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Investigation of Biaxial Creep of Hybrid Woven Fabric of (LDPE/Nylon, Polyester) Composite Materials

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Abstract

Hybrid woven fabric composite materials suffer of anisotropic in behavior. It leads to difficult in the designing and fabricating of composite material.

The present work aim to study the biaxial creep phenomena of the hybrid woven fabric composite .It consist of low density polyethylene matrix and plain weave from nylon and polyester. The study is carried out by numerical analysis and experimental .The numerical analysis (FEM) includes biaxial creep model is implemented by ANSYS (10) code. To verify the ability of this model in the prediction the effect of anisotropic on biaxial creep, the experimental work is conducted. The experimental work includes designing and fabrication of biaxial creep test Rig.

The experimental result show the creep values in the direction of polyester fiber are lower than that in the direction of nylon fiber, and also show the experimental creep values is higher than numerical values.

***Keywords**:* Composite materials, hybrid fibers, biaxial creep behavior, in-plane biaxial testing, cruciform specimens, finite element method*.*

1. Introduction

The rapidly expanding applications of textile fabric composites in the recent past years have provided much optimism for the future of engineering design and technology [1],with the recent advances in modern industrial materials, such as high polymers and polymeric base composite materials , and their extensive application in aerospace and other industries [2].Textile composite were considered for many components to improve structural performance and to reduce costs [3,4]. Polymer composites are viscoelastic in nature (i.e. their behavior is a combination of viscous and elastic behavior). While being used for load bearing structural application, polymer composites exhibit time dependent degradation in modulus and strength, as a consequence of viscoelasticity of the polymer matrix. The time dependent modulus and strength of composite materials are measured by creep and creep rupture tests, respectively .Since characterizing the time dependent modulus and strength for the entire service life is impossible, accelerated testing and extrapolation procedures are used to extrapolate creep data obtained over a short time to time frame beyond the experimental time window. Hybrid woven fabric composite materials suffer of anisotropic in behavior. It leads to difficult in the designing and fabricating of composite material. There are a numerous of the researchers deals with this subject. Such as, D.E.Duvall & D.B.& Edwards (1993),in their work presented a method for evaluating the creep and stress rupture response of polyethylene sheet under equal bi-axial loading . Specimens have been tested at 23, 60, 80 °C, [5,] .V.Shekar (2000) investigated tensile creep behavior of woven fabric composite stitched through the thickness with carbon threads along the loading direction. Creep tests were conducted at various temperatures. It was found that through - thickness stitching significantly improved resistance for creep deformation and creep rupture of stitched composites [6]. P. Boisse & et.al. (2001**)** studied of the mechanical behavior under bi-axial tension. The study results are obtained for a set of fiber fabric reinforcements that show the consequences of undulations and interactions at the macroscopic scale[7].K.J. Philps (2002)studied stress relaxation of tufted carpet*s* components .This research seeks to analyze the various components and which plays in the phenomena of stress relaxation .Since a carpet is always stretched in both dimensions simultaneously during installation ,the results of this work show that fabrics may have higher creep and stress relaxation values due to the greater opportunities for movement in the fabric structure since the yarns and the fibers within the yarns may be able to shift positions in order to alleviate stress[8]. The present work aim to study the biaxial creep phenomena of the hybrid woven fabric composite .It consist of low density polyethylene matrix and plain weave from nylon and polyester.

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2. Modeling process:

Modeling process includes three stages are (model constituent, solution and results output) as follows:

2.1. Model constituent:

2.1.1 Assumptions

To simplify of the numerical solution and investigation of biaxial creep of pure low density polyethylene, several assumption are used in this model are:
1- The clamping system is equal in all directions.2-The load is apply by weight.3- The friction across the clamp and rollers is neglected.4-The creep movement across the fix clamp is zero.5- test is conducting at room temperature. 6-The load is distribution along line.7-Applied stress is not found at z direction. 8-The model assume that the movement across the fix clamp is zero.

2.1.2. The geometry sub model:

Three dimensional models were built by ANSYS (10)code as shown in Figure(1) .The central biaxial test specimen size was (20*20mm) square, with an overall cruciform specimen dimensions of some 160×160 mm, . The sizes of the biaxial woven fabrics test specimens were chosen in order to be representative of the macro-structure of the woven fabrics.

2.1.3. Mesh generation:

Models are meshed by using automatic mesh generation process and the element configuration and size are shown in Figure (2). To obtain the best results of the modeling process, also to become more active to describe the real case of the analysis. Solid element SOLID95 is used in the modeling process. Load is applied on the loading area of the specimen along two perpendicular directions.

2.1.4. Boundary conditions of applied loads:

The symmetry boundary conditions about X, Y, and Z-axes are imposed in the finite element model as shown in Figure (3) The dead weight applies loads as drawing force, on all test levels the loads are equal to 450N in each direction(X and y). A zero-displacement boundary condition was imposed at the clamp.

2.2. Solution&Result output:

Nonlinear and large deformation solution is carried out with time steps are taken according to the experimental test time, while the results are recorded as contour results.

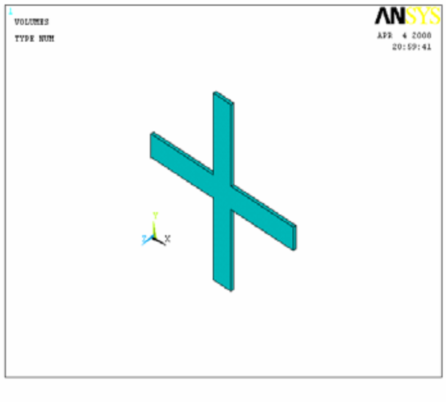


Figure (1) The geometry sub- model of biaxial creep sample.

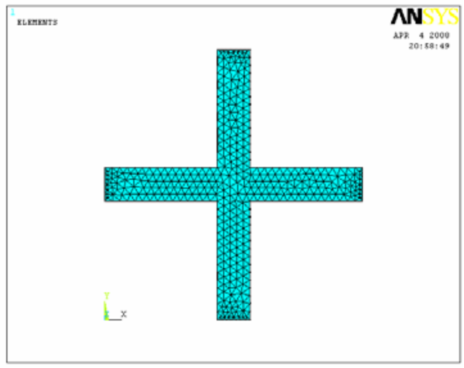


Figure (2) The FEM model of biaxial creep sample.

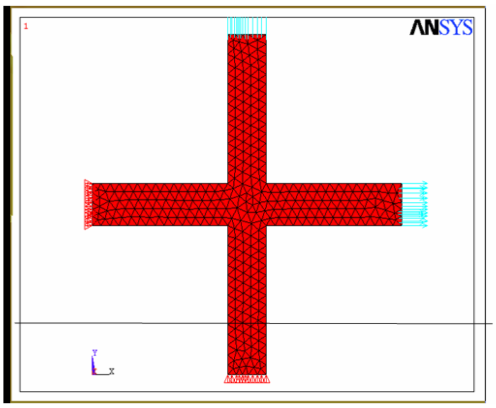


Figure (3) The Boundary conditions and applied load.

3. The Experimental Work:

Experimental work includes, test rig design and manufacturing, samples preparation and testing as following:

3.1. The materials

The following input materials were used in the current experiments: Nylon and polyester fibers are using as reinforces material .the woven fabrics of this fiber used as reinforce material. Low density polyethylene sheet used as matrix phase .characteristics of these material are shown in table (1).

Table (1) describe the used materials properties

<table>
<tr><th colspan="3">NYLON FIBER</th><th colspan="2">POLYESTER FIBER</th></tr>
<tr><td>min =37</td><td colspan="2">tension force</td><td>twist</td><td>(290-330)</td></tr>
<tr><td>(8.2-9.2)</td><td colspan="2">at(45N)the extension</td><td>cutting force</td><td>Min(185N)</td></tr>
<tr><td>(0.204-0.216)grim/m</td><td colspan="2">the weight to one meter</td><td>extension at(67 N)IS</td><td>(3.5-5.5)%</td></tr>
<tr><td>(0.15-0.57)mm</td><td colspan="2">Diameter(D)</td><td>Diameter average(D)</td><td>(0.65)mm</td></tr>
<tr><td>max5%</td><td colspan="2">exothermal shrinkage(150c°)</td><td>exothermal shrinkage(177 C°)</td><td>Max(3.5)%</td></tr>
<tr><td>max 4N</td><td colspan="2">exothermal shrinkage force(150)</td><td>(N)diameter upside</td><td>weight upside</td></tr>
<tr><td>(4-6)%</td><td colspan="2">Dip pick up</td><td>chemical treatment</td><td>(4.5-7.5)%</td></tr>
<tr><td>min(80N)</td><td colspan="2">adhesion</td><td>adhesion</td><td>(140N)</td></tr>
<tr><td>max(3%)</td><td colspan="2">humidity</td><td></td><td></td></tr>
<tr><td>(440-470)</td><td colspan="2">twist force</td><td></td><td></td></tr>
<tr><td colspan="5">PURE LOW DENSITY POLYETHYLENE</td></tr>
<tr><td>Tem-C°</td><td>V_m</td><td>E_m(Mpa)</td><td>Matrix volume(mm)^3</td><td>V_m%</td></tr>
<tr><td>23</td><td>0.4</td><td>68</td><td>337.5</td><td>90</td></tr>
<tr><td>75</td><td>0.45</td><td>11</td><td>337.5</td><td>90</td></tr>
<tr><td>110</td><td>0.49</td><td>0.68</td><td>337.5</td><td>90</td></tr>
</table>

3.2 Specimen design and preparation:

3.2.1. Hybrid woven fabrics preparation:

Manual method is used for preparation plain weave hybrid woven fabrics from nylon and polyester fibers. This required a wood frame which was made in square shape and fixed on the outside dimensions of dies .The nails were fixed on the wood frame in equal space to fix the fibers.

3.2.2 Manufacturing hybrid woven fabrics composite materials:

The specimens is made by put the hybrid woven fabrics between two sheet from polyethylene and put them in carbon steel die after that the mold is heating to (180°C°). The closed die remained inside the heater for(1 hours)under pressure value equals (0.5)MPa ,and then the composite sheet was removed, after cooling process with water .

4. Testing:

4.1. Tensile test:

Sheet of hybrid woven fabrics of composite materials is cutting to uniaxial tensile test. Uniaxial tensile test is used for getting hybrid woven fabrics properties in (x,y) directions. Specimen is cutting in warp direction and cut another specimen in fill direction. The testing procedure and the specifications were selected according to ASTM standard(D412-88).test specifications are : initial speed =5 mm/minute with stress range 50 MPa and strain range 100% , secondary speed = 10 mm/minute, and strain range 100% .

4.2. Biaxial Creep Testing:

The apparatus design and Manufactured depended on the literature survey from different studies as biaxial specimen's dimensions and the applied load to reaching to the comprehensive knowing for studying requirements of the creep phenomena . It is described in the Fig (4).

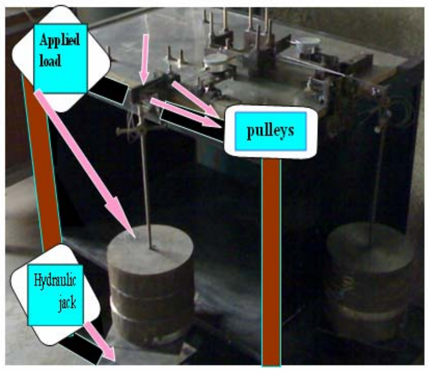


Figure (4) biaxial creep apparatus.

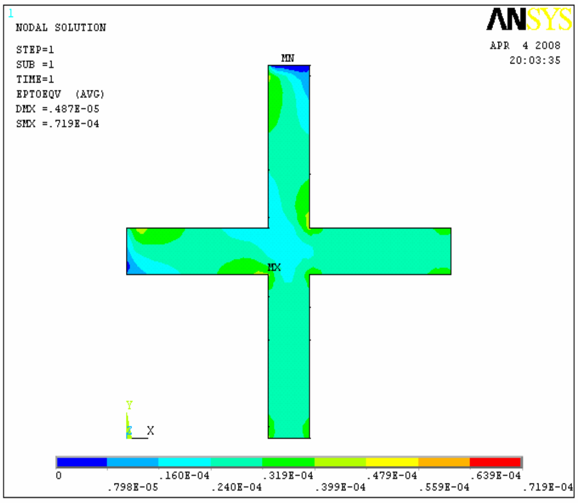
5. Results and discussion

From observing the numerical results of biaxial creep analysis which is carried out by ANSYS (10)code for pure low density polyethylene as shown in Figure (5) and which represent the contour results of creep behavior in (x,y)direction under applied load (450 N) at room temperature. From observation these results can be concluded that the strain with time behavior in (x) direction symmetry with the (y) direction for creep, and increasing from beginning of the creep test until (10) hours periods. The symmetry in the results in (x,y)directions is due to the isotropic behavior properties of pure low density polyethylene . These results show that the model is useful to predict the change in the creep behavior with direction; these results are compared with the experimental results for pure low density polyethylene as shown in Figure (6).the comparison is very clear and certify that the model is active to predict the creep results in this types of material and to verification of creep test rig accuracy, also the results of deformations in(x,y) direction were evaluated by this model and listed as contour as shown in fig(9).these results is appeared that the deformation is summitry.

From Figure(7) we observing the results of the stress-strain curves of samples with warp(Nylon)+ fill(Polyester),with warp(Polyester)+fill(Nylon) .thy appear difference in the values of the stress of polyester fiber compared with nylon fiber and that is because of increasing of polyester strength .

From Figure (8) which represents the experimental results of woven fabrics composites materials under (450N) and for the (7days),we note the increasing of the creep strain with time because of undulation of fiber yarns in the fabric at the first stage but, with increasing time the fibers begin with damage in the fabric that behavior leads to increase the strain with time ,But we observe the difference in the values of the strain for every each one of fiber ,where seems the polyester strain value is lower than from nylon fiber strain and that belongs to rise the polyester strength also, that difference is caused by the morphology structure and method of manufacture.

A-



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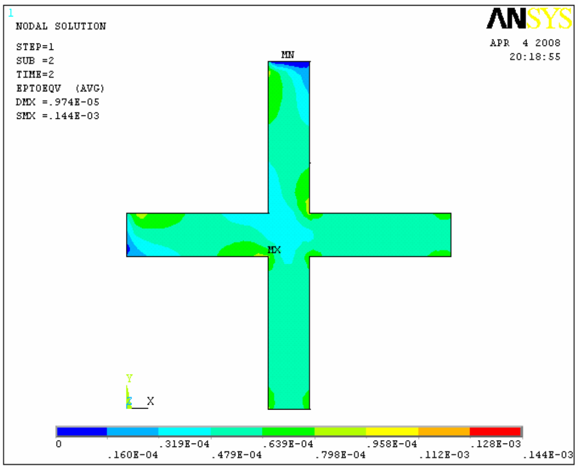

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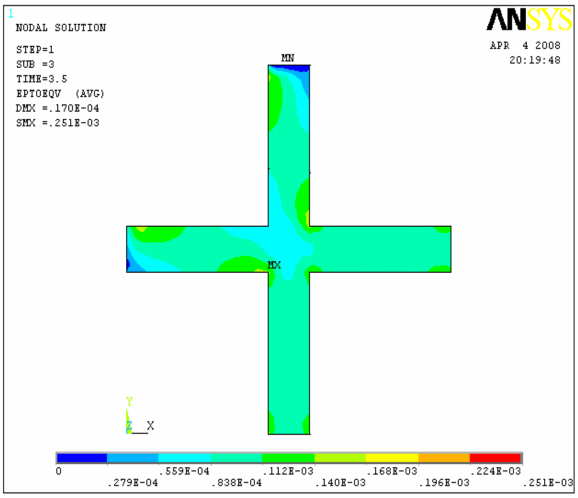

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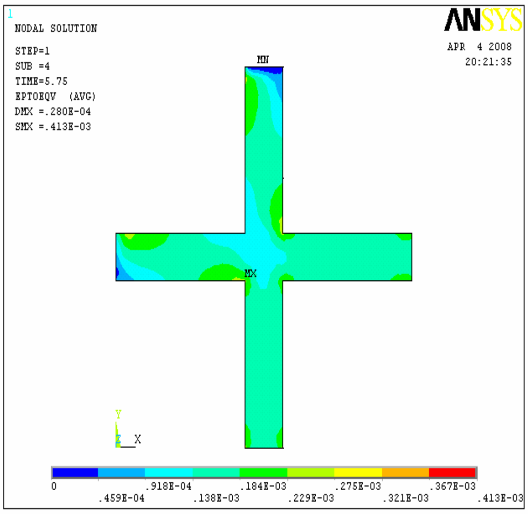
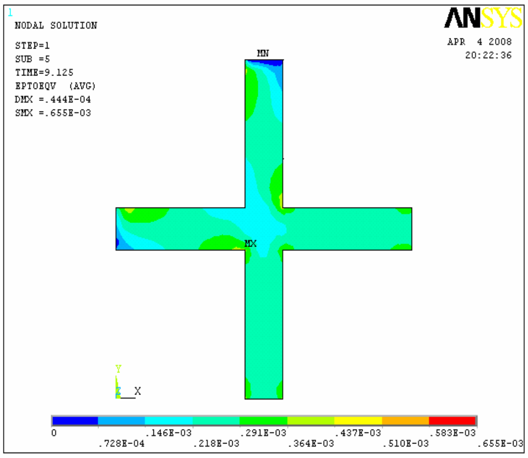
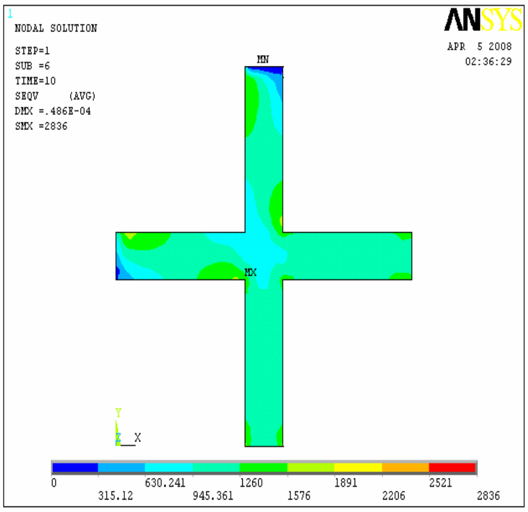


E-



F-



Figures (5-A,B,C,D,E,F))numerical results for biaxial creep of pure low density Polyethylene

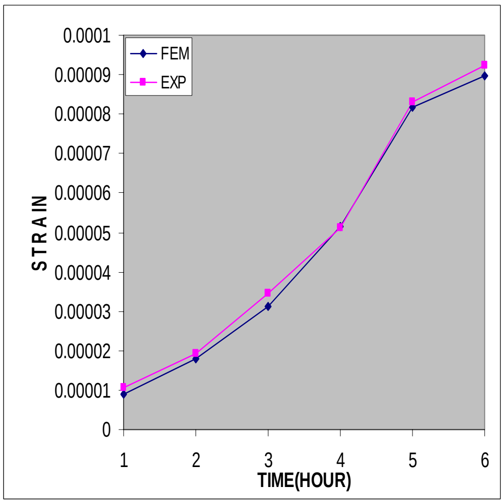


Figure (6) the experimental and theoretical creep results (in x &y direction) of pure low density polyethylene.

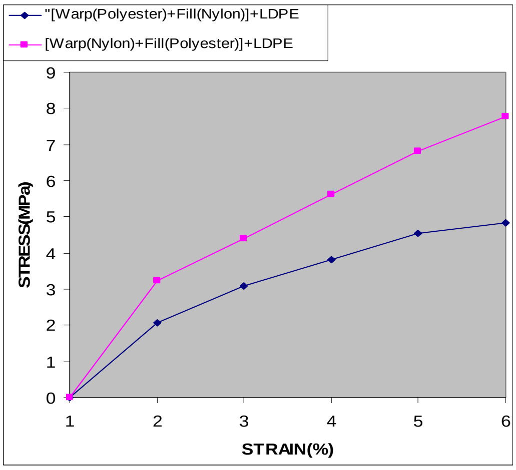


Figure (7) Tensile strength of composite material from(Hybrid woven fabrics (Nylon, Polyester) fibers and pure low density polyethylene(LDPE).

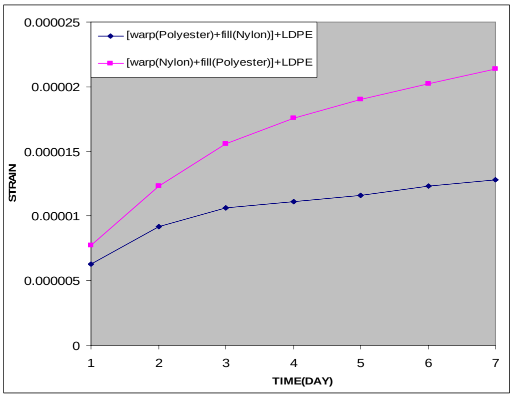


Figure (8 biaxial creep of composite material from hybrid woven fabrics (Nylon with Polyester) fibers and pure low density polyethylene (LDPE) under (450N).

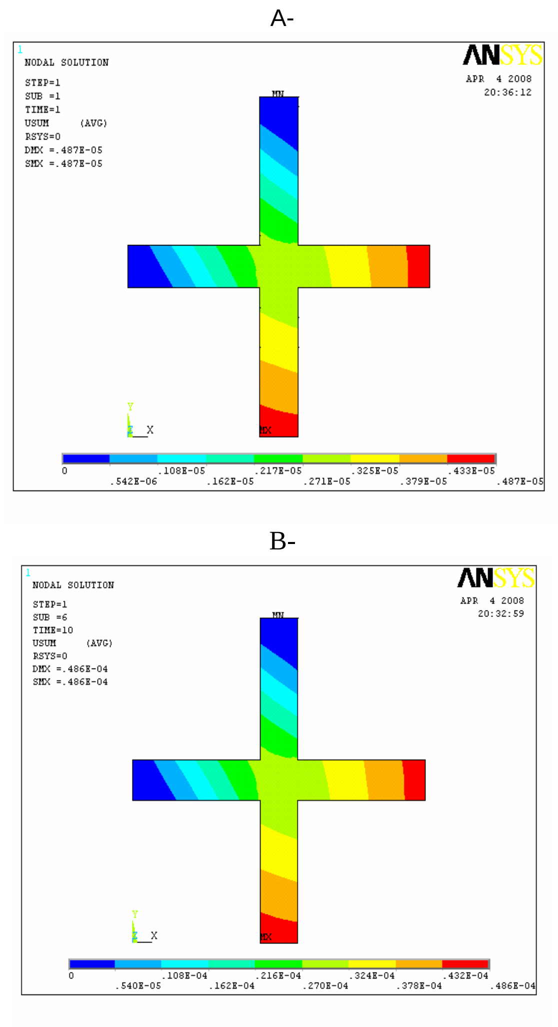


Figure (9(A,B)) FEA of deformation in the biaxial(x,y) specimen of pure low density Polyethylene.

6. Conclusions:'

From the results and the discussions of the numerical and experimental study of biaxial creep of pure low density polyethylene and experimental results of biaxial creep of hybrid woven fabrics composite materials we can be conclude. 1- The creep value in the direction of polyester fiber is lower than that for nylon fiber direction. 2-Creep value, creep strength, deformation are equal in all directions in pure low density polyethylene in theoretical analysis and experimental and that means the model is active to predict creep behavior in biaxial direction for hybrid woven fabrics of composite materials.

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