

Experimental Investigation on Thermal Properties of Fly Ash Reinforced Epoxy Composite

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ABSTRACT: The present investigation has focused on the maximum utilization of abundantly available industrial waste fly ash in a useful manner. The fly ash particle sizes ranging from (0.1-100 μ m) were used in the preparation of composites. Composite specimens of 100mm \times 6mm were fabricated at 0% 50%, 60% and 70% volume fraction of fly ash (FA). The thermal properties of the composites like Thermal conductivity, Specific heat capacity, Linear coefficient of Thermal expansion and Thermal diffusivity were experimentally determined in the engineering laboratory. The Scanning Electron Microscopy (SEM) analysis was carried out and result shows that good interfacial interactions or adhesion existed between the fly ash particles and the epoxy matrix. The increase of fly ash percentage in composite increases the thermal properties, which enhances thermal insulation capability of reinforced epoxy composites.

KEYWORDS: Epoxy resin, Fly ash, Thermal conductivity, Specific heat capacity, Thermal diffusivity, Thermal expansion, Guarded heat flow meter, Dilatometer.

I. INTRODUCTION

Polymer matrix composites are widely used because of their favourable mechanical and thermal properties. The word composite material signifies that it is a combination of two or more materials that differ in physical form and chemical composition, combined at a macroscopic scale to form a useful third material. Out of which one material is called as reinforcing phase in the form of fibres or particles and is embedded in the other material called matrix phase. Different materials are used in production of composites to rectify a weakness in one material by the strength in other material. Materials of different compositions are combined on a microscopic scale, such as in alloying of metals, but the resulting material is macroscopically homogeneous, i.e., the components cannot be distinguished by the naked eye and essentially act together. The advantage of composite materials, if well designed, they usually exhibit the properties distinctly different from those of the individual constituents and often some qualities that neither constituent possesses.

Some of the characteristic properties of a composite material are, Strength, Stiffness, Corrosion Resistance, Wear Resistance, Fatigue life, Thermal Insulation, Thermal Conductivity, Weight, etc. Composite materials are designed to meet the desire set of engineering properties and characteristics. Anyhow, not all of these properties are improved at the same time or is there usually any requirement to do so [1].

Dispersion of the constituent materials and strength of composite material are characterized by a microstructure consisting of an elemental matrix within which fine particles of 1 to 100 μ m in diameter are uniformly dispersed in a volume concentration of 50 to 70% [2].

II. RELATED WORK

Most of the investigations are aimed at improving mechanical and thermal properties of polymer composite rather than attempting to enhance its insulation capabilities variety of particulates have been used as fillers. However few attempts have been made to investigate thermal insulation capabilities of fly ash reinforced Epoxy composites.

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Arun Kumar Rout, Alok Satapathy, Ashok Kumar Sahoo and Dipak Kumar Jesthi [1] have presented paper on mechanical and thermal properties of rice husk particles reinforced with epoxy composites and found that the effective thermal conductivity and CTE of pure epoxy is diminished by 74.38% and 22% respectively and the glass transition temperature (T_g) is expanded by 14°C with the addition of 15 wt% rice husk content.

K. Devendra and T. Rangaswamy [2] have studied the thermal properties of GFRP composite laminates with fillers. The matrix material L-12 and hardener K-6 was used for the fabrication of GFRP laminates, hand layup technique is adapted. Epoxy based composite laminates with various concentrations up to 15% of Fly ash was used. Thermal conductivity test was carried out in accordance with ASTM E1530 standard. Experimental results show that the composite with 15% FA exhibits the lower thermal conductivity and thermal expansion co-efficient.

Eeday.Saranya, Goteti, Satyanarayana, Anne. Srihari Prasad [3] has studied the thermal properties on the Borassus flabefiller reinforced composites with the addition of fly ash. Four different sets of composites are prepared with different volumes of reinforcement material 0%, 10%, 20% and 30% fly ash and at different ranges 30-120°C. They have concluded that the maximum thermal conductivity can be obtained for toddy palm with 10% FA at 120°C

III. MATERIALS AND METHODOLOGY

Matrix material

Araldite LY556 is an unmodified liquid epoxy 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 and the corresponding hardener (HY 951) are mixed in a ratio of 10:1 by weight as recommended.

Table1. Physical properties of epoxy resin (LY 556) and Hardener (HY 951)

	Epoxy resin (LY 556)	Hardener (HY 951)
Viscosity	1350 – 2000 MPa-s	10-20 MPa-s
Specific Gravity	1.1-1.2 g/cm ³	0.98 g/cm ³
Appearance	clear liquid	clear liquid
Flash point	160°C	110°C
Epoxy content	4.20-4.35 eq/kg	--

Fiber (Fly ash)

Fly Ash is the residue or waste generated abundantly by the combustion of coal in thermal power plants. Due to the environmental concerns and disposal difficulties, the utilization of fly ash has become of great importance, although the beneficial use of fly ash in concrete, brick making, soil stabilization treatment and other applications have been recognized, only a small quantity of the total fly ash is being utilized in our country currently in such applications. In this work we used 'Class-F' fly ash for the preparation of the composites.

Composite fabrication

Hand layup is a simple technique used for production of composites. To prepare specimens of required dimensions PVC pipes was cut to required sizes. The following table shows the compositions of different composites used for the preparation of composites.

Table2. Composition of different composites

Specimen	%by weight of epoxy	%by weight of fly ash
S1	100	00
S2	50	50
S3	40	60
S4	30	70

IV. EXPERIMENTAL WORK

A. THERMAL CONDUCTIVITY

Thermal conductivity measurements are carried out under steady state condition. According to ASTM E1530 guarded heat flow meter method, disc shaped specimens with diameter of 100mm and thickness of 6mm are used for thermal conductivity measurements. The constant heat is applied from one side of the specimen. When the thermal equilibrium is attained and the system approaches to steady state situation, the temperature of top and bottom surfaces were recorded by using thermocouples installed on top and bottom surfaces of the specimen. Knowing the values of heat supplied, temperatures and thickness the thermal conductivity was determined by employing one-dimensional Fourier’s law of conduction.

$$Q = -K \times A \times \frac{dt}{dx} \times W$$

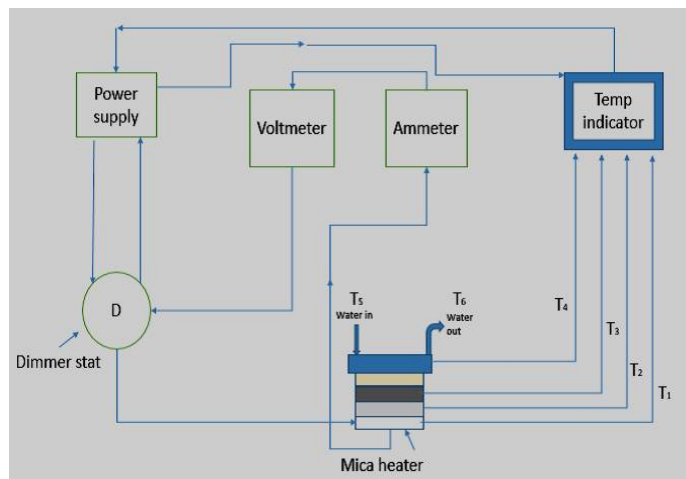


Fig 1. Electrical flow diagram of the thermal conductivity test setup

B. SPECIFIC HEAT

Specimen whose specific heat is to be measured is heated with the help of mica heater by supplying heat with dimmer stat, up to certain temperature. Once the specimen reaches the desired temperature it is dipped inside the insulated container. The heat transfer will take place from composite to surrounding water. After some time interval both metal temperature and water temperature becomes equal. That temperature is used as the final temperature of water as well as composite.

Now by usual proceeding i.e. by using the formula ($Q = mCp\Delta t$) (By balancing this equation) specific heat capacity of composite is calculated. Electrical flow diagram for the measurement of specific heat capacity is shown in below figure.

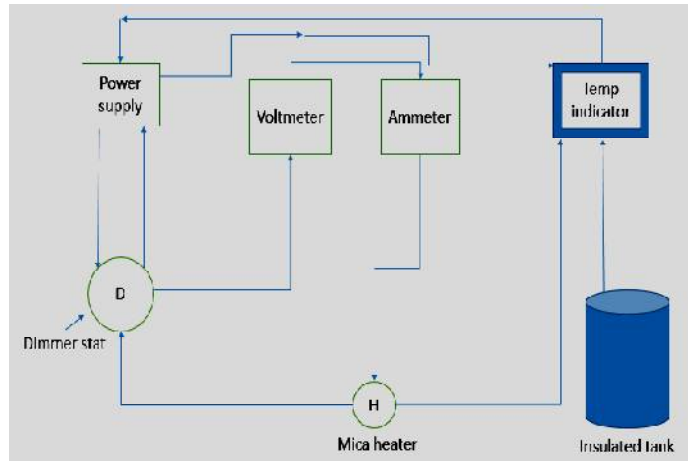


Fig 2. Electrical flow diagram of the specific heat test setup

C. THERMAL DIFFUSIVITY

It measures the capability of a material to transfer thermal energy relative to its ability to withheld thermal energy. In heat transfer analysis, thermal diffusivity is the thermal conductivity divided by density and specific heat capacity at constant pressure.

$$\alpha = \frac{k}{\rho C_p}$$

D. CO-EFFICIENT OF THERMAL EXPANSION

In simple terms it can be defined as the ratio of change in length to product of temperature change and original length. Dilatometer test setup is used for measure the linear coefficient of thermal expansion of composites.

$$CTE = \frac{\Delta L}{L \Delta T}$$

V. EXPERIMENTAL RESULTS

Thermal conductivity

The thermal conductivity of the composite material is influenced by its compositions. As the filler material Fly ash is added to the composite the thermal conductivity of the compositions reduces as compared to that of the pure epoxy. It is observed from the figure that the composition S4 shows maximum decrease of about 68.2% compared to pure epoxy this is due to decreasing percentage of epoxy and increasing percentage of Fly ash.

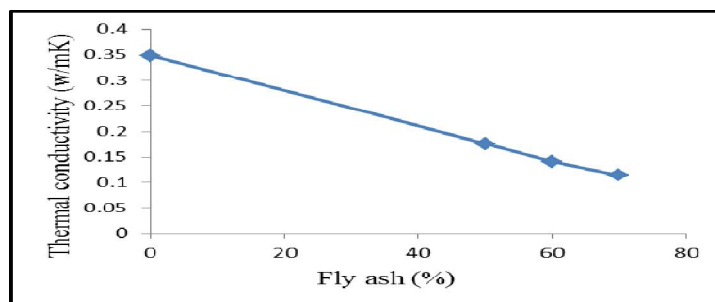


Fig 3. Variation of thermal conductivity for different composition of fly ash

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Specific heat

Figure illustrates the variation of specific heat carrying capacity of composite material with different weight fractions of fly ash particles. It is observed from the graph that specific heat carrying capacity is increasing with increase in fly ash percentage. This is due to higher specific heat carrying capacity fly ash particles compared to Epoxy.

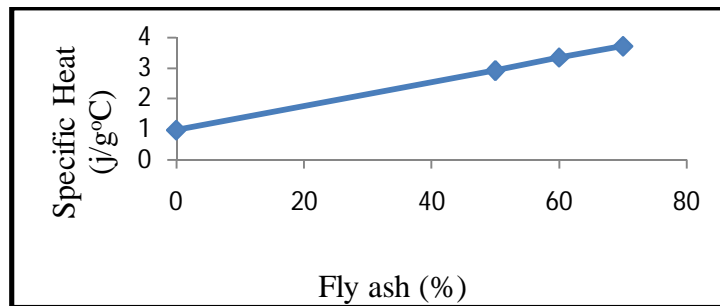


Fig 4. Shows the specific heat of different composition of fly ash

Thermal diffusivity

The effect of various percentages of fly ash particles on thermal diffusivity of Epoxy/fly ash PMCs is presented in Figure. It is evident from the figure that the incorporation of fly ash particles significantly reduces thermal diffusivity. This may be due to low thermal conductivity, low thermal expansion and high specific heat capacity of composites. The uniform distribution of fly ash particles provides good strength hence thermal diffusivity.

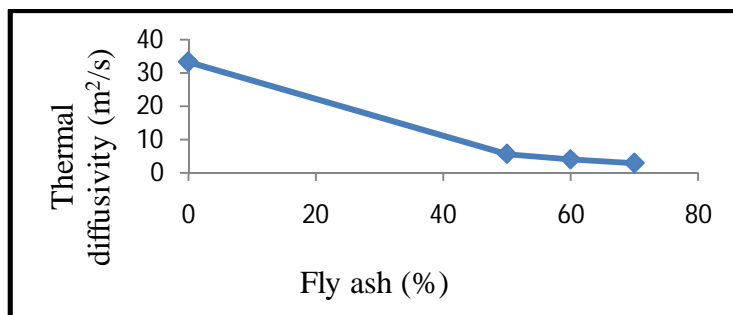


Fig 5. Variation of thermal diffusivity of different composition of fly ash

Co-efficient of Thermal expansion

It is observed from the figure that with increase in temperature thermal expansion of composite materials is increases. This increase in the thermal expansion of material is due to higher kinetic energy of molecules in the matrix material at an elevated temperature. It is observed that with increase in FA percentage and decreasing the epoxy percentage shows lower thermal expansion compared to that of pure epoxy. For 70% FA a maximum decrease of about 65.2% is observed compared to pure epoxy.

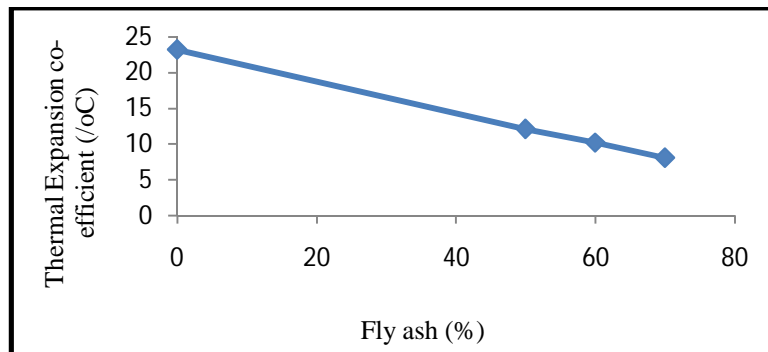


Fig 6. Shows the specific thermal expansion of different composition of fly ash

SEM Micrographs of composites

The Figures show microstructure of Epoxy with 50, 60 and 70% weight fractions of fly ash particles sized within 0-100 μ m. It is clearly observed from figure that epoxy with 50% fly ash particles are uniformly distributed in Epoxy. With increase in the dispersion of fly ash particles into the matrix they were not distributed well. Scanning electron microscopy analysis showed that there was poor interfacial adhesion (bonding) between the fly ash particles and the epoxy with 60 and 70% of FA when compared to 50% FA.

With increase in FA percentage some of the mechanical properties may be decreased but thermal properties like thermal conductivity, specific heat thermal diffusivity and thermal expansion are enhanced compared to pure epoxy.

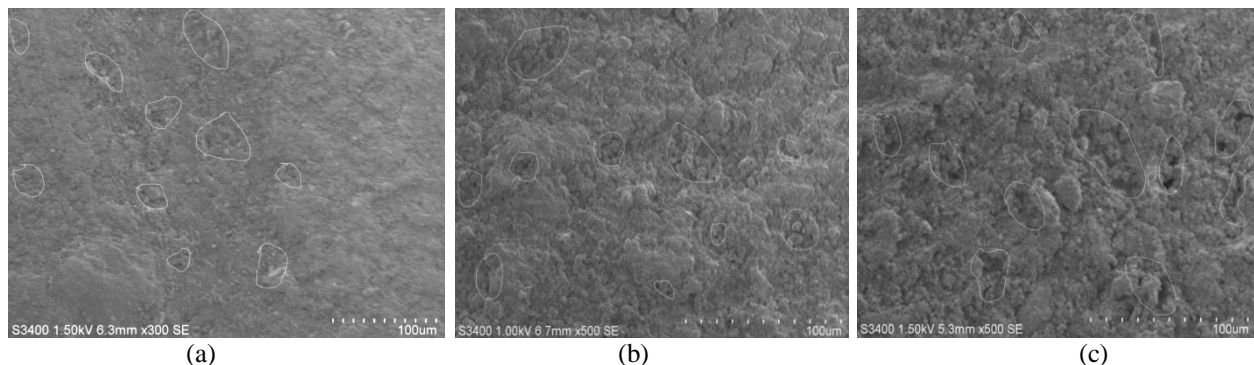


Fig 7. Microstructure of composite with (a) 50% of Fly ash. (b) 60% of Fly ash. (c) 70% of Fly ash

V. CONCLUSION

The thermal properties of the composite such as thermal conductivity, specific heat and thermal diffusivity of the composites are measured with and without the addition of fly ash.

- It is observed that the incorporation of fly ash particles results in decrease in the thermal conductivity compared to that of pure epoxy thereby improves its thermal insulation capability. This decrease in the thermal conductivity is widely accepted in the automobile and aerospace applications.
- It is observed that composite with fly ash particles exhibit higher specific heat carrying capacity than composite without fly ash because higher fly ash content in composite higher will be the heat carrying capacity of the composite.
- It shows that with increasing the fly ash percentage in epoxy reduces the Thermal expansion. However it will not respond quickly to thermal loads or deform faster since it can be used in high temperature regions.

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- Thermal diffusivity is decreased with addition of fly ash. This is because the composite has higher specific heat. It requires more heat to heat up.

REFERENCES

- [1]. A.v.pradeep, P.srinivas Reddy and Chaitanya Mayee “Effect of flyash on mechanical properties of glass fiber polymer composites” Proceeding of 3rd International conference, May 2014 pp 110-112
- [2]. N. Senthilkumar, K. Kalaichelvan and K. Elangovan “Mechanical behaviour of aluminium particulate epoxy composite – experimental study and numerical simulation” international journal of Mechanical and materials Engineering, volume 7, issue 3, pp. 214-221
- [3]. K. Devendra and T.Rangaswamy, “Thermal Conductivity and Thermal Expansion Co-efficient of GFRP Laminates with Fillers”, International journal of Science and technology, Volume 2 Issue 5 September 2013 pp 39-44.
- [4]. V.K Joshi, Arun Kumar Chaudry, Vijay Upreti, “Investigation of Thermo-Mechanical Properties of reinforced Rice husk Composites” International journal for Research in Emerging science and technology, Volume 2, Issue 7, July2015 pp 1-7.
- [5]. Arun kumar Rout, AlokSatapathy, Ashok Kumar Sahoo, DipakkumarJesthi, “A study on Evaluation of Mechanical and Thermal properties of Rice husk filled Epoxy composites” , 5th International & 26th All India Manufacturing Technology, Design and Research Conference December 2014, pp 828.1-828.5.
- [6]. A.Vikram, V.Nikhil Murthy, C.B.N Murthy, “Mechanical and Thermal properties of Fiber/Epoxy composites with different fiber-orientation”, International journal & magazine of engineering, technology, Management and research, volume 2, issue 7, July 2015 pp 1394-1403.
- [7]. Eeday saranya, Goeti., satyanarayana anne “Experimental investigation of thermal properties of Borassus flabe filler reinforced composite and effect of addition of flyash” international journal of Engineering trends and technology, volume 15, Issue 8, September 2014 pp379-382.
- [8]. Manoj single and vikas chawla, “Mechanical properties of Epoxy resin-Fly ash composite”, journal of minerals and material characterization and engineering, volume 9, issue 3, 2010 pp 199-210.
- [9]. “Heat and mass transfer book” by R.K Rajput, 5th Edition, S. Chand publication.
- [10]. Ashutosh pattanaik, Mantra Prasad satapathy, Subash Chandra mishra, “Dry sliding wear behaviour of Epoxy flyash composite with Taguchi optimization” Elsevier publications, Engineering science and technology, November 2015pp 1-7 .
- [11]. “Analysis of Heat Transfer” by E. R. G. Eckerst ad R. M. Drake. Springer Publication.
- [12]. “Heat transfer Laboratory Manual” Bapuji Institute of Engineering and Technology, Davangere.