The Effect of Carbon Black, Graphite Content on the Thermal Conductivity of (Epoxy- Carbon Black, Epoxy – Graphite) Composites

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Abstract

The thermal conductivity of Epoxy filled with carbon black and graphite materials are measured in order to study the effect of these particles on the thermal conductivity of these composite materials. With the increase of content of filler particles, the amount of formed conductive chains increases then the conductive chain tends largely to increase the thermal conductivity of a composite.

الخلاصة

تم قياس التوصيلية الحرارية لمتراكبات من الايبوكسي المدعم باسود الكاربون والايبوكسي المدعم بالكرافيت لغرض دراسة تأثير اضافة اسود الكاربون والكرافيت على قيم التوصيلية الحرارية لهذه المتراكبات. عند زيادة نسبة الجسيمات المضافة فإن مقدار السلاسل الموصلة يزداد وهي بدورها تؤدي الى زيادة التوصيلية الحرارية لهذه المتراكبات.

Introduction

While polymers are widely used for their excellent insulating properties, there is a growing need for thermally conductive polymer compounds. The thermal conductivity of metal particle, mineral particle, a carbon filled compounds are examined at volume concentrations up to the maximum packing fraction of each filler [1].

The description of heat transfer in polymers requires different theories depending on whether the polymer is amorphous, 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 used is made of the phononic theory of heat transfer in a 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 phenomenon of phonon scattering, or the phenomenon of heat transfer by chemical bonds. The first of these is used of low temperatures, where the wavelength of the vibrations is much lower than the distances between the structural elements; the second is used at higher temperatures.

Theoretical Part

1. Graphite

The uses of natural graphite flow from its physical and chemical properties. It has a high melting temperature; high thermal and electrical conductivity has a low coefficient of friction, and has a low absorption coefficient for X -rays and electrons. The principal use for graphite is in the manufacturing of refractory products. This is followed by foundries, lubricants, brake linings, crucibles, and pencils. All of the mentioned together account for 80% of total usage [2]. Most of the remaining 20% is accounted for by uses such as carbon brushes, batteries, and expandable graphite for the production of graphite foil, for example.

2. Carbon Black.

Thermoset composites including many types of unsaturated polyester, epoxy, and vinyl ester resins will normally behave as insulators. Special types of carbon black must be used to color the composite part and also make the formulation conductive. The methods of incorporation and effectiveness of dispersion are important in developing good conductivity properties in thermoset applications [3]. To make a composite panel conductive and to ensure that the surface coating application is enhanced, an optimum percentage level of conductive carbon black and the right combination of raw materials are required.

3. Composite Material

Material system composed of a mixture or combination of two or more macro constituents that differ in form or material composition and are essentially insoluble in each other.

To be too broad by some engineers because it includes many materials that are not usually though of as composites. For example, in many of the particulate –type composites, such as dispersion –hardened.

However, instead of trying to establish a distinction between materials and structures , it is more useful to make a distinction between mill composites, (such as non metallic laminates ,clad metals and honeycomb) and specially composites (such as tires, rocket nose cones, and glass-reinforced plastic boats)[4].

Experimental Part

1. Materials Used

Two types of conductive filler were used, carbon black and graphite, Epoxy resin type (EP10) used to reinforce these materials to form composite materials.

2. Composites Preparation

In order to obtain a composite materials, carbon filler should be added to epoxy resin in the amount of the filler range from 1% for (carbon black and graphite) to 20% for 3gm weight of the total composite.

3. Steady State Testing Apparatus

The conductivity of small thin slabs of material has been determined by Lee's by a method which is applicable over a wide range of temperatures [5]. 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.

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

$(\pi r^2 + 2\pi rd\ m)\ h\ t\ m$ ……..1

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

$(\pi r^2 + 2\pi rd\ m)\ htm + 2\pi rdsh\ .1/2\ (t_m + t_u)$ …2

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

$\pi r^2 k\ t_u\ - t_m\ /\ ds$……………….3

We may assume that the heat 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,

$k(tu - tm/\ ds) = h[tm + 2/r\ (dm+ds)\ tm + ½\ r\ ds\ tu]$..4

In the theory given up, the following symbols are used;

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

h = heat loss per second per sq. cm for 10 excess of temperature of discs over that enclosure.

t = excess temperature over that enclosure.

d = thickness of discs.

r = radius of discs.

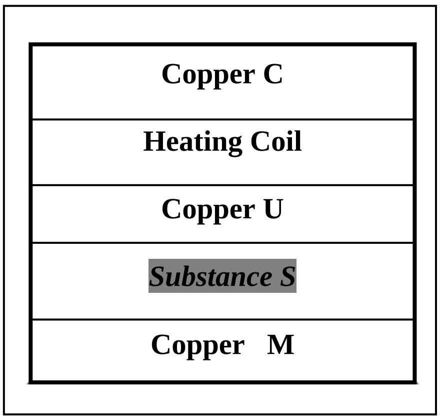

Fig. (1): Thermal Conductivity Apparatus

Results and Discussion

1. Thermal conductivity of epoxy filled with graphite

Carbon materials are often added to polymers to obtain composite material with improved mechanical and electrical properties, but there reports on improving the thermal conductivity by adding carbon materials [6].

In general, 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 a large increase in thermal conductivity of composite (attached system) [7].

The thermal conductivity of epoxy filled with various volume contents of graphite, which shows that the thermal conductivity increases, because particles begin to form conductive graphite chains, and heat flows not only through the formed conductive graphite chains, but also through the epoxy itself.

2. Thermal conductivity of epoxy filled with carbon black

The thermal conductivity of polymers are elevated by adding carbon black is required to elevate thermal conductivity in comparison with the amount of graphite required to have the same effect, this occurs because carbon black is able to form conductive chains more easily than graphite [8]. In general, the thermal conductivity of carbon black and graphite with high content of particles (attached system) tend to increase largely compared with carbon black and graphite with low content of particles (dispersion system), fig.(2). Contact resistance also explains the effect of introducing crystalline materials of relatively high conductivity into epoxy resin, at high temperatures; the conductivity is increased by the presence of high conductivity filler, but below a certain temperature it is decreased by the presence of internal boundaries which give rise to a resistance which increases with decreasing temperature [9].

An increase in the adhesion between the components in the filled polymer produces a decrease in the heat resistance at the component boundaries and an increase in the coefficient of heat transfer of the material [10].

Conclusions

1. The thermal conductivity of carbon black and graphite with high content of particles (attached system) tends highly increase compared with carbon black and graphite with low content of particles (dispersion system).

2. Addition carbon black is required to elevate thermal conductivity in comparison with the amount of graphite required to have the same effect. This occurs because carbon black is able to form conductive chains more easily than graphite.

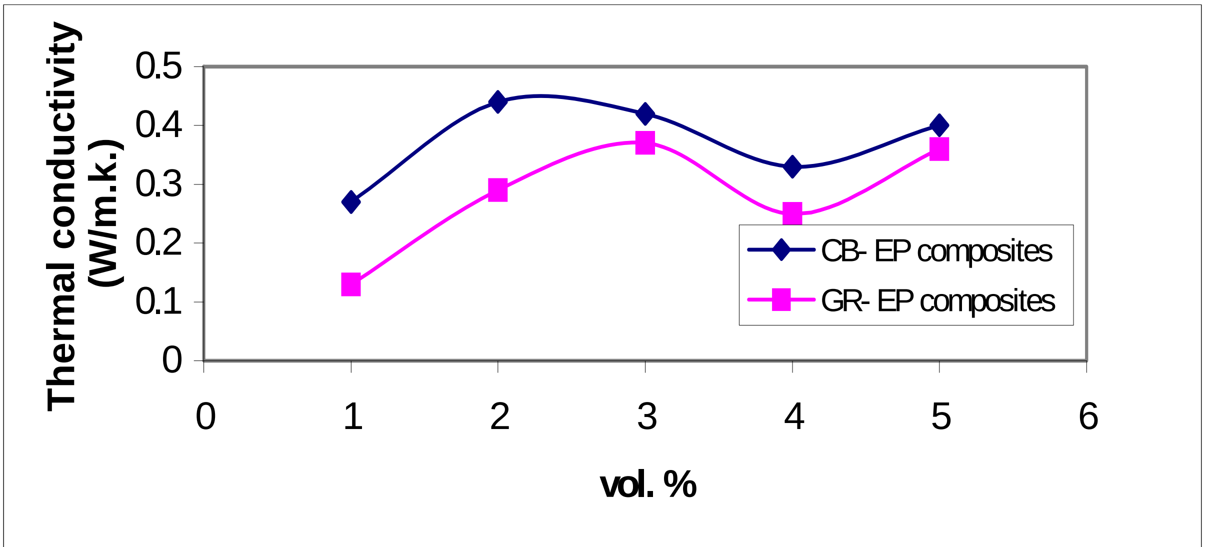

Fig. (2): The relation between thermal conductivity and vol. percent for (CB.EP & GR.EP) composites.

References

1. Perepechko, I.I. (**1981**): "*An Introduction to polymer physics*", Mir Publishers. Moscow.
2. Raymond B.S. (**1981**): "*Conductive Polymers*", Plenum Press, New York.
3. Harper (**1975**): "*Hand book of plastics and elastomers*", McGraw–Hill Inc.
4. Tye R.P. (**1969**): "*Thermal conductivity*", vol 2.
5. Berman, R. (**1976**): "*Thermal conduction in solids*", Clarendon Press Oxford.
6. Piorkowska, E. and Galeski,A. (**1985**): "*Thermal conductivity of polymers* " , Int . Poly. Sci. and Tech. Vol.12, no.10, p.102-107.
7. Benedetta Marmiroli (**2002**): "*Thermal conductivity measurement of nanoparticle based solid propellant mixtures*"
8. Choy, C.L. (**1977**): "*Thermal conductivity of polymers*", Polymer, vol.18, p.984-1003.
9. Jassim, M.M. (**2002**): "*The study of the effect of addition carbon black on the some mechanical properties and thermal conductivity of fired kaolin- fiber glass composite* "M.Sc. thesis.
10. Benjamin, G. (**1993**): "*Heat conduction and mass diffusion*", McGraw-Hill, Inc.