Thermo-Mechanical Properties of Unsaturated Polyester Reinforced with Silicon Carbide Powder And with Chopped Glass Fiber

Bushra Hosnie Musa
Applied Science Department , material Science, University of Technology
100137@uotechnology.edu.iq
Rami Joseph Aghajan
Applied Science Department ,Material Science, University of Technology
rami_j_ag@yahoo.com
Muaed Faik abd al Majed
Applied Science Department ,Material Science, University of Technology
muaed@yahoo.com

Abstract

The work studied the effect of fine silicon carbide (SiC) powder with (0,3,5 ,7) wt % on the thermal conductivity and mechanical properties of unsaturated polyester composite in the presence of a fixed amount of chopped glass fiber. The hand lay-up technique was employed to prepare the required samples. Results showed that tensile, impact strength and thermal conductivity increased with increasing the weight fraction of reinforced materials.

Keywords: SiC powder, Unsaturated polyester, Chopped glass fiber, Thermal conductivity

الخلاصة

يدرس هذا البحث تأثير مسحوق كاربيد السيليكون الناعم وبنسب وزنيه مقدارها (0،3،5،7) % على الخواص الحراريه والميكانيكيه لمتراكب البولي استر غير المشبع وبوجود نسبه ثابته من الياف الزجاج المقطعة . استخدمت طريقة القولبه اليدوية لتحضير العينات . لقد اظهرت النتائج ان مقاومة الشد ومقاومة الصدمة والتوصيلية الحرارية تزداد بزيادة النسبة الوزنية للمواد المدعمة .

الكلمات المفتاحية :مسحوق كاربيد السيليكون ، بولي استر غير مشبع ، ليف زجاج مقطع ، توصيلية حرارية

Introduction

Silicon carbide (SiC) is a ceramic material and an important non-oxide refractory material. It is the product of the high temperature electrochemical interaction of carbon with silica [Ritesh.Kaundal *et al.*, 2012; Sivasankaran *et al.*, 2015]. It characterized by low density of 3.1 g/cm^3, high hardness and strength because it consist of tetrahedral carbon and silicon atoms with strong bonds in the crystal lattice, chemical and thermal stability at high temperatures, high melting point, oxidation resistance, good tribological properties , high erosion resistance, wear resistance, high elastic modulus, fracture toughness, creep resistance , excellent thermal shock resistant qualities due to high thermal conductivity besides low thermal expansion , and high strength . It has superior chemical inertness to acids, alkalis, and molten salts up to 800 ºC [Ritesh.Kaundal *et al.*, 2012; Sivasankaran *et al.*, 2015; Mallick, 1997; Johnson *et al.*, 1998] . Due to their outstanding thermo-mechanical properties, silicon carbide is used as a filler in different polymer matrixes and it has various industrial applications as in abrasives, cutting tool applications, refractories, ceramics, electrical conductor, resistance heating, flame igniters, electronic components, motor and gas turbine parts and many high performance applications [(Ritesh.Kaundal *et al.,* 2012; Sivasankaran *et al* ., 2015)].

Several studies highlights on fiber/filler reinforced composites for many practical applications. For example, [Gaurav *et al*.. 2013] studied the effect of addition of silicon carbide filler with (0, 5, 10, 15, and 20)wt % on physical, mechanical and thermal properties of epoxy composite reinforced with chopped glass fiber . They concluded that the physical-mechanical properties of epoxy composites reinforced with silicon carbide-filled by glass fiber are better than epoxy composites reinforced by glass fibers. [Amal and Eman , 2014] found that mechanical and physical properties of epoxy composite reinforced by fine SiC and filled with carbon fiber are improved in comparison with epoxy composite reinforced by carbon fiber.

[Kaundal *et al.*, 2012] presented a comparison between particulate filled (SiC particles) and unfilled glass fiber - polyester composite on their thermo- mechanical properties. There results showed that particulate filled composites have revealed a decrease in mechanical properties when compared to the unfilled glass fiber- polyester composite.

The aim of present research is to improve mechanical and thermal properties of unsaturated polyester composites by adding SiC particles and glass fiber.

Experimental work

1- Matrix Material

Unsaturated polyester resin (UPE) ,which used as a matrix in the preparation of polymer composite , was a product of Industrial Chemical of resins Co. LTD) in Saudi Arabia with density of (1.2 g/cm^3).The resin solidifies by the addition hardener ,Methyl Ethyl Ketone Peroxide, (MEKP)at a ratio of 2 to 100 parts of resin at room temperature and cobalt octate is used as accelerator and with either MEKP alone or with MEKP mixed with t – butyl perbenzoatemay also be used to increase the hardening rate.

2 - Reinforced materials

(A) E - Glass fibers is used as strengthening phase in the form of choppy glass fibers with density of 2.56 g/cm^3 .These fibers provided by (Mowding LTD. UK**)**English company .

(B) Silicon carbide (SiC) powder with particle size less than 10 μm and with density of 3.1 g/cm^3 was used also as filler in reinforced (unsaturated polyester/ E-glass fiber) composite.

Composite preparation

The composites were prepared by using hand lay-up technique in polymer and composite Lab in the University of Technology. Four different samples of polymer composites were prepared .These samples consist of SiC in different weight ratios (0, 3, 5 and 7wt.%) reinforcement with fixed amount (20 wt.%) of chopped glass fiber reinforcement to unsaturated polyester resin. Firstly, UPE resin was mixed gradually by glass rod with its hardener at weight ratio of (100:2) . Then, fine SiC particles were added to it regularly with homogenous mixing and the short glass fibers were added to this mixture. This mixture has been poured in a mold with required dimensions, then weights were put on top of the mold. Polymer composites are left for solidification at room temperature for 24 h. After that, the castings are removed from the mold and cured for two hours in 60 °C. Finally, the samples were cut according to the standard qualifications to fulfill the required tests.

Tests

Tensile test

Tensile test was done by using tensile test machine (Jianolao) with capacity of 20 KN applied load. The samples were cut according to dimensions of the standard qualificationsASTM-D638 . Tensile strength was calculated by the relation [Jawad *et al.*, 2014] .

$$\text{Tensiles trength} = \frac{\text{Load at break}}{(\text{original width})(\text{original thickness})} \quad \ldots\ldots\ldots(1)$$

Impact test

Charpy impact test of un notched samples is achieved by using pendulum impact testing machine made in New York, USA. The test is carried out in accordance with ISO-179 and the hammers are used with (30 Joules) fracture energy. Impact strength (KJ/m^2) can be calculated from the following equation [Raghad. H. Al-Janabi., 2004] .

$$\text{Impact strength} = \frac{\text{FractureEnergy}}{\text{Crosssectionalareaforthesample}} \quad \ldots\ldots\ldots(2)$$

Where A : is the cross – sectional area of the specimen (A = b*t) .
b, t : are the width and thickness of the sample respectively .

Thermal conductivity test

It is carried out by using Lee's disc instrument under steady state condition. This instrument composed of three discs fabricated from brass (A,B,C) and heater connected to electrical circuit . Heat transfers from the heater to the next two discs then to the third disc through the sample. The temperature of brass discs (T_A, T_B, T_C) are measured by using thermometer installed on top of sample. A supplied voltage (V) was 6 V value was applied to the heater, the current value (I) was 0.25A, and the temperatures of three discs were recorded when the system approached steady state condition. Thermal conductivity values are calculated by the equations 3 and 4 [Rafah A. Nassif , 2010] :-

$$I.V = \pi r^2 e(T_A + T_B) + 2\pi re[d_A T_A + d_S \frac{1}{2}(T_A + T_B) + d_B T_B + d_C T_C] \quad \ldots\ldots\ldots(3)$$

Where r : is the radius of disc, T_A, T_B and T_C are the temperatures of the brass discs A, B and C respectively. d_A, d_B and d_C are the thickness of the brass discs A, B and C respectively. d_S : is the thickness of the sample. e is the amount of heat transferring through cross sectional area of the sample per unit time ($W/m^2.K$) , which measured by the relation [Sua F, et al., 2005] [11].

$$K(\frac{T_B - T_A}{d_S}) = e[T_A + \frac{2}{r}(d_A + \frac{1}{4}d_S)T_A + \frac{1}{2r}d_S T_B] \quad \ldots\ldots\ldots.(4)$$

Where K is the thermal conductivity coefficient (W/m. K)

Results and discussions

Figure. 1 shows the effect of SiC particles on the tensile strength of chopped fiber reinforced polyester composite. Tensile strength of UPE is increased when it reinforced with glass fiber because glass fiber has high tensile strength . It is clear that the tensile strength increases with increase of SiC content and 20 % glass fiber comparing with UPE. The reason behind this increasing was related to the presence of glass fibers, which improves the tensile strength and also presence of SiC filler acts as a barrier in transferring stress from one position to another. In addition the increase in bonding surface area as a result to the increase of the fiber/filler content [(Sua *et al.*, 2005; Devendra and Rangaswamy, 2012)] .

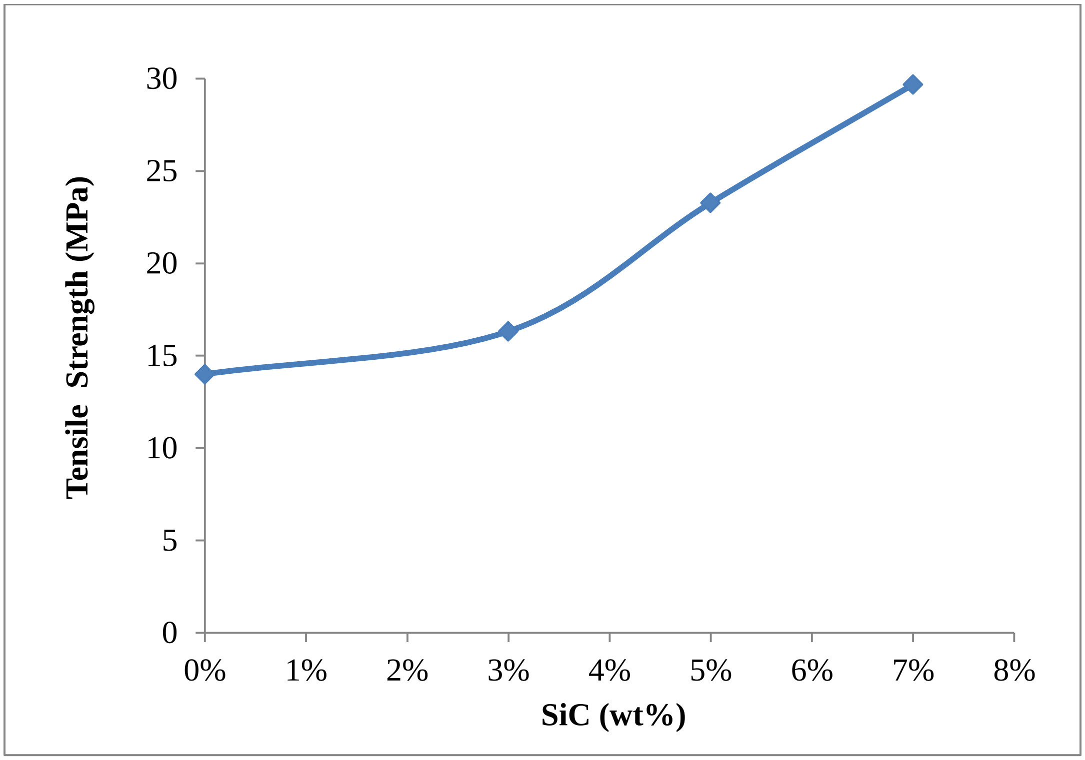

Fig (1) Effect of SiC contents on the tensile strength of polyester composites reinforced chopped glass fibers.

Impact Test

Figure. 2 shows the effect of SiC particles on the impact strength of chopped fiber reinforced polyester composite. It is clear that the impact strength increases with increase the percentage of fiber/filler reinforcement due to good bonding strength between matrix (UPE), SiC filler and glass fiber, so that the impact energy absorbing ability of the polymer composite is increased. Thus a large amount of energy will be absorbed by the crack initiated along the fiber/filler and matrix interface during deboning [Kaundal *et al.*, 2012].

Rothon studied mechanical properties of mineral filled polymer composites and interpret that the higher aspect ratio filler particulates needed to achieve stiffness in the composites which caused increased stresses near the particulate edges in the polymer matrix, which finally caused failure under impact loads [Roger, 2003] .

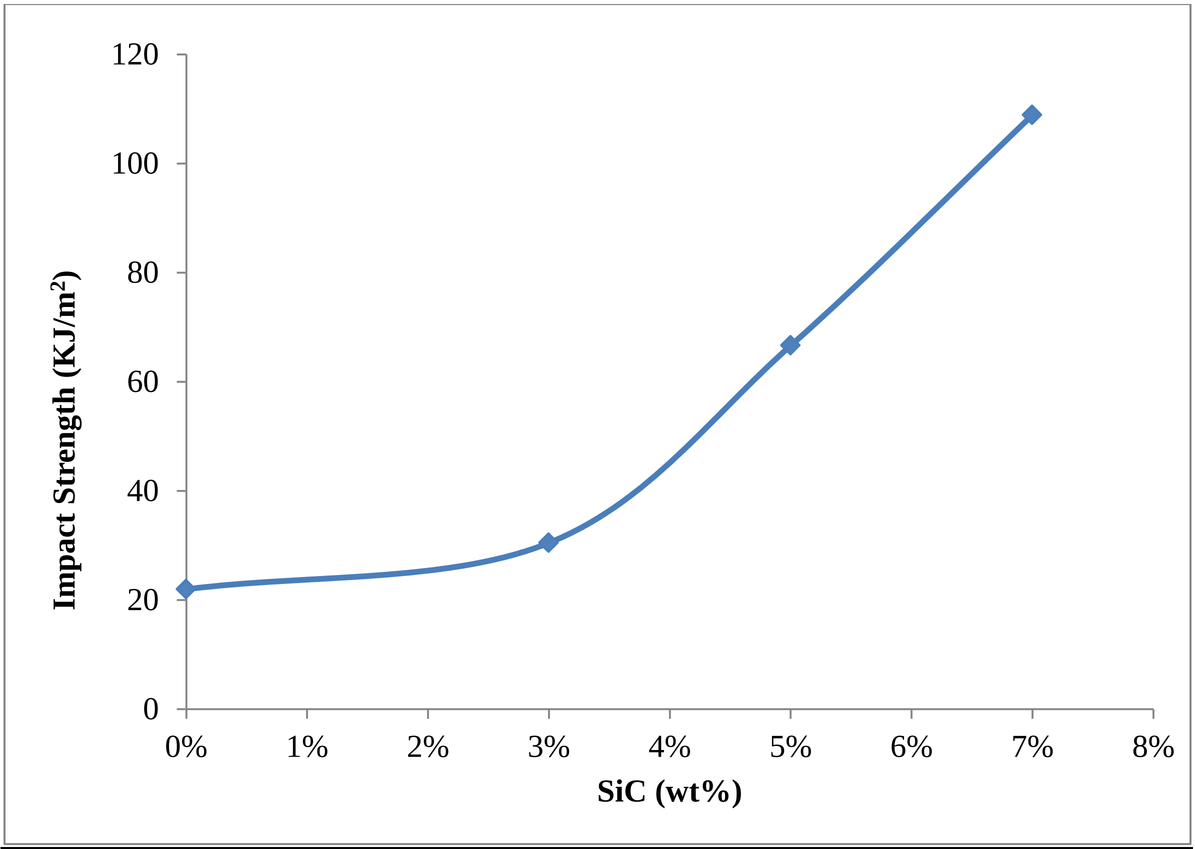

Fig (2) Effect of SiC content on the impact strength of chopped glass fiber-reinforced polyester composites .

Thermal conductivity

Figure. 3 illustrates the effect of SiC particles on the thermal conductivity of short fiber reinforced polyester composite. It is clear that, the thermal conductivity increased with the increase in the ratio of the reinforcement. The thermal conductivity increase was attributed to the decrease in the interfacial thermal resistance of the composites [Bai, *et al.*, 2006] . Therefore, SiC thermal conductivity is being higher than that of UPE and glass fiber which was improved it.

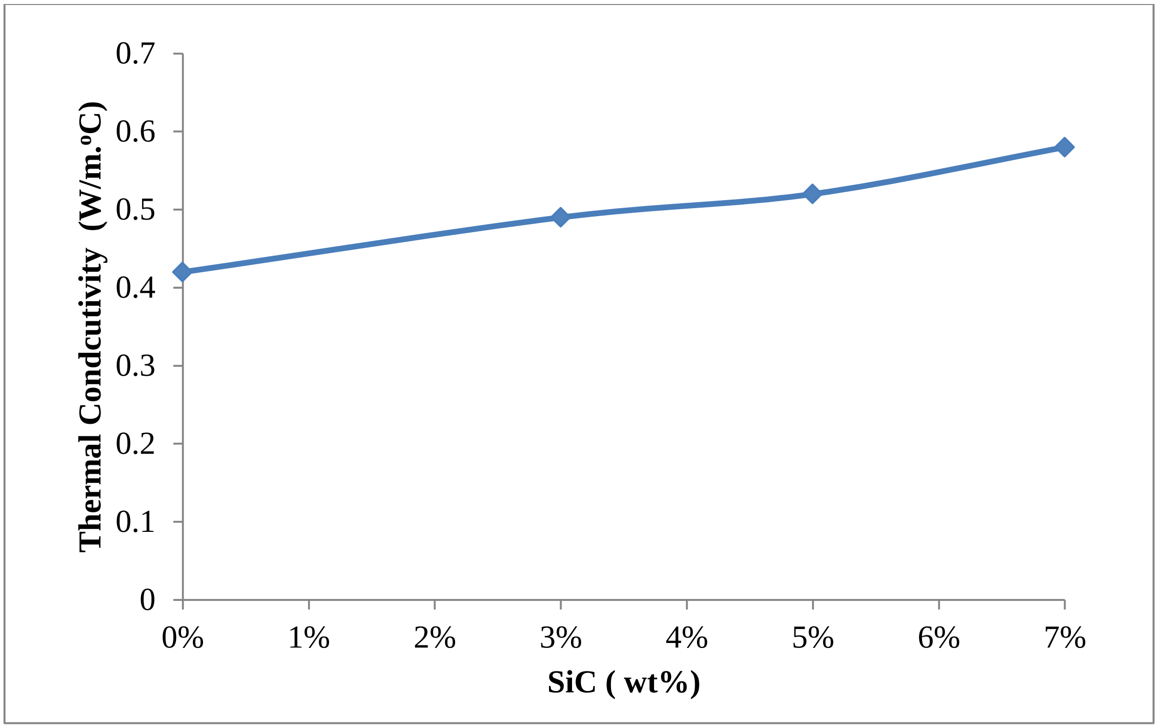

Fig (3) Effect of SiC content on the thermal conductivity of polyester composite reinforced by chopped glass fiber.

Conclusion

Reinforcement of unsaturated polyester resin with SiC particles improves the mechanical properties (tensile strength, impact strength and thermal conductivity) with increasing this filler contents at a fixed content of chopped glass fiber.

Acknowledgement

The authors are grateful to the Department of Applied Sciences for the support and to Dr. Mahmood M. Barbooti for his interest and effort in the revision of the manuscript.

References

Amal Nassar and Eman Nassar, (2014)"Thermo and Mechanical Properties of Fine Silicon Carbide /Chopped Carbon Fiber Reinforced Epoxy Composites" , Universal Journal of Mechanical Engineering 2 (9) , 287-292.

Bai, G.; W. Jiang and L. Chen , (2006) " Effect of Interfacial Thermal Resistance on Effective Thermal Conductivity of $MoSi_2$/ SiC Composites, Materials Transactions, Vol. 47, No. 4 , 1247 – 1249.

Devendra K, Rangaswamy T (2012)" Determination of mechanical properties of Al_2O_3, Mg $(OH)_2$ and SiC filled E-glass/epoxy composites" Int J Eng Res Appl , 2(5) ,2028–2033

Gaurav Agarwal, Amar Patnaik and Rajesh Kumar Sharma (2013)," Thermo-mechanical properties of silicon carbide-filled chopped glass fiber-reinforced epoxy composites , "Agarwal et al. International Journal of Advanced Structural Engineering, 5:21 .

Jawad Kadhim Oleiwi , Emad Saadi Al- Hassani and Alaa Abd Mohammed , (2014) " Experimental Investigation and Mathematical Modeling of Tensile Properties of Unsaturated Polyester Reinforced by Woven Glass Fibers "Eng & Tech. Journal , Vol.32,Part (A) , No.3, 653-666.

Johnson J .Harold, Robert, T. Kiepura, Dorene and A. Humphries, (1998) "Engineering materials handbook", Composites, ASM international, Ohio,Vol.1, p. 983 .

Kaundal R, Patnaik A and Satapathy (2012) " A Comparison of the mechanical and thermo-mechanical properties of unfilled and SiC filled short glass polyester composites" , Silicon , Vol. 4 , 175–188.

Mallick. P.K., (1997) "Composites engineering handbook", Marcel Dekker, New York Inc. 101–165.

Rafah A. Nassif , (2010)" Effect of Chemical Treatment on The Some Electrical And Thermal Properties For Unsaturated Polyester Composites Using Banana Fibers" ,Eng.& Tec. Journal, Vol.28, No.10, 191-197.

Raghad. H. Al-Janabi., (2004) "Studying the Effect of Weathering Conditions on Some Properties of Epoxy Composites"; M.Sc Thesis., the School of Applied Science; University of Technology

Ritesh.Kaundal, Amar. Patnaik and Alok. Satapathy , (2012) " Effect of SiC Particulate on Short Glass Fiber Reinforced Polyester Composite in Erosive Wear Environment" , Walailak J Sci& Tech , 9(1) 49-64 .

Roger Rothon. , (2003)"Particulate-filled Polymer Composites ", 2 nd , Rapra Technology Limited, Shrewsbury, U.K.

Sivasankaran S. and K. Kumar, (2015) "A novel sonochemical synthesis of nano-crystalline silicon carbide ceramic powder and its characterization", International Journal of Recent Scientific Research, Vol. 6, Issue, 2, 2630-2633.

Sua F, Zhang Z, Wang K, Jiang W, Liu W , (2005)" Tribological and mechanical properties of the composites made of carbon fabrics modified with various methods". Compos Part A, 36: 1601–1607.