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Study the Effect of Different Percentages of Natural (Orange Peels and Date Seeds) and Industrial Materials (Carbon and Silica) on the Mechanical and Thermal Properties of Polymeric Reinforced Composites

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Abstract

Mechanical and thermal properties of composites, consisted of unsaturated polyester resin, reinforced by different kinds of natural materials (Orange peels and Date seeds) and industrial materials (carbon and silica) with particle size 98 µm were studied. Various weight ratios, 5, 10, and 15 wt. % of natural and industrial materials have been infused into polyester. Tensile, three-point bending and thermal conductivity tests were conducted for the unfilled polyester, natural and industrial composite to identify the weight ratio effect on the properties of materials. The results indicated that when the weight ratio for polyester with date seeds increased from 10% to 15%, the maximum Young's modulus decreased by 54%. When the weight ratio was 5%, the maximum Young's modulus, yield stress and ultimate tensile stress occurred in the polyester with date seeds. The results of tensile and flexural tests showed that the natural composite material has a higher strength than the industrial material. While the results of flexural tests manifested that the maximum improvement in the flexural strength is obtained for orange peels at 5 wt. %, where the maximum increasing percentage is 153.4% than pure polyester. The thermal conductivity of orange peels decreased to the half value when the weight ratio increased from 10% to 15%. The thermal conductivity for polyester with orange peels was greater than the thermal conductivity of polyester with date seeds with maximum percentage occurred at weight ratio 10% is 14.4%, but the thermal conductivity of the industrial composite material was higher than the natural composite material. Finally, the date seeds composite was a good insulator and it had a reduced heat transfer rate in comparison to the rest of the samples, also the maximum variation of temperature with time occurred in date seeds composite.

Keywords: *Natural material, polyester resin, weight ratio.*

1. Introduction

Two or more materials mixed homogenously at a microscopic scale defined as composite materials.one of its constituents is named as reinforcing phase and the other which is considered the base is named the matrix [1]. The main reason for using the natural materials in the reinforcement the composite materials is to decrease the cost and the pollution as well as these natural materials don't cause any harm to the humans. In 2012, Arumuga Prabu and etal. [2] analyzed and studied the effect of adding the rec mud into banana fiber, sisal fiber reinforced polyester. It is concluded that this addition increase the mechanical properties of the composite. In 2013, Mohammed Razzaq[3], presented and studied the mechanical properties of three composites materials i.e (sunflower-polyester), (water-melon-polyester) and (seed shells-polyester) with different mixing ratio from (5wt% to 25wt%) and made a comparative between these composites. It was concluded from the results that the young modulus and hardness increase with increased the mixing ratio. In 2014 ishaya M. Dagwa and Josiah O. Ohaeri[4], studied and investigated the mechanical and physical properties of hybrid composite materials consist of banana fiber-glass oil palm-polyester with different ratio. The results showed that the decreasing of flexural strength when the weight ratio of banana increased but increase the impact strength.

The purpose of the present work was to study the effect of adding natural material (Orange peels and Date seeds) with particle size 98 μm to polyester resin on the mechanical and thermal properties compared with composite material made from industrial material (carbon and silica) with particle size 98 μm and polyester because the natural materials are cheap and not harmful to the people. The weight ratios are (5,10, and 15 wt. %) Were studied, in experimental work, all samples were prepared manually and cutting by CNC machine. Tensile tests, flexural tests, Thermal Conductivity Test were performed to evaluate mechanical, thermal performances.

2. Experimental Work

2.1 Materials Processing

In the present work, the composite which are hand lay-up for five kinds of composite material with three mass fraction (5%, 10%, 15%). The types of composite material that uses in this work is: Pure polyester, Orange peels particle with particle size 98 μm and unsaturated polyester, Date seeds particle with particle size 98 μm and unsaturated polyester, Silica particle with particle size 98 μm and unsaturated polyester, Carbon particle with particle size 98 μm and unsaturated polyester.

To fabricate the natural composite material there are several steps. First, collecting the material (date seeds, orange peels), second drying them by furnace for 30 minute at 60°C.

Third milled those by electrical mill machine, fourth the set of sieves were employed to get on date seeds and orange peels powder by the suitable size 98μm. Finally, drying the powder of natural material for 30 minute at 60°C.The artificial material (silica and carbon particle) sieve to get the suitable particle size 98μm.

Rectangular flat panels were fabricated this materials using (290mm * 230 mm) glass open mold with four strip glass to be borders and adhesive by silicon. To avoid stick sheet paper put it on the glass plate

The polyester (which has 1.05 g/cm^3 as density) is mixed with hardener together (hardener weight 0.02from polyester weight) and adding polyester.

The weight of each particle and resin depends on the weight ratio of particle and resin, and they can be calculated from the following expressions

Weight of pure polyester

$w=\rho_m * v_c$ ... (1)

$m_f=w * \vartheta$ ... (2)

$m_p=w * (1-\vartheta)$ ...(3)

ϑ =weight ratio

Where:

ρ_m: Density of matrix (1.05 g/cm^3). m_f, m_p: weight of particle and polyester respectively. The weight measured by digital Sensitive (Libra SCA-301). When the samples manufactured, cutting it with cutting tool (CNC machine) shown in fig. 1 to make the tests.

Fig. 1. Cutting tool CNC machine (Rapimill700)

2.2 Mechanical and Thermal Tests

2.2.1 Tensile Test

Test specimens were cut from the plates using cutting tool CNC machine, as depicted in figure (1). The dimensions of the tensile specimens was milled according to ASTM E 8M as shown in Figure 2. All tensile tests were performed at room temperature and constant speed rate (1 mm/min) by a Tinius Olsen universal testing machine, which has a maximum capacity of (50 kN). The specimen's tensile test is mounted vertically in a servo testing machine, and pulled with stroke control with large steel grips. Tensile test done for five types of composite material and for three different mass fraction (5%, 10%, 15%). The tensile specimen's before and after tensile test are shown in Figure 4.

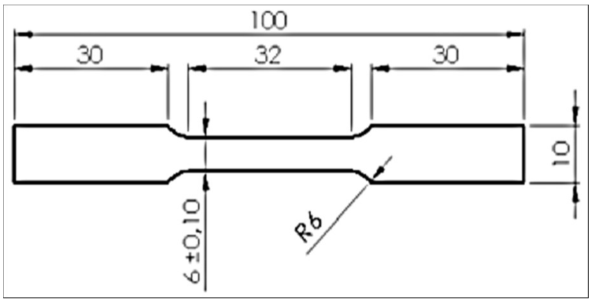

Fig. 2. Section of tensile test specimen.

Fig. 3. Tensile test machine according to ASTM E8-M. All dimensions in millimeters.

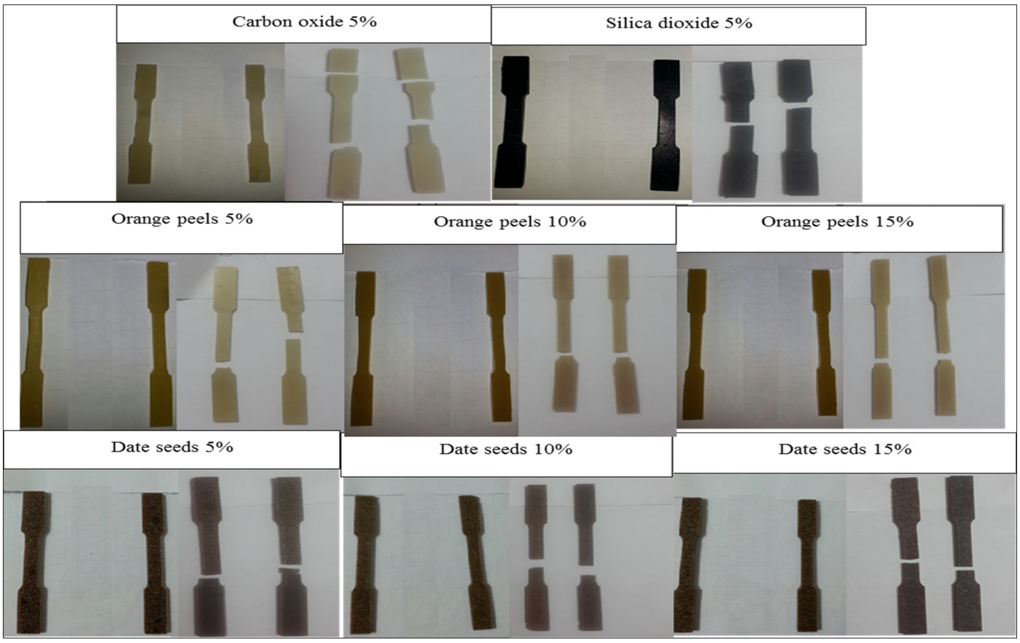

Fig. 4. Speciemens before and after tensile test.

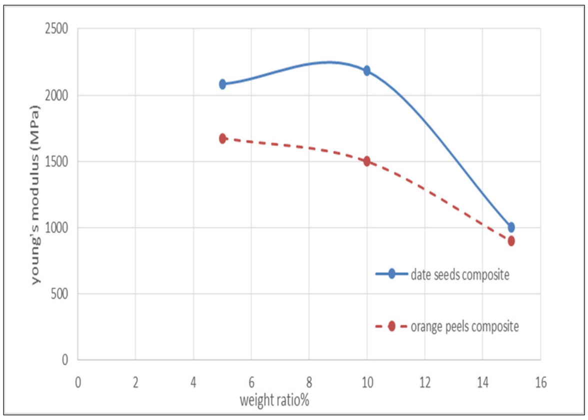

Fig. 5. Effect of weight ratio on Young modulus (natural material).

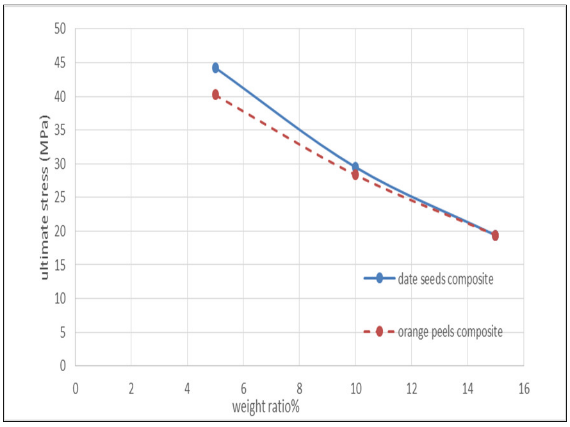

Fig. 6. Effect of weight ratio on ultimate stress (natural material).

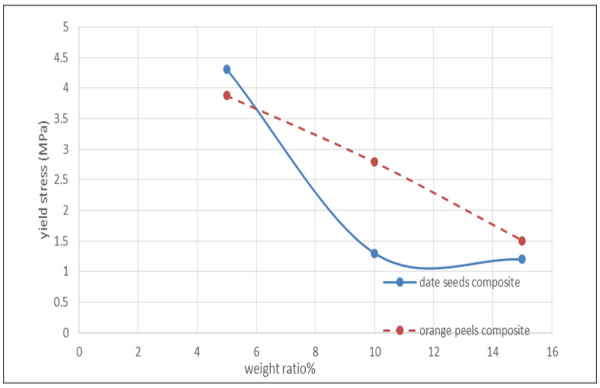

Fig. 7. Effect of weight ratio on yield stress (natural material)

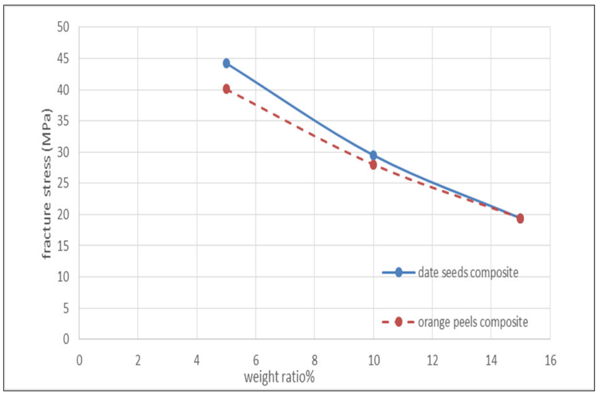

Fig. 8. Effect of weight ratio on fracture stress (natural material)

Table 1,
Mechanical properties of natural and artificial composite material with mass fraction 5% and particle size 98µm

Composite material	Young's modulus (MPa)	Ultimate stress (MPa)	Yield stress (MPa)
Pure polyester	1375	20.6	1. 6
Polyester +Carbon	1125	31.2	2.3705
Polyester+ Silica	1705	39.75	3.879
Polyester + date seeds	2084	44.24	4.306
Polyester+ Orange peels	1675	40.25	3.879

The results of tensile test that represented as (tensile strength, yield stress, and Young modulus**)** are listed in table (1). In figure (5) should be noted that when the weight ratio for date seeds composite the increase from 10% to 15% the maximum young modulus decrease by 54%. And, the maximum for specimen that made from orange peel composite when the mass fraction increase from 10% to 15% the young modulus decrease by 40%. When the weight ratio for date seeds composite increase from 10% to 15% the maximum ultimate stress decrease by 34.3% , as shown in figure (6). Also, it can be observe for specimen that made from orange peels composite that when the weight ratio increase from 10% to 15% the ultimate stress decrease by 31.6%. Figure (7) shown that the maximum increasing in yield stress for date seeds composite occurs when the weight ratio changes 5%to 10% about three times and for orange peels composite when mass fraction change from 10%to15% with 46%. The maximum decreasing in fracture stress for date seeds composite occurs when the mass fraction changes10%to 15% with 34.2% and for orange peels composite when weight ratio change from 10%to15% with 30.7%, as noted in figure (8). When the weight ratio is 5% the maximum young modulus and ultimate stress occur in date seeds composite. But maximum yield stress occurs in date seeds composite. And the minimum young modulus occur in specimen made from carbon composite. The decreasing in strength is attributed to the poor interface between (natural composite) and (polyester). So the crack propagation occurred at this interface, the natural composite (orange peels, date seeds) in the unsaturated polyester matrix provides stress concentration, therefore providing sites for crack initiation, the larger mass fraction, the larger the stress concentration, along the naturally weak interface of the natural and polyester, and lowers tensile strength.

2.2.2 Bending Test

Flexural tests were performed according to ASTMD790 under a three-point bending. The tests were done using a servo-hydraulic testing machine, WDW-200 with speed of 5.0 mm/min. The results of the flexural tests are shown in Figure 9 and table 2 the maximum improvement in the flexural strength was obtained at the orange peels ratio of 5 wt. % with has the maximum increasing percentage is 153.4% from pure polyester. From results of bending test could observe that orange peels composite material have the value of flexural strength greater than date seeds composite also could observe that the natural composite material give the good improvement than industrial composite material at weight ratio 5% because the natural of these materials increased the strength of the material reinforced. The flexural strength decrease when the loading ratio of natural composite increase this due to low degree of adhesion between the polymer and the natural composite and the cross-link density was lowered at high mass friction contents because the distance between the polymers chain increase and natural particles prevent the contact between them, besides that in high percent of weight ratio the particles act as stress concentrators

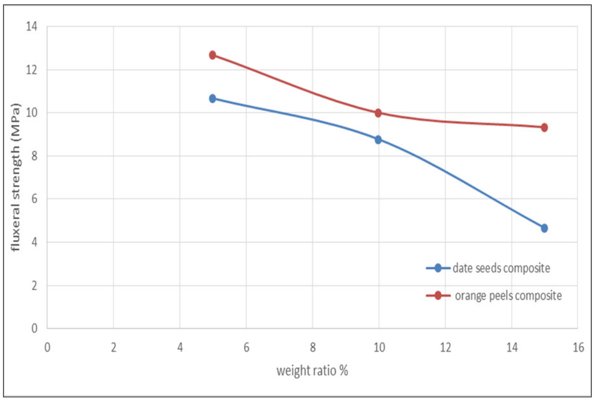

Fig .9. Flexural strength of natural composite material in various weight ratios.

Table 2,
Flexural strength of natural and artificial composite material with mass fraction 5% and particle size 98µm

Composite material	Flexural strength (MPa)
Pure polyester	5
Polyester +Carbon	6
Polyester+ Silica	6
Polyester + date seeds	10.667
Polyester+ Orange peels	12.67

2.2.3 Thermal Conductivity Test

Coefficient of thermal conductivity of all specimens was measured using hot disk thermal conductivity method [7]. Very often composite materials results in anisotropic media and their thermal conductivity change along the axes because of the presences of reinforcing fibers embedded in the matrix. Fig.10. represents the test apparatus (hot disk apparatus) and fig11 shows the principles of hot disk (two samples put in the device and change the temperature to same range and measure the temperature of the sample). The Hot Disk TPS 500 Thermal Constants Analyzer quickly and accurately measures thermal conductivity, thermal diffusivity and specific heat capacity of a wide range of materials. The economical TPS 500 condenses the patented TPS technology with next-generation analysis software, resulting in the smartest, and simplest-to-use thermal conductivity apparatus [8] .

The TPS 500 measures the thermal transport properties of solids, pastes, liquids and powders over a temperature range of -100 °C to 200 °C. The TPS 500 encompasses similar accuracy and sample size flexibility as the benchmark TPS 2500 S and workhorse TPS 1500. In general, steady-state techniques are useful when the temperature of the material does not change with time. This makes the signal analysis straightforward (steady state implies constant signals). The disadvantage is that a well-engineered experimental setup is usually needed [9]. The transient techniques perform a measurement during the process of heating up. Their advantage is quicker measurements. Transient methods are usually carried out by needle probes. In this technique, the hot disk sensor (copper disk) serves as a heat source and a thermometer. During the measurement, the sensor is sandwiched between two halves of a sample and a constant current is supplied to the sensor. The temperature increase at the sensor surface is strongly dependent on the thermal transport properties of the surrounding material. By monitoring the temperature increase as a function of time, one can determine the thermal conductivity and thermal diffusivity of the surrounding material. [10] The results of temperature with time and thermal conductivity shown in figs [12, 13].

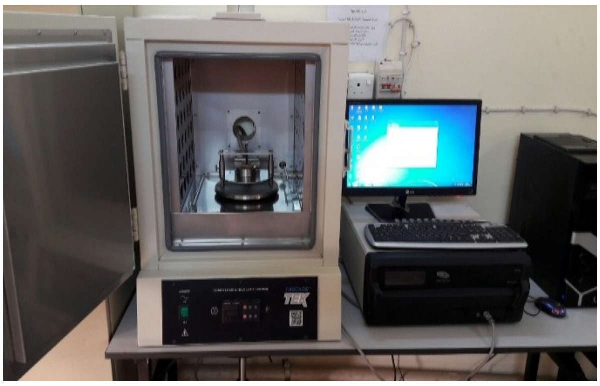

Fig. 10. Hot disk apparatus.

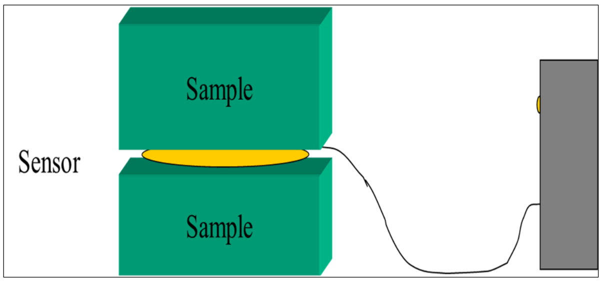

Fig.11.hot disk principles.

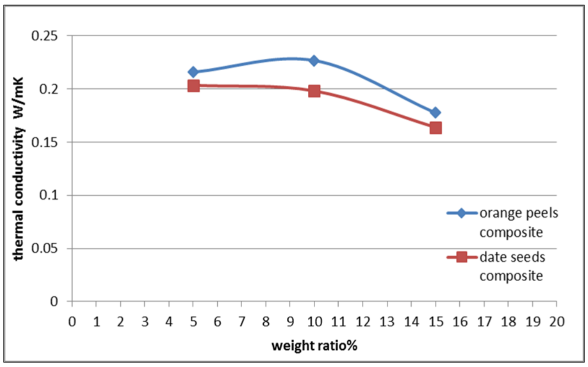

Fig. 12. Thermal Conductivity coefficient results for natural composite material for different weight ratio.

Table3,
Thermal conductivity of natural and artificial composite material with weight ratio 5% and particle size 98µm

Composite material	Thermal conductivity W/m.K
Pure polyester	0.2101
Polyester +Carbon	0.2254
Polyester+ Silica	٠.2161
Polyester + date seeds	0.2036
Polyester+ Orange peels	0.2159

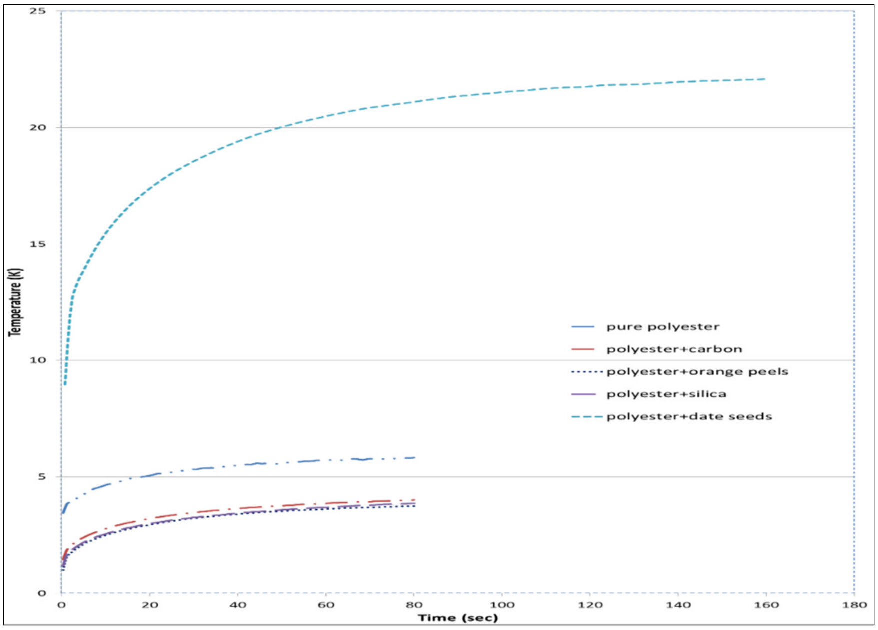

Fig. 13. Variation of temperature with time

From fig 12, it can be seen that the increasing of weight ratio of orange peels composite caused slightly increasing of thermal conductivity by 5% but when the weight ratio increase from 10% to 15% thermal conductivity decrease to the half value. From fig 12 can be note the increasing of adding material more than 10% caused decreasing in thermal conductivity, this decreasing attributed to the influence of additive, this is for both type but orange peels composite increased thermal conductivity more than date seed composite this mean that orange peel have influence on thermal conductivity than date seed. Also can be seen that the thermal conductivity for orange peels composite is greater than thermal conductivity of date seeds composite the maximum percentage is at 10% mass fraction is 14.4% that mean the date seeds composite is good insulator for temperature.

Also can see from table3 that the material that has maximum thermal conductivity is carbon composite second silica composite third orange peels composite fourth pure polyester finally date seeds composite that mean adding date to pure polyester made it good insulator and it had a reduced heat transfer rate in comparison to the rest of the samples. From fig 13. Can see the maximum variation of temperature with time occurs in date seeds composite because it is good isolator and the copper disk with is the source of temperature don't lose it temperature.

3. Conclusion

In this paper, the mechanical and thermal properties of natural (date seeds, orange peels) and industrial (carbon and silica) composite materials at different weight ratios (5, 10, and 15wt. %) were investigated. According to the obtained results, the following conclusions can be drawn:

1- Regarding the mechanical properties, when the mass fraction for the date seeds composite increased from 10% to 15%wt, the maximum Young's modulus decreased by 54%, the maximum ultimate tensile stress decreased by 34.3% and the maximum fracture stress decreased by 34.2% When the mass fraction is 5%, the maximum Young's modulus, yield stress and ultimate tensile stress occurred in date seeds composite. The results of the flexural tests showed that the maximum improvement in the flexural strength was obtained at the orange peels ratio of 5 wt. % with a maximum increasing percentage of 153.4% than pure polyester. From result of tensile and flexural tests, the natural composite material has strength more than industrial material

2- Referring to the thermal properties, the value of thermal conductivity for the natural composite material with orange peels increased by 5% when the mass fraction increased from 5% to 10%, but when this ratio increased from 10% to 15%, it decreased to the half value. Also, the thermal conductivity for the orange peels composite is greater than that for the date seeds composite, and the maximum percentage is 14.4% at 10% weight ratio. This means the date seeds composite is a good insulator for temperature, but the industrial composite material has a higher thermal conductivity than the natural composite material. Finally, the addition of date seeds made the pure polyester become a good insulator and it had a reduced heat transfer rate in comparison to the rest of the samples, also the maximum variation of temperature with time occurred in the date seeds composite because it is a good isolator.

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دراسة تاثير اضافة المواد الطبيعية (نوى التمر وقشور البرتقال) والصناعية (الكاربون والسليكا) على الخواص الميكانيكية والحرارية للمواد المركبة البولمرية

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الخلاصة

تم دراسة الخصائص الميكانيكية والحرارية للمواد المركبة التي تتكون من بولي استر غير مشبع المقواة بأنواع مختلفة من المواد الطبيعية (قشر البرتقال ونوى التمر) والمواد الصناعية (الكربون والسيليكا) مع حجم حبيبي ٩٨ ميكرون. تم اخذ قيم متلفة من النسب الوزنية، %٥و %١٠و %١٥. وقد تم اضافة مواد صناعية ومواد طبيعية الى البولي استر. وقد تم أجراء اختبارات الشد و الانحناء والتوصيل الحراري للبولي استر والمواد المركبة الطبيعية والصناعية لتحديد تأثير النسبة الوزنية على خصائص المواد. وأظهرت النتائج أنه عندما زادت نسبة الوزن للبوليستر مع نوى التمر من ١٠٪ إلى ١٥٪، انخفض معامل المرونة بنسبة ٥٤٪. عندما تكون النسبة الوزنية لنوى التمر٥٪ الحد الأقصى لمعامل المرونة والإجهاد الخضوع والإجهاد الكسر. وأظهرت نتائج اختبارات الشد واالانحناء أن المواد المركبة الطبيعية لها قوة أعلى من المادة الصناعية. في حين أظهرت نتائج اختبارات الانحناء أن الحد الأقصى من التحسن في قوة الانحناء يتم الحصول عليه لقشور البرتقال بنسبة ٥٪ ، حيث الحد الأقصى لزيادة هي ١٥٣,٤٪ بالمقارنة مع البوليستر النقي. وانخفضت الموصلية الحرارية من قشور البرتقال إلى قيمة النصف عندما زادت النسبة الوزنية من ١٠٪ إلى ١٥٪. الموصلية الحرارية للبوليستر مع قشور البرتقال أكبر من الموصلية الحرارية من البوليستر مع نوى التمر. وكانت النسبة المئوية القصوى عند النسبة الوزنية ١٠٪ هي ١٤,٤٪ ولكن التوصيل الحراري للمواد المركبة الصناعية اعلى من المواد المركبة الطبيعية. وأخيرا، فإن المركب نوى التمر هو عازل جيد وله معدل نقل حراري منخفض بالمقارنة مع بقية العينات، وكذلك الاختلاف الأقصى لدرجات الحرارة مع مرور الوقت في مركب نوى التمر.