A Study on Thermal Properties and Wear Characterization of Glass Fiber Hybrid Composite Materials

Gurushanth B. Vaggar
Alvas Institute of Engineering and Technology

A Study on Thermal Properties and Wear Characterization of Glass Fiber Hybrid Composite Materials

Gurushanth B Vaggar
Associate Professor,
Department of Mechanical Engineering
Alva's Institute of Engineering and Technology
Moodbidri, Karnataka State, India.

S C Kamate
Principal
Hirasugar Institute of Technology
Nidasoshi, Karnataka State, India.

***Abstract*— Hybrid polymer composite materials (HPCM) are new solution for high thermal resistivity and stability of composites under thermal conditions. In the present study, investigation on thermal properties and wear resistance of silicon inserted glass fiber (GF) hybrid composite materials was carried out. The specimens were prepared by hand layup technique by compression moulding machine. Thermal conductivity (K) and Coefficient of thermal expansion (CTE) of HPCM materials were assessed. Also failure of HPCM was determined using Thermal gravimetric analysis (TGA). The results indicated that K of silicon inserted HPCM increased with increase in percentage of silicon and the value of CTE was decreased with increase in percentage of silicon. TGA indicated that the failure of HPCM occurred at 280^{0}C for 25 minutes. Further, the wear behaviour of HPCM was studied under varying speeds and percentage of silicon.**

Keywords*— *Thermal conductivity (K); Coefficient of Thermal Expansion (CTE); Thermal Gravimetric Analysis (TGA); Silicon; Wear.

I. INTRODUCTION

Composites are engineered materials made out of two or more components. Most of the composites can be tailored to obtain properties better than individual constituents. A polymer composite reinforced with fibre is called FRP composite. Considering a composite, which involves two or more macro constituent phases, the matrix is referred to as continuous phase and the fibres are called the reinforcing phase. The fibres increase the strength and stiffness, increase thermal and fatigue properties, provide better dimensional stability and electrical resistivity. Whereas the primary function of the resin is to transfer load, to hold the fibres, protect fibres from environment and mechanical abrasion. Matrix also carries transverse loads and interlaminar shear stresses. The advantages of composites include high strength to weight ratio, non-corrosiveness, less maintenance, high electrical resistance, wear resistance, electromagnetic transparency, appeasing appearance etc. Composites can be manufactured in different ways depending upon matrix, reinforcement and application. Different manufacturing methods include Hand-layup, Compression moulding, Resin Transfer Moulding (RTM), Pultrusion, Autoclave and Filament moulding etc. [16].

In the present work a study of thermal properties are carried out to the prepared specimens of silicon inserted hybrid composite materials (on silicon inserted glass – fiber chop strand). The specimens were prepared by hand layup followed by compression molding machine by non-heating molding technique. The thermal properties, 1) Thermal conductivity (K), 2) Coefficient of thermal expansion (CTE), and 3) Thermo gravimetric analysis (TGA) are found experimentally and specimens and experimental setups are prepared as per the ASTM standards [4]. Thermal properties of any materials decides withstanding and sustainability of that material under variable temperature conditions it may be high temperature or low temperature.

II. THERMAL PROPERTIES

A. Thermal Conductivity (K):

The measurements of K carried out under variable heat inputs at ATP condition. According to ASTM E1530 circular slab type HPC specimen diameter 150 mm and thickness 10 mm are used as shown in figure 1. A known value of heat is applied from one side of the composite slab wait till the system reach steady state, the temperature of each interface surfaces were measured by thermocouples. Thermal conductivity determined by using one-dimensional Fourier's law of conduction equation [2]. The conduction equation can be stated as "The rate of heat conduction in a given direction is proportional to the temperature gradient in that direction". This statement can be represented by equation

$$Q = -KA\frac{dT}{dL} = -KA\,\frac{(T_2 - T_1)}{L}$$

Where,

Q = Heat Supplied (W).

K = Thermal conductivity (W/m $^{\circ}$C).

A = Area (m^2).

L = Thickness of the HPC specimen (m).

T_1= Temperature of lower interface surface of HPC Specimen ($^{\circ}$C).

T_2= Temperature of upper interface surface of HPC Specimen ($^{\circ}$C).

$\frac{dT}{dL}$ = Temperature gradient ($^{\circ}$C/m).

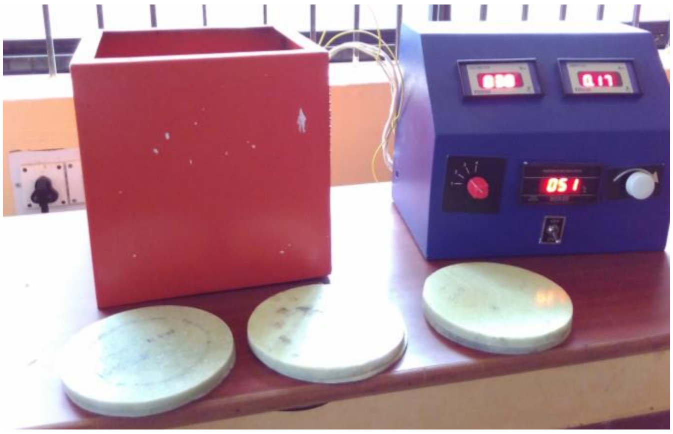

Figure.1: Thermal conductivity experimental setup.

B. Coefficient of Thermal Expansion (CTE):

Most solid materials expand by heating and contract when cooled. Thermal expansion is a property of a material is indicative of the extent to which a material expands upon heating. The change in length with temperature for a solid material may be expressed as follows [9].

$$\alpha_1 (T_2 - T_1) = \frac{(L_2 - L_1)}{L_1}$$

$$\alpha_1 (\Delta T) = \frac{(\Delta L)}{L_1}$$

Where,

L_1 = Initial length

L_2 = Final length

T_1 = Initial temperature

T_2 = Final temperature

α_1 = linear coefficient of thermal expansion

ΔT = Temperature change (˚C)

ΔL= Change in length of the sample (mm)

The CTE test conducted to HPC specimens had length 90mm and thickness 10mm. The CTE tests were done for the temperature range of 25˚C to 90˚C using temperature controlled muffler furnace. The HPC specimens heated from room temperature to 90˚C in the muffler furnace and kept at 90˚C for 10 minute.

C. Thermo Gravimetric Analysis (TGA):

Thermo gravimetric analysis is one of the method thermal analysis in which the changes in physical and chemical properties of specimens measured with reference to the increase in temperature. The TGA test carried out to the square specimens of size 50mm x 50mm and thickness 10mm. The TGA tests were performed over the temperature range of 30˚C to 300˚C using temperature controlled muffle furnace. Specimens heated from room temperature to 300˚C in the muffler furnace for 20 minutes. After heating specimens check for decompose of hybrid polymer composites and % of loss material in weight is calculated.

Fig.2a shows specimen before TGA test and Fig.2b shows the decomposed specimen after TGA test.

Fig.2a: Specimen before TGA test

Fig.2b: Specimen after TGA test

D. Wear Test):

Wear test is conducted as per the ASTM Standards with specimen sizes 10 mm x 10 mm square cross section and length 50 mm the wear testing setup shown in figure 3**.** Wear test conducted for three variable speeds and three different composition hybrid polymer composite specimens [10].

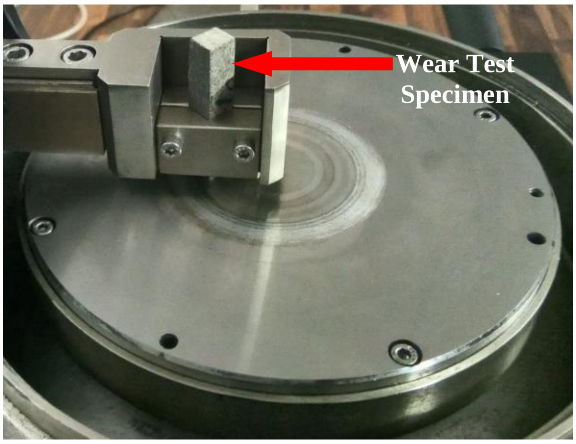

Fig.3: Wear test setup

III. METHOD TO PREPARE HYBRID POLYMER COMPOSITES

Machine moulding is used to prepare hybrid polymer composites by hand layup method. Mould box is prepared as per the size of the HPC with the proper mixture of resin hardener and filler particles pasted on glass fiber layups then pressure applied on mould by using SANTAC compression moulding machine allowed cure for 24 hours under normal atmospheric conditions. This method of preparing hybrid polymer composites is the simplest and economical than other methods.

TABLE I. SPECIMEN COMPOSITIONS

Material Designation	**Weight Quantity in Grams**			
	Silicon	**E-Glass Fiber**	**Epoxy Resin**	**Hardener**
GE10	0	116.40	291.00	29.10
GE10SI10	24.32	121.60	218.88	21.88
GE10SI20	46.00	115.00	184.00	18.40
GE10SI30	78.18	130.20	182.42	18.242

IV. RESULTS AND DISCUSSION

Variation of thermal properties K, CTE, TGA and Coefficient of friction (μ) for different composition hybrid polymer composite materials are shown in figures 4 to 6 respectively.

In figure 4 it shows that the thermal conductivity value increases as the percentage of silicon filler material increases. The thermal conductivity of silicon is greater than that of epoxy resin hence the coefficient of thermal expansion of hybrid polymer composite decreases with increase in percentage of silicon as shown in figure 5. Thermogravimetric analysis indicated that the failure of HPCM occurred at 280^0C for 25. Figure 6 shows coefficient of friction varies to higher value with increase in % of silicon as well as speed, means the material can sustain more frictional force.

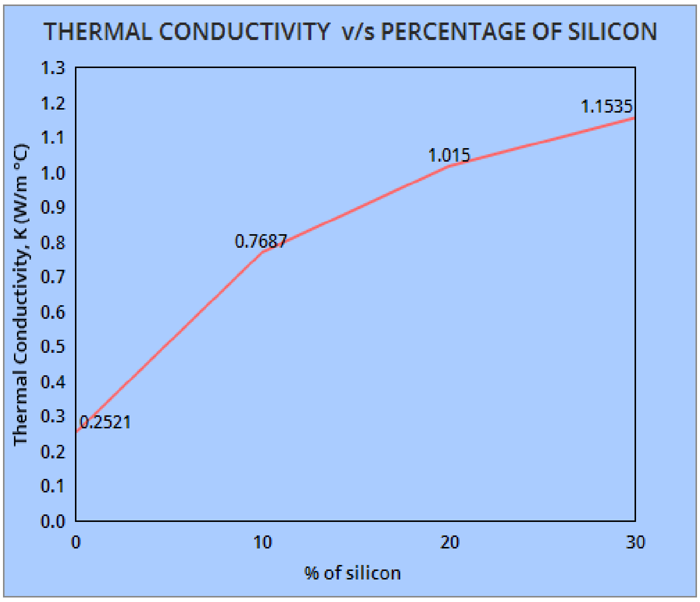

Figure.4: Variation of Thermal conductivity with % of Silicon

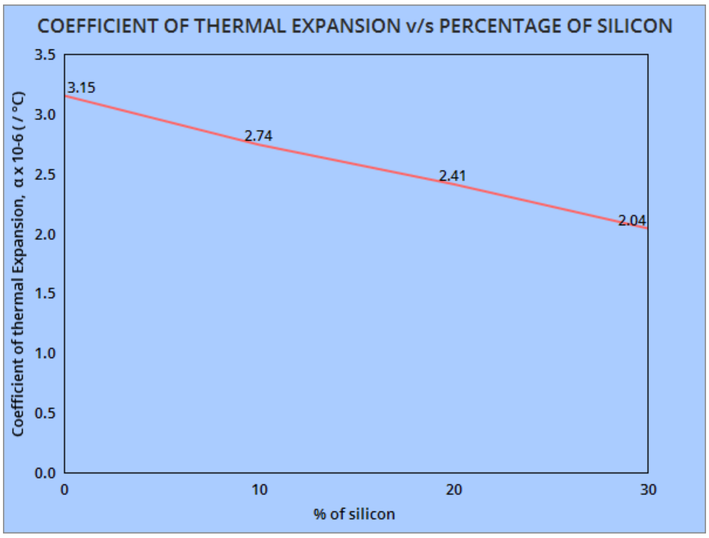

Figure.5: Variation of Coeeficient of Thermal Expansion with % of Silicon

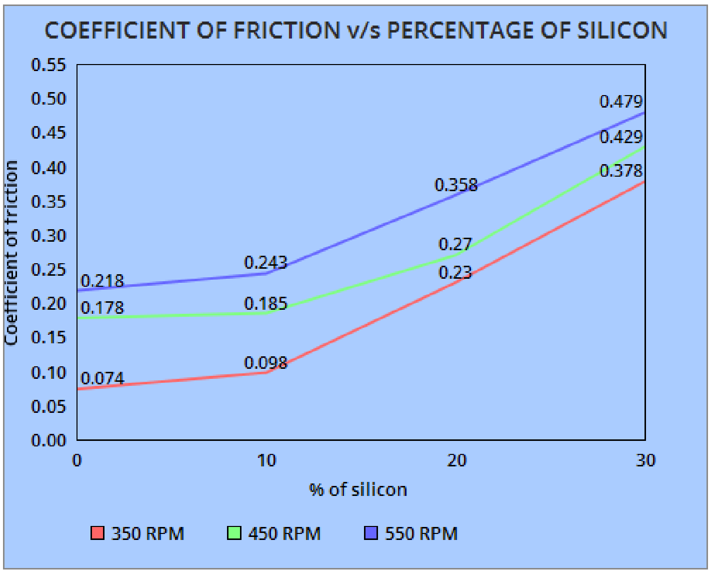

Figure.6: Variation of Coefficient of Friction with % of Silicon & Speed.

V. CONCLUSIONS

The following conclusions are inferred from this study.

- Thermal conductivity of hybrid polymer composite materials increases as the percentage of SiC filler material increases.
- The coefficient of thermal expansion decreases as the percentage of filler material SiC increases.
- By Thermogravimetric analysis it shows that the specimens gets decomposed around 275^0C to 280^0C.
- Increase in coefficient of friction with increase in percentage of SiC and speed.
- With the above results it is concluded that hybrid polymer composite materials can withstand high temperatures up to 300^0C. Silicon can be used as filler material in GFER composites successfully.

ACKNOWLEDGMENT

The Authors are very much grateful to Dr. K. Devendra, Dept. of Mechanical Engineering, SKSVMACET, Laxmeshwar, Karnataka, India. Dr. Basava T, Dept. of Mechanical Engineering, SDMIT, Ujire, Karnataka, India. for their valuable suggestions, guidance and support. I Thank GOD almighty for his grace throughout the work.

REFERENCES

[1] Malla Surya Teja, M V Ramana, D Sriramulu and C J Rao. “Experimental Investigation of Mechanical and Thermal properties of sisal fibre reinforced composite and effect of SiC filler material”. IOP Conf. Series: Materials Science and Engineering 149 (2016) 012095 doi:10.1088/1757-899X/149/1/012095.

[2] Krishnamachar Srinivas, Mysore Siddalingappa Bhagyashekar. “Thermal Conductivity Enhancement of Epoxy by Hybrid Particulate Fillers of Graphite and Silicon Carbide”. Journal of Minerals and Materials Characterization and Engineering, 2015, 3, 76-84.

[3] Tahir Ahamad, Rafiq Ahamad, Muhammad Kamran, Bambang Wahjoedi, Imran Ahakoor, Faraz Hussain, Farhad Riaz, Zuhaib Jamil, Sirjeel Isaac, Qaiser Ashraf. “Effect of Thal Silica sand nanoparticles and glass fiber reinforcement on epoxy-based hybrid composite”. Iran Polym J (2015) 24: 21-27.

[4] K. Devendra and T. Rangaswamy. “Thermal Conductivity and Thermal Expansion Coefficient of GFRP Composite Laminates with Fillers”. ISSN: 2320-2491 (2013).

[5] Alok Agrawal, and Alok Satapathy. “Development of a Heat Conduction Model and Investigation onThermal Conductivity Enhancement of AlN/Epoxy Composites”. Elsevier Procedia Engineering 51 (2013) 573 – 578.

[6] Watthanaphon Cheewawuttipong, Daisuke Fuoka, Shuichi Tanoue, Hideyuki Uematsu, and Yoshiyuki Iemoto. “Thermal and Mechanical Properties of Polypropylene/Boron Nitride Composites”. Elsevier Energy Procedia 34 (2013) 808 – 817.

[7] Ravi Kumar B N, Ananda.G.K, Shivaappa.D, Mahesh.H.R. “Effect of Fillers on Thermal and Fire Resistance Properties of E-Glass Epoxy Composites”. International Journal of Mechanical Engineering Research & Applications (IJMERA) Vol. 1 Issue 4, September – 2013.

[8] MaximeVilliere, Damien Lecointe, Vincent Sobotka, Nicolas Boyard, Didier Delaunay. “Experimental determination and modelling of thermal conductivity tensor of carbon/epoxy composite”. Elsevier Composites, part A46 (2013) 60-68.

[9] Yang Hua, Qing-Qing Ni, Atsuhiko Yamanaka, Yoshihiko Teramoto and Toshiaki Natsuki. “The Development of Composites with Negative Thermal Expansion Properties Using High Performance Fibers”. Advanced Composite Materials 20 (2011) 463–475.

[10] Basava T, A N Harirao. “Development of Graphite Particles filled Epoxy Resin Composite Material and its Erosive wear Behaviour”. AMAE Int. J. on Manufacturing & Material Science, Vol.01, No.02, November 2011.

[11] Th. Schubert, T. Weibgarber and B. Kieback. “Fabrication and properties of Copper/Carbon composites for thermal management applications”. Advanced Materials Research Vol. 59 (2009) pp169-172.

[12] Moran Wanga, Qinjun Kang b, Ning Pan. “Thermal conductivity enhancement of carbon fiber composites”. Applied Thermal Engineering 2008.

[13] Dr.Jawad Kadhim Uleiwi, Sura Salim. “Study of Thermal Characteristics of a Composite Specimen Experimentally and by Using Finite Element Method”. Eng. & Tech. Vol26, No4, 2008.

[14] Sudarisman, I.J. Davies, H. Hamada. “Compressive failure of unidirectional hybrid fibre-reinforced epoxy composites containing carbon and silicon carbide fibres”. Compos. Part A, 38(3) pp. 1070 - 1074 (2007).

[15] ZHENG Jing, SONG Wen-juan, MA Guang, JIA Zhi-hua. “Thermal expansion and mechanical properties of Al/Si composites fabricated by pressure infiltration” Science Press Trans. Nonferrous Met. Soc.China 17(2007) s326-s329.

[16] Brian Y. Lattimer, Jason Ouellette. “Properties of composite materials for thermal analysis involving fires” Elsevier Composites, part A37 (2006) 1068-1081.

[17] Bhyrav Mutnuri, “Thermal Conductivity Characterization of Composite Materials”. *Morgantown, West Virginia University, 2006*.

[18] Dilek Kumlutas, Ismail H, Tavaman, M. Turhan Coban. “Thermal conductivity of particle filled polyethylene composite materials”. Elsevier Composites Science and Technology 63 (2003) 113 – 117.