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Original Research Article

A STUDY ON E-GLASS FIBRE BRAIDED COMPOSITES

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Abstract:
Braiding technique is perhaps the earliest production process of textile structures and to form continuous fibre reinforced composite materials. Now a days, braided structures are used in broad range of structural applications such as aerospace industries, automobile industries etc. These types of industries need materials with high impact resistance, light weight, longer fatigue life and so on. Braided composite structures have very good fatigue life, impact resistance, delamination resistance and better dimensional stability. This paper presents an experimental work with E-glass braided fiber.

Keywords: Braided composites, mechanical properties, braid angle, applications.

I. Introduction

Composites are engineered materials made from two or more constituents with different material properties, which remain separate and distinct within the completed structure. Over the last thirty years textile composite materials and plastics have been the leading emerging materials. Textile composites have been victorious as secondary structural components and are increasingly being considered for primary structural applications. It has higher strength-to-weight ratios, better impact resistance, better vibration damping properties and higher flexibility. Textile fibre composites are cost effective replacements for pre-impregnated (pre-preg) based laminated composites due to lower manufacturing costs and near net shape production. [1] Textile composites have properties that are naturally more balanced, which is beneficial when unexpected or unusual loading conditions arise. He reported that the straight-ply laminates have a large number of layers to achieve the same balance, reducing their advantage in strength-to-weight ratio. [2] Braiding is the one of the textile fibre composite material preform manufacturing technique where a braiding machine deposits continuous, intertwined, fiber tows to create desired reinforcing braid architecture before or

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during the impregnation of the fibers.[3] The important features of the braided fabric are the continuity of all fiber bundles diagonally oriented. Therefore the braided fabric reinforced composites have superior mechanical properties.[4]

In this paper, a systematic review has been made on the terminology of braided composites, braid angle, application of braided composites and an experimental work was conducted on mechanical properties with E-glass braided fiber also presented here.

A. Terminology of Braided Composites

The following are the common terminology used for braiding which was discussed by Cagri *et al*.[3] in their report.

Braiding: A composite material preforms Fig. 1. (a) manufacturing technique. A braiding machine is used to intertwine fibers to create desired braid architecture before or during the impregnation of the fibers.

Braid angle: The angle between the longitudinal direction of the braided preform and the deposited fiber, Fig. 1. (b).

Volume fraction: Relative amount of one constituent of the composite to the remaining constituents.

Unit cell: Smallest repeating element of a braided composite, Fig. 1. (b).

Crossover regions: Regions where intertwining fiber tows are deposited on top of each other in a unit cell. Undulation region: The region where fiber tows undulate from one crossover region to the other, Fig. 1. (b).

Matrix only region: Remaining parts of the unit cell where fiber undulations or fiber crossovers do not exist, Fig. 1. (b).

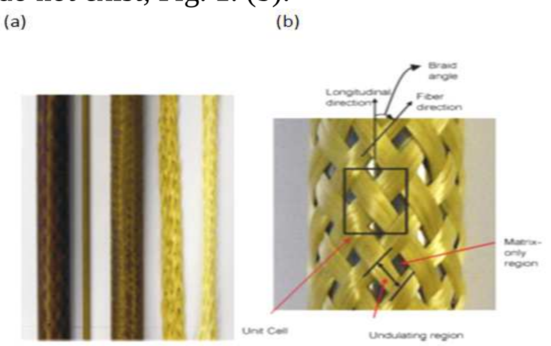

Fig. 1. (a). various braided composites (first three from the left), different preform sizes (last two on the right); (b) braid architecture (i.e., unit cell, braid angle, undulating region, matrix only region).

B. Biaxial Braid

The biaxial braid is characterized by two bias yarn systems Karin et al.[5], which are interwoven in an arbitrary braiding angle as shown in Fig. 2.

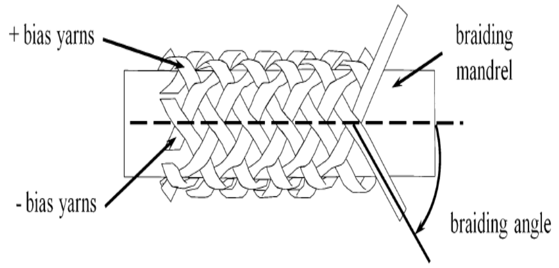

Fig. 2. Biaxial braid

Chiu et al.[6] observed that the axial yarns in 3D braided composite tubes are the main supplier for the energy absorption and the braider yarns dominate the crushing failure modes. He showed that the 3-D carbon braided composite tube have higher specific energy absorption capability than the Kevlar braided tubes. This higher specific energy absorption capability exposed that the carbon tubes could absorb more energy in crush tests. He also found that the Kevlar braided tubes demonstrated good post-crush structural integrity. The impact properties of the braided and laminated composites were compared and shared that braided composites absorb impact energy with a lower load, through a longer period of time with larger deformation as propagating the stress for the larger area than the laminated composites.

C. Triaxial braid

The triaxial braid is characterized by a third yarn system, the zero degree yarns, which are positioned in the braid in parallel to the mandrel axis Fig. 3.[5]

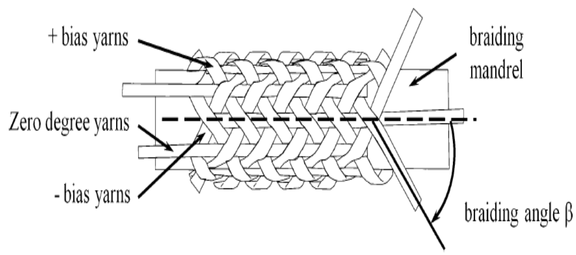

Fig. 3. Triaxial braid

Alison and Daniel[7] were investigated the effects of axial yarn crimping on the compressive strength and stiffness of 2D triaxially braided composites (carbon epoxy panels). They showed that the axial compressive strength of braided composite structures may be improved significantly by minimizing axial yarn crimping and suggested that high compaction pressures, which result in greater yarn crimping in addition to high fiber volume fractions, may not produce optimal compressive strength performance.

II. Applications of Braided Composites

Braiding technique is perhaps the earliest production process of textile structures. Braiding is generally used technology to produce sectional performs in the aerospace, medical, sports and automotive industries. Fangueiro et al.[8] reported that braided is normally used for ropes and cables, braided fabrics are also very interesting for composite reinforcements due to their characteristics: in-plane multiaxial orientation, conformability, excellent damage tolerance and cost. They used braiding technique to produce a wide range of preforms for composite reinforcements (T´s, I, hollow fabrics). A&P technology[9] manufactured the composite materials that are currently of most interest for engine fan cases are made by resin infusion processes using two-dimensional triaxial braided preforms and 177^{o}C (350^{o}F) cure epoxy resins. They proved that in composite fan cases, braided fabric improves energy absorption, contains crack propagation, and offers 30% better containment properties while saving a significant amount of weight. Due to the fatigue life of braided composites, they have outperformed unidirectional laminates for jet engine stator vanes in fatigue strength. Braids are used in fan blade containment in commercial aircraft and energy absorbing crash structures in Formula one racing cars.[10] Near-net-shape preforms for mainly longish components are suitable to be realized with braiding, e.g. crash cones or frame structures in cars or aircrafts.[1] Karbhari et al.[11] Braid energy absorbing capabilities could be eventually used in industrial applications such as car bumpers. They observed that triaxially braided composites increased the energy absorbing performance of the braided composites. Guoquan et al.[12] used the four steps three-dimensional braiding process to manufacture the flange preform. They reported that many structures with different cross-sectional shapes can be braided by the four steps, for example, tabular, tubular, semicylinder, and cylinder. Kevlar/graphite braided hybrid preforms impregnated with epoxy resin for the design and fabrication of braided bicycle frame.[13] Braided material are used in high end hockey sticks because it provides superior strength, ease of use, design predictability, part to part repeatability and has negligible scrap rate.[3] Katherine et al.[14] investigated that the tubular braided composite bone cast for improving the efficiency and quality of bone fracture treatment. They reported that a shape adaptable composite braid that wraps entirely around the bone fracture site could be used to eliminate the need for screws. Brouwer et al.[15] given that the viscosity of the resin for vacuum-assisted infusion process of large structural components, such as wind rotor blades and a long boat hulls, is usually limited to 100–500 mPa.s, even if values up to 1000 mPa.s are still acceptable. Strong[16] considered the typical shear rates involved in the resin infusion process, it is possible to assert that the introduction of the OM clays in concentration up to 5wt% does not compromise a possible usage of this epoxy resin for infusion processes, as recently experimentally verified by Quaresimin[17].

III. Experimental Investigation

An experimental work was undertaken to reduce the number of unproven assumptions and design decisions, and to test the extent to which distrustful conclusions of certain earlier studies apply to this study.

A. Material Selection

Braided E-glass fiber with three different angle 30^{o}, 45^{o}, and 60^{o} was selected for preliminary studies. The density of the fibre mat is 250g/m^{2} supplied by Binani Industries Limited (Glass Fibre Division). Initially eight layers of fiber mat were cut with a dimension of 330mm x330mm for fabricating each composite. The fiber content in the three composites are 30 wt% of total weight of the composite. A commercial grade of epoxy resin (Araldite LY556/ HY 951) was used as matrix. Araldite LY556 is insoluble in water and has a flash point of over 200^{o}C.

The Araldite LY556 aspect (visual) appears clear and pale yellow liquid in colour. The viscosity at 25^{o}C is 10000 to 12000(cps). The density of Araldite LY556 is 1.15 to 1.2 g/cm3. The hardener used for this is HY951 which has the capability of curing at room temperature and having a density of 0.97 to 0.98 g/cm3. The Aradur HY951 aspect (visual) appears clear liquid in colour. The viscosity at 25ºC is 1000 to 1200(cps). The density is around 0.97 to 0.99 g/cm^3. The flash point is 110ºC. They are mixed in 10:1 weight ratio.

B. Composite Preparation

The composite material used for this study is prepared by hand layup method. Mold release agent is applied to milar sheet of 75 micron. Epoxy resin and hardener are mixed and applied to the milar sheet. Then the fibre mat is kept. A brush and roller is used to impregnate the fibers with resin. The roller is used to eliminate air bubbles. The same procedure is repeated for all eight layers of the fibre mat and also the same procedure is repeated to prepare the other three composites. Then the composite so prepared are cured at room temperature for 18 hours. Another four hours is carried out in sun light for post curing on each side of all the three samples of composites. E-glass braided fiber composite specimens are shown in Fig. 4.

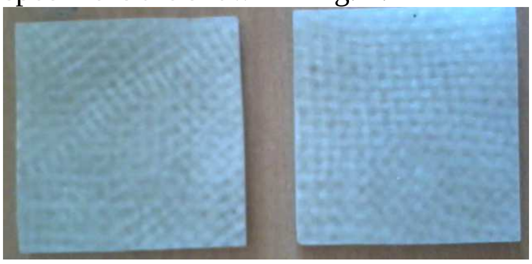

Fig. 4. E-glass braided composite specimen

C. Tensile test

Tensile test is important for selecting materials for engineering applications and to compare different materials in the development of new materials. Uniaxial tensile strength, Young's modulus and poisons ratio can be determined using tensile test. The tensile test was carried out using an universal testing machine of capacity 5 tons. The test specimen is prepared according to ASTM D 3039 standard. The ASTM standard D 3039[18] for tensile testing of properties of fibre-resin composites was used as guide in carrying out the test. It recommends specimen width in the range of 12.7 mm–25.4 mm for samples with 6–16 plies; the length of the test section should be at least 127 mm as shown in Fig. 5.

The tensile strength is calculated according to the following formula

$\sigma t = P / bh$ ………. (1)

P-ultimate load on the specimen in N

b- Initial width of specimen in mm

h- Initial thickness of specimen in mm

Fig. 5. Specimen for tensile test

D. Impact test

The impact testing machine is a drives used to test the sudden impact or load absorbed by the material or work piece. For impact tests, all three specimens were made by following the ASTM standard, ASTM D256. The specimen for impact specimen is as shown in Fig. 6. The impact strength is calculated according to the following formula.

$I = K/A$ ………. (2)

K – Energy absorbed in joules

A – Cross sectional area sqmm

Fig. 6. Specimen on impact testing machine

E. Compression test

Compressive strength is the capacity of a material or structure to withstand loads tending to reduce size. It is a method for determining behaviour of materials under crushing loads. Some material fracture at their compressive strength limit and some material deform irreversibly, so a given amount of deformation may be considered as the limit for compressive load. The test was conducted in compression testing machine supplied by Heico. The capacity of the machine 100KN. Specimen is prepared according to ASTM D3410 standard and it is shown in Fig. 7.

Fig. 7. Specimen on compression testing machine.

IV. Results and Discussions

A. Tensile properties

The tensile strength of the composite increases with increase in fibre volume content because the glass fibre are the main load carrying member and matrix acts as stress transfer medium and when the load increase maximum stress it taken up by the fibers.[19]

It was observed that the tensile strength of 30^o biaxial specimens is greater than the 45^{o}and 60^o specimens as shown Fig. 8. The influence of axial yarn results in good compact structure and better cohesion between the reinforcement and matrix material, the strength and modulus in 30^o composites are higher than the other two braided angle composites.

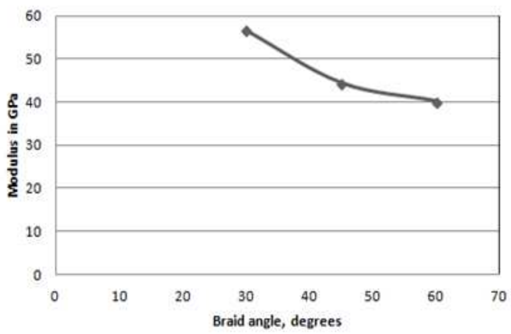

Fig. 8. Variation in modulus with braid angle.

B. Impact properties

The impact properties of the braided and laminated composites are compared and shared that composites absorb impact energy with a lower load, through a longer period of time with larger deformation as propagating the stress for the larger area than the laminated composites.[20]

It was observed that the impact energy of 30^o specimen is greater than the other two specimens. Due to better compact structure and better cohesion between the reinforcement and matrix material, the impact strength in 30^o specimen is higher than the other two braided composites are shown in Fig. 9 (a) and (b).

(a)

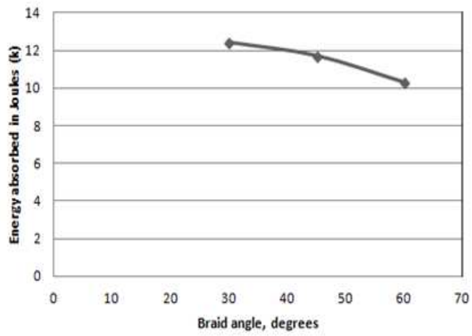

Fig. 9. (a). Variation in impact energy absorbed with braid angle.

(b)

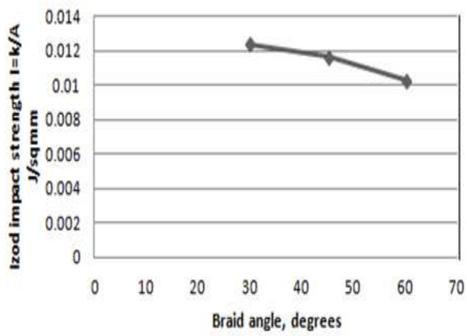

Fig. 9. (b). Variation in izod impact strength with braid angle

C. Compressive properties

In compression test ,the deformation is homogeneous, there appears to be no edge effects and there is good fiber/matrix bonding. Angle 30^o braided composites shown higher compressive strength than the other two composites as shown in Fig. 10. (a) and (b).

(a)

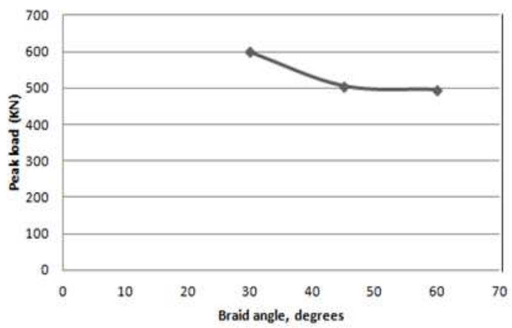

Fig. 10. (a). Variation in peak load with braid angle.

(b)

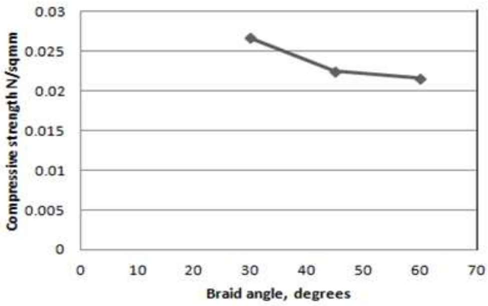

Fig. 19. (b). Variation in compressive strength with braid angle.

V. Conclusion

Braiding is an old technology, which has existed in the literature for several years and yet is an unmellowed but the most possible method for the fabrication of continuous fibers. A comprehensive as well as state of art review on this braided techniques together with their applications of braided has been made in this paper. So far only small number of braided composites has been tried and understanding of braided technology with nano is very limited. Extensive researches and developments in these areas are required in the future. An experimental work was conducted with E-glass fibre braided composites. In this study, the effects of E-glass fibre braided composites and mechanical properties are outlined. The current improvements in their fabrication techniques and sympathetic of their mechanical behaviors contribute to the increasing popularity of braided materials. In general, the behaviour of braiding materials in composites possesses the higher properties.

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