iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 5 **Issue:** VII **Month of publication:** July 2017

DOI:

A Sliding Wear Behavior of Basalt Fiber Reinforced TIO2 Filled Epoxy Resin Composite

Mr. Arun Kumar K R[1], Mr. Mohd Azaruddin[2], Mr. Anand S L[3]
[1,3] *Assistant Professor, Dept. of Mechanical Engineering, T. John College of Engineering, Bangalore*
[2] *CAE Engineer, Autosoft Solutions, Bangalore*

Abstract: The use of basalt fibers was investigated in low cost composites for civil infrastructure applications requiring excellent mechanical properties and long lifetimes. Basalt fibers were thought to have great potential as reinforcement in both polymer materials and in concrete. However, this research focused on the use of basalt fiber reinforced polymer composites. Fiber reinforced polymer composites find widespread applications these days in hostile environment due to their several advantages like high wear resistance, strength-to-weight ratio and low cost. The performance of the composites can further be improved by adding particulate fillers to Basalt fiber. To this end, this work successfully uses TiO_2 as a filler material in polymer. The present work includes the processing, characterization and study of the sliding wear behavior of a series of such TiO_2 filled basalt-epoxy composites. It further outlines a methodology based on Taguchi's experimental design approach to make a parametric analysis of sliding wear behavior. The systematic experimentation leads to determination of significant process parameters and material variables that predominantly influence the wear rate.

Keywords: Composites, Fiber Reinforced Polymers, Basalt Fibers, TiO_2, sliding wear behaviour, Taguchi's Method.

I. INTRODUCTION

Composite materials are engineering materials made from two or more constituent materials that remain separate and distinct on a macroscopic level while forming a single component. There are two categories of constituent materials: matrix and reinforcement. At least one portion of each type is required. The matrix material surrounds and supports the reinforcement materials by maintaining their relative positions. The reinforcement imparts their special mechanical and physical properties to enhance the matrix properties. The primary functions of the matrix are to transfer stresses between the reinforcing fibers/particles and to protect them from mechanical and/or environmental damage whereas the presence of fibers/particles in a composite improves its mechanical properties such as strength, stiffness etc. A composite is therefore a synergistic combination of two or more micro-constituents that differ in physical form and chemical composition and which are insoluble in each other. The objective is to take advantage of the superior properties of both materials without compromising on the weakness of either. The synergism produces material properties unavailable from the individual constituent materials. Due to the wide variety of matrix and reinforcement materials available, the design potentials are incredible. Composite materials have successfully substituted the traditional materials in several light weight and high strength applications. The reasons why composites are selected for such applications are mainly their high strength – to weight ratio, high tensile strength at elevated temperatures, high creep resistance and high toughness.

Most commonly used matrix materials are polymeric. The reason for this are twofold. In general the mechanical properties of polymers are inadequate for many structural purposes. In particular their strength and stiffness are low compared to metals and ceramics. These difficulties are overcome by reinforcing other materials with polymers. Secondly the processing of polymer matrix composites need not involve high pressure and doesn't require high temperature. Also equipment's required for manufacturing polymer matrix composites are simpler. For this reason polymer matrix composites developed rapidly and soon became popular for structural applications.

A. Objectives

Objectives of the present work defined as follows

1) Fabrication of basalt fiber reinforced epoxy based hybrid composite with/without filler content.
2) Evaluation of mechanical properties (tensile strength, hardness, wear strength etc.)
3) Dry sliding wear of composite samples under various operating conditions.
4) The study of effect of fiber and filler content on sliding wear analysis. Besides the above all the objective is to develop new class of composites by incorporating TiO2 reinforcing phases into a polymeric resin. Also this work is expected to introduce a new class of polymer composite that might find tribological applications.

B. Methodology

1) The method implemented in the fabrication of continuous unidirectional Basalt fiber and epoxy resin composite is Hand layup procedure and it is open molding technique done manually.
2) Continuous unidirectional Basalt fiber is cut to the required length and laminated layer by layer using epoxy resin.
3) Different weight fraction of Basalt fiber and TiO2 is added to matrix material that is 0.5%, 1.0%, 1.5%, 2.0%, 2.5% of TiO2. The four samples were cut to required ASTM standard.
4) Mechanical tests conducted on the specimen to know the tensile strength of tensile specimen and hardness of the sample.
5) Robust condition of composite material under wear test is predicted using Taguchi method.

II. LITERATURE REVIEW

Myshkin et al (2005) reviewed the tribological behavior of polymers and studied the surface energy of different coatings by new contact adhesion meter. They reported results related to friction of plastics, effect of load, sliding velocity and temperature on friction, abrasive and adhesive wear and friction on polymers. This chapter outlines some of the recent reports published in literature on composites with special emphasis on erosion wear behavior of glass fiber reinforced polymer composites.

Polymers have generated wide interest in various engineering fields including tribological applications, in view of their good strength and low density as compared to monolithic metal alloys. Being lightweight they are the most suitable materials for weight sensitive uses, but their high cost sometimes becomes the limiting factor for commercial applications. Use of low cost, easily available fillers is therefore useful to bring down the cost of component. Study of the effect of such filler addition is necessary to ensure that the mechanical properties of the composites are not affected adversely by such addition. Available references suggest a large number of materials to be used as fillers in polymers [1]. The purpose of use of fillers can therefore be divided into two basic categories; first, to improve the mechanical, thermal or tribological properties and second, to reduce the cost of the component. There have been various reports on use of materials such as minerals and inorganic oxides, such as alumina and silica mixed into widely employed thermoplastic polymers like polypropylene [2,3] and polyethylene [4,5]. But very few attempts have indeed been made to utilize cheap materials like industrial wastes in preparing particle-reinforced polymer composites.

A key feature of particulate reinforced polymer composites that makes them so promising as engineering materials is the opportunity to tailor the materials properties through the control of filler content and matrix combinations and the selection of processing techniques. A judicious selection of matrix and the reinforcing solid particulate phase can lead to a composite with a combination of strength and modulus comparable to or even better than those of conventional metallic materials [6]. Hard particulate fillers consisting of ceramic or metal particles and fiber fillers made of glass are being used these days to dramatically improve the wear resistance of composites, even up to three orders of magnitude [7]. The improved performance of polymers and their composites in industrial and structural applications by the addition of particulate fillers has shown a great promise and so has lately been a subject of considerable interest. Various kinds of polymers and polymer matrix composites reinforced with metal particles have a wide range of industrial applications such as heaters, electrodes [8], composites with thermal durability at high temperature [9] etc. These engineering composites are desired due to their low density, high corrosion resistance, ease of fabrication, and low cost [10, 11]. Similarly, ceramic filled polymer composites have been the subject of extensive research in last two decades.

A. Materials Used

Basalt fiber is made from a single material, crushed basalt, from a carefully chosen quarry source and unlike other materials such as glass fiber, essentially no materials are added. The basalt is simply washed and then melted. The manufacture of basalt fiber requires the melting of the quarried basalt rock at about 1,400 °C (2,550 °F) .The molten rock is then extruded through small nozzles to produce continuous filaments of basalt fiber. The fibers typically have a filament diameter of between 9 and 13 µm which is far enough above the respiratory limit of 5 µm to make basalt fiber a suitable replacement for asbestos. They also have a high elastic modulus, resulting in excellent specific tenacity—three times that of steel.

Epoxy LY 556 resin, chemically belonging to the „epoxide" family is used as the matrix material. Its common name is Bisphenol A Diglycidyl Ether. The low temperature curing epoxy resin (Araldite LY 556) and corresponding hardener (HY951) are mixed in a ratio of 10:1 by weight as recommended. The epoxy resin and the hardener are supplied by Ciba Geigy India Ltd. Basalt fiber and epoxy resin has modulus of 89GPa and 3.42GPa respectively and possesses density of 2590 kg/m3 and 1100kg/m3 respectively.

TiO2, the oxide of the metal titanium, occurs naturally in several kinds of rock and mineral sands. TiO2 is typically thought of as being chemically inert. Titanium dioxide (TiO2) is a white solid inorganic substance that is thermally stable, non-flammable, poorly soluble, and not classified as hazardous according to the United Nations' (UN) Globally Harmonized System). Titanium oxide is used as interstitial bong filler material in composite material. Titanium oxide is used in various weight percentages to enhance the mechanical properties of the composite material.

Table -1: Materials used in fabrication of composite.

Sl.no	Materials	Sample dimensions (mm)
1	Mould made of granite	600x600x10
2	Beadings	200x200x3
3	Mylar sheet	200x200x3
4	Wax	
5	Weighing machine	0.2kg to 3kg capacity
6	Plastic container	5 liter capacity
7	Concrete block	30 kg weight

Table -2: Sample preparation calculation for Tio2 filled composite.

samples	% wt of Resin	% wt of fiber	% wt of TiO2	Mass of resin gram	Mass of fiber gram	Mass of Tio2 gram	Totally weight
A	60	39.5	0.5	111.20	73.20	0.556	185.332
B	60	38	1.0	111.95	70.90	1.866	186.588
C	60	38.5	1.5	112.06	70.04	2.801	186.778
D	60	37	2.0	112.83	67.70	3.751	188.057
E	60	37.5	2.5	112.95	66.80	4.706	188.250

III. MECHANICAL CHARACTERIZATION

Composite materials were subjected to various mechanical tests to measure strength elastic constants and other material properties. The results of such tests were used for the two primary purposes: 1) engineering design (for example, failure theories based on strength or deflections based on the elastic constants and component geometry) and 2) quality control either by the materials producer to verify the process or by the end user to confirm the material specifications.

The tests which are carried out are as follows

A. Tensile Test
B. Hardness Test
C. Wear Test

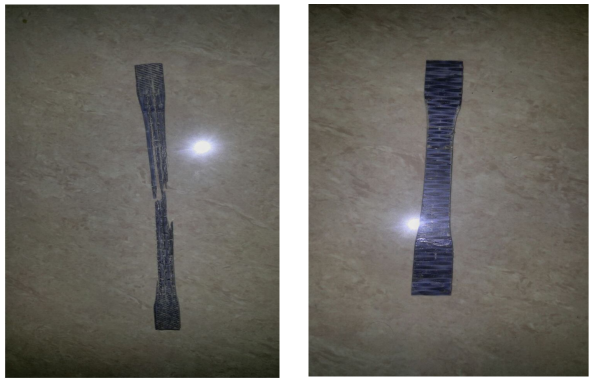


Figure 1.1: Tensile specimen before testing and after Testing

Figure 1.2: Wear specimen before testing and after Testing

1) *Design of Experiment:* Design of experiment is a powerful analysis tool for modeling and analyzing the influence of control factors on performance output. The most important stage in the design of experiment lies in the selection of the control factors. Therefore, a number of factors are included so that non-significant variables can be identified at earliest opportunity. The wear tests are carried out under operating conditions. The tests are conducted at room temperature as per experimental design. Three parameters viz., sliding velocity, normal load, filler content and sliding distance each at three levels, are considered in this study in accordance with L9 (313) orthogonal array design. The experimental observations are transformed into signal-to-noise (S/N) ratios. The S/N ratio for minimum wear rate coming under smaller is better characteristic, which can be calculated as logarithmic transformation of the loss function as shown below. Smaller is the better characteristic:

$$\frac{S}{N} = -10 \log\frac{1}{n} \sum_{y} 2$$

Where n is the number of observations, and y is the observed data. "Lower is better" (LB) characteristic, with the above S/N ratio transformation, is suitable for minimization of wear rate.

Table 1.3: Control factors and levels used in the experiment.

Control factors	Levels			
	1	2	3	Units
A: Sliding track diameter	40	50	60	mm
B: Tio2 %	0.5	1.0	1.5	% wt
C: Load in N	3	3.5	4	Newton

The plan of the experiments is as follows: the first column is assigned to sliding velocity (A), the second column to normal load (B), the third column to filler content C respectively to estimate interaction between sliding velocity (A) and normal load (B), and filler content (C).

ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 6.887
Volume 5 Issue VII, July 2017- Available at www.ijraset.com

Table 1.4: Test conditions with output results using L9(33) orthogonal array

A Sliding track diameter	B Tio2 %	C Load in N	Wear rate mm^3/Nm	S/N ratio
40	0.5	3	1.48472	-3.4349
40	1.0	3.5	1.20878	-1.6469
40	1.5	4	1.031106	-0.2661
50	0.5	3.5	0.65953	3.6153
50	1.0	4	0.34339	9.2842
50	1.5	3	0.44885	6.9580
60	0.5	4	0.024815	32.1057
60	1.0	3.0	0.017805	34.9892
60	1.5	3.5	0.0170430	35.3691

Table 1.5: Response Table for Means

Level	SlidingTrack Diameter	Tio2 %	Load in N
1	1.24154	0.72302	0.65046
2	0.48392	0.52332	0.62845
3	0.01989	0.49900	0.46644
Delta	1.22165	0.22402	0.18402
Rank	1	2	3

IV. RESULTS AND DISCUSSION

A. *Tensile Test*

In this study, the reinforcement of TiO2 particulate in Basalt fiber reinforced epoxy resin has not shown encouraging results in terms of mechanical properties. The tensile strengths of the composites with 1 Tio2 wt% and 1.5 Tio2 wt% are recorded as 263.65 MPa and 257.76 MPa respectively where as that of neat epoxy with short glass fiber is about 370 MPa.

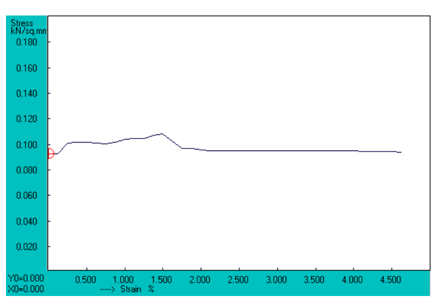


Figure 1.3: Stress-Strain curve of o.5%Tio2 filled Basalt fiber composite.

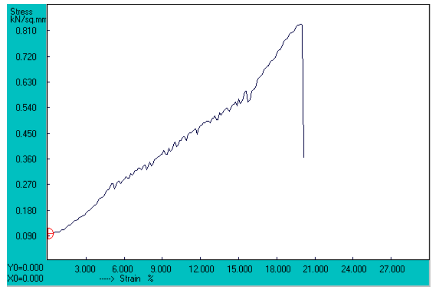


Figure 1.4: Stress-Strain curve of 1%Tio2 filled Basalt fiber composite.

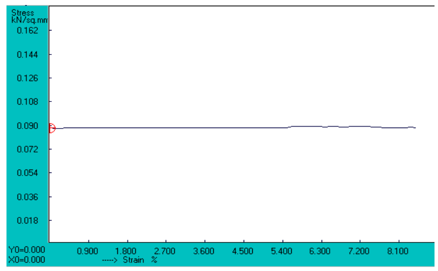


Figure 1.5: Stress-Strain curve of 1.5%Tio2 filled Basalt fiber composite.

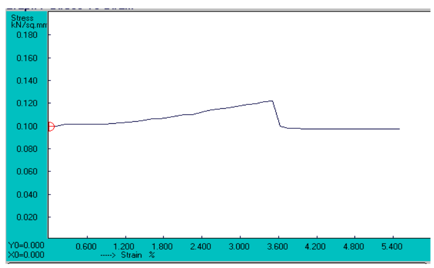


Figure 1.6: Stress-Strain curve of 2%Tio2 filled Basalt fiber composite.

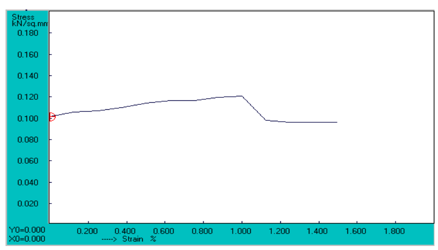


Figure 1.7: Stress-Strain curve of 2.5%Tio2 filled Basalt fiber composite.

B. *Hardness Test*

Figure 1.8: BHN Vs Weight% of Tio2 curve.

The hardness of the Basalt fiber composite material is significantly increasing with increase in filler material up to 1.0% Tio2 and decreases as the concentration of Tio2 increases. Because increase in interstitial bonding of composite material.

C. Wear Test

The experimental results are analyzed using Taguchi method and the significant parameters affecting material erosion have been identified. The results of the Taguchi analysis are also presented here. The analyses are made using the popular software specifically used for design of experiment applications known as MINITAB 14. Sliding velocity is most significant factor followed by fiber content and normal load while the sliding distance has the least or almost no significance on wear rate of the reinforced composite. Analysis of the results leads to the conclusion that factor combination of A1, B2, C3 and D2 gives minimum specific wear rate. The interaction graphs are shown in Figures 8-10. As for as minimization of wear rate is concerned, factors A, B and C have significant effect. It is observed from Fig. 6 that the interaction between A B shows greater significant effect on wear rate. Similarly, interaction between B and C has second highest significant effect on the output performance.

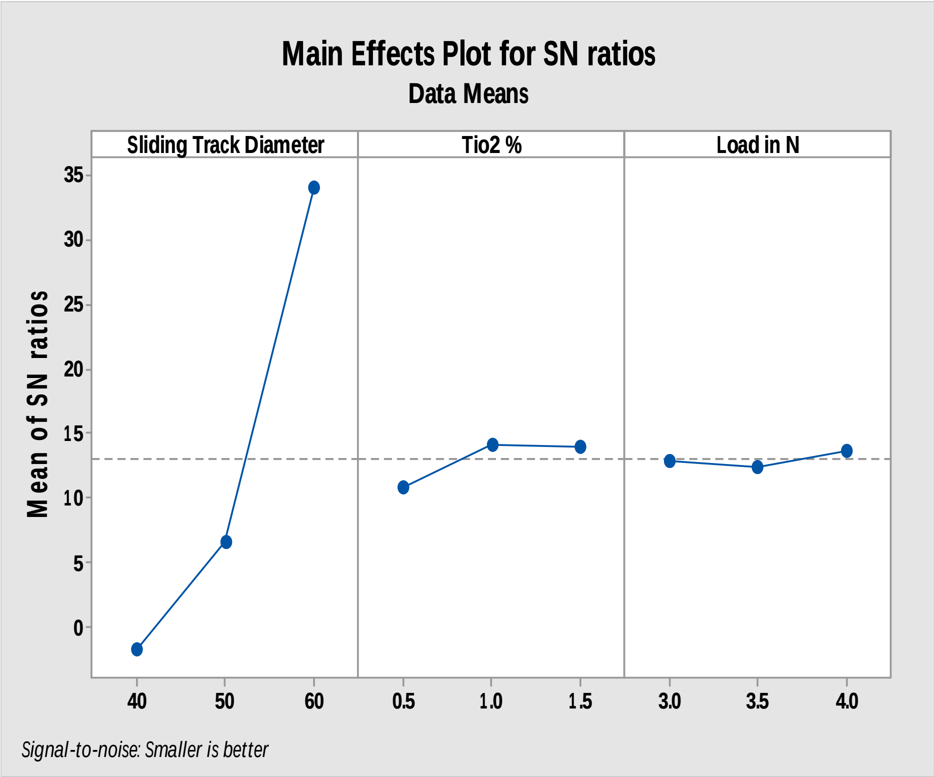


Figure 1.9: Main effects for plot of S/N ratio-wear rate.

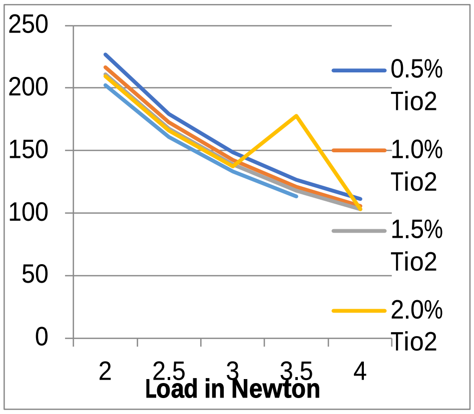


Figure 1.10: Wear rate vs Load in N curve for Wt% Tio2 Basalt fiber composite with 40mm sliding diameter.

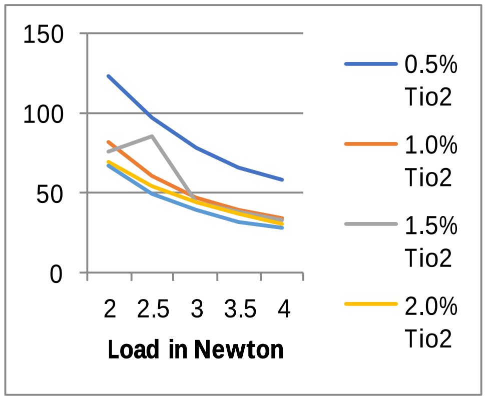


Figure 1.11: Wear rate vs Load in N curve for Wt% Tio2 Basalt fiber composite with 50mm sliding diameter.

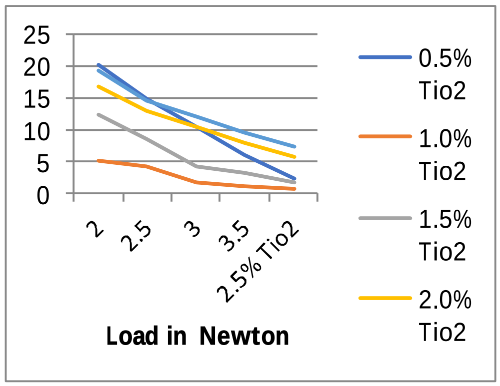


Figure 1.12: Wear rate vs Load in N curve for Wt% Tio2 Basalt fiber composite with 60mm sliding diameter.

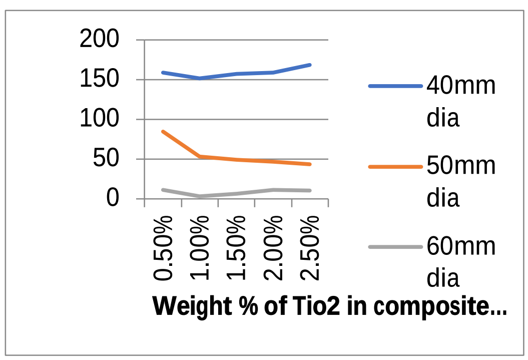


Figure 1.13: comparison of wear rate for 40, 50 and 60 mm sliding diameter.

V. CONCLUSIONS

A. This analytical and experimental investigation into the erosion behavior of TiO2 filled Basalt-epoxy hybrid composites lead to the following conclusions:

B. This work shows that successful fabrication of a Basalt fiber reinforced epoxy composites with filler by simple hand lay-up technique.

C. These composites using TiO2 have adequate potential for tribological applications. With the reinforcement of filler, they exhibit significantly improved sliding wear resistance.

D. Dry sliding wear response of these composites under different loads and sliding distances can be successfully analyzed using Taguchi experimental design scheme. Taguchi method provides a simple, systematic and efficient methodology for the optimization of the control factors. While filler content emerges as the most significant factor affecting wear rate of these composites, other factors like sliding distance and normal load and their interactions have been found to play significant role in determining wear magnitude.

E. This work shows that the properties of Basalt resemble the properties of Carbon. Some of the properties like wear loss and sliding wear rate of Basalt almost matches that of Carbon. Characteristics obtained justify the above statement.

F. The cost of Basalt is less compared to that of Carbon and for economic purpose Carbon can be replaced by Basalt.

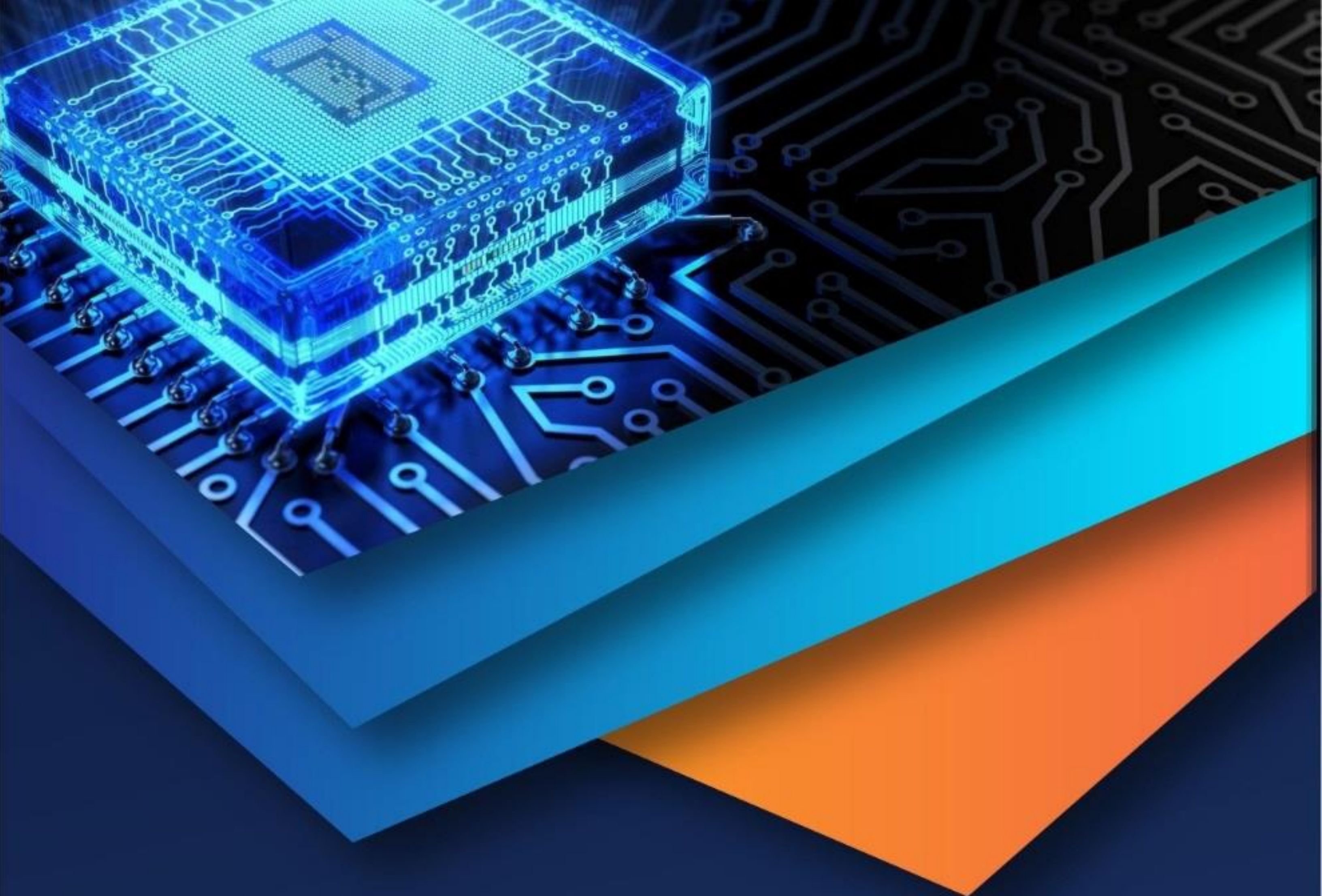
VI. FUTURE SCOPE OF WORK

A. This study leaves wide scope for future investigations. It can be extended to newer composites using other reinforcing phases and the resulting experimental findings can be similarly analyzed.

B. Tribological evaluation of TiO2 filled short glass fiber reinforced epoxy resin composite has been a much less studied area. There is a very wide scope for future scholars to explore this area of research. Many other aspects of this problem like effect of fiber orientation, loading pattern, weight fraction of ceramic fillers on wear response of such composites require further investigation.

REFERENCES

[1] Kruckenberg, T.P., R., Resin transfer moulding for Aerospace Structures. Dordrecht, The Netherlands: Kluwer Academic Publishers.,1998.
[2] Medvedyev, O.O.T., Y. L., The Outlook for the use of basalt continuous fibers for composite reinforcement. International SAMPE Symposium and Exhibition,. 49: p. 2299-2303,2004.
[3] Bader, M.G., Smith, Wilburn, Isham, Allan B., Rolston, J. Albert, Metzner, Arthur B., Delaware Composites Design Encyclopedia. Processing and Fabrication Technology. Vol. 3. 1990.
[4] Hull, D., An Introduction to Composite Materials. New York, NY: Cambridge University Press,1985.
[5] Rudd, C.D.e.a., Liquid Moulding Technologies., Cambridge, UK: Woodhead Publishing Limited,1997.
[6] Hoes, K., Development of a New Sensor-based Set-up for Experimental Permeability Identification of Fibrous Media, University of Brussels: Brussels,2003.
[7] Wambua, P.a.V., I. Hemp fabric reinforced polypropylene composites: an investigation of the mechanical properties. in Composite for the future - 10th Europen Conference on Composite Materials. Bruges, Belgium, 2002.
[8] Katayama, T.e.a. Study on injection molding of bamboo fiber reinforced thermoplastics in the International Conference on High Performance Structure & Composites. Seville, Spain, 2002.
[9] Wool, R.P., Hu, B. and Shenton, H. W. Composites from Soybeans. in Composite for the future - 10th Europen Conference on Composite Materials. Bruges, Belgium, 2002.
[10] Katori, S.a.K., T. Injection molding of silk fiber reinforced biodegradable composites. in the International Conference on High Performance Structure & Composites. Seville, Spain, 2002.
[11] Ashby, M.F.a.J., D. R. H., Engineering Materials 2 - An Introduction to Microstructures, Processing and Design.: Pergamon Press, 1988.
[12] Jones, R.M., Mechanics of Composite Materials, Boston: McGraw-Hill Book Corporation. 1975.



10.22214/IJRASET

INDEX COPERNICUS 45.98

IMPACT FACTOR: 7.129

TOGETHER WE REACH THE GOAL

IMPACT FACTOR: 7.429

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY