The effect of Aluminum Oxide, Iron Oxide on the thermal conductivity of (Epoxy-Aluminum Oxide, Epoxy-Iron Oxide) Composites

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Abstract:

Thermal conductivity for epoxy composites filled with Al_2O_3 and Fe_2O_3 are calculated, it found that increasing the weight ratio of Al_2O_3 and Fe_2O_3 lead to increase in the values of thermal conductivity, but the epoxy composite filled with Fe_2O_3, have values of thermal conductivity less than for epoxy composite filled with Al_2O_3, for the same weight ratio. Also thermal conductivity calculated for epoxy composites by contact to every two specimens (like sandwich) content same weight ratio of alumina-oxide and ferrite-oxide, its found that the value of thermal conductivity lays between the values of epoxy filled Al_2O_3 and of epoxy filled Fe_2O_3.

تأثير أوكسيد الألمنيوم، أوكسيد الحديد على التوصيلية الحرارية لمتراكبات (ايبوكسي- أوكسيد الألمونيوم، ايبوكسي-أوكسيد الحديد)

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الخلاصة:

تم حساب التوصيلية الحرارية لمتراكبات الايبوكسي بأوكسيد الألمنيوم وأوكسيد الحديد وقد وجد إن زيادة النسبة الوزنية لأوكسيد الألمنيوم وأوكسيد الحدبد قد أدت إلى زيادة قيم التوصيلية الحرارية لكن قيم التوصيلية الحرارية للايبوكسي المملوءة بأوكسيد الحديد كانت أقل منها للايبوكسي المملوءة بأوكسيد الألمنيوم ولنفس النسب الوزنية. كذلك تم حساب التوصيلية الحرارية لمتراكبات الايبوكسي وذلك بوضع نموذجين في حالة تماس (بشكل طبقة بينية) يحتويان على نفس النسب الوزنية من أوكسيد الألمنيوم وأوكسيد الحديد، وقد وجد أن قيم التوصيلية الحرارية للايبوكسي المملوءة بأوكسيد الألمنيوم والايبوكسي المملوء بأوكسيد الحديد.

Introduction

In order to obtain materials of desired thermal, mechanical and electrical properties. Fillers may be in the form of fibers or in the form of particles uniformly distributed in the polymer matrix material [1] . The choice of particle fillers depends on the desired properties. Also we can note here the size and geometry of particle filler is an important role in the composite properties [2, 3]. The particle fillers are distributed randomly in the matrix material, this type of distribution led the properties of composite material being anisotropic. The gross of particle sizes (greater than 1μm) decrease the ratio of homogenate of composite material, also decrease the strengthening. It is evident that thermo physical properties of the filled composites are anisotropic, except for the very short randomly distributed fibers. Whereas, thermo physical properties of particle filled polymer are isotropic. Many theoretical, numerical and experimental studies exist about thermal conductivity of micrometer sized particles and fiber filled polymer composites.

Thermal conductivity of Particle filled Polymer Composite

Thermal conductivity is a measure of materials ability to transfer heat through itself [4,5]. Polymers belong to those substances which are poor conductors of heat, their coefficient of heat transfer not generally exceeding 0.5W/m.k, and in the case of orientated, or partially crystalline and on the range of temperature studied. In the interpretation of the relationship between the coefficient of heat transfer of the crystalline phase and temperature, use in made of the phononic theory of heat transfer in the crystalline phase description of heat transfer in the amorphous phase uses the theory of solid bodies, taking into account the motion of combined structural elements and the phenomenon of phonon scattering, or the phenomenon of heat transfer by chemical bonds. The irregular structure of glass and plastics gives rise to large amount of phonon scattering. The mean free path will be very small and it will be temperature in dependent [6].The thermal conductivity improvement is largely related to the volume fraction of filler and its thermal conductivity [7,8]. Thermal conduction systems containing high volume fractions of particles are "attached" systems in which particles interact with each other and affect the position of particles in a composite. Therefore; it is considered that powdery properties of particles, greatly affect the thermal conductivity of the composite [9].

Experimental Part

Material Used

Two types of filler were used , Al_2O_3 and Fe_2O_3,Epoxy resin used to form composite materials.

Composites Preparation

In order to obtain a composite, Al_2O_3 and Fe_2O_3 filler should be added to epoxy resin in the filler range from (10%, 20%, 40% and 50%) by weight ratio. Hand lay out method was used to prepare specimens as discs with diameter (2cm).

Steady State Testing Apparatus

The conductivity of the small thin slabs of material has been determined by lee's by a method which is applicable over a wide rang of temperature [10]. The arrangement is shown in Fig. (1), the substance S was contained between two copper blocks or discs U and M, and the heating coil between U and a third copper block C. The temperatures of all the copper blocks were measured by thermocouples. When the discs had been assembled they, were varnished to give them the same emissivity, and the whole apparatus was suspected in an enclosure of constant temperature. The apparatus is calibrated with materials of known thermal conductivity.

In the theory given below, the following symbols are used:

H= rate of supply energy to the heating coil, after the steady state has been reavhed.

h= heat loss per second per sq. cm.

t= excess temperature over that enclosure.

d= thickness of discs.

r= radius of discs.

The heat received per second by the disc M and given up to the air is

$$\left(\pi r^2 + 2\pi r d m\right) h t m \qquad (1)$$

The heat received per second by S and given up to the air from it's exposed surface or passed on to M is

$$\left(\pi r^2 + 2\pi r dm\right) htm + 2\pi r dsh \cdot 1/2\left(t_m + t_u\right) \quad (2)$$

If k is the thermal conductivity of the discs S, the heat flowing through it is

$$\pi r^2 k t_u - t_m / ds \quad (3)$$

We may assume that the flowing through S is the mean of the quantities of the heat flowing into it and out of it, i.e that the third of the above quantities is half the sum of the other two. We have, therefore, on dividing by πr^2,

$$k\left(t_u - t_m / ds\right) = h\left[t_m + 2/r\left(dm + ds\right)t_m + \tfrac{1}{2} r ds t_u\right] \quad (4)$$

Methods of test

Two method of test are used, first method is done by put the preparation specimens in part (3-2) in place of substance S Fig. (1). The second method of test is done by put to type of specimens in place of substance S, like sandwich Fig. (2), every two specimens tested have the same ratio of filler as example; first specimen ($EP90\%/Al_2O_3 10\%$), second specimen ($EP90\%/Fe_2O_3 10\%$).

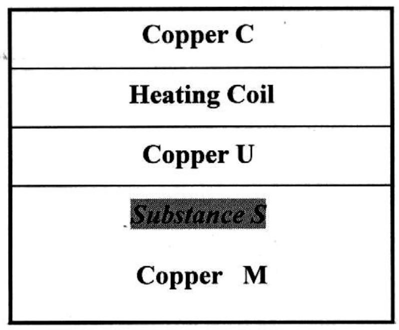

Fig. (1): Thermal Conductivity Apparatus

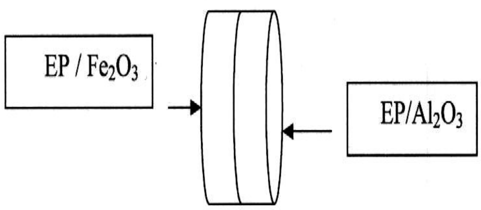

Fig. (2): show two specimens as sandwich

Results and Discussion

Thermal Conductivity of epoxy filled with Al_2O_3

It can be reduce the thermal condictivity by adding Al_2O_3 to one of the insulator polymers, like epoxy resin to form a composite with alow thermal condictivity, as shown in Fig. (3), the value of the thermal condictivity was increased with the increasing of the weight ratio of the Al_2O_3, that can be explane because particles begin to form conductive Al_2O_3 chains, and heat flows not only through the formed conductive Al_2O_3 chains, but also through the epoxy itself .The thermal conduction systems in polymers filled with high conductive particles vary with the volume content of particles and can be classified into two systems , one is a system with low content of particles in which dispersed particles hardly touch each other (dispersed system), while the other is a system with higher content , in which conductive chains formed by particles and contribute to alarge increase in thermal conductivity of composite (attached system) [12]. Another explanation is based on solid state theory deals with the cooperative motion of monomers and the phenomenon of a phonon scattering which limit the region of energies of transfer [13]. According to this theory, the modification may cause reduction in molecular mobility at considerable distance from the filler surface.Since the ends of many chains segments are firmly anchored at the filler surface. The reduced molecular mobility in the boundary layers will influence the intermolecular vibrations .So the thermal conduvtivity is increased [14].

Thermal conductivity of epoxy filled with Fe_2O_3

As shown in Fig. (3) the thermal conductivity of epoxy filled with Fe_2O_3 was stabilaze, although there is a smole increace with the increasing of weight ratio of Fe_2O_3 in specimens, indded there is alow varaition in values of the thermal conductivity. Also we can see from Fig. (3) that the value of thermal conductivity of epoxy filled with Fe_2O_3 is less than of epoxy filled with Al_2O_3 which they have the same weight ratio of filler , because the thermal conductivity of Fe_2O_3 is 12.5 W/m.k. [11] which lead to reduce the value of thermal conductivity of EP/ Fe_2O_3 composite .

Thermal conductivity of Sandwich

The results of the thermal conductivity of the sandwich (EP/Al_2O_3) with (EP/ Fe_2O_3) Fig. (4) show that the increasing of weight ratio to Al_2O_3 and Fe_2O_3 in the speciemens lead to increasing in the thermal conductivity , also we can see that the value of the thermal condictivity lays between the value of epoxy filled with Al_2O_3 and epoxy filled with Fe_2O_3,that can be explain by the effect of the air cap between the tested speciemens which lead to increasing of the heat transfer across the specimens, and at high filler concentration, the conduction is the main mechanism of heat transfer [15].

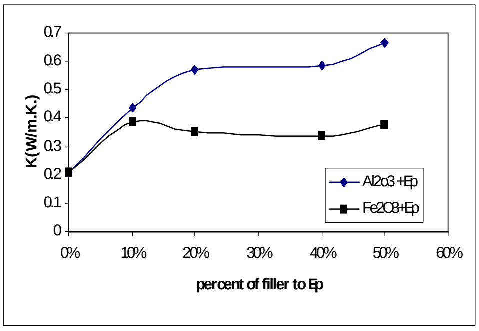

Fig. (3): Thermal conductivity of EP filled with Al_2O_3 and Fe_2O_3 composites

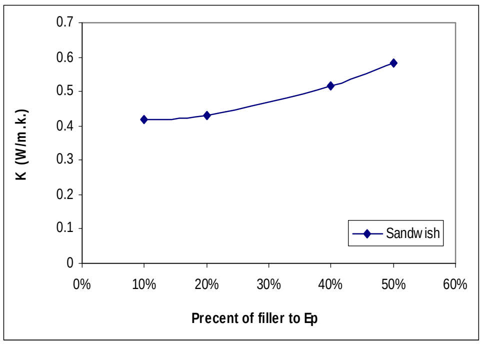

Fig. (4): Thermal conductivity of sandwich composites

Conclusions

1- It found that increasing the weight ratio of Al_2O_3 and Fe_2O_3 lead to increase in the values of thermal conductivity, but the epoxy composite filled with Fe_2O_3, have values of thermal conductivity less than for epoxy composite filled with Al_2O_3, for the same weight ratio.

2- Thermal conductivity calculated for epoxy composite by contact to every two specimens (like sandwich) content same weight ratio of alumina-oxide and ferrite-oxide, its found that the value of thermal conductivity lays between the values of epoxy filled with Al_2O_3 and of epoxy filled with Fe_2O_3.

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