International Journal of Recent Technology and Engineering (IJRTE)
ISSN: 2277-3878, Volume-8 Issue-3, September 2019

Effect of Cryogenic Treatment on Bisphenol Based Polymer Composite on Mechanical Properties

Shashi Kumar M.E., Mohan Kumar S., Ravi Kumar V.

Abstract: ***Presently there are lot of materials that can be used in the fabrication of any item, so choosing a material is a major criteria. So the materials are chosen depending on the properties desired by the resulting item. The composite materials have better properties when compared with its individual components, metals and ceramics. The overall appeal of the product depends mainly on its durability, aesthetics and its final cost. Composite materials are cost effective and significantly satisfy the needs of the clients. By utilizing composite materials we can obtain high strength to weight ratio at a relatively economical cost. Moreover, they can be produced easily by basic part forming. Hybrid polymer composites have been studied of late which improves a specific property of the composite that is under question. Here a hybrid composite made of laminate of Nomex and HS glass sheets with varying percentage (1% - 2.5 %) of bisphenol dispersed in resin is prepared. The same samples were subjected to cryogenic treatment (24 hrs and 72 hrs). The results of tensile strength, flexural strength and hardness were compared for all the specimens 24 hrs cryogenic, 72hrs cryogenic and non-treated specimens. The results showed that the hardness of the cryogenic treated bisphenol based PMCs has increased with the weight percentage of Bisphenol indicating the fact that the laminates can withstand more loads at subzero temperatures The increase observed was about 3 – 4 % more in terms of BHN number. At the same time the tensile and flexural strengths have considerably reduced after treating the PMC cryogenically as the laminates becomes more brittle when treated. The tensile strength increased by about 10% approximately and the flexural strength reduced by 300%.***

Keywords: ***cryogenic treatment, Bisphenol, Polymer Composite, Mechanical Properties.***

Manuscript published on 30 September 2019
* Correspondence Author
Shashi kumar M.E.*,Department of Mechanical Engineering, Amrita School of Engineering, Bengaluru, Amrita Vishwa Vidyapeetham, India . Email: me_shashikumar@blr.amrita.edu
Mohan Kumar S., Department of Mechanical Engineering, Amrita School of Engineering, Bengaluru, Amrita Vishwa Vidyapeetham, India . Email: s_mohankumar@blr.amrita.edu
Ravi Kumar V., Department of Mechanical Engineering, Amrita School of Engineering, Bengaluru, Amrita Vishwa Vidyapeetham, India . Email: v_ravikmr@blr.amrita.edu

I. INTRODUCTION

Composite materials extend the design horizons for all eng ineering fields. The likelihood of getting new answers to the troublesome designing issues is offered by this group of combined materials. By inundating fibers in a matrix of light weight, low strength material, a stronger material can be acquired, in light of the fact that the fibers stop the spread of the crack in the lattice. A polymer with deficient quality or firmness could be strengthened with these new fibres to create a more grounded, stiffer and lighter weight product. For the most economical and productive output, use of material with increased property combination is the present day demand. Composites have a mixture of characteristics including very high strength-to-weight, stiffness-to-weight ratio, extraordinary fatigue resistance, enhanced wear resistance, enhanced corrosion resistance, higher resistance to thermal expansion, outstanding optical and thermal characteristics and good fracture toughness. Multitude amount of research on PMCs embedded with graphene have been carried out globally. The polymer composites have been laminated by the adding varied percentages of Graphene. These composites showed changes in characteristics viz. tensile strength, hardness value and flexural strength with weight proportion differences ranging from 1- 3 % of graphene nanoparticles. The introduction of Graphene particles and EGlass fiber to the laminate shows enhanced mechanical characteristics in a laminate [1,3]. Hybrid polymer composites by varying the stacking orders in an average 55 % polymer matrix content, shows increased hardness with high number of layers of High silica (HS) fibers. Addition of Nomex T410 and High silica glass fiber increased the flexural strength[20]. These laminates have proven to be more chemical stability and also possess good temperature stability up to 300°C [2,4,8]. E-Glass fiber reinforced epoxy composites shows better mechanical properties in terms of tensile strength [6,23,24]. Bisphenol based polymer matrix composites can be used for elevated temperature applications [5,9]. Several coating / additives techniques have been employed on MMC to enhance their mechanical, Tribological and corrosion characteristics [18,19,21,25,27]. Similarly addition of additives into PMCs are being researched extensively for improved characteristics.

Polymer nanocomposites with Graphene additives are highly promising research interest mainly arising from the interface between graphene particles and polymer. Graphene offers good bonding at the interface with the polymer [22] and hence provided good mechanical and electrical property enhancements [7,16]]. Materials with Graphene additives improves thermal conductivity showing good barrier characteristics[14,15,17].

This is combined with their low price and large-scale production potential [10]. It was noted that the laminate with nanocarbon has shown higher hardness and greater tensile strength [11,13]. Increase in functionalized graphene with Nomex fibre in a polymer increases tribological properties [12]. The shift in wear rate, however, happened because of the shift in Nomex's layer. Carbon –Nomex composites in line with aluminum produce lower wear rate and increased strength value. This composite is therefore suitable for applications of light weight in sectors such as aerospace and related areas. Though products based on phenol-formaldehyde resins have been widely accepted in many applications, they have their own shortcomings in order to improve their performance; studies continue to be made concerning replacement of the phenolic as well as the aldehyde component of the risen. The present paper is based on preliminary work undertaken to develop a new resin based on Bisphenol-A furfural. Theoretical considerations indicated that such a resin should have highly desirable properties. Hence, studies are carried out to optimize the condition for resin formation. Preliminary evaluations of the product in molding the powders have indicate great potentialities for the resin, Because of its superior thermal, mechanical, and chemical properties. The probable industrial applications of this resin have been indicated. [6] This article reviews latest progress in grapheme enhancement and the manufacture of polymer nanocomposites based on graphene. Grapheme has recently drawn scholarly and industrial interest because at very small filler content it can yield a drastic improvement in characteristics. The functionalized grapheme / grapheme oxide in the manufacture of nanocomposites with various polymer are investigated. Many organic polymers are being extensively used in variety of techniques to manufacture grapheme-filled polymer nanocomposites. In the case of modified polymer nanocomposites based on Graphene, it is possible to achieve the percolation threshold at a very low filler load. Here, together with thorough examples from scientific literature, the structure, preparation and characteristics of polymer / grapheme nanocomposites are discussed in particular.[7]

II. LAMINATE PREPARATION

Fig. 1 shows the fabrication of laminates through Hand Layup process. The required number of Nomex and HS glass sheets (7 sheets each for one laminate) is cut into size of 300mm×300mm. Now a glass of size 300mm×300mm is kept as a base and on top of which mould releasing agent is applied. The required amount of hardener is added to the prepared mixture of resin and graphene. The mixture thus obtained is then smeared in one direction using blades. Alternate layers of Nomex and HS Glass are stacked together after applying the resin- hardener-graphene mixture at the interface of two consecutive layers. To this stacked layers, a final layer of plastic sheet is placed followed by glass which is pre-applied with mould releasing agent. After stacking the laminates to a definite thickness, the laminate is applied with a constant pressure to vent out the air entrapped inside. It is then cured at room temperature for 48 hours [26]. Cured samples are taken out by breaking the outermost layers of glass.

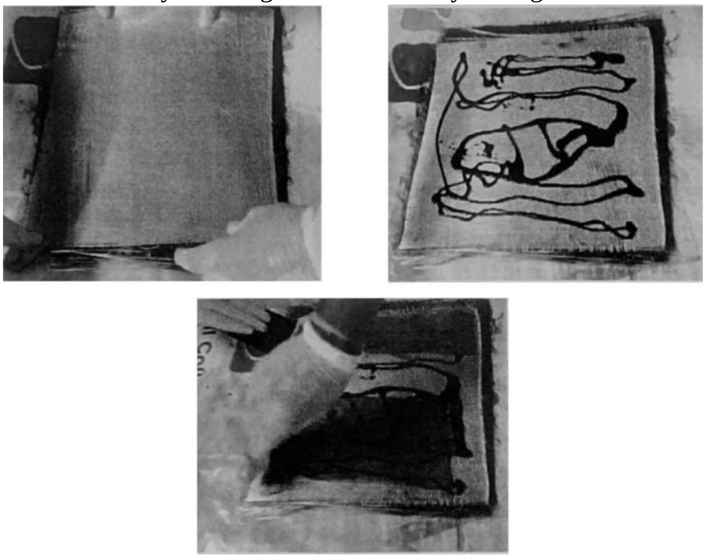

Fig. 1. Laminate preparation through Hand Layup

III. TENSILE TEST

ASTM standard ASTMD3039/3039M-08 is used for Tensile Test of the hence prepared specimens. And the size for the same is shown below. Dimensions of the specimen for tensile test, has a gauge length of 50mm and thickness of 3mm as per the ASTM standard.

IV. FLEXURAL TESTING

ASTM standard *ASTMD790* and standard test methods were used for the finding the bending strength of the samples prepared using 3 - point bending mechanism. The flexural test calculates the load required to bend the specimen. The test rig represents a simply supported beam with a point load acting on the mid span in a predefined rate until the delamination is formed at one end of the specimen in the center plane. The parameters for this test are the support span, the loading speed and the maximum test deflection. The flexural strength is given by $(3Pl/(2bd^2))$ N/mm^2 with thickness of the 3.2mm.

V. HARDNESS TEST

ASTM standard ASTM D0785: which is the standard testing method for (RHN) Rockwell Hardness of Polymers and Electrically Insulating Materials was used. Specimens were cut to the dimensions 25mm × 25mm × 6mm for the test.

VI. RESULTS AND DISCUSSIONS:

A. Tensile Test

On the specimen, tenisle test was performed, cut according to the above norms. Tensile load has been introduced to the composite in a gradually growing way and is progressively expanded to fracture of the specimen. The load, deflections of the samples were recorded throughout the experiment, control system and related software. Graph was plotted against various % of reinforcement and tensile strength, the same is shown in the figure below.

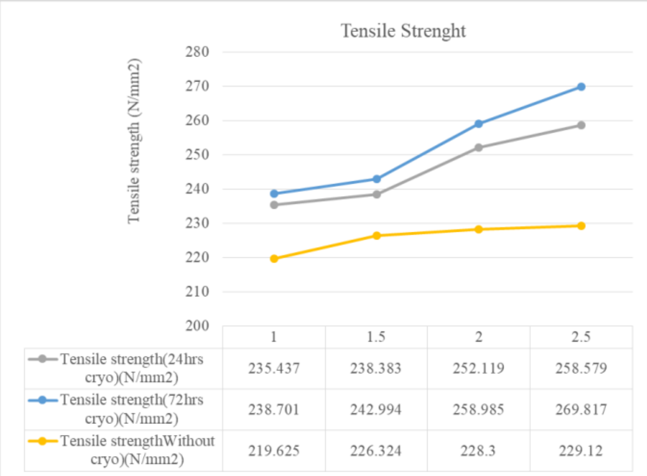

Fig. 2. Tensile strength of Bisphenol based PMC subjected to 24hrs & 72hrs Cryogenic treatment and without Cryogenic treatment

It could be observed that the tensile strength for laminate with 1% of bisphenol is low. This increases with the increase in the % bisphenol and higher for the laminate with 2.5% bisphenol. Further, the cryogenic treated laminates exhibit Higher tensile strength when compared to the laminates which are not cryogenic treated. Among the cryogenic treated laminates, the laminates which were exposed to 24hrs of cryogenic treatment, exhibited lower tensile strength than the laminates exposed for 72hrs of cryogenic treatment. These variations occurs due to the fact that with the increase in the bisphenol content improves the tensile strength. But, in addition to that, prolonged exposure to cryogenic treatment makes the laminates harder and brittle.

B. Flexural test

The specimen was created in accordance with the ASTM standards for flexural testing. Flexural load was applied to the composite in a gradually growing way until it fails. The control system with the associated software keep track of the load and any changes in the specimen for the entire length of the test. Graph was plotted against various % of reinforcement and flexural strength, the same is shown in the figure below.

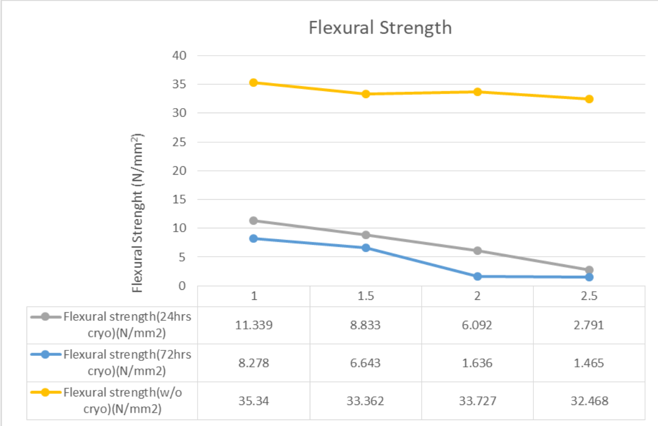

Fig. 3. Flexural strength of Bisphenol based PMC subjected to 24hrs & 72hrs Cryogenic treatment and without Cryogenic treatment

It could be observed that the flexural strength for the sample with 1% of bisphenol is higher and lower for the laminate of 2.5% of bisphenol. Further, the cryogenic treated laminates exhibit lower flexural strength when compared to the laminates which are not cryogenic treated. Among the cryogenic treated laminates, the laminates which were exposed to 72hrs of cryogenic treatment, exhibited lower flexural strength than the laminates exposed for 24hrs of cryogenic treatment. These variations occur due to the increasing levels of bisphenol in the laminates, which leads to the decrease in flexural strength. But in addition to the prolonged exposure to cryogenic treatment makes the laminates even harder and brittle thus making the laminates less effective towards bending loads. Before being subjected to cryogenic treatment, laminates exhibited higher Flexural strength when compared to the Flexural strength of the laminates after the cryogenic treatment.

C. Hardness Test

This test method used is Rockwell hardness test, this is used principally to determine the indention hardness in polymers and associated electrical insulators. A ball indenter 1/16" of diameter is used and the results are measured taken from the B-scale at a constant load (100Kgf).

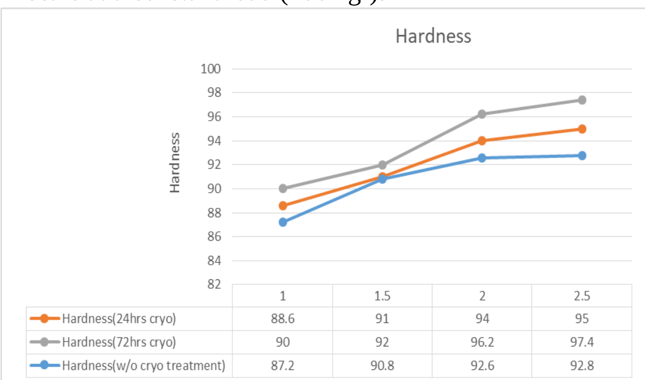

Fig. 4. Hardness of Bisphenol based PMC subjected to 24hrs & 72hrs Cryogenic treatment and without Cryogenic treatment

Retrieval Number C4675098319/2019©BEIESP
DOI: 10.35940/ijrte.C4675.098319
Journal Website: www.ijrte.org

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

It could be observed that the hardness for the laminate of 1% of bisphenol is higher and lower for the laminate of 2.5% of bisphenol. Further, the cryogenic treated laminates exhibit higher hardness when compared to the laminates which are not cryogenic treated. Among the cryogenic treated laminates, the laminates which were exposed to 72hrs of cryogenic treatment, exhibited higher hardness values than the laminates exposed for 24hrs of cryogenic treatment. These variations occur due to the increasing levels of bisphenol in the laminates, which leads to the increase in hardness of the laminates. But, in addition to that, prolonged exposure to cryogenic treatment makes the laminates more brittle with no significant increase in hardness. Before being subjected to cryogenic treatment, laminates exhibited lower hardness when compared to the tensile strength of the laminates after cryogenic treatment.

VII. CONCLUSION

The hardness of the cryogenic treated bisphenol based PMCs has increased with the weight percentage of Bisphenol indicating the fact that the laminates can withstand more loads at subzero temperatures. The flexural strengths have considerably reduced after treating the PMC cryogenically as the laminates tend to become more brittle in nature when being subjected to subzero temperatures. The Tensile strength for the treated specimens have nearly increased by 10% this increase also depends on the duration of the treatment process. Between the cryogenically treated samples 72hr treated samples have shown higher tensile strength but only by a small margin (1%) hence increasing the treatment process beyond 72 hrs may not show any substantial increase in the tensile strength. Cryogenic treatment made the PMC more brittle thus making the laminates more susceptible to fracture when subjected to flexural test. The advantage of using PMC at subzero temperatures is that the laminates will not be subjected to corrosion.

REFERENCES

1. Arun G K, Nikhil Sreenivas, Kesari Brahma Reddy, K Sai Krishna Reddy, Shashi Kumar M E, Pramod R, "Investigation on Mechanical Properties of Graphene Oxide reinforced GFRP", IOP Conf. Series: Materials Science and Engineering 310 (2018) 012158 doi:10.1088/1757-899X/310/1/012158
2. R Pramod, M E Shashi Kumar "Evaluation of Mechanical and Insulation Properties of Nomex-T410 and HS Glass Polymer Matrix Composites", 5th International Conference of Materials Processing and Characterization (ICMPC 2016) Materials Today: Proceedings 4 (2017) Page no: 3233-3242
3. Jeffrey R.Potts, Daniel R.Dreyer, Christopher W. Bielawski, Rodney S.Ruoff, Graphene-based polymer nanocomposites, Polymer, Volume 52, Issue 1, 7 January 2011, Pages 5-25, https://doi.org/10.1016/j.polymer.2010.11.042
4. Shashi Kumar M E, Pramod R, "Experimental investigations on Carbon Nomex T410 reinforced polymer matrix composite for enhanced mechanical and tribological properties", AIP Conference Proceedings 1859,- 020089 (2017); http://doi.org/10.1063/1.4990242.
5. B. Jabusaria, S.P.Potnis, "Bisphenol-furfural. A High Temperature Thermosetting Resin", Polymer journal Vol.6, No.5, Page 333-340
6. G. Devendar, K.Srinivas Reddy, P.Raghavendra Rao, "Mechanical properties of E-Glass Fiber Reinforced epoxy composites with SnO2 and PTFE", International Journal of Emerging Research in Management and technology, ISSN 2278-9359 (Volume-6, Issue-7)
7. Tapas Kuilla, Sambhu Bhadra et.al., 21 July 2010, Recent advances in graphene based polymer composites, Progress in Polymer Science, pg.no.1350–1375.
8. Ramon D. Sellers and Virgil J. Carr, Jr., "Performance of nomex military uniforms in attacks by flame field expedint weapons – A literature study," Applied Research Associates, Air Force Research Laboratory, March 2007.
9. U Aditya Chainulu, R Agam Prakash Singh, Aditya YS, Phanindra, KSVKN and Shashi Kumar ME, Experimental Study of Bisphenol Based Polymer Matrix Composites for Mechanical and Insulation Properties, International Journal of Mechanical Engineering and Technology, 9(5), 2018, pp. 238– 245..
10. Shen XJ, Pei XQ, Fu SY, Friedrich K. Significantly modified tribological performance of epoxy nanocomposites at very low graphene oxide content.Polymer 2013;54 (3):1234e42.
11. Arash B, Park HS, Rabczuk T. Mechanical properties of carbon nanotube reinforced polymer nanocomposites: a coarse-grained model.Compos Part B Eng 2015;80:92e100.
12. Ren G, Zhang Z, Zhu X, Ge B, Guo F, Men X, et al. Influence of functionalgraphene as filler on the tribological behaviors of Nomex fabric/phenoliccomposite. Compos Part A Appl Sci Manuf 2013;49:157e64.
13. Lalit M Manocha, "High Performance Carbon–Carbon Composites", Sadhana Vol.28, Parts 1 & 2, pp. 349–358, February/April 2008
14. Minh-Tai Le and Shyh-Chour Huang, Thermal and Mechanical Behaviour of Hybrid Polymer Nanocomposite Reinforced with Graphene Nano platelets, Materials, 8, pg.no.5526-5536,August 2015
15. Nariman Yousefi, Xinying Sun, et.al., " Highly Aligned Graphene/Polymer Nanocomposites with Excellent Dielectric Properties for High Performance Electromagnetic Interference Shielding", Advanced Materials, Volume 26, 20 August 2014.
16. D J Akshaykumar, V N Vivek Bhandarkar, M R Haseebuddin, " Study on Two Body Wear Behaiviour of Graphene Filled E-Glass Fabric Epoxy Composites", IJRET September 2016.
17. Minh-Tai Le and Shyh-Chour Huang, " Thermal and Mechanical Behaviour of Hybrid Polymer Nanocomposite Reinforced with Graphene Nano Platelets", Materials, 8, pg.no.5526-5536, August 2015.
18. Mohan Kumar, S., Pramod, R., Shashi Kumar, M.E., Govindaraju, H.K. Evaluation of fracture toughness and mechanical properties of aluminum alloy 7075, T6 with nickel coating, Procedia Engineering, Volume 97, 2014, Pages 178-185.
19. Mohan Kumar, S., Ravi Kumar, V., Shashi Kumar, M.E., Govindaraju, H.K. Mechanical characterization and fracture toughness of electroplated cadmium coating of Al -Zn alloy, T6, AIP Conference Proceedings 1859, 020085, 2017; https://doi.org/10.1063/1.4990238.
20. Aditya Sai Priyanka Komanduri, S Gleams Raman, Suri Sai Raghava Bhargavi and Shashi Kumar M E, Investigation of Mechanical Properties of Graphene, Nomex T410 & High Silica Glass Reinforced Hybrid Polymer Matrix Composite, International Journal of Mechanical Engineering and Technology, 9(5), 2018, pp. 75–82.
21. Effect of electroless nickel (EN) coating on mechanical properties of Al-6061 Saketh, H.L., Chanduri, P., Mallikarjuna Reddy, G., Vikranth Reddy, B., Shashi Kumar, M.E.2019 International Journal of Mechanical and Production Engineering Research and Development 9(4),IJMPERDAUG201914, pp. 129-136
22. Praveen, D., Kumar, M.S. and Pramod, R., 2018, February. Dielectric studies of Graphene and Glass Fiber reinforced composites. In IOP Conference Series: Materials Science and Engineering (Vol. 310, No. 1, p. 012153). IOP Publishing.
23. Prakash Marimuthu, K., Mohan Kumar, S., Ravi Kumar, V. and Govindaraju, H.K., 2019. Characterization of Mechanical Properties of Epoxy Reinforced with Glass Fiber and Coconut Fiber. Materials Today: Proceedings, 16, pp.661-667.
24. Mohan Kumar, S., Ravikiran, K.R. and Govindaraju, H.K., 2018. Development of E-glass woven fabric/polyester resin polymer matrix composite and study of mechanical properties. Materials Today: Proceedings, 5(5), pp.13367-13374.
25. Krishna, D., Jyothish, J., Kumar, A.A., (...), Mohan Kumar, S., Ravi Kumar, V., 2017. Electrochemical corrossion studies and mechanical characterization of al7050 metal matrix composite reinforced with ZRO2 particulate by stir casting method International Journal of Mechanical Engineering and Technology : 8(11), pp. 949-957.

26. Ravi Kumar, V., Prakash, K.R., "Mathematical modeling of unsaturated isophthalic resin's curing cycle" 2018 International Journal of Mechanical and Production Engineering Research and Development 8(2),IJMPERDAPR201891, pp. 805-810.
27. Ravi Kumar, V., Dileep, B.P. and Vital, H.R., 2017, July. Tribological and mechanical characterization of Al-Ni-SiC metal matrix composites. In AIP Conference Proceedings (Vol. 1859, No. 1, p. 020020). AIP Publishing.

AUTHORS PROFILE

Mr. Shashi Kumar M. E. is currently working as Assistant Professor (Sr. Gr), Department of Mechanical Engineering, Amrita School of Engineering, Bengaluru campus and pursuing his Ph.D. from Visvesvaraya Technological University Belgaum, India. His research interests include Fracture Mechanics, Composites, Concurrent Engineering and Complex Products Development. He is a member of IAENG. He has published papers in international and national level Journals and conferences. Most of his papers are indexed in Scopus.

Mr. Mohan Kumar S. is currently working as Asst. Professor (Sr. Gr) in Dept of Mechanical Engineering at Amrita School of Engineering, Bengaluru. He received his M.Tech and B.Tech Degree from Visevsavaraya Technological University. His research interest focuses mainly Composite Material, Fracture Mechanics, FEM. He has published papers in international and national level Journals and conferences. Most of his papers are indexed in Scopus.

Mr. Ravi Kumar V. is currently working as Asst. Professor (Sr. Gr) in Dept of Mechanical Engineering at Amrita School of Engineering, Bengaluru. He received his M.Tech and B.Tech Degree from University Visevsavaraya College of Engineering, Bangalore University. His research interest focuses mainly on Polymer Nano composites , carbon nanofiber. He has authored a text book on Operations Research with IK International Publisher with over 1000 pages. He has published papers in international and national level Journals and conferences. Most of his papers are indexed in Scopus.