Preparation And Study of Some PhysicalProperties for Polyester Reinforcement by (Al) Powder Composites

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ABSTRACT

In view of the developments of industrial applications, this happened in recentyears and the need to use composite materials in general and polymer compositeespecially in the various industrial applications developed.In this workunsaturated polyester resin (UPE) mix with different ratio of weight fractions 10, 20, 30 and 40% of aluminum chip were used to prepare polyester composites to examine and study some mechanical tests (Impact strength) and physical tests (Thermal Conductivity and dielectrically constant) for all specimens.The molding method was used to prepare UPE and UPE/Al composites specimens. The results showed that the samples of Al chip gained highest values of Impact strength (5.59KJ/m2) at ratio percent (40%). The results show increased thermal conductive of the resin (UPE) samples by increased thermal conductivity coefficient value after addition this material. Also the value of thermal conductive increased with increasing of additive percentage of Al chip as illustrated in diagram which represents the relation between thermal conductivity (k) with weight fraction.Dielectrical properties of UPE and UPE/Al composites show; the dielectric constant of UPE/Al composites decrease with increasing of the weight percentage of Al chip.

Keywords:- Aluminum chip, Impact strength,Unsaturated Polyester Resin, and Composite Materials.

1.INTRODUCTION

A composite material has been defined as: "A substance consisting of two or more materials, insoluble in one another, which are combined to form a useful engineering material possessing certain properties not possessed by the constituents" [1]. Such materials offer advantages over conventional isotropic structural materials such as steel, aluminum, and other types of metal .These advantages include high strength, low weight, good fatigue strength and corrosion resistance. In addition, by changing the arrangement of the fibers, the properties of the material can be tailored to meet the requirements of a specific design [2]. The design of a structural component using composites involves both material and structural design. Unlike conventional materials, the properties of the composite material can be designed simultaneously with the structural aspects. Composite properties (e.g., stiffness, thermal expansion, etc.) can be varied continuously over a broad range of values, under the control of the designer [3]. Many works have been devoted to use of particulate fillers in composite in recent past. For instant, silica, alumina, coconut shell particulates, wood flour and rice husk are the most commonly particles used to reinforce polymers. In general, particles enhance the stiffness of the composite to a limited extent. Particle fillers are widely used to improve the properties of matrix materials. In (2009), I. w. Watan studied the influence of adding unsaturated polyester as a matrix material with Alumina as a filler of particle size (30µm) with different weight fraction, some of its mechanical and thermal properties have been studied for the prepared specimens. The results of impact and hardness tests showed an increase with the increase of weight fraction as non- linear relationships whereas the thermal conductivity increased with the increment of weight fraction for ceramic particles [4]. In (2012), Ali H.A. et al. prepared Polyester matrix composites with chip and powder Copper , Mechanical properties such as flexural strength and impact test of polymer reinforcement Copper (powder and chip)were done, The maximum flexural strength for the polymer reinforcement with Copper (powder and chip) are (85.13Mpa) and (50.08Mpa) respectively was obtained, While the maximum observation energy of the impact test for polymer reinforcement with Copper (powder and chip) are (0.85 J and 0.4 J) respectively [5].

The aim of this work is to:-
1. prepare and testing samples of particulate composite, which consists of unsaturated polyester resin as a matrix, with chip of aluminum as filler with different weight percentage (10, 20, 30, and 40 %).
2. Evaluation of mechanical properties of the composites.

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3. Study the effect of filler weight percentage adding on   mechanical (impact strength), electrical (dielectric constant) and Thermal (thermal conductivity) properties.

2.EXPERIMENTAL WORK

RAW MATERAILS

One type of polymers was used; unsaturated polyester resin (containing styrene as a cross – linking agent), (having a symbol SIR SIROPOL) which was supplied from Saudi industrial resin CO. LTD , p. o. box 7764, Jeddah 21472 , Kingdom of Saudi Arabia. It is a liquid with moderate viscosity which can be cured to the solid state by adding (Methyl Ethyl Ketone Peroxide, MEKP) as a hardener, while cobalt naphthenate acts as a catalyst to accelerate the solidification process. The percentage of the hardener to the resin is (2%) while it is (0.5%) for accelerator. UPE is distinguished by desirable physical properties, easily handled, quickly cured and stable dimensions after solidification and Aluminum chip was used in this work as a filler materials shown in Fig. (1). The typical properties of unsaturated polyester resin are shown in Table (1).

`**Table (1):** Typical properties of unsaturated polyester resin (UPE)

Materials	Density (gm/cm³)	Tensile strength (Mpa)	Tensile modulus (Gpa)	Cure shrinkage %	Tg (K)
(UPE)	1.05-1.4	23.4- 89.7	1.1-4.5	5-12	340

Figure (1): Photograph shows (Al) chip

CAST MOULD

The cast mould used for casting the polymeric specimens and composites

1. A glass plates of dimensions (400 mm ×400 mm×6 mm) were used as a mould stages.
2. Glass strips of dimensions (200mm × 20mm × 6mm) were used as boundaries for the cast mould.

Before casting, a glass plates were cleaned with water and soapsolution, after drying in oven, one base of the glass plates was coated with wax, then glass strips were fixed on glass plates and left for one hours todry at room temperature**.**

3.COMPOSITES PREPARATION

The composites were prepared from unsaturated polyester resin (as a matrix) and (AL) chip(as a filler) with different weight percentages of (10,20,30 and 40%) wt.% by Hand lay-up molding method which can be summarized by the following steps:

1. First of all, AL was passed to heat treatment in an oven at 100 ˚C for 1 h to remove the moisture.
2. Determine the weight of AL by using a sensitive balance (four digits type: Sartorious, H51, made in Germany).
3. Determine the weight of resin and its (hardener and accelerator) and mix them carefully.
4. Mix the content thoroughly in a clean disposable container by a fan type stirrer before casting it as sheets (of dimensions 200 × 150 mm2) by using glass mould.
5. Leave the composite at room temperature about 24 hours and then for post-curing, the sheets were left for 2 hours in an oven at temperature 60˚C.

4.IMPACT TEST SAMPLE CUTTING

The sheets of the composites are cutting into specimens, by using a circular iron saw, pluses from the samples were removed by using the iron rasp, the samples were polished by using abrasive emery papers of grade 400.The shape and dimension of the samples cut for impact test, thermal conductivity test, dielectric constant test, are shown at figures (2), (3), (4), (5), (6) and (7) respectively.
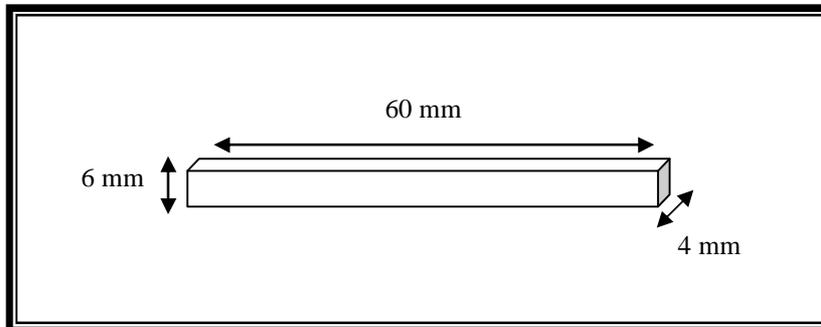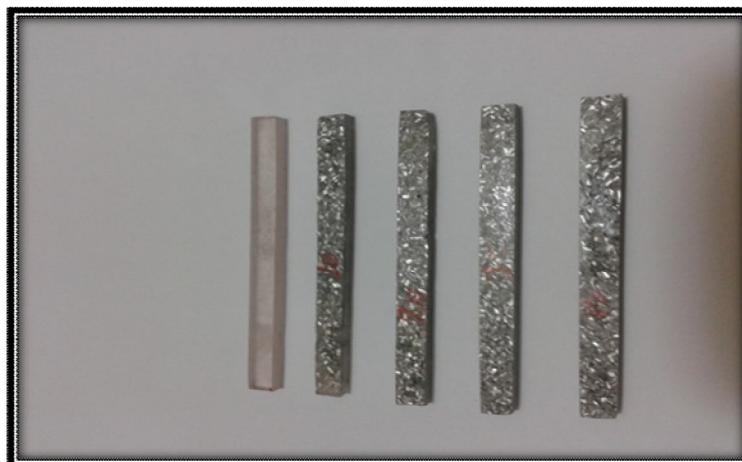

Figure (2): Dimensions of Impact Test Specimens[ISO-179 TYPE D][6].

Figure (3): Photograph of impact test specimens for pure polyester and theircomposites.
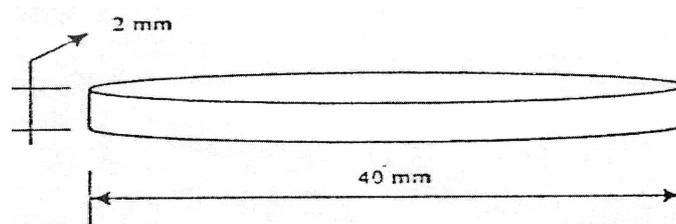

Figure (4): Dimensions of thermal conductivity Specimens [According to specification of instrument]
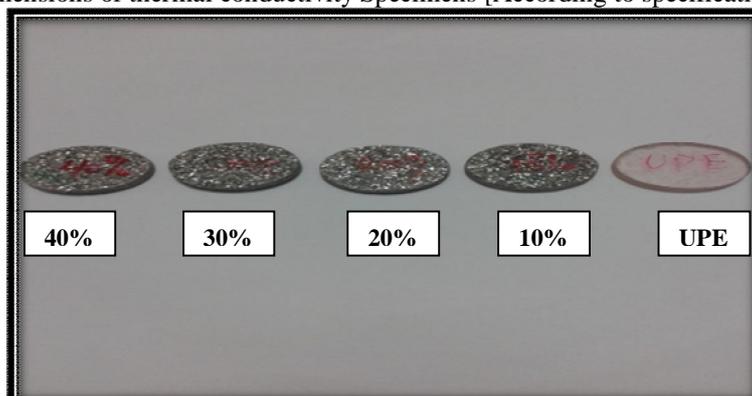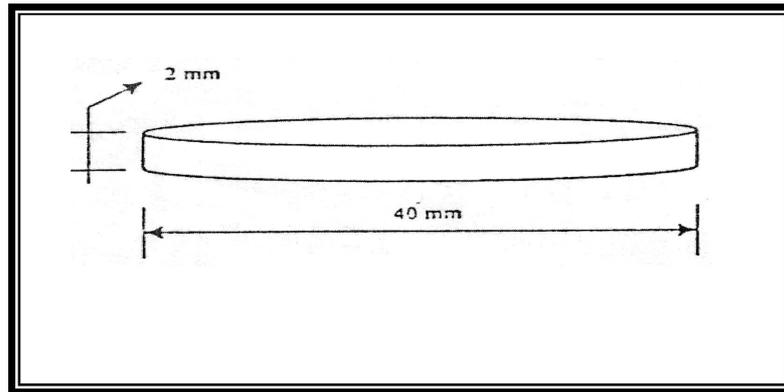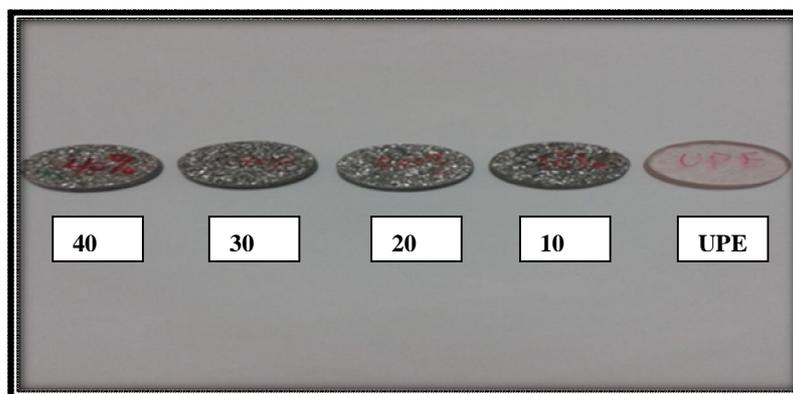

Figure (5): Photograph of thermal conductivity test specimens for pure polyester and their composites.

Figure (6): Dimensions of dielectric constant Specimens.[ASTM-D150]

Figure (7): Photograph of dielectric constant test specimens for pure polyester and their composites.

5.CHARPY IMPACT TEST

Pendulum-type hammers testing machine model IMPACT TESTER TMI NO 43-1 was used in the charpy impact mode of full scale 2 J. In charpy type the specimen is supported as a horizontal simple beam and is broken by a single swing of the pendulum with the impact line midway between the supports. In this method used a special un notched specimen according ISO-179 standard (Type-D).

Impact strength is calculated from the relation. [7]

$$I.S = U/A \quad (KJ/m^2) \quad (1)$$

Where

I.S = Impact strength

U = Energy of fracture in (kilo joule)

A = Cross section area in (m^2)

6.THERMAL CONDUCTIVITY TEST INSTRUMENT

Lee's disc instrument showed in figure (8), 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 (0.25Amp). 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 (T_A, T_B, and T_C) is measured by using a thermometers placed inside them. After reaching thermal equilibrium, the temperatures were recorded.

Figure (8): Thermal Conductivity Test Instrument

The value of thermal conductivity is determined by using the following equations [8]:

$$K[(T_B - T_A)/d_s] = e[T_A + [(2/R)(d_A + 1/4 d_s)T_A + (1/2r)d_s T_B]] \qquad (2)$$

Where:

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

T_A, T_B, & T_C: Temperature of the metal discs A, B, C respectively (°C).

d_A, d_B & d_C: Thickness of the discs A, B & C respectively (mm).

d_S: 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 [8]:

$$IV = \pi r 2 e (T_A + T_B) + 2\pi r e [d_A T_A + d_S (1/2)(T_A + T_B) + d_B T_B + d_C T_C] \qquad (3)$$

Where:

I= Current through the heater (Ampere)

V= Applied voltage (Volt)
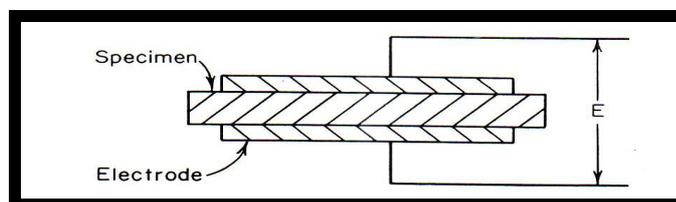
7.DIELECTRIC CONSTANT TEST INSTRUMENT

The illustrated instrument in Fig. (9) is utilized to measure the dielectric constant values of polymer and its composites. This instrument represents an electrical circuit (in series connection) which consists of capacitor, coil, resistor, ammeter and frequency generator. After was placed the sample between the capacitor's plates, the frequency of the power supplier was alternated till get maximum current value. At this maximum value, the frequency was recorded which represents the resonance frequency value (f_r). After that, the (f_r) value was determined without the presence of the sample (i.e with existence of the air only). The capacity of the capacitor can be calculated from the relationship:-

$$C = \frac{1}{4\pi^2 f_r^2 L} \qquad (4)$$

Where (L) is the inductance of the coil, Dielectric constant (ε_r) can be calculated from the equation:-

$\varepsilon_r = C/Co$,

where Co is the capacity of the capacitor with existence of the air while C is the capacity of the capacitor with the presence the sample.

Figure (9): Dielectric constant instrument

8.RESULTS AND DISCUSSION

IMPACT STRENGTH OF COMPOSITES

The conventional charpy impact test is used to evaluate the impact strength of the composites that have (10, 20, 30, 40) % of aluminum chip (Al). The results of this test are shown in Table (2), Fig. (10), which show the effect of aluminum chip content on the impact strength values of the prepared composites.The table (2) showed that the samples of UPE/Al gained highest values of Impact strength (5.59 KJ/m^2) at ratio percent (40%). The addition of Al chip in ratio of 40% to UPE is the right addition to transition and distribution of the energy in equal form from polymer to the filler materials which means that interference between UPE and Al at the ratio (40%) leads to improvement of the compatibility between the two materials UPE and Al. Table (2) demonstrate that the charpy impact strength of (thermoset /reinforcement material) composites is higher than that of brittle matrix itself, which implies the positive role of reinforcement material on the impact fracture toughness of brittle materials. The good adhesion between the UPE resin and aluminum chip is behind the improved values of impact strength for UPE composites, whereas, the higher value of the impact strength of the composites material consisting of the reinforced with Al can be attributed to the strong interfacial adhesion between UPE and Al. Also, it is ascribed to the stringing of the chemical bond and interaction between the matrix and fillers materials. The addition of Al chip to UPE resin at ratio percent (10%) acts to decrease the impact strength of composites. This obtained result may be attributed to the poor adhesion at the filler/matrix interface. In addition, the interfaces between particles and matrix will be under stresses, so many micro cracks will appear and the stress concentration on the ends of these micro cracks will increase, so that the crack will spread and fracture occur. This means the addition of powder filler to the polymer matrix lead to decrease in stress. This can be explained via returning to the different mechanisms, which depends on the bonding type between the particles and the matrix.

Table (2): The effect of AL particle content (wt. %) on the (I.S) of (UPE/ AL) composites.

Composition	Impact Strength (I.S), KJ/m^2			
	AL particle content (wt. %)			
	10%	20%	30%	40%
UPE/AL	3.3	4.9	5.24	5.59

$I.S_{UPE} = 4.6$ KJ/m^2
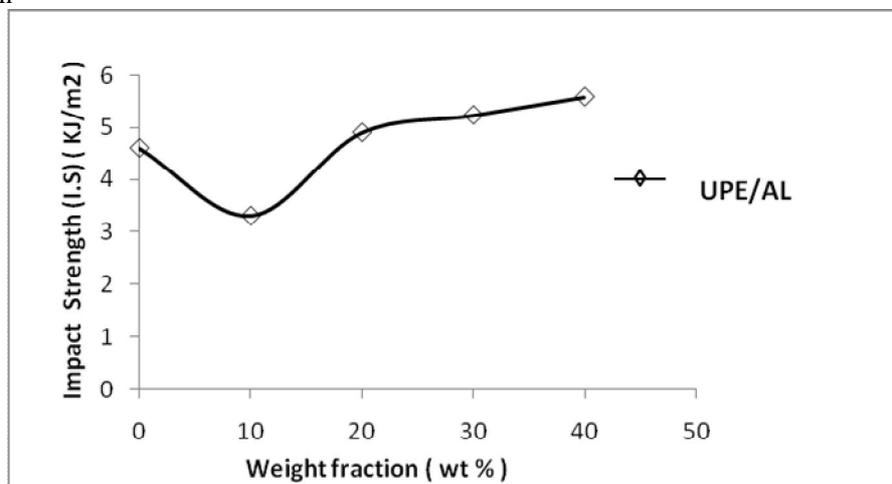
Figure (10): Charpy impact strength variation with Aluminum chip (Al) content in UPE resin
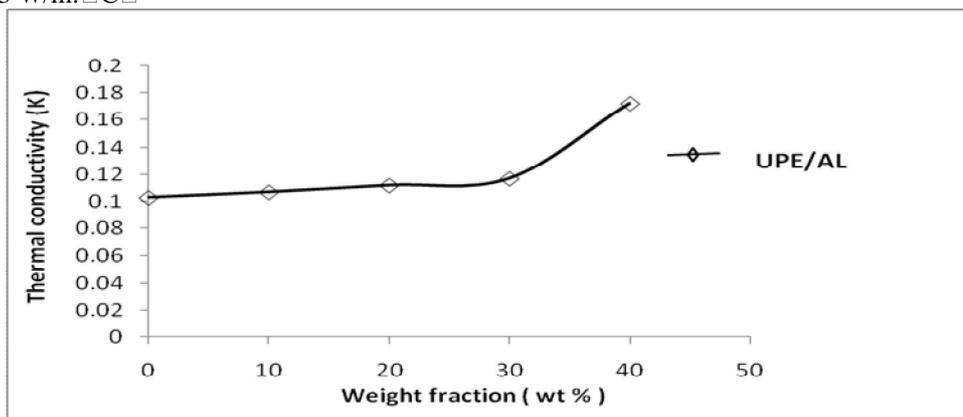
9.THERMAL CONDUCTIVITY

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 [9]. 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 [10].The thermal conductivity (K) of the UPE and its composites were measured at room temperature as shown in Table (3). The results are represented in the Figure (11). Thermal conductivity results show that K values for UPE/Al composite increase with increasing filler weight percentage wt%, with maximum value 0.171 W/m.⬜⬜C at 40% filler weight percentage as shown in Table (3). From Table (3), it can be noticed, that the average value of the thermal conductivity of these composites is less than ($0.172W/m.^oC$) which reflects the high resistance of those materials to heat transfer. This means, their suitability to be used as thermal insulators, this low thermal conductivity is due to the fact that these polymers have no free electrons and low phonon velocity. Piorkowska [11] states that polymers with coefficient of heat transfer not exceeding ($0.5W/m.^oC$), are considered as poor conductors of heat (i.e. good thermal insulators).

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Table (3): The effect of AL chip content (wt. %) on the (K) of (UPE/Al) composites.

Composition	Thermal conductivity (K), W/m.$\square$C			
	AL chip content (wt. %)			
	10%	20%	30%	40%
UPE/AL	0.107	0.112	0.117	0.172

K_{UPE} = 0.103 W/m.$\square$C$\square$

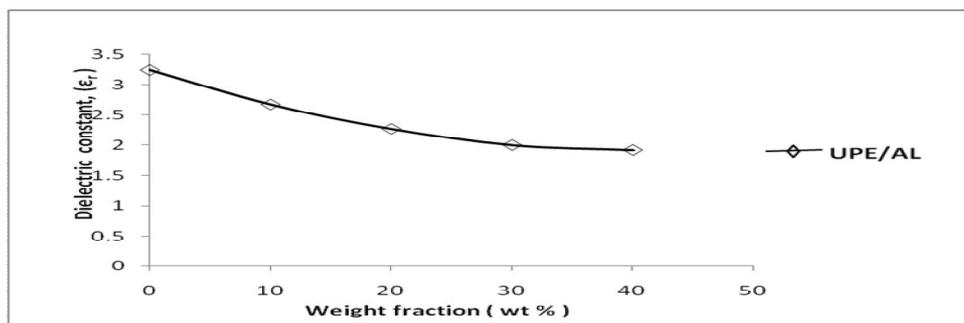**Figure (11):** Thermal conductivity variation with Aluminum chip (Al) content in UPE resin

10.DIELECTRIC CONSTANT

The variation of the dielectric constant of the polyester composites with respect to wt. % of aluminum chip (Al) to polyester resin is shown in Fig. (12). Epoxy and polyester, like other polymers, have been used in electronics as insulators, dielectrics and other applications due to their unique ability to be tailor-made for specific needs[12]. To investigate whether the polymer and modified composites can be used as electrical insulators, like their matrices, the dielectric constants of these materials were measured and the results organized in Table (4). In any polymer, the dielectric properties depend on the chemical constituents of the chain and the impurity levels. The polarity and rigidity of the polymeric chain are also important factors. The value of dielectric constant (ε_r) is influenced by several factors, namely, type of material, frequency and the temperature [9, 13]. For plastics, in general, the values of (ε_r) range from (2-10) [9].The values that are represented in Table (4) indicate that all the materials under investigation can be used as electrical insulators, as their matrices. According to the obtained results table (4), the dielectric constant showed that the samples of UPE/Al composites gained lower values of dielectric constant (1.92) at ratio percent (40%). It can be seen that ε_r for UPE/ AL composites at percent 10% is higher than that of others, the reason is obvious. It is due to low value of (ε_r) of Al; this may be because of the ability of the particles to conduct.

Table (4): The effect of AL chip content (wt. %) on the (ε_r) of (UPE/ AL) composites.

Composition	Dielectric constant, (ε_r)			
	AL chip content (wt. %)			
	10%	20%	30%	40%
UPE/AL	2.68	2.27	2	1.92

εrUPE = 3.24

Figure (12): Dielectric Constant variation with Aluminum chip (Al) content in UPE resin

11.CONCLUSION

This experimental investigation of mechanical and physicalbehavior of AL chip as a fillers filled polyester composites leads to the following conclusions:

- The polyester resin is a good adhesive material which can use as a matrix withAL chip.
- The above experimental results indicate that this AL chipmay be a good filler material forpolymer composite materials.

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