin by adding alumina  $Al_2O_3$  and different weights 10% 20% 30% resin and to study the effect of these additions on the thermal conductivity  $K$ . The resin material, and I tried to evaluate this change in behavior using Fourier's law of thermal conductivity to calculate the  $K$  value of the resin before and after adding alumina. The results showed that the thermal insulation increased by increasing the percentage of alumina in the resin and decreasing the thermal conductivity value. This graph summarizes the relationship between thermal conductivity and temperature.

**Keywords:** unsaturated polyester resin, alumina, thermal insulation, thermal conductivity.

## I. INTRODUCTION

Thermal insulators are materials that reduce or prevent the transfer of heat from the outside to the inside. Reduces the need for conditioning and its benefits at any time of the year. By maintaining the building's temperature in summer and winter, it can remain cool or moderate from heat damage in winter and from heat in summer [1].

Thermal insulating materials are classified into three main materials, which are as follows: [2] Fibrous insulation materials, such as: silica materials, glass, and rock wool, and fiberglass and mineral wool are among the most widely used types. Cellular Insulations, such as: polystyrene, polyurethane, Granular Insulations, examples of which are; Calcium silicate, cellulose, and expanded polystyrene. There are several examples of heat island materials: [3] Mineral glass wool. Mineral glass wool is used for thermal insulation in steam piping, hot water piping, industrial applications and in the aerospace industry. These materials are distinguished by their reasonable price and suitability for thermal insulation use. Calcium silicate: A non-combustible material with a pressure strength of  $600 \text{ kN} / \text{m}^2$ . Calcium silicate is used in hot water and steam pipes and as insulation in vessels, furnaces and

boilers. Rockwool: This material has many uses in thermal insulation applications. It is also used in the industrial and commercial sector as a fire protection material in systems and devices.

The material's ability to insulate heat is one the basic properties of thermal insulation materials. They are usually measured by its coefficient of thermal conductivity. Higher the material's resistance to heat transfer, then lower is the coefficient of thermal conductivity. Thermal resistance can be defined as one which is inversely proportional to the coefficient of thermal conductivity through the dielectric material, which is common to all different transmission media (conduction, convection, and radiation).

### 1.1 Composite Materials

A composite is a mixture of two substances that have different mechanical and physical properties. The purpose of this composite is to engineer new properties not found in the original materials.

In nature, there are many examples of composite materials, including cellulose fibers with wood material. In industry, reinforcing resins with synthetic fibers is the most common [4]. For the manufacture of a composite material, two materials must be available:

#### 1. Base materials: (Matrix Material)

They are either metallic, ceramic, or resinous materials, which are the most widely used and widely used for their good mechanical and thermal properties. Examples of resins are phenolic resin, epoxy, and polyester resin.

#### 2. Reinforcement Material

There are several methods of reinforcing, including particle strengthening, dispersion strengthening, and fiber strengthening. An example of the types of fibers used is glass fibers, Kevlar fibers and glass fibers .Reinforcing by Fibers is

the most common reinforcement material due to its great strength compared to resin materials [5].

### 1.2 Unsaturated Polyester Resin

Unsaturated polyester resin belongs to the group of thermosetting resins, where these resins are not able to be reformed by heat after turning into a solid material as a result of forming long polymeric chains intertwined with each other, which is called cross-linking. It is prepared from a reaction with a dibasic unsaturated acid, and it is required that one or both of the monomers have a double bond in its composition. Along the polymer chain, polyester is formed [6].

Polyester resin is characterized by good thermal properties as it withstands high temperatures. Polyester resin has good thermal properties as it withstands high temperatures (for resins) up to 260° C, but it spontaneously decomposes at a temperature of about (300°C) even in the absence of oxygen. It is also characterized by excellent electrical and chemical resistance to solvents, acids, salts, wear and tear and environmental influences, it is also inexpensive but characterized by weakness and brittleness [4.7]. Polyester is added to fiberglass for the manufacture of mold structures, aircraft and automobile fuselage components, and other industries.

### 1.3 Fillings

Fillings can be defined as metal or metallic materials. They are added to resin materials in different proportions to change their properties. And obtaining new properties and one of the properties that requires changing and as needed is resistance. Stiffness, bladder, thermal and electrical resistance [8].

Fillers are added to polyester resin for two purposes, the first to reduce cost due to its low cost, and the second to strengthen the resin and have high resistance properties. Ceramic materials are considered one of the most important fillers added to the resin and knead for high hardness, resistance to wear and poor conduction of heat, and they are widely used in thermal insulators. Among the materials used are silicon oxide (silica), magnesium oxide, alumina, and others[9]. The researchers, Salem and Khaled, studied the thermal behavior of polyester resin added to hybrid materials. This paper was published in the first conference of engineering sciences in the city of Sirte - Libya [10], where the same material manufactured in the Plastics Research Center - Tajoura - Libya will be used, which is the resin and edging alumina and the study of thermal resistance of the manufactured material.

## II. EXPERIMENTAL WORK

The practical part includes the following:

First - the materials used in the research, the following materials were used in this research

1. Unsaturated polyester resin obtained from Tajoura Plastics Research Center.
2. Alumina: used alumina or aluminum oxide  $Al_2O_3$  - with particle size and purity (95.5%  $\mu m$ 10%).

### 2.1 Sample preparation

These models are 25 mm in diameter and 4 mm thick. The preparation is done by mixing a quantity of resin after it hardens by adding 2% methyl ethyl ketone peroxide with the precipitate. After that, aluminum oxide is added in different proportions 10% 20% 30%.

### 2.2 Thermal conductivity measurement

The Fourier Law can be used to calculate the thermal conductivity coefficient (k):

$$Q = -k \times A \times \left( \frac{\Delta T}{\Delta X} \right)$$

Where:

Q = the amount of heat that passes per unit time and is measured in units (W)

k = coefficient of thermal conductivity, measured in units (W/m °C)

A = heat flow cross-sectional area, measured in units (m<sup>2</sup>)

$(\Delta T / \Delta X)$  = temperature gradient relative to distance, measured in units (C/m).

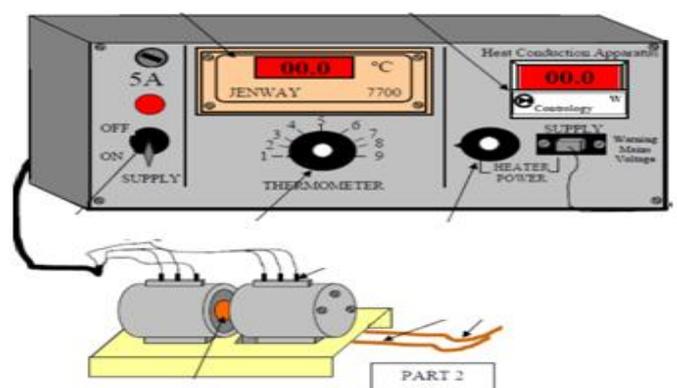


Figure 1: Thermal conductivity measurement device

The device relies in its working principle on shedding electrical power.

It works on heating the model inside the device after, it is based electronic thermometers distributed on either side The model and each thermometer are separated by a distance (10 mm) .to measure the temperature change on both side The model, and through the temperatures recorded by the device

To measure the thermal conductivity, the curve shown in Figure (2) can be drawn, which shows how to calculate the value of the temperature gradient applied in the Fourier equation. Represent ( $X_3, X_1$ ) the distance between the thermometers on both sides of the model, and  $X_2$  represents the thickness of the model [11].

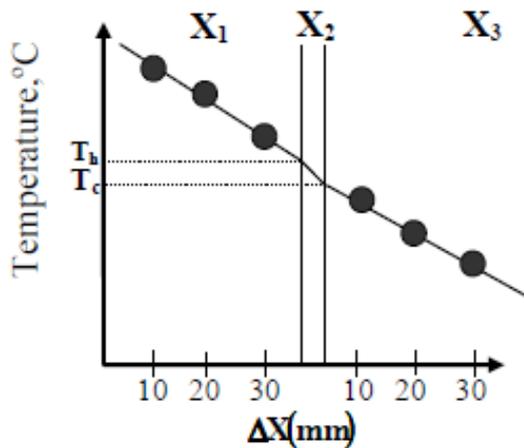


Figure 2: Temperature gradient

### III. RESULTS AND DISCUSSIONS

Where it begins, the conductivity increases with the increase in temperature and the reason for this is due to the vibrations in the internal structure of the resin that increase with the increase in temperature [12]. These vibrations begin to decrease when fillings are added to the resin, which works to impede the vibration and thus reduce the value of the thermal conductivity

Figure (4) represents the thermal conductivity of polyester resin plus of (10%) Alumina material, as the percentage of thermal insulation increases as a result of obstruction. The internal structural vibration of the oxide, in addition to the Alumina is a poor conductor of heat due to its being of ceramic oxides.

The thermal insulation value and the percentage of retardation of vibrations increase with the increase in the percentage of added alumina, as is clear from Figure (5), which represents the thermal conductivity of the polyurethane resin in addition to (20%) of the alumina ester, as the obstacles to heat transfer increase with the increase in Magnesium oxide minutes [13]. This behavior continues with the increase in the

proportion of magnesium oxide added and as in Figure No. (6), which represents the thermal conductivity of polyester resin in addition to (30%) of alumina.

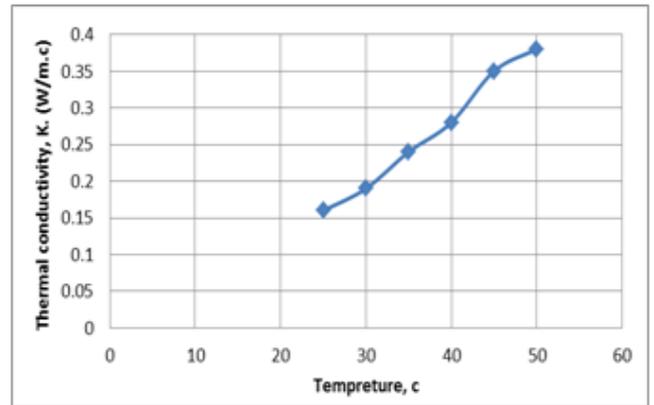


Figure 3: Polyester Resin

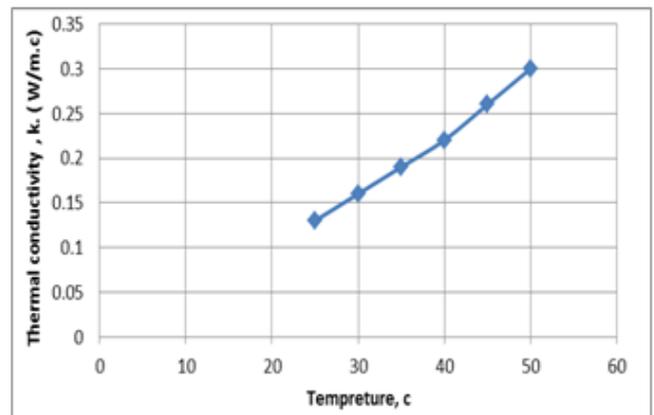


Figure 4: Polyester + 10% Al<sub>2</sub>O<sub>3</sub>

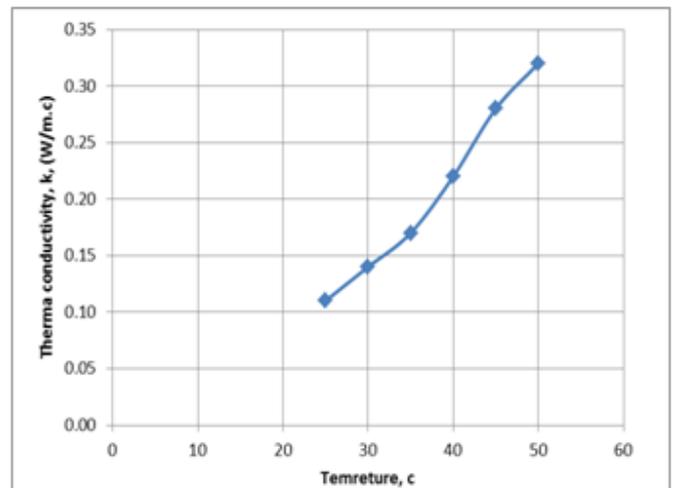


Figure 5: Polyester resin + 20% Al<sub>2</sub>O<sub>3</sub>

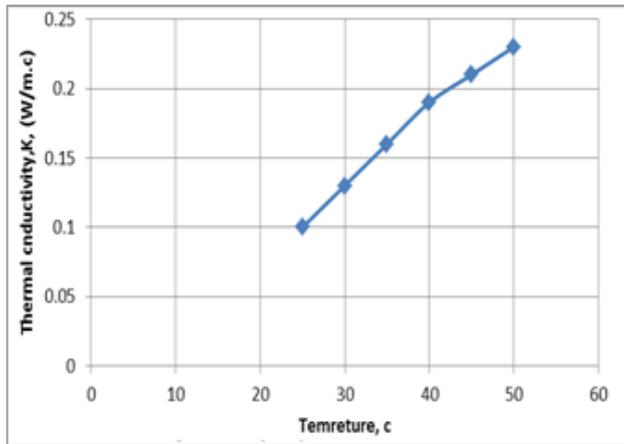


Figure 6: Polyester resin + 30% Al<sub>2</sub>O<sub>3</sub>

#### IV. CONCLUSION

Through the results obtained from testing the thermal conductivity of polyester resin before adding alumina and after that, a number of conclusions were reached.

1. The heat conductivity value of polyester resin increases with increasing temperature.
2. Low conductivity of polyester resin after adding alumina to it. Increasing the rate of thermal insulation by increasing the proportion of alumina added to polyester resin.

#### REFERENCES

- [1] "Insulation Materials ", [www.uomustansiriyah.edu.iq](http://www.uomustansiriyah.edu.iq), Retrieved 2019-5-29 (Page 5).
- [2] "Thermal Insulation Materials", [www.netzsch-thermal-analysis.com](http://www.netzsch-thermal-analysis.com), Retrieved 2019-5-29 (page 2).
- [3] "Thermal Insulation Materials: A Tool for Energy Conservation", [www.researchgate.net](http://www.researchgate.net), Retrieved 2019-5-30 (page 2).
- [4] Halem, Ali Hoby "Improvement Properties of Reinforced Plastic Materials", *MSC Thesis Engineering College, Babylon University, Iraq*, 1999.
- [5] Market Report, "Glass Fibers US Industry Forecasts to 2011 and 2016", *Freedonia publisher*, 2007.
- [6] Craig W. Ohlhorst Wallace L. Vaughn, Philip O. Ransone, and Hwa-Tsu Tsou, "Thermal Conductivity Database of Various Structure Glass-Glass Composite Materials", *NASA Technical Memorandum 4787*, November, 1997.
- [7] Mallick, P.K. "Fiber-Reinforced Composites: Materials, Manufacturing, and Design", *3rd Edition, CRC Press*, Nov, 2007.
- [8] E.P. DeGarmo, J.T. Black, and R.A. Kohser "Materials and processes in Manufacturing", *10th Edition, John Wiley & Sons*, 2008.
- [9] Dr. Kahtan K.Al-Khazraji , Ali I.Al- Mosawi "Effect Study of MagnesiumOxide on Thermal Conductivity of Unsaturated Polyester Resin", *Journal of Babylon University, Engineering Sciences*, Vol 9, No 5, pp.867 – 876, 2004.
- [10] Alburki, Salem, Aljfairi Khaled, "ChE-13-ICES2022 Study of the thermal behavior of a composite material consisting of unsaturated polyester resin", (1-3- 2022).
- [11] Incropera, F.P. and DeWitt, D.P. "Introduction to Heat Transfer", *3rd Edition, John Wiley & Sons*, 1996.
- [12] Bogomolov V and Kartenko N, "Thermal Conductivity of the Opal-Epoxy Resin Nanocomposite", *Physics of the Solid State*, Vol 45, No 5, PP. 957-960, 2003.
- [13] P. L. Teh, M. Jaafar, H. M. Akil, K. N. Seetharamu, A. N. R. Wagiman, K. S. Beh, "Thermal and mechanical properties of particulate fillers filled epoxy composites for electronic packaging application Polymers for Advanced Technologies", Volume 19, Issue 4, PP 308-315, 2008.

\*\*\* End of the Article \*\*\*