# A Study on the Effects of Salt Concentration Environment on the Mechanical Properties of Polyester and Composite Materials

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## ABSTRACT

The study investigates the effects of salt concentration on some mechanical properties of thermoset polyester resin without reinforce and polyester resin reinforced with random fiber glass mat. The volume fraction of the composite material varies in (15%, 25%, 35% and 45%). The two types of material were immersed for (40) days in different salt concentrations ratio (15%, 35% and 55%). The environment consists of salt 99.9% and 0.008% magnesium carbonate and potassium iodide. The study depends on the experimental results of impact test and tensile test to describe the mechanical properties of polyester resin and composite material. It is found that the fracture toughness of composite material increases at approximate ratio of (2.9%) while the polyester resin increases at approximate of (2.25%) due to increasing the salt concentration in water with ratio (40%), so that the fracture toughness increases with approximate ratio (3%) due to increase in the volume fraction ratio from (15%) to (45%). The elastic modulus of composite material increases with ratio of (14.9%) and (90.29%) for polyester due to increase in the salt concentration ratio in the water at approximate ratio of (40%).

The elastic modulus increases at ratio of (13.73%) , the yield stress of polyester increase at ratio (50.32%) and yield stress of composite material increases at ratio (55%) as a results of increase in the volume fraction ratio from (15%) to (45%).

**Keywords:** fiber glass, volume fraction, environment conditions, magnesium carbonate, potassium iodide, fractures toughness.

# دراسة تأثير تركيز المحيط المالحي على متانة الكسر و معامل المرونة للبولستر والمادة المتراكبة

**الخلاصة**

تبحث الدراسة الحالية في تاثير المحيط الملحي في بعض الخواص الميكانيكية للبولستر الحراري بدون تقوية وللبولستر الحراري المقوى بحصيرة من الالياف الزجاجية العشوائية الترتيب. الكسر الحجمي للمادة المتراكبة يتغير بـــ(15%, 25%, 35%, 45%) لان نوعي المواد غُطِّست لـ(40) يوم في نسبة تركيز



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ملحي مختلفة ( 15%, 25%, 35%). يتكون المحيط من ملح بنسبة (99.9%) و(% 0.008) من كاربونات المغنسيوم وايوديد البوتاسيوم . الدراسة اعتمدت على النتائج العملية لاختبار الصدمة واختبار الشد لوصف الخواص الميكانيكية للبولستر وللمادة المتراكبة. الدراسة وجدت ان متانة الكسر للمادة المركبة تزداد بنسبة تقريبية (2.9%) بينما في البولستر تزيد بنسبة تقريبية (2.25%) بسبب ازدياد نسبة الملوحة في الماء بمقدار (40%) كما ان متانة الكسر تزداد بنسبة تقريبية (3%) بسبب ازدياد نسبة الكسر الحجمي من (15%) الى (45%). معامل المرونة للمادة المركبة يزداد بنسبة (14.9%) و(90.29%) للبولستر بسبب ازدياد تركيز الملوحة بنسبة (40%) .
معامل المرونة يزداد بنسبة ( 13.73%) ، اجهاد الخضوع للبولستر يزداد بنسبة (٥٠,٣٢%) واجهاد الخضوع للمادة المتراكبة يزداد بنسبة (٥٥%) نتيجة لازدياد نسبة الكسر الحجمي من (15%) الى (45%).

## INTRODUCTION

A composite is a structural material that consists of two or more combined constituents that are combined at a macroscopic level and are not soluble in each other. One constituent is called the reinforcing phase and the one in which the reinforcing constituent is embedded is called the matrix. The reinforcing phase material may be in the form of fibers, particles, or flakes. The matrix phase materials are generally continuous. Examples of composite systems include concrete reinforced with steel and epoxy reinforced with graphite fibers, etc. These materials are not generally usable as fibers alone, and typically they are impregnated with a matrix material that acts to transfer loads to the fibers, and also to protect the fibers from abrasion and environmental attack. The matrix dilutes the properties to some degree, but even so very high specific (weight-adjusted) properties are available from these materials. The fibers may be oriented randomly within the material, but it is also possible to arrange them to be oriented preferentially in the direction expected to have the highest stresses. Such a material is said to be anisotropic (different properties in different directions), and control of the anisotropy is an important means of optimizing the material for specific applications [1]. Camelia Cerbu et al. describe some aspects concerning the effects of the type of wood species on some mechanical characteristics of some hybrid composite materials reinforced with both E-glass woven fabric and wood flour. They also show the effects of the moisture absorption on the mechanical behavior in bending after immersion in two different environments: water and seawater. The specimens were manufactured by reinforcing a polyester resin Copoly 7233 with both E-glass woven fabric EWR145 and wood flour. Two kinds of wood flour, oak wood flour and fir wood flour were used to manufacture the two composite materials tested. The immersion time was approximately eight months. Finally, the paper recommends using of the oak wood flour with the parts made of composite material analyzed, that works in humid environment excepting the case when its salt content is greater.[2]. The problem of predicting the effective elastic properties of multi-cracked and/or composite materials is both fundamental in materials mechanics and of large technological impact. The study describes a continuum elasticity model , based on the Eshelby theory and on the differential homogenization technique, for the effective elastic moduli of a fibro-reinforced system and they address it to elaborate an estimation of the average failure condition of such composites [3]. M. M. Davoodi et al. [4] have investigated thermoplastic toughening used to improve impact properties in hybrid natural fibre epoxy composite for automotive bumper beam and have achieved reasonable impact improvements. C. Santulli and A.P. Caruso [5] in there study have made, a comparison between two composite architectures namely a hemp/epoxy random mat and a jute/epoxy plain weave laminate, both with 45 ±2% vol. of reinforcement fibres. Work carried out concentrated on comparing and discussing the falling weight impact performance of the two laminates with different fiber architecture, by studying their impact hysteresis cycles and investigating their respective modes of damage. This was done in view of a possible application of a hybrid of the two laminates for impact resistance purposes. A. K. Bledzki et al. [6] have investigated abaca fiber reinforced PP composites were fabricated with different fiber loadings of (20, 30, 40, 50 wt% and in some cases 35 and 45 wt%). Flax and jute fiber reinforced PP composites were also fabricated with 30 wt% fiber loading. The mechanical properties, dour emission and structure properties were investigated for those composites. Tensile, flexural and Charpy impact strengths were found to increase with fiber loadings up to 40 wt% and then decrease. Falling weight impact tests were also carried out and the same tendency was observed.

Apusraporn Prompunjai and Waranyou Sridach [7] studied have the use of a hot compression moulding process to prepare the composites based on cassava starch, NR latex and sawdust. The study was also aimed to assess the effect of varying the proportion of these three components on the physicochemical and mechanical properties of composites, and the relationship between these mechanical properties and morphology in composites.

Hernández, M. et al [8] have studied the impact properties of Polypropylene / Styrene - Butadiene-Styrene Block Copolymer (PP/SBS) Blends. Concentrations of SBS were 15, 30 and 40 %wt. Impact measurements exhibited that pure PP has extremely low impact strength. Improved impact strength can be achieved by blending PP with SBS.

The aim of this research is to define the effects of environment of salt concentration and volume fraction on the impact energy and elastic modulus and other characteristics of polyester resin Figure (1-a) and polyester resin reinforced with random fiber glass mat Figure (1-b).

**a- Random fiber glass mat** **b- Thermoset polyester resin**

**Figure (1-a, b) Pictures of fiber glass mat and polyester resin.**

## THE EXPERIMENTAL FRAMEWORK

The unsaturated polyester resin has been used in composite material reinforced with multilayer of random mat fiber glass with curing catalyst (MEKP) at a concentration of (0.01%) of the polyester resin weight. The composite material specimens of the tensile and the impact specimens were immersed in salty environment consisting of 99.9% salt and 0.008% magnesium carbonate with potassium iodide ratio of (15%, 35%, 55%) in water for (40) days before the test. The standard properties of fiber glass are shown in Table (1) and of polyester resin shown in Table (2).[9].

**Table (1) Mechanical Properties of Polyester Resin [9].**

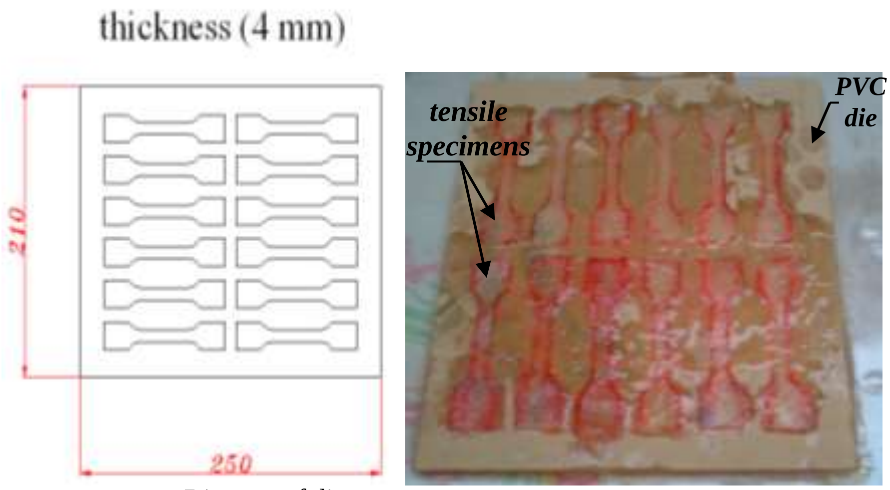
| Properties | Value |
|---|---|
| Specific Density (at 20 C$^o$) | 1.22 |
| Tensile Stress at Break | 65 N/mm$^2$ |
| Elongation at Break (50mm gauge length) | 3.0 % |
| Modulus of Elasticity | 3600 N/mm$^2$ |
| Density ( $\rho$ ) | 1268 kg/m$^3$ |
| Rockwell Hardness | M70 |

**Table (2) Mechanical Properties of E-glass Fibers [9].**

| Glass type | Specific gravity | $\sigma_{ult}$ (MPa) | Modulus of Elasticity (Gpa) | Liquids Temperature °C |
|---|---|---|---|---|
| E-glass | 2.58 | 3450 | 72.5 | 1065 |

## PREPARING THE TENSILE AND IMPACT SPECIMENS

The preparing of specimens was achieved by using open moulding in die made from plastic type (PVC) layer where the shape of test specimen in the die was made by laser cut machine with high accuracy and high finishing (open die) as shown in Figure (2).




a- Diagram of die b- Photograph of

**Figure (2-a, b) The die of tensile test specimens made from the plastic type (PVC).**

Tensile tests were made on different types of composite material according to D412 ASTM [10] as shown in Figure (3). The tensile tests speed was equal to (8 mm/min). The standard impact specimen in dimensions of (1 cm * 1 cm * 5 cm) at crack depth (1 mm) is as shown in Figure (4). Charpy impact test consists of standard test piece that would be broken in one blow of a swinging hammer. The technique of the instrument is done through lifting up the hammer to the highest point and fixing it well, and then the sample is placed in its position. The potential energy of the swinging movement will change to kinetic energy part of which will be lost in breaking the sample; therefore, the pointer gauge will read breaking energy value of the sample.

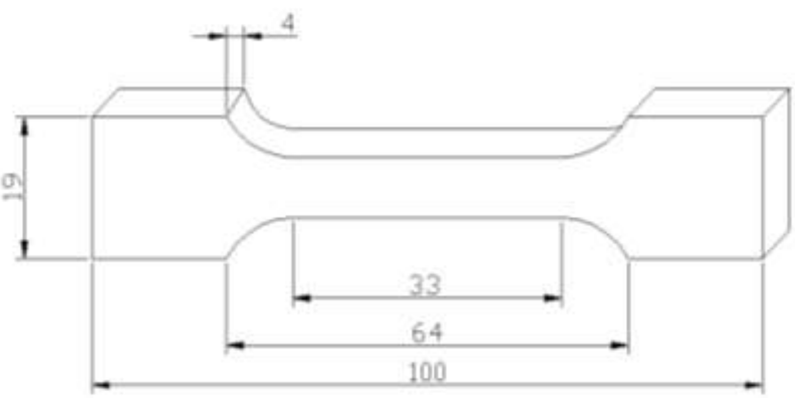



**Figure (3) the standard tensile test specimen (ASTM D412) [10].**

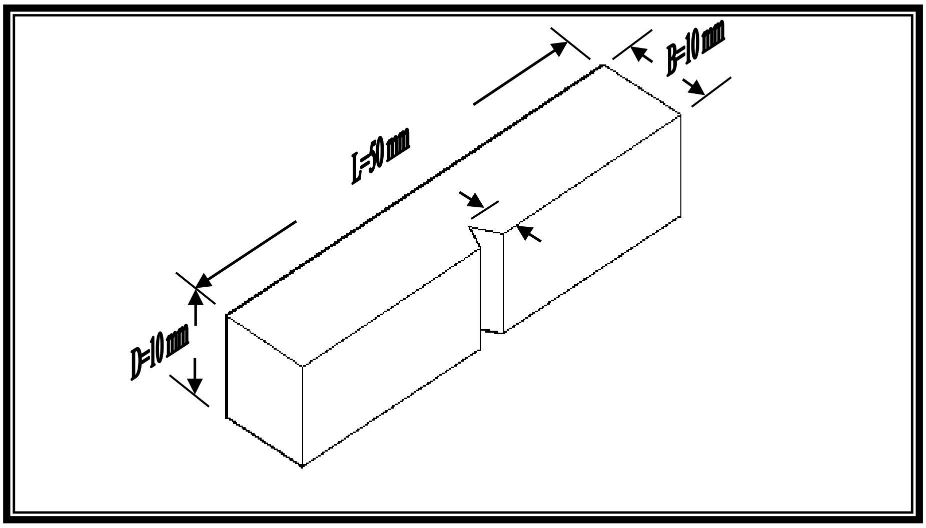



**Figure (4) the standard impact Charpy test specimen.**

Impact strength is calculated from the relation [11].

$$I_S = U/A \quad (J/m^2) \qquad ... (1)$$

Where:
$I_S$ = impact strength
U = energy of fracture in (joule)
A = cross section area in ($m^2$).
The value of volume fraction of composite material is calculated by measuring the weight of fiber and polyester each one in itself where the volume fraction *(φ)* is combined with the weight fraction ($\psi$) by the relation [12]:

$$\varphi = \frac{1}{1 + \frac{1-\psi}{\psi}\frac{\rho_f}{\rho_m}} \qquad \dots (2)$$

where
$\varphi$ is the volume fraction and ψ the weight fraction, ($\rho_f$) the fiber density and ($\rho_m$) the density of polyester.
The density of the blend is
determined using the relation:

$$\rho_m = X_1\rho_1 + X_2\rho_2 \qquad ... (3)$$

Where
$\rho_m$: the density of the matrix (polymer

blend).
$\rho_1$, $\rho_2$: the density of the first and the second polymers respectively.
$X_1$, $X_2$ : the percentages of the first and the second polymers respectively.
The investigation depends on tensile machine type (XHEAD100) to get the experimental results as shown in Figures (5, 6, 7,8,9,10,11, 12 and 13).

## RESULTS AND DISCUSSION

The experimental results of tensile test of composite material are shown in Figures (5,6,7,8,9,10,11, 12 and 13) in which the elastic modulus of composite material increases at approximate rate of (14.9%) as a result of increase in the concentration of salt in water (15%-55%) as shown in Table (3) , so that yield stress increases at approximate ratio of (55 % ).

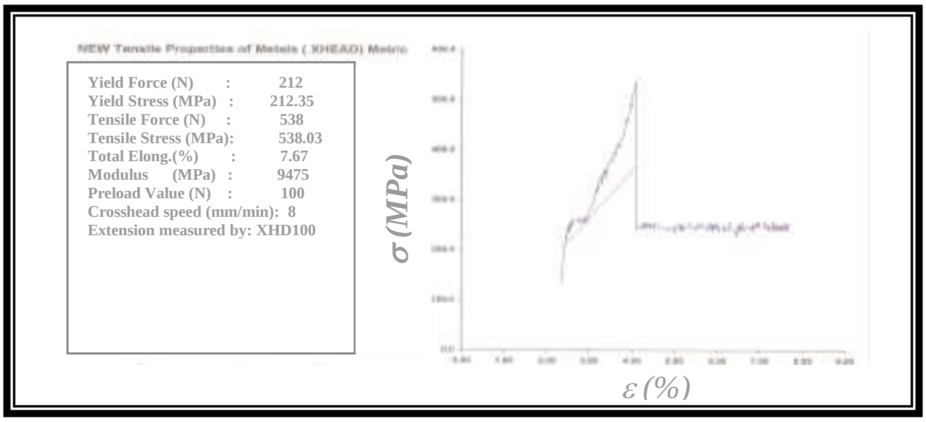



**Figure (5) the tensile test of polyester resin at (15%) salt concentrations ratio.**

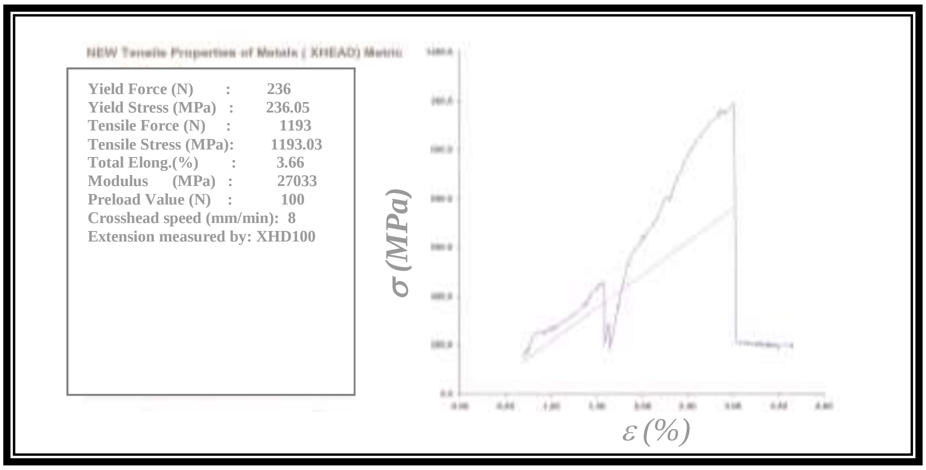



**Figure (6) the tensile test of composite material with volume fraction ($v_f$ =15%) at (15%) salt concentrations ratio.**

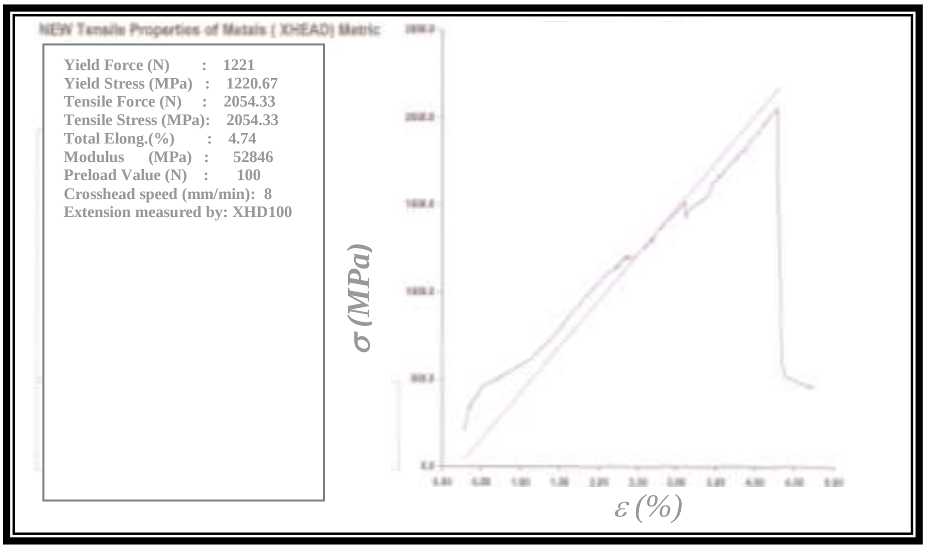



**Figure (7) the tensile test of composite material with volume fraction ($v_f$ =45%) at (15%) salt concentrations ratio.**

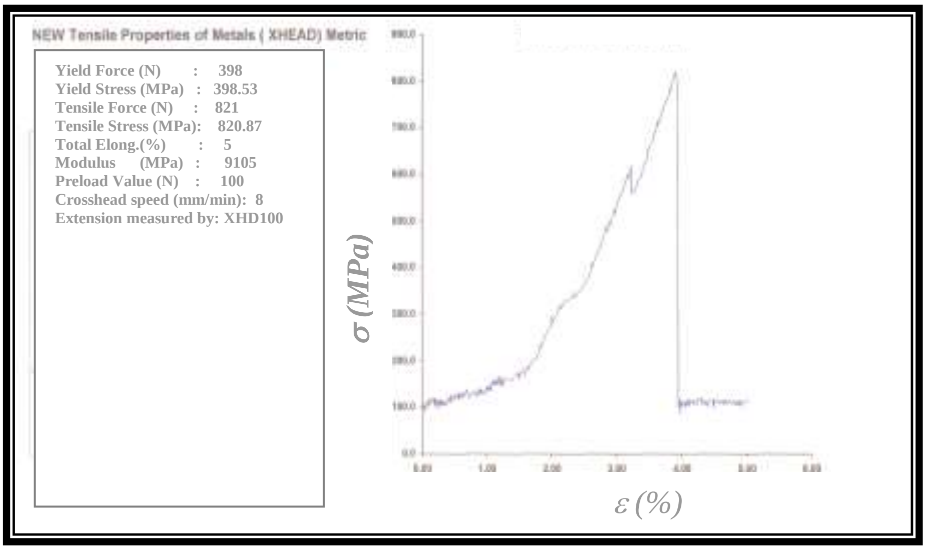



**Figure (8) The tensile test of polyester resin at (35%) salt concentrations ratio**

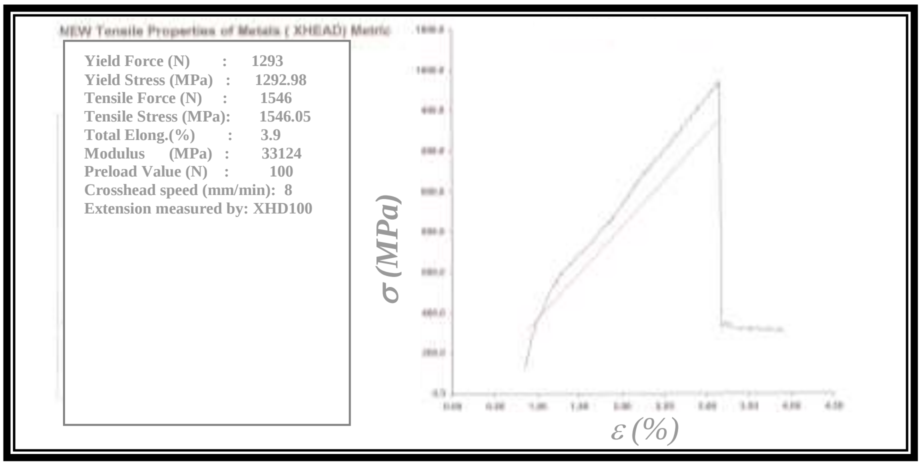



**Figure (9) the tensile test of composite material with volume fraction ($v_f$ =15%) at (35%) salt concentrations ratio.**

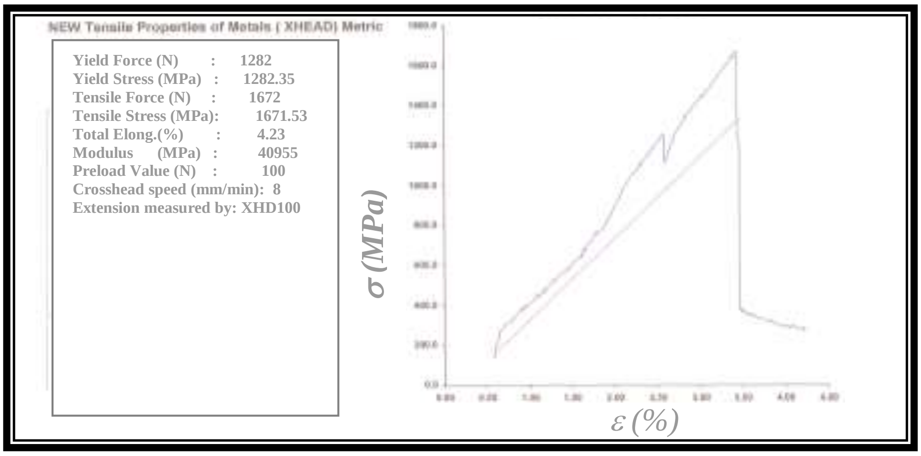



**Figure (10) the tensile test of composite material with volume fraction ($v_f$ =45%) at (35%) salt concentrations ratio.**

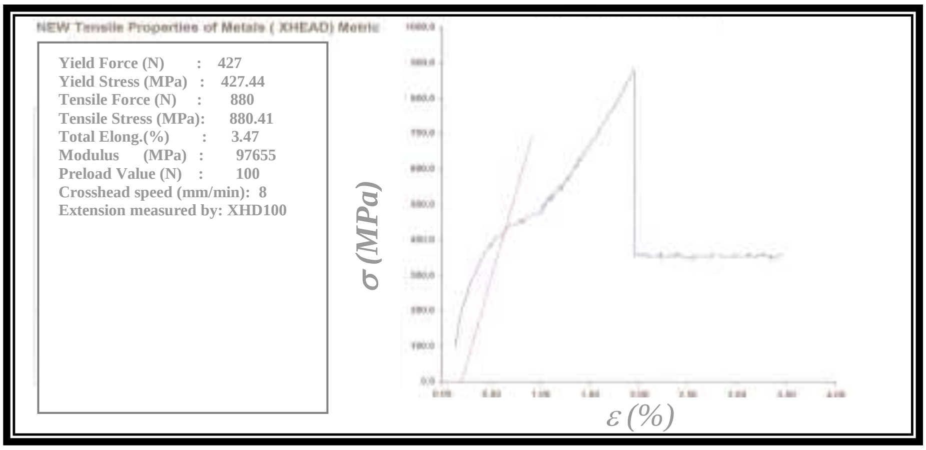



**Figure (11) the tensile test of polyester resin at (55%) salt concentrations ratio.**

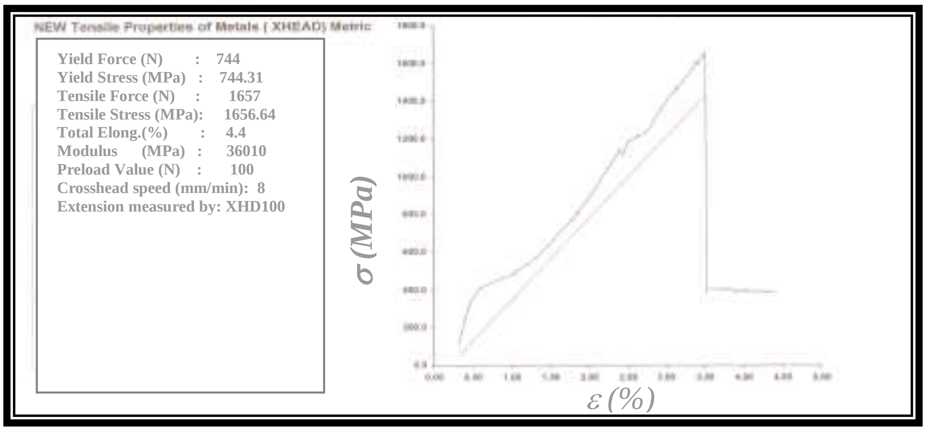



**Figure (12) the tensile test of composite material with volume fraction ($v_f$ =15%) at (55%) salt concentrations ratio.**

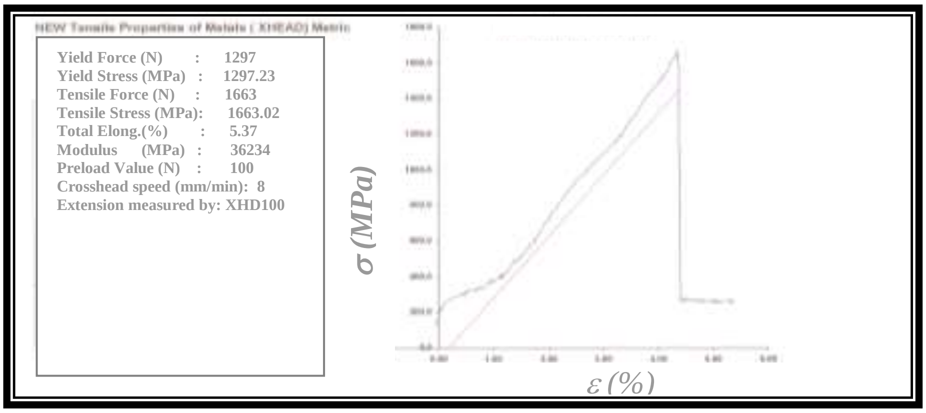



**Figure (13) the tensile test of composite material with volume fraction ($v_f$ =45%) at (55%) salt concentrations ratio.**

**Table (3) the elastic modulus at different volume fractions and salty concentration ratio.**

| *Salty concentration ratio* | *E Modulus(Gpa) polyester* | *E Modulus(Gpa) $V_f$=15%* | *E Modulus(Gpa) $V_f$=25%* | *E Modulus(Gpa) $V_f$=35%* | *E Modulus(Gpa) $V_f$=45%* |
|---|---|---|---|---|---|
| 0.15 | 9.475 | 27.033 | 31.996 | 34.012 | 40.846 |
| 0.35 | 91.05 | 45.705 | 32.898 | 34.18 | 42.955 |
| 0.55 | 97.655 | 46.26 | 33.816 | 34.616 | 45.587 |

The results are shown in Figure (14) in which the absorbent energy of composite material increases with increasing the salt concentration. The rate of increasing the absorbent energy due to increase in the salt concentration in the water is nearly constant when the composite material reaches saturated limit with salt therefore, the change in absorbent energy rate in the concentration of salt in the water ranges between (15%-35%) it is greater than the change in rate concentration of salt in the water which is at (35%-55%) as shown in Table (4).

**Table (4) the impact energy at different volume fraction and salty concentration ratio.**

| Salty concentration ratio | Impact energy (J) $V_f$=15% | Impact energy (J) $V_f$=25% | Impact energy (J) $V_f$=35% | Impact energy (J) $V_f$=45% |
|---|---|---|---|---|
| 0.15 | 130 | 131 | 132 | 134 |
| 0.35 | 132 | 133 | 135 | 136 |
| 0.55 | 133 | 133.5 | 136 | 136.5 |

The fracture toughness of composite material increases with increasing the volume fraction ($v_f$) of approximate rate of (2.9%) as a results of increasing the volume fraction from (15%) to (45%).

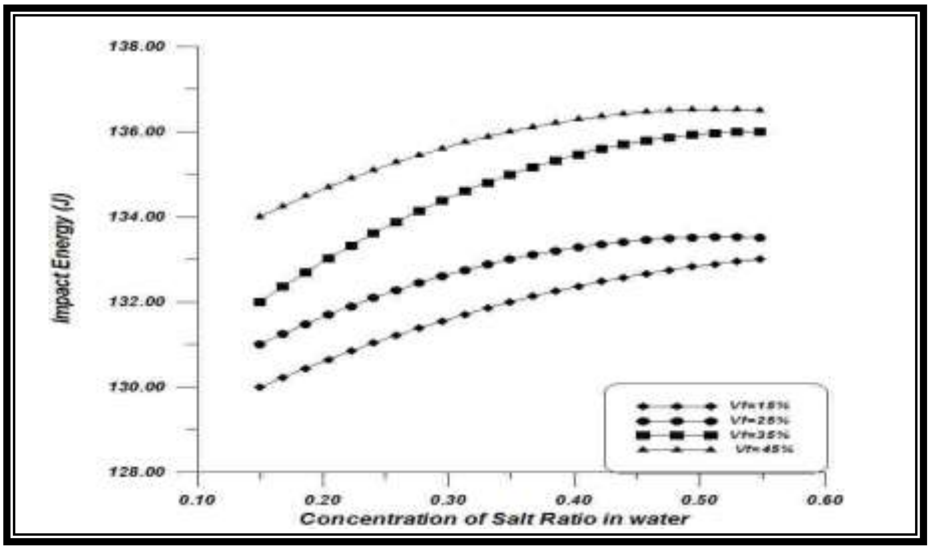



**Figure (14) the results of Charpy V-notch impact test for different volume fractions and concentrations of salt ratio.**

Figure (15) shows the relationship between the yield stress and salt concentration ratio at different volume fractions where the yield stress of composite material increases approximate at ratio of (42.6%) as a result of increasing the volume fraction ratio from (15%) to (45%) Table (5).

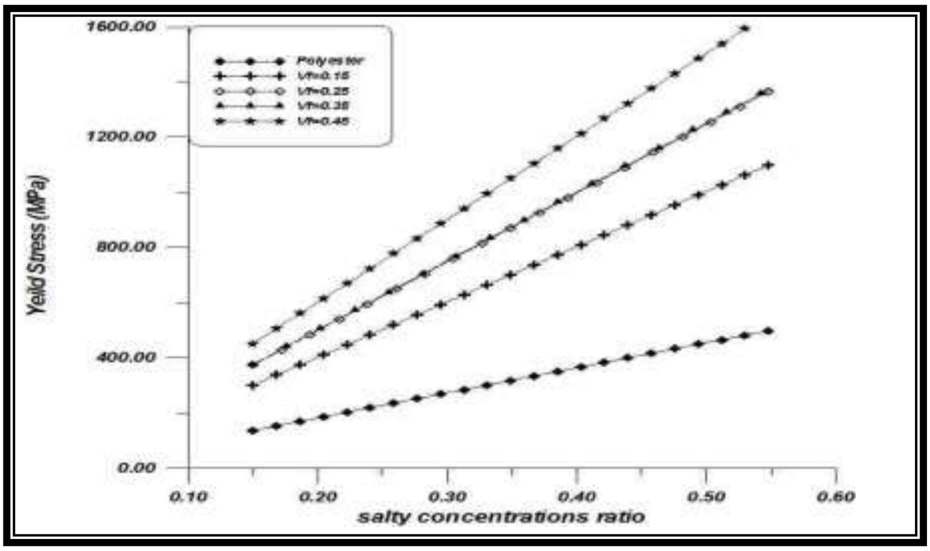



**Figure (15) the relationship between the salt concentration ratio and the yield stress at different volume fractions.**

**Table (5) The yield stress at different volume fraction and salty concentration ratio.**

| *Salty concentration ratio* | *Yield stress(MPa) polyester* | *Yield stress(MPa) $V_f$=15%* | *Yield stress(MPa) $V_f$=25%* | *Yield stress(MPa) $V_f$=35%* | *Yield stress(MPa) $V_f$=45%* |
|---|---|---|---|---|---|
| 0.15 | 212.35 | 236.05 | 279.38 | 296.58 | 1220.67 |
| 0.35 | 398.53 | 1292.98 | 1116.47 | 1088.82 | 1282.35 |
| 0.55 | 427.44 | 744.31 | 1248.32 | 1253.31 | 1297.23 |

Figure (16) shows the relationship between the elastic modulus and volume fraction of different salt concentration ratios in the environment where the elastic modulus increases with increasing the salt ratio.

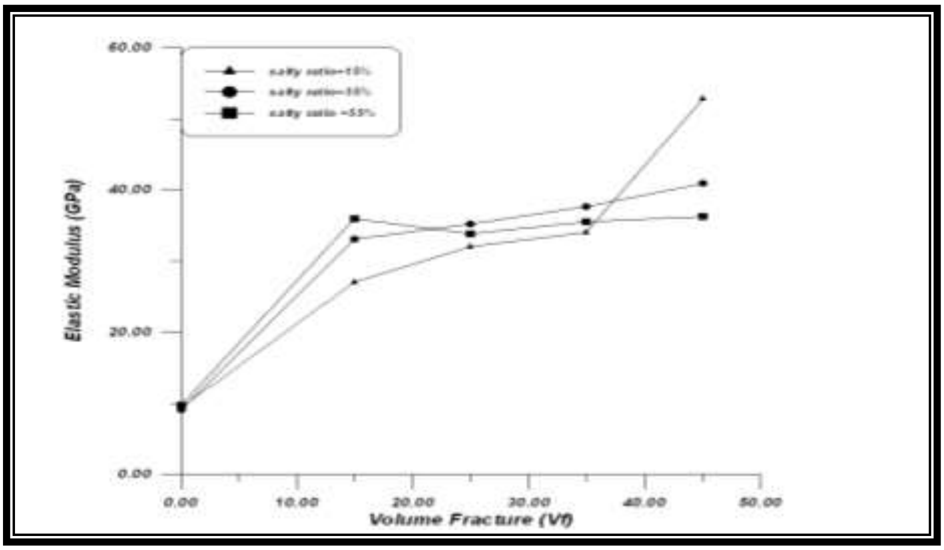



**Figure (16) the relationship between the elastic modulus and volume fraction at different salt concentration ratios.**

Figure (17) shows the elongation of polyester decreases at approximate ratio of (54.7%) which means decrease in the ductility of polyester while the composite material increases with average approximate ratio of (18.34%) (Increasing the ductility of composite material) due to increase in the salt concentration ratio from (15%-45%) see Figure (18).

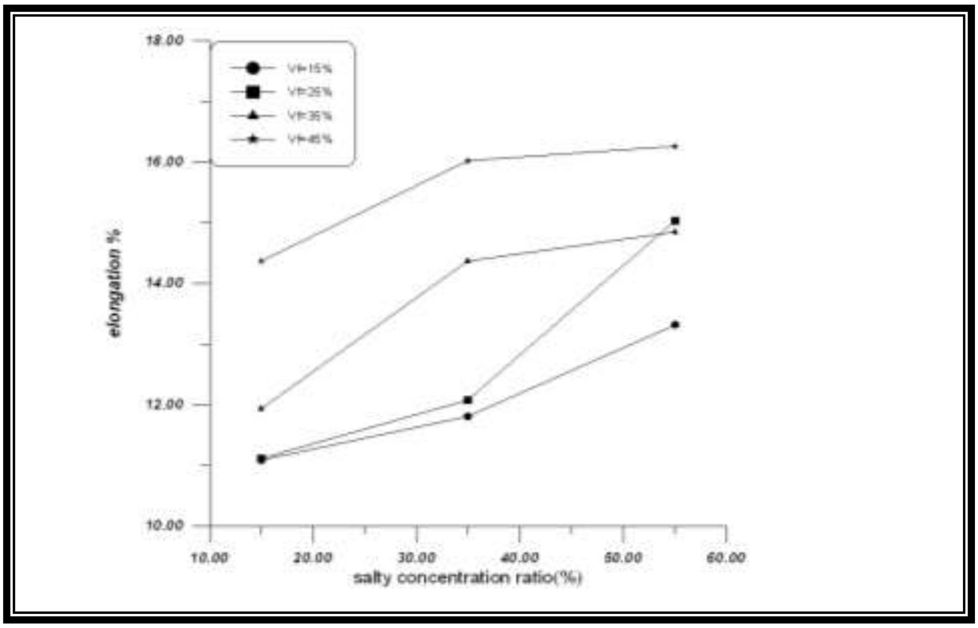



**Figure (18) the effects of salt concentration ratio on the elongation of composite material.**

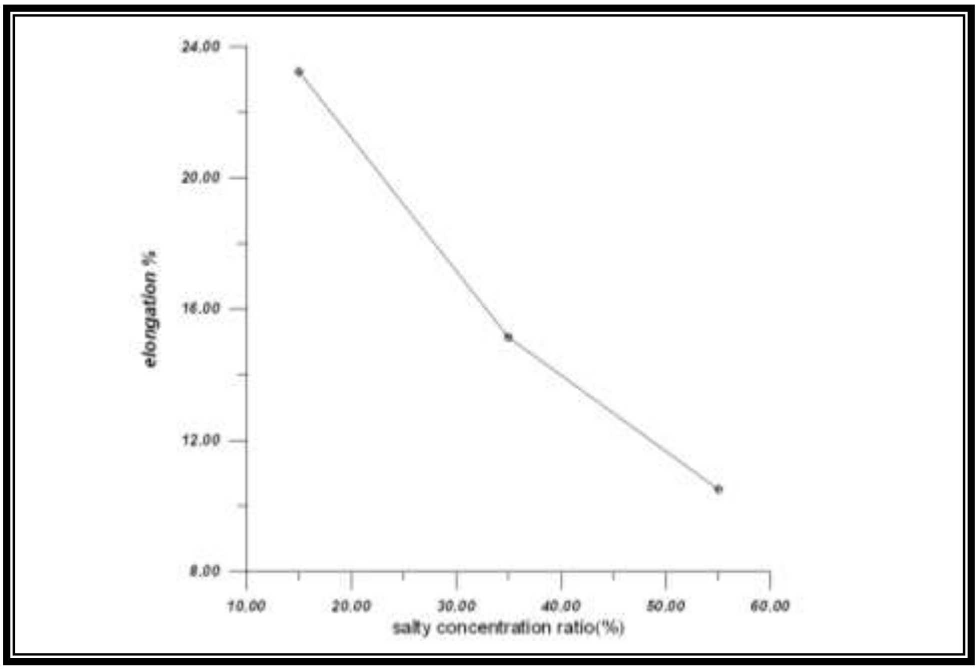



**Figure (17) the effects of salt concentration ratio on the elongation of polyester.**

## CONCLUSIONS

The following conclusions can be drawn from the results of experimental investigation into properties of composite material under different conditions:

- The fracture toughness of composite material increases at approximate ratio of (2.9%) and (2.25%) for polyester due to increase in the salt concentration in water at ratio is (40%) and it increase by approximately (3%) due to increases in the volume fraction at approximate ratio of (30%).
- The yield stress for polyester increases at approximate ratio of (50.32%) and for composite material it increases at average ratio of (55 %) due to increase in the salt concentration ratio in the water at approximate ratio (40%). So, the yield stress of composite material increases approximate at ratio of (42.6%) as a result of increasing the volume fraction ratio from (15%) to (45%).
- The elastic modulus of composite material increases at average ratio of (14.9%) and of (90.29%) for polyester due to increase in the salt concentration ratio in the water of approximate ratio of (40%).

It increases at average ratio of (13.73%) as a result of increasing the volume fraction at approximate ratio from (15%) to (45%).

- The elongation of polyester decreases with approximate ratio of (54.7%) while the composite material increases at average ratio of (18.34%) due to increase in the salt concentration ratio from (15%) to (45%).

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