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Thermal conductivity behavior of epoxy resin reinforced by nanoparticles

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ABSTRACT

In this research work, a resinous matrix, epoxy with a hardener at a ratio of 1:2 at room temperature, was prepared with nanoparticles (nano-magnesium, nano-zinc and nano-boron) at a ratio of 1% and 2%.
All samples for thermal tests were prepared using the mechanical method.
The method of hand-lay was used to prepare the resinous molds.
Thermal tests were conducted that involved using a Lee's disk to calculate the coefficient of thermal conductivity at room temperature.
The results showed a significant improvement in the properties of the composite material containing nanoparticles due to its properties that led to the improvement of the thermal properties. The positive effects of the dispersion and mixing process in the composite materials was also observed through the results obtained from the composite materials reinforced by nanoparticles and comparing it with the resinous matrix.

Introduction

The use of composite materials with a resin matrix has been popular in most modern designs due to the superiority of Its thermal properties over the rest of the other materials. There are many applications in which the need for materials with high tolerance to high temperatures to which material can exposed during service has emerged so that it can be used as thermal protectors [1].

The thermal properties of epoxy resin before and after reinforcing with zinc nanoparticles with a volume fraction of 1% and 2% were studied and compared with the same material reinforced by magnesium nanoparticles with a volume fraction of 1% and 2% also compared with the same material reinforced by boron nanoparticles with a volume fraction of 1% and 2%. The effect of the thermal conductivity coefficient on was studied at room temperature and the comparison was made with the aim of obtaining the best properties [2]. The results showed that nanoparticles positively affect the thermal conductivity property. The results also showed that materials reinforced by nanoparticles have a high thermal conductivity coefficient compared with materials that are not reinforced [3].

The aim of this test is to study the thermal conductivity of the polymeric material. Thermal conduction is one of the basic physical phenomena that can be studying and explaining how material effects by heat and most of the applications of composite materials, especially those with a polymer matrix are in the outer periphery, such as building parts, planes, cars, and others. Therefore, studying the properties of these composites has become necessary to measure their tolerance for such conditions [4].

Materials and Methods

Five samples were prepared from the composite materials (epoxy resin with hardener without reinforcement (E), epoxy resin reinforced with nanomagnesium (E+Mg), epoxy resin reinforced with nanozinc (E+Zn), epoxy resin reinforced with nano boron trioxide (E+B), all samples at 1% and 2% weight fraction. Thermal conductivity test was conducted on all prepared samples at lab temperature and the following figures shows the change in thermal conductivity values with 1% and 2% weight fraction.

The purpose of measuring the thermal conductivity of the samples, a Lee's disc method was used to calculate the thermal conductivity of the insulating materials. The equipment consists of three discs (1,2,3) and an electric heater that connects the equipment to an electrical circuit [5]. We put the sample between the first and second discs, and the heater is between the second and third discs, and it has a power supply unit that starts transfer of heat from the heater to the second and third discs and from the 2nd disc to the 1st disc through the sample and after 20 min, the reading of the thermometers contained in the discs is recorded and by applying the equation (1), we get the value of thermal conductivity using the two equations below [6]. The thermal conductivity can be calculated by:

$$K=\left(\frac{T_B-T_A}{d_s}\right)=e\left[T_A+\frac{2}{r}(d_A+\frac{1}{4}d_s)T_A+\frac{1}{2r}d_sT_B\right]\ldots\ldots(1)$$

$$H=IV=\pi r e^2(T_A+T_c)+2\pi re\left[d_AT_A+d_s\frac{1}{2}(T_A+T_B)+d_BT_B+d_cT_c\right]\ldots\ldots(2)$$

where:
K: Thermal conductivity
H: Thermal energy passing through the heating coil per unit area (watt)
e: The amount of heat energy passing through a unit area per second ($W/m^2.C$)
r: Disc radius
d: Disc thickness.

Composites Preparation

Hand layup system was utilized to make sheets of pure epoxy composites or reinforced with many types of nanoparticles filler. The casting mold consists of glass plates with dimensions (100x100x4 mm) and under the casting mold putted nylon sheets to prevent adhesion of the composite specimens. All the examination samples are complete through abrading the edges on a fine carborundum paper.

Preparation of pure epoxy: Initially, hardener and epoxy resin are measured for fit blending proportion, and by hand mixed after that hardener (B) and epoxy resin (A) were blended through magnetic stirrer on (800 rpm) used for (15 min) to take best homogeneous among hardener (B) and epoxy resin (A) and casting the solution with the mold of glass plates. The mixture was cured at room temperature until neat epoxy dries fully before specimens cutting. The same procedures are used with nanoparticle samples. The mixture was cured at room temperature until the composite specimens dry fully then finally, take off from the molding to obtain a good complete composites laminate. All these procedures should be in the laboratory free from dust, clean and dry with precautions taken by wearing protective gloves, goggles and procedure mask at good ventilated room.

Specimens Cutting

The composite specimens were cut according to ASTM to prepare specimens where cutting by computer numerical control (CNC) machine containing a rotary head with a drill piece used for cutting various hard specimens.

Fig. 1: Rotary head of (CNC) machine and specimens cutting by (CNC) machine.

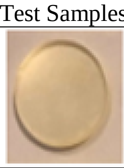
Thermal Conductivity Test Samples

This test was performed by (CNC) machine for Lee's disc test and according to (ASTM: E 285) at room temperature.

Table 1: Thermal conductivity test samples of different types of composite materials.

Symbol of sample	Thermal Conductivity Test Samples
E	
E+1%Zr	
E+1%Mg	
E+1%B	

Table 2: Thermal conductivity test samples of different types of composite materials

Symbol of sample	Thermal Conductivity Test Samples
E	
E+2%Zr	
E+2%Mg	
E+2%B	

Results and discussion

Thermal conductivity behavior of E composites exhibited the minimum value at E and this value increase when reinforced E by the nanoparticles and when increase the mass fraction of the nanoparticles and this due to the strong bound between the chains of E which increase the thermal conductivity of E [7,8].

We take the best result from thermal conductivity test of E and reinforced with (1% and 2% wt). and nanoparticle grain size of Mg (40-50) nm, Br (30-45) nm and Zr (≤ 50) nm. The thermal conductivity properties of nanocomposite materials depend on the type, size and mass fraction of the nanoparticles and notice E+Mg, E+B and E+Zr have higher thermal conductivity values than E due to Mg and Zr nanoparticles have high thermal conductivity as shown in the figure (1) and (2). The reason for this behavior is that the Mg, B and Zr nanoparticles act as barriers to the transfer of heat because Mg, B and Zr nanoparticles are strongly conducting heat and impede the vibratory motion of the resin structure, thus increase the thermal conductivity [5,9].

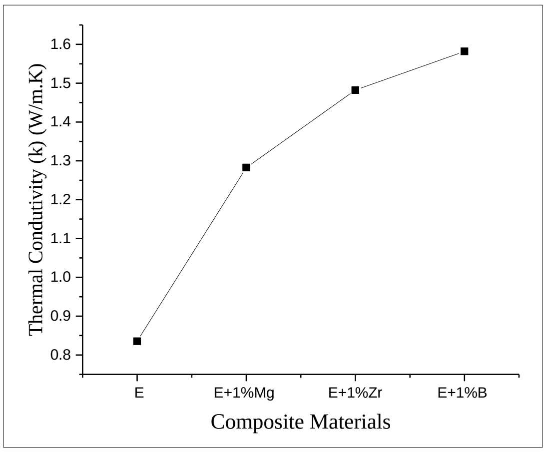


Fig. 1: Thermal conductivity of Mg, B and Zr 1%wt nanoparticles with E.

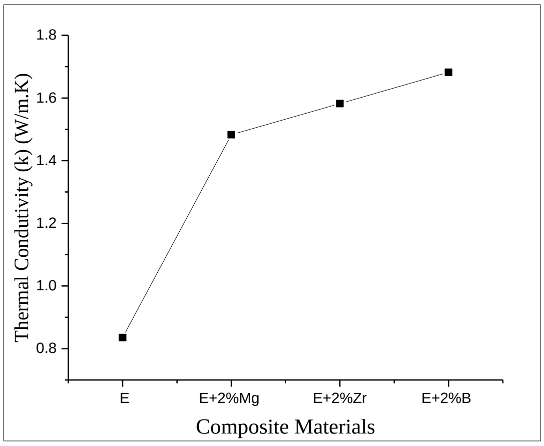


Fig. 2: Thermal conductivity of Mg, B and Zr 2%wt nanoparticles with E.

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TJPS

سلوك التوصيل الحراري لراتنج الايبوكسي المعزز بالجسيمات النانوية

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الملخص

في هذا البحث ، تم تحضير المادة الاساس الايبوكسي مع مادة المصلبة بنسبة 1: 2 في درجة حرارة الغرفة، مدعمة بجسمات نانوية (نانو مغنيسيوم و نانو زنك ونانو بورون) بنسبة 1٪ و 2%. تم تجهيز جميع عينات الاختبارات الحرارية بالطريقة الميكانيكية باستخدام الطريقة اليدوية لتحضير القوالب المواد المتراكبة. أجريت الاختبارات الحرارية التي تضمنت استخدام قرص لي لحساب معامل التوصيلية الحرارية في درجة حرارة الغرفة. أظهرت النتائج تحسنًا ملحوظًا في الخواص المادة المتراكبة المدعمة بالجسيمات النانوية نظرًا لخصائصها التي أدت إلى تحسين الخواص الحرارية , كما لوحظت الآثار الإيجابية لعملية التشتت والخلط في المواد المركبة على النتائج التي تم الحصول عليها من المواد المتراكبة المقواة بالجسيمات النانوية ومقارنتها بالمادة الاساس الايبوكسي الغير المدعم.