Effect of Chemical Solutions on Mechanical Properties of Epoxy Composite Reinforced With Glass Fibers

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Abstract

Hand lay-up molding is used for preparing sheets of epoxy composites reinforced with chopped strand mat (randomly direction) glass fibers by weight fraction of (44%). The sheets were left to solidify at room temperature (23± 2) ˚C. The samples immersed in (HCL, KOH, distilled water, Benzene, and Kerosene) for equal period of time at constant temperature (23± 2) ˚C. The impact and compressive strength were calculated for the samples before and after immersion in different chemical solutions.

The results shown that the impact strength of the samples that immersed in (HCL, KOH) solutions were decreased after immersion, while the impact strength of the samples immersed in (distilled water, Benzene, Kerosene) were increased after immersion.The results showed also that the compression strength of the samples immersed in (HCL, KOH, distilled water) decreased after immersion, while the compressive strength of the samples immersed in (Benzene, Kerosene) were increased after immersion. Finally the results showed that the maximum relative mass gain (minimum absorption resistance) was of the samples immersed in (HCL) solution in both impact and compression test. While the minimum relative mass gains (maximum absorption resistance) was of the samples immersed in (KOH) solution in both tests

تأثير المحاليل الكيميائية على الخواص الميكانيكية لمتراكبات الايبوكسي المقواة بألياف زجاجية

الخلاصة

استخدمت تقنية القولبة اليدوية لتحضير الواح من متراكبات الايبوكسي المدعمة بالالياف الزجاجية العشوائية الاتجاه بكسر وزني (44%). تركت الالواح لتجف في درجة حرارة الغرفة (23± 2)م^{o} . تم غمر النماذج في محاليل (HCL, KOH, distilled water, Benzene, Kerosene),) لفترات زمنية متساوية في درجة حرارة الغرفة. تم حساب مقاومة الصدمة ومقاومة الانضغاط لجميع النماذج قبل وبعد الغمر في المحاليل الكيمياوية.

أظهرت النتائج ان مقاومة الصدمة تقل للنماذج المغمورة قي HCL, KOH بعدالغمر بينما تزداد مقاومة الصدمة للنماذج المغمورة في (الماء المقطر والبنزين والكيروسين) بعد الغمر. و أظهرت النماذج ان مقاومة الانضغاط تقل للنماذج المغمورة في (الماء المقطر وHCL, KOH) وتزداد مقاومة الانضغاط للنماذج المغمورة في (البنزين والكيروسين) بعد الغمر.اخيرا اظهرت النتائج ان النماذج المغمورة في محلول HClهي الاقل مقاومة للامتصاصية بينما النماذج المغمورة في KOH هي الاعلى مقاومة للامتصاصية في كل من الصدمة والانضغاطية.

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Introduction

Composite materials are materials which are made by artificially combining two or more components, thus interface are present in a composite material [1].Many composites used today are at the leading edge of materials technology with performance and costs appropriate to ultra demanding applications such as spacecraft. But materials combining the best aspects of dissimilar constituents have been used by nature for million of years [2].

Traditional advanced polymer-matrix composites are materials usually consisting of highly continuous fibers in a polymeric matrix, the fiber most often glass sometimes Kevlar, carbon the matrix is usually a thermoset like an epoxy resin, unsaturated polyester and vinylester [3]. The unidirectional alignment results in an anisotropic property profile- high strength and high stiffness in fiber orientation direction and sometimes comparatively poor mechanical behavior perpendicular to the fiber axis [4]. Many composite properties are strongly dependent on the arrangement and distribution of fibers, this expression encompasses intrinsic features of the fibers, such as their diameter and length, as well as the volume fraction of fibers and their alignment and packing arrangement [5]. The resistance to failure under impact loads is one of the most critical properties of plastics. The impact energy is affected by a number of factors such as yield strength, ductibility, notches, temperature, strain rate, and fracture mechanism [6]. Compression stress-strain may be conducted in service forces are of this type. A compression test is conducted in a manner similar to tensile test except that the force is compressive and the specimen contracts along the direction of the stress. Compressive tests are used when a material behavior under large and permanent strains is desired as in manufacturing application or when the brittle material is in tension [7].

Polymeric matrix composites differs from other materials in the sense that low-molecular weight substances such as water may easily migrate even at room temperature generating a vibration of the materials structure, morphology, and composition. This phenomenon occurs only in the matrix or in the fiber-matrix interface since the solutions can not penetrate the fiber [8]. The epoxy matrix show moisture sensitivity due to interactions between some polar groups of the macromolecules and the solution molecules, which leads to a reduction of both glass transiting (Tg) and mechanical properties, this sensitivity increases with the increasing degree of cross-linking and the polarity concentration of the molecular groups, the physical phenomena that occur are dissolution, diffusion, swelling and relaxation together with deformation and stress build up in the matrix [9].

Many synthetic organic polymers are oxidized in contact with the atmosphere, at room temperature in the absence of light the reaction may be very slow, but at elevated temperatures or during exposure to

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ultraviolet light the rate of oxidation is often quite rapid.

Oxidation of a polymer usually leads to increasing brittleness and deterioration in strength as well as a yellowing in color. Clearly the utility of a polymer for a particular application may depend on its resistance to oxidation.

The oxidation degradation of an organic polymer generally proceeds through free- radical reaction, free radicals are formed by the thermal or photolytic cleavage of bonds. The radicals then react with oxygen to yield peroxides and hydroperoxides, such reactions leads to both chain cleavage and cross- linking [10].

The aim of this work is to study the effect of aggressive solutions on some mechanical properties of epoxy reinforced with E-glass fibers.

Experimental work

- Epoxy resin type (DGEBA) was used with its hardener in ratio (3:1).
- The glass fibers used for reinforcing the epoxy resin was chopped standard mat (E- glass) with surface density of (0.277 Kg/m^2).
- Hand lay-up technique was used to prepare sheets of epoxy composites reinforced with (randomly direction) glass fibers with weight fraction equal to (44%).
- The sheets were left to solidify at room temperature (23+2) ˚C for 24 hours.
- Epoxy composites with standard dimensions (ISO -179) for impact test and (ASTM-D695) for compression strength test were prepared.

The impact strength is calculated by applying the relation ship:

$$I.S. = E_f / A \quad \ldots\ldots (1)$$

Where:

E_f : the fracture energy (joule) which is determined from charpy impact test instrument.

A: cross section area of the specimen.

And the compressive strength was calculated from the following relation:

$$C_s = 2F/ A \quad \ldots.. (2)$$

Where:

Cs: compressive strength.

F: the load applied on the sample.

A: cross section area of the sample before deformation.

Simple way used for studying solutions effect on DGEBA composites reinforced with E-glass fibers include the immersing an initially dry samples in different solutions at constant temperature for equal period of time and recording weight gain.

The solutions used in this study were kerosene, benzene; distilled water, and (KOH, HCL) both with normality (0.5).

The relative mass gain can be obtained by:

$$M\% = \frac{\text{mass wet} - \text{mass dry}}{\text{Mass of dry sample}} \times 100 \quad \ldots (3)$$

Result and Discussion

1. Impact Test

Impact test was introduced for the samples before immersion and after immersion the samples in different chemical solutions.

All the samples reinforced with E-glass fibers which have good ability to absorb large share of impact stresses and kinetic energy so fibers role should be crack stopper [11].

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The results in table (1) shown that the impact strength of the samples immersed in (HCL, KOH) decreased after immersion due to the effect of (HCL, KOH) in breaking the hydrogen bond between polymer chains and interfacial bonds in the interface between fibers and epoxy resin, therefore the composite become more brittle than before immersion. While we notice that the impact strength of the samples immersed in (distilled water, Benzene, Kerosene) increased after immersion because of the hydroxide groups in those solutions making the composite more ductile and can absorb more energy before fracture [12].

2. Compression test

The style of failure in compression test differs from impact test according to the type of fiber and the matrix materials knowing that the stress in this test is slowly imposed and not quickly as in the impact test and the dominant style of failure on specimen is the shearing style, bending the atom level in an angle before the final failure happens [13].

From the result shown in table (3) the compression strength of the samples immersed in (HCL, KOH, distilled water) decreased after immersion because of that polymers are permeable and may allow looser contamination into polymeric structures such as adhesive joints or fiber-reinforced composites and cause weakening and as a result the mechanical properties will decreases [14].While compression strength of the samples immersed in (Benzene, Kerosene) increased after immersion because of relaxation the polymer chains will increase the movement of the chains and acts as a plasticizer increasing the ductibility of the composite and leads to an increase in the compression strength of the composite [15].

From the results in table (2), Fig (2) & table (4), Fig (4). The relative mass gain of the samples in both impact and compression test increased with increasing the immersion time.

The maximum mass gain in both tests was of the samples immersed in (HCL) solution as a result of hydrogen bonding between epoxy hydrophilic groups with hydrogen in (HCL) solution, and the minimum mass gain in both tests was of the samples immersed in (KOH) alkali solution, and the others had relatively mass gain between them [16].

Conclusions

- The impact strength of epoxy composite reinforced with chopped glass fibers decreased after immersion in (HCL, KOH) solution, while the impact strength of the same samples increased after immersion in (distilled water, kerosene, Benzene) solution.
- The compressive strength of epoxy composite reinforced with chopped glass fibers decreased after immersion in (HCL, KOH, distilled water), while the compressive strength of the same samples increased after immersion in (Benzene, Kerosene) solution.
- The maximum mass gain (minimum absorption resistance) was of the samples immersed in (HCL) solution in both impact and compression test, while the minimum relative mass gain

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(maximum absorption resistance) was of the samples immersed in (KOH) solution in both test.

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Table (1) Impact strength of the samples before and after immersion

Samples No.	Samples description	E (Joul)	A (mm^2)	I_s (KJ/m^2)
1	Before immersion	4.2	55	76.363
2	Immersed in HCL	3.8	55	69. 909
3	Immersed in KOH	3.6	55	65.454
4	Immersed in distilled water	5	55	90.909
5	Immersed in Benzene	5.4	55	98.181
6	Immersed in Kerosene	5.6	55	101.818

Table (2) Changing the relative mass gain of the impact samples as a function of time

samples	Solution	M_1%	M_2%	M_3%	M_4%	M_5%	M_6%
1	HCL	0.1700	0.2088	0.2432	0.2749	0.3176	0.3530
2	KOH	0.0971	0.1045	0.1137	0.1159	0.0963	0.1003
3	Distilled water	0.1081	0.1103	0.1132	0.1133	0.1149	0.1207
4	Benzene	0.0744	0.0794	0.1036	0.1398	0.1596	0.1714
5	Kerosene	0.1522	0.1490	0.1509	0.1495	0.1500	0.1516

Table (3) Compressive strength of the samples before and after immersion

Samples No.	Samples discretion	F (N)	A (mm^2)	Cs (N/mm^2)
1	Before immersion	3700	39.55	93.552
2	Immersed in HCL	1800	39.55	45.5120
3	Immersed in KOH	2600	39.55	65.7395
4	Immersed in distilled water	3000	39.55	75.8533
5	Immersed in Benzene	3600	39.55	94.0240
6	Immersed in Kerosene	3800	39.55	96.0809

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Table (4) Changing the relative mass gain of the compression samples as a function of time

samples	Solution	M_1%	M_2%	M_3%	M_4%	M_5%	M_6%
1	HCL	0.3115	0.3701	0.4183	0.4612	0.5048	0.5078
2	KOH	0.0942	0.1027	0.1117	0.1157	0.1232	0.1332
3	Distilled water	0.2404	0.2434	0.2471	0.2476	0.2539	0.2564
4	Benzene	0.2422	0.2773	0.3220	0.3729	0.4023	0.4185
5	Kerosene	0.1489	0.1456	0.1476	0.1466	0.1469	0.1466

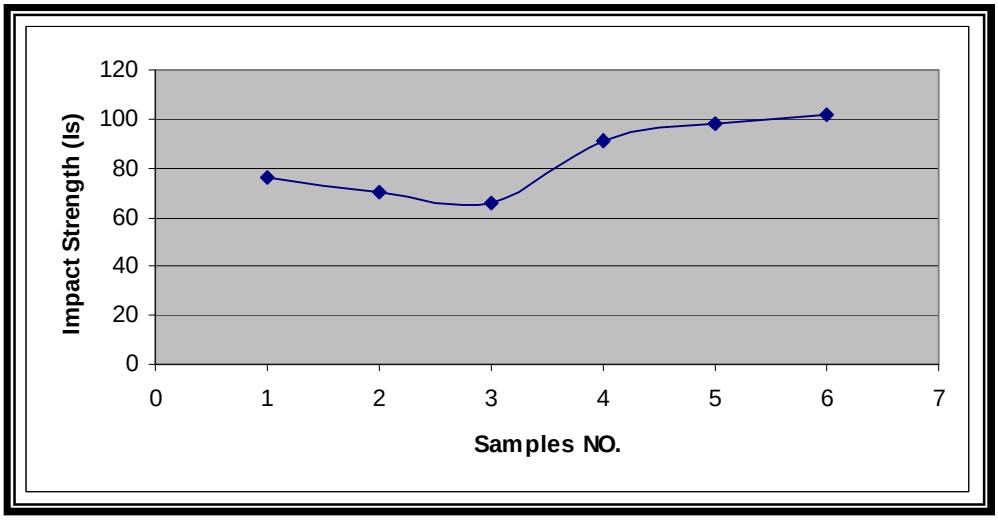

Figure (1) Impact strength of the samples before and after immersion

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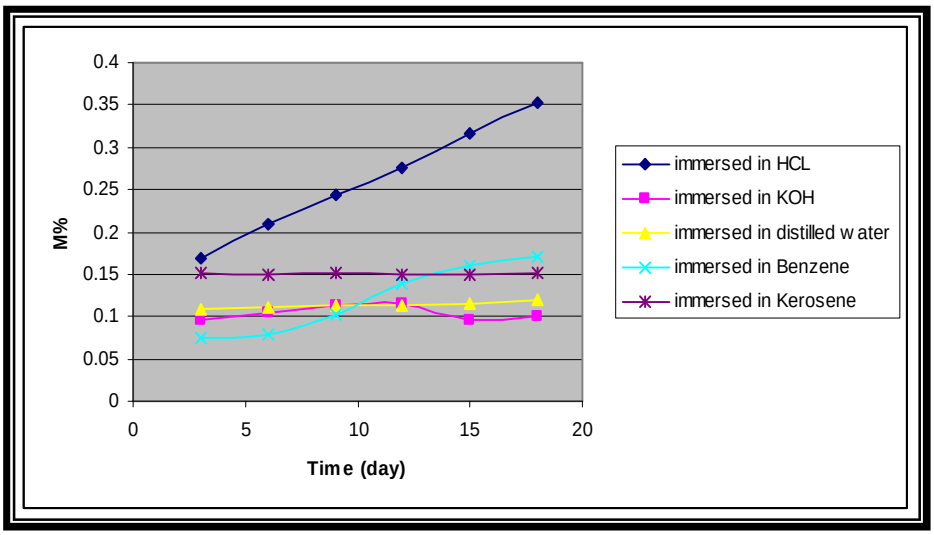

Figure (2) Changing the relative mass with immersion time for the samples

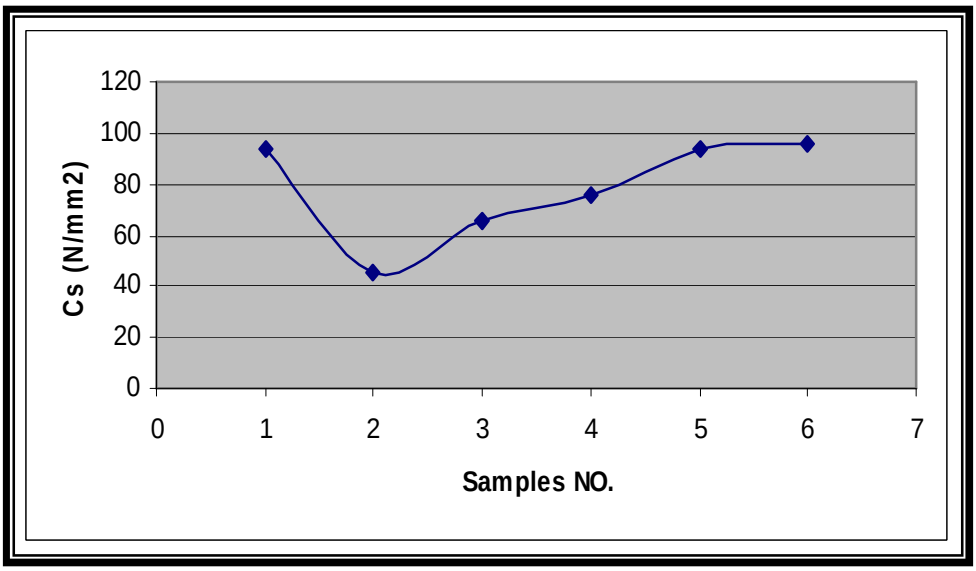

Figure (3) Compressive strength of the samples before and after immersion

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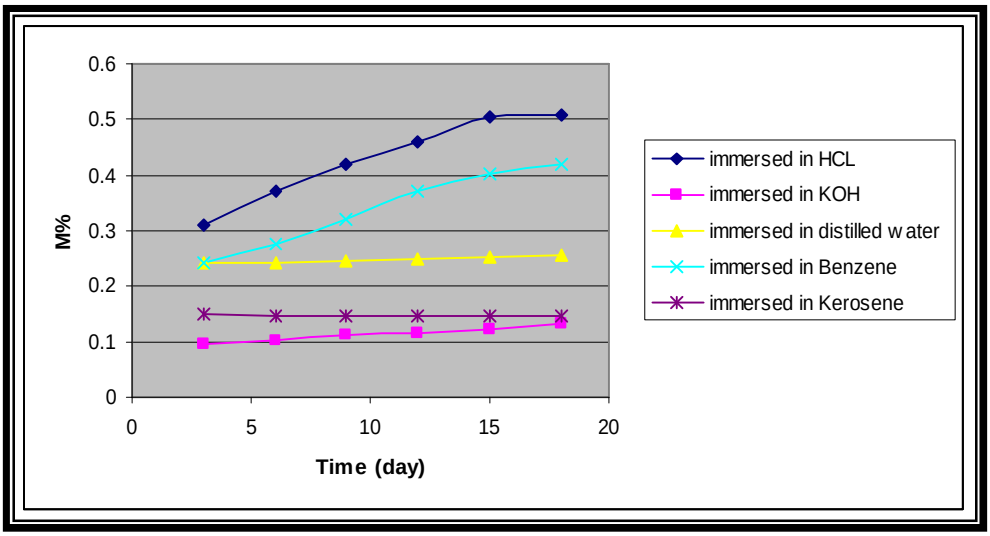

Figure (4) Changing the relative mass with immersion time for the samples

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