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Determination Of The Crack Length, Stiffness And Strength Of Notched Weft-Knitted Glass Fiber Variable Width Composite Plates

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ABSTRACT

In this paper, the crack length (CL), stiffness and strength of the knitted composite plates with different central holes and different plate width were determined. The comparative study has been made to evaluate the suitability of different modeling schemes to predict the stiffness and strength properties of knitted fabric composites. Various thicknesses of knitted fabric composite plates was fabricated by 360 grams per m^2 glass fiber woven mat with the 10; 1 ratio of LY 556 epoxy resin and HY 951 hardener. The fabrication of thick plates consist of 22, 41 and 49 layers having thicknesses 7, 12 and 13. 5 respectively.Further, a comparative study of flexural, tensile and compression test is carried out based on a plain weft knitted glass fiber reinforced composites. In flexural test the ultimate stress will be maximum at 13. 5 mm thick plate.The compression test having the ultimate stress of maximum at 12 mm thick plate and tensile test the ultimate stress was maximum at 13. 5 mm thick plate.Specimens were prepared for two configurations CWC and WCW. The stiffness and strength data is plotted with respect to load v_s displacement curves. Mechanical properties of variable thickness glass fiber composites stiffness and strength depends on the material size as well as thickness of the plate. The test results in that the CL, stiffness and strength is determined by using the experimental data.

Key words: knitted fabric, composite, woven mat, glass fiber, properties

INTRODUCTION

1. 1CHARACTERISTICS WEFT-KNITTEDGLASS FIBER

Fiber mats, braided and woven fabrics have been used in composite materials for a long time. The increasing use of knitted fabrics in composite materials has motivated the investigators to understand their behaviors. In recent years, some of these traditional textile technologies have been adopted to produce fabrics for reinforcement in advanced composites using various technical fibers including glass fiber, knitted fabric reinforced composites have received increasing attention in the literature. Compared with unidirectional (UD) fiber reinforced composites and with some other types of textile fabric such as woven and braided fabric reinforced composites, knitted fabric composites do not perform mechanically very well. Actual stiffness and strength of knitted fabric composite are only relativelyhigher than those of short fiber reinforced composites. Bernard Lorrain and MoussaKarama was conducted a non-contact measurement method, namely electronic speckle pattern interferometer (ESPI), was used to investigate the tensile strain field of a composites plate in the presence of stress concentrations caused by a geometrical defect consisting of circular hole. ESPI uses the principle of 3D speckle interferometry to measure the deformation and contour of the measuring field with sub micrometer accuracy. The ESPI technique clearly revealed the strain concentrations near the singularity. The experimental results are compared with the predictions of a theoretical model previously developed by Lekhnitskii's and a finite element study[1].

Although knitted fabric composites generally have lower stiffness and strength due to relatively low fiber volume fractions and looped fiber yarn architecture, they do have several advantages over the other fiber performs, including mass productivity, low fabrication cost, superior resistance to impact, and high ability to conform to complicated contours. Camanho was investigated a new methodology to predict the onset of damage, final failure and failure mode of mechanically fastened joints in composite laminates. The stress distribution at each ply is obtained using semi-analytical or numerical methods [2]. Theproblem becomes more serious in knitted fabric composites. Since the thickness of the knitted fabric reinforced compositeis usually small, it is difficult to prepare a testing samplefor the composite along the thickness direction. A completethree-dimensional (3D) description for the constitutiveequations of knitted fabric composites, which requires thematerial properties in all three orthogonal planes, would prove impractical using testing results only. In this study, CL stiffness & strength of the knitted composite plates withdifferent central holes and different plate width were determined. Specimens with 7, 12 and 13.5 mm Thickness(T), and containing 4, 8 and 12 mm diameterholes, D, were prepared and then tested for two configurations. The specimen configurations are course/wale/course (CWC) and wale/course/wale (WCW). The CLstiffness & strength found through the stress criteria from the experimentaldata. Falconnet (2002) had investigated the mode I inter-laminar fracture toughness of advanced knitted textile composite[3].

LITERATURE SURVEY

Two complex weft-knitted glass fabrics were selected for the study: a triple rib knit and a Milano knit were impregnated with a tough epoxy resin and tested using double cantilever beam geometry. For both knitted composites, the influence of the growth direction was studied by investigating crack propagation in both the wale and course directions. The fracture toughness was quantified by determining the critical strain energy release rate ($G_{IC)}$ using the modified beam theory. The specimens had to be stiffened with layers of glass woven composites added on top and bottom of thebeams. This was necessary in order to avoid plastic deformation of the beams and crack deviation out of the inter-laminar plane. The results clearly showed that knitted fabric composites have exceptional inter-laminar fracture toughness properties. [4]Green has been performed to investigate the effect of scaling on the tensile strength of notched composites. Hole diameter, ply and laminate thickness, were investigated as the independent variables, whilst keeping constant ratios of hole diameter to width and length, over a scaling range of 8 from the baseline size. In most cases strength decreased as specimen size increased, with a maximum reduction of 64 percentage. [8]Hallett, Wisnomwas investigate the effect of size on the tensile strength of composite laminates containing circular holes show that there is a large difference both in failure stress and mechanism due to changes in test configuration. This is particularly true of the ply and laminate thickness, and hole diameter. Interrupted tests have been performed on open hole tensile specimens at different load levels to determine the progressive damage development, evaluated through non-destructive testing (X-ray and C-scanning). The tests were also analyzed using a novel Finite Element Modeling technique. [8]Mevlu and Osman Asi (2007) carried out to investigate the bearing strength of a weft-knitted 1 · 1 rib glass-fiber composite plate pinned-joint in three directions. The knitted fabrics used for the study are manufactured from the 200 tex glass yarn with epoxy resin and cured in a hot press machine. The experiments were carried out according to the ASTM D953 standard. [5]Ramakrishna and K. H. Leong aims to bring together these two sets of literature to provide the reader with a comprehensive understanding of the subject of knitted composites. Consequently, this paper contains a detailed outline of the current state of knitting technology for manufacturing advanced composite reinforcements. Selected mechanical properties of knitted composites and some of the predictive models available for determining them are also reviewed. [3, 9]Zheng Ming Huang presents a review of currently developed micromechanical modeling techniques for predicting the stiffness and strength of knitted fabric composites. Further, a comparative study of the predictive capabilities of various techniques is carried out based on a plain weft knitted glass fiber fabric reinforced epoxy matrix composite. Useful conclusions are drawn based on the comparative study. [11]

METHODOLOGY

The 360 grams per m^2 glass fiber mat was used to fabricate 1×1 inch rib knit structure, produced by means of 5 gauge flat bed knitting machine. The flat panels used for the experimental procedure were manufactured from LY556 epoxy resin and HY951 hardener. The flat composite panels were produced using a hot press machine. In order to obtain the panels, the knitted-fabrics were put into a mould in the following manner, first and third layers were positioned in the wale direction, i. e., WCW, and the second one was positioned between them in the course direction, i. e., CWC. Thus, it was obtained that a 0 to 90˚_ angle between the wale directions of first and second layers, while the wale directions of first and third layers were parallel to each other. After that resin was impregnated. The hot press machine was set at a temperature of 70 ˚C, pressure at 12 MPa for the whole pressing process. At the end of the process, the complete set-up was cooled to room temperature.

Fig-1 Image of fabricated materials

Fig-2 Image of fabricated materials

EXPERIMENTAL PROCEDURE

The weft-knitted glass-fiber composite blanks are cut into rectangle shapes for testing through a Universal testing machine. The Universal testing machine was illustrated in Fig-1. Specimen thicknesses were varied as 7, 12, and 13. 5 mm and they were prepared in the wale and course directions according to first layer. Three specimens are prepared for given thickness and while keeping the thickness of specimens as 7, 12, and 13. 5 mm.

Compared with unidirectional (UD) fiber reinforced composites and with some other types of textile fabric such as woven and braided fabric reinforced composites, knitted fabric composites will perform mechanically very well. Actual stiffness and strength of knitted fabric composite are only relatively higher than those of short fiber reinforced composites. Although knitted fabric composites generally have higher stiffness and strength. The specimen configurations are course/wale/course (CWC) and wale/course/wale (WCW). The stiffness & strength found through the experimental data.

Fig-3 Tensile Testing Machine.

4. 1 Geometry of knitted fabric composites

Knitted fabrics are made with interlooping of yarns. Basically, they are categorized into two type's namely warp-knit and weft-knit fabrics. If a knitted fabric is constructed from a single yarn or thread and the loops are made horizontally across the fabric, the knitting procedure is called weft knitting, see Fig. 3a. Alternatively, if at least one thread may be supplied to each needle of a complete set of needles and the threads formed into loops which run lengthwise in the fabric, the procedure is called warp knitting, see Fig. 3b. In a knitted fabric the lengthwise rows of loops are known as Wales, whereas the rows running across the fabric are referred to as courses. Although an almost infinite variety of knitting structures exists in textile industry, only a limited number of them are being considered for composite reinforcements in engineering applications. Reasons are: (a) most engineering applications require only simple knit structures and(b) unlike textile fibers (cotton and polyester), stiffer reinforcement fibers such as glass and carbon still display some difficulty in forming complicated knit structures. Both the warp and weft knitted fabrics can be further classified into four types based on the dimensional arrangement of yarns. This fabrics are simple 2D flat knitted fabrics. These fabrics can be cut to the required dimensions and laminated (stacked) in multilayers. Using fully-fashioned knitting machines it is possible to produce 2D fabrics into the net shape of components, which are categorized as stitching multiaxial layers of parallel yarn. Because of minimum fiber crimp, they are also called as non-crimp fabrics. This fabrics, also known as sandwich fabrics or 3D hollow fabrics,are produced by binding 2D-face fabrics together using pile yarns. Sometimes these fabrics are referred as 2. 5D fabrics, as the amount of fibers in the thickness direction is less than the fibers in the planar direction of the fabric. They are being considered to achieve optimum design of high-performance and damage-tolerant compositestructures. Green has been performed to investigate the effect of scaling on the tensile strength of notched composites. Hole diameter, ply and laminate thickness, were investigated as the independent variables, whilst keeping constant ratios of hole diameter to width and length, over a scaling range of 8 from the baseline size. In most cases strength decreased as specimen size increased, with a maximum reduction of 64 percentage[8]

The effective mechanical properties of the knitted fabric composites depend on: (i) properties of the constituent materials; ii) knit loop structures; and (iii) overall fibervolume fraction. Amongst them, the most challenging work is to identify the knit loop structures, as the other two are relatively easy to be determined. This can be accomplished bycharacterizing the fabric geometry of an RVE of the composites. Because of the coherence of the fiber yarns in the knitted fabrics by means of loops, the fiber yarns will generally not change their positions or orientations too much especially in the plane of the fabric when the fabrics are impregnated with resins and cured. This means that we can investigate the fiber yarn geometry using neat fabrics instead of the resin-impregnated fabrics, i. e. fabric composites. Ideally, the fabric geometry should be described by some analytical function in the global coordinates. However, except for the plain weft knitted fabrics the yarn positions of which can be specified by Leaf and Glaskin’s analytical model [8], there is no satisfactory function available for other kind of knitted fabric structures. Measurements have to be performed to determine the yarn positions. A frequently used methodology is to evaluate polished cross-sections with an image analysis program and to calculate the fiber orientation distributions by use of the ellipticity of the cut fibers [6, 10]. Such kind of measurement, however, is usually performed using micrographs such as photographs under a stereomicroscope, and it is difficult to achieve high accuracy. Most existing geometric models have been developed for identifying the geometry of Type I knitted fabrics, i. e. 2D fabrics.

4. 2 TESTING METHOD

4. 2. 1 DETERMINATION OF CRACK LENGTH

Some photography and typical load-displacement curves for the wale and course directions of specimen widths 7, 12 and 13. 5 mm and containing 4, 8, and 12mm hole diameter were fabricated to carry out the CL. It can be observed from the curves that the curves firstly show a linear elastic phase characterized by an elastic module E up to a second point where the curve loses its linearity thus translating the nonlinear behavior and the beginning of damage of the composite. Secondly, this phenomenon also goes up to a last point where the specimens catastrophically rupture. It is also observed from the curves that the failure displacement increase with increasing of the holes. In addition, the strength of the specimens decreases with the increasing of the holes diameter. The experimental results of weft knitted glass fiber composite will find out through delaminating method. Practical tests using the finite-width specimen require a correction to convert it to the notched strength of the infinite-width specimen. The CL increases with an increase in the hole diameter (D) and in the specimen width (W) for the same hole size. The values of m and n for all curves are plotted with respect to the values of W and given in for both course and wale directions, respectively. The CL can be found for any configuration easily. As a result of that the CL can be found from the less experimental data.

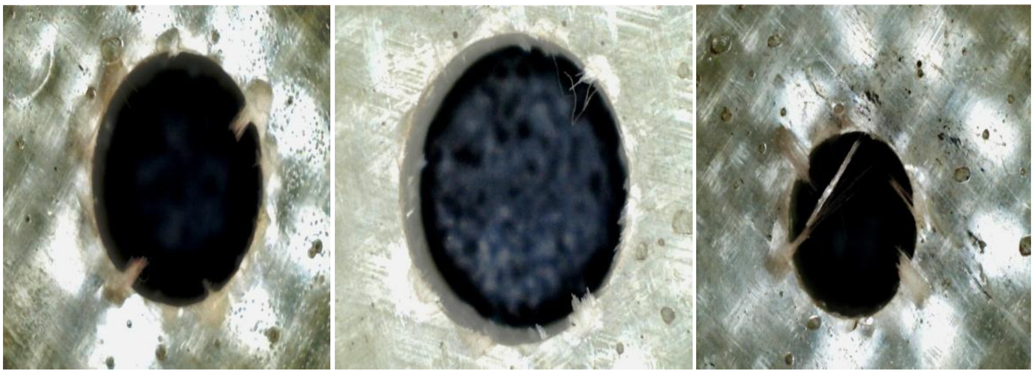
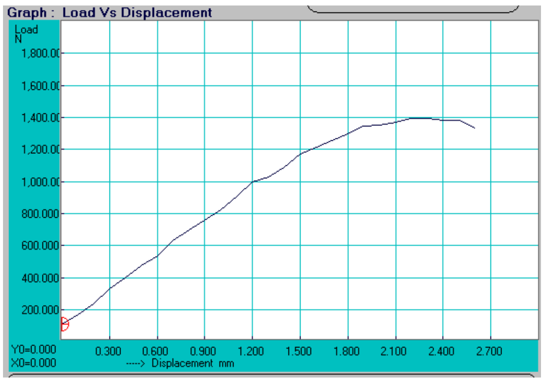


Fig-4 various thickness of drilled and tested materials

4. 2. 2 TESTING OF STIFFNESS

The mechanical properties of knitted fabric composites depend on the properties of constituent fiber and matrix materials used. It is seen that the polymer matrix significantly influences the overall mechanical performance of the composites. The flexural test is recommended to calculating specimen stiffness. This test is also called bend test with the suitable fixture as given in the specifications and subjected to flexural test. The Test is conducted in the universal testing machine in compression mode. The sample is kept on bending fixture and the compressive load is given under specified conditions and the curve generated till the failure of the testing specimen takes place and then noted the various values.



Ult./Break Load	1,395.000 N
Disp. at FMAX	2.200 mm
Max. Disp.	2.600 mm
Area	83.233 mm²
Ult. Stress	16.760 N/mm²

Fig-5 Load Vs Displacement curve for Flexural test

The stiffness of glass fiber composite plates is calculated by means of flexural test and 7 mm thick specimen test was illustrated. ASTM-D 790 material size is used to test the specimen. While testing the material it breaks the ultimate load of 1, 395 KN at 2. 6 mm maximum displacement.

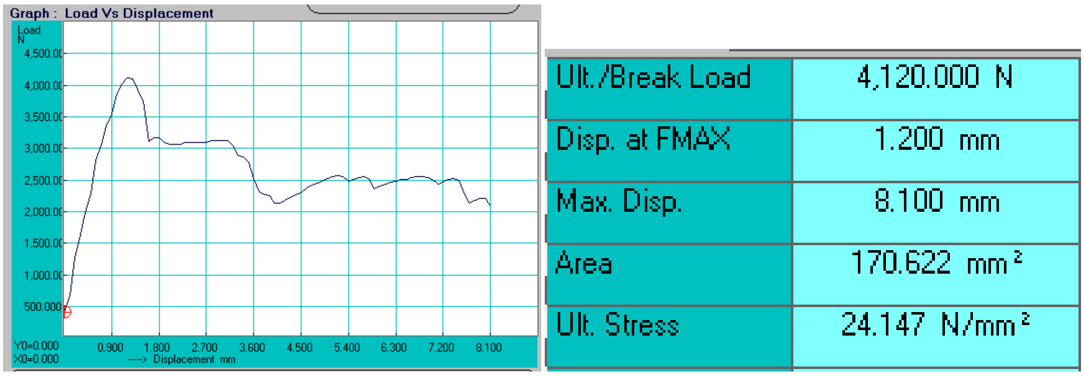


Fig-6 Load Vs Displacement curve for Flexural test

The 12 mm thick specimen test was illustrated. ASTM-D 790 material size is used to test the specimen. While testing the material it breaks the ultimate load of 4, 120 KN at 8. 1mm maximum displacement.Compare to 7 mm thick test specimen it will be more effective because the breaking point and maximum displacement of 12 mm thick specimen is approximately three times higher.

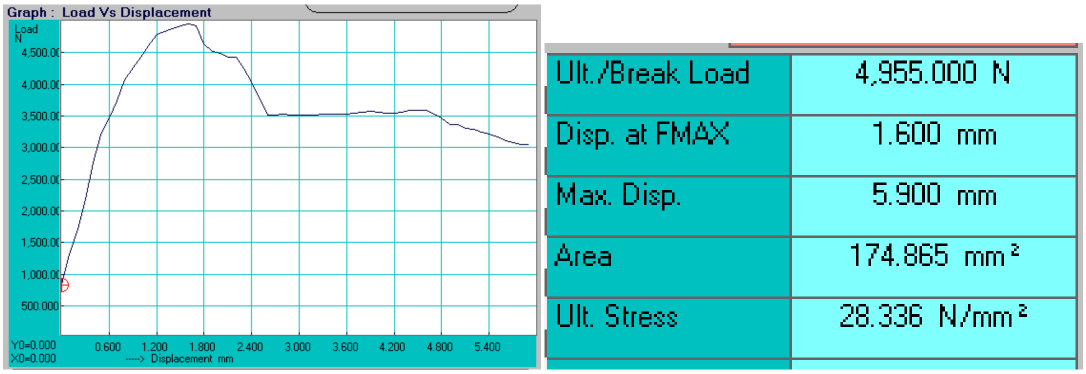


Fig-7 Load Vs Displacement curve for Flexural test

Table-1 Flexural test results

Sl. No	Specimen thickness (mm)	Ultimate break load (KN)	Maximum displacement (mm)	Area (mm)	Ultimate stress (N/mm^2)
1	7	1395	2. 6	83. 233	16. 760
2	12	4120	8. 1	170. 622	24. 147
3	13. 5	4955	5. 9	174. 865	28. 336

The 13.5 mm thick specimen test was illustrated. ASTM-D 790 material size is used to test the specimen. While testing the material it breaks the ultimate load of 4, 955 KN at 5. 9 mm maximum displacement.Bending characteristics of both 12 and 13.5 mm thick specimen will be similar.

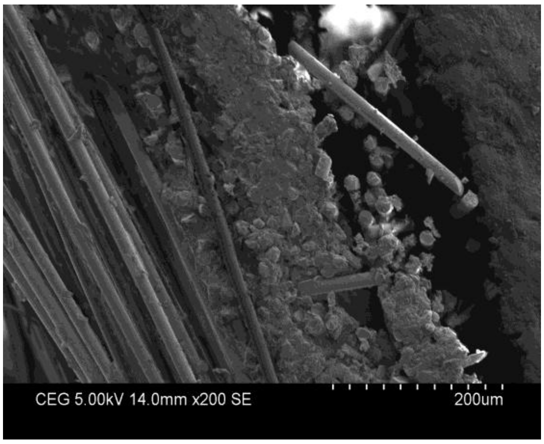


Fig-8 SEM image for Flexural test

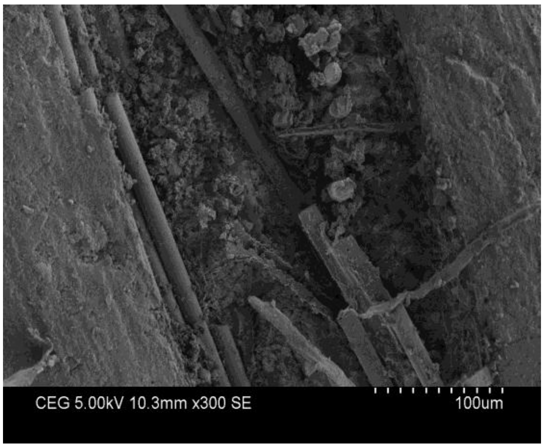


Fig-9 SEM image for Flexural test

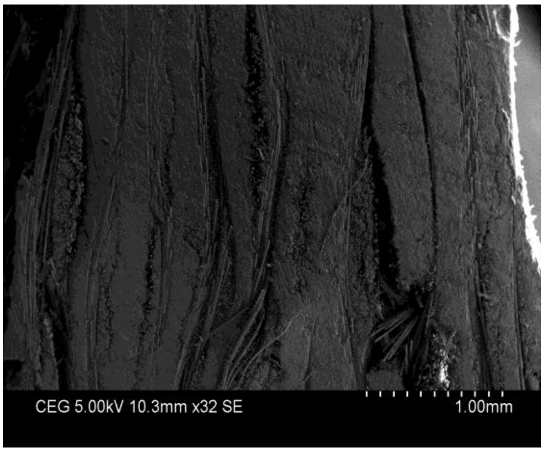


Fig-10 SEM image for Flexural test

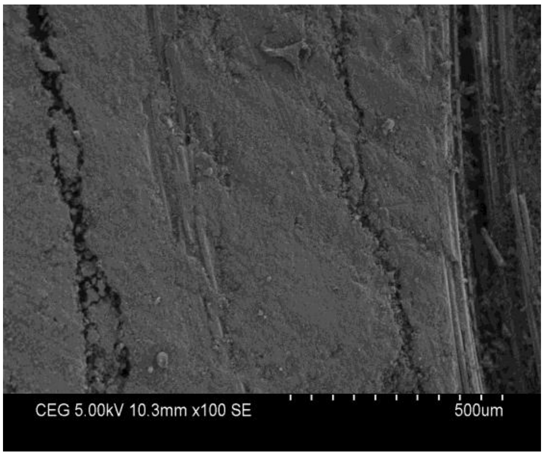


Fig-11 SEM image for Flexural test

Above figsshows the SEM image of the flexural tested surface of glass fibre reinforced composites based on modified epoxy matrices. Interlaminar shear failure modes are obvious in the micrographs. Epoxy matrix residues that are observed on the fibre bundles for the modified epoxy cases indicate good fiber–matrix adhesion. It can be seen that one layer of fibre is perpendicular to the other layer.

4.2.3 TESTING OF STRENGTH

It represents the maximum load carrying capacity of the knitted fabric composites, and hence is another important material property for design and application. One must be confident in this load carrying capacity before making any efficient use of the composites. In the theoretical modeling, they used the maximum stress criterion to predict the ultimate strengths of the composites. The internal stresses exerted on the yarn segments (unidirectional laminas) and pure matrixes were determined based on the elastic stiffness matrices for the yarns and pure matrix materials.

The compression test is recommended to determine the specimen strength. This specification gives the drawing of the specimen to be prepared for conducting the test with tolerances. The prepared compression specimen were inspected after machining and loaded in the compression testing machine or universal testing machine and the compression force is given. The Load Vs displacement curve is generated till the specimen is broken.

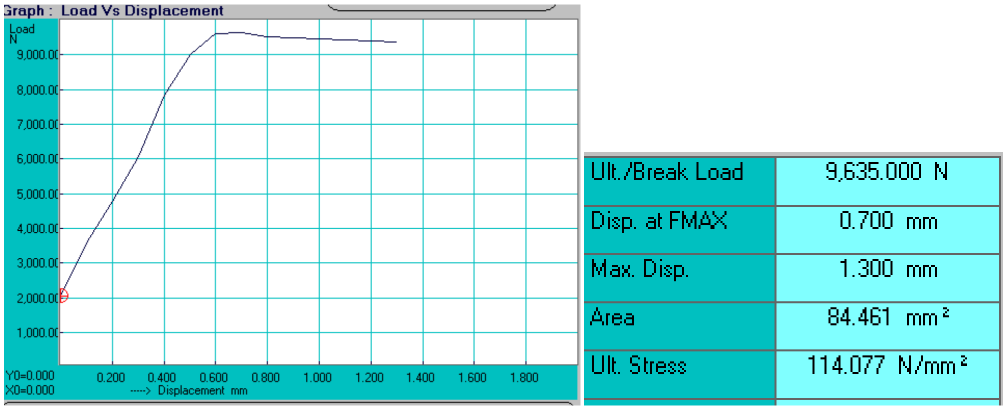


Fig-12 Load Vs Displacement curve for compressive test

The strength of glass fiber composite plates is calculated by means of compression test and 7 mm thick specimen test was illustrated. ASTM-D 256 material size is used to test the specimen. While testing the material it breaks the ultimate load of 9, 635 KN at 1. 3 mm maximum displacement.

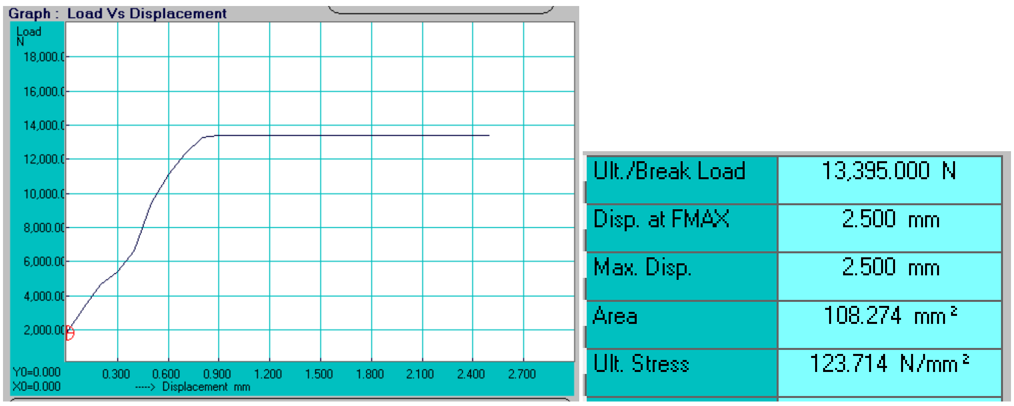


Fig-13 Load Vs Displacement curve for compressive test

The 12 mm thick specimen test was illustrated. ASTM-D 256 material size is used to test the specimen. While testing the material it breaks the ultimate load of 13, 395 KN at 2. 5 mm maximum displacement.Compare to 7 mm thick test specimen there was no significant changes. According to material thickness the strength is gradually increases.

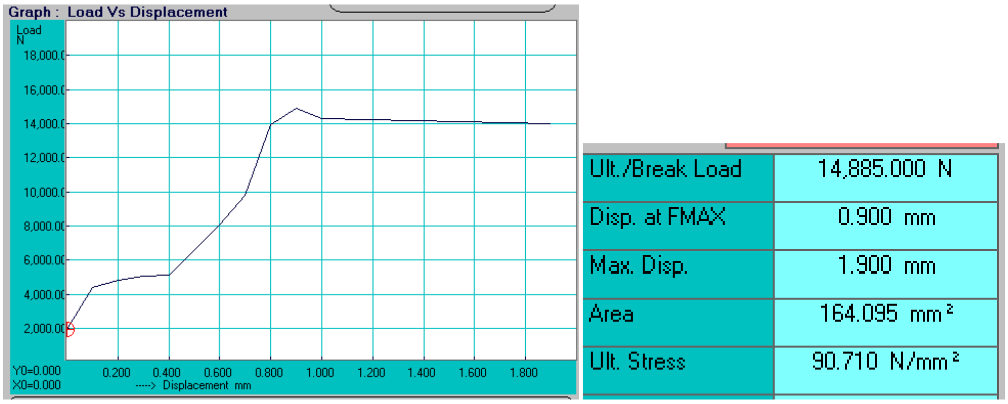


Fig-14 Load Vs Displacement curve for compressive test

Table-2 compressive test results

Sl. No	Specimen thickness (mm)	Ultimate break load (KN)	Maximum displacement (mm)	Area (mm)	Ultimate stress (N/mm^2)
1	7	9365	1. 3	84. 461	114. 077
2	12	13395	2. 5	108. 274	123. 714
3	13. 5	14885	1. 9	164. 095	90. 710

The 13.5 mm thick specimen test was illustrated. ASTM-D 256 material size is used to test the specimen. While testing the material it breaks the ultimate load of 14, 885 KN at 1. 9 mm maximum displacement.

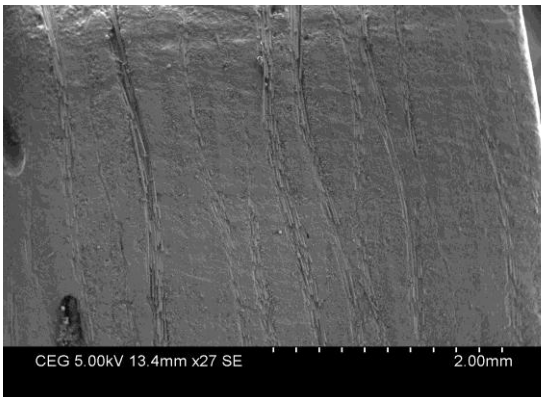


Fig-15 SEM image for Compressive test

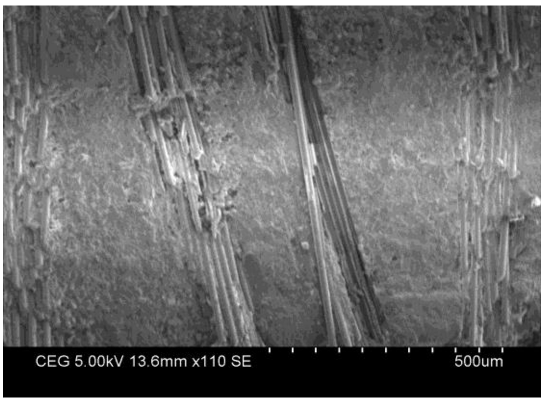


Fig-16 SEM image for Compressive test

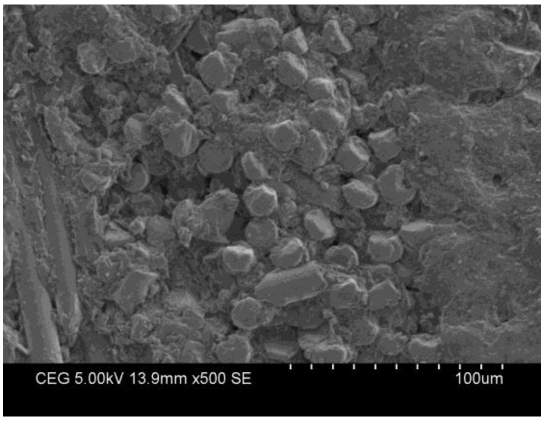


Fig-17 SEM image for Compressivetest

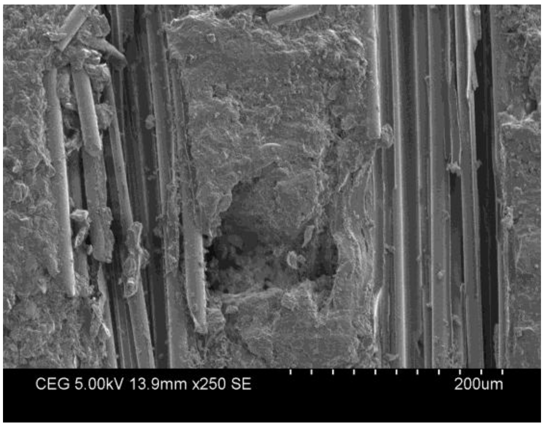


Fig-18 SEM image for Compressive test

Above figsshows the SEM image for the compression fracture surfaces of glass fibre reinforced composites based on modified epoxy matrices. Interlaminar shear failure modes are obvious in the micrographs. Epoxy matrix residues that are observed on the fibre bundles for the modified epoxy cases indicate good fiber–matrix adhesion. Inter- phase delamination is found at the cross-section of a composite due to flexural load applied. Presence of voids in the specimen is found to be minimal due to uniform load applied on it. The crack propagates through the natural fibres rather than the glass fibre and causes failure.

4.3 RESULT AND CONCLUSION:

The critical crack length of the knitted composite plates with different central holes and different plate width were predicted by means of point and average stress criteria. The knitted fabrics used for the study are fabricated from the 360 grams per m^2glass with epoxy resin and cured in a hot press machine. Specimens with 7, 12 and13.5 mm thickness (T) and containing 4, 8 and 12 mm diameter holes (D) were prepared and then tested in two configurations, CWC and WCW. The CL found through the stress criteria from the experimental data. The CL data plot with respect to D/T ratios and then the following results are found. The load-displacement curves show a linear elastic phase up to a second point where the curve loses its linearity thus translating the non-linear behavior and the beginning of damage of the composite. This phenomenon also goes up to a last point where the specimens catastrophically rupture. The CL curves with respect to D/T ratios are presented the same character and very close. The enhanced performance of stiffness and strength is satisfied at 12 mm thickness GFRP. The load-displacement curves show a linear elastic phase up to a second point where the curve loses its linearity thus translating the non-linear behavior and the beginning of damage of the composite. This phenomenon also goes up to a last point where the specimens catastrophically rupture. So 12 mm thickness is complosit plate is recommended in this paper after all necessary tests proving the need for the strength of the composite material.

REFERENCES

1. Falconneta, D. Bourbana S. Pandita J. E. Manson and I. Verpoest "Fracture toughness of weft-knitted fabric composites" Composites Part B Vol No-33, Pg No; 579-588, (2002).
2. Huysmans. G, I. Verpoest, P. Van Houtte "A damage model for knitted fabric composites" Composites: Part A 32 Pg No: 1465-1475 (2001).
3. Leonga, Ramakrishnab. S "The potential of knitting for engineering composites" composites Part AVol No-33, Pg No; 583-588, (2002).
4. LotfiToubal, MoussaKarama, and Bernard Lorrain "Stress concentration in a circular hole in composite plate" Composite structures Vol No-68Pg No; 31-36, (2005).
5. Mevlu¨Tercan a, 1, Osman Asi b, 1, and AlaattinAktas_ "An experimental investigation of the bearing strengthof weft-knitted 1 ×1 rib glass fiber composites" Composite Structures Vol No-78, Pg No; 392-396, (2007).
6. Khondker[a,] K. H. Leong and Herszberg "Study of composite compressive properties due to biaxial deformation of the weft-knitted glass fabrics"composites; Part A Vol No-32, Pg No; 1303-1309, (2001).
7. Camanho. P. P a, M. Lambert b "A design methodology for mechanically fastened joints in laminated composite materials"Composites Science and Technology Vol No-66, Pg No; 3004-3020, (2006).
8. Hallett. S. R, Green B. G, Jiang. W. G 2, and Wisnom.M. R "An experimental and numerical investigation into the damage mechanismsin notched composites" " Composite structures Vol No-68, Pg No; 31-36, (2005).
9. Ramakrishnab. S, Leonga. K. H, Huangb. Z. M, and Biboa.G. A "The potential of knitting for engineering composites—a review" composites Part AVol No-33, Pg No; 583-588, (2002).
10. Kennedy. T. C, Kassner. M. E "Predicting failure of composite structurescontaining cracks"Composites:PartA 33Pg No: 583-588 (2002)
11. Zheng Ming Huanga, Ramakrishnab. S "Micromechanical modeling approaches for the stiffness and strength of knitted fabric composites: a review and comparative study" Composites Part AVol No-31, Pg No; 479-501, (2000).