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## *Abstract :*

The aim of this research is to study the effect of fiber glass on the thermal insulation property of polyester resin . Different amounts of fiber glass were added to the polyester resin with hardener then cast as sheet of composite material of dimension (20*20*0.3) $cm^3$ with different fiber glass weight percentage : ( 0% , 4 % , 8 % , 12 % , 16 % , 20 % ) of the total weight. The thermal conductivity was calculated by using Lee's Disk method . The mean value of five measurements of thermal conductivity ( k ) for each specimen was measured , also the hardness of the specimens was measured by using shore method type D and then sketch the relation between thermal conductivity and hardness with the percentage of fiber glass. The results showed that the thermal conductivity (k) of polyester decreased (which mean thermal insulation increased ) with an increase of fiber glass percentage , and the hardness increased with the increase of fiber glass percentage due to the restricted movement of the chain end of polymer .

**Key words:** Thermal insulation , Polyester resin , fiber glass , hardness .

## *Introduction :*

The thermal insulation is one of the important properties in industry. The main uses of materials for insulation, which is defined as a combination of materials to retard the flow of heat [1] .

All insulator materials is porous materials depending on retardation heat transfer between two surfaces .The reduction heat transfer is the major purpose for using thermal insulation material , where the suitable insulation reduce thermal conduction, therefore thermal conductivity coefficient makes major criteria in a choice of insulations .Thermal insulators are material or combinations of materials that are used primarily to provide resistance to heat flow. Most insulators are heterogeneous materials made of low thermal conductivity materials. Heterogeneous materials consist of polymer with fillers or different material embedded randomly with it in [2].

## *Materials used :*

### 1.Polyester resins

Polyester resins are thermosetting which means the plastic softens when initially heated , but sets permanently rigid once it has cooled or has been chemically "cured/set"(as opposed to "thermoplastics", which re-soften with heat). Polyester resin is often purchased in liquid form for the production of glass-reinforced plastic. In this case, a catalyst (typically methyl ethyl ketone

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peroxide (MEKP) (also known as butanone peroxide) is used to initiate the polymerization reaction; benzoyl peroxide is a somewhat less hazardous alternative suitable for some purposes. The process of curing polyester resins using a catalyst is an exothermic process. The use of excessive catalyst can cause an excess of heat during the cure process and thus damage the resin by charring or even cause ignition [3].

Polyester was used as molding or casting materials for a variety of applications and as a matrix for fiber-reinforced composites. The polyester can be either thermo setting or thermo plastic [ 4]. Polyester resins can be cured at room temperature with a hardener or alone at (70-150) ºC, it was used mostly for glass reinforced plastic (GRP) molding .In this study commercial polyester used with density 1.21 g/cm $^3$ at 200 ºC .

## 2.Fiber glass

Fiber glass is a material made of extremely fine fibers of glass. It is used as a reinforcing agent for many polymer products . The resulting composite material, properly known as fiber-reinforced polymer (FRP) or glass-reinforced plastic (GRP), is called "fiberglass" in popular usage. The basis of textile-grade glass fibers is silica, $SiO_2$. In its pure form it exists as a polymer $(SiO_2)n$. It has no true melting point but softens at 2000°C. At 1713 °C, most of the molecules can move about freely. If the glass is then cooled quickly, they will be unable to form an ordered structure, In the polymer, it forms $SiO_4$ groups which are configured as a tetrahedron with the silicon atom at the center and four oxygen atoms at the corners. These atoms then form a network bond at the corners by sharing the oxygen atoms, which is used for regular fiberglass include mats, thermal insulation, electrical insulation, reinforcement of various materials, sound absorption, heat- and corrosion-resistant fabrics, high-strength fabrics, bows and crossbows, translucent roofing panels, automobile bodies, electrical insul-+ation [5] .

## ***Literature Review***

Abdulreda [ 6 ] studied the effect of adding asbestos on the thermal insulation of polyethylene and polyester . He found that the thermal insulation , the impact strength and hardness increased with the increase of adding the asbestos .

Emad S. Al-Hasani [ 7 ] studied the effect of adding layers of fiber glass on the tensile strength and hardness of the epoxy ( DGEBA) resin . He found that the sandwich composite of the layers gives higher tensile strength , while the composite reinforced with woven roven fiber has maximum hardness values .

Tavman [8] studied the thermal conductivity of composite materials for HDPE in poder form with filler $Al_2O_3$ particle. The models predicting the effective thermal conductivity of composites filled with particles . He obtained that materials is desired thermal, mechanical and electrical properties.

Wang et al. [9] studied and determined the effects of pre-treated flax fibers on the performance of the fiber-reinforced composites , these composites consisting of HDPE or LDPE or mixed HDPE/LDPE, the samples of fiber and additives were prepared by the extrusion process and rotational molding . They investigated the effects of the different chemical treatments on the mechanical and thermal properties.

Ogorkiewicz and Turner [10] investigated the mechanical characteristics of reinforced thermoplastics. They showed experimentally that for (20-40) % by weight, glass fibers. The stiffness factor is in the range of 2-3.

Jones [11] studied the effect of thickness and temperature on heat transfer through foamed polymers . He selected polystyrene with different densities . He concluded that the apparent thermal conductivity of still layers of air is a function of the temperature as well as the thickness of the layer .

Hollingsworth[12] prepared an experiment to study the effect of insulator thickness on thermal conductivity for some materials . He found that the thermal conductivity influence in their location and the direction heat transfers in the case of discontrol density through the thickness of specimen, that means if the upper portion or lower portion is thick , then the change of specimen turns over influence in value the of thermal conductivity especially for material to high absorb radiation .

Gotoh [13] recognized many theoretical expressions, which have been derived for evaluating the effective thermal conductivity of heterogeneous substances.

These expressions fall into two categories exact solutions and simplified solutions, and yield good agreement with experimental results on low concentration, while they have not yield good agreement in the high concentration.

Peter et al. [14] studied the insulating material under restorations to protect against thermal shock, and assess that the heat transfer through four lining materials.

Zinc oxide eugenol cement , calcium hydroxide paste and two more contemporary material . A resin modified glass polyalkenoate (RMGP) and dentine binding system , seven samples of each material was tested by utilizing a Lee's disk apparatus.

Duncan and Mark [15] suggested to study thermal conductivity of (PTFE) by using apparatus called Lee's disk , and incorporating fillers into a PTFE/glass fiber . They showed that crystallinity effected on thermal conductivity and compared with different methods , also they found that thermal conductivity of PTFE with different levels of crystallinity was measured at 232 C° increase linearly with this parameter.

## *Experimental work*

### Instrument:

**Mechanical instruments :** Mechanical properties tests having the instruments used in this study:-

- **Hydraulic press .**
- **Cutting specimens machine.**

The specimens produced from molding process must cut into the desired shape using cutting machine with their specification: Di punch automatic hollow supply from CEAST of American company, Pneumatic jack , Air compressor up to 11 bars , Electrical motor 5.6 A, 250V, 1100 w, 2830 r.p.m, 48240 k.

### Hardness tester (shore D)

usually shore hardness tester was used. The most commonly used type (A) tester for soft materials while type (D) tester is used with slightly harder materials , with the following specification : MFG-company, Inc., U.S.A. , Indenter diameter = 0.1 ± 0.01 mm , Max load = 50 N

Five measurements were made for each test specimen type , i.e. all prepared of alloy composites with different constituents.

### Thermal conductivity instruments

Thermal conductivity instrument used in this study is the Lee's Disk apparatus , infrared thermometer , Power supply .

### Lee's Disk Apparatus

The Lee's Disk apparatus was fabricated locally in the laborato ry of college of engineering , material Department, according to ASTM-E1225-04 [16].

The general features of Lee's Disk apparatus are shown in Fig (1 ).

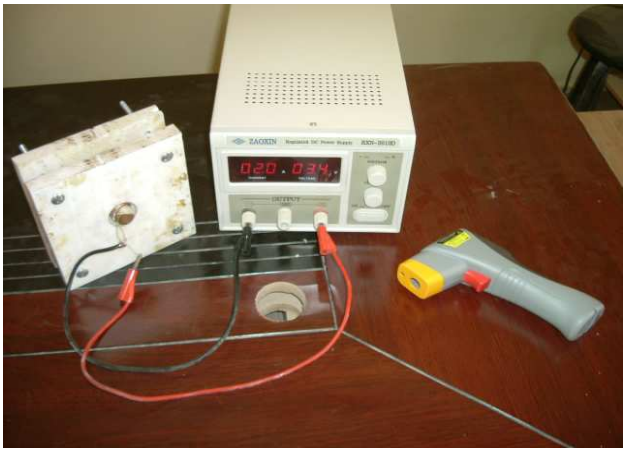

**Fig.( 1 ) Lee's disk apparatus**

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When heat source is switched on and the whole is left to equilibrate , the first brass plate removed carefully and the sample placed onto the second Brass plate .Then measured the inlet temperature on the first brass plate $T_1$ and outlet temperature on the second brass plate $T_2$ were measured each 10 min. using infrared thermometer .

## *Preparation of alloys :*

Several alloys consisting of different percentages from the hardener and polyester were prepared using the quantities of 99 % polyester resin + 1 % hardener .The predetermined quantities from the polyester resin and hardener [MEKP] were added wise portion with continuous mixing for (10 min) the reaction constituents were left at 60 °C to get red off the bubbles formed due to the reaction. The products were cast in the plastic mold and left for curing at room temperature overnight with dimensions ( 20*20*0.3 ) $cm^3$.

Fiber glass adding to these alloys with different percentages [0 , 4 , 8 , 12 , 16 , 20] is as shown in table (1).

**Table (1): composition of polyester with harder and fiber glass**

| specimen | ( Polyester + Hardener ) % | Fiber glass % |
|---|---|---|
| 1 | 100 | 0 |
| 2 | 96 | 4 |
| 3 | 92 | 8 |
| 4 | 88 | 12 |
| 5 | 84 | 16 |
| 6 | 80 | 20 |

## *Measurements of thermal conductivity*

Using Lee's Disk apparatus ( figure 1 ) to measure the thermal conductivity ( K ) . To calculate the thermal conductivity for every thermal insulator, we use a standard sample of 6 mm thickness and 25 mm diameter , and small disk specimens of 35 mm diameter were cut from sheets prepared , and using the following equation :

$$K = K' \frac{d(T_2 - T_0)(T_1' - T_2')A'}{d'(T_2' - T_0')(T_1 - T_2)A}$$

Where :

K = thermal conductivity of checked sample .

K' = = thermal conductivity of stander sample = 0.23 W/m.k

d = thickness of sample = 3 mm d' = thickness of standard sample = 6 mm

$T_0$ = ambient temperature = 22 °C $T_0'$ = ambient temperature of standard sample = 28 ºC

$T_1$ , $T_2$ = inlet and outlet temperature $T_1'$ , $T_2'$ = inlet and outlet temperature of standard sample = 100 ºC , 60 ºC

A = surface area of sample = ($\pi$ / 4 ) $D^2$ A' = surface area of standard sample = ($\pi$ / 4 ) $D'^2$

D = sample diameter = 25 mm D' = standard sample diameter = 35 mm

## *Result & Discussion*

from table ( 2 ) and figure (2) , the results showed the relation between thermal conductivity (K) and fiber glass percentage . Thermal conductivity of the polyester resin decreased with

the increasing of fiber glass percentage , which means increasing of the thermal insulation of the polyester due to the effect of fiber glass which is used as filler material with the polyester resin . Heat transfer in solid materials happen due to the vibration and collision of molecules with other particles until cure the material. The force which is binding atoms by itself inside molecule much more from that which connected molecules form for material that lead to large freedom molecules in motion and easy to transfer energy between them , so the fiber glass absorb the vibration of molecules of polyester , and that causes more difficult in heat transfer in the polyester . Also , the thermal conductivity is lower by increasing the force between the molecules while its increase when the binding force is less leading to heat transfer from hot surface to the cold surface [6] , therefore the thermal conductivity became less gradual by increasing the percentage of fiber glass to 20 % .From figure ( 3 ) which showed the relation between the hardness and fiber glass percentage , we saw that the hardness of the composite materials of the polyester resin and fiber glass measured by shore method type D increased with the increasing of fiber glass percentage . This is due to increasing the retardant of end chains movement and increasing cross linking force .

**Table ( 2 ) Thermal conductivity of the polyester resin and fiber glass percent and hardness**

| Fiber glass percent % | Thermal conductivity k (w/mk) | Shore hardness D ( kg / $mm^2$ ) |
|---|---|---|
| 0 | 0.039 | 71 |
| 4 | 0.034 | 84 |
| 8 | 0.028 | 92 |
| 12 | 0.024 | 101 |
| 16 | 0.021 | 108 |
| 20 | 0.0117 | 118 |

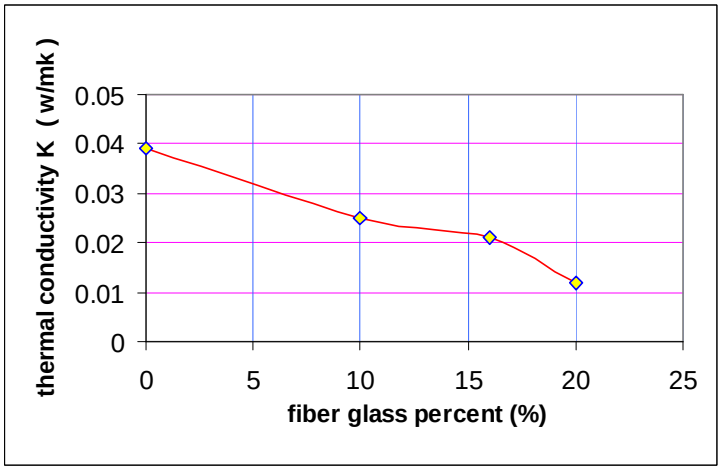


**Figure ( 2) The relation between thermal conductivity and fiber glass percent**

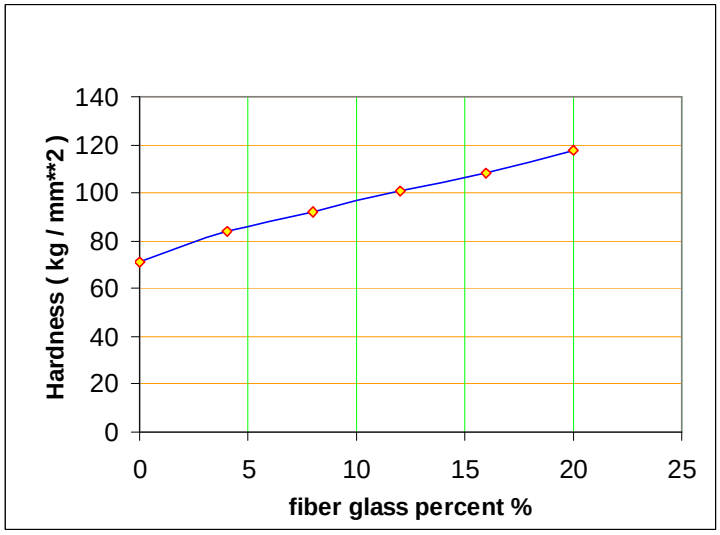


**Figure ( 3 ) The relation between hardness and fiber glass percent**

## *Conclusion*

From the results , which are obtained in this study , the following conclusion can be drawn :

1. increasing fiber glass ratio lead to increase in thermal insulation .
2. hardness increased with the increasing of fiber glass.

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# تحسين العزل الحراري للبولي استر بإضافة الألياف الزجاجية

***الخلاصة:***

يهدف هذا البحث إلى دراسة تأثير إضافة الألياف الزجاجية إلى البولي استر على خاصية العزل الحراري ، وكذلك على الصلادة .حيث تم إضافة كميات مختلفة من الألياف الزجاجية مع البولي استر المخلوط بمادة مصلبة لتكوين شرائح من المادة المركبة ذات أبعاد ( 20 * 20 * 0.3 ) سم$^3$ . تم تحضير ست عينات يختلف فيها نسبة وزن الألياف الزجاجية المضافة وهي ( 0 % ، 4 % ، 8 % ، 12 % ، 16 % ، 20 % ) على التوالي من الوزن الكلي لكل عينة مستخدمة.

تم حساب التوصيل الحراري باستخدام طريقة Lee's Disk ، وذلك باستخدام قيم مختلفة للتيار الكهربائي وحساب معدل التوصيل الحراري ( k ) لكل عينة . كذلك تم قياس صلادة العينات باستخدام طريقة شور للصلادة نوع D . من رسم العلاقة بين كل من التوصيل الحراري ( k ) والصلادة مع النسب المئوية المختلفة لمادة الألياف الزجاجية المستخدمة لوحظ الآتي : انخفاض مقدار التوصيل الحراري k ( أي زيادة العزل الحراري ) وزيادة الصلادة ، كلما زادت نسبة الألياف الزجاجية المستخدمة .