Mechanical Properties for Polymer Hybrid Composites Reinforced by Fibers and Particles

Ruaa Haitham Abdel-Rahim
Materials Engineering Department,University of Technology/Baghdad.
Email:lolo-ru1982@yahoo.com

Received on:2/3/2014 & Accepted on:8/1/2015

ABSTRACT

The Mechanical properties of hybrid composites based on epoxy resin (ER) filled with metal powders (Al) and Glass fibers (GF) have been studied. The specimens are prepared using hand lay-up techniques according to ASTM standard for different volume fractions of fiber, particles & matrix material. Glass fibers (GF) are one of the most useful filler materials in composites, its major use being the manufacture of components in the aerospace, automotive, and leisure industries. The epoxy was reinforced with GF :(metal powders) in the ratio 10%:40%, 20%:30%, 30%:20%, and 40%:10%. It was observed that in the ratio 40%:10% has the maximum (UTS), fracture strength, flexural strength, fracture toughness and hardness are shown to increase with increase volume fraction fibers when compared to unfilled epoxy.

Keywords: Epoxy, Glass fibers, Hybrid composites, mechanical properties.

الخواص الميكانيكية لمتراكبات بوليمرية هجينة مقواة بالالياف والدقائق

الخلاصة

تم في هذا البحث دراسة الخواص الميكانيكية من متراكبات هجينة ذات اساس راتنج الايبوكسي مقواة بدقائق معدنية من الالمنيوم والياف الزجاج. العينات حضرت بطرية الصب اليدوي وفقا لمعيار ASTM لكسورحجمية مختلفة من الألياف والدقائق والمادة الاساس. الألياف الزجاجية (GF) هي واحدة من مواد حشو الأكثر فائدة في المواد المتراكبة، وتدخل في كثير من الصناعات منها صناعة الطائرات والسيارات، والصناعات الترفيهية. الايبوكسي كانت تقويته مع GF: MP في نسبة 10٪: 40٪، 20٪: 30٪، 30٪: 20٪، و 40٪: 10٪. لوحظ أنه نسبة 40%:10% تمتلك اقصى اجهاد شد, مقاومة كسر,مقاومة انحناء,متانة كسر وصلادة ونلاحظ تزداد مع زيادة الكسر الحجمي للالياف مقارنة مع الايبوكسي الغير مدعم .

INTRODUCTION

Composites are a blend of two or more components, the matrix material can be polymeric (e.g. polyester resins, epoxies), metallic or ceramic. When the filler and the matrix are combined to form a composite, they retain their individual

https://doi.org/10.30684/etj.33.3A.1
2412-0758/University of Technology-Iraq, Baghdad, Iraq

identities and structure influences the final composite properties. The resulting composite will usually be composed of layers of the filler and matrix stacked to achieve the desired properties in one or more directions [1]

Polymer composites are playing an increasing role as construction materials in a wide variety of applications. They are also increasingly gaining importance as substitute materials for metals in application with aerospace, automotive, marine, sporting goods and electronic industry. Their light weight and superior mechanical and electrical properties make them especially suited for some of these applications.

At the present, epoxy resins are widely used in various engineering applications, such as electrical industries, and commercial and military aircrafts industries. In order to improve their processing and product performances and to reduce cost, various fillers are introduced into the resins during processing[2].

Moloney et al. (1983) studied the mechanical properties for different types of composite materials that include epoxy resin reinforced with silica particles and epoxy reinforced with particle of aluminum oxide. They noticed that the value of the Elastic Modulus increases with increasing the volume fraction of particles (silica and aluminum oxide) [3].

Amiya Kumar et al., (2010) developed an epoxy based hybridized composite material comprising of glass fiber, jute fiber andred mud as filler material and evaluated its mechanical properties and observed that Flexural strength, tensile strength and density of the material increases with increase in number of layers of reinforcement[4].

Karim J. S. et. al., (2011), have prepared a polymer – metallic (composite material) reinforced by aluminum particles with different grain size and various volume fraction. Using filing particles from aluminum with a grain size (13 µ*m*), and aluminum dust particles. The results show that the mechanical impact resistance of the composite material reinforced particle dust increases with increasing the volume fraction, reaching a maximum value of (81.25 kJ/m^2) when the volumetric fraction is (9.2%). While the composite material reinforced aluminum particle (Refrigerator) also increases with increasing volumetric fraction, but less than in the composite material reinforced aluminum dust a few particle which is (63.158 kJ/m^2) when the volumetric fraction was (9.2%)[5].

Objectives of The Research

The objective of this research is to:

1- Prepare composites of epoxy resin reinforced with glass fibers and metal powders Al.

2- Study of some mechanical properties (UTS, fracture strength, flexural strength, fracture toughness and hardness.

Experimental Work

Materials Used

The basic materials used in the preparation of research samples consisting of Mat Glass fibers(GF) from the Tenax company_ England, Table 1 Show Typical Properties of Fibers Glass. And the epoxy resin used has the number 105 as a specification, manufactured by Ayla Construction Chemicals under license from DCP, England, with a density 1.4 g/cm^3.

Fibers Glass	Young's modulus(GPa)	Tensile strength(MPa)	Elongation (%)	Density (gm/cm^3)
	72	3450	4.3	2.58

Table (1): Typical Properties of Fibers Glass.

Preparation of Composites

The composites samples were prepared from Epoxy resin reinforced with Glass fibers and Aluminum particles in the ratio 10%:40%, 20%:30, 30%:20%, 40%:10%. The method used in the preparation of the samples in this research is the (Hand lay-Up Molding) because it is simple to use and can make different shapes and sizes of composites. Samples are then extracted from the mould and then heat treated in an oven at (60^{o}C) for a period of (60) minutes [6]. This process is very important for the purpose of obtaining the best cross Linking between polymeric chains, and to remove the stresses generated from the preparation process and complete the full hardening of the samples.

Mechanical Test

Tensile Test Measurement

The samples for tensile testing were prepared according to the ASTM D-638. At room temperature with 20KN applied load and strain rate of 0.5 mm/min by using the machine type WDW-200E, Chinese made. For each specimen three tensile test measurements were taken and the average tensile is calculated.

Flexural Strength& Shear Stress

This test is performed according to (ASTM D790) at room temperature by three- point bending test machine (Lybold Harris No.36110).Samples have been cut into the dimensions(100*10*4.8) mm^3.

The flexural strength & maximum shear stress are calculated according to the equations [7,8]

$$F.S = 3PL/2bh^2 \quad \text{.... (1-1)}$$

$$\tau = 3P / 4bd \quad \text{.... (1-2)}$$

Where

F.S: flexural strength (MPa).
P: force at fracture (N).
L: length of the sample between Predicate (mm).
b:thikness(mm).
d:width(mm).
τ:maximum shear stress (MPa)
P: force at fracture (N).
b:thikness (mm).
d:width (mm).

Impact Test

Impact resistance is calculated for samples from the following relationship [9].

$$Gc = Uc / A \qquad \ldots(1\text{-}3)$$

Where

G_c: impact strength of material (J/m^2).

Uc : impact energy (J).

A: cross- sectional area of specimen (m^2).

Fracture toughness can be expressed as [8].

$$K_c = \sqrt{G_c E} \qquad \ldots.(1\text{-}4)$$

Where:

K_c: fracture toughness of material (MPa.$m^{1/2}$).

E: elastic modulus of material (MPa).

This test is performed according to (ISO- 180) at room temperature. Samples have been cut into the dimensions (80*10*4) mm^3.

Hardness Test

The hardness test was carried out using a Shore D hardness tester, with a measuring range 0-100 Duron at room temperature.The machine was manufactured by DTS with model T02E0392 and ASTM 2240. Samples have been cut into a diameter of (40mm) and a thickness of (5mm).

Results and Discussion

Tensile Strength

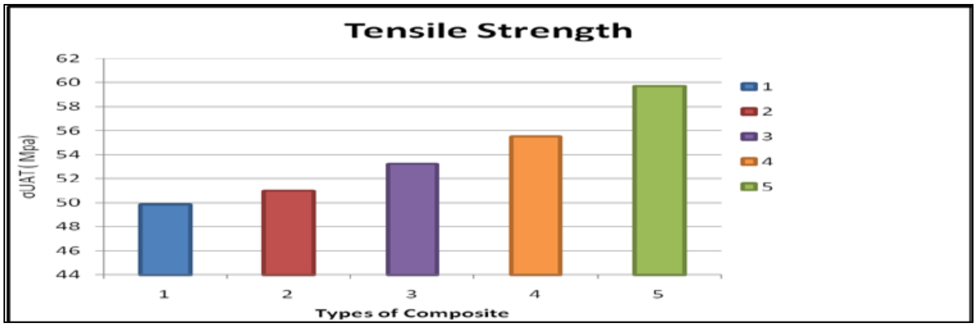
Table 2 and Figures (1, 2) shows the resulted values of ultimate tensile strength (σ_{UTS}) and fracture strength for pure Epoxy and hybrid composites. In general, it shows that the hybrid composites had gave the higher values of σ_{UTS} and fracture strength than none reinforced (Pure epoxy).

The increase in volume fraction of fibers results in increase in ultimate tensile strength (σ_{UTS}) and fracture strength. Fibers are the main load carrying agents in composites and as the number of load carrying elements increases in a material, its strength increases [10] At the same time the tensile strength of the composite is influenced by the strength and modulus of fibers [11].

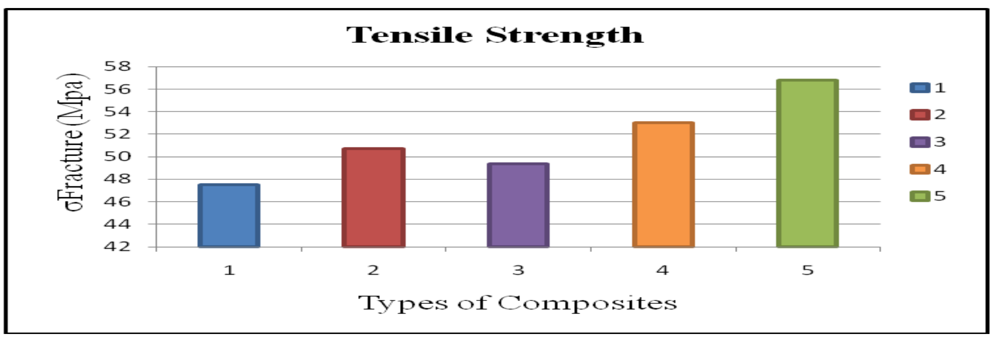
Type of composite	σ UTS (MPa)	σ fracture (MPa)

Table (2): values of ultimate tensile strength (σ_{UTS}) and fracture strength for Epoxy and hybrid composites.

1-Pure Epoxy	49.841	47.502
2-Epoxy +10%GF+40%Al	51.015	50.743
3- Epoxy +20%GF+30%Al	53.241	49.365
4- Epoxy +30%GF+20%Al	55.520	53.002
5- Epoxy +40%GF+10%Al	59.681	56.790



Figure(1): Ultimate tensile strength of : 1-Pure Epoxy2- Epoxy +10%GF+40%Al 3-Epoxy +20%GF+30%Al4- Epoxy +30%GF+20%Al 5- Epoxy +40%GF+10%Al



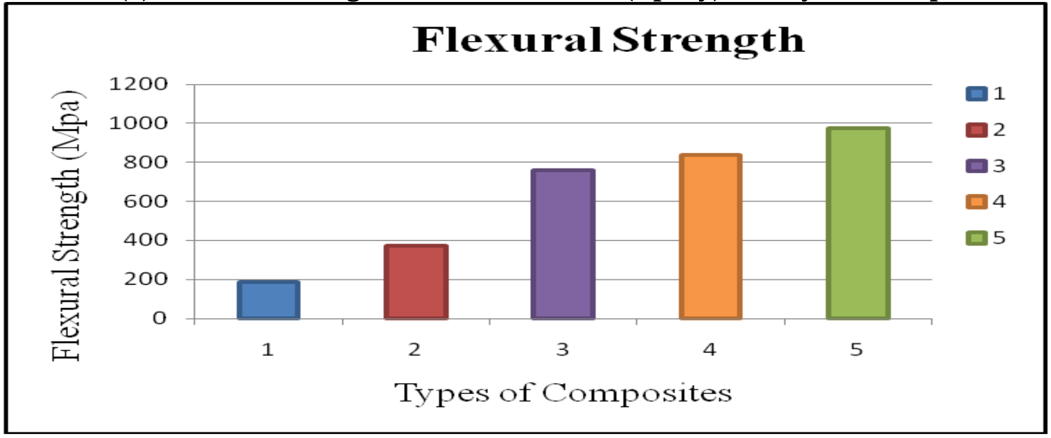
Figure(2): Fracture strength of : 1-Pure Epoxy 2- Epoxy +10%GF+40%Al 3-Epoxy +20%GF+30%Al 4- Epoxy +30%GF+20%Al 5- Epoxy +40%GF+10%Al

Flexural Strength& Shear Stress

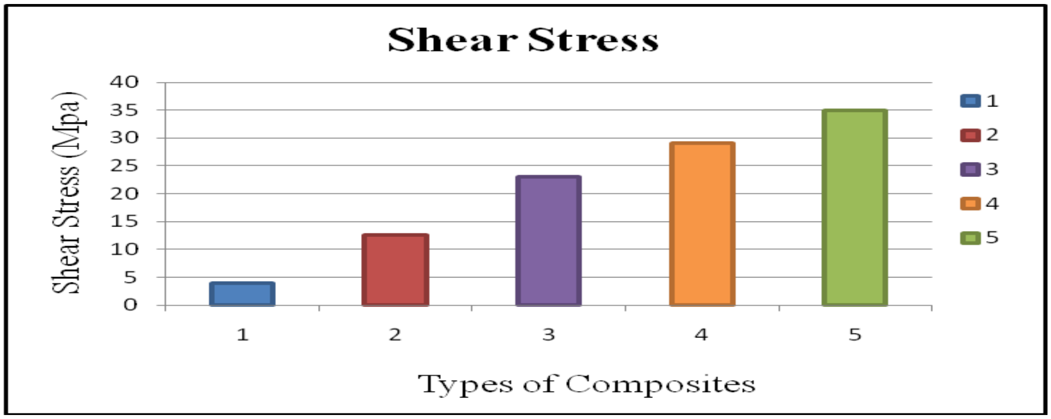
Table (3) and Figures (3, 4), show the values of flexural strength & maximum shear stress for pure Epoxy and hybrid composites. The use of fibers and particles in hybrid composites gives the higher strength in due to their higher hardness and even higher in 40%Gf+10%Al due to the using of more fiber volume fraction.

Adhesive between matrix and reinforcing material has a large effect in giving the maximum shear stress that load to increase shear stress of (particle/ fiber) reinforced (Epoxy) to a higher amount than that of (Epoxy) specimen alone [11].

Table (3): Flexural strength & shear stress for (Epoxy) and hybrid composites.



Figure(3): Flexural strength of : 1-Pure Epoxy, 2- Epoxy +10%GF+40%Al 3- Epoxy +20%GF+30%Al 4- Epoxy +30%GF+20%Al 5- Epoxy +40%GF+10%Al



Figure(4): Shear stress of :1-Pure Epoxy 2- Epoxy +10%GF+40%Al 3-Epoxy +20%GF+30%Al 4- Epoxy +30%GF+20%Al 5- Epoxy +40%GF+10%Al

Impact Energy

Table (4) and Figures (5, 6), shows the values of impact strength (G_c) & fracture

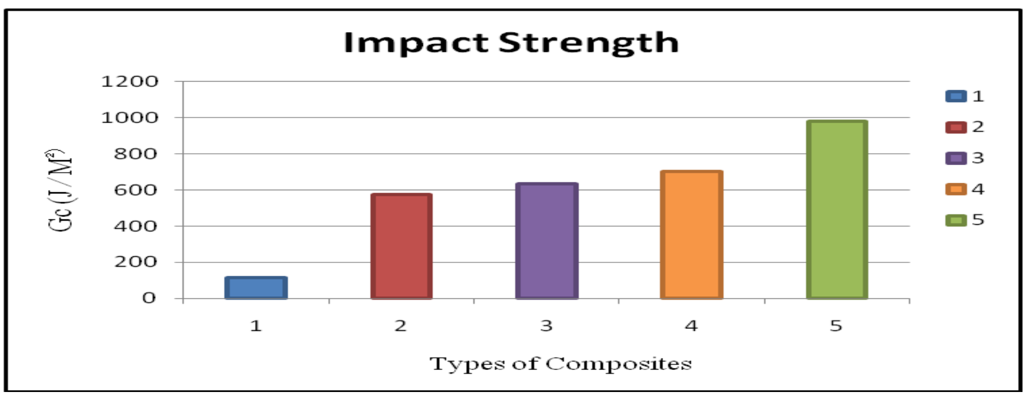
Type of composite	Flexural Strength (MPa)	Shear Stress(MPa)
1-Pure Epoxy	188	4
2-Epoxy +10%GF+40%Al	370	12.5
3- Epoxy +20%GF+30%Al	758	23
4- Epoxy +30%GF+20%Al	840	29
5- Epoxy +40%GF+10%Al	976	35

toughness (K_c) for pure Epoxy and hybrid composites. The results of (G_c) & (K_c) for pure Epoxy are lower than that of hybrid composites. The reinforcements affect positively in bearing impact load and increasing the impact energy required to fracture the specimen.

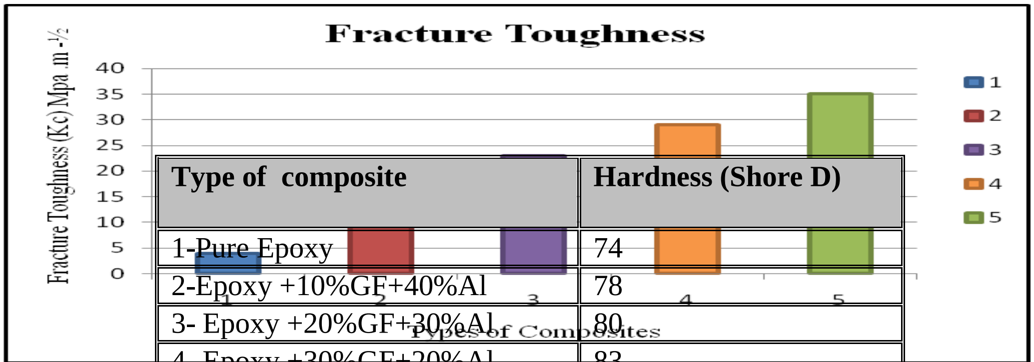
Type of composit	Impact Strength (Gc) J / m^2	Fracture Toughness (Kc) MPa .$m^{1/2}$
1-Pure Epoxy	115	6.5
2-Epoxy +10%GF+40%Al	577	11.51
3- Epoxy +20%GF+30%Al	634.4	30.45
4- Epoxy +30%GF+20%Al	701.34	32.764
5- Epoxy +40%GF+10%Al	978	35.210

It is important to note that (GF) have high shock resistance and durability. Also the addition of particles during composite preparation can lead to form a high viscose mixture that may lead to decrease resin wettability which in turn weakening the linkage between matrix and reinforcement and that is an additional reason for the lower results of particle composites.

Table (4): Impact strength of material & fracture toughness for (pure Epoxy) and hybrid composites



Figure(5): Impact strength of : 1- Pure Epoxy 2- Epoxy +10%GF+40%Al 3- Epoxy +20%GF+30%Al 4- Epoxy +30%GF+20%Al 5- Epoxy +40%GF+10%Al



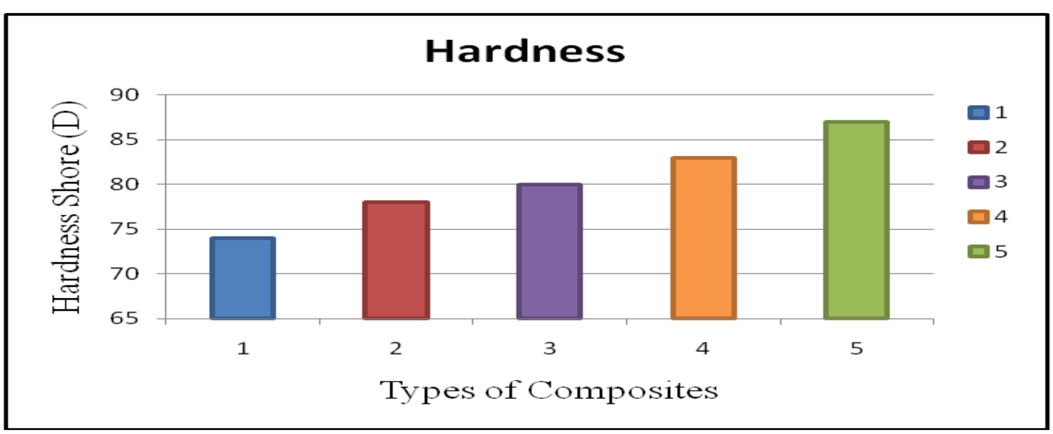
Figure(6): Fracture toughness of : 1- Pure Epoxy 2- Epoxy +10%GF+40%Al 3- Epoxy +20%GF+30%Al 4- Epoxy +30%GF+20%Al 5- Epoxy +40%GF+10%Al

Hardness Shore (D)

The results of Shore (D) hardness for the pure Epoxy and hybrid composites are illustrated in Table (5) and Figures (7). It shows that the hybrid composites have the higher hardness and it increases with increasing the fiber volume fraction. It can be seen that the added 40% metal particles have given lower hardness than other composites because of the latter higher plasticity.

Table (5): Hardness for (pure Epoxy) and hybrid composites.

Type of composite	Hardness (Shore D)
1-Pure Epoxy	74
2-Epoxy +10%GF+40%Al	78
3- Epoxy +20%GF+30%Al	80
4- Epoxy +30%GF+20%Al	83
5- Epoxy +40%GF+10%Al	87



Figure(7): Hardness of : 1- Pure Epoxy 2- Epoxy +10%GF+40%Al 3- Epoxy +20%GF+30%Al 4- Epoxy +30%GF+20%Al 5- Epoxy +40%GF+10%Al

Conclusions

This work shows that successful fabrication of pure epoxy and component hybrid composite (using epoxy as matrix, mat glass fibers and metal particles (AL) as reinforcement). Incorporation of these fillers modifies the mechanical properties of the composites.

(Epoxy +40%GF+10%Al) has the maximum (UTS) and fracture strength (59.681, 56.790)MPa respectively, flexural strength, shear(976,35)MPa respectively, impact strength(978J/ m^2), fracture toughness(35.210MPa.$m^{-1/2}$) and hardness (87 shore D)are shown to increase with increase volume fraction fibers when compared to unfilled epoxy.

REFERENCES

[1]. Subita, B. and Pardeep, K.," Effect of Graphite Filler on Mechanical Behaviour of Epoxy Composites", International Journal of Emerging Technology and Advanced Engineering, Vol.3, 2013,PP. 664-665.

[2]./Huang Z. M., "Tensile Strength of fibrous Composites at Elevated Temperature", J. Materials Science and Technology, January, vol. 16.81-9.5, 2000.

[3]. Moloney, A. C., Kausch, H. H. and Stieger, H. R., "The Effect of Particulate-Filled Epoxide Resins", Journal of Material Science, Vol.18, 1983, pp 208-216.

[4]. Amiya Kumar Dash, D.N.Thatoi and M.K.Sarangi,"Analysis of the mechanical characteristics of red mud filled hybridized composite", Frontiers in Automobile and Mechanical Engineering, pp: 8-11, 2010.

[5]. Karim J. S. , Jassim A. S. & Naji Z. H. ,"Studying of thermal conductivity and impact Strength for unsaturated polyester material reinforced by Aluminum particles" Journal of Material Science , Iraq, (2011), PP. 1.

[6]. J. McColm " Ceramic Science for Materials Technologists ", Leonard Hill, New York, (1983).

[7]. Annual Book of ASTM Standard, "Standard Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics ", D 790- 86, Vo. 10.01, (1986).

[8]. Tomas R., Meng J.& Latta M. A.," Physical Properties of Four Acrylic Denture Base Resins", The Journal of Contemporary Dental Practice, Vo. 6, N. 4,(2005),PP. 3.

[9]. Sideridis E.& Papadopoulos G. A.," Short-Beam and Three- Point- Bending Tests for the Study of Shear and Flexural Properties in Unidirectional-Fiber- Reinforced Epoxy Composites", National Technical University of Athens, Vo.93,(2004),PP. 64.

[10]. Editer S. M. L.," International Encyclopedia of Composite", VCH Publishers, (1990).

[11]. Van den Heuvel PVD, Peijs T, Young RJ. In: The Sixth Int. Conf. on Comp. Interf.,Israel, May 1996.

[12]. Deaa B. M. & Abdel-Hussein H. J.," Wear Resistance for Thermosetting Polymer Blend", Eng. & Tech. Journal, Vo.27, N.14,(2009), PP.512.(In Arabic).