International Journal of Recent Technology and Engineering (IJRTE)
ISSN: 2277-3878 (Online), Volume-8 Issue-4, November 2019

Experimentation with Flexural Properties of the Carbon Fiber Graphite Fiber and Glass Fiber Composites

BabuKiran B.V., Debjyoti Sahu, Aravinda Kumar M.S.

Abstract*: In the present work the flexural properties of selected composite plates are examined. The three point bending test happens to be widely acceptable method for the evaluation of flexural properties of the composite plates because of its simple geometry and structure. In this paper the influence of filler material and thickness of laminates under three point bending load on simply supported pins are reported for selected filler material combination. Filler materials used here are Glass fiber epoxy with silicon carbide, Graphite fiber epoxy with silicon carbide and Carbon fiber epoxy with silicon carbide. Investigation is carried out as per ASTM D790 standard. The mechanical properties such as flexural strength, flexural stiffness of the composite plates were investigated and reported. This work broadly points out that the flexural strength is dependent on the thickness of the laminates and amount of the filler material of the laminated composites. It was found that Carbon fiber composite shows the superior flexural strength with 6 wt% of SiC among the specimens under study.

Keywords*: Flexural strength, Silicon carbide composite, Three point bending.

I. INTRODUCTION

A composite plate is multi-layered lamination of resin consisting of different type of fiber as reinforcement and particles as filler material [1]. Because of the low thermal expansion, excellent strength and stiffness to the weight ratio, the application of composite material plays major role in the fabrication of transportation vehicles, Aerospace component, Marine and Aviation industry [2]. Thousands of researchers across the globe are involved in composite material research [3-5]. Cho *et al.* reported that the mechanical property of polymer matrix composite (PMC) depends upon the particle type, particle size and adhesion of the matrix interface and loading pattern [6].

Srivastava and Shembekar reported that the epoxy matrix toughness can be increased by adding fly ash as a filler material and it has been identified that fracture toughness composite specimens filled with fly ash as a filler material are independent of the initial crack length on the specimen [7]. But it depends on the fiber orientation and concluded that the toughness of the specimen can be improved by addition of fly ash as a filler materials to the fiber reinforced epoxy composites. Hartikain *et al.* reported the behaviour of glass fiber reinforced composites with $CaCO_3$ as a filler material [8]. They have shown that the stiffness of the specimen will increase with the addition of $CaCO_3$ as a filler material. Leonard *et al.* studied the fracture behaviour of Glass fiber reinforced polyester composite (GFRPC) materials and concluded that with the increase content of the fiber up to 60 wt% enable the increase in the fracture toughness of the specimens and critical energy rate of the matrix [9]. Naveed *et al.* experimented on the Carbon reinforced and nano-clay filled epoxy matrix composites and they studied the mechanical properties and fracture behaviour of inter-laminar structure [10]. They concluded that there was 60% improvement in the fracture toughness and flexural modulus by addition of 3 wt% of nano-clay.

However, Known *et al.* identified that varying the filler materials composition ratio might not affect the bending elastic modulus but bending strength and fracture toughness depends on particle composition [11]. They studied the effect of compounding two different size silica particle into bisphenol A-type epoxy matrix [11]. Lassila and Vallittu studied the influence of fiber position and polymerization on the strength of the composite [12]. Nakamura et al., studied the effect of silica particle size (6-42 µm) in composite and found smaller particle composite show higher flexural strength [13]. Lee and Soutis laminated composites with various stacking sequence with an open hole in the centre. The conclusions shows that the strength of the specimen with the higher thickness is found increased and the measured failure strength is predictable [14].

Paiva *et al.* conducted experiments on different matrix materials with carbon fiber as the reinforcement material [15]. They concluded that there was significant influence on the mechanical properties with respect to the matrix material used than the fabric arrangement type or carbon fiber arrangement type. The mechanical properties were improved due to the toughening of epoxy matrix and probably its interface with the reinforcement. Based on the literature survey it was identified that the combined constituents such as filler materials and fiber in thermosetting resin shows the major improvements in the mechanical properties of the material and in some cases improvement in the fracture toughness [16,17].

Manuscript published on November 30, 2019.
* Correspondence Author
Babukiran B.V., Department of Mechanical Engineering, SVCE Bangalore, India 562157
Debjyoti Sahu*, School of Mechanical Engineering, KIIT Bhubaneswar, India 751024
Aravinda Kumar M. S., Department of Mechanical Engineering, SVCE Bangalore, India 562157

The main aim of this study is to investigate the role of filler material on the glass fiber, graphite fiber and carbon fiber reinforced with polyester resin.

II. EXPERIMENTAL INVESTIGATION

2.1. Materials

Biwoven glass fiber, carbon fiber and graphite fiber are used as reinforcement material and Polyester resin is used as Matrix and filler material is silicon carbide (SiC, 240 Mesh) with the weight ratio of 3%, 6% and 9% in combination of two different thickness, silicon wax is used as releasing agent on mould.

2.2. Preparation of composite plate

Conventional hand lay-up technique is incorporated in laboratory to prepare the test specimens. The matrix material used here is epoxy resin, is mixed in 3:1 ratio with hardener at room temperature then the SiC powder is used as a filler material into polyester resin in different weight fractions of the mixture is mixed thoroughly using glass rod for 15 minutes. The surface of the mould is thoroughly cleaned first, then the releasing agent is applied, where the silicon wax is coated on the mould surface using cotton cloth. Then thick film of polyvinyl alcohol is applied over the wax surface using sponge.

The initial layer of the Bi-woven glass fiber fabric is laid on the clean surface and on the fabric resin is applied using brush and which spread uniformly throughout the surface of the glass fabric on this next layer of Bi-woven glass fiber fabric cloth is laid again resin is applied over it later to enhance the wetting the steel roller with teeth is passed over the layers of the fabric. By using spatula the resin is dubbed and tapped before spreading the another layer of the resin on the fabric this cycle should be repeated until the 10 layers (for 2 mm thickness specimens) and 16 layers for the 4 mm specimen thickness. The pressure should not be applied on these layers and which should be cured at 100^{o} C at oven temperature for 2 hrs.

Fig. 1: composite plate allowed for curing at room temperature.

Fig. 2: Vacuum Bagging Technique

Soon after curing process is completed the composite specimens are cut into required dimensional sizes as per the ASTM D790 standards using water jet machine and all the sharp edges of the specimens are removed using carborundum paper.

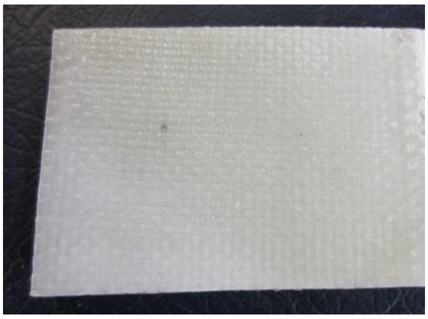


Fig. 3: Cured composite plate

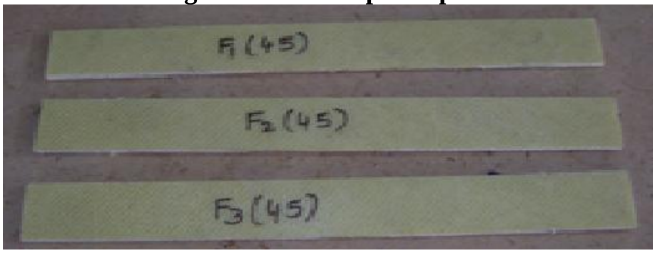


Fig. 4: Flexural strength test specimens

2.3. Nomenclature of specimen

Nomenclature of Carbon fiber composite specimen, Graphite fiber composite specimen and Glass fiber composite specimens (2mm thickness) reinforced with polyester resin with the filler material as SiC (3 wt%, 6 wt% and 9 wt% respectively) is shown in Table 1. Nomenclature of Carbon fiber composite specimen, Graphite fiber composite specimen and Glass fiber composite specimens (4mm thickness) reinforced with polyester resin with the filler material as SiC (3 wt%, 6 wt% and 9 wt% respectively) is shown in Table 2.

Table 2: Nomenclature of first set of specimens of expected thickness of 2 mm

Sl No.	SPECIMEN	Specimen Composition Expected Thickness =2mm
1	CAFP/03/02	Carbon fiber +3 wt% of SiC
2	CAFP/06/02	Carbon fiber +6 wt% of SiC
3	CAFP/09/02	Carbon fiber +9 wt% of SiC
4	GRFP/03/02	Graphite fiber +3 wt% of SiC
5	GRFP/06/02	Graphite fiber +6 wt% of SiC
6	GRFP/09/02	Graphite fiber +9 wt% of SiC
7	GLFP/03/02	Glass fiber +3 wt% of SiC
8	GLFP/06/02	Glass fiber +6 wt% of SiC
9	GLFP/09/02	Glass fiber +9 wt% of SiC

Table 2: Nomenclature of specimens of expected thickness of 4 mm

Sl No.	SPECIMEN	Specimen Composition Expected Thickness = 4mm
1	CAFP/03/04	Carbon fiber +3 wt% of SiC
2	CAFP/06/04	Carbon fiber +6 wt% of SiC
3	CAFP/09/04	Carbon fiber +9 wt% of SiC
4	GRFP/03/04	Graphite fiber +3 wt% of SiC
5	GRFP/06/04	Graphite fiber +6 wt% of SiC
6	GRFP/09/04	Graphite fiber +9 wt% of SiC
7	GLFP/03/04	Glass fiber +3 wt% of SiC

8	GLFP/06/04	Glass fiber +6 wt% of SiC
9	GLFP/09/04	Glass fiber +9 wt% of SiC

Actual dimension is marginally different form the expected composite plates and its necessary to use the actual dimension to calculate flexural properties. Measured dimensions of the each specimen of Glass fiber composite, Graphite fiber composite and carbon fiber composite specimens (2 mm thickness) reinforced with Polyester resin shown in table 3. Measured dimensions of the each specimen of Glass fiber composite, Graphite fiber composite and carbon fiber composite specimens (4 mm thickness) reinforced with Polyester resin shown in table 4.

Table 3: Measured dimensions of the each specimen of expected thickness of 2 mm

Sl No.	Specimen code	Measured length	Measured width	Measured thickness
1	CAFP/03/02	200.01	12.1	2.1
2	CAFP/06/02	200.2	12.3	2
3	CAFP/09/02	200.21	12.4	2.2
4	GRFP/03/02	200.15	12.02	2
5	GRFP/06/02	200.01	11.99	2.01
6	GRFP/09/02	200.12	12.05	2.04
7	GLFP/03/02	200.16	12.01	2.01
8	GLFP/06/02	200.07	12	2.02
9	GLFP/09/02	200.05	12.1	2.03

Table 4: Measured dimensions of the each specimen of expected thickness of 4 mm.

Sl No.	Specimen Code	Measured Length	Measured width	Measured thickness
1	CAFP/03/04	200.02	12.07	4.04
2	CAFP/06/04	200.01	12.07	4.01
3	CAFP/09/04	200	12.1	4.03
4	GRFP/03/04	200.05	11.99	4.02
5	GRFP/06/04	200.02	11.97	4.05
6	GRFP/09/04	199.98	12.04	4.04
7	GLFP/03/04	200.02	12.06	4.01
8	GLFP/06/04	200.01	12.04	4.02
9	GLFP/09/04	200.06	12.02	4.01

2.4. Experimental Setup

The testing Machine used in the current research work is Universal Testing Machine (Model PNP-01) manufactured by BISS Bangalore. It can be used as standalone machine or inter linked to remote computer and data analysis software. Specification is given in Table 5. The specimen is marked into 4 equal parts to ensure that the load pin of the UTM should act exactly at the specimen.

Table 5: **Specification of Universal Testing Machine and fixture**

Machine specification	
Actuator capacity:	10 kN
Stroke:	+/- 30 mm
Vertical day light:	570 mm
Horizontal day light:	40 mm
Power Supply/control	6kHz digital servo control
Rate of loading :	1mm/min
Fixture Details	
Capacity :	15 kN
Bending fixture	3 Point
Model:	B1-10-101

We know that flexural stress in case of a three-point bending test can be calculated by using the equation 1:

$$\sigma_{fs} = \frac{3F_f L}{2bt^2} \tag{1}$$

where F_f is the highest l ad (in Newton) at the point of failure, L is the distance betwe n the supports (in mm), b and t are the width and thickness of the specimen (in mm), respectively. Similarly, flexural modulus can be calculated using the equation 2:

$$E = \frac{mL^3}{4bt^3} \tag{2}$$

where 'm' is the slope of t e linear portion of load–deflection plot, b and t are the width and thickness of the specimen (in mm).

III. RESULT AND DISCUSSION

Current experimental study on the flexural properties and the results obtained from the present work is illustrated in the table 6, the table gives the complete details of flexural strength, flexural modulus (refer equation 2) and the maximum load of each specimen [4]. The results are obtained for thickness of 2 mm with polyester resin as matrix material and filler material is SiC constituting 3 wt %, 6 wt % and 9 wt % respectively. Load-deformation plot for 3 wt% SiC composite is shown in figure 5, 6 and 7 respectively. For other composition of SiC respective plot remains nearly identical.

Table 6: Flexural properties of composite specimens with expected thickness 2 mm

Sl No.	Specimen	Maximum Load, N	Deflection At Max Load, mm	Flexural Modulus, GPa	Flexural Strength, MPa
1	CAFP/03/02	594	12.3	32	512
2	CAFP/06/02	601	12.5	28	516
3	CAFP/09/02	622	11.6	29.7	510

4	GRFP/03/02	468	10.9	26.5	464
5	GRFP/06/02	499.5	10.2	27	468
6	GRFP/09/02	511	11	25.5	471
7	GLFP/03/02	104.4	10.2	24.3	432
8	GLFP/06/02	106.2	10.3	24.6	465
9	GLFP/09/02	110	9.6	25.1	472

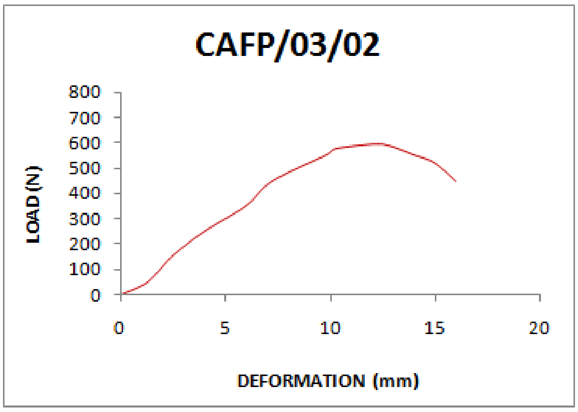


Fig. 5: Deformation curve of CAFP/03/02 specimen

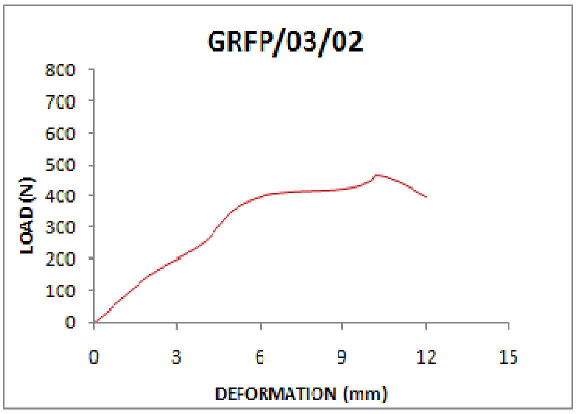


Fig. 6: Deformation curve of GRFP/03/02 specimen

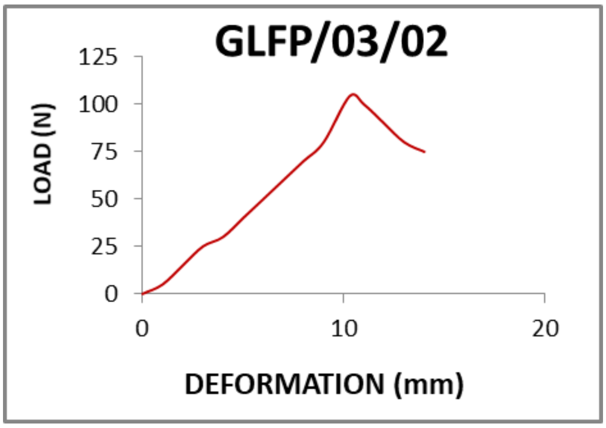


Fig. 7: Deformation curve of GLFP/03/02 specimen

It is clear from the table 6 the maximum value of flexural strength, 516 MPa is found for the Carbon fiber composite with 6 wt% of SiC but maximum flexural modulus 29.7 GPa is recorded for carbon fiber composite with 9 wt% SiC. With respect to reinforcement, carbon fiber composite shows better flexural modulus than glass fiber and graphite fiber composite. Now in carbon fiber composite with respect to the filler material content highest flexural strength is observed in case of 6% SiC content, may be because of optimum packing [18,19]. In case of Glass fiber and graphite fiber composite highest flexural strength observed, is almost identical, 471 MPa and 472 MPa respectively at 9 wt% SiC content but with respect to maximum load both can withstand are drastically apart (for graphite fiber 511 N and for glass fiber 110 N). Therefore carbon fiber composite plate may carry 20-25% more load than graphite fiber plate but its five to six time higher than glass fiber composite plate [20].

Table 7: Flexural properties of Carbon, Graphite and Glass fiber composites with expected thickness 4 mm

Sl No.	Specimen	Maximum Load, N	Deflection At Max Load, mm	Flexural Modulus, GPa	Flexural Strength, MPa
1	CAFP/03/04	589	10.6	34	560
2	CAFP/06/04	600	10.4	31	574
3	CAFP/09/04	612	10.2	32.6	512
4	GRFP/03/04	512	9.6	29.2	476
5	GRFP/06/04	514.2	9.4	30.2	482

6	GRFP/09/04	518	9.8	26.4	491
7	GLFP/03/04	124	8.86	26.8	445
8	GLFP/06/04	126.2	7.89	25.3	472
9	GLFP/09/04	126.8	8.2	25.8	481

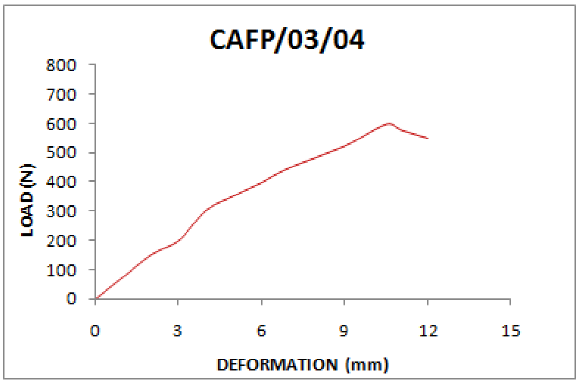


Fig. 8: Deformation curve of CAFP/03/04 specimen

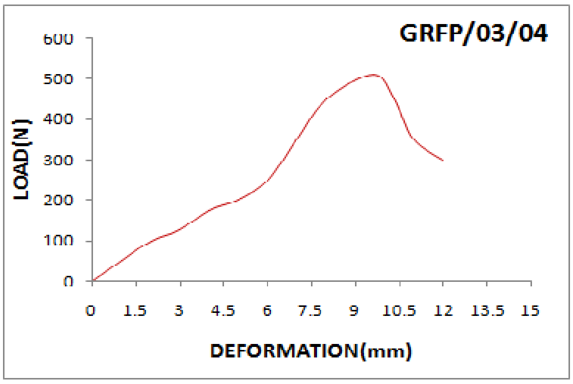


Fig. 9: Deformation curve of GRFP/03/04 specimen

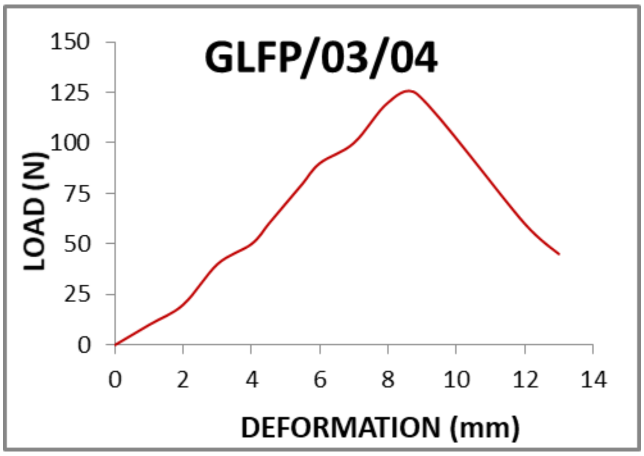


Fig. 10: Deformation curve of GLFP/03/04 specimen

Flexural properties are obtained for 4 mm thick specimen with SiC content of 3 wt %, 6 wt % and 9 wt % respectively following the similar procedure and presented in table 7. Load-deformation plot for 3 wt% SiC composite is shown in figure 8, 9 and 10 respectively. It has been observed that flexural strength and flexural modulus of carbon/polyester composites increased significantly in both the thickness 2mm and 4 mm respectively, when compared to graphite and glass fiber specimens [12]. However just doubling the thickness of the plate not necessarily double the strength of the plate. In case of graphite fiber composite and glass fiber composite 4 mm plate with 9 wt% SiC shows flexural strength of 491 MPa and 481 MPa respectively which are higher than other two compositions. However similar to 2 mm specimen carbon fiber composite with 6% SiC shows the highest flexural strength of 574 Mpa which is significantly high in this class of material [11]. It was found that Carbon fiber shows the superior load carrying capacity with 9 wt% of SiC and least value found in the case of glass fiber specimen with 3 wt% SiC. There is 10 to 12% increase in the flexural strength and flexural modulus but decrease in the deflection in the case of 4 mm specimens when compared to 2 mm specimens. It is found that as the weight percentage of filler material SiC increases, the load carrying capacity increases in case of all the composites.

1. Conclusions

In this experimental study the flexural properties of composite plates consisting of of glass fiber reinforced in polyester resin, graphite fiber reinforced in polyester resin and carbon fiber reinforced in polyester resin along with SiC in three different weight percentage is under consideration. Based on the analysis of the selected composites clarity on the role of filler material is obtained. The experimental study has also given the clarity about the role of the thickness on the specimens of the composite plates subjected to three point bending test in the laboratory. It was found that Carbon fiber shows the superior load carrying capacity with 9 wt% of SiC content and least load carrying capacity is found in case of glass fiber specimen with 3 wt% SiC content.

Acknowledgement:

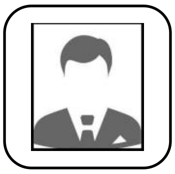
Authors are thankful to Dr. Shantharaja M. from UVCE Bengaluru for his technical support.

REFERENCES

1. Mijajlovikj M., Risteska S., Samakoski B., Stevanoska, Mathematical model on flexural properties of composite laminates, Int. J. Eng. Res. Technol., 2017, 6(6), 526-530.
2. Mazumdar S.K., Composites Manufacturing: Materials, Product and Process Engineering, New York, CRC Press, 2002.
3. Strong A.B., Fundamentals of Composites Manufacturing: Materials, Methods, and Application, Dearborn, Michigan, SME, 2008.
4. Asi D., Gun H., Effect of Al_2O_3 – 40 wt. % TiO_2 ceramic particle size and shape on flexural properties of glass fiber reinforced epoxy composites, Int. J. Eng. Res. Invention, 2019, 7(5), 56-63.
5. DeArmitt C., Rothon R., Particulate Fillers, Selection and Use in Polymer Composites, in R. Rothron (Ed.), Fillers for Polymer Applications, Switzerland, Springer, 2017, 3-27.
6. Cho J., Joshi M. S., Sun C. T., 2006, Effect of Inclusion size on Mechanical properties of polymer composites with micro and nano particles, Composites Science and Technology, 66(13), 1941-1952.
7. Srivastava V.K., Shembekar P. S., 1990, Tensile and fracture properties of Epoxy resin filled with Fly Ash Particle, Journal of Materials Science, 25, 3513-3516.

8. Harikainen J., Hine P., Szabo J.S., Lindner M., Harima T., Duckett R.A., Friedrich K., 2004, Polypropylene Hybrid composites reinforced with long glass fibers and particulate filler, Composites science and Technology, 65, pp257-267.
9. Leonard L. W.H., Wong K. J., Low K.O., 2009, Fracture Behaviour of Glass fiber reinforced polyester composite, Journal of materials: Design and Applications, 83, 223-228. (doi.org/10.1243/14644207JMDA224)
10. Naveed A. S., Woo, R.S.C., Kim J.K., Leung C.C.K., Munir A., 2007, Mode I Interlaminar Fracture Behaviour and Mechanical properties of CFRP's with Nanoclay filled Epoxy Matrix, Composites part A: Applied Science and Manufacturing, 38(2), 449-456
11. Kown S.C., Adachi T., Araki W., Yamaji A., 2008, Effect of Composing Particles of two sizes on Mechanical Properties of Spherical Silica Particulate Reinforced Epoxy Composites, Applied Science and Manufacturing, 39(4), 740-746
12. Lassila L.V., Vallittu P. K., 2004, The effect of fiber position & Polymerization condition on the flexural properties of fiber reinforced composite, J Contemp Dent Pract., 5(2), 14-26.
13. Nakamura Y., Yamaguchi M. Okubu M., Matsumoto T., 1992, Effect of particle size on Mechanical and impact properties of Epoxy resin filled with Spherical silica, Journal of applied polymer science, 45(7), 1281-1289.
14. Lee J., Soutis C., 2005, Thickness effect on the compressive strength of T800/924C carbon fiber-epoxy laminates, Composite part A: Applied science and manufacturing, 36 (2), 213-227.
15. Paiva J. M. F., Mayer S., Rezende M.C., 2005, Evaluation of mechanical properties of four different carbon/epoxy composites used in aeronautical Field, Material Research, 8(1), 91-97.
16. Davies I. J., Hamada H., 2001, Flexural properties of a hybrid polymer matrix composite containing carbon and silicon carbide fibers, Advanced Composite Materials, 10(1), 77-96.
17. Reis P. N. B., Ferreira J. A. M., Antunes F. V., Costa J. D. M., 2007, Flexural behavior of hybrid laminated composites, Composites: Part A: Applied science and manufacturing, 38(6), 1612–1620.
18. Asi O., Mechanical Properties of Glass-Fiber Reinforced Epoxy Composites Filled with Al_2O_3 Particles, Journal of Reinforced Plastics and Composites, 28(23), 2009, 2861-2867.
19. Fu S.Y., Feng X.Q., Lauke B., Mai Y.W., Effects of particle size, particle/matrix interface adhesion and particle loading on mechanical properties of particulate–polymer composites, Composites Part B: Engineering, 39(6), 2008, 933-961.
20. Christopher W., Joachim G., Go¨ran F., Elvis C., Comparison of mechanical properties of glass fiber/vinyl ester and carbon fiber/vinyl ester composites, Composites: Part B, 2005, 36, 417–426.

AUTHORS PROFILE



Babukiran B. V. obtained his PhD from University Visvesvaraya College of Engineering Bengaluru and currently serving as a faculty of Mechanical Engineering, Sri Venketswar College of Engineering Bengaluru.

Debjyoti Sahu obtained his PhD from IIT Guwahati and currently serving as a faculty at School of Mechanical Engineering, Kalinga Institute of Industrial technology, Bhubaneswar. He has 11 international publications to his credit.

Aravinda Kumar M. S. obtained his PhD from IIT Guwahati and currently serving as faculty of Mechanical Engineering, Sri Venketswar College of Engineering Bengaluru. He has 10 international publications to hois credit.