P- ISSN 1991-8941 E-ISSN 2706-6703 *Journal of University of Anbar for Pure Science (JUAPS)* Open Access
2009,(3), (3) :109-115

Fibers Direction Effect on Tensile Elasticity of Epoxy Composites Using Computer modeling

Salah S. Al-Rawi

University of Anbar- College of Computer

ARTICLE INFO

Received: 19 / 5 /2022
Accepted: 28 / 5 /2022
Available online: 14/6/2012
DOI: 10.37652/juaps.2009.15573
Keywords:
Fibers Direction,
Tensile Elasticity ,
Epoxy Composites ,
Computer modeling.

ABSTRACT

In this research a sample of glass fiber, reinforced Epoxy Composite was subjected to a tensile load to study the effect of fiber directions on the tensile elasticity theoretically using Finite Element Method (FEM). MSC-NASTRAN computer package was used for the purpose of this study. Tensile test was done on the design samples when fibers angled with the Load direction at 0o, 45o and 90o in order to find out the direction, which provides the best mechanical properties. Through the tests result and color spectrum analysis, we found that 0o angle provides the best properties, followed by 45o angle, while at 90o angle shows lowest value of elasticity modu.

Introduction:

The main problem for this study is to find out the effect of changing the fiber direction with the load applied on the composite materials.We used here NASTRAN package by (MSC) an Australian Company for High technologies of Construction Materials[1]. Other packages were used by ABAQUS and ANSYS, which have different techniques than NASTRAN we used[2].

The finite element method is utilized since it is proven to be one of the most reliable tools[3]. The software packages, based on the (FEM) can be used in order to predict stress distribution on the examinated model [4]. NASTRAN one of the most computer packages uses Finite Element Method (FEM), when a sample of the tested material is provided in a form of Mesh (consisting all the composition of the material). Upadhyay and Kalyanaraman[3] studied the shear lag phenomenon in a simply supported composite box beam subjected to central point load using MSC. NASTRAN.

The analysis was done using analytic mechanical equations to find out value of stress and to find out the maximum and minimum internal stress by applying Finite Element Method Analysis package (FEMAP)[5].

* Corresponding author at: University of Anbar- College of Computer, Iraq.E-mail address: dr_salah_rawi@yahoo.com

In this paper we used a computer aided to analyze and study the effect of fiber direction on the tensile properties of the Epoxy Composite reinforced by-Glass Fibers. These methods form a part of the optimization methods which allows to find structures with better performance or strength[4]

The main advantage in structure projects by computer use is the possibility of simulations. In that way the behavior of structures in real working conditions is examined. It can be said that the FEM solution process consists of the following steps[6]:

- Divide structure into piece elements with nodes (discretization/ meshing).
- Connect (assemble) the elements at the nodes to form an approximate system of equations for the whole structure (forming element matrices).
- Solve the system of equations involving unknown quantities at the nodes.
- Calculate desired quantities (e.g. strain and stresses) at selected elements.

Boundary Conditions [7][8]:

Figure (1) shows the displacement boundary colditions and the surface load, when U and Su are known on a section of the boundary, we have:

U=0 on Su dx …………..1

Su- cross section area on the surface U.

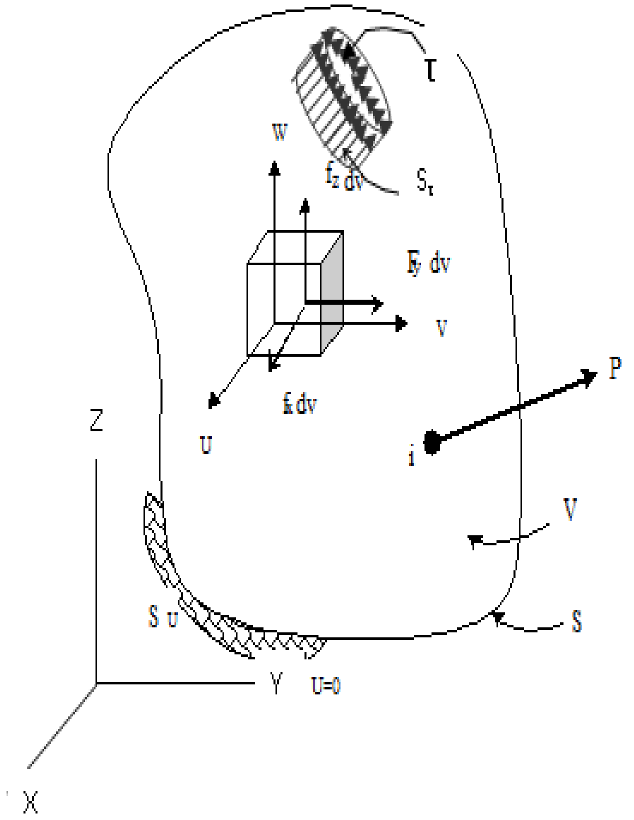


Figure (1) volume Element in a three dimensional body

We can also notice in the figure the boundary conditions at U=α, where (α) is a known displacement .

Strain – Displacement Relations [8][9]:

The relations between corresponding strains with stresses can be written as :

$$\varepsilon=[\varepsilon_X,\varepsilon_Y,\varepsilon_Z,\gamma_{YZ},\gamma_{XZ},\gamma_{XY}]^T \quad .....2$$

when $\varepsilon_X,\varepsilon_Y,\varepsilon_Z$ are normal strains, while $\gamma_{yz},\gamma_{xz},\gamma_{xy}$ are the engineering shear strains. Strain as a function for a small deformations may be written as :

$$\varepsilon=\left[\frac{\partial u}{\partial x},\frac{\partial \upsilon}{\partial y},\frac{\partial \omega}{\partial z},\frac{\partial \upsilon}{\partial z}+\frac{\partial \omega}{\partial y},\frac{\partial u}{\partial z}+\frac{\partial \omega}{\partial x},\frac{\partial u}{\partial y}+\frac{\partial \upsilon}{\partial x}\right]^T \quad .....3$$

the relations above are true just for a small deformations (in the limits of elasticity)

Stress-Strain Relations [9][10] :

For linear elastic materials, stress – strain relations are found through Hook's law for linear elasticity, while in a homogenized materials, young modules (E) and Poison ratio (ν) are found by observing a cubic element inside a solid object (figure 1). The following relations are given by Hook as :

$$\left.\begin{aligned}\varepsilon_x &= \frac{\sigma_x}{E}-\nu\frac{\sigma_y}{E}-\nu\frac{\sigma_z}{E}\\ \varepsilon_y &= -\nu\frac{\sigma_x}{E}+\frac{\sigma_y}{E}-\frac{\sigma_z}{E}\\ \varepsilon_z &= -\nu\frac{\sigma_x}{E}-\nu\frac{\sigma_y}{E}+\frac{\sigma_z}{E}\end{aligned}\right\}\quad ....4$$

$$\gamma_{yz}=\frac{\tau_{yz}}{G}$$

$$\gamma_{xz}=\frac{\tau_{xz}}{G}$$

$$\gamma_{xy}=\frac{\tau_{xy}}{G}$$

Where G is the shear modulus, which is shown below:

$$G=\frac{E}{2(1+\nu)} \quad ....5$$

From Hook's equations (4) we find :

$$\varepsilon_x+\varepsilon_y+\varepsilon_z=\frac{(1-2\nu)}{E}(\sigma_x+\sigma_y+\sigma_z) \quad .... 6$$

by substituting (σx+σz) in equation (4), we get the generalized relations between strain and stress...

$$\sigma=D\varepsilon$$

When D is the symmetric matrix for the material in two dimensions (6x6) given as shown below:

$$D=\frac{E}{(1+\nu)(1-2\nu)}\begin{bmatrix}1-\nu & \nu & \nu & 0 & 0 & 0\\ \nu & 1-\nu & \nu & 0 & 0 & 0\\ \nu & \nu & 1-\nu & 0 & 0 & 0\\ 0 & 0 & 0 & 0.5-\nu & 0 & 0\\ 0 & 0 & 0 & 0 & 0.5-\nu & 0\\ 0 & 0 & 0 & 0 & 0 & 0.5-\nu\end{bmatrix} \quad ....7$$

Procedures:

Three samples of the composite were Designed, each one consists of 132 node and of (10cm*11cm) dimension. The matrix elements entered in the package, then reinforced fibers entered to the composite. Then the direction of the fibers was changed with in the load direction in order to study the effect of that change, as shown in the figures below :

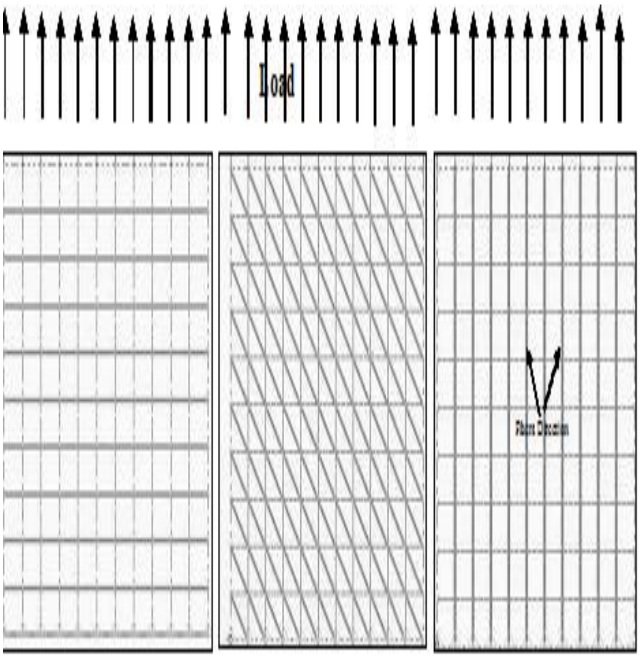


Figure (2-a) fibers at 90^0 with load direction
Figure (2-b) fibers at 45^0 with load direction
Figure (2-c) fibers at 0^0 with load direction

All the data concerning the materials used in the composite was recorded in the data box of NASTRAN program, as shown in table (1) below:

Table(1) properties of the (rigidity) for the materials used in the composition:

Material	Young Modulus E (Pa)	Poison Ratio ν	Shear Modulus G (Pa)
Cast Epoxy Resin DGEBA	2.8E+08	0.2	1.2E+08
E-glass fiber (Unidirectional)	7.6E+10	0.22	3.1E+10

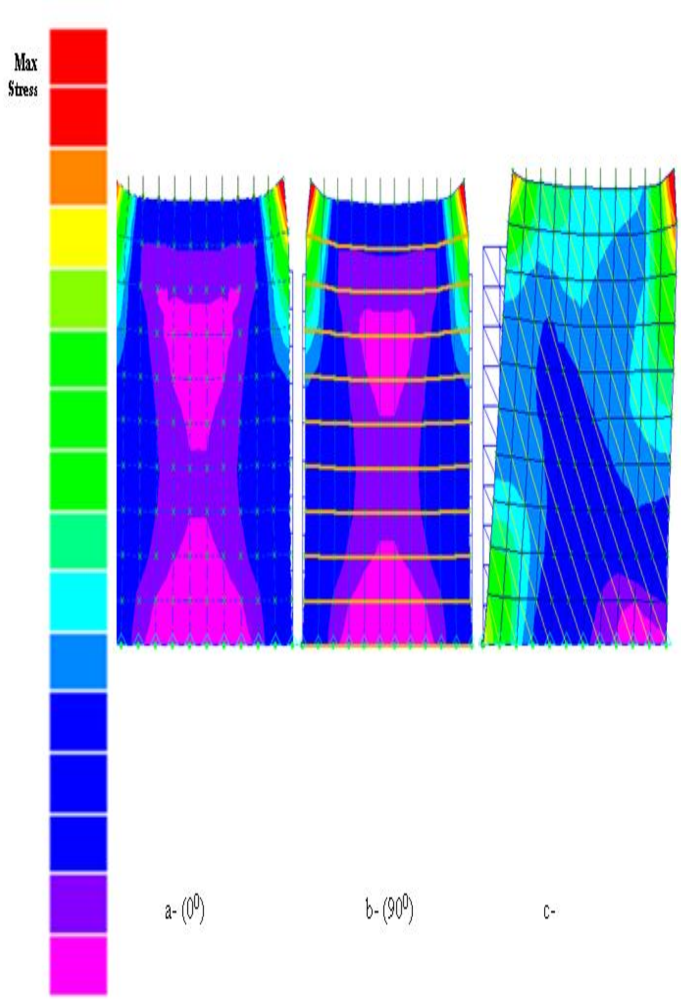
All the data concerning the specification of the material, such as width and other geometric inputs was entered in the package data base as shown in table (2).

Table(2) Engineering properties for the materials used in the composition:

Material	Type	Property
Epoxy Resin DGEBA	Plate	Thickness = 0.004 m
E-glass fiber (Unidirectional)	Rod	C.S. Area = 0.0000007854 m2

Tensile load was Applied as shown by arrows in figures (2a,b,c) .Then stress tests were done for the 3 samples within the load range of 500-5000Nt . stress values were recorded with a corresponding strains and deformations using M.S. Excel program a stress-strain curve was drawn for each material within the elasticity limits to find out the slope of the curve (which represents a Yong modulus of elasticity) for each material. A comparison was made also for each case to find out the direction with the best value of elasticity and the critical areas of the stress among the samples figures (3,4).

P- ISSN 1991-8941 E-ISSN 2706-6703 Journal of University of Anbar for Pure Science (JUAPS) Open Access
2009,(3), (3) :109-115



Fig(3-a,b,c)Stress distribution for a three samples By NASTRAN (FEM) Package

Results and Discussion:

The results of the study showed that the highest value of the elasticity modulus was 23.3Gpa at 00 angle with the load direction followed by the value of 22.9Gpa, at 450 angle, while the angle 900 gives a value of 22.6Gpa which is the least value for elasticity modulus. This may explained by the mechanical theories of the composite materials, we found that the direction of load fibers causes a stress distributed on the fibers and the base materials, i.e. stress force is equal to the total of fiber resistance and the matrix material.

As the fibers angled with the load direction this leads to distributing the internal stresses on the fibers and matrix which mean that the tensile strength produced from total strengths for both the fibers and matrix, likewise the fiber with direction of the load executed to reduce most of stresses by the matrix and fibers the resultant a high strength and high elasticity the results have referred.

If the load was perpendicular to the fiber direction(the second case 900), the strength of composite produce from the polar adhesive force between the fiber and matrix only, fig(3-b) show the maximum stress sites (the region with orange color) for this case the maximum stresses is concentrated in the joint area of the fiber and matrix, that means that the region of the interface support the most of applied stresses which causes the least value of tensile elasticity. In the case of the fibers at 450 angle with the load direction (third case) the value of elasticity modulus was greater than the value of second case (fibers angled 900 with the load direction) and less than the first case (at fibers has 00 angle with the load direction),

If we return to the analytical results for this case fig(3-c) we find that there is another effect for this angle on the composite specification, the figure shows that the load caused a shifting for the specimen about its pivot, this produced a mount of shearing stress added to the original tensile stress, this may assign to the un isotropic distribution of the fibers within this angle, we also notes that the shifting direction reversed to the fiber angle, that’s mean the fiber direction support the tensile strength in the opposite side for the shifting.

We may also refers to the other figures (3a,b,c) which shows that the stresses concentrated generally in the ends belong the load area (the red color area), and reduces gradually towards the middle of samples (the least value of the stress represented by the purple color) except the third sample (450) which had a least stress in the right bottom end and an amorphous deformations in the other areas . The high stresses at the top ends may interpreted as their existing in the matrix area.

From the results of the research, we got the following conclusions:

1- The modulus of elasticity for the composites reinforced with fibers is strongly affected when the angle of the fiber inside the composite material changed with the direction of the load and it reaches the highest value when the load direction is parallel to the fiber direction at 00 angle (that's correct for the unidirectional continuous fibers) . When the direction of fiber changed to a vertical (at 900 with the load direction) , the modulus of elasticity the has a least value.

2- When the fibers angled at 450 with the load direction, the modulus of elasticity is higher than the case when the load is vertical. Nevertheless, this position is not preferred in constructing composite material reinforced with the fibers because of the shearing stresses produced vertically to the direction of the tensile load goes through the whole sample which reduces the strength of the material.

3- Generally the greatest strains are situated at the ends of the sample produced to load and specifically at the area where load was imposed and in the base material, therefore it is preferred to distribute the load on the fibers areas equally, i.e. similar load should de directed on the composite material (straight load not linear or spotted). This type of load can be achieved by increasing the space of load sector to include the base material and fibers together.

4- The other procedure to get a homogeneous load and better results was to construct a composite which has the same properties in the shape of a multilayer composite so as to distribute the load on a bigger space of the layers and as a result the strains will be less.

References

[1] The Premium Computer Aided Engineering (CAE) Tool for Producing Safe, Reliable, Faster and Optimized Designs .htm 2000.

[2] http:// MSC-Stress analysis .com , 2000 .

[3] Upadhyay A. Kalyanaraman V. (2003), "Simplified analysis of FRP box-

[4] T Burczynski and W Kus, "Identification of material properties in multi-scale modeling", Journal of Physics: Conference series 135 (2008) 012025.

[5] FEMAP Basic.htm , 2000.

[6] Dragan D.Kreculj, "Stress analysis in an unidirectional Carbon/ Epoxy composite material", FME Transactions (2008), Vol. 36, No. 3, 27- 132.

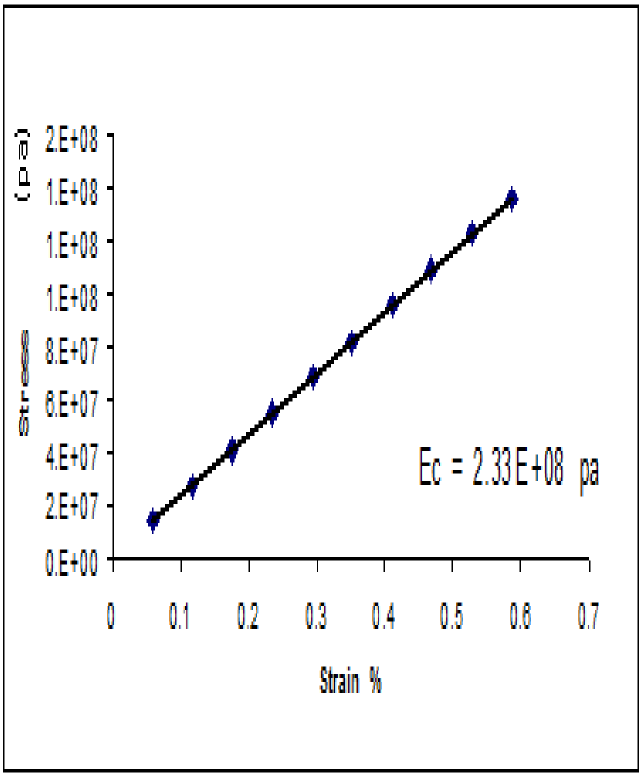
[7] Niels Ottosen & Hans Peterson, "Introduction to the FEM" 1992 .

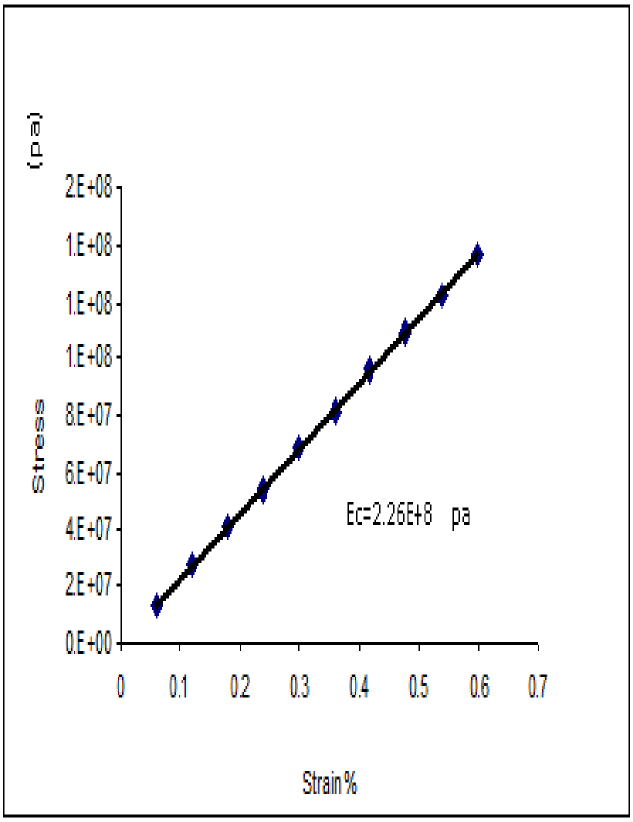
[8] T.R. Chandrupatla & A.D.Belegundu , " Introduction to Finite Elements in engineering ", New Delhi – 110001 ,1996 .

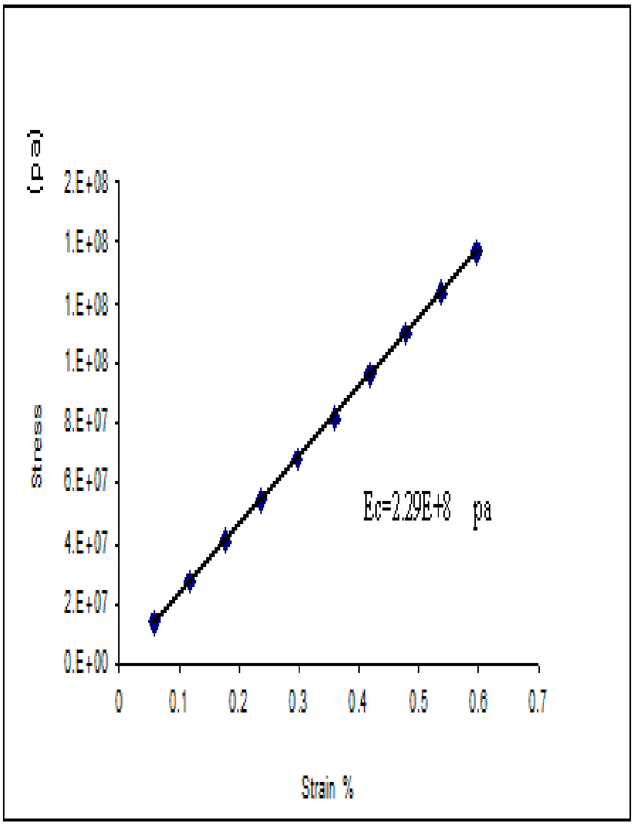
[9] K.C.Rockey , H.R.Evans, D.W.Griffiths , D.A.Nethrcot, "The Finite Element Method a basic introduction for engineering " ,1975

[10] Robert D.Cook, " Concepts and applications of Finite Element Analysis ", 2.Nd Ed., John Willie & Sons 1992 .

P- ISSN 1991-8941 E-ISSN 2706-6703 2009,(3), (3) :109-115







Fig(4) Stress-Strain Curves for the composite

a. at 0^0
b. at 45^0
c. at 90^0

"تاثير اتجاه الالياف على معامل مرونة الشد لمتراكبات الايبوكسي باستخدام النمذجة الحاسوبية"

صلاح صليبي الراوي

E .mail :dr_salah_rawi@yahoo.com

الخلاصة

في هذا البحث تم تصميم نموذج من متراكبات الايبوكسي المقوى بألياف الزجاج وتعريضه لإجهادات الشد ودراسة تأثير اتجاهات الالياف على مرونة الشد باستخدام طريقة العناصر غير المحددة (FEM). استخدمت برمجية (MSC-NASTRAN) لهذا لغرض تفعيل اختبارات الشد للنموذج المصمم عندما تصنع الألياف زوايا(0o,45o,90o) باتجاه الحمل لغرض الوصول الى أفضل الخصائص الميكانيكية. من خلال نتائج الاختبارات وتحليلات الطيف اللوني وجد ان أفضل قيم لمعامل مرونة الشد تكمن عند الزاوية(0o) تليها الزاوية (45o) ثم الزاوية(90o) التي اعطت اقل قيمة لمعامل المرونة.