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BEHAVIOR OF PRE-STRESSED GLASS FIBER REINFORCED POLMER (PGFRP)

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الملخص العربى :

فـي هـذا البحـث تـم إسـتنتاج الخصـائص الميكانيكيـة لمركبـات البـوليمر المقـوى بالأليـاف الزجاجيـة سـابقة الإجهـاد PGFRP مـن خـلال برنـامج عملـي يشـتمل علـى مـرحلتين. المرحلـة الاولـى هـى إختبـار الخـواص الميكانيكيـة للمـواد والخامـات المسـتخدمة و المرحلـه الثانيـه تحضـيرعنيات اختبـار قياسـيه وفقًـا لــ ASTMD3039 عـن طريـق دمـج خيـوط الاليـاف الزجاجيـه أحاديـة الاتجـاه مسـبقة الإجهـاد مـع الحصـائر المصـنوعة مـن الأليـاف الزجاجيـة و تشـريبهم بالبوليسـتر ، حيـث تـم تطبيـق قـوة الشـد محسـوبه مسـبقا علـى الأليـاف الزجاجيـة أحاديـة الاتجـاه بسـته مسـتويات مختلفـة 25 و 50 و 60 و 65 و 70 و 80٪ مـن إجهـاد الشـد النهـائي للخـيط أحـادي الاتجـاه بالاضـافه الـى عينـات تحكـم غيـر مسـبقة الاجهـاد . تـم صـب جميـع العينـات بنسبة حجم الياف 29.1 ٪.

تـم مناقشـة وتحليـل النتـائج مـع إجـراء مقارنـة بـين النتـائج المعمليـة التـي تـم الحصـول عليهـا للعينـات مسـبقه الاجهـاد و عينـات الـتحكم . نـتج عـن هـذة التقنيـة الموضـحة PGFRP خصـائص ميكانيكيـة محسـنة. عـززت خيـوط الأليـاف الزجاجيـة أحاديـة الاتجـاه المجهـدة مسـبقًا والمـزودة بحصـائر مصـنوعه مـن الاليـاف الزجاجيـه تحسـن بشـكل كبيـر فـي أداء عنـد زيـادة مسـتوى الإجهـاد المسـبق إلـى حـوالي 65٪ ،حيـث زاد إجهـاد الشـد ومعـاير الشـد وإنفعـال الشـد بحـوالي 46.1٪ و 37.8٪ و 7.5٪ علـى التـوالي مقارنـة بعينـة الـتحكم غيـر مسـبقة الإجهـاد. عنـدما يـتم زيـادة مسـتوى الإجهـاد المسـبق إلـى مـا بعـد هـذه القيمـة ، تـنخفض الخـواص الميكانيكية ، ولكنها أعلى من تلك الخاصة بالحالة غير المجهدة مسبقًا.

ABSTRACT

In this research the mechanical properties of PGFRP pre-stressed glass fiber reinforced polymer composites was investigated in an experimental study . the glass fiber- stitched mats with unidirectional prestressing glass fiber single filament were impregnated with the polyester matrix the tensile force was applied to the unidirectional glass fiber that had been determined in advance. To cast pre-stressed laminates for pre-stressed fiber reinforced polymer composites. A standard test specimen with different pre-stressing levels were prepared. five standard test specimens were prepared according to ASTM D3039 were cut

with Six distinct prestressing levels of 25, 50, 60, 65, 70, and 80 **%** from ultimate tensile stress of the unidirectional single filament In addition, a non-prestressed (control) specimen was generated , all specimen were casting with a 29.1% fiber volume fraction .
The shown technique produces pre-stressed PGFRP with improved mechanical characteristics. the pre-stressed unidirectional glass fiber filament with fiber-stitched matting significantly enhanced the performance of glass fiber/polyester composites. When the pre-stressing level was increased to about 65 %, the tensile stress, tensile modulus, and tensile strain increased by about 46.1 %, 37.8 % and 7.5 % respectively in comparison to the non-pre-stressed control specimen. When the pre-stressing level were increased beyond this value, the mechanical properties decrease, but it is higher than that of the non-pre-stressed condition

KEYWORDS: Fiber Reinforced polymer, Composite Materials, Pre-stressing Techniques, Fiber Pre-stressing Levels, PGFRP

INTRODUCTION

Most modern FRB applications had low tensile strength , modulus and strain specially for stander materials. Composites are unique sophisticated structural used materials that could meet criteria. They are defined as multiphase materials that exhibit a considerable stages to get a better combination of properties, There is a rising need to create manufacturing techniques that can increase the mechanical performance of sophisticated materials. Although there are already available composites Meat the Mechanical features of typical metallic materials. [1-4]
A lot of criteria influence the overall performance of (FRP) composite, Such as constituent characteristics, fiber volume frication, manufacturing processes, and Some imperfections that was appeared during the composites production process, such as waviness of fiber, voids Ratio [5] , The shrinking of the polymeric matrix during curing and Residual stresses were caused by a mismatch in thermal expansion between the fiber and matrix materials[6-7]. The existence of residual fiber stresses may had a important influence on the mechanical characteristics of composite structures, limiting their service life [8-9]. Depending on the fiber-matrix combinations and laminate stacking sequences, residual stresses might generate fibre waviness [10], Warping, buckling, or matrix cracking of laminates [11]. As a result, it's crucial to keep the magnitude of adverse residual stresses and fiber waviness to a minimum. Prestressed technique were initially developed to alleviate leftover manufacturing stresses. The ideas employed in prestressed concrete production were used by Zhigun [12] and Tuttle [13].
Recently, there has been a surge of interest in the use of fiber prestressing techniques. Throughout the manufacturing process of FRP composites. The mechanical characteristics of FRP composites can be improved using prestressed method without increasing the section size or the composite part's mass. By creating compressive residual stress inside the cured matrix, this improvement in composite performance was achieved by boosting fiber straightness and lowering the onset and cracking propagation inside the matrix. [14]. Fiber prestressing is a

technique used to reduce fiber waviness in fiber reinforced composite materials by carrying the fibers a calculated static load throughout the resin curing process. As a result of removing the load After hardening compressive stress is generated inside the resin matrix that remaining fiber tensile attempt at elastic recovery, which might improve the composite's mechanical properties. The composite's overall mechanical qualities tend to improve. Many prestressing methodologies have recently been developed to impose Throughout the curing process, a predetermined prestress to the fibers. [15-16].

An experimental analysis of the mechanical characteristics of prestressed glass fibre/polyester composites (GFRP) concrete is presented in this paper. so that we can have a better grasp of the unidirectional prestressing polymeric composite materials under uniaxial tensile stress. A special tensile machine was designed and fabricated to apply predefined constant stress on the fiber during a moulding process. The required specimens from prestressed fiberglass/polyester composite material are produced in the laboratory with a variety of prestressing levels at ambient temperature and 29.1 % VF. The effects of the prestress levels on the tensile stress, tensile modulus and tensile strain are studied.

2. EXPERIMENTAL PROGRAM

The experimental program was divided into two phases. The first phase determines mechanical properties of used materials, cast control concrete mixture and the Geopolymer concrete without steel fiber. The second phase includes cast Geopolymer concrete reinforced by steel fiber with different ratio (1% - 2). Standard cylinders (150mm in diameter and 300mm in height) were tested after twenty-eight days to determinate indirect tensile strength. These samples were steam cured and the others cured in ambient temperature.

2. Materials

Thin laminates made from a pre-stressed glass fiber/polyester composite with VF 29.1%. Filament glass fiber and glass fiber mats are encased in polyester resin in each lamination. The physical and mechanical parameters of the resin and glass fiber utilized are summarized in Table 1. The catalyst to resin ratio should be 1 % hardener to the entire volume of resin to be used.

Table1.Mechanical and physical properties of the utilized resin and fiber

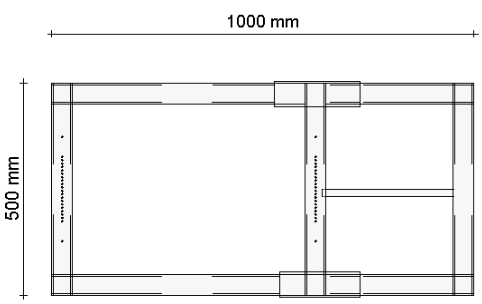
cross sectional area of glass fiber (cm^2)	**0.00231**
Density of glass fiber (g/cm3)	**2.48**
Ultimate tensile Force of glass fiber (kN)	**0.20**
Ultimate tensile Stress of glass fiber (KN/ cm^2)	**86.05**
Ultimate tensile Strain of glass fiber	**0.0592**
Ultimate tensile modulus of glass fiber (KN/ cm^2)	**1464.92**
Density of Polyester Resin (g/cm3)	**1.124**
Ultimate tensile Stress of Polyester Resin (KN/ mm^2)	**0.04134**
Ultimate tensile Strain of glass fiber	**0.081**
Ultimate tensile modulus of glass fiber (KN/ mm2)	**0.5108**

3. EXPERIMENTAL PROGRAM

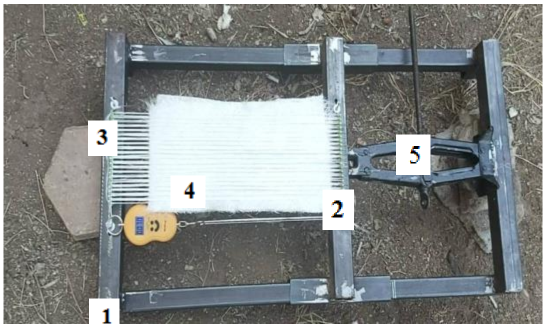
The experimental progress was divided in to 3 stages first the prestressing machine was manufactured. second the specimen was prepared with different prestressing level . finally, specimen was tested

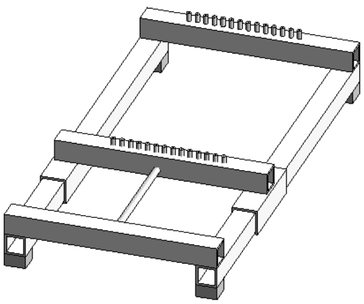
3.1 MACHINE DESCRIPITON

the prestressing machine used to prestressed , shown in Figure 1, was designed and produced as an three parallel frames to perform uniaxial tensile force on the used glass prestressed fiber filament where the filament glass fiber are woven between the machine's upper and middle frame and power screw jack positioned between the lower and middle bases to generates a tensile force onto the glass fiber filaments that allowing the middle base to move along the side guides. A digital load cell was hanging from the upper base to measure the applied tensile force, and glass fiber filaments were fixed from one end to the upper base and the other end to the digital load cell.



(a)





(b)

1. fixed bar
2. movable bar
3. pins
4. digital load cell
5. Screw jack

(C

Figure (1): a. Schematic diagram of the Uniaxial prestressing tensile machine b. Schematic 3D diagram of the Uniaxial prestressing tensile machine c. Uniaxial prestressing tensile machine

3.2 Preparation of specimens

The required specimens were manufactured at the laboratory using the hand layup process from pre-stressed glass fiber composite material. The glass fiber filaments were subjected to a

predetermined load that were maintained during the curing process. the total fiber volume fraction was adjusted to around 29.1% using the glass fiber mats.
multilayer's from polyester resin were applied by brushing and a paint with roller. the lamina was squeezed between two wooden plates by screw bolts to remove entrapped air voids and unify the laminate thickness. to give a flat surface for the finished specimen. the laminate was kept in this situation for about 24 hours. then the sheet had final dimension of 150 mm width , 400 mm length and 2.5 mm thickness as shown in Fig 2(a) . finally, five standard test specimens according to ASTM D3039
with dimensions of 30 mm width ,400 mm length and 2.5 mm thickness were cut from each lamina as shown in Fig 2(b). Six distinct prestressing levels were used of 25, 50, 60, 65, 70, and 80 **%** of ultimate tensile stress of the unidirectional
single filament were used to create prestressed specimens. In addition, a non-prestressed (control) specimen was generated at ambient temperature with used the same VF %.

(a) **(b)** **(c)**

Figure (2): a. the pre-stressed fibreglass/polyester composite tensile test specimens b. the pre-stressed fibreglass/polyester composite tensile test specimens:
c. Schematic diagram of the pre-stressed fibreglass/polyester composite tensile test specimens

3.3 Experimental measurements

the specimen was mounted to The test machine. The specimen axis must be positioned in-line with the cross-head, as indicated in Fig.3, in order to produce a homogenous stress state across the cross-section of the fiber. The cross-head and loading rate were both set to 0.2 mm/min, A linear potentiometer was fixed to the specimen and the deformation was measured and recorded using a embedded measurements device which was connected to the dial gauges by wires and readings were taken at each loading step as shown in Fig 3.

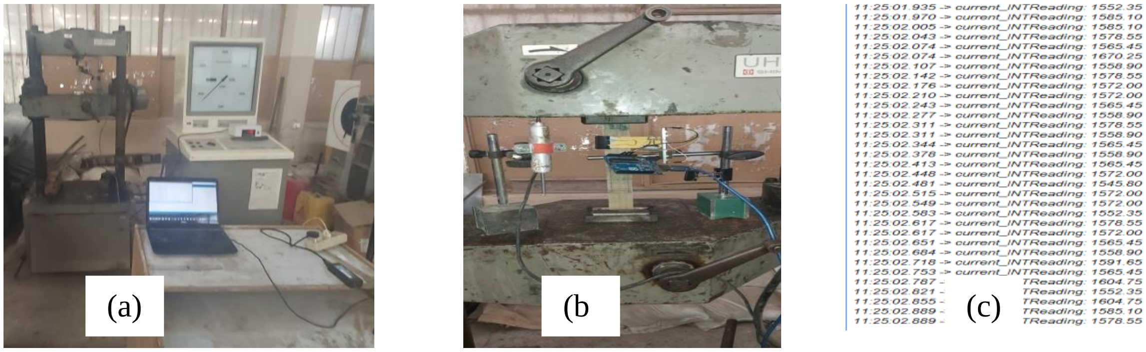


Figure (3): (a) measurement Set-up (b) The specimen to be tested is mounted on the Machine and a linear potentiometer is fixed on the specimen (c) deformation of length at every load increase

4. Results and discussion

The specimens' tensile strength and tensile modulus were chosen to serve as a point of reference for improving composite mechanical properties. The tensile tested specimens were according to the ASTM D3039 standard test method Fig.2. At different degrees of pre-stress, five specimens were cut. The universal tensile test machine was used to conduct the tensile testing with cross head speed of 0.2 mm/min Fig. 4 and Fig. 5 shows the influence of prestressing technique on the composites' longitudinal tensile strength. It is possible to see that when the rate of fiber prestressing rises, the composites' tensile strength improves Fig.8. This trend continues until the prestressed level of 65 %, at which point a modest decline in strength is noticed, which can be attributable to fiber/matrix debonding. The residual shear stress at the contact increases as prestressed levels are raised. The best fiber prestressing limit for maximal strength and hence resistance to opening and fracture initiation is 65 %, as shown in Fig.9. Increased fiber/matrix debonding damage reduces the strength qualities at this prestress value. When cured at room temperature, this approach improved longitudinal tensile strength by approximately 46.1 %.

The slope of the linear component of the stress-strain curve in each test was used to compute the tensile modules of the composites. The findings are Similar to the results for tensile strengths as shown in Figure 10, the composites' tensile modulus values appear to rise with fiber prestressing up to a 65 % prestressed level, then decline somewhat beyond that degree of prestressing . To Determine fiber volume fractions The specimen is placed in a crucible and placed in a furnace that has been deteriorated to 800 degrees Celsius. Fig.6 shows the resin is completely removed and only reinforcement was employed. The ignition loss method, often known as the burn-out process, is one such method for determining the volume percentage of cured resin composite materials. Table 2.

Table 2. Summary of Test Results to Determine Fiber Volume Fractions

Specimen no.	Mc (g)	Mm (g)	Mf (g)	Mm/ Mc (%)	Mf/ Mc (%)	Vm cm3	Vf cm3	Vm (%)	Vf (%)
1	7.44	3.94	3.50	52.95	47.05	3.51	1.40	71.49	28.51
2	6.45	3.24	3.21	50.23	49.77	2.89	1.296	69.09	30.91
3	8.96	4.86	4.10	54.24	45.76	4.33	1.65	72.41	27.59
Average								70.9	29.1

Figure (4):. The specimen during the tensile test

Figure (5): The specimen after the tensile test

Figure (6): The crucible and the specimen were placed in the furnace

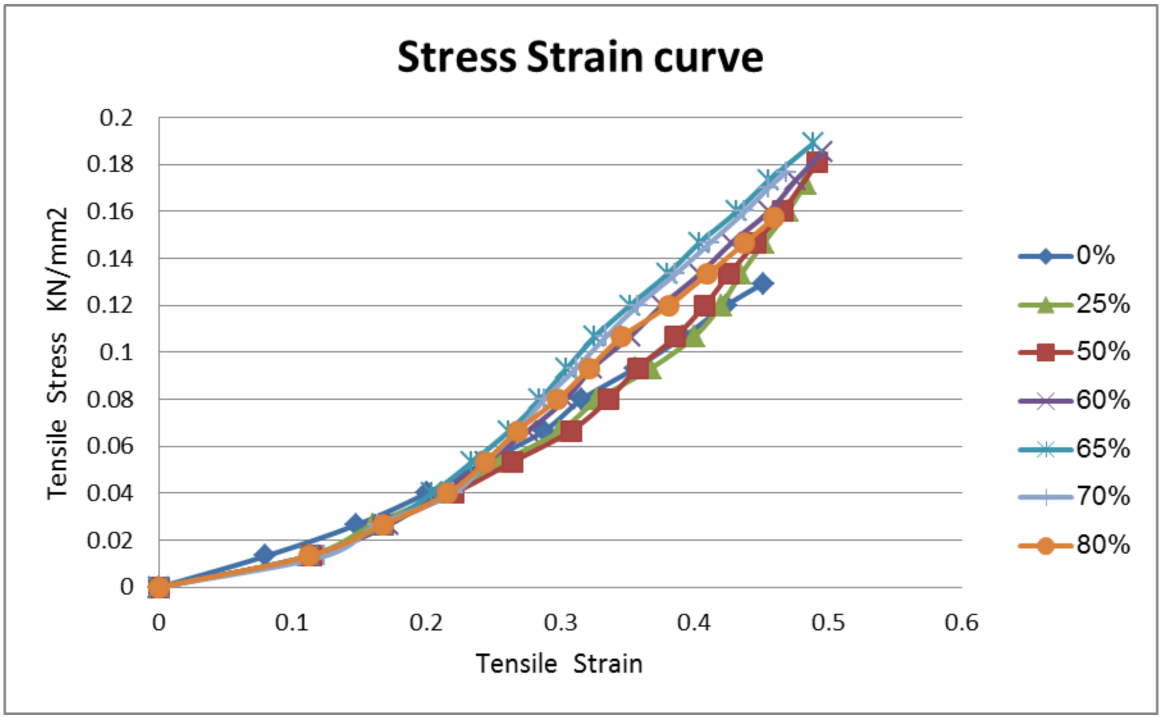


Figure (7): The variation of the tensile stress with the Tensile Strain for The tested specimens

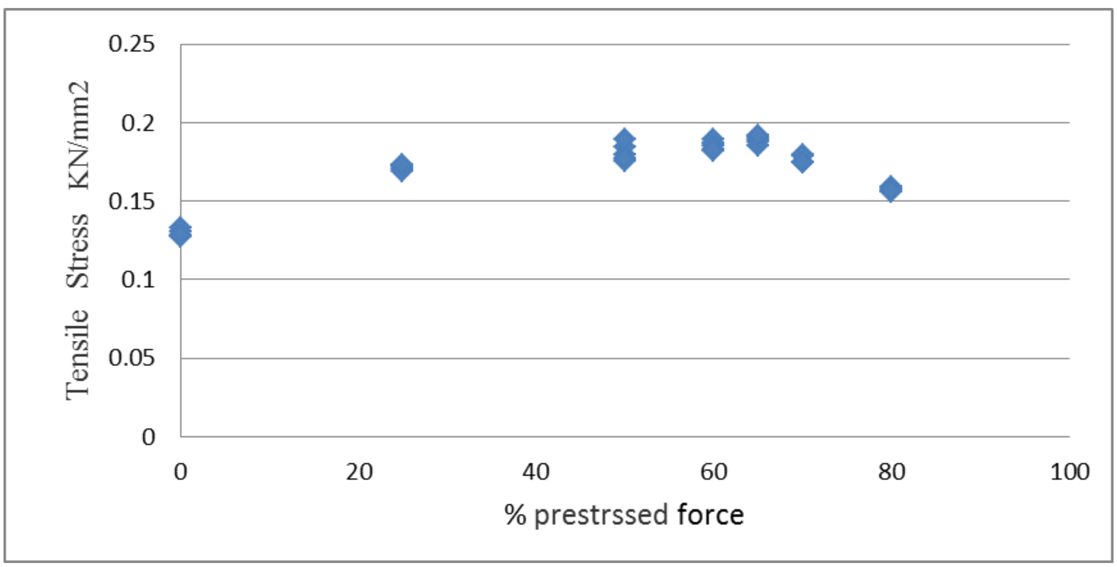


Figure (8): The variation of the tensile stress with the pre-stress force for The tested specimens

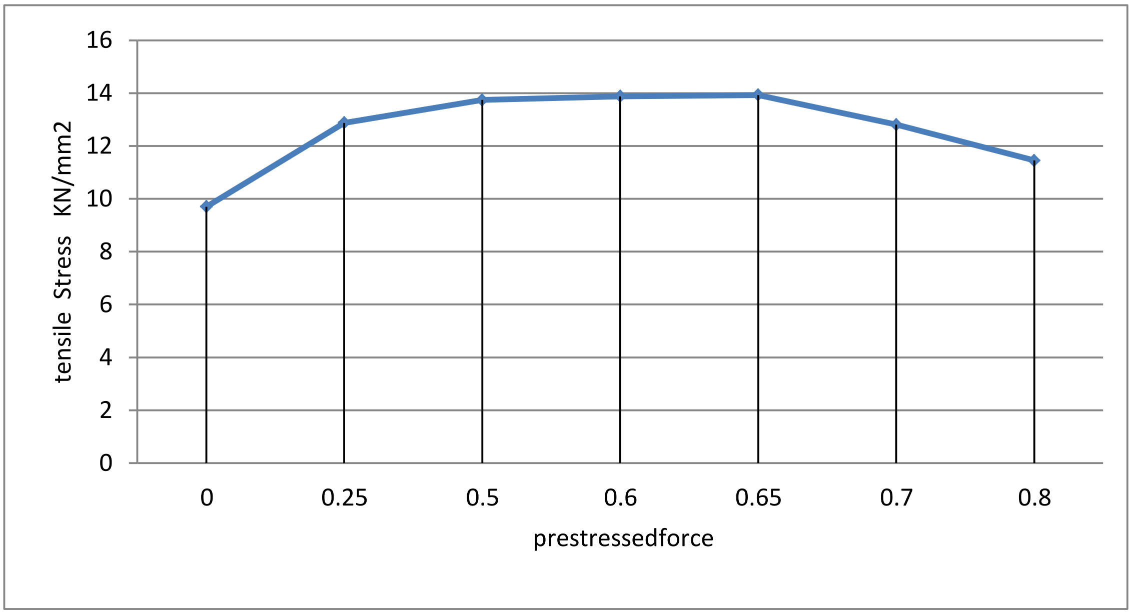


Figure (9): The effect of the prestressed on the tensile stress

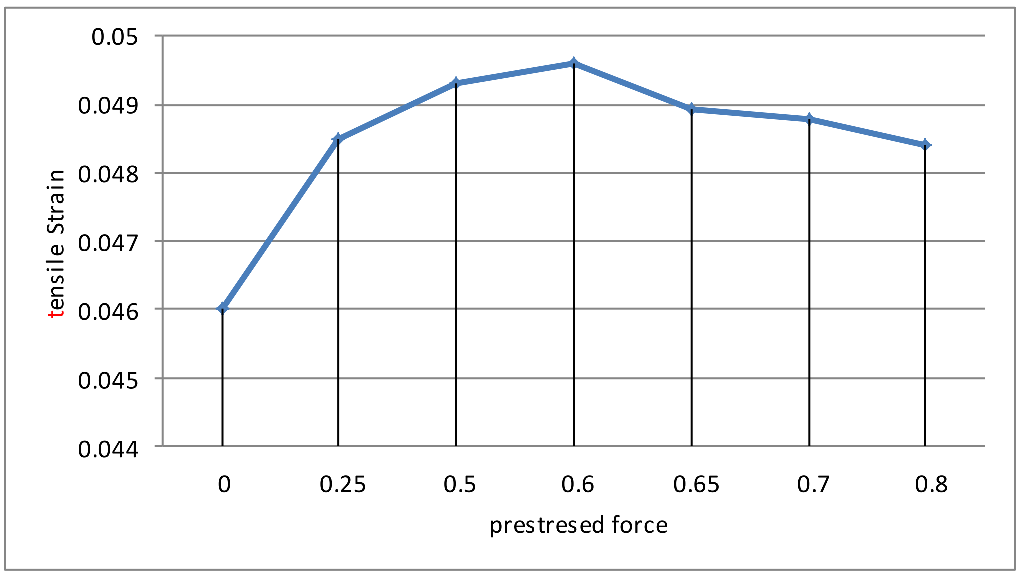


Figure (10): The variation of the tensile Strain with the level of the pre-stress

5. Conclusions

The following findings can be taken from an experimental examination of the mechanical characteristics of prestressed fiberglass-reinforced polymer composites at various fiber prestress levels.

The presented pr-stress technique and machine provide an effective method to produce uniform and homogenized test specimens.

The mechanical properties of the prestressed fiber-reinforced polymer composites are obviously increased by increasing the prestress to 25%, where the tensile strength, tensile strain and tensile modulus increases by about 32 % , 4.6 % , 26.7 % respectively.

Increasing the prestress from 25% to 50% leads to a slight improvement the tensile strength, tensile strain and tensile modulus 41 % , 6.6 % , 31.2 % respectively

Increasing the prestress from 50% to 60% leads to a slight improvement the tensile strength, tensile strain and tensile modulus 43.3 %, 7.5 %, 33.1 % respectively

The maximum improvements are reached at 65% prestress specimens where tensile strength, tensile strain and tensile modulus increasing by about 46.1 %, 5.9 %, 37.8 % respectively.

Beyond the prestress level of 65% the improvement of the mechanical properties of the tensile strength, tensile strain and tensile modulus decreases with the increase of the prestress value and reach about 36.5 % , 5.6 % , 29.1 % respectively at 70% prestress and 21.6 % , 3.9 % , 14.4 % respectively at 80% prestress.

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