Preparation a Composite Material (UP/Cann F) with Evaluation Its Toughness Under the Influence of Temperature and Humidity.

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ABSTRACT.

In this research we have prepared a composite material by using Vegetative Cellulose Fibers of Cannabis (Cann F) to reinforced a matrix of Unsaturated Polyester (UP) resin. This kind of fibers is distinguished by good properties such as high tensile strength, low elongation, thermal resistance and low cost.

The impact strength was tested by using *Charpy* method for three materials (UP resin), composite (UP / Cann F) and composite (UP/Glass F).

The results indicated that the fracture energy (Uc) decreased as the notch depth (a) increased on the sample from (0.7 mm) up to (4.9 mm). However, the fracture energy increased as the temperature of the composite increased for different temperatures of (0, 35, 50 and 75) ^{o}C. It was noticed that the Material toughness (Gc) has been improved significantly, where in case of the composite (UP /Cann F), the improvement of (Gc) was from (2.45 kJ/m^2) to (14.5 kJ/m^2) and it was (17 kJ/m^2) for composite (UP/GF) has been measured at (35) ^{o}C. When those composite materials (UP/Cann F) exposed to humidity for a period of (72 hrs) without immersion, their properties did not change, hence the effects are not of chemical but of physical nature.

The conclusion, the difference between the toughness of the material (Gc) for the reinforced composites by Cannabis and E-glass fibers for all temperatures is not large, so this encourage the development of Cannabis fiber reinforced composites in the future to abundance, and low cost for industrial investment

Keywords: Composite materials, Unsaturated polyester resin, Fracture toughness, Cellulose fibers.

1. INTRODUCTION.

Composite materials technology is playing a major role in most industries applications which developed from the last century, where the engineering properties are determined by the strength of these materials in high stress resistance and external resistance to the different conditions of use (such as temperature, humidity and radiation). There is a need for material which meet the desired properties in the industry such as light weight, corrosion resistance and available materials with low cost. Since the composite material is prepared from the installation of two or more materials in order to combine their properties according to intended use, it has devised several ways to process the link between these materials. Mechanical properties are developed upon the requested application that needs low plasticity. So, the method of reinforcing fiber is the most commonly used in the preparation of composite materials, because the tensile strength and modulus of elasticity greater than that with matrix only , the relation is working to distribute the load on the fiber [1].

The attention has been focused in recent years to develop the fiber industry where there were many types and their properties and methods of preparation for the purpose of improving the mechanical properties and preparation methods of composite materials. But the cost of manufacturing such fibers are high in developing countries. There are ideas to use some of natural fibers to strengthen some polymers own a property of good adhesion. From that, the suggestion of current research is coming to use available local fibers.

The cellulosed fibers are the largest sources of natural fibers and the most prevalent is cellulose mainly in installation and in spite of its ability to burn and damage by acids, but rising the characteristics could be done by attributes some specific technology of alkali treatment, as well as the advantage of properties hold durable high, which can be increased when it is submerged in water, and differ from synthetic fibers, low rate elongation [2].

2. THE OBJECTIVE.

The objective of this research is to find an alternative fiber material such as using Vegetative Cellulose Fibers of Cannabis (Cann F) to reinforce a resin matrix such as (UP) which should has the same characteristics of the common fibers such as fiber glass. The positive results will encourage for developing of using this kind of fiber to reinforce resins and create many composites in the future to abundance, and low cost for industrial investment

3. FRACTURE TOUGHNESS.

Fracture resistance of materials is the important mechanical property, so for the purpose of preparing a material with good resistance and toughness (durability), a broad understanding of many variables are needed to limit the spread of the fracture, which leads to breakage. Fracture mechanism is a separation of material into several parts because of external influence force with the result from the process separation of these new surfaces. There are several factors causing that; type of material, nature of stress and strain rate [3],[5].

The fractures types in the polymers materials are either brittle fracture which is fragile and it happens quickly, without preceded by deformation and depends on the glass Transition temperature (Tg) as in thermo-set resins. The second type is ductile fracture, which is less dangerous than the first type because a large amount of work would be paid by plastic deformation in the area around the edge of the original fracture as in the thermo-plastic polymers. Fractures are classified generally to: -

- Microscopic fractures: In this type should include the fraction of the virtual visual material links atomic and molecular.
- Continuum fractures: In this type material considered as a bulk of material relating to where the fraction that arises from the microscopic defects and stress is based on the type of stress and release energy on fractures formed [4].

Griffith created the principles of the mechanism of the linear flexible fracture through the theory of balance of energy (EBT), in which, he expressed the processes that occur for crack by the terms of the reversed thermal processes, where the assumed equilibrium resident of crack through the influence of energy. As well, found that the situation in which more than stress value of the critical will there would be enough energy to make the groove ahead and called the power disruption, when the imposition of slitting length (a) in the material thickness (t) leads by (∂a) is then the work (w) disbursed to load external greater than or equal to the change in energy stored in the material + energy absorbed at the head of slitting:

$$\partial w \geq \partial Ue + t\, \partial a\, Gc \qquad (1)$$

(Gc) energy absorbed to the slitting unit area (t ∂a) and called (Toughness), one of the important mechanical properties in the material, at the highest value represents the limit the spread of slitting [5].

Irwin interpreted the technical mechanism of fracture, so he has examined the rate of stresses near fractures in the material and noted that it is directly proportional to the square root of the amount (πa), (K) Fracture Toughness and symbolized by the (Kc) at the critical stress and units (MN / m $^{3/2}$), it is equal to:-

$$Kc = (E\, Gc)^{1/2} \qquad (2)$$

Where (E) is the modulus of elasticity. [6],[10]

It is worth noting the geometric shape function (Φ) value depends on the ratio between the length of the sample to the its width (S/D), and has a direct relationship with the ratio (a/D) between the depth of the groove to width the section of the sample, so if S/D=4 then the geometric shape coefficient (Y) for the sample section:

$$Y = B\ D\ \Phi \tag{3}$$

(B) is the length of the sample, (D) is width of the sample, and $\Phi = 0.135\ (a/D) - 0.77$, since the value of the function has a significant effect in the calculation of (Y). [7]

Toughness of resins is affected in general by heat, where at low temperatures under (Tg) resins are more brittle than it is in the above. In the Polystyrene for example, at different temperatures (-18) ^{o}C to (50) ^{o}C, the fracture toughness increase in value of (1.25) to (2.5) (MN / m $^{3/2}$) as temperatures increased. Epoxy resin has low value and it changes little with temperatures changes because the molecules are connected in Crosslink so crack in the material has not progress at the head of slitting. [8]

At the temperatures approach the degree of (Tg), the resins have plasticity, where appropriate lead mobility between the chains to absorb a large part of the energy shock and thus be a high durability and toughness. But when increasing the temperature above (Tg) of resins generally leads to progressive deterioration in the cases of the presence or absence of oxygen and gets degradation in the decay chains rapidly in primary weak points in the chain, branches and link placements [9].

Interference the moisture (humidity), as an effective factor in decomposition of resins when they immersed in water for long time, appears through the bonds strength of material. It is reduces the forces of the link between fractions, it proved by *Richard* when he immersed a resin in hot water at a temperature (50 ^{o}C for a period of (more than 70 hours). That leads to increase the diffusion coefficient in the resin which it leads to failure. In the low temperature, humidity it does not show this effect because the entry of water between the molecules of resin does not create free radicals. [9],[11]

4. EXPERIMENTAL WORK.

(a) Samples Preparation:

- Materials have been used in this research were:
  - Unsaturated Polyester resin (UP), classified as thermo set resin, and has specifications (semi-transparent, resistant to climatic conditions for long time and used at temperatures less than 80 ^{o}C. Usually (UP) used in many manufacturing applications such as cars, boats, and several structural parts.
  - Hardener substance (MEKP) mixed with resin by ratio 2g to 100g resin.
  - Fibers of; Cannabis (Cann), type of cellulosic fibers, and Glass fiber man-made fiber type (E-glass). Fibers represent the reinforcement material to the resin in the composites.
- An aluminum die with standard dimensions (B=10mm, D=10mm, S=50mm) according to ISO 179.
- Three types of samples prepared by powering the mixture into the die mentioned above and entered into oven less than 55 ^{o}C for 6 hours. The samples have been prepared:
  - (UP) resin.
  - Composite (UP/Cann.F) with volume fraction (V*f*=20%).
  - Composite (UP/GF) with volume fraction (V*f*=20%).
- After 24 hours the samples cleaned and prepared for measuring and test.

(b) Tests:

- Charpy device for standard impact energy test according to ISO-179 has been used for measuring required energy (Uc) with unit (kJ) to break sample per area unit for:
  - 6 samples of (UP) resin at temperatures (0, 35, 50, and 75) ^{o}C with different grooves (notches) depth (a) between (0.7 to 4.9)mm.
  - 6 samples of composite (UP / Cann.F) and 6 samples of composite (UP / GF), with different notch depth (a) as above.
  - Two samples of the composites (UP/Cann) and (UP / GF) with indented notch depth and temperature of 35 ^{o}C where they exposed to the water.

5. RESULTS DISCUSSION.

The impact resistance of materials is known from measuring the required energy to break the sample under different conditions such as type of material, depth of the notch, temperature and humidity. In this research found out that (UP) resin, used in this research under impact, has high degree of sensitivity to being Brittle & Stiff. So, by observing the measurements of the energy which needed to break are few in general and they are decreasing with increasing the depth of the notch in the sample as shown in **Fig.(1)**, plotted for different temperatures. The slope in this figure represents material toughness (Gc), it was noted that it increases with increasing temperature of samples exposed to the impact due to (UP) resin has type of ductility. The energy consumed to break the sample was high and the numbers of fractures caused were less because increasing in temperature leads to relaxation those bonds and grants it a usability of slide motion, so that (UP) resin chains will have a possibility of absorption part of the energy in the elastic behavior. The stage of deformation will take place shortly and then brittle break rapidly which means increasing fracture energy within these stages. In the low-temperature material toughness (Gc) will decrease because the motion of molecules will hold on and bonds become in tension case (low resistance) and breaks up quickly when exposed to shock.

The material toughness and its resistance to the impact shock is changing when (UP) reinforced by fibers, as in the **Figs. (2 and 3)**, where increasing the required energy to the fracture and
the material toughness. In this case fibers will act as constrains the spread of fractures (Crack Stoppers) and absorbing the stress shock , there was no separation in the parts of the material as happened with the resin material without reinforcing note **Fig.(6)**, but there were curved lines have been appeared by a succession of fractures and shock wave fronts appear to be more obvious at low temperatures. This characteristic is less with increasing temperature due to the influence of heat ductility of composite. Regarding to the type of reinforcement, which has effect on the strength of composite, found that the strength of the composite (UP / Cann.F) was satisfied and close to some extent of toughness (UP / GF) for the same conditions, note **Fig.(3)**. As well as in the case the fracture toughness (Kc), note **Fig.(4)**, but this little difference can be minimized in future by treating Cannabis fiber with substances can make the homogeneity of the matrix with a higher degree and increase the compactness / density.

When exposing samples of composite materials (used in this research) to moisture (spray) for 72 hours (short period time represents the expected exposing), the impact was very small, but shows the influence of humidity at the presence of factors that accompanied such as photo-oxidation of ultraviolet radiation or high temperatures when the composite immersed in hot water.

6. CONCLUSIONS.

Test of composite materials resistance (UP/Cann F) to the impact shocks is one of the necessary measurements to the applications where the shocks comes as a result of the service. The conclusion of this research is summarized:

1- UP (unsaturated polyester resins) are brittle material since it have high sensitivity to shocks (thermoset property) with less energy needed to fracture (Uc).
2- Increasing material toughness (Gc) of thermoset resins when reinforced by cellulosic fibers where it was for (UP) resin about (2.45) kJ/m^2 at lab temperature (35 ^oC), however it was (14.5) kJ/m^2 for the composite (UP/Cann F). For the purpose of comparison, the toughness of composite (UP/GF) was amounted to (17.1) kJ/m^2.
3- Noted that the difference between the toughness of the material for the reinforced composites by Cannabis and E-glass fibers for all temperatures is not large, so this indication will encourage the development of Cannabis fiber reinforced composites in the future to wealth, and low cost for industrial investment
4- From the modulus of elasticity found that fracture toughness (Kc) has increased for the two composites than for the resin, it has reached for the resin (2.04) $MN/ m^{3/2}$ and for the composite (UP/Cann F) was (5.27) $MN/m^{3/2}$, and it was close to some extent for the composite (UP/GF) which was (5.99) $MN/m^{3/2}$. (Kc) and (Gc) are increased frontage of changing in temperature proportionally as shown in at **Figures (4), (5).**
5- The effect of moisture on the (UP/Cann F) composite was very few when it immersed for a period of 72 hours, we have noted that excludes water molecules between the resin molecules and reinforced fibers at low temperatures, that is one of the properties of resin resistance to cold solutions.

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NOMENCLATURE.

(UP)	Unsaturated Polyester
(Cann F)	Cannabis Fiber
(GF)	Glass Fiber
(UP / GF)	Unsaturated polyester reinforced by Glass fibers
(UP / CannF)	Unsaturated polyester reinforced by Cannibs fibers
(Tg)	Glass Transition temperature
(EBT)	Energy Balance Theory
(Gc)	Material Toughness at the critical stress
(Kc)	Fracture Toughness at the critical stress
(Y)	Geometric shape coefficient for the sample section
(Φ)	Geometric shape function
(MEKP)	Methyl Ethel Keton Polymer
(ISO)	International Standard Organization
(V*f*)	Fraction Volume
(Uc)	Fracture Energy

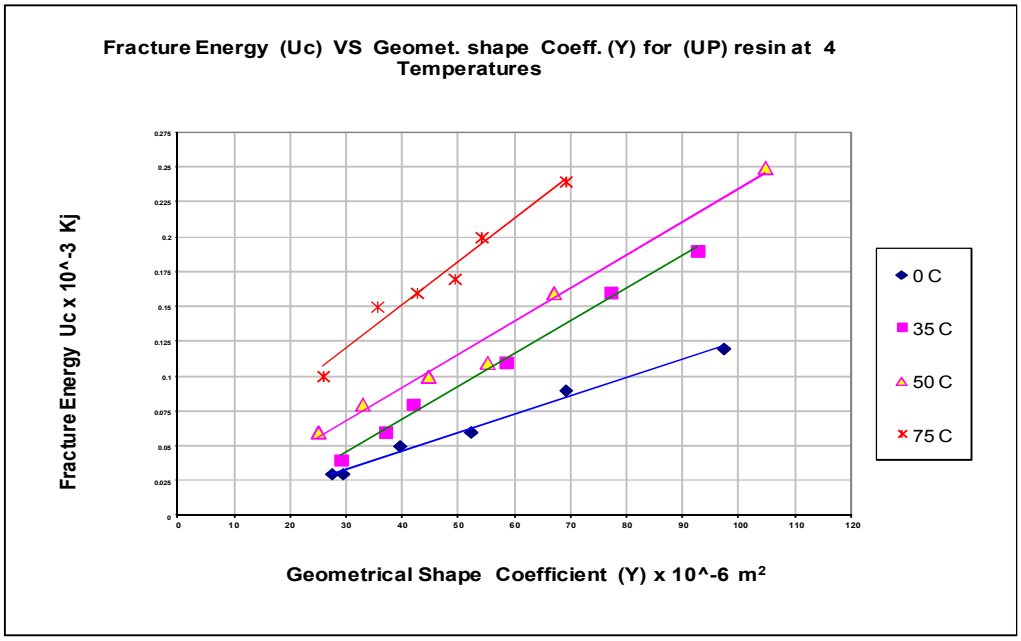


Figure (1): Fracture Energy(Uc) VS Geomet. shape Coeff. (Y) for (UP) resin at 4 Temperatures.

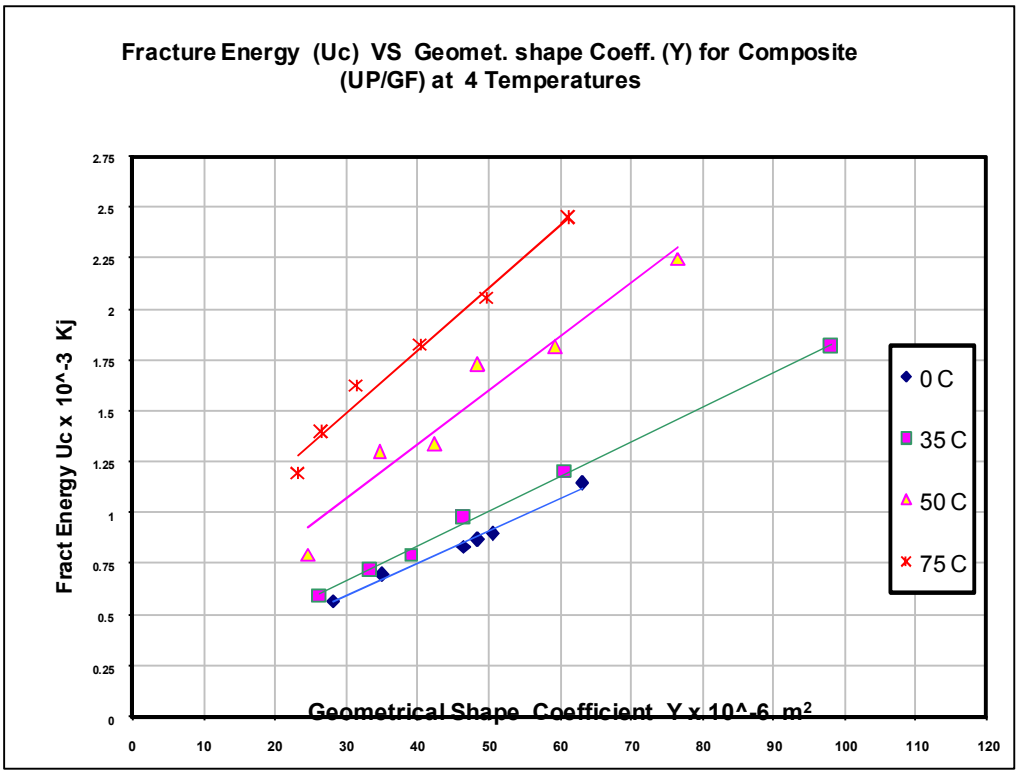


Figure (2): Fracture Energy(Uc) VS Geomet. shape Coeff. (Y) for composite (UP/GF) at 4 Temperatures.

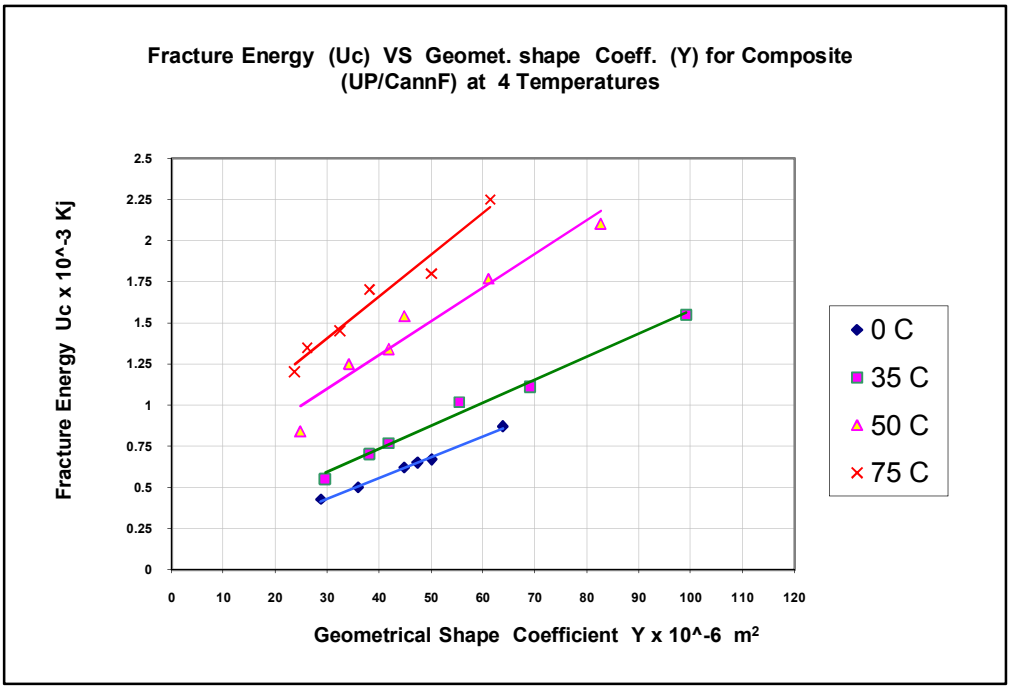


Figure (3): Fracture Energy(Uc) VS Geomet. shape Coeff. (Y) for composite (UP/CannF) at 4 Temperatures.

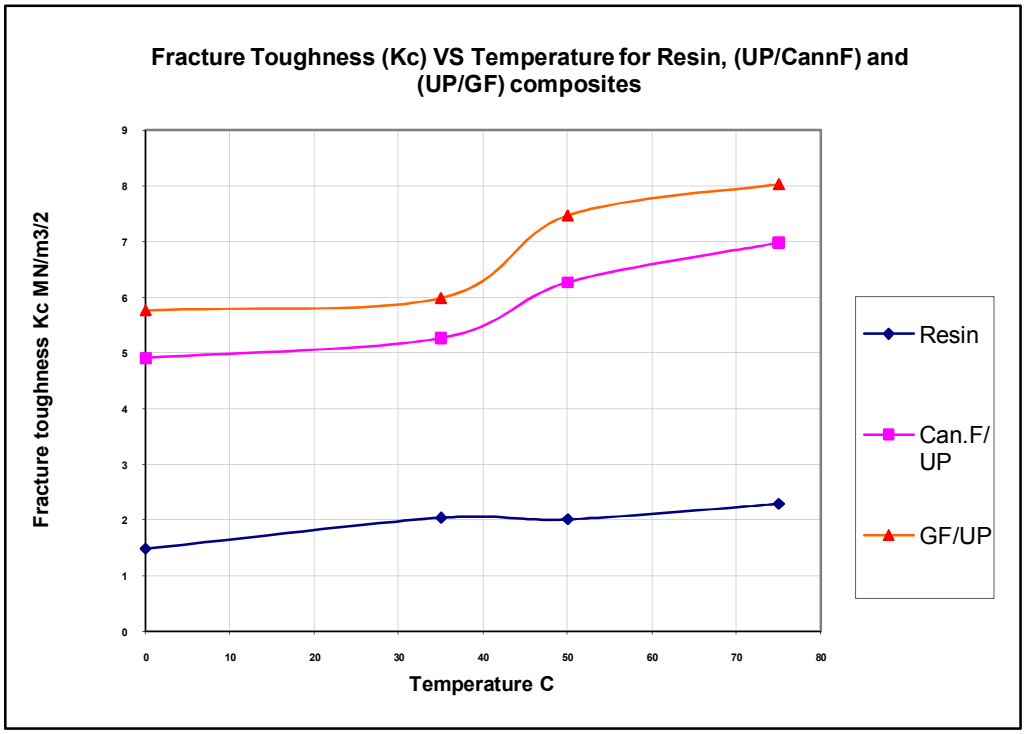


Figure (4): Fracture Toughness (Kc) VS Temperature for Resin, (UP/CannF) and (UP/GF) composites.

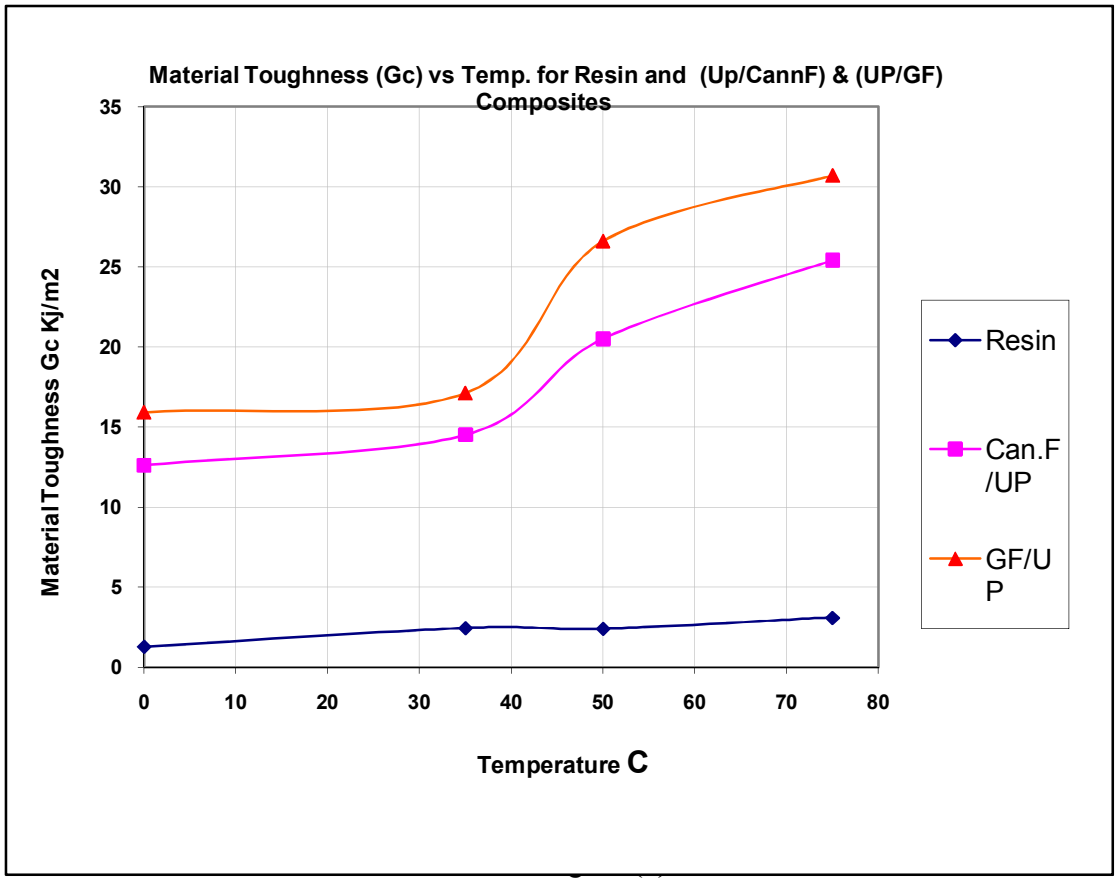
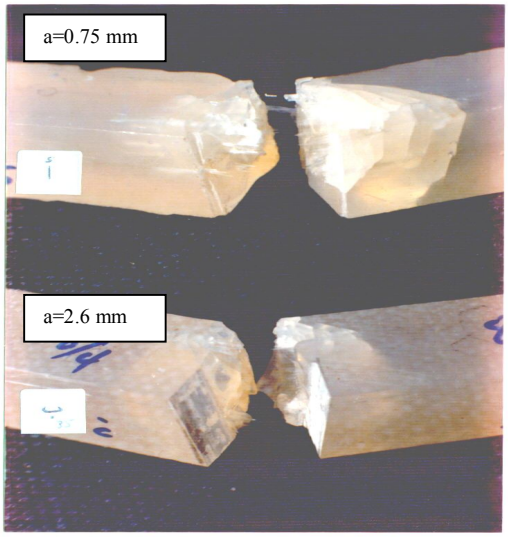
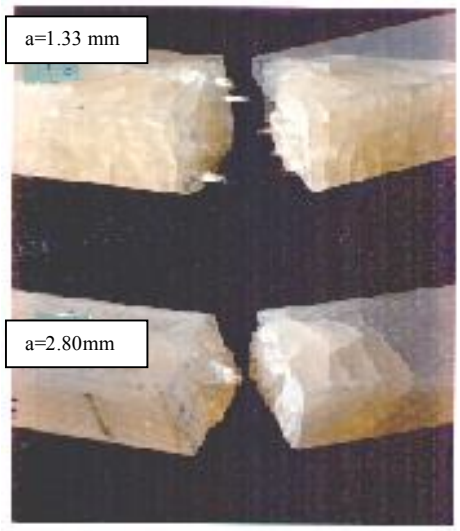


Figure (5): Fracture Toughness (Gc) VS Temperature for Resin, (UP/CannF) and (UP/GF) composites.



Temp 35 C



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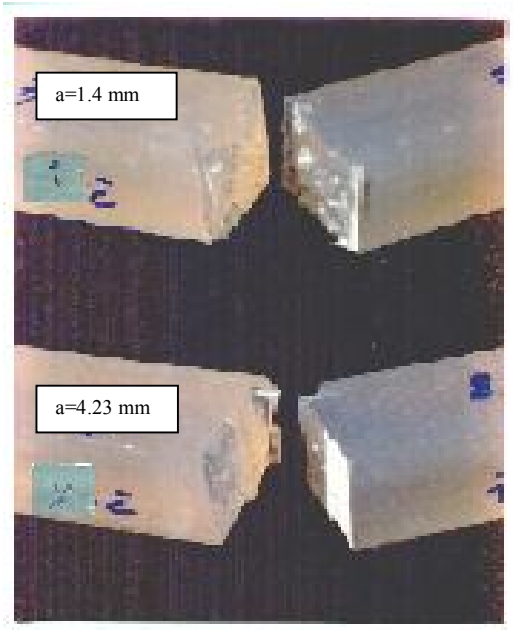
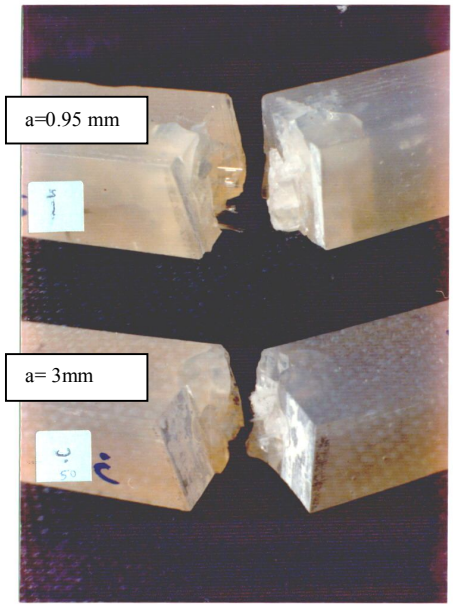


Temp 75 C



Temp 50 C

Figure (6): Photographs of 4 samples of Composites (UP/CannF) Mag. X5 for Charpy test to 4 temperatures.

تحضير مادة مركبة من (راتنج البولي إستر المدعم بألياف القنب) ودراسة متانتها تحت تأثير درجات الحرارة والرطوبة

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الخلاصة.

مع زيادة الحاجة الى المواد المركبة Composite Materials في التطبيقات الصناعية الحديثة أصبح توفير المواد البديلة في تحضيرها أمر في غاية الأهمية لتقليل الكلفة والاحتفاظ بنفس المواصفات الهندسية العالية التي تتمتع بها تلك المواد في مقاومة ظروف الخدمة (الصدمة ، الحرارة والرطوبة) .

في البحث الحالي تم استخدام الياف نباتية من نوع القنب Cannabis في تقوية نوع من الراتنجات المصلدة حرارياً Resin Thermosetting هوالبولي استرغير المشبع Unsaturated Polyester (UP) ، حيث تمتاز تلك الالياف بالمتانة العالية ومقاومتها للشد وقلة استطالتها وتحملها لدرجات الحرارة العالية بالاضافة الى وفرتها وكلفتها القليلة (وهو سبب اختيارها لمادة البحث).

تم اختبار مقاومة الصدمة Impact Strength لثلاث أنواع من المواد (راتنج ، راتنج مدعم بالياف القنب وراتنج مدعم بالياف زجاجية) بطريقة Charpy وقياس طاقة الكسر Fracture Energy لها لحزوز Notches مختلفة العمق تراوحت بين (0.7-4.9)ملم ولدرجات حرارية مختلفة (0,35,50,75)ْم ، فقد لوحظ بأن الطاقة اللازمة للكسر لعينات من الراتنج (غير المدعم) تزداد بنقصان عمق الحز وبزيادة درجة الحرارة وتبعاً لذلك تزداد متانة المادة Fracture Toughness(Gc) . أما في حالة تدعيم الراتنج بالياف القنب فأن الطاقة اللازمة للكسر ازدادت وبمقدار اكبر مما هو علية في عينات الراتنج غير المدعم حيث امتصت الالياف الجزء الاكبر من طاقة موجة الصدمة لذا زادت متانتها بمقدار كبير ولجميع درجات الحرارة ففي درجة حرارة المختبر (35)ْم زادت المتانة من 2.45 الى 14.5 كيلوجول/م^2 عند تدعيمه بألياف القنب , ولغرض المقارنة كانت متانة الراتنج المدعم بالالياف الزجاجية أكبر من متانة الراتنج المدعم بالياف القنب بمقدار قليل حيث بلغت (17.1 كيلوجول/م^2) لنفس درجة الحرارة نظراً للمرونة والكثافة العاليتين التي تمتلكها الالياف الزجاجية لكنها مادة مكلفة وغير متوفرة . أما عند تعريض المادة المركبة للرطوبة ولفترات قصيرة (مامجموعه 72 ساعة رش بالماء دون غمرها) وجد أنها لاتتأثر لأن الرطوبة لاتدخل مع الراتنجات بعلاقة كيميائية بل تحدث تأثيرا قليلاً (غير سلبي) على خواصها الفيزيائية .

الكلمات الرئيسية:مواد مركبة ، راتنج بولي استر غيرالمشبع ، متانة الكسر ، الألياف السليلوزية.