



MEASUREMENT OF WATER DIFFUSION COEFFICIENT FOR UPE/PVC BLEND REINFORCED WITH E-GLASS FIBERS

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Abstract

The objective of this work was to study the influence of weight percentage ratios of (Unsaturated Polyester/Poly vinyl chloride) blends and E-glass fibre content on the diffusion coefficients of the blends from the relationship between water weight gain M_t and diffusivity for water immersed samples. Unreinforced and reinforced (by one or two layers of chopped E-glass fibers) samples were prepared by hand lay up method with the ratios (95%UPE+5%PVC, 90%UPE+10%PVC and %85UPE+15%PVC), the prepared samples were immersed for 60 days in water to get the absorption curves. The results of laboratory examinations show the absorption curves of water gain M_t against the square root of the immersion time \sqrt{t} are gradual increase until saturation then deviate lower due to weight loss of the immersed samples. The diffusion coefficients values have been calculated from the plotted curves, the calculated values reveal diffusion coefficients values increased with the increasing of PVC weight percentage and fibre content.

قياس معامل انتشار الماء لخلائط UPE/PVC المدعمة بالالياف الزجاجية

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الخلاصة

الهدف من إجراء البحث هو دراسة تأثير تغيير النسب المئوية لخلائط UPE/PVC وكذلك تأثير التدعيم بالالياف الزجاجية على معامل انتشار الماء لهذه الخلائط. حضرت العينات غير المدعمة والمدعمة (بطبقة او طبقتين من الالياف الزجاجية) بطريقة التشكيل اليدوي بالنسب الوزنية () 95%UPE+5%PVC, 90%UPE+10%PVC and %85UPE+15%PVC غمرت العينات بالماء لمدة 60 يوماً لغرض الحصول على منحنيات الامتصاص بين كمية الماء الممتصة والجذر التربيعي لمدة الغمر. أظهرت النتائج المختبرية ان منحنيات الامتصاص للعينات المغمورة بالماء تأخذ بالزيادة تدريجياً حتى تصل حد الإشباع ثم تنحرف نحو التناقص التدريجي. حسبت قيم معاملات الامتصاص من هذه المنحنيات فوجد ان قيم معاملات الانتشار تزداد بزيادة النسب المئوية لمادة ال PVC وكذلك بزيادة التدعيم بالالياف الزجاجية.

Introduction

Using polymers depend on their properties, there are many factors can affect the properties of polymer materials. External factors such as temperature, humidity, applied external forces

and other factors. Inner factors include samples structures, materials type, regularity, direction and strength of molecular chains which form the polymer materials [1].

Moisture absorption characteristics of polymers comprise an important aspect of moisture/durability studies. Such information can generally be used to obtain some insight into how and why the material is influenced by moisture [2].

The absorption process for all polymer materials when humidity found in atmosphere or when these materials immerse in water or other solutions followed Fick's law in diffusion, i.e. absorption mass from the water or solutions increasing linearly with the square root of time gradually and slowly until saturation state [3].

Water enters the composite by diffusion through the resin and by capillary action along the fiber matrix interface in fibrous composites. The surface damage and cracks produced as a result of weathering further facilitate the entrance of water. The effect of water on the resin which causes swelling and plasticization-hydrolysis is not considered to be an important process under the conditions encountered outdoors [4].

There is two main types of basic moisture conditioning; fixed conditioning, where a test specimen is exposed to a conditioning environment for a specified time, and equilibrium conditioning, where a specimen is exposed until the material reaches equilibrium with the conditioning environmental. The rate of moisture uptake is fairly rapid in early stages of conditioning with the rate of moisture uptake then decreasing with time as shown in (Figure 1).

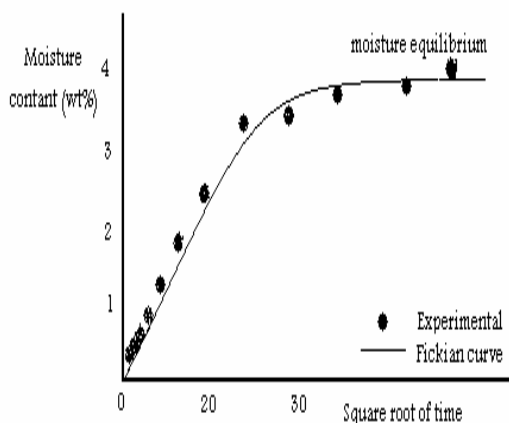


Figure 1: Fickian diffusion curves for polymer matrix composite [4]

It is therefore necessary to make frequent weight measurements in the early stages, followed by a gradual decrease in frequency as

the rate of weight gain diminishes. The weight percentage of uptake water (M) can be determined as follows;

$$M = \frac{(W_t - W_o)}{W_o} \times 100\%$$

Where the weights of the sample after and before immersion are denoted by W_t and W_o respectively [4].

At temperatures well below the glass transition T_g of the conditioned material, water absorption of most polymers correlates well with Fick's laws. The diffusion coefficient D is independent of moisture concentration, it can be calculated from the initial linear region of Fickian diffusion curve of (Figure 1) using the following equation[4]:

$$D = \frac{\pi}{16} \left(\frac{h(M_2 - M_1)}{M_\infty(\sqrt{t_2} - \sqrt{t_1})} \right)^2 \dots\dots\dots (1)$$

Where M_∞ is the equilibrium moisture content (maximum water content), M_1 is the moisture uptake after time t_1 , M_2 is the moisture uptake after time t_2 and h is the sample thickness

The term $\left(\frac{M_2 - M_1}{\sqrt{t_2} - \sqrt{t_1}} \right)$ is the slop of the linear portion of the plot of M against \sqrt{t} .

**Experimental
Material used Preparation**

The material used to prepare the test samples were Unsaturated polyester resin (UPE) type (H-265), with hardener MEKP and accelerator cobalt naphthenate, supplied by IPI Jordan and PVC (polyvinyl chloride), supplied by industrial chemical and resin CO.LTD,kingdom of Saudi Arabia. The reinforcement used was chopped mat E-glass fibres supplied by (Moulding Comp.Ltd.,UK.).

The UPE /PVC blends were prepared with diferent weight percentage ratios for both polymers as matrix system, reinforced by one or two layers of chopped E-glass fibers.

The test specimens were prepared by hand lay-up method with dimensions (20x15x3)mm³. The details of the test samples presented in (Table 1).

Table 1: details of the test samples

No.	Blends Ratios	Reinforcing type
1	95% UPE + 5 %PVC	Unreinforced
2	90% UPE +10% PVC	
3	85% UPE +15% PVC	
4	95% UPE + 5 % PVC	Reinforced with one layer of E- Glass Fiber
5	90% UPE +10% PVC	
6	80% UPE +15% PVC	
7	95% UPE + 5 % PVC	Reinforced with two layers of E- Glass Fiber
8	90% UPE +10% PVC	
9	85% UPE +15% PVC	

Testing Procedure

The samples were weighted before immersion, then immersed in water free of any admixture or any other wetting agent for 60 days. The test was performed under ambient temperature. The immersed samples were frequently removed from water and weighted and then replaced again to monitor the water uptake by using an analytical balance of accuracy 10⁻⁴g.

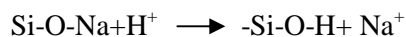
Water weight gain (M_t %) as percentage of the original dried specimen weight was calculated from the following equation [4].

$$M_t \% = \frac{W_2 - W_1}{W_1} \dots\dots\dots(2)$$

W₂ = weight of the sample before immersion
W₁ = weight of the sample after immersion

The plotted curves of (Figures 2 to 4) of water gain M_t against the square root of the immersion time √t for the test samples show that the water uptake increased linearly with the increasing of the square root of immersion time in early stages until maximum moisture content, this is similar to the prediction of Fickian behavior[5], then the curves show deviation as a “knee” with increasing the period of immersion for all the samples, because the absorbed water diffuse through the material weaken the cross-links of the polymers and dissolve the polymer molecules then the samples suffered from weight loss and bubbles appear on the surface of

the samples. The effect of water tends to decrease the hydrogen bonding between polymer chain which is reflected by plastization of resin. As the absorbed water enters the resin and reaches the fibres, it dissolves the surface layer to create an osmotic pressure which will rapidly debond the whole fibres. The effect is usually attributed to hydrogen exchange [6, 7].



However when Na⁺ or K⁺ of E-glass fibres released by hydrolysis degradation the PH value of the interface region raises[8].

(Figure 2) of unreinforced samples declare a drastic increase of weight gain (M_t) with PVC content, which is attributed to occurrence of voids due to the difference in degree of miscibility at different blends ratios that facilitate diffusion of water molecules [9].

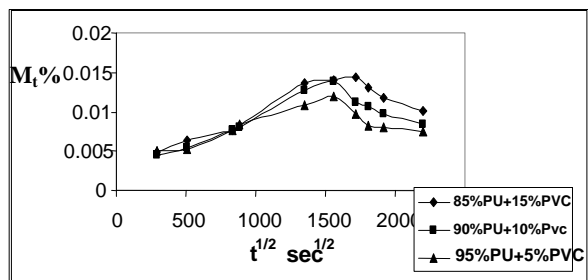


Figure 2 weight gain M_t% versus square root of immersion time for unreinforced blends

On the other hand it was found that most polymer blends are heterogeneous and consist of polymer matrix in which the second polymer is embedded, consequently the effects on permeability are very dependent on the degree of heterogeneity of the system and therefore free volume formation [10].

(Figure 3) and (Figure 4) of the reinforced samples, declare water absorption (M_t%) of samples reinforced with two laminates exceed that of specimens reinforced with one laminate.

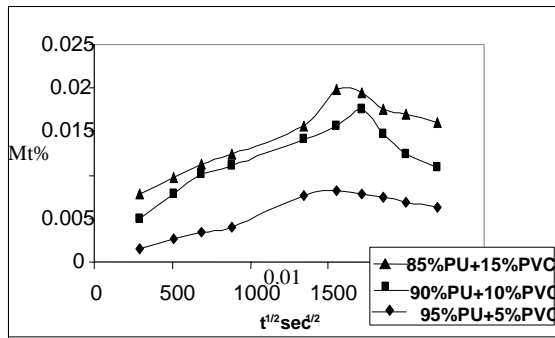


Figure 3: weight gain $M_t\%$ versus square root of immersion time for blends reinforced with one layer of glass fibres

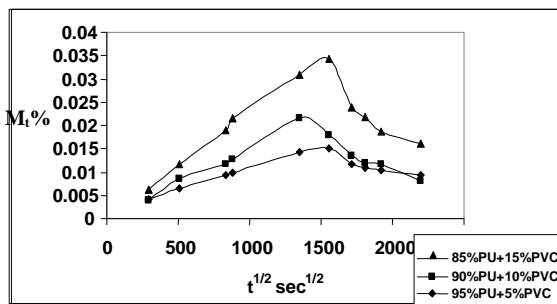


Figure 4: weight gain $M_t\%$ versus square root of immersion time for blends reinforced with two layers of glass fibres

This can be explained as follows: When the polymeric matrix is viscous and the filler is partially incompatible with the matrix, voids tend to occur at the interface (Figure 5)[11], which lead to an increase in free volume of the system, and consequently an increase in permeability results, also voids can occur because air gets trapped between layers during the lay-up process, the voids facilitate water diffusion and increase the moisture content [10].

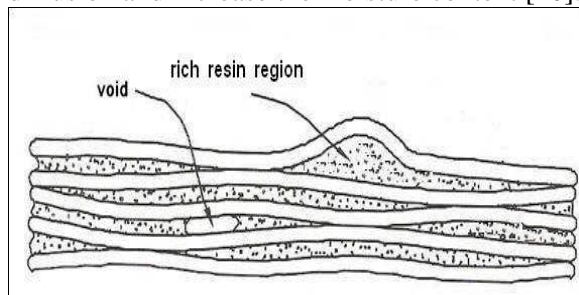


Figure 5: Schematic diagram shows trapped air between layers of composites[10]

Diffusion coefficient were calculated from the relationship between weight gain M_t and diffusivity D during initial water uptake for Fickian diffusion which is given by the following equation [4]:

$$\frac{M_t}{M_\alpha} = \frac{4}{h} \left(\frac{Dt}{\pi} \right)^{1/2} \text{-----} (3)$$

The calculated values of diffusivity were listed in (Table 2) that reveals the values of diffusion coefficients of the unreinforced blends are much less than that of the reinforced blends. This is possibly attributed to the presence of fibres which introduce fibre/matrix interface that can be considered as channels for water flow [11].

The discrepancy between the values of diffusion coefficients of the reinforced blends is due to the difference in PVC ratio and fibre content.

Table 2: The values of Diffusion Coefficient for reinforced and unreinforced samples after 60 days immersion in distilled water

Blends Ratios	reinforcing type	Diffusion Coefficient (cm ² /sec)
95% UPE + 5 %PVC	Unreinforced	2.5x10 ⁻⁶
90% UPE +10% PVC		5.2x10 ⁻⁶
85% UPE +15% PVC		7.7x10 ⁻⁶
95% UPE + 5 % PVC	Reinforced with one layer of E-Glass Fiber	1.01x10 ⁻⁵
90% UPE +10% PVC		1.9x10 ⁻⁵
85% UPE +15% PVC		3x10 ⁻⁵
95% UPE + 5 % PVC	Reinforced with two layers of E-Glass Fiber	5.7x10 ⁻⁵
90% UPE +10% PVC		6.1x10 ⁻⁵
85% UPE +15% PVC		8x10 ⁻⁵

Conclusion

It is concluded that the water gain increases with the increasing of PVC ratios for the unreinforced blends. For the reinforced specimens water gain increases with the increasing of PVC ratios and fibre content, and the samples differ in the saturation state. The diffusion coefficient of the reinforced specimens much higher than that of unreinforced blends.

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