Effect of SiC particles and water absorption on thermal conductivity of epoxy reinforcement by (bi-directional) glass fiber

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Abstract

In this study the thermal conductivity of the epoxy composites were characterized as function of volume fraction, particle size of fillers and the time of immersion(30,60,90)days in water .Composites plates were prepared by incorporating (bi-directional) (0°-90°) glass fiber and silicon carbide (SiC) particles of (0.1,0.5,1)mm as particle size at (10%,20%,30%,40%) percent volume in epoxy matrix.

The composites shows slightly increase of the thermal conductivity with increasing volume fraction, particle size and increase with increasing the days of immersion in water. The maximum thermal conductivity (0.51W/m.K) was obtained before the immersion in water at 90 days for epoxy reinforcement by bi-directional glass fiber and SiC particles with volume fraction 40% and particle size 1mm .

Keywords
Epoxy composites,
Thermal conductivity of composite,
Ceramic composite.

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تأثير دقائق كاربيد السليكون وامتصاص الماء على التوصيلية الحرارية للايبوكسي المدعم بألياف الزجاج المتعامدة الاتجاه

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الخلاصة

في هذا البحث تمت دراسة التوصيلية الحرارية لمتراكب الايبوكسي واعتمادها على كل من الكسر الحجمي، الحجم الحبيبي لمواد التدعيم. كما تم دراسة تأثير الغمر بالماء لفترات (30,60,90) يوم على التوصيلية الحرارية.حضرت الواح المتراكب باضافة الياف الزجاج المتعامدة التجاه (0°-90°) ودقائق SiC ذات الحجم الحبيبي mm (0.1,0.5,1) والكسر ألحجمي (10%,20%,30%,40%) كمواد تدعيم والايبوكسي كمادة اساس.
اظهرت النتائج ان التوصيلية الحرارية تزداد بزيادة كل من الكسر الحجمي والحجم الحبيبي لمواد التدعيم كما تزداد عند تنقيعها بالماء لفترات اطول .وان اعظم توصيلية حرارية كانت لمتراكب الايبوكسي المدعم بالياف الزجاج المتعامدة وبدقائق كاربيد السيلكون ذات الكسر الحجمي (40%) والحجم الحبيبي (1mm) والمغمورة في الماء لفترة 90 يوم.

Introduction

Polymers have low thermal conductivity compared with metal and many inorganic materials, to resist transfer of heat by conduction[1].In order to obtain materials of desired thermal and mechanical and other properties, polymers were used as a matrix material mixed with different kinds of fillers (fibers or particles).

The thermal conductivity of composite materials which are represented as a multiphase substance depends upon the thermal conductivity of each face, the proportion of each phase, and the distribution of the phase [2]. The distribution of the phase includes their size, shape, volume fraction, weight percentage, orientation and conductivity relative to the heat flow direction [3,4].

James et al.[5] study the thermal conductivity for polyester composites reinforcement by carbon fiber with different volume fraction (45,59,72)% and study the mechanism of the heat transport along the fiber, the result shows that the thermal conductivity increase with increase the temperature for all volume fraction.

Garret et al. [6] study the effect of the particle size on the thermal conductivity for epoxy reinforcement by (Al_2O_3, diamond), the results shows that the thermal conductivity increase when the particle size increase because of decrease the photon scattering.

Yunsheng Xu et al.[7] study the effect of SiC whiskers (and /or particles) on the thermal conductivity of PVDF composites, the results shows that the use of whiskers and particles in appropriate ratio gave composites with higher thermal conductivity than the use of whiskers alone or particles alone.

Polymer composite materials are widely used in many applications such as thermal grease, die (chip) attach, thermal interface material and in building as thermal insulators of fencing structures [8].

The thermal conductivity under steady conditions is the quantity of the heat flow in unit time through a unit area of a substance caused by a unit thermal gradient [9].

$J=-K(dT/dx)$………(1)

where

J: flux of the thermal energy transmitted across a unit area per unit time.

K: is the thermal conductivity coefficient.

dT/dx: is the temperature gradient.

The random nature of the thermal conductivity process brings the temperature gradient and a mean free bath into the expression for the thermal flux[10]. It is know that the transport of heat in nonmetals occurs by phonons or lattice vibration. The thermal resistance is caused by various types of phonon scattering processes: phonon-phonon scattering, boundary scattering and defect or impurity scattering [11]. in order to maximize the thermal conductivity these phonon scattering process must be minimized. The scattering of phonons in composite materials is mainly due to the interfacial thermal barriers [12].

The possibility that absorbed water could change thermal properties of composites by weakening the bonds between the fillers and polymer resins lead to simulate the effects of long term exposure to moisture by immersion the composites in water for different periods of time at room temperature and high temperature, to study the mechanical, electrical and thermal properties of composites [13]. Soderholm et al. study the effect of immersion in water for PMMA reinforced by glass particles at volume fraction (50%), this specimen was immersed in water through 6 months at 60 °C. The result showed that the thermal conductivity increase at increase the time of immersion because of swelling and plasticization in the composites [14].

Diffusion is defined as the motion of particles from position to another in the system that results by the random molecules walk. This behavior is described by Flick's first law that represents the main law of diffusion. This law is defined as the number of diffusions atoms across a unit area in unit time [15].

$J=-D\,(dc/dx)$……(2)

where:

J: is the flux of atoms a cross unit area per unit time

D: is the diffusion coefficient

dc/dx : is the concentration gradient

Experimental

SiC particles of three different sizes (0.1,0.5,1)mm were weighted by percent volume(10%,20%,30%,40%) and then mixed with epoxy reinforcement by two layers of glass fiber (0°-90°). The epoxies

consist of two parts, resin and hardener which need to be mixed in 2:1 volumes to forms the epoxy polymer. For preparing composite samples, a weighted quantity of SiC powder was first thoroughly mixed with a measured volume of epoxy resin. Then a half volume of hardener was added and the result mixture was well mixed so as to obtain a uniform composition. The samples for thermal conductivity measurement were made in the form of circular disk with a radius 4cm. So, the last set of samples were immersed in water for (30,60,90) days at room temperature.
For this test lee's disc method was used.

Results and Discussions

Table (1) shows that the thermal conductivity (K_{exp}) of epoxy reinforcement by bi-directional glass fiber (0°-90°) large than the thermal conductivity of epoxy non reinforced because of that the bi-directional glass fiber is heaver long and oriented, in addition to decrease the air bubbles in the interface between the fiber and the matrix[16].

Table (1) the values of thermal conductivity of epoxy and epoxy composites reinforcement by bi-dierctional glass fiber (0°-90°).

Specimen type	K(W/m.K)
Ep pure	0.187
Ep comp.	0.201

Figure (1) shows that the thermal conductivity increase slightly with increase filler volume fraction .This can be explained because of precipitation of filler particle, which lead to make two layers with non homogenous in distribution, which make defect in the material structure lead to loss in energy[5,17]. Influence of interface between the matrix and the reinforcement materials was observed on thermal conductivity. In polymeric materials, heat was transfer as elastic wave, and since an interface was existed, that lead to restraint of transfers motion of these waves. Transfer of thermal energy as elastic wave are still complex process and difficult since there is disconnection in structure and transference from one structure to another, i.e, the wave lost a part of its energy at interface region between the matrix and reinforcement materials this behavior agree with the obtained results in reference[18].

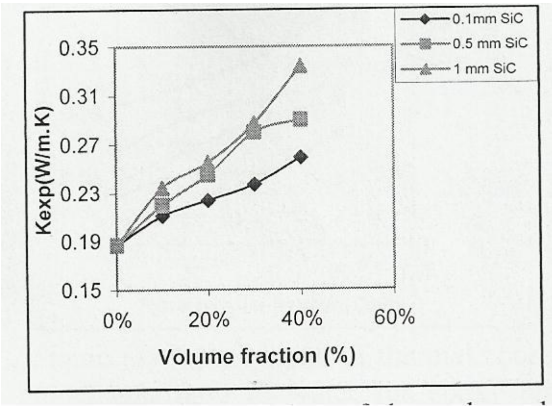

Figure (1) the variation of thermal conductivity K_{exp}(W/m.K) as a function of volume fraction of epoxy reinforced by bi-directional glass and (0.1,0.5,1)mm of SiC particles

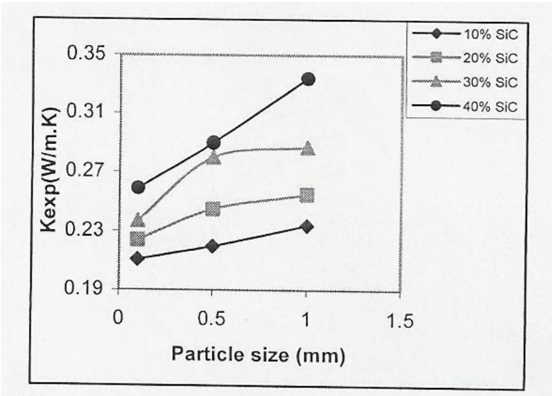

Figure (2) shows the variation of thermal conductivity K_{exp}(W/m.K) as a function of particle size of epoxy reinforcement by bi-directional glass fiber with deferent volume fraction(10%, 20%, 30%, 40%).

Figure (2) shows the variation of thermal conductivity as a function of particle size. The thermal conductivity increase when the particle size increase because of that the distribution of particles was homogenous but the small particle led to agglomerate make no homogenous media for flowing heat[19].

Figures (3,4,5) show that the thermal conductivity after immersed in water is better than the thermal conductivity without immersed in water, this can be explained because of diffusion of water through the composites. This diffusion were made by three mechanism: diffusion of water through the interface region between the matrix and filler, diffusion along the longitudinal glass fiber and diffusion through the micro cracks inside the composite, this leads to deterioration in the main properties of composites, to make the hygroelasticity results of increase swelling in polymer matrix. So the heat transfers in polymer caused by rotation and vibration motion for molecular chain. This result by the relaxation of bound may be increase the chain molecular to motion leads to increase the thermal conductivity [14,20].

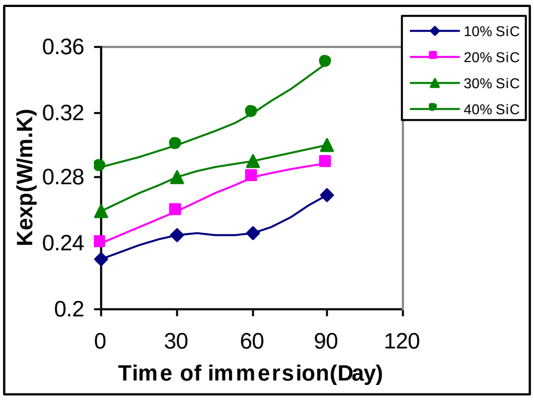

Figure (3) the variation of thermal conductivity K_{exp} (W/m.K) as a function of time of immersion (day) in water for epoxy reinforcement by bi-directional glass fiber and (0.1mm) SiC particles

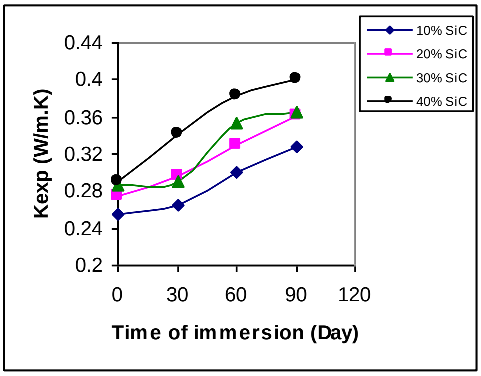

Figure (4) the variation of thermal conductivity K_{exp} (W/m.K) as a function of time of immersion (day) in water for epoxy reinforcement by bi-directional glass fiber and (0.5mm) SiC particles

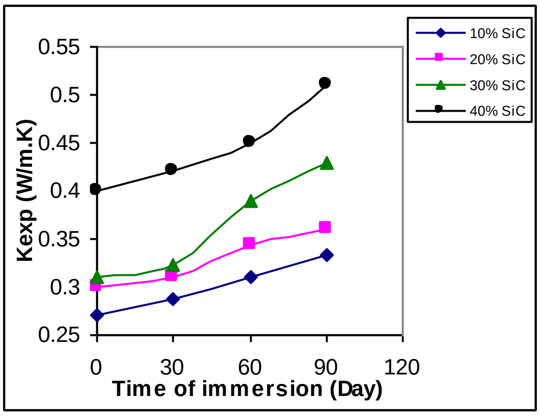

Figure (5) the variation of thermal conductivity K_{exp} (W/m.K) as a function of time of immersion (day) in water for epoxy reinforcement by bi-directional glass fiber and (1mm) SiC particles

Conclusions

Thermal conductivity increase with increasing time of immersion in water, particle size of filler, and volume fraction of filler. The thermal conductivity of the composite material reinforcement by two types of reinforced material, large than the thermal conductivity for epoxy and composite material reinforcement by one type reinforced materials.

References

[1] H. Ishida, S.Rimdst: Thermochim. Acta., 320,(1998) 86- 90.
[2] W. Gao,Q.Wang and S.Yan Yang: Acta Polymerica Sinica,1,(2001)1-4.
[3] J.O Kamoto and H.Ishida: J.Appl. Poly. Sci. 72, (1999), 1689.
[4] P. Keblinski and S. R. Phillpot: J. Heat and Mass Transfer, 45(4) (2002), 855-863.
[5] B.W.James, GH Westenholm and S.D. Mclvor: J. Phys. D. Appl. Phys., 20 (1987), 260-261.
[6] K.W.Garrett and H.M.Rosenberg: Phys. D: Appl. Phys., 7, (1999), 4067-4070.
[7] Yunsheng Xu, D.D. L. Chung, Cathleen Mroz.: "Thermally Conducting SiC, AlN Polymer Matrix Composite",: Composites, Part A 32(2001) 1749-1757.

[8] Li L, Chung DDL.: J Electron Mater,23(6), (1994) , 557.
[9] C. Kittel, "Introduction to Solid State Physics", 4th ed. Wiley Eastern Private Limited, 1971.
[10] R.Berman: Contemp. Phys., 14 (1993),101
[11] R. Ruth, K.Y. Donaldson, Hasselman DPH.: J. Am. Ceram. Soc., 75 (1992), 2887.
[12] Lai S-W. Dissertation. Buffalo(NY): State University of New York at Buffalo,1998.
[13] B. Dewimiue and A.B.Bunse: Composites, 14(1),(1983), 35-39
[14] K.J. Soderholm and P. D. Calvert: Journal of Material Science, 20 (6), June (2005) 2253-2259.
[15] H.Van Vlack" Elements of materials science add engineering" Wesley Publishing company New York 1989.
[16] R. Kienholz and G.Molinier: Vetrotex Fiber World, No.22, March (1998), 11-12.
[17] S .Cheng, R. Vachon, Int. J. Heat Mass Transfer, 13(1999); 537.
[18] Lewis Tb, Nielson JE.: J. Appl. Polym. Sci., 14 (1999),1449.
[19] H.W.Russell: J. Am. Ceram. Soc., 18 (2009), 15.
[20] G. C. Papanicoloau and R. Mercogliano, "The effect of water and temperature on the flexural and thermal properties of particulate composites": Plastic and Rubber Processing and Applications, 6 (3), (1998), 229-234.