STUDYING SOME OF THE MECHANICAL PROPERTIES OF UNSATURATED POLYESTER REINFORCED BY RE-CYCLED NATURAL MATERIALS

Shaimaa Hilal Kamel
Assist. Lecturer
Mechanical Engineering Department, University of Technology
s.h_eng@yahoo.com
Received 15 February 2015 Accepted 6 May 2015

ABSTRACT

Reinforcement of unsaturated polyester by particulates plays is an important role in the improvement of the mechanical properties of high performance materials. Hence, the mechanical behavior of recycled (grapes and dates) particulate polyester composites was studied in order to develop an engineering material for industrial applications. Different percentages (0, 1.5, 3.5 and 5) % of the reinforcement Particles were added to unsaturated polyester resin. Numbers of mechanical tests were included (thermal conductivity test, hardness test, Dielectric testing, tensile test, impact test). The results showed that the hardness and dielectric constant of filled unsaturated polyester increase with the increment of the percentage of grapes and dates particles, while impact resistance decreases. On the other hand the thermal conductivity increase at (1.5%) of percentages and decreases of (3.5%, 5%) of grapes particles while the value of thermal conductivity decrease by (1.5%) and increased when increasing (3.5 %, 5%) of the dates particle. The tensile strength improves of grapes reinforcing particles and increase with an increase in the particle percentage of grapes and the value of tensile strength increases with the dates particle content (1.5%). Also that the percentage of (3.5 %) represents the greatest value for the modulus of elasticity for unsaturated polyester reinforced with dates particle and the percentage of (5 %) represents the greatest value for the modulus of elasticity for unsaturated polyester reinforced with grapes particle.

Keywords: Mechanical properties, unsaturated Polyester, Grapes particle, Dates particle, Composite materials.

دراسة بعض الخواص الميكانيكية للبولي أستر الغير مشبع المدعم بمخلفات المواد الطبيعية

الخلاصة

الدقائق المدعمة للبولي استر الغير المشبع تلعب دوراً هاما في تحسين الخواص الميكانيكية لاداء عالي للمواد. وعلى هذا الاساس تم دراسة السلوك الميكانيكي لدقائق نوى العنب والتمر من أجل تطوير المادة الهندسية لتطبيقها في الصناعة تم اضافة نسب من الدقائق (0%,1.5%,3.5%,5%) المدعمة لراتنج البولي استر الغير المشبع وقد اجريت مجموعة من الاختبارات الميكانيكية عند درجة حرارة الغرفة شملت (اختبار التوصيل الحراري , اختبار الصلادة, اختبار العزل الكهربائي,اختبار الشد,اختبار الصدمة) وقد أظهرت نتائج البحث ان الصلادة وثابت العزل الكهربائي تزداد بزيادة النسب المضافة من العنب والتمر كما ان مقاومة الصدمة تقل بزيادة النسب المضافة من العنب والتمر. حيث لوحظ ان قيمة التوصيل الحراري تزداد عند نسبة (1.5%) وتقل القيمة

عند نسب (3.5%,5%) لدقائق العنب بينما قيم التوصيل الحراري تقل عند نسبة (1.5%) وتزداد عند زيادة النسب (3.5%,5%) لدقائق التمر. مقاومة الشد لدقائق العنب المدعمة للبولي استر الغير المشبع تتحسن وتزداد مع زيادة النسب المضافة من دقائق العنب .وقيم مقاومة الشد تزداد عند نسبة (1.5%) من دقائق التمر. كذلك قيمة معامل المرونة يكون اعظم قيمة له عند نسبة (3.5%) لدقائق التمر المدعمة للبولي استر الغير المشبع واعظم قيمة لمعامل المرونة لدقائق العنب المدعمة للبولي استر الغير المشبع عند نسبة (5%).

الكلمات المرشدة: الخواص الميكانيكية, البولي أستر الغير مشبع, دقائق العنب, دقائق التمر, المواد المركبة.

1- Introduction

The use of polymer matrix composite has found a wide application in our modern day world. This is as a result of the combination of properties which these materials possess. Some of the properties of polymer matrix composites include specific strength, high modulus, good fracture and fatigue properties as well as corrosion resistance [1].

From time immemorial, man has always strived to make use of available materials at his disposal to better the lots of the people around him and the society in general. These efforts had led to various research works being carried out for decades by trying to find alternatives and/or substitutes for some materials that appear to have outlived their existence. Studies on composites have shown that new materials have been discovered such as metal matrix composites, ceramic matrix composites and polymeric composites which were all found to be capable replacements in the many industrial applications, when compared to old used materials. There have been little developments in the use of natural fiber or particulates as reinforcement materials for polymeric composite. Though findings have shown that natural fillers reinforced polymeric materials provide materials engineers with a new group of materials that offer exceptional combinations of mechanical properties that make them equivalent to steel applications. There needs to make use of available materials/resources to produce composites with an unusual combination of properties that no traditional materials like ceramics, polymeric materials or alloys possess. It is the applications of these materials used in the industries that are the driving force behind the discovery of new materials which have led to the designing of materials for specific applications often called composites .

Generally, composite are produced when two or more materials are joined together to give a combination of properties that cannot be attained otherwise according to the principle of combined action, better property combinations are fashioned by the judicious combination of two or more distinct materials [2].

Natural filler-reinforced polymers provide increases in the degradability capability of the resulting product [3]. Fibers like oil palm empty fruit bunch, Kola nitida wood fiber, as well as several fillers such as rice husk have been used as reinforcing agents of different thermoplastic and thermosetting plastic resins [4,5]. There is an overwhelming interest in filler and natural fiber reinforced polymers owing to their ease of processing and low cost as some of these fillers are regarded as waste. In the development of polyester/eggshell particulate composites, the density and hardness values of the polyester/eggshell particulate composites increased steadily with the increasing eggshell addition, compressive strength, flexural strength and impact energy increased [6].

The effect of untreated and treated coconut shell reinforced unsaturated polyester composites was studied and it was observed that the mechanical and thermal properties of unsaturated polyester/coconut shell composites were enhanced [7].

In recent years, many studies have been dedicated for utilizing cellulose fillers such as coconut shell, wood, pineapple leaf, palm kernel shell, etc. as fillers in order to replace the synthetic fillers through utilization of natural fillers or reinforcement in thermoplastic and thermoset polymer composites in an attempt to minimize the cost, increase productivity and enhance the mechanical properties of the product [8].

Investigated the cure characteristics and the physico-mechanical properties of natural rubber, standard Nigerian rubber, SNR10 filled with cherry seed shell (CSS) and standard carbon black CB (N330) was determined. The tensile strength of both CSS and CB-filled vulcanizates increased to a maximum at 40 phr filler content before declining. The module (M100 and M300 ,specific gravity (S.G), hardness and abrasion resistance increased while the elongation at break and Dunlop resilience decreased with increasing the filler content for both vulcanizates [8].
The aim of this research is to studying some of the mechanical properties of unsaturated polyester reinforced by some local residual materials such as grapes and dates particles.

2- Experimental Procedure

2.1. Materials

2.1.1. Matrix Polymer

Unsaturated polyester produced by (SIR) is used. Unsaturated polyester is in the form of a transparent viscous liquid at room temperature and is one of the types of polymers solidified thermally (Thermosets) it turn into solid state when adding Hardener (Methyl Ethyl Keton Peroxide) MEKP is on the transparent liquid is added by the form (2g) to (100g) of unsaturated polyester resin at room temp. (Percentage of styrene 32, viscosity at 25 ºC is 1000 cups, Appearance Transparent, pH solid basis 22, specific gravity 1.15). Upon completion of the addition Hardener and catalyst to the resin mix, mixing process immediately begin mediated manual mixing for 8-10 minutes until the harmonious mixture and when exceeding this time period becomes a viscous mixture is very high as well as the temperature rises, leading to accelerating the hardening process and this hinders the casting process as well as for the final product to contain a high air bubbles. Aster features unsaturated polyester resin, mechanical properties and good scalability good correlation with various other materials, electrical insulation and good thermal and surface quality after sclerosis. On sclerosis for the user of the resin must be not less than 3 hours at room temperature. In order to complete the cross-linking process and reduce the proportion of contractions the resin is ready for a final examination.

2.1.2. Reinforcing Particle

Two types of particles were used in this research. These types were Grape and dates powder. The particles were collected and crashed by using an electrical mill. The particulates were received by vibratory sieve shaker to get a suitable size. The grain size in this research was (100 µm). The seed particle was used (0,1.5, 3.5 and 5) %. The samples were prepared by mixing unsaturated polyester with grape and dates powder using different particle contents. The two particle powder was supplementary to polyester and hardener and then they were homogeneously mixed at room temperature. The composite was cast into the mold according to the test and left 48hr to complete.

2-2- Mechanical Tests

2-2-1 Thermal conductivity Test

This test was carried out in accordance with Lee`s disk which manufactured by (Griffin and George Company England) The thermal conductivity (K) calculated from the number of equation (2) and determine the quantity of heat that flows through the cross sectional area of the sample per unit time (e) from the number of equation (1) [14].

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

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

Where
I = Current in (Ampere).
V=Applied Voltage in (volt).
r=Radius of Disk in (mm).
e= Represents the Quantity of Heat that Flows Through the Cross Sectional Area of the Sample per Unit Time ($W/m^2.^oC$).
T_A, T_B, T_C= Temperatures of the Disks A, B, C (^oC).
d_A, d_B, d_C=Thickness of the Disc A, B, C (mm).
d_S=Thickness of the Sample (mm).
K=Thermal Conductivity (watt/m. ^oC).

2-2-2 Impact test

Samples were prepared for impact standard dimensions (4*10*80) mm and without notches According to the Global Positioning System (ISO - 179) using Charpy Impact device to test the impact. The device depends on the energy required to break Account Sample hammer device that strikes the sample at room temperature.
The impact strength is calculated by applying the equation (3):

$$Gc = Uc / A \quad (3)$$

Where
Gc is the Impact Strength (J/m^2),
Uc is the Fracture Energy (joule), which is Determined from Charpy Impact Test Instrument
A: the Cross Section Area (mm).

2-2-3 Hardness test

The concept of hardness can be considered by measuring the plastic deformation the material suffered under the influence of external stress. Using Shore device (D) (Shore D No.DW53505) hardness test and private measuring the hardness of polymeric materials was conducted in a manner stitches tool penetration and bitmap tool stitches inside surface article under a certain load, where the resistance moves straight to the counter measurement to determine the value of hardness to read directly from the screen of the device. This method successfully, the sample surface must be very flat and diameter is greater than (30 mm) and a thickness of more than (3 mm).

2-2-4 Tensile Test

This test was used determine the properties of composite materials under the influence of axial load (pulling in one direction) by (Tensile test H50KT (TINIUS OLSEN)) Testing Machine, England (UK). In all tests, the rate of loading this property (50KN) operating at a crosshead speed of 10 mm/min was used for the tensile testing of the samples. The tensile test was performed on flat specimens. The tensile test specimen preparation and testing procedures were conducted in accordance with the American Society of Testing and Materials (ASTM D412).

2-2-5 Modulus of Elasticity

Elastic modulus test from stress- strain curves (tensile test). Load – elongation curves were obtained for eight the samples and the slope of these curves, the modulus of elasticity can be calculated.

2-2-6 Dielectric Test

According to ASTM- D150 the instrument used was Leybold – Heraeus (Germany) which represents an electrical circuit (in series connection) consisting of a capacitor, resistor, ammeter, coil, and frequency generator. The sample with dimensions (40) mm diameter and 5mm thickness is placed between the capacitor plates followed by alternating the frequency of the power supply till reaches the maximum current value which represents the resonance frequency value (*fr*). After that, the (Fr) was determined by the existence of air only, i.e, without the presence of the sample.
Dielectric constant (εr) was calculated from equation (4):

$$\varepsilon_r = \frac{\varepsilon}{\varepsilon_o} \qquad (4)$$

Where
ε and ε_0 are the Permittivity of the Medium and the Free Space Permittivity (8.8 x 10^{-12} F m^{-1}), Respectively.

3- Result and discussion

3-1 Thermal conductivity

Figure (1) shows the relationship between the value of thermal conductivity with percentages on addition particles (grapes and dates). It was noticed that the thermal conductivity increase at 1.5% and then it decreases at other percentages of (3.5%, 5%) for grapes particle. On other hand, the thermal conductivity decreases when the percentage of the dates particle is 1.5% while it increase for the percentage (3.5 %, 5%). Because of the thermal conductivity of composite is made of two phases one for the reinforcement material while the other for matrix (unsaturated polyester) for each phase different thermal conductivity from the other. Reinforcement material has a crystalline structure in which the atoms organize according to a three-dimensional network. thermal conductivity of reinforce phase is less than thermal conductivity of polymer materials due to random arrangement and this reduces the probability of dispersion of photons or configure complex constructs leading to emergence gaps that work. The results have good agreement with result obtained by [9].

3-2 Impact Testing

Figure (2) illustrates the effect of the grapes and dates particles percentage to resist impact composite materials with a basis of unsaturated polyester reinforced of particle where notes that the value of impact resistance decreases with increasing of the particles percentage grapes and dates because of the particles of the ability of resistance to impact recipe fragility compared with materials basically as well as the impact resistance to particles of grapes and dates of less impact resistance of unsaturated polyester as there results good agreement with result obtained by [10,11,12]

3-3 Hardness Testing

Figure (3) shows the effect of the particles percentage added in hardness. Test it shows that the hardness of unsaturated polyester increasingly adding grapes and dates of particles and continue hardness increase with the increase in the percentage, and the concept of hardness can be counted a measure of the plastic deformation of the material can suffer when under the influence external stress and so the addition of particles raise the hardness of material due to increased resistance to deform plastically. Where composite materials possessed the highest value at the percentage (3.5%) a (86.25 Shore) of particular dates as their results good agreement with results obtained by [10,13].

3-4 Tensile Strength

From **Figure (4)**, it can be seen that the grapes reinforcing particles improves the tensile strength and it increase with the increment in the particles percentage of grapes and the value of tensile strength increases with the dates particle content 1.5%, due to the power of high linkage between the matrix material and reinforcement material, which leads to reducing the slip during the tension and decrease with the increase of dates particle percentage due to the bonding force between the matrix (unsaturated polyester) and polymer molecules prohibited the movement of the polymer chain and reduced chain slippage. On the other hand because of the probability for the formation of a filler network is enhanced with further increase in loading which is caused by a closer distance between aggregates in the polymer system and a better filler-filler interaction as their results good agreement with results obtained by [14,15].

3-5 Modulus of elasticity

Figure (5) shows the relationship between the modulus of elasticity and the percentages of the grapes and dates particles which were added to unsaturated polyester.The amount of these particles plays an important role by impeding increasing by the slipping of polyester resin chains [14]. Knowing that, the chains require high stress to bend them in the narrow space between the particles. So, the percentage of (3.5 %) represents the greatest value for the modulus of elasticity for unsaturated polyester reinforced with dates particle and the percentage of (5 %) represents the greatest value for the modulus of elasticity for unsaturated polyester reinforced with grapes particle .This may be due to the strengthening mechanism and the nature of bonding adhesion of particles mentioned and causes the fraction between the particles and the matrix causes slipping among the particles in tension as there results good agreement with result obtained by [14,15].

3-6 Dielectric Testing

The effect of particle adding on unsaturated polyester is shown in **fig (6)**, when an increase percentage of particles, increasing dielectric constant because the interaction between surface particles and unsaturated polyester is poor, the polarizability is also effected on dielectric constant, if polarizability is higher the dielectric constant will be high as there results good agreement with result obtained by [16].

4- Conclusion:

From the results and discussion above, the following conclusions where observed

1- The hardness and dielectric constant of the unsaturated polyester increase with increase of addition percentage of particles (grapes and dates).
2- The impact resistance of unsaturated polyester reinforced with particles decreases with increasing of the percentage grapes and dates.
3- The value of thermal conductivity increase at (1.5%) and decreases than the value at percentages of (3.5%, 5%) of grapes particle while the value of thermal conductivity decrease by (1.5%) and increased when increases at percentages (3.5 %, 5%) of the dates particle.
4- The tensile strength improve of grapes reinforcing particle and it increase with an increase in the particle percentage of grapes and the value of tensile strength increases with the dates particle content (1.5%) and that the percentage of (3.5 %) represents the greatest value for the modulus of elasticity for unsaturated polyester reinforced with dates particle and the percentage of (5 %) represents the greatest value for the modulus of elasticity for unsaturated polyester reinforced with grapes particle.

5- References

[1] Agunsoye, J. O. ; Aigbodion, V. S. ; Talabi, S. I. and Olumuyiwa, A., "Effects of Silica Ceramic Particle Sizes on the Properties of Recycled Polyethylene Composites", Advances in Natural Science, Vol. 6, No. 3, pp. 14-22,2013.

[2] Durowaye , S. I.; Lawal , G. I.; Akande , M. A. and Durowaye ,V. O., " Mechanical Properties of Particulate Coconut Shell and Palm Fruit Polyester Composites", International Journal of Materials Engineering, 4(4), PP: 141-147, 2014.

[3] Fakhrul, T. and Islam, M.A., "Degradation behavior of natural fiber reinforced polymer matrix composites", Published by Elsevier Ltd., 5th BSME International Conference on Thermal Engineering, Procedia Engineering 56, PP: 795–800, 2013.

[4] Ahmed, A.S.; Alam, M.A.; Piee, A.;Rhman, M.R. and Hamdan, S., "Study the physical and mechanical properties of oil palm empty fruit bunch fiber reinforced polypropylene composites", Journal of energy and environment, Universiti Tenaga Nasional, 2010.

[5] Obidiegwu, M.U. and Ogbobe, O., "Mechanical and flammability properties of low density polyethylene/Kola nitida wood fibre composites", Academic Research International, Vol. 2, No. 3, May, 2012.

[6] Hassan S.B., Oghenevweta E.J. and Aigbodion V.S., "Potentials of Maize Stalk Ash as Reinforcement in Polyster Composites", Journal of Minerals & Materials Characterization & Engineering, Vol. 11, No.4, pp.445-459, 2012.

[7] Husseinsyah, S. and Mostapha, M., "The Effect of Filler Content on Properties of Coconut Shell Filled Polyester Composites", Malaysian Polymer Journal, Vol. 6, No. 1, p 87-97, 2011.

[8] OSABOHIEN, E and EGBOH, S. H. O., "Cure Characteristics and Physico-Mechanical Properties of Natural Rubber Filled with the Seed Shells of Cherry (Chrysophyllum albidum)" J. Appl. Sci. Environ. Manage. , Vol. 11 (2),PP: 43 - 48, June, 2007.

[9] أ.د.بلقيس محمد ضياء وم.فيزياوي سعد غازي أحمد وم.فيزياوي وليد خالد عبد الظاهر "دراسة خاصية التوصيل الحراري في ظروف مختلفة لمواد متراكبة دقائقية" Journal of college of education , 2011 .

[10]هناء عرير سميج "تأثير التقوية بمسحوق اوكسيد الزنك على الخواص الميكانيكية لمادة متراكبة ذات اساس من البولي أستر غير مشبع", مجلة الهندسة والتكنولوجيا ,المجلد 29, العدد 10, 2011.

[11]د.سهامة عيسى صالح ،د.كاظم مطر شبيب و قحطان عدنان حمد "دراسة الخواص الميكانيكية لمواد متراكبة ذات أساس بوليمري مقواة بالالياف والدقائق", مجلة الهندسة والتكنولوجيا ,المجلد 28, العدد 4, 2010.

[12] Nasif ,R.A., "Study the Effect of Volume Fraction of Mica with Different Particle Size on the Mechanical and Electrical Properties for Unsaturated Polyester Composites", Eng. &Tech. Journal, Vol.30, No.20, 2012.

[13]أنعام وادي وطن , "دراسة بعض الخواص الميكانيكية والحرارية للبولي أستر غير المشبع والمدعم بدقائق سيراميكية" , Diala, Jour., Volume, 37 ,2009.

[14] Oleiwi, J.K.; Othman, F.M. and Ghaze, I.F., "A Study of Mechanical Properties of Poly Methacrylate Polymer Reinforced by Silica Particles (Sio2)", Eng. &Tech. Journal, Vol.31, Part (A), No.15, 2013.

[15] Nassir, N.A.H., " Studying the Effect of Nano Carbon Black on Mechanical Properties of Uusaturated Polyester Resin", The Iraqi Journal For Mechanical And Material Engineering, Vol.13, No4, 2013.

[16] Hazz, S. Q. and Ahmed, A.M.,"Dielectric Properties of Carbon Nanotubes-Unsaturated Polyester Nanocomposites", Journal of the Faculty of education (3), 2013.

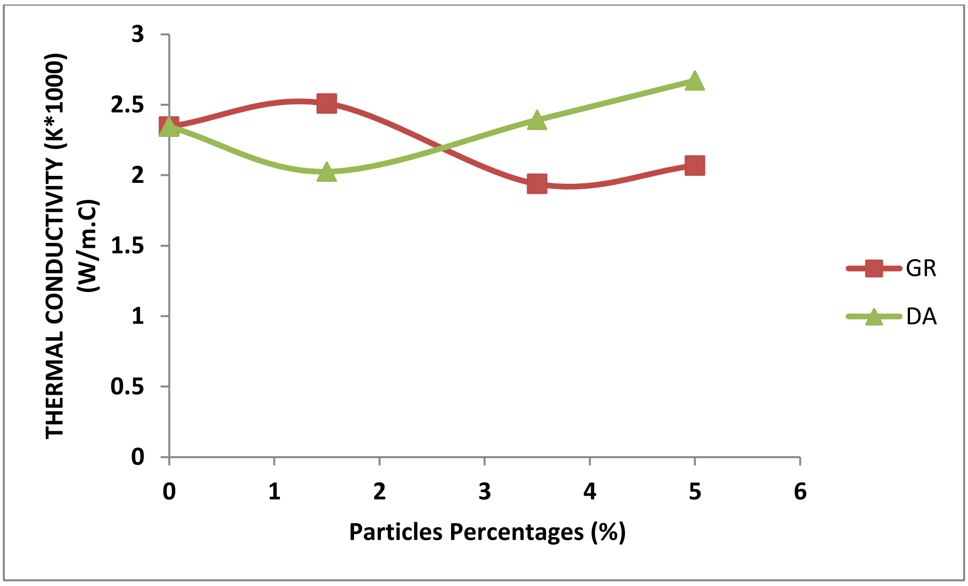

Figure (1): the relationship between the thermal conductivity of unsaturated polyester reinforced with grapes and dates particles

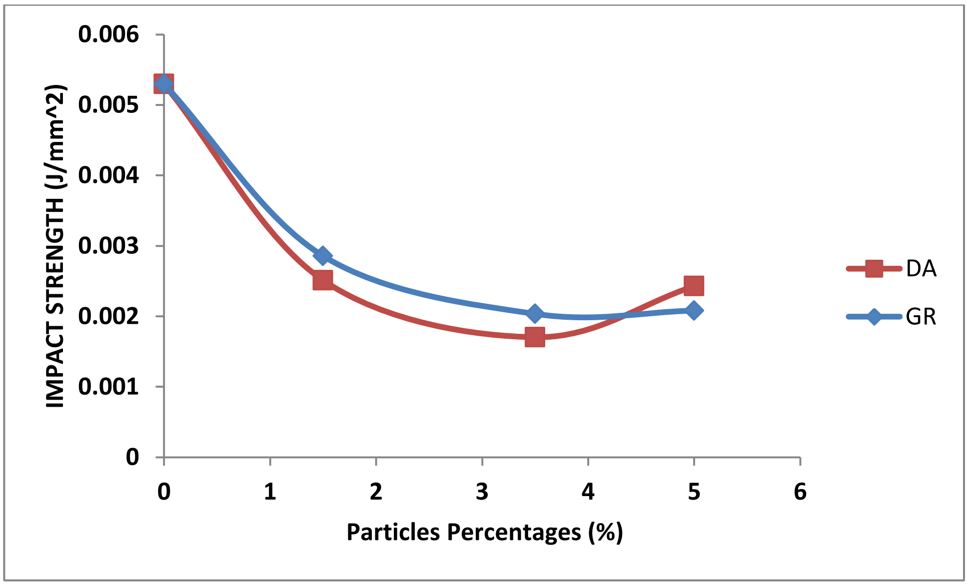

Figure (2): the relationship between the impact strength of unsaturated polyester reinforced with grapes and dates particles

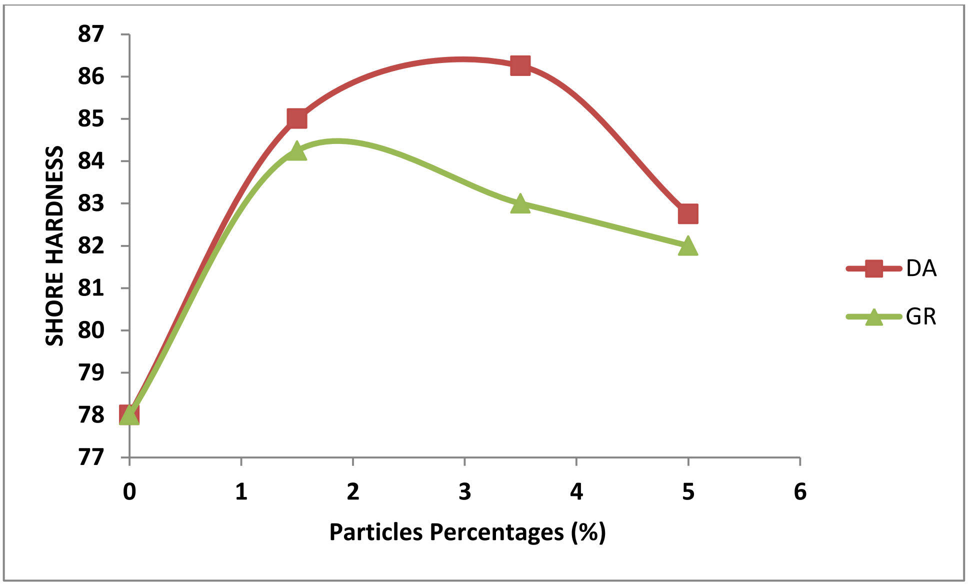

Figure (3): the relationship between the shore hardness of unsaturated polyester reinforced with grapes and dates particles

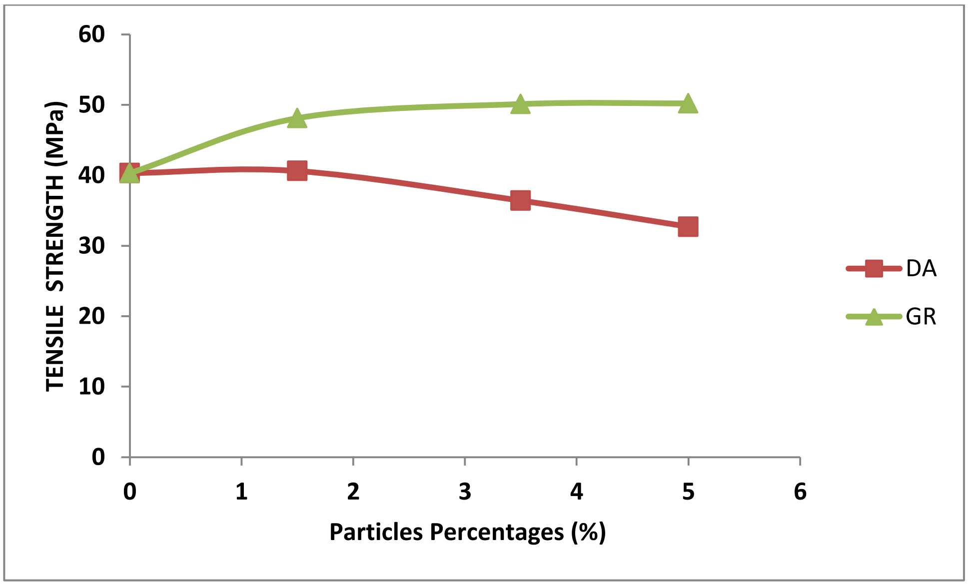

Figure (4): the relationship between the tensile strength of unsaturated polyester reinforced with grapes and dates particles

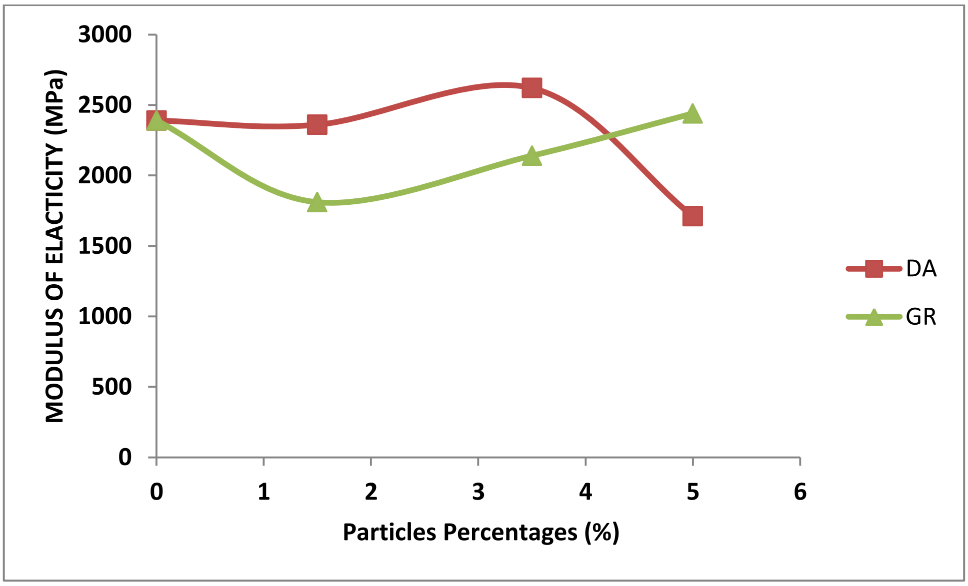

Figure (5): the relationship between modulus of elasticity of unsaturated polyester reinforced with grapes and dates particles

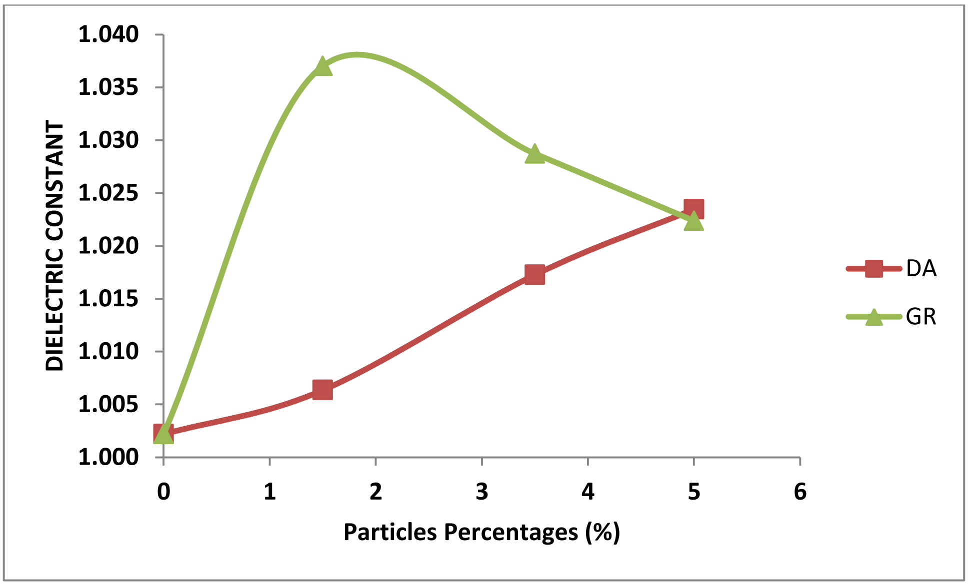

Figure (6): the relationship between dielectric constant of unsaturated polyester reinforced with grapes and dates particles