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STATE STRAIN AND DEFORMATION FOR POLYMER COMPOSITE MATERIAL BY USING NUMERICAL SOLUTION

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ABSTRACT:-This study deal with composite materials made of E-glass , carbon fiber with epoxy matrix at volume fraction 0.6 , by using mat lab 2008 a was used to state the deformation and strain in both x,y direction .

40*40 mm element was subjected to tensile stress in x direction with value 200,300,400 and 500 MPa with two angle θ=0 and θ=45 degree, the von miss stress distribution has been stated by using solid work at 400,500 MPa.

The results was showed when θ=0 glass fiber have value of strain more than carbon fibers, when θ=45 carbon fiber have value of strain more than glass fibers .the change in right angle gave us zero indicating when θ=0 ,and θ=45 the change in right angle gave us negative indication .the von miss stress at 500 MPa was low factor of safety .

Keywords:- composite material, mat lab, epoxy, strain, deformation.

1-INTRODUCTION

An introduction of new technology follows the development and use of modern materials. Today, composite materials are the subject of an intensive development and use.

These materials have significantly better mechanical and other characteristics than their constituent elements.

Properties of composite materials that make them more specific than other materials are: large strength, high stiffness, small density and mass, resistance to corrosion and high temperatures, the ability to create complex shapes. Most of composites are created in order to improve the combination of mechanical characteristics of materials, such as stiffness, toughness and strength in conditions of environment influences, or at higher temperatures.

These materials also have a considerable potential for absorbing kinetic energy during crash. The ability of these materials to meet the specific needs for different structures makes them highly desirable. Improvement in design, materials and manufacturing technology enhance the application of
composite structures (1).

The use of fiber-reinforced composite materials has grown rapidly in recent years because of their high specific strength and stiffness, particularly in the aerospace, aviation, automotive, and civil-engineering industries. Examples include wind-turbine rotor blades and submersible
Structures (2).

The study of composite materials has been one of the major objectives of computational mechanics in the last decade. The numerical simulation of composite materials may be use for studying orthotropic materials with average properties of their constituents. With this approximation, no model has been found able to work beyond the constituents elastic limit state and deformation under load . Different theories have been proposed to solve this problem, taking into account the internal configuration of the composite to predict its behavior(3).

Dragan study the stresses in the models from unidirectional carbon/epoxy composite material. Software packages, based on the Finite Element Method (FEM), can be used in order to predict stress distribution on the exanimate model [4].
OLLER et al use computational methodology for modeling the non-linear mechanical behavior of composite, the structures made of FRP (Fiber-Reinforced Polymers) laminates.

The model is based on the appropriate combination of the constitutive models of compounding materials, considered to behave as isolated continua, together with additional "closure equations" that characterize the micro-mechanics of the composite from a morphological was point of view [3].

R. Zemak and et al his focuses was on the identification of material parameters of carbon-epoxy composite with continuous ultrahigh modulus fibers. The tested structure was a cantilever beam with a rectangular cross-section manufactured with forming several fiber bundles together, each wrapped with transverse layer of fibers (5).
M. Muneer et al was studied the results of thermo-mechanical characterization of Glass/Epoxy composite specimens using Infrared Thermograph technique (6).

This work uses mat-lab and solid work to state the deformation, strain under different limit of stress and von miss stress distribution at maximum stress, the paper deal with high strength carbon fibers and E- glass fibers with epoxy matrix.

2-THEORETICAL CONSIDERATION

The main functions of the fibers in composite are to carry most of the load applied to composite and provide stiffness .for this reason, fiber materials have high tensile strength and high elastic modulus .By in corpora ting such fibers in ductile matrix it is possible to form a composite which makes use of high strength and high elastic modulus .

The properties required of a suitable matrix material are that [7]:-

1. It adheres to the fiber surface so that forces applied to the composite are transmitted to the fibers so that they can assume the primary responsibility for the strength of the composite.
2. It is protects the fibers surface from damage.
3. It keeps the fibers apart to hinder crack propagation.

The law of mixtures.

The mass mc of composite is made up of masses of matrix mm and the fibers mf ,so

$Mc= m^m+ m^f$ --(1)

Since mass is volume v times density ρ , then eq. 1 can be written as :

$Vc\, \rho^c = v^m \rho^m + v^f \rho^f$ -- ---(2)

Vm/vc is the volume fraction Vm that is matrix and V ρ/Vc is the volume fraction V_f that is fibers. Thus:

$\rho^c = V^m \rho^m + V^f \rho^f$---(3)

Note that since $v^m= v^c-v^f$ we must have

$V^m=1-V^f$. Eq(3) can be termed a low of mixtures[7].

Now consider the low of mixtures for the elastic modulus of a composite having aligned continuous fiber with direction .therefore .

$E^c\, \xi a_c= E^m\, \xi a_m + E^f\, \xi\, a_f$ ------ --(4)

And thus if we write Am as the area fraction am/ac and Af as af/ac:

$E^c= A^m E^m + A^f E^f$ ------ ---(5)

Since am =ac-af then Am= $1-A^c$. Eq(5) is the low of mixtures for the tensile modulus

For continous fibers aligned parallel to the loading direction . They are fraction are equivalent to the volume fractions and thus eq(5) can written as

$E^c=V^mE^m+V^fE^f$--(6)

Now consider the elastic modulus when the fibers are at right angle to the direction of the loading

$\sigma/E^c\,.l^c = \sigma/E^m\, l^m + \sigma\, /E^f\, l^f$---(7)

and so:

$1/E^c = L^m/E^m + L^f/E^f$ ---(8)

When,

l=original length

Lm = is the matrix length fraction

lm/lc and lf is the fiber length fraction

lf/lc the length fraction are equivalent to the volume fraction.

And the end equation becomes

$1/Ec = V^m/E^m + V^f/E^f$ ---(9)

3-NUMERICAL SOLUTION

Computing the stress and strain in composite materials within the matrix ,within the fibers and at the interface of the matrix and fibers is very important for understanding some of the underlying failure mechanism .there for we have the following assumption .

1. Both the matrix and fibers are linearly elastic .
2. the fibers are infinity long.
3. the fibers are spaced periodically in square packed or hexagonal packed arrays.

So there are three different approaches that are used to determine the mechanical properties of composite materials based on micromechanics are (8).

1. Using numerical model such as the finite element method.
2. Using models based on the theory of elasticity
3. Using rule of mixtures models based on strength of materials approach.

In this work study mat lab 2008 a and solid work 2003 .are used to state the strain ,deformation and von miss stress distribution for cubic element made from polymer matrix composite.

Mat lab used for to state the deformation and strain in X,Y direction , by using the rule of mixture models.

Carbon and E-glass fiber reinforcement materials are used with epoxy matrix with volume fraction is (0.6) V_f ,table (1) explain the mechanical properties for fibers and matrix .

Plane element of size (40*40) mm was made of carbon and E- glass fibers with epoxy matrix , the element is subjected to a tensile stress in x- direction with value (200,300,400and 500) MPa.

In addition, the study dell with the fibers in tow case:

- The fibers are aligned along the x-axis.
- The fibers are inclined to the x-axis with an orientation angle $\theta=45^o$.

In addition, the matrix materials assumed to be isotropic materials, whenever the fiber materials are assumed only transversely [9].

So that

$E_1^m = E_2^m = E^m$.

And

$E^f{}_3 = E^f{}_2, v^f{}_{13} = v^f{}_{12}$ and $v^f{}_{23} = v^f{}_{32} = v^f$ --(10)

Von miss stress distribution was stated by using Solid work 2003 package. For maximum tensile stress σx=500 MPa with element size (40*40*40) mm .Table (1) explain the materials properties used for mat lab and solid work solution ,appendix number 2 explain the sold work parameter and results.

Table (1): mechanical properties for composite material (10,11).

Properties	E-glass-fibers 1	Carbon ,high strength –fibers 2
E1 GPa	45	145
E2 GPa	12	10
V12	0.19	0.25
G12 GPa	4.95	3.93
ε 1	2.3	0.9
ε 2	0.4	0.4
σtensile1 MPa	1020	760
σ Tensile $_2$ MPa	40	41
ρ g/cm^3	2.1	1.7

1. epoxy matrix with E- glass fibers with $V_f = 0.6$.

2. epoxy matrix with carbon fibers with $V_f = 0.6$.

E1, E2=modules of elasticity

V12=Poisson ratio.

G12=shear modules.

ε =strain .

σ=tensile strength.

ρ=density

4- RESULTS AND DISCUSSION

Preventing failure of composite material system has been an important issue in engineering design (12).

In $\theta=0^o$. the relationship between stress and strain in X- direction was explained in Fig.(1) which explain strain increase when stress increase the maximum strain indicated at 0.44 with value of stress is 500 MPa in E-glass fibers also E-glass have strain more than carbon fibers . .

Fig (2) explains the relationship between stress and strain in Y –direction .the value of strain for glass and carbon fibers in mines value, carbon fibers have strain value more than glass fibers and maximum value of strain indicated at 200 MPa for carbon fibers.

The relationship between stress and deformation in Y – direction were explained in fig.(3) ,the deformation in carbon fibers was 39.97 mm at 200 MPa and decrease with increase the value of stress. Also glass fibers as compared with carbon fibers have deformation more than glass fibers, the values of strength for carbon much more glass also are explained in table (1)

Fig .(4) explains the relationship between stress and the deformation in X-direction ,the deformation increase with increase stress ,and glass fibers have deformation more than carbon fibers ,maximum deformation was 40.45 mm in 500 MPa for glass fibers.

The change in right angle of the element was explained in fig.(5) the fig. explain the relationship between right angle and stress ,the results was showed no change in right angle with increase the value of stress .

When angle =0 The change in the right angle (in radians) of the element ,calculated using the shear strain obtained from the strain vector ,it is noticed that in this case the change is zero indicating that the right angle remains after deformation this mainly due to the fibers being aligned along the x- direction [13].

$\theta=45^o$. the results was showed in fig.(6,7,8,9 and 10) respectively .

the relationship between stress and strain in X-,Y -direction were explained in fig.6,7 respectively ,fig,(6) explained stress and strain in X- direction ,the stress increase with increasing in strain the value of glass and carbon fibers are to close in value the value around 2.8-3 when stress was 500 MPa.

Fig.(7) explain the strain in Y –direction the behavior of the curve was down word the value in minus , the change is minus since it indicates a reduction in the dimension along this direction (13).

The value of carbon and glass was to close the maxim value of strain indicated at glass in stress value is 200 MPa.

In fig 8 the fig. explain the relationship between stress and deformation in X- direction the fig. was showed when stress increase the deformation increase and the carbon fibers have deformation slightly more than glass fibers .

In fig.(9) the relation between deformation in Y –direction and stress was explained when stress increase the deformation decrease and glass fibers have deformation more than carbon fibers .

Fig.(10) explain the relationship between the change in right angle of the element and the stress ,when stress increase the change in angle decrease and glass fibers have change more than carbon fibers.

When angle =45 ,it is noticed that ,there is a negative shear strain indicating that the right angle increase to become more than 90 after deformation ,this is mainly due to the fibers being inclined at an angle to the X-direction[13,14,15].

In fig. 9,3 the minus sign indicate that there is a reduction in this dimension along the fibers , the change is very small due to the fibers reducing the deformation in this direction, noticed that the change which is very small (13,14,15).

In fig.8,4 the change in the 2-direction it is a largest change because the tensile force is along this direction .this change is positive indicating an extension in the dimension along this direction(13,14,15).

5-CONCLUSION

The following conclusion can be obtained from present work:-

1. Strain and deformation in x- direction with θ= zero° glass fiber have strain and deformation more than carbon fiber at θ= zero° the maximum value of strain and deformation was (0.4 and 40.4mm) respectively at 500 MPa.
2. Carbon fibers have value of strain and deformation more than glass fiber in x-direction at θ=45°, maximum value of strain and deformation was (3,43mm) respectively.

3. The change in strain was negative for different value of θ. at θ= zeroº the Carbon strain was more than glass fiber value, while at θ=45º the glass fiber strain was more than carbon value.
4. The von miss stress distribution at 500 MPa indicated low factor of safety and value of stress reach to 1.7 G N/mm^2 for glass fiber, and 1.6 G N/mm^2 for carbon fiber.

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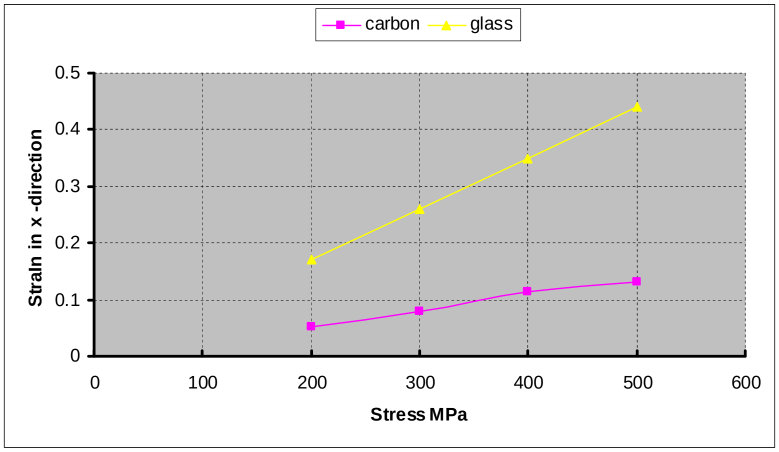

Fig.(1): Relationship between stress and strain in x – direction.

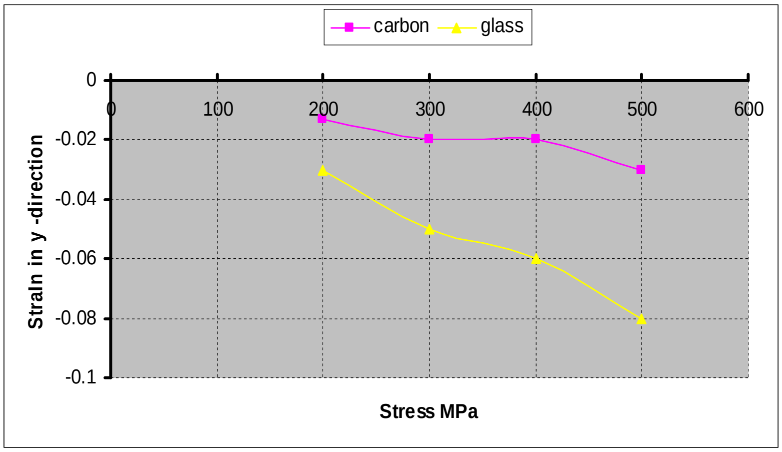

Fig.(2): Relationship between stress and strain in y – direction.

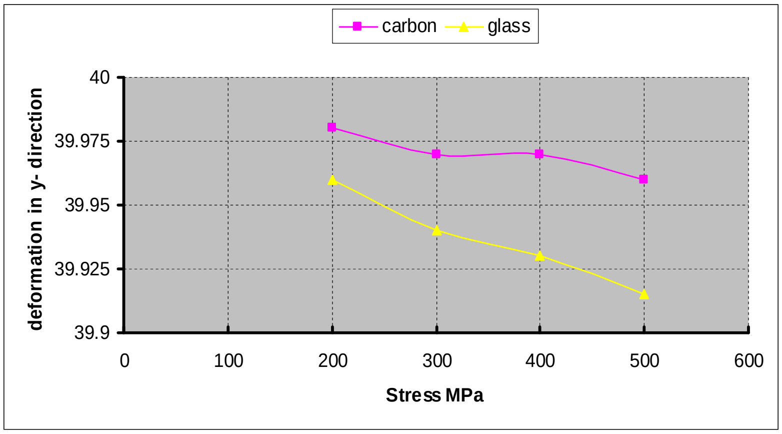

Fig.(3): Relationship between stress and deformation in y – direction.

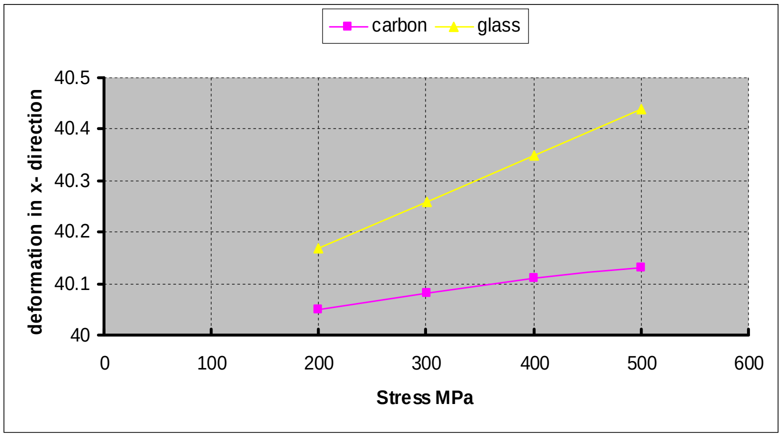

Fig.(4): Relationship between stress and deformation in x– direction.

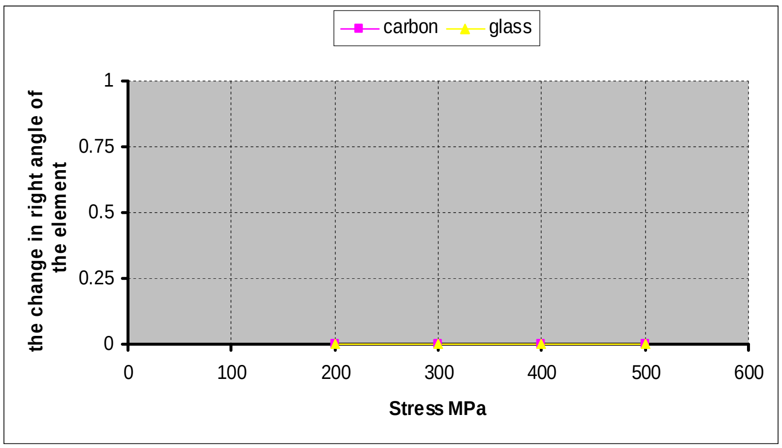

Fig.(5): Relationship between stress and the change in right angle of the element.

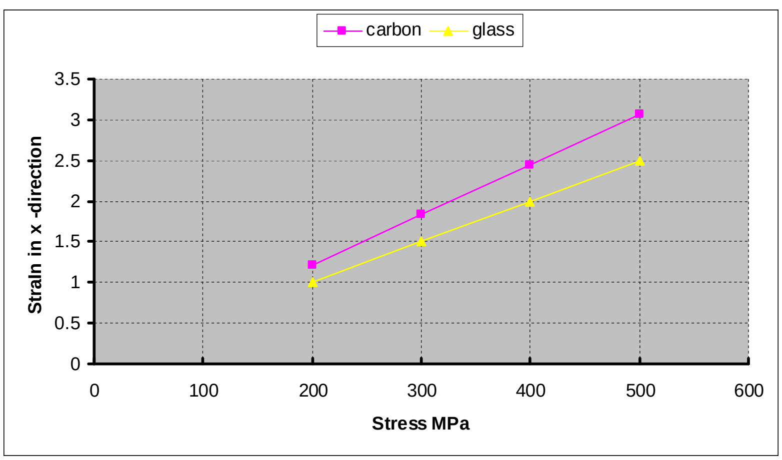

Fig.(6): Relationship between stress and strain in x – direction.

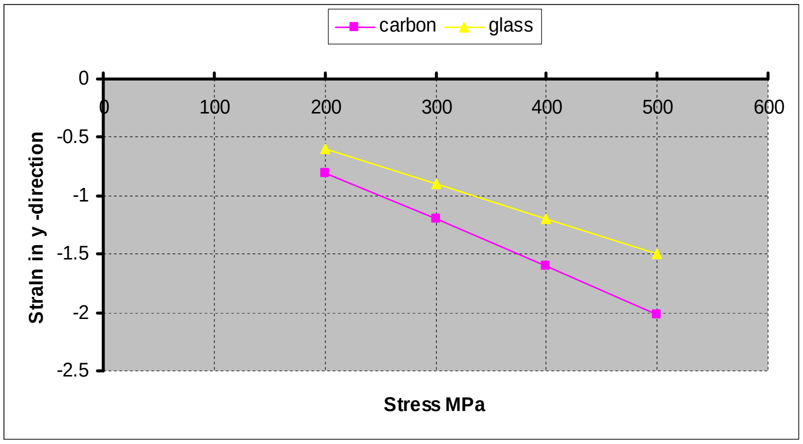

Fig. (7): Relationship between stress and strain in y– direction.

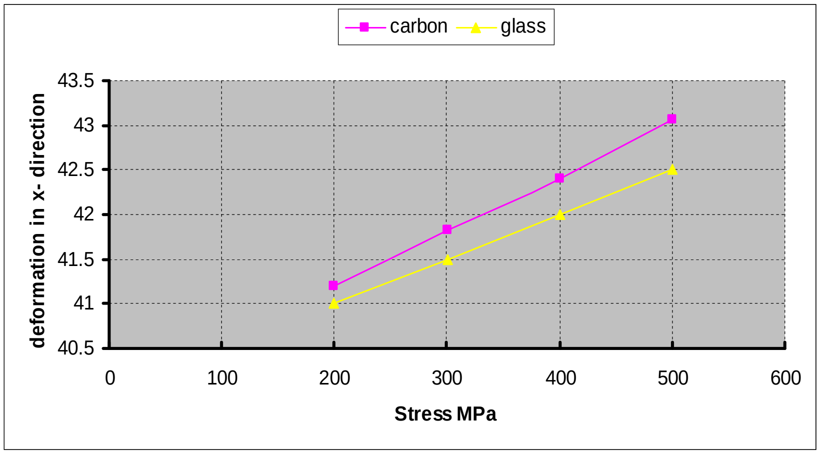

Fig.(8): Relationship between stress and deformation in x – direction.

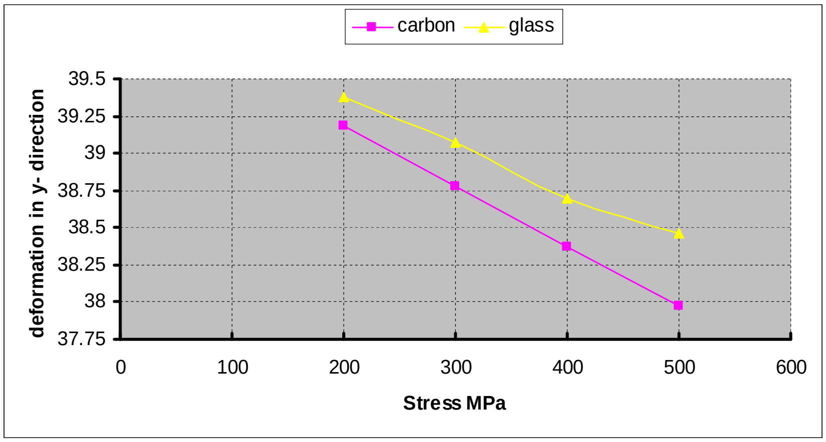

Fig.(9): Relationship between stress and deformation in y – direction.

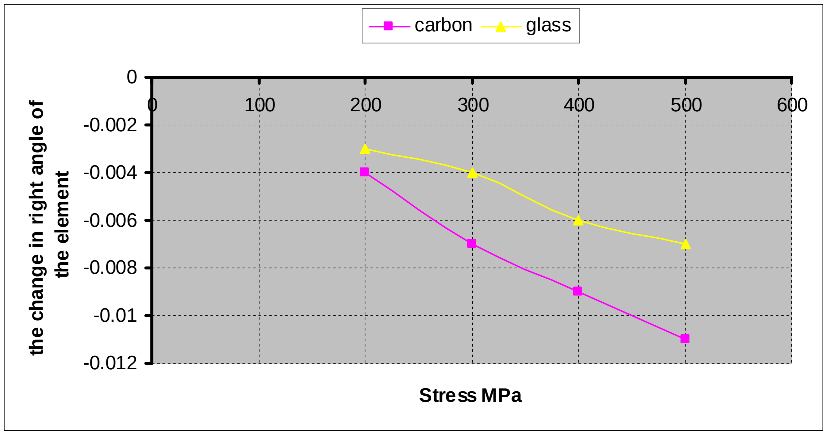

Fig.(10): Relationship between stress and the change in right angle of the element.

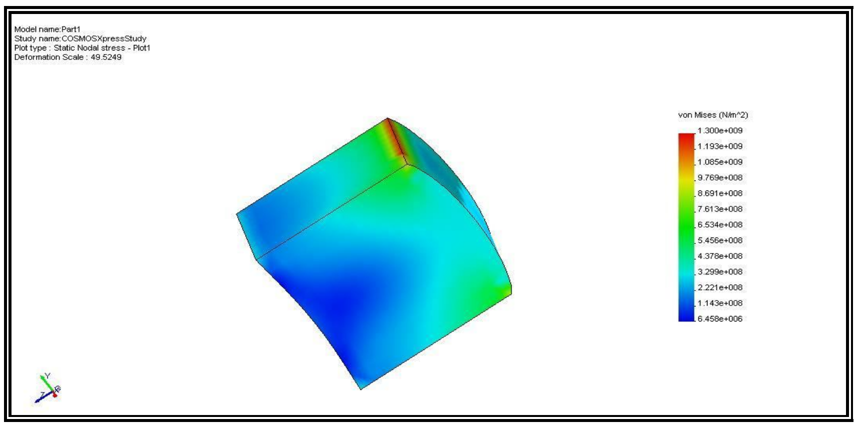

Fig.(11): Carbon fiber von misses stress distribution at 400 MPa.

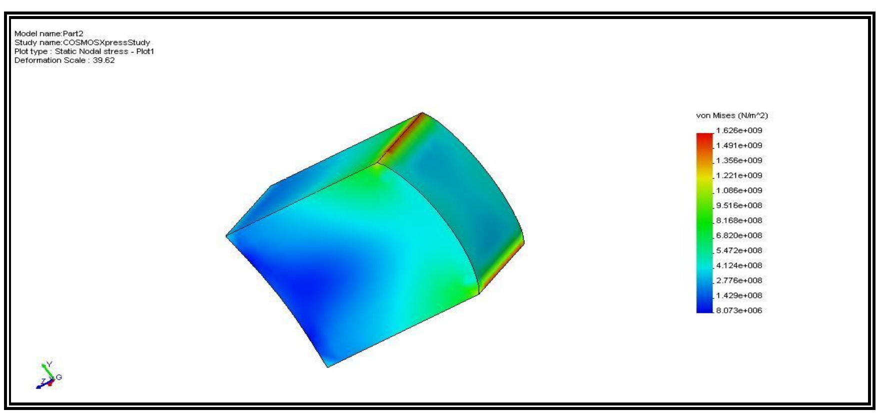

Fig.(12): Carbon fiber. Von misses stress distribution at 500 MPa

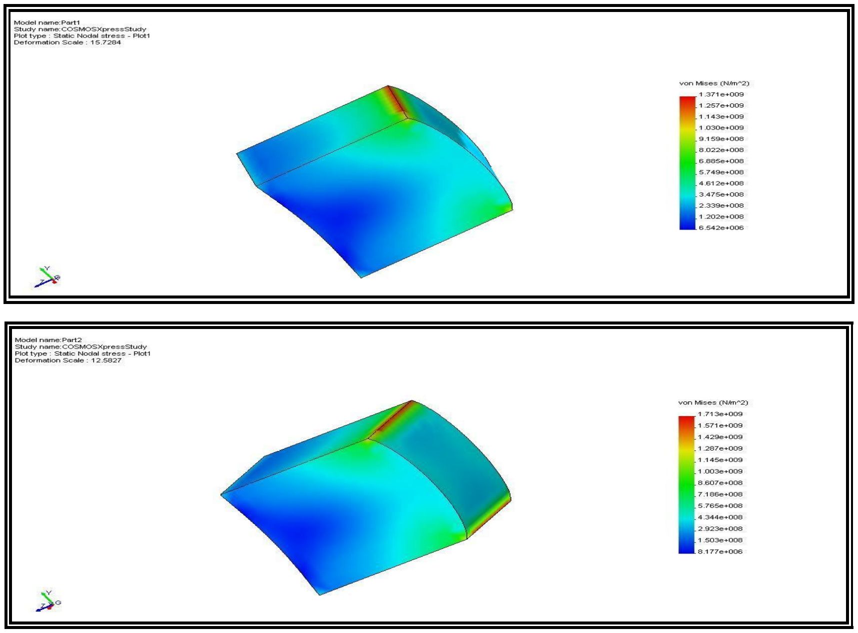

Fig.(13): Glass fiber von miss stress distribution at 400MPa.

Appendix number 1explaine the experimental result that it is compared with the result of paper (5,11)

No.	Materials	Condition	Properties
1	Carbon –epoxy vf=0.6	At maximum strength	Percent of elongation=2.3 Strain=0.9
2	E-glass-epoxy vf=0.6	At maximum strength	Percent of elongation=2.3 Strain =2.3
3	Carbon- epoxy vf= 0.6	At maximum strength	Strain=0.9
4	Glass-epoxy vf=0.6	At maximum strength	Strain=2.3
5	Glass-polyester vf=0.4	Area 250mm2 ,at stress 50mpa	Strain 1.69*10-3
6	Graphite -epoxy vf=0.6	Stress 200 mpa with 30o	Deformation at x- axis's =0.7 mm Deformation at y- axis's 1.4 mm Strain Δlx=0.7 Strain Δly=-0.5

تحديد الانفعال والتشوه لمادة مركبة ذات أساس بوليمري باستخدام الحلول الرقمية

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الخلاصة

تهدف الدراسة الحالية الى تحديد قيم التشوه والانفعال بالمحورين x,y لمادة متراكبة ذات ارضية من الايبوكسي ومدعمة بالياف تقوية من الياف الكاربون و الياف الزجاج وباستخدام برنامج mat lab -2008a حيث تم تحضير عينة بابعاد 40*40 ملم وتسليط اجهاد شد على المحور السيني ومتعامدة على الالياف وبقيم زاوية 0 و45 درجة عند قيم اجهاد (200-300-400-و 500) ميكا باسكال. وكذلك تناولت الدراسة تحديد قيم توزيع الاجهاد لهذه المادة المتراكبة بأستخام برنامج solid work 2003 عند قيم اجهاد 500و400 ميكا باسكال . من النتائج تبين ان عند زاوية صفر الانفعال والتشوه باتجاه المحور السيني الياف الزجاج ذات قيم اعلى من الياف الكاربون وعند الزاوية 45 درجة تعكس الحالة وان عند اجهاد 500 ميكا باسكال كان نتائج توزيع الاجهاد عالية للنوعين وذات معامل امان وطى.

كلمات الدالة:مادة مركبة –الانفعال و التشوه –ايبوكسي –برنامج مات لاب.