STUDYING SOME OF PHYSICAL PROPERTIES FOR POLYMER REINFORCED WITH CHOPPED CARBON FIBERS (CCF) COMPOSITES

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دراسة بعض الخواص الفيزيائية لمتراكبات بوليمرية مدعمة بألياف الكاربون المقطعة

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المستخلص

تضمن البحث دراسة بعض الخواص الفيزيائية (التوصيلية الحرارية و قوة العزل الحراري) لنوعين من المتراكبات البوليمرية , راتنج الأيبوكسي المدعم بألياف الكاربون وراتنج البولي أستر المدعم بألياف الكاربون وبنسب وزنية مختلفة (1%,3%,5%,7%), حضرت العينات بطريقة التشكيل اليدوي على ألواح زجاجية وتم تقطيع العينات حسب المواصفات المطلوبة لجهاز فحص التوصيلية الحرارية وقوة العزل الحراري. أوضحت النتائج أن العينات من النوع ايبوكسي/الياف الكاربون تمتلك أعلى قيمة للتوصيلية الحرارية عند النسبة الوزنية 7% والعينات من النوع راتج البولي استر غير المشبع/ الياف الكاربون تمتلك أعلى قيمة عند النسبة الوزنية 7% بالمقارنة مع العينات المحضرة بالنسب الوزنية الأخرى. كذلك بينت النتائج أن التوصيلية الحرارية لعينات راتنج البولي استر غير المشبع وراتنج الايبوكسي النقية تزداد عند زيادة النسبة الوزنية لألياف الكاربون المضافة. من ناحية اخرى, اوضحت النتائج ان متراكبات البولي أستر تمتلك أعلى قيمة للتوصيلية الحرارية بالمقارنة مع متراكبات الايبوكسي. كما بينت النتائج أن أعلى قيمة لقوة العزل الحراري كانت عند النسبة الوزنية 1% ولكلا النوعين من المتراكبات المحضرة لألياف الكاربون. بالاضافة الى ذلك,أوضحت النتائج أن متراكبات البولي أستر تمتلك أعلى قيمة لقوة العزل الحراري بالمقارنة مع متراكبات الايبوكسي.

Abstract

The research includes the study of some physical. Properties (thermal conductive and dielectric strength) for two types of polymer composites; epoxy resin (EP) reinforced by chopped carbon fibers (CCF) and unsaturated polyester resin (UPE) reinforced by chopped carbon fibers at different weight percentage (1%, 3%, 5%, 7%). Hand –lay up. Method was used to prepare sheets of composites (EP, UPE, EP/CCF, and UPE/CCF) on. glass mold which were cut according to the standard dimensions of the thermal conductive and dielectric strength tests specimens.

The results showed that the. Sample of UPE/CCF have highest values of thermal conductive at weight. percentage (7%) compared with prepared samples at other weight percentage. Also the results showed that the thermal conductive of. Pure UPE and EP increased with increase in weight percentage of carbon fibers addition. On the other hand, the results showed that the polyester composites have higher values of thermal conductive compared with epoxy composites.

Also the results showed that higher value of dielectric strength at weight. Percentage (1%) for both types from prepared composites of carbon fibers.In addition, the results showed that the polyester composites have higher values of dielectric strength compared with epoxy composites.

Key words: Unsaturated polyester resin; Epoxy resin; Chopped carbon fibers and Composite Materials.

1 Introduction

The industrial development and quick technical in the world drive researchers to find a multi-use material having a high engineering and technical characteristic according to the age demands. Researchers found the difference in material properties by studying properties of engineering. Materials (metals, ceramics, polymers) represented by hardness, toughness, electrical, thermal conductivity and flexural strength. Polymers for example, characterized by light weight, oxidation resistance, transparency and ability to form complex shape and high resistance, since there are a lot of modern industries and technology that need materials having a combination of unusual properties (high impact, high weight and resistance to various environmental conditions) which should be economic and suitable for industrial purposes and engineering application. All of which had led to find out what is termed composite materials.

Composites consist of one or more discontinuous phases embedded in a continuous phase. The discontinuous phase is usually harder and stronger than the continuous phase and is called the reinforcement or reinforcing material, whereas the continuous phase is termed as the matrix [1,2,3].

Carbon fiber is a form of graphite in which these sheets are long and thin. You might think of them as ribbons of graphite .bunches of these ribbons like to pack together to form fibers, hence the name carbon fiber. These fibers aren't used by themselves. Instead, they are used to reinforce materials like epoxy resins and other thermosetting materials. We call these reinforced materials composites because they have more than one component. Carbon fiber reinforced composites are very strong for their weight. They are often stronger than steel, but a whole lot lighter. Because of this, they can be used to replace metals in many uses, from parts for airplanes and the space shuttle to tennis rackets and golf clubs [4,5,6].

Many applications would benefit from the use of polymers with enhanced thermal conductivity. For example, when used as heat sinks in electric or electronic systems, composites with a thermal conductivity approximately from 1 to 30 W/m.K are required. The thermal conductivity of polymers has been traditionally enhanced by the addition of thermally conductive fillers, including graphite, carbon black, carbon fibers, ceramic or metal particles [7].

2 Experimental works

2-1 Raw Materials

Raw materials used in this experimental work are listed below:

2-1-1 MATRIX MATERIALS

Epoxy resin (EP) type (Leyco-Pox 103) with the hardener formulated amine was supplied by leyco chem. Leyde industry,used in this study. The properties of epoxy resin are given in Table (1).

Table (1): Typical properties of epoxy and unsaturated polyester resins [8, 9, 10].

Property	Epoxy (EP)	Unsaturated Polyester (UPE)
Density(g/cm3)	1.1-1.4	1.05-1.4
Tensile strength (MPa)	45–130	45-103
Tensile modulus (GPa)	2.1–5.5	1.3-4.5
Cure. shrinkage %	1–5	5–12
T_g(k)	380	340

Unsaturated polyester resin (UPE) type (A-50), hardener MEKP and with accelerator. cobalt naphthenate supplied by IPI Jordan are used, The typical properties of unsaturated. polyester resin are shown in Table (1).

2-1-2 FILLER MATERIAL

Chopped carbon. fiber as shown in Figure (1) manufactured by (F.C.F.) company is used in this work.

Figure (1) Photograph shows chopped carbon fiber used in this work.

The diameter of. chopped carbon fiber was measured by optical microscopic. The typical properties of (CCF) are shown in the Table (2).

Table (2): Typical properties of chopped carbon fiber (CCF) [6].

Property	Chopped Carbon Fiber (CCF)
Density (gm/cm3)	1.78
Length (mm)	8
Diameter (μm)	4.2
Tensile strength (GPa)	1.5- 4.8
Modulus of elasticity (GPa)	228-724
Ductility %	8
Melting temperature (^{o}C)	3700

2-2 SAMPLE PREPARATION

2-2-1 EPOXY RESIN (EP)

The neat epoxy specimens were prepared by simple direct mixing of epoxy resin with the hardener, epoxy resin and hardener are weighted for suitable mixing ratio by using electronic balance type (Sartorius BL 210S/Germany) with sensitivity of 10^{-4}g and with rang up to 2Kg, and mixed in container by mechanical stirring for 15 minutes to get good homogeneity between epoxy resin and hardener before casting it as sheets (of dimensions 15x15cm^2), by using clean glass mould (cleaned by distilled water to remove the dirt and dust present on the surfaces) were used for casting. The casting was cured at room temperature for 24 hours, then for post-curing, the sheets were left for 4 hours in an oven at temperature 60^{o} C. An EP sample is shown in figure (3).

2-2-2 UNSATURATED POLYESTER RESIN (UPE)

The neat UPE resin. was mixed with accelerator (cobalt naphthenate), and hardener (Methyl Ethyl Keton Peroxide) was added to the mixture with suitable weight percentage of hardener. The contents were mixed thoroughly until homogeneous mixture was obtained, by using a fan type stirrer, before casting it as sheets (of dimensions 15x15cm^2), by using clean glass mould (cleaned by distilled water to remove the dirt and dust present on the surfaces) were used for casting. The casting was cured at room temperature for 24 hours, then for post-curing, the sheets were left for 4 hours in an oven at temperature 60^o C. An EP sample is shown in figure (4).

2-2-3 PREPARATION OF THE COMPOSITES

The composites were prepared from epoxy resin (as a matrix) and chopped carbon fibers (CCF) with different weight percentages (wt.%) (1%, 3%, 5%, and7%) by hand lay-up method which can be summarized by the following steps:

1- The mould stage of glass plates for casting the composite sheets. The glass plates are prepared from cleaned waxed. glass plates of dimensions 15 × 15 cm^2. Wax is applied to prevent the adhesion of composite sheets with glass plates.
2- Thin layer of epoxy matrix is poured on the dried waxed glass plates using a paint brush to obtain a thin layer of EP.
3- The wt. % of chopped carbon fibers is weighted with a sensitive balance (Four digits).
4- Carbon fibers are mixed with a certain amount of epoxy matrix using a rubber roller to enhance impregnation. of the matrix to fibers. This is placed on the resin layer and some resin is added to the upper surface of the carbon epoxy mixture to cover it completely.
5- By using aluminum notched roller, the sheets are pressed to expel the voids of air from the composites.
6- A waxed glass plate is placed over the composites. This is then left under suitable load for 24 hours so as to harden well. After this they are post-cured for 4 hours in an oven at 60ºC to get the composites sheets.
7- Preparation of samples from unsaturated polyester resin as a matrix and chopped carbon fibers (CCF) as a reinforcement with different weight percentage (wt.%) from fiber1 is(1%, 3%, 5%, and7%) by using hand lay-up method can be achieved following steps 1 to 6.

3. SAMPLE CUTTING

The sheets of neat epoxy, unsaturated polyester, and their composites are cut into specimens of. the shape and dimensions that is shown in Fig.(2) A according to the instrument manual specification, by using a circular iron saw, Pluses from the samples were removed by using the iron rasp, to were made sleeking paper. The prepared EP UPE/CCF composites are show in Fig. (3) and the UPE /CCF composites are show in Fig. (4).

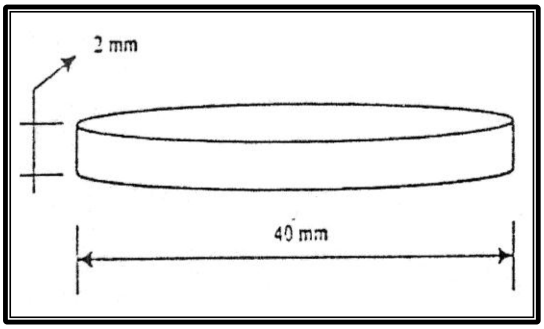


Figure (2) Dimension of thermal conductivity test and dielectric strength test specimens.

Figure (3) Photograph of thermal conductivity test and dielectric strength test specimens for pure epoxy polyester and their composites.

Figure (4) Photograph of thermal conductivity test and dielectric strength test specimens for pure epoxy polyester and their composites.

4 CHARACTERISATION TECHNIQUSE

4-1 THERMAL CONDUCTIVITY TEST

Lee's disc. instrument showed in figure (5), manufactured by the Griffen and George Company, was used to calculate the thermal conductivity of the samples under test. The figure below shows this instrument which consists of three discs of brass (40 mm diameter by 12.25 mm thickness) and a heater. The sample (S) is placed between. the discs A and B, while the heater is placed between B and C. Heater was supplied with voltage. (6 volt) and the current value through the apparatus was about (0.25Amper). The heat transfers from the heater to the near two discs then to the third disc across the sample. The temperature of the three discs (TA, TB, and TC) is. measured by using a thermometers. placed inside them. After reaching thermal equilibrium, the temperatures were recorded. The value of thermal conductivity is determined by using the following equation (1):

$$k\left[\frac{T_B - T_A}{d_s}\right] = e\left[T_A + \frac{2}{r}\left(dA + \frac{1}{4}d_s\right)T_A + \frac{1}{2r}d_s T_B\right]$$
……….(1)

Where:

K: The thermal conductivity coefficient (W/m. °C).

TA, TB, & TC: Temperature of the metal discs A, B, C respectively (°C).

dA, dB&dC: .Thickness of the discs A, B & C respectively (mm).

dS: Sample's thickness (mm).

r: disc's radius (mm).

e: The quantity. of heat flowing through the cross sectional area of the specimen per unit time ($W/m^2.°C$) is calculated from the following equation (2):

$IV= \pi r^2 (T_A+T_B) +2\pi re [d_AT_A+d_S (1/2)(T_A+T_B) +d_BT_B +d_CT_C]$ ……. (2)

Where:
I = Current through the heater (Amper)
V= Applied voltage (Volt) [11].

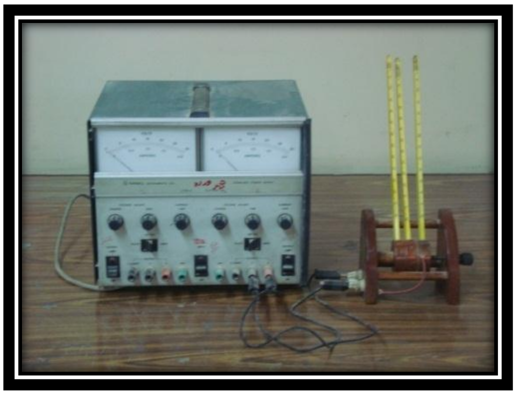


Figure (5) Thermal Conductivity test instrument.

4-2 DILECTRIC STRENGT

The average potential per unit thickness at which failure of the. dielectric material occurs. Whichever, the magnitude of the electric field required to cause dielectric breakd0wn is called the dielectric. strength. When applied to a strong electric field on the insulator is higher than the value of the specific critical, the relatively high electrical. current will apply, So the insulation properties of the insulator will lose and become a conductor. The voltage that occurs then the. breakdown is called (Breakdown Voltage). When divided by the thickness of the samples. As equation following:

$$\text{dielectric strengt} = \frac{\text{breakdown voltage}}{\text{insulator thickness}} \quad \ldots\ldots (3)$$

The sample put between two copper poles which are embedded in oil with make sure of touching poles with the sample surface then applying voltage through the sample that occurs the breakdown voltage. After knowing the area that breakdown happens which can be distinguish according to the damage that occur because of the breakdown [12]. The dielectric strength instrument consists of the following:

1-High Voltage supplier has used with the range of voltage (0-60 kV) and frequency (50 Hz) of the type (BAUR PGO S 3) Germany origin.

2-The instrument contains liquid with a high dielectric strength (voltage transformer oil (40kV/mm)) to prevent transmittal of the circumstantial. spark (Flashover), in addition to rise speed of liquid inflammation, and the oil must change. to prevent the ionization of liquid which leads to inaccuracy measurement.

3-It contains. copper poles of good electrical conduction and spherical shape, its diameter about (2mm), as in the figure (6).

Figure (6) Dielectric strength test instrument.

5 RESULTS

5-1 THERMAL CONDUCTIVITY TEST

Thermal conductivity is the ability of a material to conduct heat. This quantity represents the rate of. heat flow per unit time in a homogenous material under steady conditions, per unit area, per unit temperature gradient in. a direction perpendicular to area [13].

Polymers are often utilized as thermal insulators because. of their low thermal conductivities. For these materials, energy transfer is accomplished. by the vibration and rotation of the chain molecules[14].

From tables (3, 4) and figures (7,8), It can be seen that the thermal conductivity of the EP/ CCF and UP/ CCF composites have highest value of thermal conductive (0.250807 W/ mc°) at weight percentage (7%). The result show that thermal conductivity for composites increase with increasing wt. % of filler .It can be said that carbon fiber is a good thermal conductor. Fig. (9) Show the comparison between thermal conductivity for EP / CCF and thermal conductivity for UPE / CCF composites with different weight percentage. The behavior of thermal conductivity. values for all composites was increase with increasing in weigh percentage. The result show The EP and UP materials1convert from insulating behavior to thermal conductive behavior with addition carbon fibers.

Table (3): The values of Thermal Conductive for EP and EP/ CCF composites.

Sample	Thermal Conductive W/ mc°
EP	0.235099
EP / 1% CCF	0.238116
EP / 3% CCF	0.239232
EP / 5% CCF	0.249797
EP / 7% CCF	0.250807

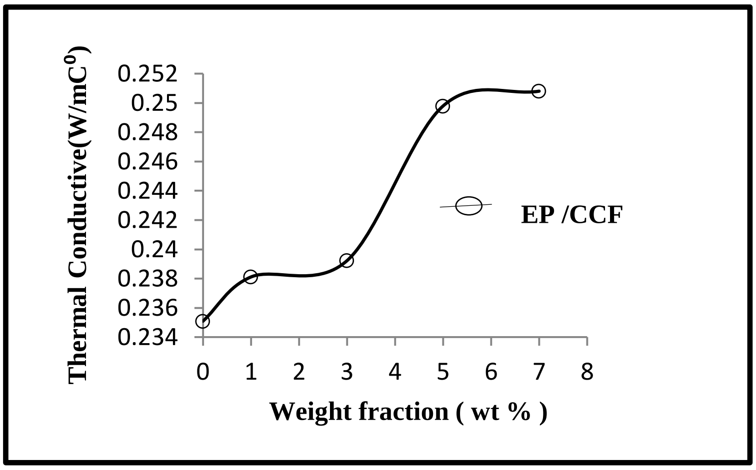
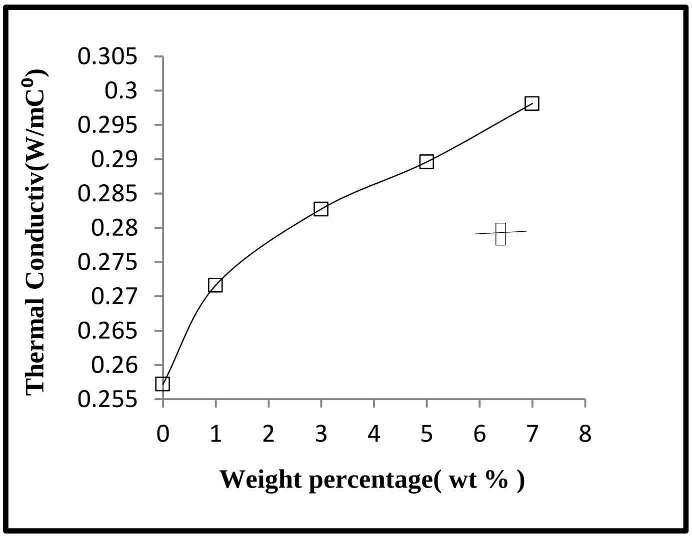


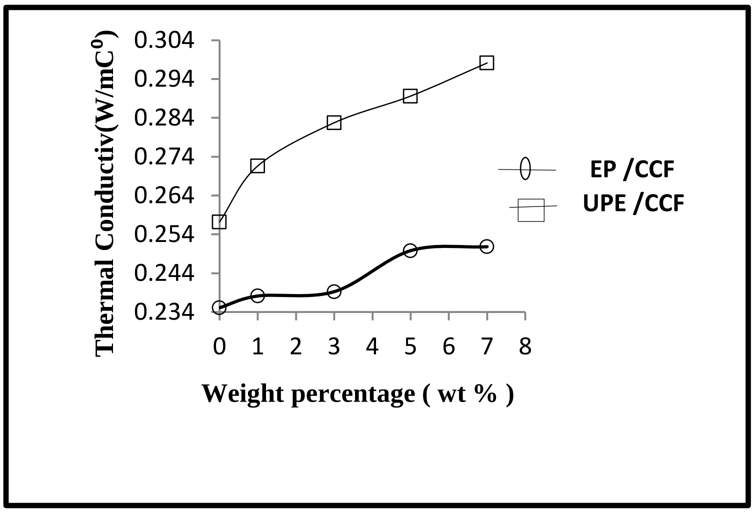
Figure (7) The variation of thermal conductive with weight fraction of EP / CCF composites.

Table (4): The values of Thermal Conductive for UPE and UPE/ CCFcomposites.

Sample	Thermal Conductive W/ mc°
UPE	0.257196
UPE / 1% CCF	0.271624
UPE / 3% CCF	0.282733
UPE / 5% CCF	0.289606
UPE / 7% CCF	0.298119



Figure(8) The variation of thermal conductive with weight percentage of UPE **/ CCF composites.**



Figure(9)Shows the comparison values of thermal conductive for EP / CCF and UPE / CCF composites.

5-2 DILECTRIC STRENGT TEST

The tables (5, 6) and figures (9, 10), explain the effect of weight percentage on the dielectric strength of the samples that prepared from composite material that has polymer matrix (EP and UP) reinforcement by chopped carbon fibers with different weight percentage (1,3,5,7)% , it was observed the decrease in dielectric strength with the addition of carbon fibers in epoxy resin and polyester resin . This is most. likely explained by the carbon fibers having a lower dielectric than the base epoxy resin or polyester resin. figures (9, 10), clearly shows that the filler content decrease dielectric behavior and composites transform from insulators to conductors behavior with addition carbon fibers. Fig. (12) Show the comparison between dielectric strength for EP / CCF and dielectric strength for UPE / CCF composites with different weight percentage.

Table (5): The values of dielectric strength for EP and EP/ CCF composites

Sample	dielectric strength (KV/sec.mm)
EP	9.24
EP / 1% CCF	0.183
EP / 3% CCF	0.173
EP / 5% CCF	0.134
EP / 7% CCF	0.121

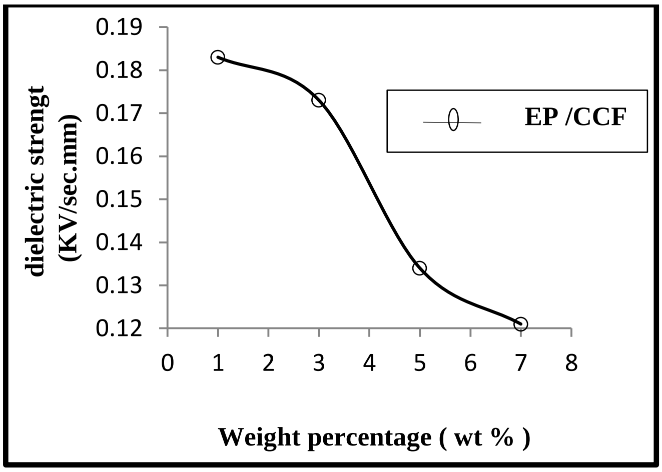
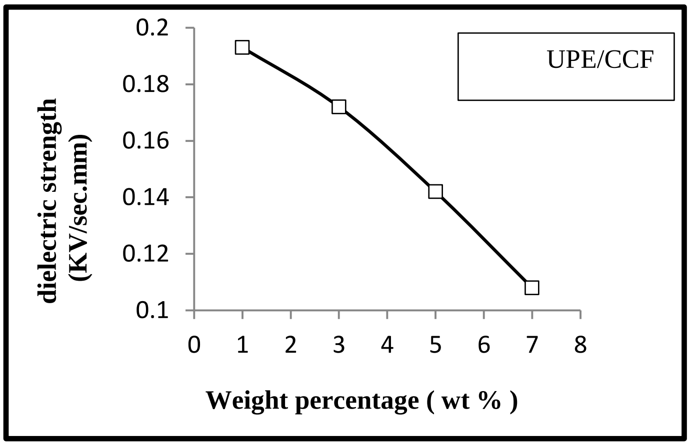


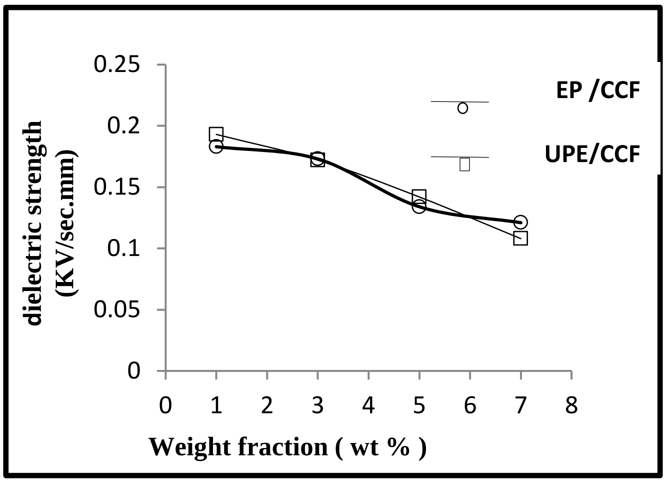
Figure (10) The variation of dielectric strength with weight percentage of EP / CCF composite.

Table (6): The values of dielectric strength for UPE and UPE/ CCF composites

Sample	dielectric strength (KV/sec.mm)
UPE	12.5
UPE / 1% CCF	0.193
UPE / 3% CCF	0.172
UPE / 5% CCF	0.142
UPE / 7% CCF	0.108



Figure(11) The variation of dielectric strength with weight percentage of UPE **/ CCF composite**



Figure(12)Shows the comparison values of dielectric strength for EP / CCF and UPE / CCF composites.

6 CONCLUSIONS

The results of thermal conductivity test showed that the carbon fibers improved the thermal property of EP and UP.

1. EP/ CCF and UP/CCF composites show increase in .thermal conductivity with the increase of the filler weight percentage.
2. EP/ CCF and UP/CCF composites show increase in .thermal conductivity with the increase of the filler weight percentage.
3. The polyester resin. and epoxy resin are good adhesive. materials which can use as a matrix with carbon fibers.
4. The polyester resin and epoxy resin are good adhesive materials which can use as a matrix with carbon fibers.
5. Carbon fibers polymer-based as composites have a great deal of future promise for potential applications as high-performance materials.
6. EP/ CCF and UP/CCF composites show decrease in dielectric strength with the increase of the filler weight percentage.

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