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A Study of Some Mechanical and Physical Properties for Palm Fiber/Polyester Composite

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K E Y W O R D S

Polyester, date palm fiber, compression, young's modulus, flexural strength, thermal conductivity.

A B S T R A C T

This research has been done by reinforcing the matrix (unsaturated polyester) resin with natural material (date palm fiber (DPF)). The fibers were exposure to alkali treatment before reinforcement. The samples have been prepared by using hand lay-up technique with fiber volume fraction of (10%, 20% and 30%). After preparation of the mechanical and physical properties have been studied such as, compression, flexural, impact strength, thermal conductivity, Dielectric constant and dielectric strength. The polyester composite reinforced with date palm fiber at volume fraction (10% and 20%) has good mechanical properties rather than pure unsaturated polyester material, while the composite reinforced with 30% Vf present poor mechanical properties. Thermal conductivity results indicated insulator composite behavior. The effect of present fiber polar group induces of decreasing in dielectric strength, and increasing dielectric constant. The reinforcement composite 20% Vf showed the best results in mechanical, thermal and electrical properties.

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1. INTRODUCTION

In general, composite materials are formed when two or more materials are combined together to give mixture of properties that cannot be reached otherwise [1]. The first fillers used for polymer composites were basically inorganic. In fact synthesis fibers such as glass, nylon, aramid, rayon, carbon and polyester are widely used for the reinforcement of plastics [2, 3].

In the previous decade, the usage of polymers over the conventional materials was increases due to many reasons. Many benefit polymers materials offers over the conventional materials, Such as easy treating, cost reduction, light weight and production. Mutually, polymer composites considered as stiff, light, tough and low scale production at lower costs. Moreover, they are also increase the energy productivity for instrument and transportation [4].

Over the years, researches approved the essential benefit of natural fibers with organic matrices due to the strength and toughness of these fibers which is higher than matrix materials used with. Moreover, lignocelluloses natural fibers possess many properties such as cheap, strength, light in weight, abundant and renewable. Natural fibers also utilized as usual resource in manufacturing low cost composite materials [5]. Natural fibers are described as a better replacement to the conventional synthetic fibers like Kevlar, glass and carbon. In addition to the special physical, mechanical and chemical properties that these fibers contain depending upon the cellulosic content [6].

Fiber–matrix interface properties are essential in the mechanical properties. Chemical treatments can be used to enhance this interface, to be noted that the efficiency of fibers varies depending on material and the method used [7]. Generally, fibers physical characterized by their physical and chemical building, such as cellulose content, fabric structure, cross section and angle of textile, and degree of the polymerization [8].

In view of finding alternative reinforcements, that are eco-friendly and can provide the similar performances as synthetic matching part, researchers' interest has focused on the use of natural fibers as reinforcement in different matrices, because of their low cost, low density, renewability, and biodegradability, non-abrasive nature, low energy consumption and using it as good insulator of heat and sound. Main industries such as construction, automotive and packaging have shown vast difference attention in the progress of new bio-composite resources and are now engaged in searching for new and alternate products to artificial fiber strengthened composites. Unsaturated polyesters are extremely versatile in properties and applications [9].

Properties like the thermal conductivity of the palm fiber reinforced polyester composites at different volume fractions were investigated. They found experimentally that the thermal conductivity of the composite increases with increasing fiber fraction [10]. Also, in different studies palm fiber collected from many trees of various age groups and prepared for three various weight fractions (5%, 10% and 20%). Then the mechanical and physical properties were investigated [10].

The effect of using both rice husks and date palm fibers as a reinforced on the sound and thermal properties of composite were studied. It was present that the properties of thermal and acoustic increased with the increase of Vf of used fibers. Yet, a slight decrease noticed with fiber length increased. The polyester composite reinforced by rice husk show a better thermal insulator. The composite reinforced with date palm fibers present best acoustic insulation [11].

Also, the thermal and acoustic isolation properties behavior of unsaturated polyester (UPE) composite reinforced with a filler of palm wastes (date seed, old leaf bases and petiole) with different weight fraction, it was found that the prepared composite reinforced with petiole filler and palm waste have good thermal insulation properties and sound absorption rather than pure unsaturated polyester material [12]. It also preparing of composite material by reinforcing the polyester resin with frond palm with different volume fractions (0%, 15%, 20%) and studied tensile strength, Impact test , and Thermal conductivity. They founded that the addition of fibers decreases, tensile, flexural strength, Young's modulus and impact strength but increases thermal conductivity [13].

Reinforcement of polymers plays an essential role in the enhancement of the mechanical and physical properties of high performance materials. Hence, the mechanical and physical behavior of polyester composites was studied in order to improve an engineering material for industrial application such as car seat, dash board, gear cams, and for interior parts of automobile. So, for these purposes is to manufacture laminates composite samples made of date palm fibers (DPF) with unsaturated polyesters resin as a matrix and also to evaluate the mechanical (compression, flexural and impact strength) and physical properties (thermal conductivity, Dielectric constant and dielectric strength) of the manufactured composites.

2. MATERIALS AND METHODES

I. Materials

The date palm tree a member of the palm tree family (phoenix Dactylifera), is normally found in our country (Iraq), India, Pakistan, Northern Africa, the Canary Islands and California. Iraq has more than 16 million date palms. It produces approximately 630,000 tons of date palm residues per year [14].

The stem of these palm trees is shielded with a mesh made of unique fibers, which consisted of a natural woven mat with specific crossed fibers of different diameters as in Figure1. Conventionally, these mat usually used to make ropes and baskets in many parts of the world after being removed from the trees and manually cleaned. The chemical components of the mentioned woven mat are given in Table1. Unsaturated polyester(UPE) is thermo set polymer used as transparence liquid which transforms into a solid state after adding the hardener to it in a weighting percentage of (100:2), according to standard specificities of manufacturing company at standard mixing time and temperature (15 min, 30 Cº) in order to achieve homogenous solution. Solidification is done with cobalt octate as accelerator and with either MEKP alone or with MEKP mixed with t-butylperbenzoate. UPE density is (1.15 g/cm3).

Figure 1: Date palm textile.

TABLE I: Chemical composition of DPF [16]

Cellulose Wt. (%)	*Lignin Wt(%)*	*Hemicelluloses Wt. (%)*	*Moisture content Wt.(%)*
46	*20*	*28*	*5-6*

II. Preparation of the composites

At the beginning, (DPF) experienced alkali treatment. The fibers are submerged in water contain 6% NaOH solution for about 3 hours, and then the fibers are dried in oven at 60ºC for 2 hours [5]. (DPF) were left for one day to dry at room temperature before used it, the treatment was apply to increase the adhesion between matrix and textile. To improve the properties of unsaturated polyester (UPE) resins, they reinforced by date palm fibers (DPF) with diameter (0.5-0.7mm) by Hand lay-up technique. All the samples of composites were prepared with volume fraction Vf(10, 20 and 30).A glass mold having dimensions of (16*10*0.7 cm) were used for this purpose. Fablone sheet was used to facilitate easy removal of the composite from the mold. After solidification, the casting sheet was released from the mold and placed in an oven at (55 Cº temperature) for (3 hour) to post cure the considered sheets. The testing samples were obtained by cutting the casted sheet. All the properties were measured at temperature of (26-30ºC).

III. Mechanical tests

1. Compressive and flexural strength test

This test was carried out using a hydraulic piston compressive device, it is ley Bold Harris, No. 36110. Compression strength (C.S) is the value determined for the prepared specimens which represent the maximum stress that the material possesses before the failure; in another way it is the maximum stress for a rigid material under longitudinal compression. The prepared specimens must cut according to (ASTM-D695) standard and can be evaluated mathematically as:

$$C.S. = Maximum\ Stress\ (\partial) = \frac{Fmax}{A} \qquad (1)$$

Where (Fmax) represent the maximum force (N) until the failure point of the sample. (A) is the cross section area (mm2) and to evaluate the Young's Modulus(E):

$$(E)=stress/Strain \qquad (2)$$

Where strain $(\varepsilon) = \frac{\Delta L}{L}$ (3)

ΔL is the elongation of the sample; L is the original length for the sample (mm).

Flexural strength *(F.S) = 3 F.L/ 2 b h*^{2} (4)

Where F is the load necessary to produce fracture in the bending test, L is the distance between supports, b is the width of beam sample, and h is the sample height.

2. Impact strength test

The Charpy impact test is used. This test evaluates the amount of energy absorbed by a material during fracture, which refers to the material 's toughness. The impact strength test for samples was obtained by using Charpy impact device (Testing Machines INC. AMITYVILLE, New York). Pendulum of energy (5 Joul) was used in this test. The tested specimens cut according to ISO-179 standard; the impact strength (I.S) is evaluated from the following equation [16]:

$$(I.S) = \frac{Energy\ of\ fracture\ \ (K\ Joul)}{Cross\text{-}sectional\ area\ (m2)} \quad (5)$$

IV. Physical tests:

1. Thermal conductivity

Thermal conductivity of the specimens under test is calculated by Lee's disc device. The heat (e) (W/ m2.K) that flows through across sectional area of the sample per unit time is calculated from the following equation [17]:-

$$IV = \pi r^2 e \cdot (T_A + T_B) + 2\pi r e \cdot \left[d_A \cdot T_A + d_S \frac{1}{2}(T_A + T_B) + d_B \cdot T_B + d_C \cdot T_C \right] \quad (6)$$

Where I is the applied current value through the electrical circuit.V is the provided voltage; r is disc radius of (2cm).

TA, TB and TC are the temperature of the brass discs A, B and C, respectively.

dA, dB and dC are the thickness of the mention discs A, B and C, respectively.

dS is the thickness of the sample. The values of thermal conductivity K (W/m. K) are determined by applying the equation [17]:-

$$K\left[\frac{T_B - T_A}{d_S}\right] = e\left[T_A + \frac{2}{r}\left(d_A + \frac{1}{4}d_S\right)T_A + \frac{1}{2r}d_S T_B\right] (7)$$

2. Dielectric Constant

The value that can be measured in this test is relative static permittivity (εr) for static electric fields as follows: first the capacitance of a test capacitor (Co) is calculated with air space between its plates. After that, the same capacitor used and distance between its plates, the capacitance C with composite sample is calculated [18]. Then the relative permittivity can be measured by equation;

$$\varepsilon r = C/Co \quad (8)$$

3. Dielectric strength

This test used to find out the ability of the resistance of the electric current without breakdown, and the electrical breakdown means that the material loss the insulation property. The dielectric strength measurement was carried out by using a breakdown test cell BAUR (0-60) KV provided with the appropriate electrodes. The breakdown tests done in a medium of transformer lubricant. The dielectric breakdown voltage was evaluated at several points for testing samples. The test was carried out at temperature (30°C).The dielectric strength was obtained from the following equation [19]:

$$E = V/\,t \quad (9)$$

Where E is the Dielectric strength, V and t are breakdown voltage (KV) and specimen thickness (mm), respectively

3. RESULT AND DISCUSSION

I. Compressive and flexural strength results

From Figures 2, 3 and 4 and Table2 can be notice that the ultimate compression strength UCS and young's modulus increased for (10% and 20%Vf)DPF/UPE composites, this could be explaining due to the presence of these fibers which become as an obstacle or barrier for rapid failure [20]. Also, the reason of such behavior is the high interfacial shear strength between the polyester matrix and fibers because of the formation of cross-links bonding which shield or cover the fibers in a way that this shield prevents the propagation of the cracks inside the material, as well as the propagation of the crack can be deflect by good bonding between the UPE matrix and fibers [21]. These additions of fibers work on increasing the stiffness of the prepared composite by restricting the matrix chain mobility, while 30% Vf DPF/UPE composite decrease, this may belong to presence manufacturing defects that lead to stress concentration in composites and weak interface adhesion between the fiber and resin. The flexural strength result is shown in Figure 5 and Table2. In flexural test various mechanisms such as compression, tension, and shearing take places simultaneously [22]. It is noticed that the flexural strength increased as the date palm fibers volume fraction increase, this could be explained according to good compatibility between polymer used and fiber.

This strong compatibilizer presence between (DPF) and UPE had a very essential influence on increasing of flexural strengths value for new composites [23].At 30% Vf, The flexural strength decreases as the fiber loading increasing. However, in general the higher volume fraction of fiber decreases the flexural strength compared with smaller volume fraction, they found the significant decrease in the flexural strength is observed at the highest fiber volume fraction which is due to the increased fiber to-fiber interactions and dispersion problem which results in low mechanical properties of composites [24].The samples after applied flexural strength test showed in Figure10.

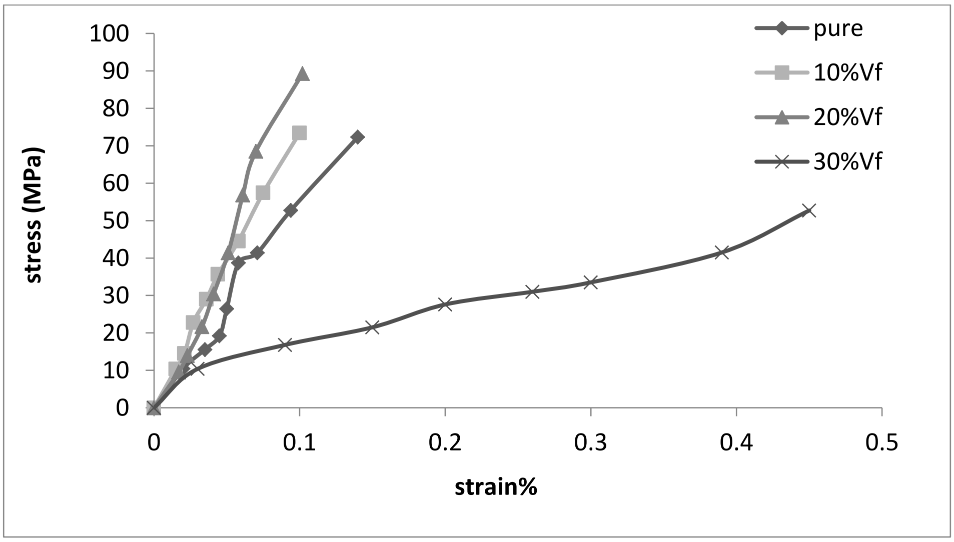

Figure 2: Compression (stress –strain) curves for UPE, 10%, 20%and 30% V_f (DPF/UPE) composites.

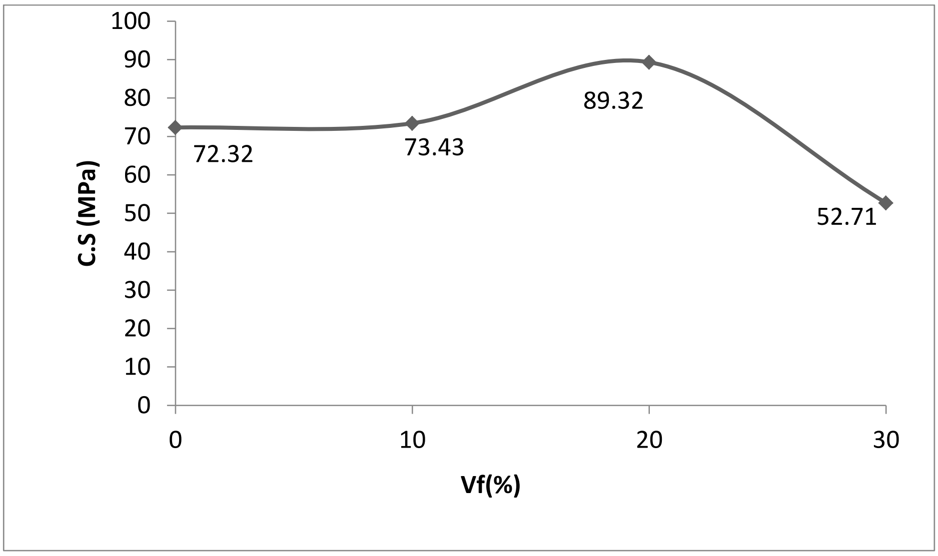

Figure 3: Compression strength for UPE, 10%, 20%and 30% V_f (DPF/UPE) composites.

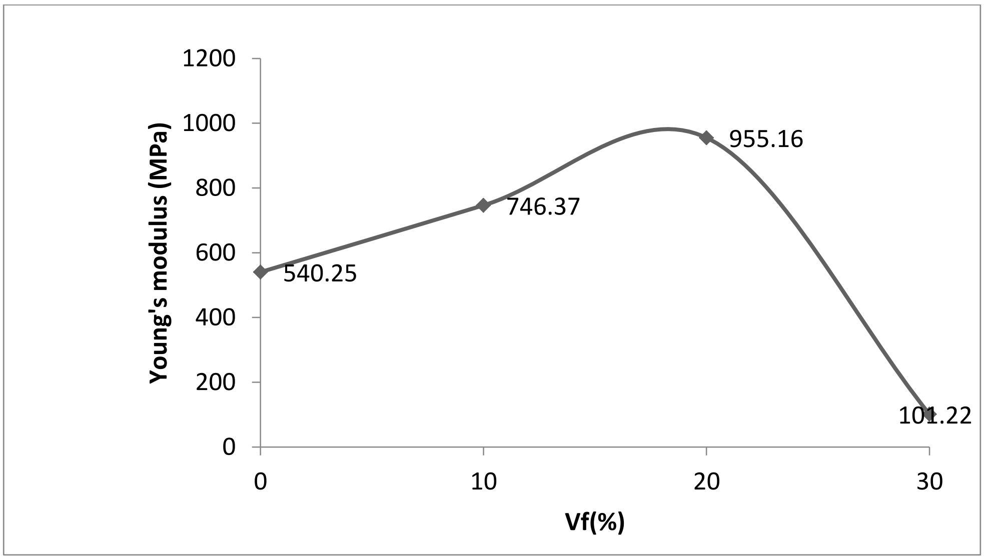

Figure 4: Young's modulus for UPE, 10%, 20%and 30% V_f %(DPF/UPE) composites.

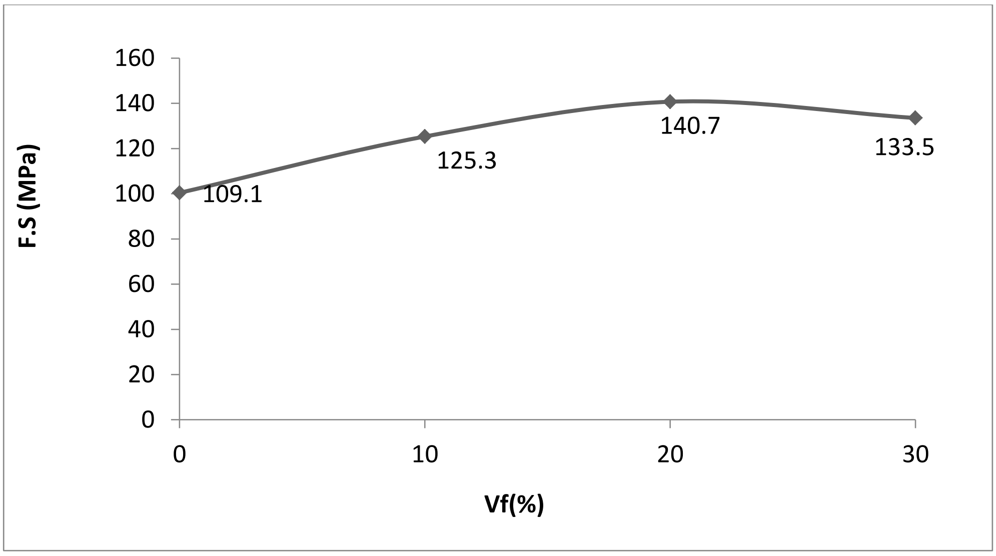

Figure 5: Flexural strength value for UPE, 10%, 20%and 30% Vf (DPF/UPE) composites.

II-Impact strength result

Impact characteristics were influenced by the initiation of cracks and the mechanism of spread cracks between the fiber and the matrix polymer.Figure6 and Table 2 showed that the impact strength decreases as the volume fraction of date palm fibers increases, which is related to decrease of matrix elasticity due to (DPF) addition and so decreasing the distortions of polyester resin. The increase in fiber concentration inside the composite decreases the capability to absorb energy and this lead to reduce in value of toughness for composite materials samples; therefore, impact strength decreases [25]. On the other hand, the impact strength results for the composite with (30%) Vf of DPF increases, this could be belongs to the increase in the fibers layers that increase the composite ability for energy absorption. The samples after impact test illustrated in Figure10.

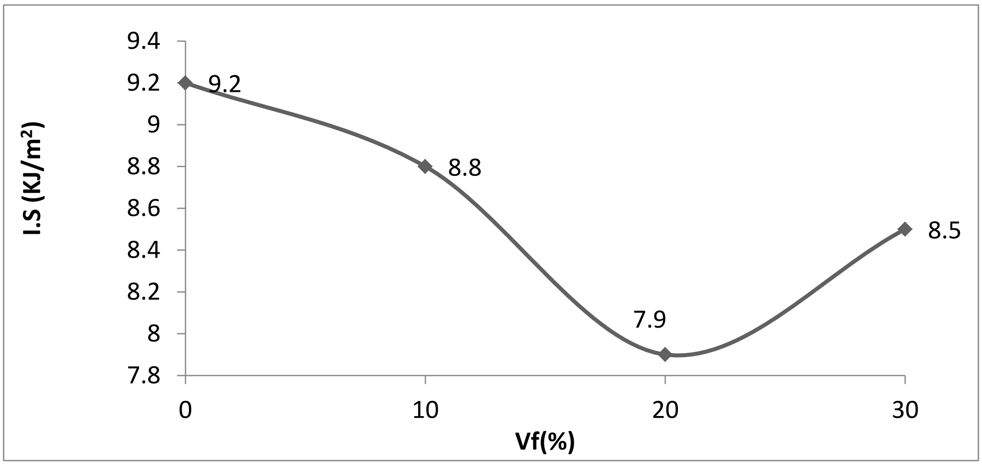

Figure 6: Impact strength value for UPE, 10%, 20%and 30% V_f (DPF/UPE) composites.

III. Thermal conductivity result

The conductivity of a composite is affected by the interface adhesion between fibers and matrices, since the conductivity may be reduced by the occurrence of some holes or cracks in the surface interface between the fiber and matrix. Moreover the moisture content of natural fibers. The results obtained in Figure 7 and Table 3 indicating of increase thermal conductivity behavior. The maximum value at 20%Vf (DPF/UPE) composite while decreased at 30%Vfthis belong to increases the moisture content of natural fibers and weak adhesion between the resin and fiber. In general, the thermal conductivity of fiber reinforced composites depends on the type of fiber, its direction and distribution within the base material. Therefore, heat transfer occurs during the layer of resin and fiber and the interface between them [26].

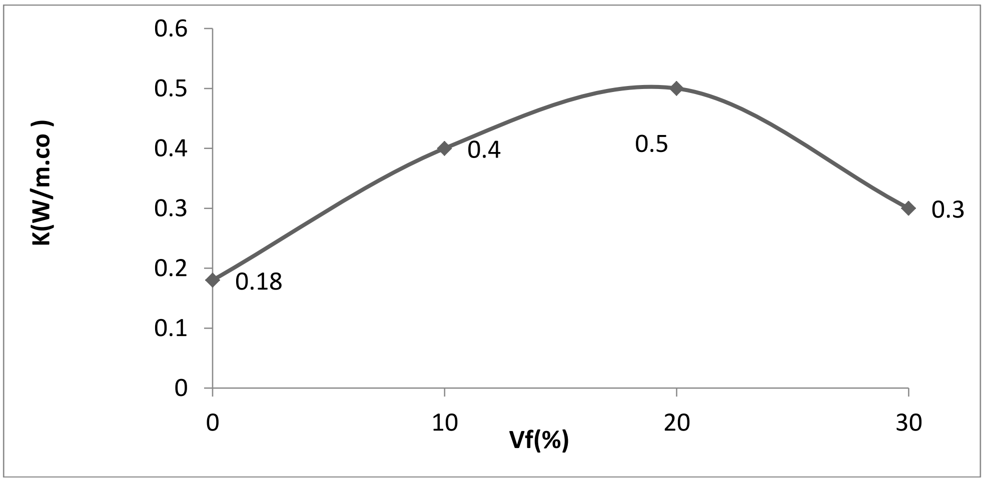

Figure 7: Thermal conductivity value for UPE, 10%, 20%and 30% Vf (DPF/UPE) composites.

IV-Dielectric Constant result

The dielectric constant of a material depends upon the polarizability of the fibrils. Figure 8 and Table3 shows increasing of dielectric constant values with increasing volume faction for date palm fiber unless at 30% Vf is decreased. The presence of natural fillers in polyester leads to presence of polar groups which give rise to dipole or orientation polarizability, and hence an increase in dielectric constant as compared with virgin value [27].The lower value for 30%Vf belong to low adhesion forces between the matrix and the fibers that also appeared in mechanical characters.

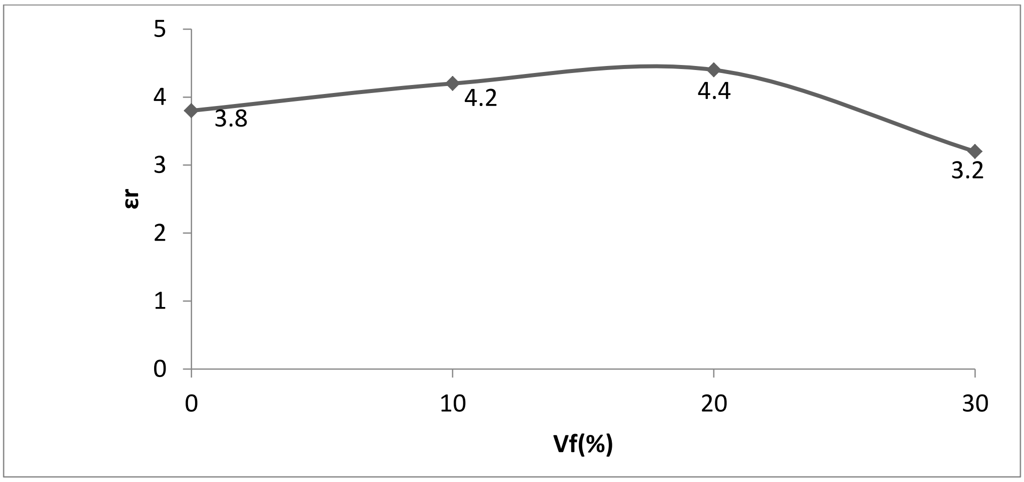

Figure 8: Dielectric constant value for UPE, 10%, 20%and 30% V_f (DPF/UPE) composites.

V. Dielectric strength result

Many factors affect the property of dielectric strength such as ambient temperature, humidity, duration of test and impurities or structural defects. The effect of filler content on composites dielectric strength is shown in Figure 9 and Table 3.It is noticed that this property value of the prepared composites is lower than that of virgin polyester. This is due to the existence of polar groups and that led to facilitate the current flow and consequently lower breakdown voltage [27]. Except of the composite reinforced with 30%Vf PDF showed slightly down because of an increase in moisture content of fiber and the presence of industrial defects. The samples that applied in thermal and electrical tests showed in Figure10.

TABLE II: Results of mechanical properties

sample	Young's modulus(MPa)	Compression Strength(MPa)	Flexural Strength(MPa)	Impact Strength (Joul/mm2)
UPE Pure	540.25	72.32	40.5	**9.2**
10%Vf DPF/UPE	746.37	73.43	55	**8.8**
20%Vf DPF/UPE	955.16	89.32	60.5	**7.9**
30%Vf DPF/UPE	101.22	52.71	60	**8.5**

TABLE III: Results of physical properties

sample	Thermal Conductivity (W/m.C ^{o})	Dielectric constant	Dielectric strength(KV/mm)
UPE Pure	0.4	3.8	**33.7**
10%Vf DPF/UPE	0.7	4.2	**33.4**
20%Vf DPF/UPE	0.8	4.4	**32.6**
30%Vf DPF/UPE	0.5	3.2	**33.5**

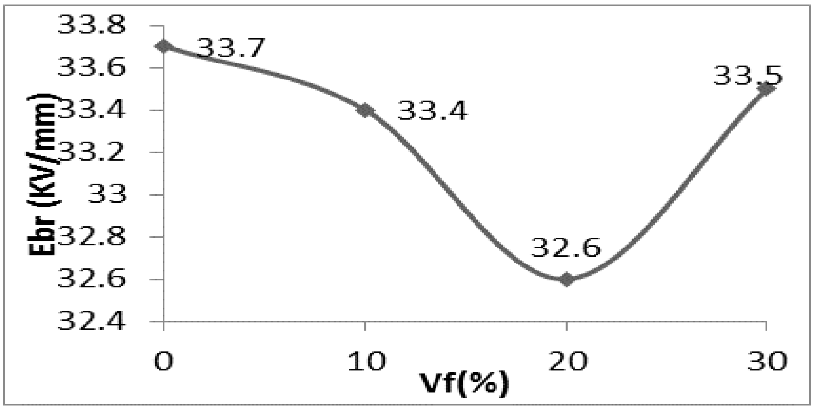

Figure. 9 Dielectric strength value for UPE, 10%, 20%and 30% V_f (DPF/UPE) composites.

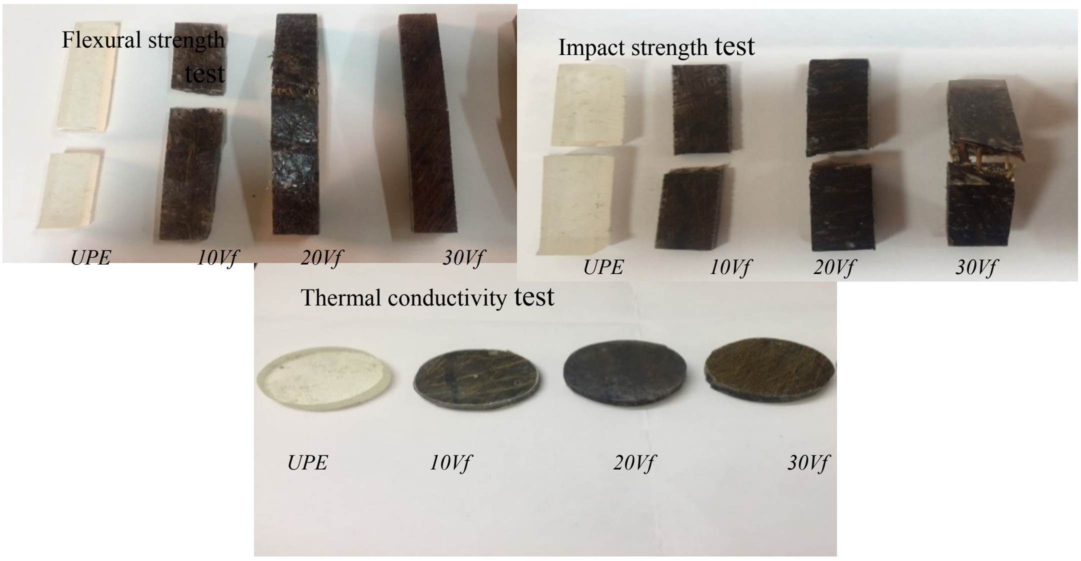

Figure 10: photos for samples after testing

4. CONCLUSION

Composite of date palm fiber based on polyester resin matrix was introduced with three volume fraction (10%, 20%and30%). Mechanical and physical properties Investigated. It is found that:

1-An increase in young's modulus, compression and flexural strength, especially at reinforcement volume fraction 20% while showed decreasing at 30% Vf, but impact strength took the opposite behavior.
2-Thermal conductivity result indicated of insulator composite behaves. The effect of present filler polar group induces of decreasing in dielectric strength and increasing dielectric constant.
3-The supported composite 20% Vf showed the best results in mechanical, thermal and electrical properties.

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