Static mechanical properties test of 3 dimensional and 4 direction braid angle composite materials

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Abstract

As the advantage of composite materials of high strength, low weight ratio, widely used in the field of aerospace. The static mechanical experiments of 3D braided composites with different braid angles and different thicknesses are carried out to study the effects of different braid angles and thicknesses on the microstructure, mechanical properties and failure modes of the materials. Due to the anisotropy of 3D braided composites and their in-plane properties were tested, the longitudinal tensile test and the transverse tensile test were carried out respectively ,from the experiment ,the static elastic modulus, Poisson's ratio, ultimate strength are obtained.

Keywords: composite materials, static mechanical

Introduction

Laminated composite material due to the presence of pure base region easily brought interlayer delamination[1], cracking and damage propagation speed sensitive , in the thickness direction of weakness low stiffness and strength mechanical properties ,three-dimensionally braided composite as it contains no delamination the overall three-dimensional network structure to solve the problem in line with laminate materials[2].Three-dimensional braided composite material due to its series of advantages , general concern engineering sector , an important structural materials in aviation, aerospace , and has been in terms of bio-medical has also been applied[3].At present,there are studies on the elastic properties of woven composites[4];Avva et al[5] lists the test process, test data and compression test results of three-dimensional braided composites;Li Suhong[6],Liu Qian[7] Considering the influence of braiding angle on the tensile properties ,Yang Zhaokun[8] found that under the premise of the knitting angle , the tensile modulus increased with the increase of fiber volume content

In this paper,the static mechanical experiments of 3D braided composites with different braid angles and different thicknesses were carried out to study the effects of different braid angles and thickness on the microstructure, mechanical properties and failure modes of the composites. As a result of the anisotropy of 3D braided composites, the in-plane properties were tested and subjected to longitudinal tensile tests and transverse tensile tests, respectively. In order to obtain data effectively, the T -strain gauge and the extensometer are used for the test at the same time.

Test equipment introduce

MTS793-10T tension and fatigue test system, the maximum tension 100KN , with dynamic / static tensile (compression, bending), fracture mechanics, low fatigue, high fatigue and high temperature and other conditions of the test capacity. Static tension and compression testing at MTS793-10T performed on the material type hydraulic servo fatigue testing machine, the

major components of the test system includes a load frame, an oil pump, the cooling system, as in FIG1.

（a）Load framework （b）hydraulic system （c）cooling system

Fig1. MTS-793# Hydraulic servo tension and compression and composite fatigue test system

In the fatigue test, the test system records the cyclic load and displacement response values by load and displacement sensors, and in order to record the response values of the tensile strain strain,634.12F-24Positive Strain of Test Section of Static and Dynamic Stretch Tensile at Normal Temperature. The data collected for the measurement of T-type bi-directional BE120-3BB resistive strain gauges are used to calculate the Poisson's ratio.

Three-dimensional four-way braided composite materials is commissioned by the Tianjin University of Technology Institute of composite materials processing, using 12K T700 carbon fiber braid molding, TDE86 epoxy resin for curing. The specimen size and die size, is first processed to FIG.2, illustrated 380mm*180mm*2mm or 4mm plate, and then cutting the test piece according to the material specifications. Tensile test pieces are cut by the standard of GBT 1447-2005[9], see FIG.3.

Test specimen introduce

Fig2 Three-dimensional four-way composite board

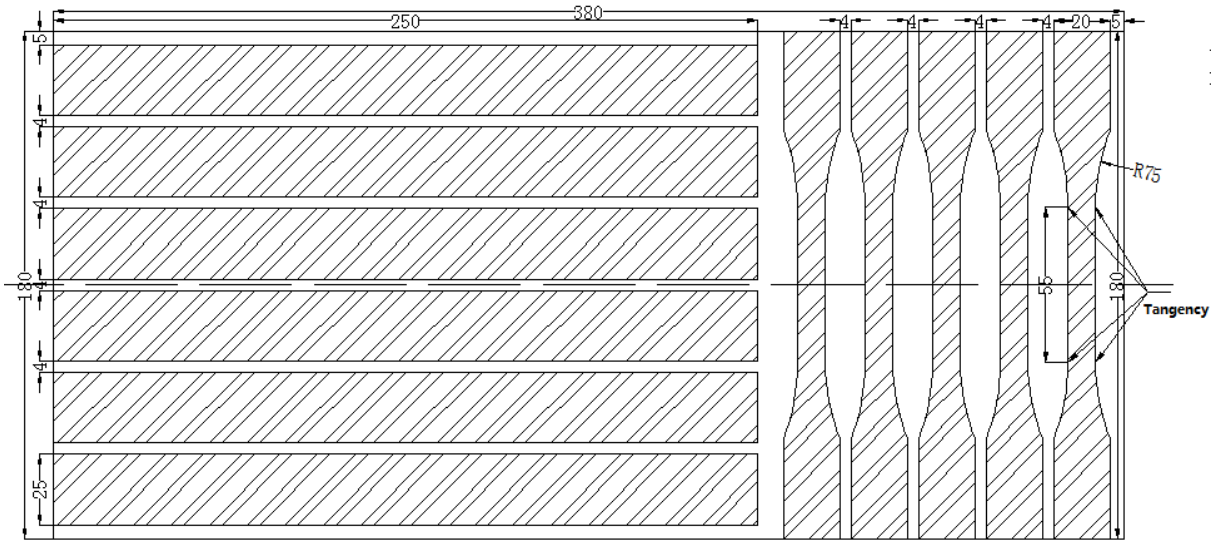
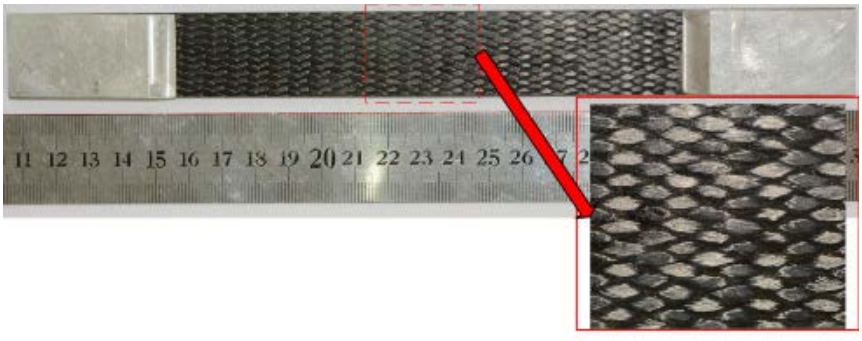
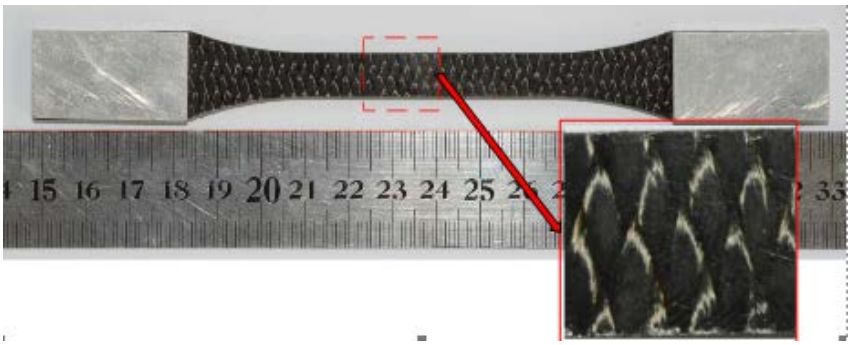
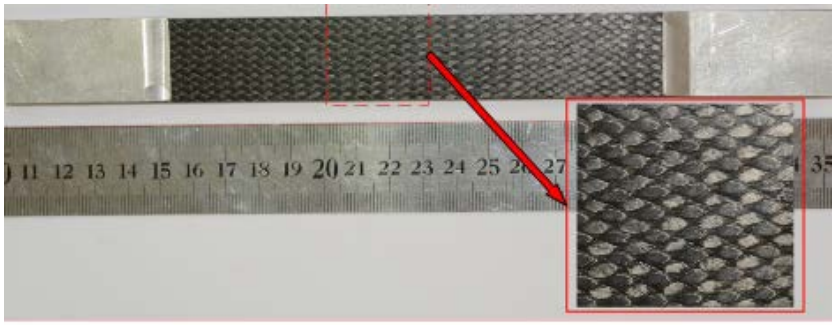


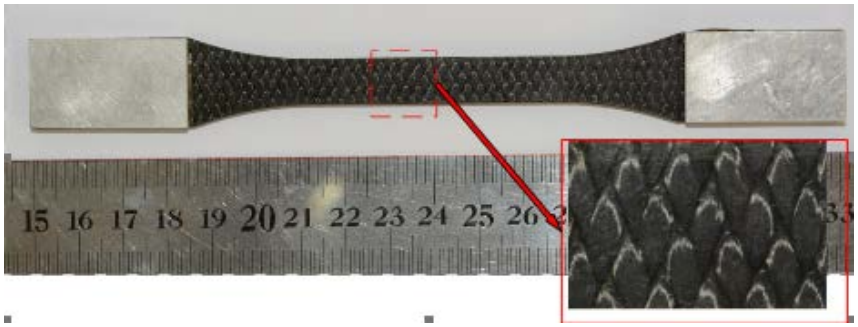
Fig3 Tensile test piece cutting scheme



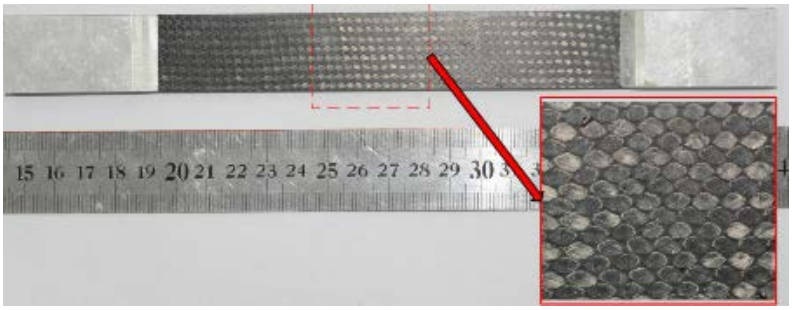


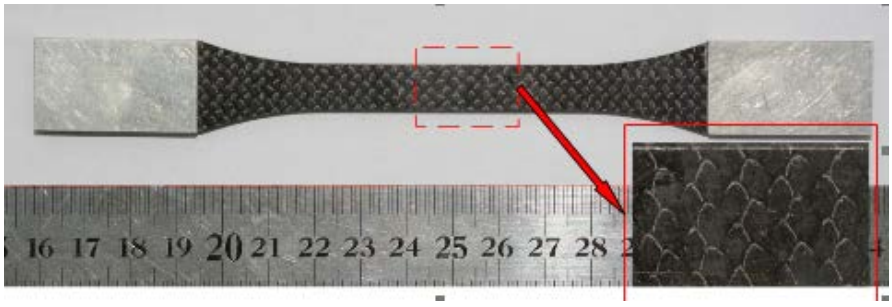
(a) longitudinal tensile 20° braiding angle test specimen (b) transverse tensile 20° braiding angle test specimen





(c) longitudinal tensile 30° braiding angle test specim (d) transverse tensile 30° braiding angle test specimen





(e) longitudinal tensile 45° braiding angle test specimen (f) transverse tensile 45° braiding angle test specimen

Fig4 tensile test specimen

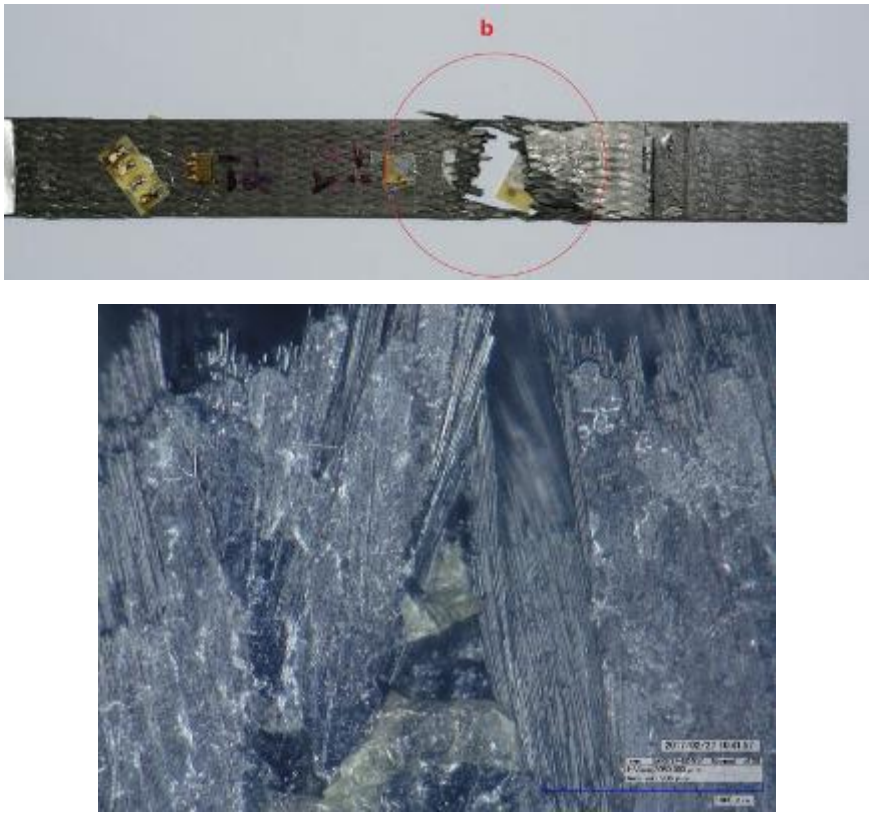
As a result of the quasi-static test, the strain rate effect can be neglected, initially set in the MTS793-10T equipment, a certain degree of tension, combined with the length of the test piece parallel to the length of the strain rate in the order of $10\text{-}4S^{-1}$, in line with static test Requirements, the test pieces of the clamping and loading force needs to be strictly aligned, the installation process to adjust the clamping position, to maintain the vertical tensile test pieces, to avoid the tilt caused by the shear stress. As shown in Fig.5(b), the extensometer is fixedly fixed in the tensile section of the test piece and the strain data is measured.

(a) (b)

Fig 5 Speicemen Clamped way

Test results

In order to compare the influence of different braiding angles on the static mechanical properties, a quasi - static tensile test was carried out on the test pieces with a strain rate of 10-4 S -1 and 20 °, 30 ° and 45 ° thickness of 4 mm . A static tensile test was carried out on the longitudinal cut test piece until the test piece was broken and the test procedure was observed and the data recorded. The stress-strain curves are obtained from the strain collected by the extensometer and the force collected by the MTS , as shown in the following figure.



（a） （b）

Fig 6　20° longitudinal tensile speicemen damage morphology

（a） （b）

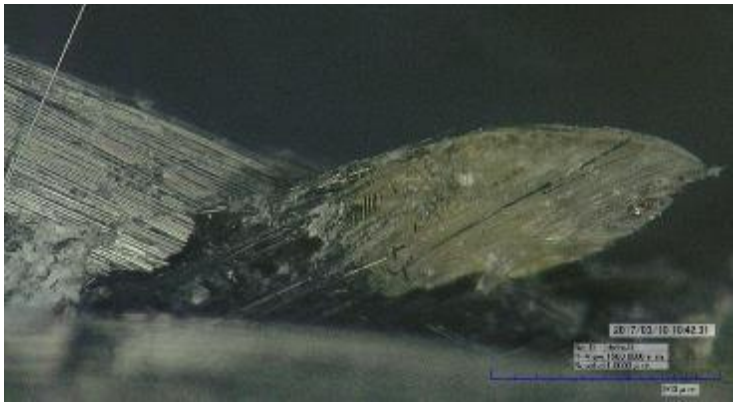
Fig 7　30° longitudinal tensile speicemen damage morphology

（a） （b）

Fig 8 45° longitudinal tensile speicemen damage morphology

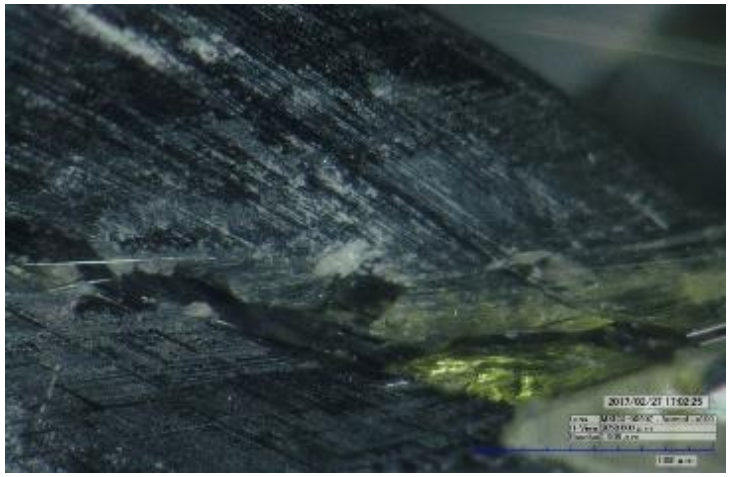
During the tensile test of the longitudinal test piece, due to the different modulus of elasticity of the matrix and the fiber bundle, the load and displacement of the matrix and the fiber bundle are different, resulting in the initial separation of the matrix from the fiber bundle, The crack. When the load reaches a certain value, the specimen began to issue a slight sound, then the matrix and fiber bundles gradually separated. As the load increases, the force bearing from the matrix fiber complex to the fiber bundle, fiber bundle to bear the main longitudinal tension, until a certain value, fiber bundles break[10], then the material was completely pulled off. From the analysis of the tensile section of the figure, you can see the fracture is basically flat fracture, can explain the fiber bundle at the last moment is almost simultaneously pulled off.

In order to compare the difference between the transverse cutting and the longitudinal cutting test piece and the mechanical properties, the test results were carried out on the transverse cutting test pieces. The experimental results are shown below.



（a） （b）

Fig 9　20° transverse tensile speicemen damage morphology



（a） （b）

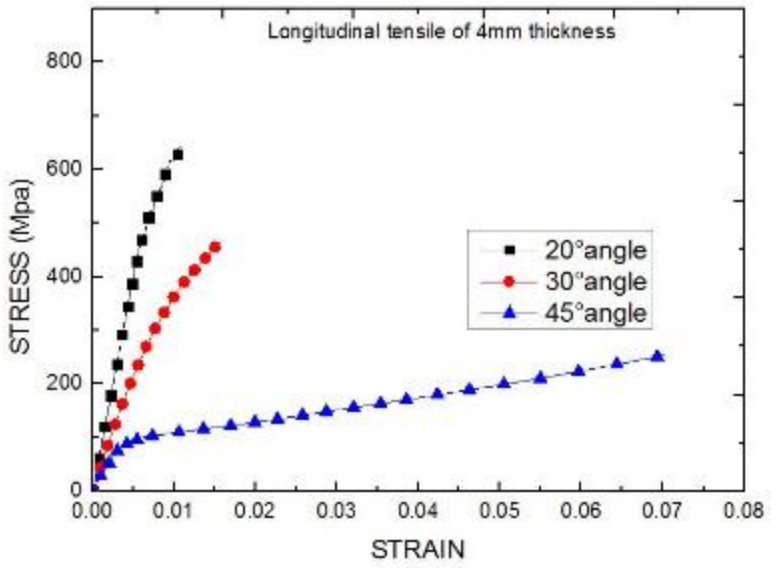
Fig 10　30°transverse tensile speicemen damage morphology

（a） （b）

Fig 11 45° transverse tensile speicemen damage morphology

Horizontal cutting test pieces of the fiber can not afford the basic tensile force, the specimen surface a small amount of cracks, which is the fiber bundle and resin interface caused by the phenomenon of localized debonding. Mainly for the fiber slip, interface debonding, matrix yield cracking. Showing a clear brittle failure characteristics. The transverse tensile strength at this time is determined by the properties of the fiber bundle and the matrix. With the increase of the braid angle, the longitudinal force of the fiber is increased and the tensile strength is increased.

Using the origin to export 4mm tensile test pieces of the horizontal, longitudinal tensile test data, as shown below:



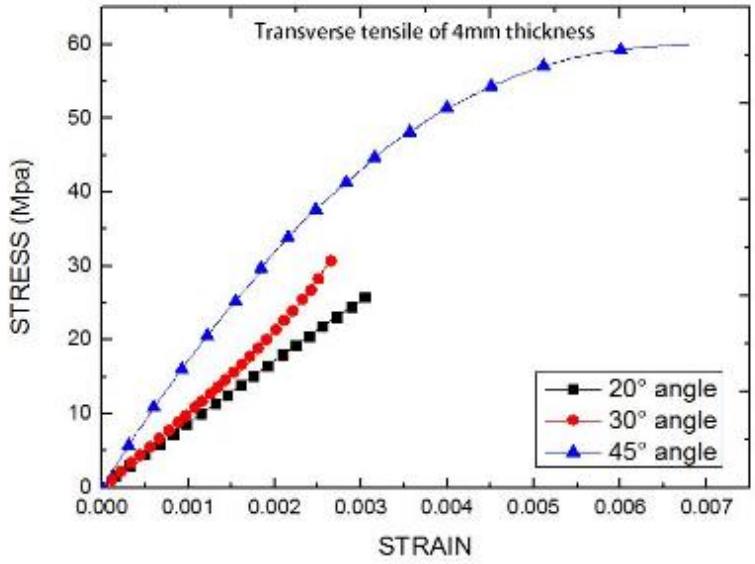


Fig 12 stress-strain curve of longitudinal tensile in 4mm Fig 13 stress-strain curve of transverse tensile in4mm

The longitudinal tensile and transverse tensile tests of the three - dimensional four -direction braided composites with thickness of 4mm were used to compare the static mechanical properties. The following conclusions can be drawn:

1) When the thickness and fiber volume fraction are constant, the elastic modulus and the ultimate strength of the longitudinal tensile test piece decrease with the increase of the knitting angle. This is because the larger the knitting angle is, The greater the angle between the direction of force, the smaller the component force that the test piece can bear in the longitudinal direction, so the longitudinal tensile mechanical properties will decrease;

2) When the thickness and fiber volume fraction are constant, the elastic modulus and the ultimate strength of the transverse tensile test piece increase with the increase of the knitting angle. This is because the larger the knitting angle is, the longitudinal yarn and the force The greater the angle of the direction, the test piece in the horizontal capacity to bear the greater the force, so the lateral tensile mechanical properties will increase.

3) The longitudinal mechanical properties of the test piece are better than those in the transverse mechanical properties, and the elastic modulus and ultimate strength of the former are higher than those of the latter (except for the 45 ° compression test, the longitudinal and lateral results are similar) The mechanical properties are mainly determined by the strength of the fiber bundle. The transverse mechanical properties are mainly determined by the strength of the matrix, and the strength of the fiber bundle is obviously higher than that of the matrix.

4) From the transverse stretching and longitudinal stretching can be seen, 45 ° braided composite material, because the fiber can withstand the absorption of the load, solid show better toughness, and 20 °, 30 ° prepared fiber, fiber by Force is not broken in the form of fiber bundle fracture and fiber and matrix fracture, almost no yield stage, showing brittleness.

In order to understand the effect of thickness on mechanical properties, a quasi-static tensile test with a thickness of 2 mm was carried out on the base of 4 mm test piece . The test results are shown below.

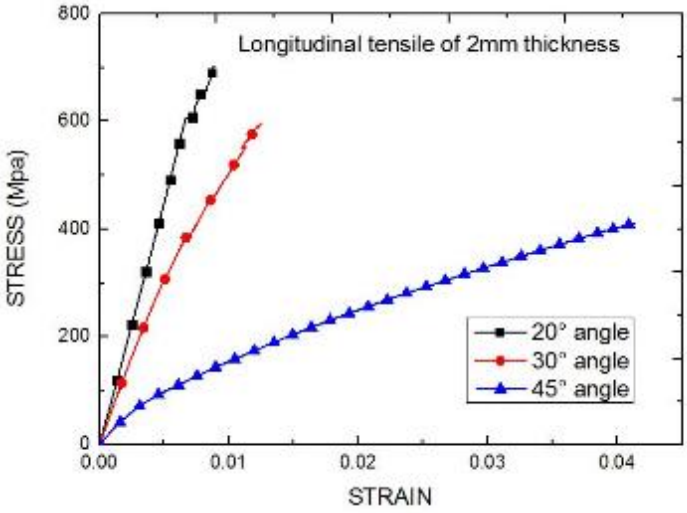


Fig 14 stress-strain curve of longitudinal tensile in 2mm

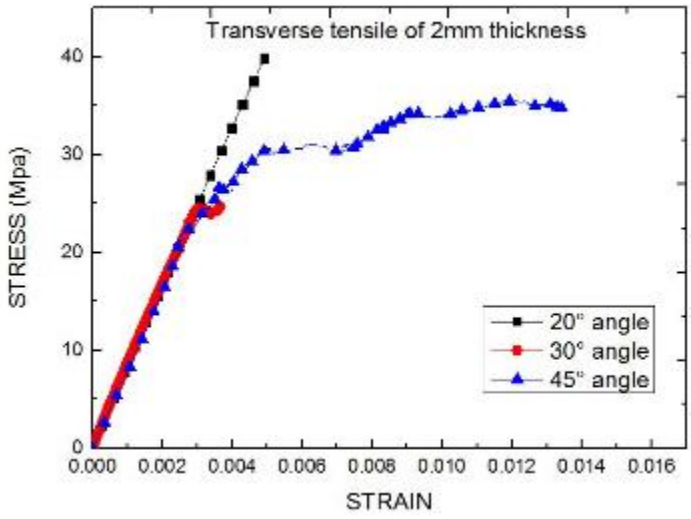


Fig 15 stress-strain curve of transverse tensile in 2mm

According to ASTM_D3039M—2014, the calculation of elastic modulus is based on strain 0.001, and strain 0.003 is the straight slope of the endpoint.

T -strain gauges were attached to the test pieces , and the longitudinal and transverse strain values were measured, and then connected to the strain gauge to obtain the corresponding test pieces Poisson's ratio.

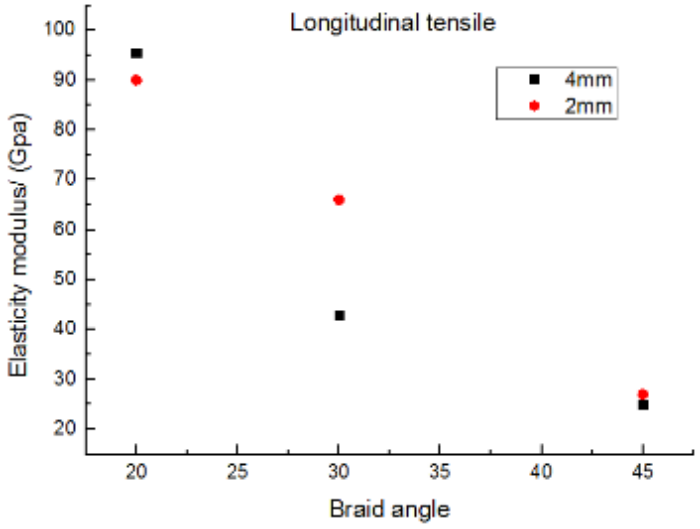
Table 1 Longitudinal tension mechanical parameter

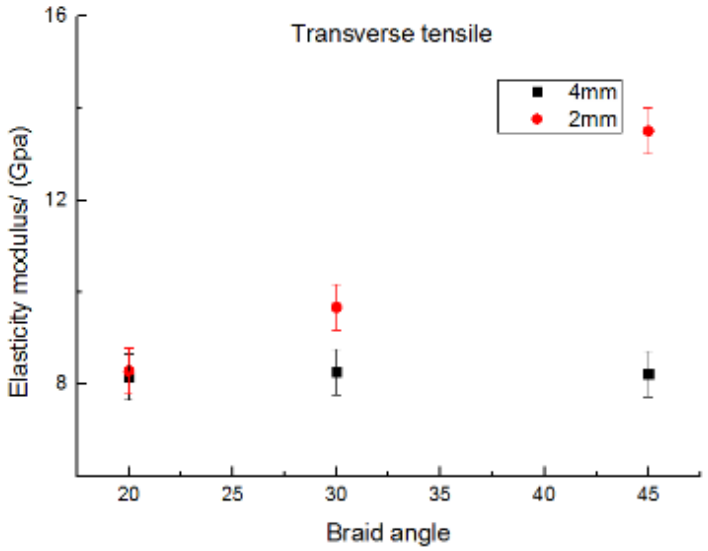
thickness	braid angle	elasticity modulus/Gpa	ultimate strength/Mpa	Poisson's ratio
2mm	20	90.66	741.70	0.71
	30	66.27	592.36	0.89
	45	27.35	409.93	1.00

	20	95.6	821.5	0.88
4mm	30	43.25	469.3	1.11
	45	25.4	258.8	0.55

Table 2 Transverse tensile mechanical parameter

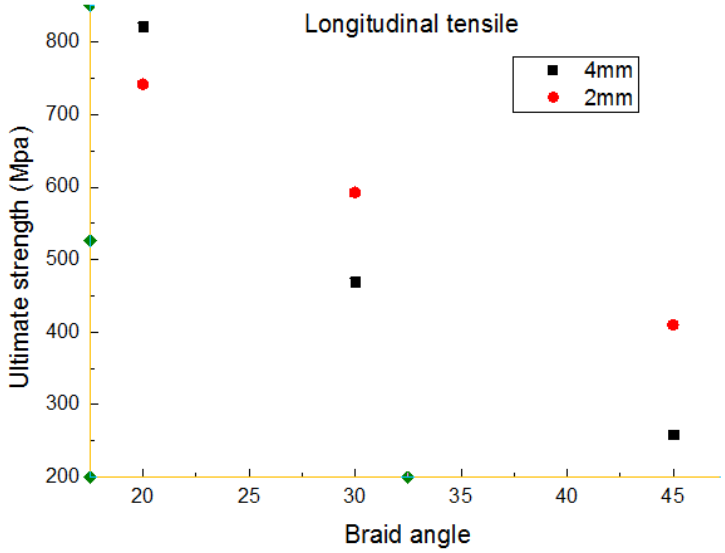
thickness	braid angle	elasticity modulus/Gpa	ultimate strength/Mpa	Poisson's ratio
	20	8.16	38.71	0.07
2mm	30	8.27	40.24	0.12
	45	8.23	47.60	0.27
	20	8.29	25.60	0.069
4mm	30	9.67	32.85	0.16
	45	13.50	56.62	0.43

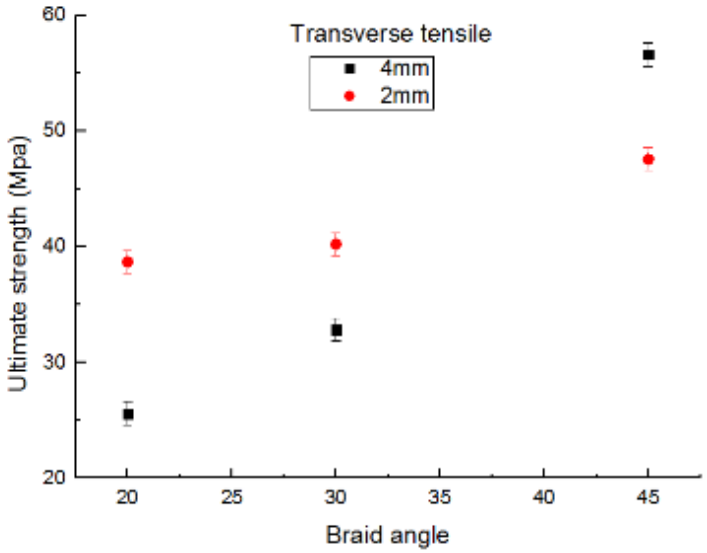




(a) (b)

Fig 16 Elastic modulus along with braiding angle





(a) (b)

Fig 17 Ultimate strength along with braiding angle

Then,conclusions can be drawn:

1)4mm and 2mm different thickness of the quasi - static tensile modulus is basically flat, indicating that the thickness of the static tensile modulus of the mechanical properties of little impact;

2)The transverse tensile strength of 2mm is not obvious at the angle of 38~48Mpa . When the thickness increases to 4mm , the ultimate strength increases with the angle.

3)Comparison of the longitudinal and transverse tensile strength of 2mm and 4mm with the bending angle of the trend. Compared with the 4mm test piece, the tensile strength of 2mm is less sensitive to the direction of braided angle, and 4mm is more sensitive.

References

[1] Wu Delong , Shen Huairong . Mechanical properties of textile composite materials [M]. Changsha : National University of Defense Technology Press , 1998

[2]Li Jialu,Xiao Lihua .Dimensional braided structure to multiple impact on the performance of the composite [J]. Composite Materials Journal,1996, (3): 71-75.

[3]Tao Xiaoming,Xian Xingjuan ,crested Hoon.Textile Structural Composites [M].Academic Press,2001, 1~9.

[4]Sun HY, Qiao X. Prediction of mechanical properties of three-dimensionally braided composites [J]. Composite Science and Technology,1997,57:623-630.

[5]Avva VS,Sadler RL,Shivakumar KN,et al.Mechanical properties of 3-D braided composite panels fabricated form using RTM techniques [D].1996,1838-1847

[6]Li Suhong etc, Affect the three-dimensional braided structure parameters on tensile properties of the composites.FRP/composites, 2014 (07):on 69-73

[7]Liu Qian,Li Jialu , Li Xueming .Affect the three-dimensional braiding process parameters on tensile properties of the composite [J].Aerospace Materials & Technology,2000,1:55-58.

[8]Institute of Materials Science and Engineering, Central South University, Changsha 410083, China Measurement and Analysis of Mechanical Properties of Braided Structure Composites [J]. FRP/composites,2002,3:11-14.

[9] nationwide fiber-reinforced composite material Standardization Technical Committee Secretariat . Fiber reinforced composites (FRP) Standard Series [M]. Beijing : China Standard Press , 1986:230-235.

[10]Meng Songhe , Tian Xiaoxiao . 3D woven carbon / epoxy composite mechanical properties testing and failure mechanism [J] Composite Materials, 2012