The Effect of Fiber Orientation on Creep Behavior And Flextural Strength In Epoxy Composites

Dr. Emad S. AL-Hassani * & Sheelan R. Areef**

Received on:30/8/2009
Accepted on:7/1/2010

Abstract

The creep behavior, flexural strength, shear stress was investigated in this paper for epoxy, epoxy composite reinforced with glass fibers: (chopped strand mat), woven roven (90^o-0^o) and chopped strand mat together as a sandwich composite with volume fraction (21, 25, 29) % for each type. The tests were done at constant temperature (room temperature (23± 2) ^oC.

The results shown that the increasing in volume fraction increases the creep behavior, flextural strength, shear stress for all samples also the results shown the effect of fiber orientation in increasing the creep behavior, flextural strength, shear stress in sandwich composites in comparession with the composites reinforced with randomly glass fibers.

تأثير اتجاه الالياف على خاصية الزحف ومتانة الانحناء لمتراكبات الايبوكسي

الخلاصة

تم في هذا البحث دراسة سلوك الزحف, متانة الانحناء, اجهاد القص لراتنج الايبوكسي, متراكبات الأيبوكسي المدعمة بالالياف الزجاجية: حصيرة محاكة عشوائيا و حصيرة متعامدة الاتجاه (90^o-0^o) والعشوائية الأتجاه معاً بشكل متراكب متوالف وبكسر حجمي مقداره (29 ,25 ,21) % لكلا النوعين. تم اجراء الاختبارات بدرجة حرارية ثابتة وهي درجة حرارة الغرفة ^oC (2 ± 23) أظهرت النتائج ان زيادة الكسر الحجمي يزيد من سلوك الزحف, متانة الأنحناء, اجهاد القص للعينات كافة كما أظهرت النتائج تأثير اتجاه الألياف في ازدياد سلوك الزحف ومتانة الانحناء واجهاد القص للعينات المدعمة بالألياف الزجاجية المتوالفة مقارنة بالعينات المدعمة بالألياف الزجاجية العشوائية الاتجاه.

Introduction

A composite may be defined as any multiple phase material that exhibits a significant proportion of the properties of both the constituent materials, a judicious combination of two or more distinct materials can provide better combination of properties. Fiber reinforced composites are those composites in which the dispersed phase is in the form of fibers, technologically, these composites are very important as they provide high strength and stiffness on a weight basis [1] .

Many researchers studied in this field, Balkees [2] showed that the orientation of fibers had a major role in increasing the creep resistance according to applied load,

* Materials Engineering Department, University of Technology /Baghdad
**Applied Sciences Department, University of Technology /Baghdad

microstructure of the composite, and adhesion between the resin and the fibers.

Papanico laou [3] gave an excellent review for damage development in polymeric materials which is completely different from the respective one of metals, leading to complex damage mechanisms such as fiber breakage, matrix cracking, fiber debonding and ply- delamination, addition all the damages appears not only in different types, but also in different levels and location, which have different effects on the residual life of a composite structure.

Houshyar [4] gave that the incorporation and increase of the fiber concentration gave rise to a considerable increase of tensile, flexural strength, the maximum improvement in properties was observed for the composite with W_f = 50% which is equal to V_f = 26%, is chosen as a critical fiber concentration, this was due to the reinforcement imparted by the fibers that allowed stress transfer from the matrix to the fibers.

Lee & Jyongsik [5] reported that as fiber content increased, the tensile and flexural modulus of the glass fiber composite showed a linear increment.

Another study by Abot & Yasmin [6] showed that the interface region between the matrix and glass fibers limited the mechanical properties of the composite.

Amorphous materials such as high polymers show high rate of deformation under relatively low stress and temperature because of their less rigidity, and thermosetting polymers are much more creep resistant than thermoplastic polymers, the creep strain, creep constant calculated from the equation [7]

$$\epsilon = \frac{\Delta l}{l_0} \qquad \ldots\ldots\ldots (1)$$

When

ϵ: strain

ΔL: change in length

L_o: original length of the sample

$$k = slope\ \frac{\log \epsilon}{\log t} \qquad \ldots\ldots (2)$$

When

k: creep constant

t: creep time

The ability of a material to undergo flexural distortions without weakening or shattering is a key property for the use of polymers in many components and structural parts, the flextural strength calculated from the equation [8].

$$F_s = \frac{3pl}{2bt^2} \qquad \ldots\ldots. (3)$$

When

F_s: flextural strength.

p: applied load till failure occurs.

L: span of the sample.

b: width of the sample.

t: thickness of the sample.

While the shear stress predicted from the equation

$$\tau = \frac{3p}{4bt} \qquad \ldots\ldots.. (4)$$

When

τ: shear stress

In the present work aim to study the creep behavior, flexural strength and sheer stress for the epoxy composite reinforced with glass fibers.

Experimental work

1. The epoxy resin used in this study was (contextra Ep10, Jordan Industry), with its hardener (Ep10) in ratio (3:1), and left at room temperature (23± 2) ^{o}C to solidified after (24) hours.
2. Hand lay – up molding technique used to prepare:-
   a- epoxy composite reinforced with [chopped strand mat glass fibers with surface density 0.277 Kg/m^2] from Mowding LTD. UK
   b- Epoxy composite reinforced with [woven roven (0^o–90^o) with surface density 0.5 Kg/m^2] from Mowding LTD. UK, and chopped strand mat together as a sandwich composite.
3. The volume fraction used for each type in (a, b) was V_f = (21, 25, 29) %.
4. The creep test was carried with technical equipment machine model (SM 160 MK2) manufactured in England with constant applied load P=200 N.
5. flextural test was carried out using (hydraulic press / No . 36110) manufactured by (Ley BOLD Harries) with a three point loading apparatus.
6. The samples were cut with standard dimension (ASTM-BS1178) for creep test and (ASTM-D 790) for flextural test.

Result and Discussion

In Flextural strength the sample is exposed to two kinds of stress, the first is compressive stress from the point of exertion of weight and the second is tension stress of the lower surface of the sample [9].

From the results in fig (1) reinforcing of epoxy (matrix) with glass fibers increased the flextural strength, this attributed to the fact that the reinforcement imparted by the fibers allowed stress transfer from the matrix to the fibers.

At low fiber volume fraction V_f =21% the matrix is not restained by enough fibers and highly localized strains occurs in the matrix at low stresses, as the fiber volume fraction increased to 25% and up to 25%, the stress was more evently distributed and the composite stiffness increased [10]. The results in fig (1) shown that the flextural strength of the composite reinforced with both sandwich and random glass fibers increased with increasing the volume fraction of the fibers and in compare between the two types noticed that the flextural strength of the composite reinforced with sandwich is higher than the flextural strength of the composite reinforced with chopped strand mat glass fibers, this is due to length and packing of (0^o–90^o) glass fibers, strong interface region between the matrix and the fibers [11].

From the results in fig (2), the shear stress of the epoxy resin increased after reinforcing in both (sandwich and chopped strand mat) glass fibers due to the role of fibers in absorbing shear loads [12].

From the results in fig (3) and (4) when the loads applied on the sample the elastic deformation occurs due to the extension of bonds between molecular chains as a result the molecular chains extended and rotated this region in creep curve called primary stage.

The most important region in creep curve that the strain becomes approximately constant with time which called secondary stage and this stage appears the visco-elastic properties of the sample which gives the estumatied life of the part. The final region in creep curve is tertiary stage, when the strain decreased rapidly as a result of local necking resulting failure in the sample [13].

From the result in fig (3) and (4) noticed that the strain increased rapidly in the beginning called initial instantaneous strain.

The composite materials have different strain according to type of fiber, composition of fiber and adhesion between the fibers and the matrix in the interface region [14]. Generally reinforcing the polymers increased the secondary stage in creep curve mean that needing more time to approach final fracture due to the role of fibers which absorbing the maximum part of the loads as a result the strain increased [15].

Conclusions

These results characterize the creep behavior and flextural strength, shear stress of composites with three volume percentages of an E-glass fiber in a room temperature curable epoxy matrix from them, the following conclusions can be drawn:-

1. Change in volume percentage of fibre produces no change in mechanical properties.
2. The creep rate in sandwich composite was higher than creep rate in random composite as a result the creep resistance of sandwich composite is lower than the creep resistance of random composite.
3. The creep constant (k) decreased in each type of composite with increasing the volume fraction of fibers.

References

[1]-Harry, R., Allcook, Fredrick, W., James, E., "Contemporary Chemistry" third edition, printed in United States of America (2003).

[2]-Al-dabagh. balkees, "Study the creep and diffusion behavior of epoxy composite" 8th scientific conference of technical education faculty, Baghdad, Iraq, March (2002).

[3]-Papanicolaou, G.C., "Effect of water uptake on the creep behavior of glass-epoxy composites", 13th European conference on composite materials, Sweden, June (2008).

[4]-Houshyar. R.A, Shanks.R.A, "The effect of fiber concentration on mechanical and thermal properties of fiber- reinforced poly

propylene composites", Journal of applied polymer Science, Vol.96, pp. (2260-2272), (2005).

[5]-Lee. B.K. & Jyongsik. N.R., "Effect of moisture on the mechanical properties of glass fiber reinforced vinyl ester resin composites" Bull. Mater. Sci., No. 1, Vol.24, pp (87-94) February (2001).

[6]-Abot, J.L., Yasmin, A., Jacobsen, A. J. and Danial, I. M., "Hygroscopic behavior of woven fabric carbon-epoxy composites", Journal of reinforced plastics and Composites. No. 2, Vol. 24, pp (195-207) (2005).

[7]-Dara, S.S., Chand, S., "A Text book of engineering chemistry" tenth revised edition, LTD company, New Delhi (2007).

[8]-Abot, J.L., Yasmin, A., Jacobsen, A. J. and Danial, I. M., "In-pane mechanical, thermal and viscoelstic properties of a satin fabric carbon /Epoxy composite", Compos. Scie. tech, No. 64:pp (263-268) (2004).

[9]-Mezzenga, R., Manson, J., "Thermo-mechanical properties of hyper branched polymer modified epoxies", Journal of materials science 36: pp (4883-4891) (2001).

[10]-Birger, S., Moshonor, A., and kenig, S., "The effect of thermal and hygrothermal ageing on the failure mechanisms of graphite-fabric epoxy composites subjected to flextural loading", composites, No.4, Vol.20, pp.(143-158), July (1989).

[11]-Yong Zhou, Daniel, M. "Size effect on flextural strength of fiber – composite laminates", Journal of engineering materials and technology, Vol. 126: PP (29-37) Jan (2004).

[12]-Pascault, J.P., Sautreau, H., Williams, R. J., "Thermosetting polymers" Marcel dekker, New York (2002).

[13]-Bledzki, A.K., Faruk, O., "Creep and impact properties of wood fiber-polypropylene composites" composites Sci. & tech No. 64: PP (693-700) (2004).

[14]-Seifert, O.E., Schumacher, S.C., Hansen, A.C., "Viscoelastic properties of a glass fabric composite at elevated temperature" composites part B, No. 34: PP (571-586) (2003).

[15]-Van Krevden, D.W., "Properties of polymers" Elsevier, Amsterdam (1997).

Table (1) Creep constant with volume fraction for each type of composite

V_f %	K
21(S)	7.264737
25 (S)	4.255027
29 (S)	4.019867
21 (R)	9.169572
25 (R)	4.674599
29 (R)	3.69584

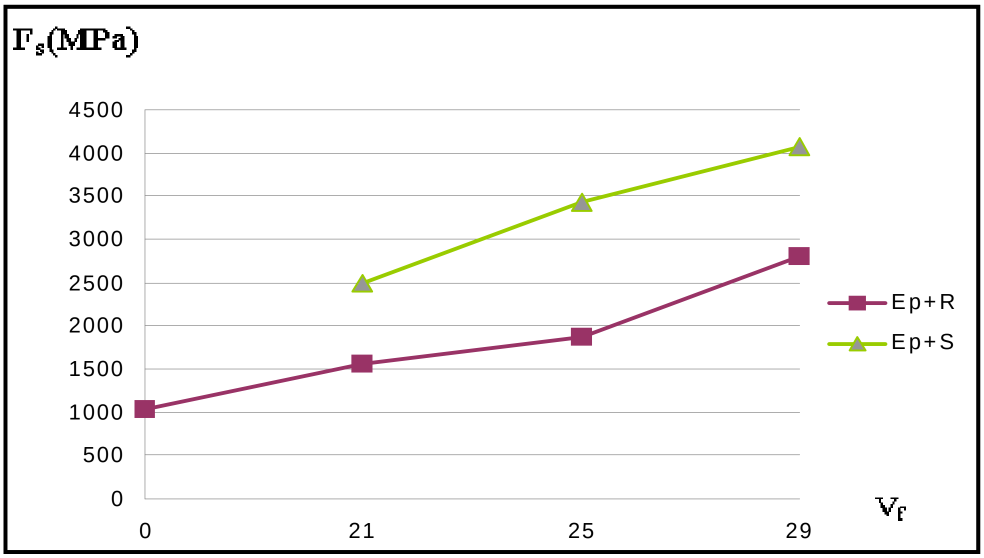

Figure (1) flextural strength of the composite reinforced with each type of glass fibers
R: chopped strand mat S: Sandwich glass fibers

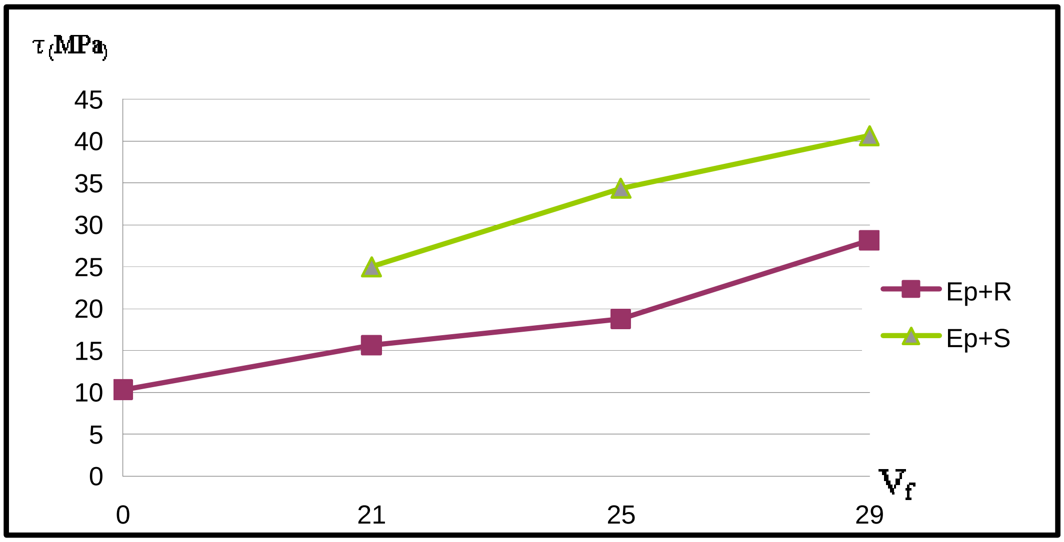

Figure (2) shear stress of the composite reinforced with each type of glass fibers

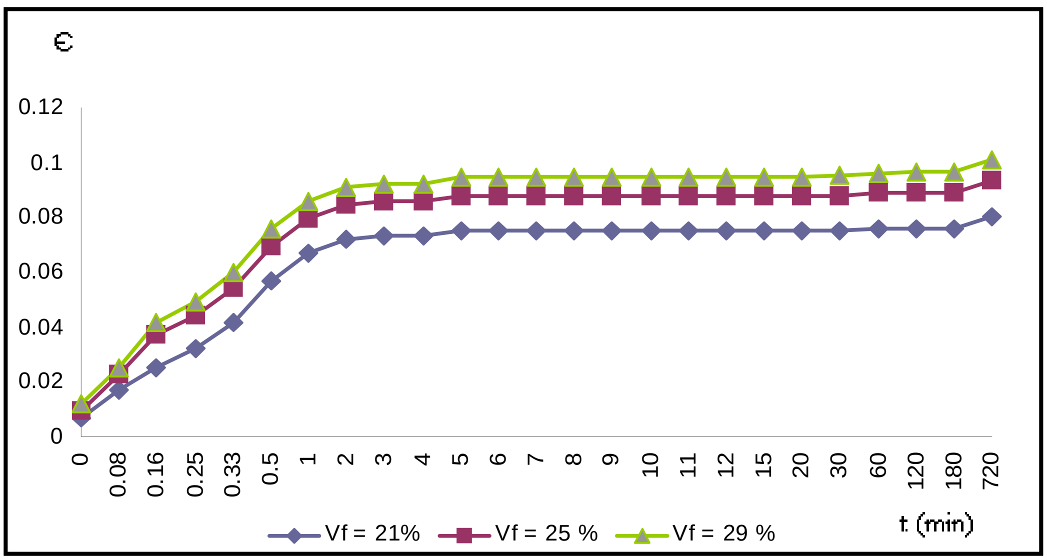

Figure (3) creep behavior of sandwich composite

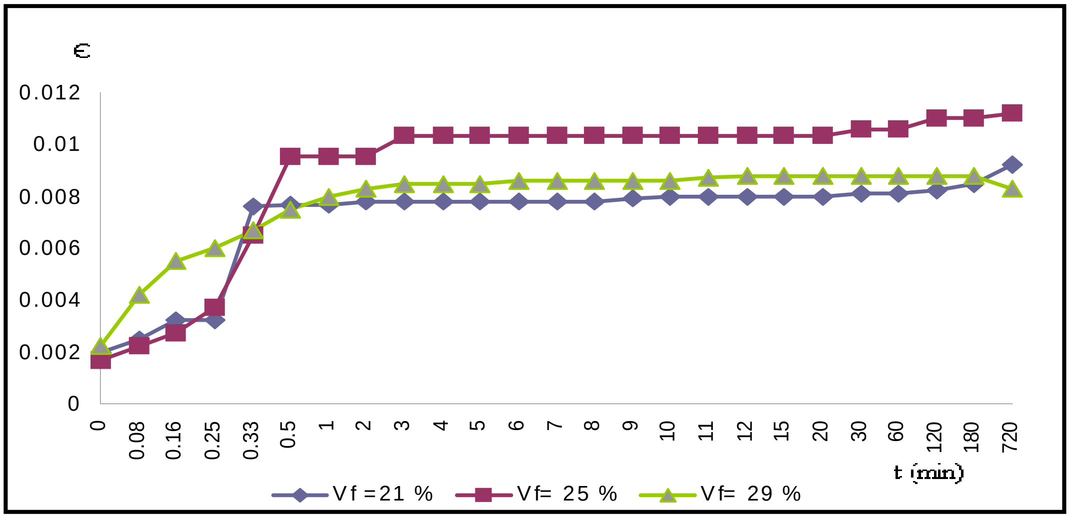

Figure (4) creep behavior of random composite

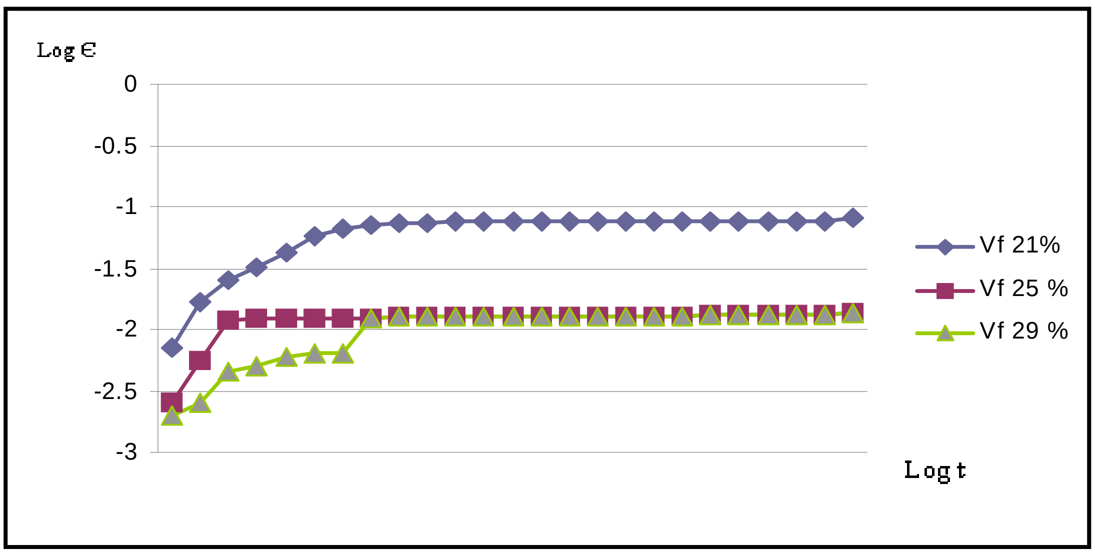

Figure (5) Changing Log of Strain with Log of time for sandwich composite

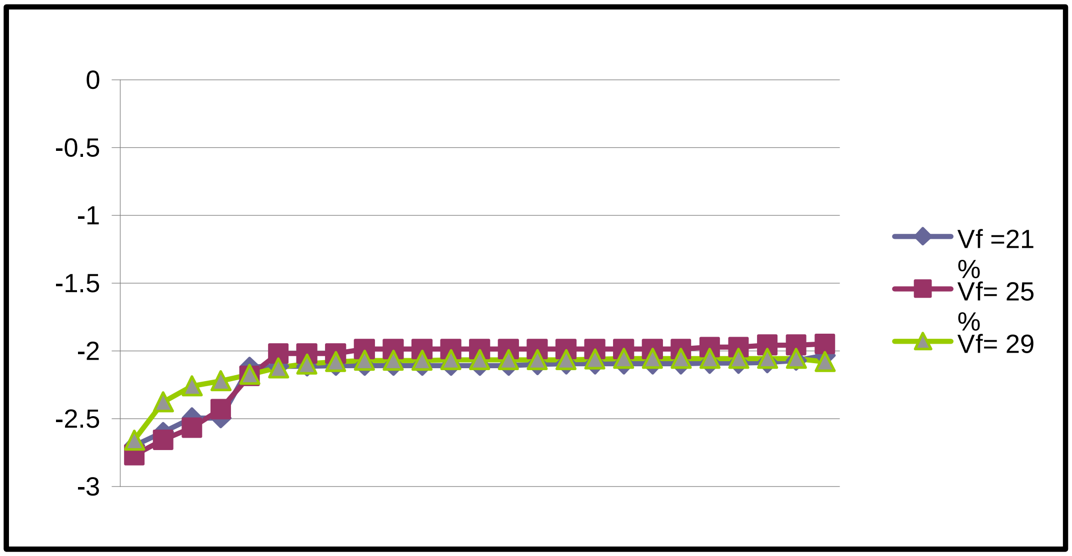

Figure (6) Changing Log of Strain with Log of time for random composite