A Comparison Study of Different Ceramic Filler on Mechanical and Thermal Properties of Glass, Carbon, Kevlar / Polyester Composites

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Abstract

Fillers play a major role in determination of the properties and behavior of particles on (glass, carbon, and Kevlar fiber) reinforced polyester composites. These particles are fabricated using both alumina (Al_2O_3) and silicon carbide (SiC) particles as filler materials for such systems. The effect of these two different ceramic polyester composites are investigated at different additive ratios as (0.2, 0.4, 0.6, 0.8, 1.0) volume fraction.

Comparative analysis shows that the bending distortion, Hardness, and Impact resistance are affected by the type and content of filler particles, where both impact and Hardness is increased with increasing volume fraction specially in case of (0.5) volume fraction for both filler particles and decreased for bending distortion specially in case of glass fiber/ polyester at (0.5) volume fraction for both filler particles. Also high electrical properties for all filler/ fiber/ polyester composites.

It is shown that silicon carbide (SiC), have better filler characteristics compared to those of alumina (Al_2O_3) .Hopefully, these results provide a cost effective solution to composite applications.

Keywords: polyester composite system, different fibers (glass / carbon / Kevlar), comparison mechanical, thermal properties.

دراسة انظمة متفرقة لحشوات سيراميكية على الخصائص الميكانيكية والحرارية لأنظمة متراكبة مختلفة للبولي استر مع الياف (زجاج ، كاربون، كفلر)

الخلاصة

ان الحشوات السيراميكية تلعب دوراً رئيسياً في تحديد سلوك الجزيئات بالانظمة المتراكبة المختلفة (زجاج، كاربون، كفلر) المدعمة للواصق البولي استر وذلك بأستخدام كل من الالومينا (Al_2O_3) وكاربيد السليكون (SiC) كمالئات في هذا التطبيق.

ان تأثير هذه المواد السيراميكية على الانظمة المتراكبة للبولي استر تم التحري عنه بنسب خلط حجمية مختلفة تتراوح بين (0.2, 0.4, 0.6, 0.8, 1.0) كسر حجمي.

والتحاليل المنجزة للانظمة لمتراكبة المختلفة اثبتت ان الخصائص الميكانيكية (مقاومة الانحناء، الصلادة، ومقاومة الصدمة) تتأثر بنوع وكمية الحشوة السيراميكية المستخدمة، حيث تحسنت كل من مقاومة الصدمة والصلادة وخصوصاً عند النسبة (0.5 vol.fraction) كسر حجمي. وقلت نسبة التشوه الحاصل في فحص الانحناء وخصوصاً بالنسبة للنظام المتراكب (الياف الزجاج / بولي استر) وعند نفس النسبة السابقة للخلط لكلا النوعين من االحشوات. اضافة الى ارتفاع الخاصية العازلية لكل الانظمة المتراكبة المحضرة والتي استخدم فيها الحشوة (الحشوة/ ليف/ بولي استر). وكانت افضل النتائج لحشوة كاربيد السليكون (SiC) المستخدمة

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مقارنة بالالومينا (Al_2O_3) المتوفرة وهذا يؤمل ان يقلل من تكاليف التصنيع وبالتـــالي يـــدعم الخصائص التطبيقية المختلفة (الميكانيكية والعزلية الحرارية).

Introduction

The fiber reinforced polyester composite (FRP/C) plastic products is widely applied to wide range of industries ranging from household vanity installation to complex structural composites for the aerospace industry. as an example of application is in the use of composite plastic as part of the manufacturing process of the automotive, ship and boat building. Reinforced plastics make up about (5%) of the total plastic demand, but new developments in blending compounding and fabrication will increase that demand [1-5].

Glass fiber is the dominate reinforcing material representing about (90%) of reinforcement materials in use. Other common types of reinforcement materials used are aramid (Kevlar) and carbon fibers. The glass fiber reinforced structural composite market is expected to grow at a rate of (10-15%) per year, primarily as a result of its increasing importance in the construction of automotive components [6-10].

Another rapidly growing market for fiber reinforced structure composite plastics is the automotive and aerospace industry. Composite are becoming the preferred materials for certain passenger car components, drive shafts, and door structure. [10]

In addition, Kevlar FRP shows superior and consistent performance at lower cost and longer shelf life, which is suited for all (FRP) resin system including polyester, epoxies, and urethanes. This is due to thyrotrophic properties, becomes useful in such applications like bath tubes, shower stalls truck caps, boats and other molded parts, with Kevlar, cost saving of (1-2%) per pound have been achieved in a standard polyester laminating resin. Using only (0.2%) Kevlar pulp gives the same viscosity in the low-shear, gravitational region as (1.5%) fumed silica. [11].

Alight weight handled member with high stiffness heat resistance and chemical resistance, that improve handily of a applied material, such as a semiconductor liquid crystal glass and carbon-fiber-reinforced composite material caused by the transferring environment and effectively static electricity of the utilized material using the grounding method.[12]

Amar P. etal [13] have a comparative study of different ceramic filler as (ash, alumina , SiC) in a glass-polyester composite system to improve its characteristic properties in addition of a mechanical one where the comparative analysis shows that with the incorporation of these fillers, the tensile strength of the composites decrease significantly. The flexural properties, interlaminar shear strength, density and hardness are also affected by the type and content of filler particles. It is found that the presence of SiC improves the hardness of the glass—polyester composites, whereas the other two fillers show marginal effect. The study reveals that the reduction in tensile strength is the minimum in case of fly ash among all the fillers. Further, the composite with low fly ash content (10 wt %) exhibits improved flexural strength.

Other researchers used Kevlar fibers in a normal polymer composite in order to improve thermal and chemical resistance by applying with fumed silica filler. [14-16].Or applied the same composite glass-fiber-polyester system with aggregated in order to prepare high tensile and flexural mechanical properties requirement to resist wall collapses or buckling. [17]

Recently many researchers aim to study the effect of different particle fillers (fly ash, alumina, and silicon carbide) on the mechanical properties of polyester composite system under heating or chemical load. [18].

The aim of this work:-

The aim of this work is:

1- Study the effect of different types of ceramic particles on the composite polyester system.
2- Improving the mechanical properties such as (hardness, bending and impact resistance) for these composite systems.
3- Improving thermal – physical properties of prepared system by these additives.
4- Comparison which system has optimum properties.

Experiment

1- Materials:

- Chemical adhesives: commercial polyester. gulf international chemical (SAOG)
- Commercial glass fiber, carbon fiber, and Kevlar fiber.
- Alumina (Al_2O_3) and silicon carbide (SiC) powder (purity 99.9 %).

2- procedure:

- **Preparation of adhesive polyester system**:

A fixed weight of polyester / hardener (100 / 2) w/w weight ratios according to the standard specification of manufacturing company at standard mixing time and temperature (15min, 30C°) in order to achieve homogenous solution . The optimum operating conditions including mixing speed, mixing time, are investigated and found experimentally to be 500 rpm, 15 min respectively. These conditions are followed in the preparation of experiments in this work.

-Preparation of reinforced primary composite system:

The Preparation of reinforced primary composite system is carried out by the addition of ceramic particles by different volume fraction of alumina and silicon carbide (0.2, 0.4, 0.6, 0.8, 1) respectively to prepare resin system (PE / H).Gradual continuous mixing at (30C°) for

(15min) is performed in order to achieve homogenous liquids.

-Preparation of reinforced composite polyester systems:

This step is carried out by using different types of fibers glass, carbon, and Kevlar fibers at different additive volume fraction as (0.2, 0.4, 0.6, 0.8, 1) respectively. Where an open mold is used to give different shapes of parts depending on test that to be carried out. The mold surface is in contact with the exterior of the part. Vaseline gel is first applied to the molder to prevent the fibers from adhering to the molder, then coating with pigmented resin to give the part fibers (glass, carbon, and Kevlar) afterward resin system (PE / H) were deposited to the molder and the fibers are compressed by the roller machine, evenly distributes the resin and removes air pocket multiple layers of fibers are deposited until the desired weight and thickness are achieved. When the resin is cured, the part is removed from the mold, Excess material is trimmed off, and the part is ready for paint and assembly for tests.

Measurements instruments:-

Experiments were performed to characterize the mechanical properties of the reinforced polyester system of fibers and particles (0.2, 0.4, 0.6, 0.8, and 1.0) volume fraction respectively. The mechanical (impact, bending, hardness, and thermal conductivity) tests are performed. The impact strength is determined using charpy impact instrument. While the bending distortion are determined using PHYWE, three point bending tester according to ASTM D790. The hardness is determined using Wlestor Amsler, Harkeprufer DIN 53505, Shore D., the thermal conductivity test is achieved using Lee's disk instrument (Koeyigit Electronic, UK). The thermal conductivity is calculated by the following equations:

$$e = P / \pi r [r (T_1 + T_3) + 2 (d_1 T_1 + 0.5 ds (T1 + T_2) + d_2 T_2 + d_3 T_3] \quad \text{....(1)}$$

$$K = e\, ds [T_1 + 2 T_1 (d_1 + 0.5 ds) / r + T_2 ds / r] / (T_2 - T_1) \quad \text{....(2)}$$

Where:

e = loss in heat per unit area in (w /cm^2 . C˚).

P = supplied power in (w).

r = radius of disk in (cm).

d_1, d_2, d_3 = thickness of disks in (cm).

ds = thickness of specimen in (cm).

T_1, T_2, T_3 = measured temperatures of disks no., 1, 2, and 3 in (C˚).

K = thermal conductivity in (w / cm .C˚).

Results and Discussion

1. Bending test

The effect of different volume ratios of prepared samples in terms of bending distortion in (mm) versus load in (g) is shown in figure (1). It indicate that the resistance to bending distortion is decreased due to high volume ratio for all fibers(glass, carbon ,and Kevlar) filled with alumina particles .High resistance appeared for Kevlar samples due to chemical compatibility between matrix (PE) and reinforcement parts (fibers & fillers) (f/p).[13]

Figure (2) shows same behavior of the second filler particles (SiC) with high bending resistance for

Kevlar fiber which attributes to the chemical compatibility between Kevlar and filler particles (SiC).(13)

2. Impact strength

Figures (3,4) shows the effect of different volume ratios from all fibers (glass, carbon and Kevlar) and particles (Al_2O_3,SiC) of prepared composite samples on the mechanical property impact strength in (J/cm^2). It is shown that the values of impact strength of these composites are increased with the increasing volume fraction of all fibers (glass, carbon and Kevlar) and particles (Al_2O_3, SiC) with improvement results for [matrix + Kevlar fiber) + (Al_2O_3 %)] and [matrix Kevlar fiber Sic%] systems due to high chemical compatibility between reinforced materials (fiber and particles) and matrix base resin polyester.(13)

3. Hardness test

Figures (5, 6) show the effect of different volume ratios from all fibers (glass, carbon and Kevlar) and particles (Al_2O_3, SiC) on the values of hardness for the composite prepared samples.

The values of hardness are increased with increasing volume fraction of both fibers and particles with improvement results for Kevlar system due to a chemical compability between Kevlar and polyester resin. (16)

4. Thermal conductivity

The effect of different reinforcing particles (Al_2O_3, SiC) and fibers (glass, carbon and Kevlar) to polyester composite is shown at different mixing ratios on the thermal conductivity. It is clear that the thermal conductivity (W/m.ºC) decreased from [0.73 to 0.05 w/m.ºC)] with increasing the blend ratio from (0.2 to 1.0)% vol with improvement results for carbon fiber for both reinforced particles system (SiC and Al_2O_3) due to high dipole groups of carbon and high strong bond of (C-C) at the applied loads of heat or power respectively .(12) as shown in figures (7,8).with improvement results for (PE/F/SiC) composite system due to high rigidity and heat insulation properties and heavy strong bond of (C-SiC) groups (12) which gave thermal conductivity as high as 0.005 (W/m.ºC).

Conclusions

From the results presented it can be concluded by:

1. The optimum ratio of prepared blend characterized by mechanical and thermal properties was at the ratio of PE/f/p (0.5) % vol.
2. The optimum mechanical properties were found at 0.28mm 0.23mm for PE/K/A and PE/K/SiC composite system and maximum impact and hardness occurs at 2.8 J/cm^2 and 3.2 J/cm^2 for PE/K/SiC system and 77 shores for PE/K/A and 82 shores for PE/K/SiC system respectively.
3. Experimental results showed that the heat treated samples of type led to enhance and improve in the

mechanical and thermal properties when compared with untreated one.

5. The reinforced composite system of polyester carbon fiber /SiC have best thermal properties and little minimum thermal load than that of alumina.

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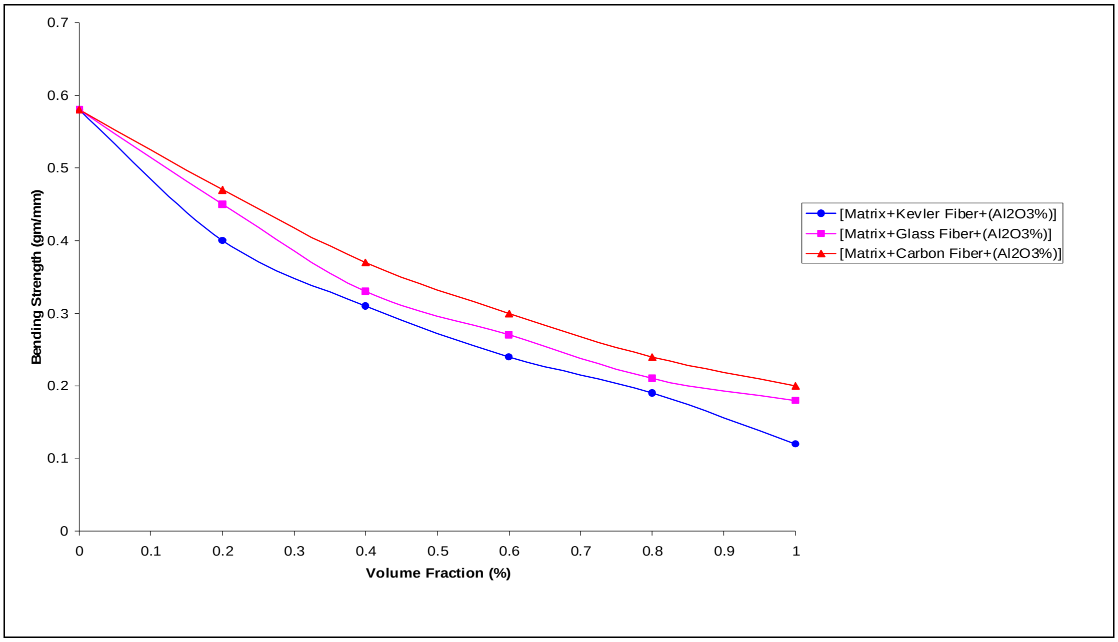

Figure (1): Effect of additive Al_2O_3 on bending strength of polyester composite system.

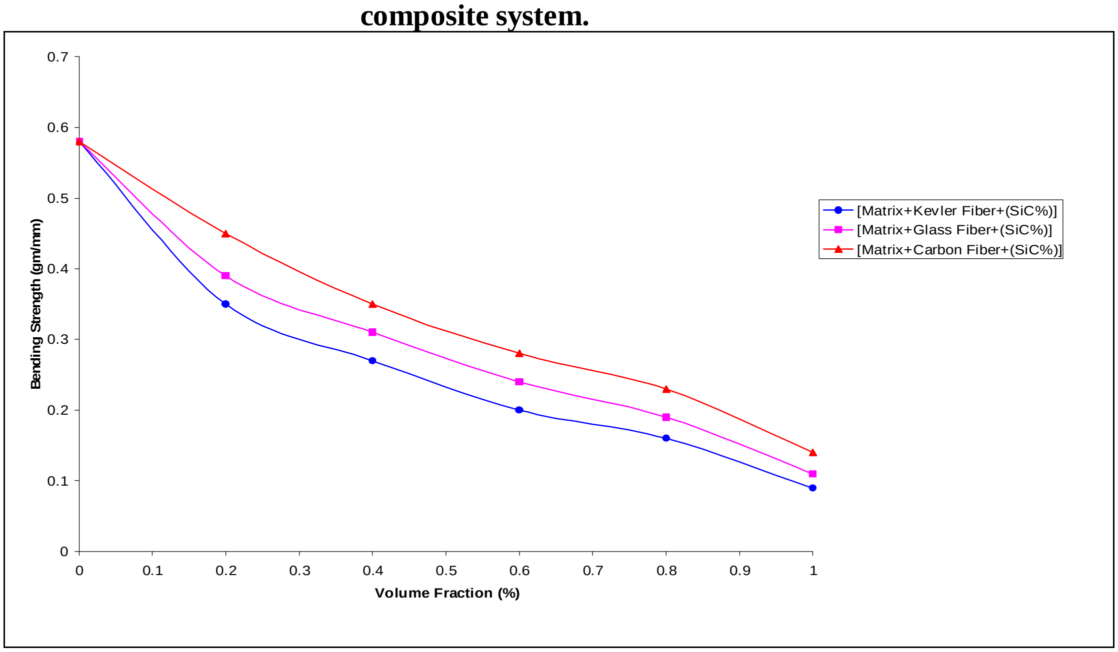

Figure (2): Effect of additive SiC on bending strength of polyester composite system.

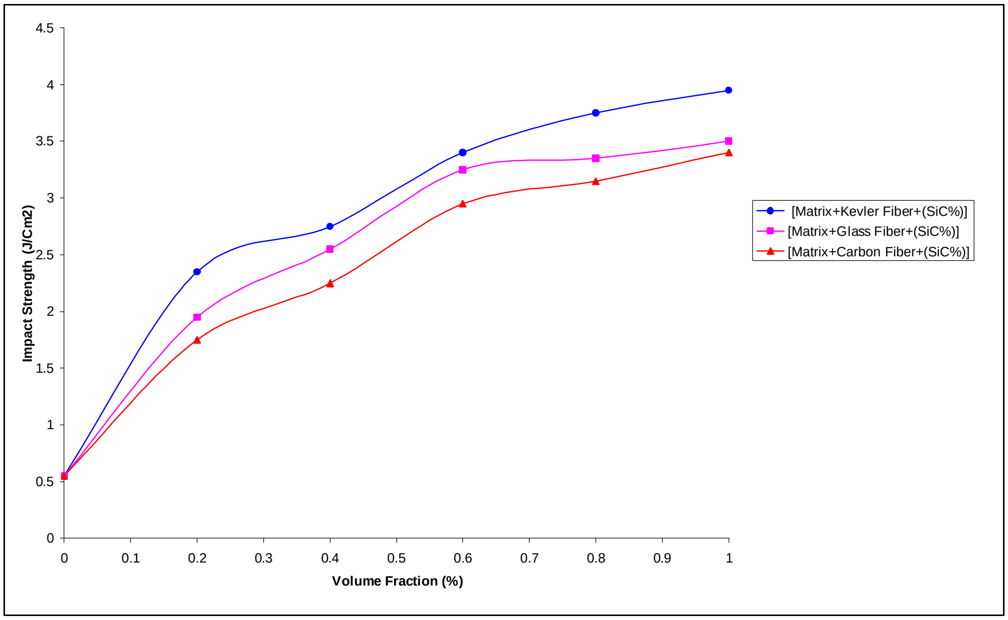

Figure (3): Effect of additive SiC on impact strength of polyester composite system.

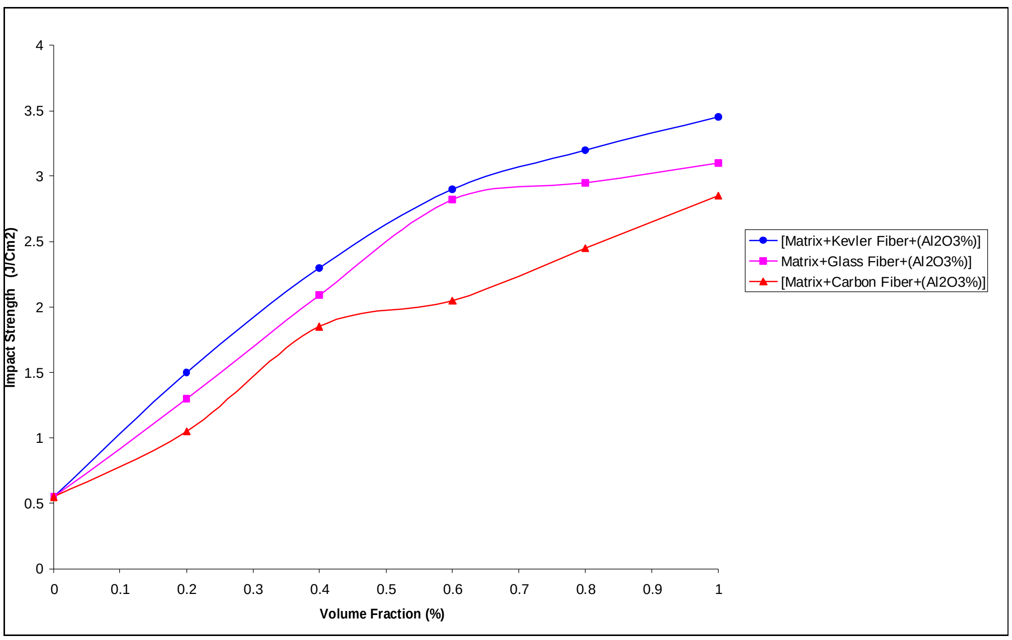

Figure (4): Effect of additive Al_2O_3 on impact strength of polyester composite system.

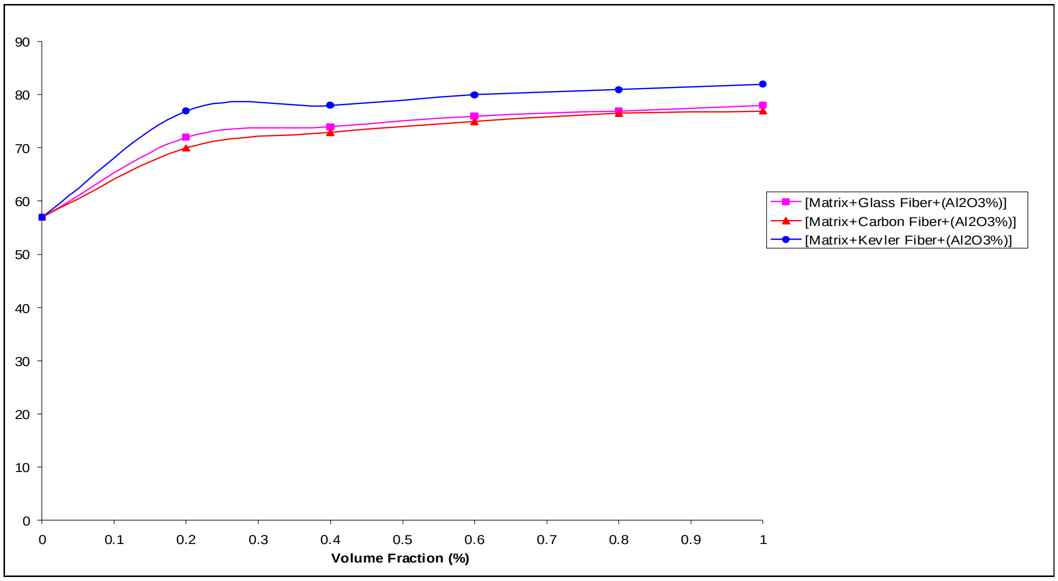

Figure (5): Effect of additive Al_2O_3 on hardness test of polyester composite system.

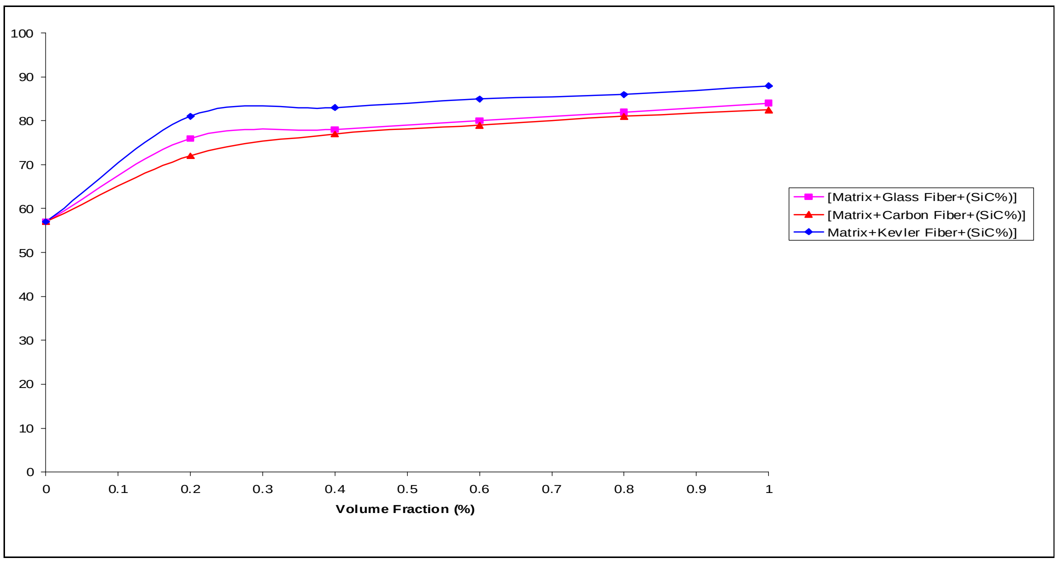

Figure (6): Effect of additive SiC on hardness test of polyester composite system.

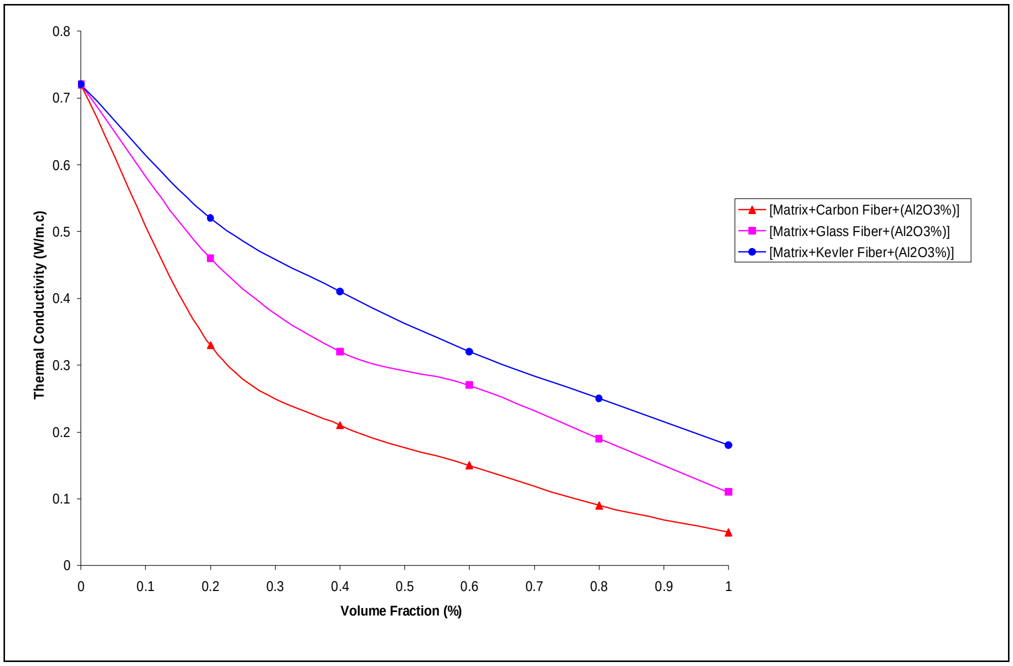

Figure (7):Effect of additive Al_2O_3 on thermal conductivity of polyester composite system.

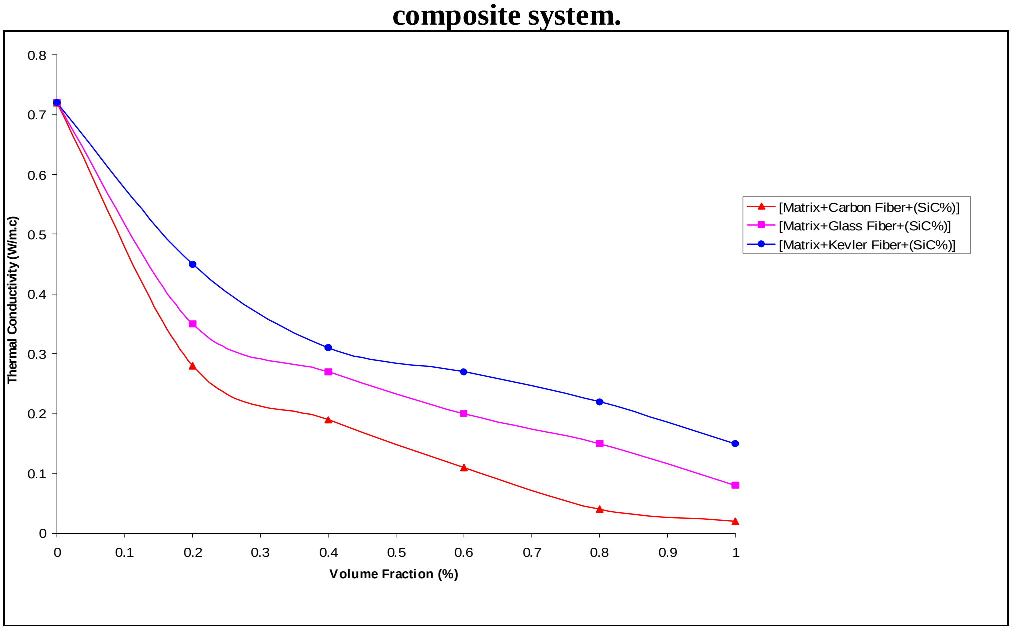

Figure (8): Effect of additive SiC on conductivity thermal of polyester composite system.