THE STUDY OF SOLUTION ABSORPTION AND DIFFUSION COEFFICIENT IN EPOXY COMPOSITE REINFORCED WITH GLASS FIBERS

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Abstract

Diffusivity behavior and diffusion coefficient was investigated in this paper for epoxy composite reinforced with glass fibers (woven roven and random direction) together as a sandwich with volume fraction (44). The samples were immersed in different solution for equal time at constant temperature (room temperature $\pm 18^{o}C$). The result show that the relative mass gain increased with increasing the immersion time till they tend saturation moisture mass ($M\infty$) after that the relative mass gain decreased. The result show that the samples immersed in (kerosene) solution had higher mass gain while the samples immersed in distill water had lower mass gain and the samples immersed in other solution (Benzene, HNO_3, KOH, H_2O as received) had relatively mass gain between them.
Also the results show that the samples immersed in benzene has maximum diffusion coefficient ($30.219 mm^2/day$) which means minimum absorption resistance while the samples immersed in (H_2O as received) has minimum diffusion coefficient ($0.191 mm^2/day$) (maximum absorption resistance).

الخلاصة

تم في هذا البحث دراسة خاصية الانتشارية ومعامل الانتشار لمتراكبات الايبوكسي المدعمة بالالياف الزجاجية (المتعامدة الاتجاه والعشوائية معا) بشكل متراكب متوالف وبكسر حجمي مقداره (٤٤%).
غمرت النماذج في محاليل مختلفة لفترات زمنية متساوية وبدرجة حرارية ثابتة وهي درجة حرارة الغرفة ($\pm 18C^{o}$).
اظهرت النتائج ان الزيادة النسبية في اوزان النماذج بعد الغمر تزداد بازدياد زمن الغمر لحين الوصول الى حد الاشباع تبدا بعدها الزيادة النسبية للاوزان بالانخفاض. كما اظهرت النتائج ان محلول الكيروسين كان الاكثر تاثيرا في النماذج ومحلول الماء المقطر الاقل تاثيرا في النماذج وتاثير بقية المحاليل (الماء الغير معامل،والبنزين، وHNO_3،وKOH) نسبيا تتراوح بين المحلولين.
كما اظهرت النتائج ان اعلى معامل انتشارية (٣٠,٢١٩ mm^2/day) كانت للعينات المغمورة في محلول البنزين مما يعني اقل مقاومة للامتصاصية.
في حين ان اقل معامل انتشارية (٠,١٩١ mm^2/day) كانت للعينات المغمورة في الماء الغير معامل مما يعني الاكثر مقاومة للامتصاصية.

Introduction

Fiber-reinforced polymeric composites are currently used in a variety of applications where they could be subjected to mechanical loads or environmental effects such as a wide range of temperatures, moisture, radiation, or aggressive solvent- rich atmospheres[1].
Polymeric matrix composites differ from other materials in the sense that low- molecular weight substances such as water may easily migrate even at room temperature generating a variation of the material's structure, morphology, and composition [2].This phenomenon occurs only in the matrix or at the fiber- matrix interface since water can not penetrate the fiber. In many cases, it could lead to an irreversible degradation of the material in the so- called humid aging that includes both chemical aging and physical aging. The epoxy matrix show moisture sensitivity due to interactions between some polar groups of the macromolecule and the water molecules, which leads to a reduction of both glass transition (Tg) and mechanical properties. This sensitivity increases with the increasing degree of cross- linking and also with the polarity concentration of the molecular groups [3]. The physical phenomena that simultaneously occur are dissolution, diffusion, swelling, and relaxation, together with deformation and stress build up in the matrix [4].
A dimensionless quantity called the diffusive Deborah number (DEB)Δ must be determined

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this criterion is based on the relative importance of a mean relaxation time compared to the characteristic diffusion time, If it is much greater than 1, this implies that a two- stage process takes place, first an apparent equilibrium is achieved by means of the Fickian diffusion process and then a slow relaxation process that leads to a true thermodynamic equilibrium. If (DEB)Δ is much lower than 1, the mass transport process is diffusion controlled and the two mechanisms act together. If (DEB)Δ is close to 1, the two mechanisms have the same time and the process called an anomalous diffusion [5].

The relative mass gain can be obtained by:

$$M\% = \frac{\text{mass of wet sample} - \text{mass of dry sample}}{\text{Mass of dry sample}} \times 100 \quad ..(1)$$

And the diffusion coefficient can be obtained by:

$$D = \pi \left(\frac{kb}{4M\infty}\right)^2 \quad \text{……..(2)}$$

Where:

D: diffusion coefficient
b: thickness of the sample.
M∞: saturation moisture mass.
K: the slop of the curve between mass gain and immersion time.

This diffusivity D, defined as the amount of liquid passing per second through a unit area under the influence of a unit gradient of concentration is still a function of the temperature T given by an Arrhenius expression:

$$D = Do \exp(-H_D/RT) \quad \text{……} \quad (3)$$

Where:

H_D: activation energy for diffusion.
R: gas constant.

The diffusion time (t_D) defined as the duration of the transient and can be calculated as:

$$t_D = \pi b^2/16\, D \quad \text{……..} \quad (4)$$

Experimental

The material considered for this study was Epoxy resin (DGEBA) mixed with it's hardener in ratio (3:1) and left at room temperature (±20°C) to solidified for 24 hours. Hand lay- up used to prepare composites of epoxy with the glass fibers [woven roven, (0°-90°), and random] direction as a sandwich composite with volume fraction equal to (44).

The aim of this work to study the effect of solutions and calculating diffusion coefficient for glass fibers reinforced epoxy composites. The samples were immersed in different solutions at constant temperature for equal time and recording weight gain.

The solutions used in this study were kerosene, benzene; distill water, water as received and HNO3, KOH both with normality (0.5).

Result and Discussion

The generally accepted mechanism for solution sorption in polymers is an activated sorption- diffusion process. The molecules first dissolve into the polymer surface and then diffuse through the bulk of the polymer by a series of activated steps. The amount of absorbed water depends on the temperature, the structure and the morphology of the polymer [6].

From the results in Table (1) and Figure (1) the higher relative mass gain was for the samples immersed in kerosene solution because of the chemical structure of the kerosene which make chemical reaction with the epoxy resin and the water molecules not stay as free water molecules but changed to polar groups form clusters, which are linked by strong hydrogen bonds to hydrophilic groups such as hydroxyl and amine groups [7,8] therefore the concentration of water molecules in any solution limited the reaction of the solution with the resins and resin-glass composites [9].

From the results in Table (2) the samples immersed in benzene solution has maximum diffusion coefficient which means minimum absorption resistance because of the behavior of benzene and its capability for self-association through intermolecular hydrogen-bonding [10]. While the samples immersed in (H_2O as received) has minimum diffusion coefficient (maximum absorption resistance) because of reaction between epoxy and (H_2O) through the interface making a separation between the epoxy and plates of glass fibers [11].

Table (1): Changing the mass gain of the samples with immersion time.

Time (day)		2	4	6	8	10	12
Sample	Solution	%M1	%M2	%M3	%M4	%M5	%M6
1	HNO_3	2.4	3	3.6	3.9	4.3	3.8
2	KOH	2	2.1	2.6	2.8	3.9	3.3
3	H_2O as received	2.2	2.5	3.4	3.8	4	3.6
4	distill water	1.2	1.8	1.9	2	3.4	2.6
5	Kerosene	3.5	4.5	5	6.1	7.1	3.9
6	Benzene	4	4.3	4.6	5	5.7	2.7

Table (2): Changing the diffusion coefficient with diffusion time.

Sample	K	b (mm)	$Dx10^{-3}$ (mm^2/day)	t_D (hours)
1	0.3	2.5	5.836	214
2	0.25	2.5	5.021	248
3	0.5	2.5	0.191	654.4
4	0.3	2.5	9.528	131
5	0.5	2.5	6.076	205
6	0.9	2.5	30.219	413

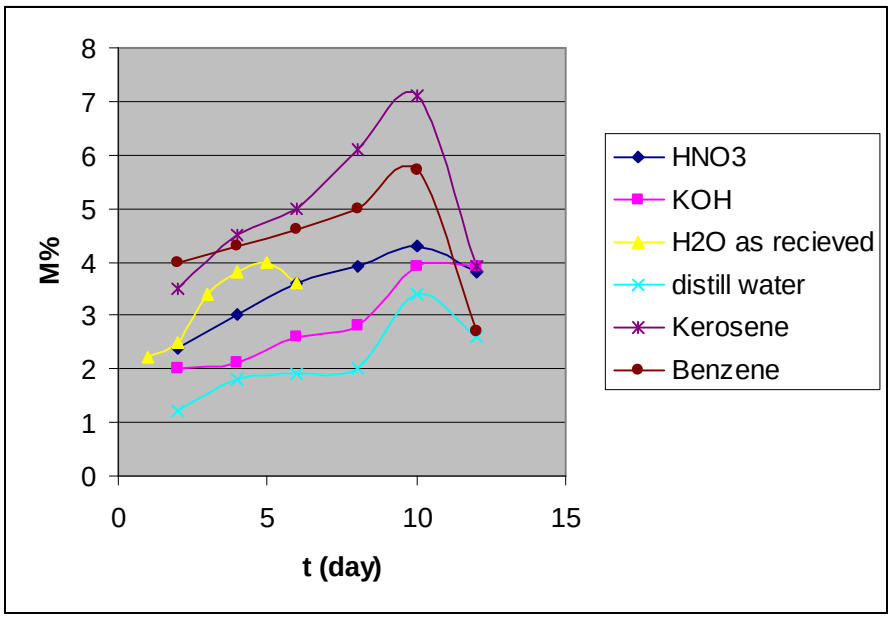
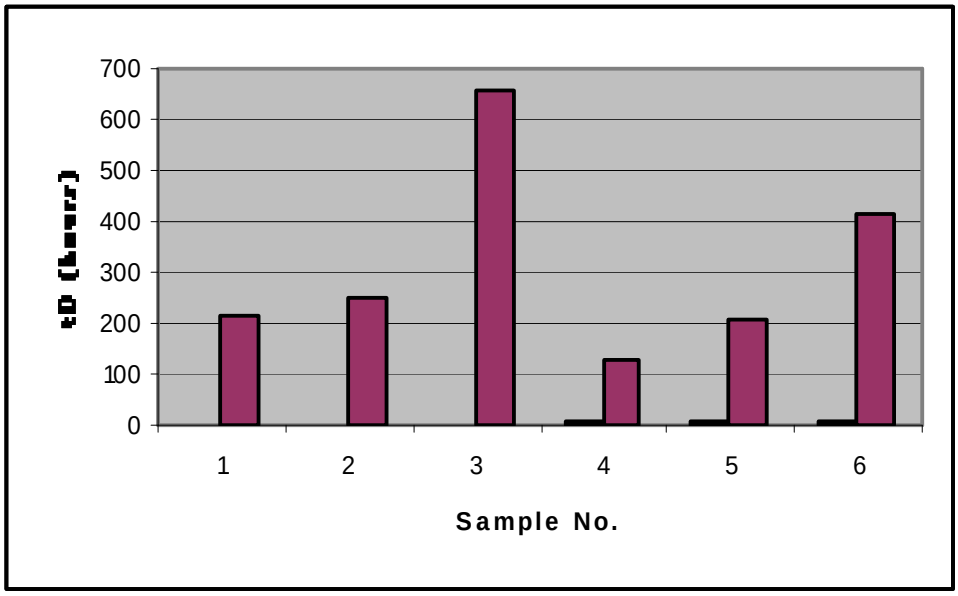


Figure (1): Changing the mass gain with immersion time



. Figure (2): Changing the diffusion time of samples in different solution.

Summary

An experimental study was performed on the solution absorption behavior of a sandwich glass fibers- epoxy composite, the diffusion coefficient and the time of diffusion previously fully determined.

The results show that the mass gain of the samples immersed in the organic solution (kerosene, benzene) has maximum value in compare with the samples immersed in other solutions, and the samples immersed in distill water has minimum mass gain. The maximum diffusion coefficient was for the samples immersed in Benzene (minimum diffusion time) while the minimum diffusion coefficient was for the samples immersed in H_2O as received (maximum diffusion time).

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