GLOBAL JOURNAL OF ENGINEERING SCIENCE AND RESEARCHES

EVALUATION OF TENACITY OF GFRP COMPOSITES

Karthik S[*1], Darshan R[2], Prabhanjan R[3] & Saarang Suresh[4]

[*1]Assistant professor, Department of Mechanical Engineering, Vidya Vikas Institute of Engineering and Technology (VVIET), Mysuru - 570028, Karnataka, India

[2,3&4]Under Graduate Students, Department of Mechanical Engineering, Vidya Vikas Institute of Engineering and Technology (VVIET), Mysuru - 570028, Karnataka, India

ABSTRACT

Tenacity, the specific strength, of glass fabric reinforced polymer matrix (GFRP) composites has been evaluated. A reinforcement of plain woven glass fabric and a matrix of vinylester resin constituted the composites. The GFRP composites were fabricated by hand lay-up process. The composites were tested for their tensile properties using the ASTM standards of testing. The determined tenacity of GFRP composites was comparable with that of certain engineering metals and alloys.

Key words: *Tenacity, Specific strength, GFRP Composites, Glass fabric, Vinylester*

I. INTRODUCTION

A composite material or in short, a composite, is constituted of two or more materials, with at least one reinforcement and a matrix. However, filler materials could also be added to improve the properties of the resulting composite material. The reinforcing phase provides the necessary strength and stiffness. Usually, the reinforcing phase is harder, stronger and stiffer than the matrix phase. The combination of two or more phases as in case of a composite, results in better properties than those of the individual components used separately. In contrast with metallic alloys, each constituent material retains its mechanical and physico-chemical properties. The main attributes of composites are their high strength and high stiffness, combined with low density. Thus, when compared with bulk materials, use of composites allows for a weight reduction in the finished part. The reinforcement would usually be in fibrous or particulate form. A fiber has a length that is much greater than its diameter. Continuous-fiber composites are often made into laminates by stacking single sheets of continuous fibers in different orientations to obtain the desired strength and stiffness properties with fiber volumes as high as 60 to 70 percent. Fibers produce high-strength composites because of their small diameter and they contain fewer surface defects compared to bulk of the material thus produced. Typical fibers include glass, aramid and carbon, which may be in continuous or discontinuous form [1]. A number of individual long fibers stacked and held together along the given direction(s) and the given length forms a fabric. The type of fabric may be differentiated depending on the number of fiber layers in the final fabric, type of weave, direction(s) of fiber placement etc.

Weight is often a key factor in evaluating the use of composites. Hence, strength and stiffness are often listed as specific strength or specific modulus respectively. The specific values are normalized by dividing the property value by the density [2]. Tenacity or specific strength is the ratio of a material's strength and its density. It is also known as strength-to-weight ratio or strength/weight ratio. Strength, stiffness and weight are functions of constituent materials, their relative quantities, and placement. Materials with the highest specific strengths are typically fibers such as carbon, glass and various polymers, and are frequently used to make composite materials [3]. While fiber reinforced polymer matrix (FRP) composites are also light in weight, there is a great advantage with their high tenacity and/or specific stiffness over conventional materials.

Over recent years, thermoset matrices have gained popularity because of their ease of processing and application in fiber reinforced polymer matrix (FRP) composites. Epoxies, as matrices, yield high strength, low shrinkage and good adhesive properties. Also they are good electrical insulators, resist chemicals and solvents to a fair extent, available at low cost, and have low toxicity [2]. They are used extensively in aerospace structural applications. They have better mechanical properties and are more resistant to moisture than the polyesters and vinyl resins. Polyimide resins are employed in application involving high temperatures. On the contrary, vinylester resins are highly tough with low shrinkage and have better chemical resistance than polyester resins [4, 5]. Glass-polyester composites are already well established whereas if glass-vinylester composites are capable of exhibiting adequate mechanical properties, then the use of vinylesters in composites may be more fruitful. The use of bi-directional woven fabric is becoming popular because of their balanced properties in the fiber plane as well as their ease of handling during fabrication. Woven fabric offers rapid build up of thickness needed for thick ship hull structures.

Numerous researchers and/or authors have studied various aspects of tenacity (specific strength), both analytically and experimentally. S. Vijayarangan et. al. [6] have shown that by the introduction of fiber reinforced plastics (FRP), it is possible to reduce the weight of a machine element without any reduction in its load carrying capacity. Because of FRP's high elastic strain energy storage capacity and high specific strength compared with that of steels, mono-leaf FRP springs are being used in place of multi-leaf steel springs [7, 8]. The use of hybrid composites technology is also gaining importance. The merits of using composite materials in automotive drive shafts due to high specific strength and stiffness have been illustrated by R.P. Kumar Rompicharla et. al [9]. A. Agarwal et al. [10] have demonstrated that the carbon nanotube (CNT) reinforced metal matrix composites (MMC's) are projected for use in structural applications due to their high tenacity. Owing to the lower specific gravity of the natural fibers compared to the synthetic fibers, the strength per unit weight (specific strength) of the natural fiber reinforced composites is usually higher or close to that of synthetic fiber reinforced composites. This performance is afforded at low costs with an added advantage of biodegradability. Thus these composites can potentially replace glass-fiber composites in applications where the strength can be traded off for less weight, lower cost, ease of recyclability or energy recovery [11].

With perusal of the above, in this study, an attempt has been made to investigate the tenacity of glass fabric reinforced vinylester composites.

II. MATERIAL SYSTEM

A bisphenol–A epoxy-based vinylester resin, having a density of 1.06 ± 0.03 g/cm^3, was used as the matrix material in this study. 3 % cobalt octoate, 10 % N¸N-dimethyl aniline and 50 % methyl ethyl ketone peroxide were used as accelerator, promoter and catalyst respectively while fabricating the composite material panels. Plain woven E-glass fabric having an aerial weight of 360 g/cm^2 was used as the reinforcing material. The weight percentage (wt %) of the glass fabric in the composite panels was kept constant at 65 %. Composite panels of size 450 mm x 450 mm x 5 mm were fabricated by hand lay-up process. During fabrication, it was made sure to drive away the entrapped air from inside the stacked layers of uncured composites, to reduce voids thus produced. The panels were kept in a hydraulic press at a pressure of 0.42 MPa and were cured in a hot air oven at a temperature of 90^0 C for 45 minutes. The material composition of the fabricated glass fabric reinforced vinylester (GFV) composite panels is shown in Table 1.

Table 1. Material composition of fabricated composite panels

Material	**Vinylester (V) (wt %)**	**E-glass woven fabric (G) (wt %)**
GFV	35	65

III. EXPERIMENTATION

Tensile Test

Tensile test specimens were wire-cut from the fabricated composite panels. Tensile tests were conducted at room temperature, on specimens, to measure the ultimate tensile strength, σ_Y, as per ASTM D 638 [12] standard of testing. Specimens prepared from the cured composite panels were 175 mm long, 21 mm wide and 5 mm thick respectively. The test gauge length was 57 mm. Tests were conducted on a servo-hydraulically controlled computer-aided universal testing machine at a crosshead speed of 5 mm/min and the corresponding stress-strain curves were recorded. Tests were conducted on six specimens cut from the same panel. All specimens resulted in brittle fracture between the extreme points of the gauge length.

IV. RESULTS AND DISCUSSIONS

Density

The theoretical and measured densities of the composites with the corresponding values of volume fraction of voids are presented in Table 2. The theoretical density was determined using the 'Rule of Mixtures', and the actual density was determined using the Archimedes' Principle. It could be evinced that the density values of composites calculated theoretically are not in agreement with that of experimentation. The difference between the two densities was a measure of volume fraction of voids present in the composites which was calculated using Equation 1. Voids are a characteristic of composites fabricated especially by the hand lay-up process.

$$\text{Void fraction} = [(\rho_{ct} - \rho_{ce}) / \rho_{ct}] \quad (1)$$

Table 2. Density and void fraction of composites

Material	**Thickness of composite panels (mm)**	**Theoretical density (ρ_{ct}) (g/cm^3)**	**Measured density (ρ_{ce}) (g/cm^3)**	**Volume fraction of voids (%)**
GFV	4.92	1.6288	1.5920	2.67

Volume fraction of voids is a measure of percentage of voids present in materials. Voids significantly affect some of the mechanical properties and even the performance of composites during their use. Higher void contents may be detrimental to the performance of composites. The knowledge of void content was desirable for estimating the quality of the composites produced. The produced composite panels were visually inspected for surface defects and were found to be defect-free. It is understood that a good composite should have less voids for it to perform well. However, the presence of voids is unavoidable in composites made particularly by hand lay-up process.

Tensile Strength and Tenacity

Table 3. Tensile strength of composites

Material	**Tensile strength (σ_Y) (MPa)**
GFV	310

The tensile strength of composites was determined using the ASTM D 638 standard of testing. Data regarding the measured tenacity of the GFV composites has been presented in Table 3. The strength of a composite material depends largely on the interfacial adhesion between the matrix and the reinforcement. Also, tensile strength values may be directly attributed to depend on the presence of voids. Tenacity was calculated as the ratio of tensile strength and the measured density of composites. The average tenacity of the composites has been illustrated in Table 4.

Table 4. Tenacity of composites

Material	**Tenacity (σ_Y/ρ_{ce}) (kNm/kg)**
GFV	195

V. CONCLUSIONS

The tenacity of glass fabric reinforced vinylester composites was evaluated and has been reported in this manuscript. The values of the same are readily comparable with that of certain metals and alloys. Hence, use of these composites in structural applications may be justified. However it may be observed that tenacity is largely dependent on tensile strength, density and void content of a given material. The tenacity of composites constituting engineering materials like carbon, aramid fibers, epoxy, polyimide, polyester resins etc., could be investigated to evaluate their strength-based performance for their appropriate use..

REFERENCES

1) *Campbell F.C., 2010, "Structural Composite Materials", ASM International.*
2) *2001, "ASM Volume 21: Composites", ASM International.*
3) *Deepak Singla and Mediratta S. R., 2013, "Evaluation of Mechanical Properties of Al 7075-Fly Ash Composite Material", International Journal of Innovative Research in Science, Engineering and Technology, Vol.2, No.4.*
4) *Davies P. and Petton D., Mar. 1999, "An Experimental Study to Scale Effects in Marine Composites", Composites Part A: Applied Science and Manufacturing, Vol.30, No.3, pp. 267 - 275.*
5) *Hussain M., Nakahira A. and Niihara K., 1996, "Mechanical Property Improvement of Carbon Fiber Epoxy Composites by Al2O3 Filler Dispersion", Journal of Materials Science Letters, Vol.26, pp. 185-191.*
6) *Vijayarangan S., Ganesan N., 1994, "Static Stress Analysis of a Composite Bevel Gear using a Three-dimensional Finite Element Method", Computer Structures, Vol.5, No.6, pp. 771 - 783.*
7) *Tanabe K., Seino T. and Kajio Y., 1982, " Characteristics of Carbon/Glass Fiber Reinforced Plastic Leaf Spring", SAE 820403, pp. 1628 - 1634.*
8) *Yu W. J. and Kim H. C., "Double Tapered FRP Beam for Automobile Suspension Leaf Spring", Comp. Structure, 1998, pp. 279 - 300.*
9) *Kumar Rompicharla R. P. and Dr. Rambabu K., 2012, "Design and Optimization of Drive Shaft with Composite Materials", International Journal of Modern Engineering Research, Vol.2, No.5, pp. 3422 - 3428.*
10) *Agarwal A., Bakshi S. R. and Lahiri D., 2010, "Carbon nanotube reinforced metal matrix composites - a review", International Materials Reviews, Vol.55, No.1.*
11) *Ramani Narayan, Rajeev Karnani and Mohan Krishnan, 1997, "Biofiber-Reinforced Polypropylene Composites", Polymer Engineering And Science, Vol.37, No.2.*
12) *ASTM D 638 - 02a, 2008, "Standard Test Method for Tensile Properties of Plastics", ASTM International.*