IOSR Journal of Polymer and Textile Engineering (IOSR-JPTE)
e-ISSN: 2348-019X, p-ISSN: 2348-0181, Volume 6, Issue 1 (Jan. - Feb. 2019), PP 52-58
www.iosrjournals.org

Mechanical Behaviour of Aluminium Powder ModifiedCarbon/Basalt Reinforced Vinyl EsterComposites

M.S. Santhosh[1*], T. Thangavel[2], R. Sasikumar[1],M. Vignesh[3], M. Vishnu[4], M. Vinu[5], V.T. Vinvath Ragav[6]

[1] Selvam Composite Materials Research Laboratory, Selvam College of Technology, Tamilnadu, India*
[1] Selvam College of Technology, Namakkal, Tamilnadu, India
[2 – 6] Department of Mechanical Engineering, Paavai Engineering College, Tamilnadu, India
Corresponding Author: M.S. Santhosh

Abstract –*Polymer matrix composites (PMCs) deserves a significant role in the new age engineering materials due to its unique properties like formability, room temperature processing, and economic nature. Main aspire of this proposed work is to investigate mechanical behaviour (flexural and tensile) of unfilled and 5, 10 Wt. % aluminium powder filled carbon/basalt hybrid composites produced via open mould followed by a compression process. Results collected from the experiments reveals that the inclusion of nano-aluminum powder greatly influences the mechanical properties of carbon/basalt/vinyl ester composites. Void fraction and densities intensified reasonably by the annexation of Al powder while the tensile strength shows a steady decrease. Carbon/basalt with 5 wt. % Al possess better properties whereas 10 wt. % Al reinforcement shows better tensile modulus. The Al included fiber configurations were compared with unreinforced composite laminate to grasp the optimum filler reinforcement percentage. SEM images of the fractured surfaces also analyzed for a better understanding of failure conditions.*

Index Terms: *Mechanical behaviour, Carbon, Basalt, Aluminium powder, Open mould, Reinforcement, Vinyl ester, Polymer matrix composite.*

Date of Submission: 22-02-2019 Date of acceptance: 08-03-2019

I. Introduction

Composites made with basalt and carbon fiber is very prominent in the various engineering industries such as commercial vehicle components, defence, and aerospace industries because of its peculiar properties like strength to weight ratio, flexibility in design and formability [1]. As a reinforcement uni and bidirectional carbon, basalt fiber fabric plays momentous role in the replacement of various conventional metal counterparts due to its wider availability and room temperature processing methods [2]. Santhosh et al fabricated kevlar/E-Glass and basalt/E-Glass reinforced hybrid epoxy matrix composites and revealed that higher volume of basalt improves the flexural behaviour whereas higher kevlar reinforcement improves impact energy absorption [3]. Nadia et alprepared the epoxy composites with different filler percentage of Al_2O_3 and SiO_2 (0.5%, 1%, 1.5%, 2%, 2.5%, and 3%) nano particles to interrogate its impact and mechanical properties and stated that Al_2O_3/SiCaddition lowers the wear resistance and improves the hardness and impact energy absorption natures fairly (Up to 30%) [4].

Raju et al produced alumina filled glass fiber epoxy composites with 0, 5, 7.5 and 10 wt. % to test its wear, mechanical properties and proposed that up to 10% of Alumina inclusion significantly improves the tensile modulus and wear resistance. More than 10 % of reinforcement shows a gradual decrease in wear resistance [5]. Yusriah studied mechanical response of phenolic hollow microspheres (PHMS) and calcium carbonate (CC) filled (1%, 3%, and 5% by weight) vinyl ester composites and stated that CC and PHMS inclusion greatly improves specific flexural and impact strengths [6]. Ali Reza included multiwall carbon nanotube into silicone elastomer and reported that MWCNT reasonably enhances the mechanical and flexural properties of rubber matrix [7]. Fatigue and thermal conductivity of the epoxy matrix aluminium particulate composites were studied by Senthil kumar et al. They reported that the resultant composites possess better service temperature and mouldability [8].

Rout et al developed hybrid multiphase epoxy composites filled with rice husk particles to analyse mechanical, wear and corrosion responses. They revealed that the inclusion of rice husk steadily improves the mechanical and wear behaviour of hybrid composites [9]. Santhosh fabricated hybrid Al reinforced GLARE composites and analysed its impact and flexural behaviour. He stated that up to 30% of Al reinforcement greatly improved flexural and impact resistance [10]. Reinforcement of nano aluminum particles or fillers with the polymer matrix fiber hybrids remarkably improves mechanical, thermal and chemical properties of hybrid composites [11, 12, and 13]. In general most of the researchers have attempted different filler materials such as ceramics, natural fillers and metal particles with different proportions. But still, there is a growing opportunity to reinforce Al particles with hybrid basalt/carbon fiber vinyl ester composites. This proposed work investigates the tensile and flexural behaviour of carbon/basalt/vinyl ester hybrid configurations, fabricated through compression moulding. The microstructure of the fractured surface also analysed by using scanning electron microscope (SEM).

II. Experimental Work

2.1 Materials

Vinyl ester resin with low viscosity (350 centipoises) level (Derakane momentum 411–350) with 970 g/mol, molecular weight, density of 1.045 g/cm3 (55 wt. % vinyl ester and 45 wt. % styrene monomers) is used as a matrix system. Aluminium fine grade particles with an average size of 40 microns (98.90 % Purity) is used as filler material. Basalt and carbon bidirectional fabrics were used as a reinforcement. Figure 1 (a) and (b) represents the basalt and carbon fabrics. Similarly, figure 1 (c) and (d) depicts aluminium particles and its SEM image respectively.

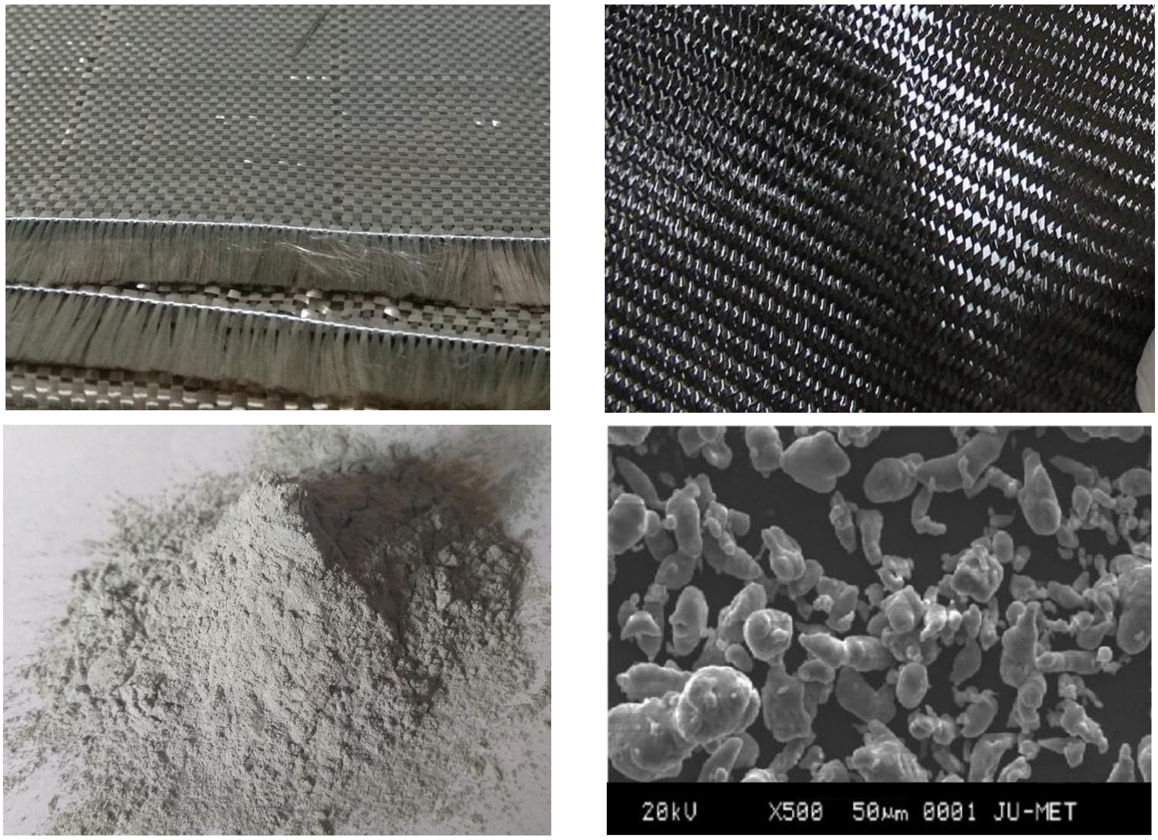

Fig. 1 (a) Basalt Fabric, (b) Carbon Fabric, (c)Aluminium Powder, (d) SEM Image of Al Particle

Some details of constituent reinforcement and filler materials (As mentioned by a supplier) were depicted in table 1. The matrix materials were supplied by Hindustan composites (Maharashtra), reinforcement and Al fillers were supplied by CF composites (Mumbai).

Table 1 Properties of Filler and Reinforcements

Property	Basalt	Carbon	Aluminium
Tensile strength Gpa	4.4	3.9	$47x10^{-3}$
Elastic modules Gpa	110	105	80
Poision's ratio	0.2	0.22	0.33

2.2 Composite Fabrication

The proposed composites with various filler ratios were fabricated by the open-compression moulding process, which is well known for room temperature polymer processing with low pores and superior quality. Figure 2 shows the compression moulding setup.

Fig. 2 Compression Mould Setup

The Vinyl eater polymer matrix is maintained 30 wt. % throughout all hybrid configurations. Composite laminates with the dimension of 30 cm x 30 cm x 6mm were prepared. Table 2 depicts the composition of various configurations.

Table 2 Compositions of Hybrid Composites

Sample Code	Composition
B	Vinyl ester (30 wt. %) + Basalt (35 wt. %) + Carbon (35 wt. %)
C1	Vinyl ester (30 wt. %) + Basalt (35 wt. %) + Carbon (30 wt. %) + Al (5 wt. %)
C2	Vinyl ester (30 wt. %) + Basalt (30 wt. %) + Carbon (30 wt. %) + Al (10 wt. %)

2.3 Specimen Preparation and Testing

Fabricated unfilled basalt/carbon and Al powder filled composite configurations were cured in the room temperature under a compression load and prepared as samples as per ASTM standards for tensile, flexural and impact tests by using water jet machining process. Table 3 shows the sample specimen dimensions prepared for various testing's. Three specimens from each configuration were prepared in order to get the accurate values.

Table 3 Test Sample Dimensions

S.No	Test Name	Sample Dimension
1	Density	30 mm× 12 mm× 6 mm
2	Micro hardness	16 mm× 12 mm× 6 mm
3	Tensile strength (ASTM D3039-07)	150 mm× 12 mm× 6 mm
4	Flexural test (ASTM D790-10)	60 mm× 12 mm× 6 mm

III. Results and Discussions

3.1 Density and void fraction

Most of the weight sensitive engineering applications consider density as a prime characteristic. A density of the materials varies generally depends upon the proportion of matrix and reinforcement materials. Due to the presence of pores and voids, there is always a difference between theoretical and actual densities. The theoretical density of the composites was calculated by the following equation.Similarly, actual densities were calculated by normal water immersion test. These difference of densities for various hybrid composites were depicted in table 4.

$$\rho_{ct} = \frac{1}{\left(\frac{W_f}{\rho_f}\right)+\left(\frac{W_m}{\rho_m}\right)+\left(\frac{W_p}{\rho_p}\right)}$$

Where,
W – Weight fraction, ρ – Density, f – Fiber, m – Matrix.

Table 4 Measured and Theoretical Densities of Composites with Void Fractions

Sample Code	Composition	Measured Density (gm/cc)	Theoretical Density (gm/cc)	Volume Fraction of voids (%)
B	Vinyl ester (30 wt. %) + Basalt (35 wt. %) + Carbon (35 wt. %)	1.7	1.79	1.23
C1	Vinyl ester (30 wt. %) + Basalt (35 wt. %) + Carbon (30 wt. %) + Al (5 wt. %)	1.84	1.90	1.42
C2	Vinyl ester (30 wt. %) + Basalt (30 wt. %) + Carbon (30 wt. %) + + Al (10 wt. %)	1.91	2.03	1.65

As expected the theoretical and actual densities were different for various compositions of hybrid composites. From table 5 it is clearly understood that the inclusion of Al powder influences the density of the composites.

3.2 Micro-HardnessTest

Hardness generally referred to as ability of a material to resist deformation, scratching or indentation. In this proposed work Vickers hardness test is carried out to determine the hardness of the prepared samples. The micro hardness test results of various test samples were shown in figure 3.

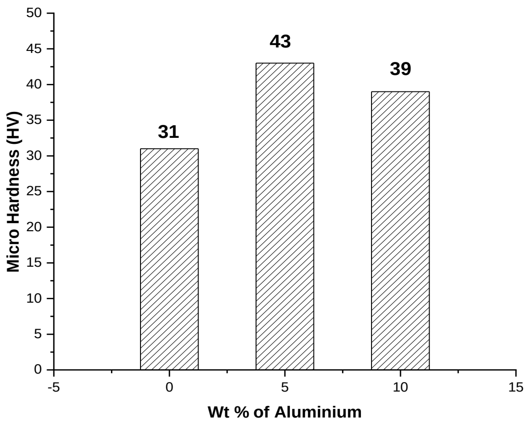

Fig. 3 Micro Hardness Test Results

Test results indicate that the inclusion of aluminium powder up to 5 wt. % hardness gradually improves and shrinks when Al inclusion exceeds 10 wt. %. It is noted from the results, for getting better hardness the Al filler inclusion should be limited within 10 wt. %.

3.3 Tensile Test

The tensile results of basalt/carbon hybrid configurations with and without Al fillers are shown in figure 4 and 5. From the results it is found that there is a gradual shrinkage in tensile strength with the inclusion of Al powder.

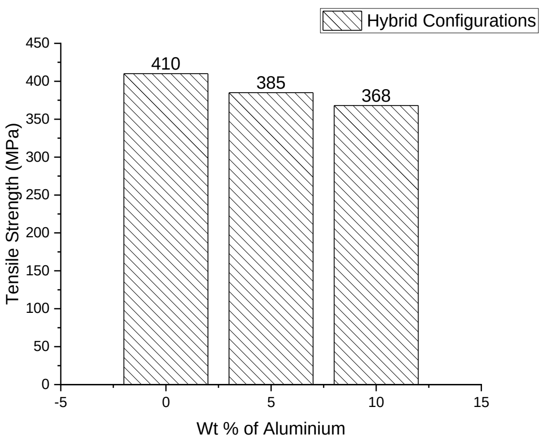

Fig. 4 Tensile Strength of Hybrid Configurations

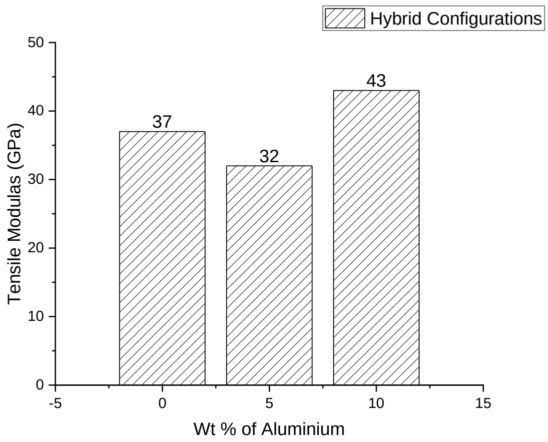

Fig. 5 Tensile Modulus of Hybrid Configurations

The unfilled basalt/carbon laminates have a tensile strength of 410 MPa and it gradually reduces to 385 MPa and 368 MPa with the 5 % and 10% weight proportion of aluminium powder respectively. It is observed that the reduction of strength due to the average bonding between filler and reinforcement, the formation of stress concentration zones. Figure 5 indicates the tensile modulus of the prepared composite samples. Moduli of the composites improve with the addition of Al filler. It is noted that 10 wt. % of filler addition improves moduli up to 30 % and 10 wt. % Al is an optimum hybrid structure.

3.4 Flexural Test

Composites of structural applications are prone to fail under bending load, it is essential to produce composites with higher flexural strength for specific engineering needs. Flexural behaviour of prepared hybrid composites obtained from three-point bending flexural test has been shown in figure 6. From the experimental results it is observed that 5 wt. % Al powder filled configuration possess better flexural strength than 10 % Al filler.

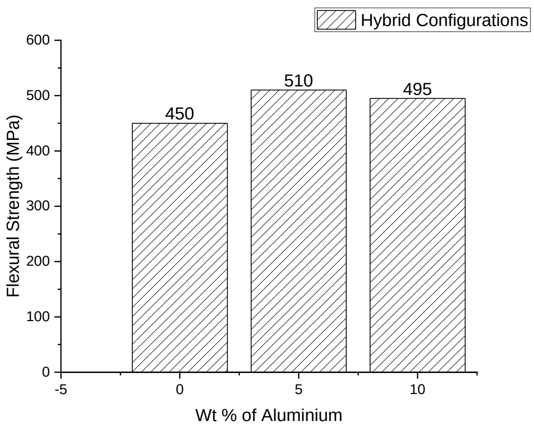

Fig. 6 Flexural Strength of Hybrid Configurations

3.5 Scanning Electron Microscopy Analysis

The samples with the dimensions of 5 mm x 5 mm (Cross-section) were cut from the tensile test fractured surfaces and coated with the gold to achieve better electrical conductivity. TESCAN VEGA3 machine with 5 nm resolution is used to carry out SEM analysis. The SEM images of the cross-sectional surface with different magnification rations were shown in figure 7. Matrix phase, dispersed phase, fillers, and pores are clearly indicated for a better understanding of impact due to load. It shows that a higher ratio of filler inclusion may result in the poor matrix reinforcement bonding, higher deformation, poor load carrying capacity and delamination.

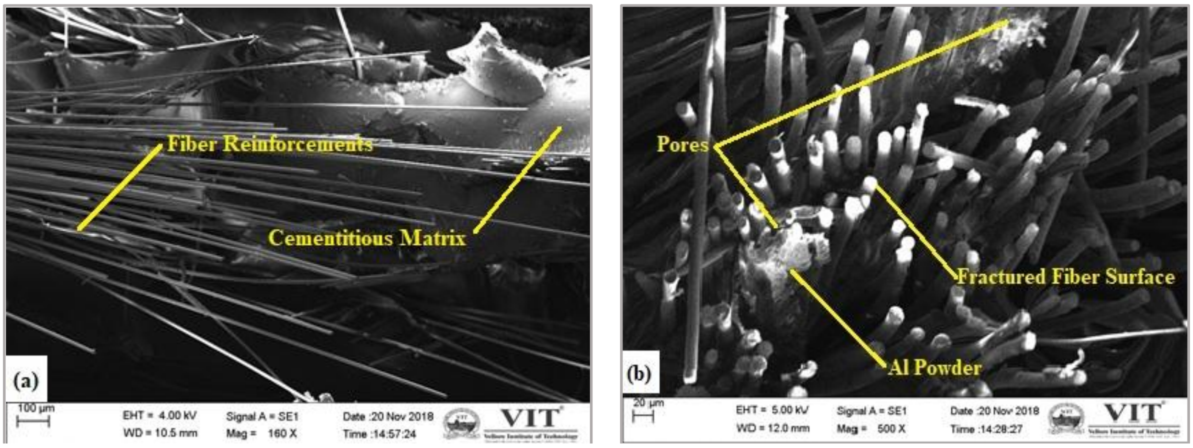

Fig. 7 SEM Images of Fractured Surface

IV. Conclusion

In this proposed study basalt/carbon reinforced vinyl ester matrix composites with different filler (Aluminium powder) percentages were fabricated by book press compression moulding process and its mechanical properties along with microstructure analysis also done to predict the behaviour of hybrid composite configurations. The experimental results reveals the following main conclusions.

1. Improvement of aluminium percentage more than 10 wt. % may results in higher rate of void fractions and pores in the resultant composites.
2. 5 wt. % Al included composites possess better flexural and micro hardness. Further addition of Al powder gradually shrinks the flexural and hardness properties.
3. A gradual decrease in tensile strength occurs with the increase of Al powder weight fraction.
4. In order to achieve ultimate mechanical properties 10 wt. % of Al powder inclusion is preferable.

Acknowledgement

We thank the management of selvam college of technology, for their deliberate support to carry out this collaborative research in selvam composite materials research laboratory (SCMRL).

References

[1]. S.K. Bhattacharya, *Metal filled polymers, Vol. 11, CRC Press,* 1986.

[2]. D. Hull, T.W. Clyne, An introduction to composite materials, *Cambridge university press,* 1996.

[3]. M.S. Santhosh, R. Sasikumar, L. Natrayan, M. Senthil Kumar, V. Elango and M. Vanmathi. Investigation of mechanical and electrical properties of Kevlar/E-glass and Basalt/E-glass reinforced hybrid composites, *International Journal of Mechanical and Production Engineering Research and Development, 2018, Vol. 8(3), 591-598.*

[4]. A. Nadia et al., Effect of Al_2O_3 and SiO_2 nanoparticle on wear, hardness and impact behaviour of epoxy composites, *Chemistry and Materials Research. Vol. 7,* 2015, 34-39.

[5]. B.R. Raju et al., "Investigations on mechanical and tribological behaviour of particulate filled glass fabric reinforced epoxy composites, *Journal of Minerals and Materials Characterization and Engineering. Vol. 4,* 2013, 160-167.

[6]. L. Yusriah, M. Mariatti, A. Abu Bakar, "Mechanical properties of particulate filler/woven glass fabric filled vinyl ester composites", *Journal of Vinyl and Additive Technology. Vol. 16 (1),* 2010, 98-104.

[7]. Alireza Golshahr, Elango Natarajan, M.S. Santhosh, R. Sasikumar, S. Ramesh, Rajkumar Durairaj, "Multiwall Carbon Nanotube Reinforced Silicone for Aerospace Applications", *International Journal of Mechanical and Production Engineering Research and Development Vol. 8 (4),* 2018, 743-752.

[8]. N. Senthilkumar, K. Kalaichelvan, K. Elangovan, "Mechanical behaviour of aluminium Particulate epoxy composite – Experimental study and numerical simulation", *International Journal of Mechanical and Materials Engineering. Vol. 7,* 2012, 214-221.

[9]. A.K Rout, A. Satapathy, "Study on mechanical and tribo-performance of rice-husk filled glass–epoxy hybrid composites", *Materials & Design. Vol. 41,* 2012, 131-141.

[10]. Santhosh M. S, Sasikumar R. "Influences of Aluminium / E-Glass volume fraction on flexural and impact behaviour of GLARE hybrid composites", *Journal of Engineering Sciences, Vol. 6 (1),* 2019. DOI: 10.21272/jes.2019.6 (1).c2.

[11]. M. N. F. Pargi, P. L. Teh, S. Hussiensyah, C. K. Yeoh, and S. Abd Ghani, "Recycled-copper-filled epoxy composites: the effect of mixed particle size," *International Journal of Mechanical and Materials Engineering, Vol. 10 (1),* 2015, pp. 3.

[12]. S. A. Bello, J. O. Agunsoye, J. A. Adebisi, and B. H. Suleiman, "Effects of aluminium particles on mechanical and morphological properties of epoxy nanocomposites," *Acta Periodica Technological, vol. 48,* 2017, pp. 25-38.

[13]. Manjunatha CM, Taylor AC, Kinloch AJ, Springer S. The tensile fatigue behaviour of a silica nanoparticle-modified glass fibre reinforced epoxy composite. *Composites Science and Technology, 70(1),* 2010, 193-9.

[14]. Kabir A and Hoa SV. "Improvement of vibration damping and flexural fatigue property incorporating nanoclay into glass/epoxy composite". In: Jerzy Komorowski (ed.) ICAF 2011 Structural Integrity: Influence of Efficiency and Green Imperatives. *Netherlands: Springer,* 2011, pp.155–165.

[15]. Gupta S, Raju Mantena P, Al-Ostaz A. "Dynamic mechanical and impact property correlation of nanoclay and graphite platelet reinforced vinyl ester nanocomposites". *Journal of Reinforced Plastics and Composites. Vol. 29(13),* 2010, 2037-47.
[16]. M.S. Santhosh, R. Sasikumar, T. Thangavel et al. "Fabrication and Characterization of Basalt/Kevlar/Aluminium Fiber Metal Laminates for Automobile Applications", *International Journal of Materials Science, 2019, Vol. 14 (1),* 1-9.
[17]. R.D. Hemanth, M. Senthil Kumar, Ajith Gopinath and L. Natrayan, "Evaluation of Mechanical Properties of E-Glass and Coconut Fiber Reinforced with Polyester and Epoxy Resin Matrices", *International Journal of Mechanical and Production Engineering Research and Development, vol. 7, Issue 5*, 13-20, 2017.
[18]. Wang Z, Huang X, Bai L, Du R, Liu Y, Zhang Y, Zaho G. Effect of micro-Al2O3 contents on mechanical property of carbon fiber reinforced epoxy matrix composites. *Compos Part B, Eng. Vol. 91,* 2016, 392–98.
[19]. Kumar A, Roy S. Characterization of mixed mode fracture properties of nanographene reinforced epoxy and Mode I delamination of its carbon fiber composite. *Compos Part B, Eng. 114,* 2017, 173-87.
[20]. Alsaadi M, Erkliğ A. Effect of perlite particle contents on delamination toughness of Sglass fiber reinforced epoxy matrix composites*. Composites Part B Eng, 141,* 2018, 182-190.
[21]. Zabihi O, Ahmadi M, Nikafshar S, Preyeswary KC, Naebe M. A technical review on epoxy-clay nanocomposites: Structure, properties, and their applications in fiber reinforced composites. *Compos Part B Eng, 135*, 2017, 1-24.
[22]. Dorigato A, Pegoretti A. Flexural and impact behaviour of carbon/basalt fibers hybrid laminates. *Journal of Composite Materials. Vol. 48(9),* 2014, 1121-30.
[23]. Alok Satapathy and Ganguluri Kranthi, " Mechanical Characterisation of Glass Epoxy Hybrid Composites Reinforced with SiC Derived from Bamboo Leaves",*Proceedings of Recent advances in fluid and solid mechanics*, 2010, 27-28 Feb 2010, Rourkela.