EXPERIMENTAL INVESTIGATION ON THERMAL PROPERTIES OF BAGASSE FLY ASH REINFORCED EPOXY COMPOSITE

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Abstract - *The present investigation has focused on the maximum utilization of abundantly available industrial waste bagasse fly ash in a useful manner. The bagasse ash particle sizes ranging from (1-150μm and 150-325μm) were used in the preparation of composites. Composite specimens of 100mm× 6mm were fabricated at 0%, 30%, 40% and 50%volume fraction of bagasse fly ash (BFA). The thermal properties of the composites like Thermal conductivity, Specific heat capacity, and linear coefficient of Thermal expansion, Thermal diffusivity were experimentally determined in the engineering laboratory .FEM analysis is carried out to know the temperature distribution across the composite. Increase of bagasse fly ash percentage in composite, increases thermal properties which enhance thermal insulation capability of reinforced epoxy composites.*

Key Words: Epoxy resin, bagasse fly ash, Thermal conductivity, Specific heat capacity, Thermal diffusivity, Thermal expansion,

1. INTRODUCTION

A polymer matrix composite (PMC) constitutes an important class of design and weight efficient structural materials that are encouraging in every sphere of engineering applications. Among the various discontinuously dispersed solids used as reinforcement, bagasse fly ash is one of the most abundant, inexpensive and low density reinforcement materials available as solid waste by-product during combustion of sugar cane bagasse in thermal power plants. Composite materials with bagasse fly ash as reinforcement are likely to overcome the cost barrier for wide spread applications in aerospace, automotive, small engine applications etc. Most of times engineers are facing a problem of developing a new material that has light weight, low cost and good mechanical and thermal properties.

A promising option to this task is to use a low density particulate material like fly ash in a polymer matrix to form a polymer composite. Bagasse ash is results of ignition of sugar cane bagasse at thermal power stations. Researchers are currently investigating the use of ash for composite production since ash is an abundant waste, is renewable and has low bulk density. Bagasse ash had been applied in other areas like manufacturing insulating powder, production of refractory bricks, cement production and sand Crete block production. However there are limited applications of bagasse ash in composite production.

1.1 Objectives of the Study

The main objective of this project is to characterize composite materials produced from different compositions of epoxy and bagasse fly ash. The specific objectives of study are:

1. To produce epoxy-bagasse ash composite using bagasse ash considered as an industrial waste as a filler.
2. Preparation of the test specimens as per ASTM standards
3. To study the effect of bagasse ash volume fraction on some thermal properties of epoxy reinforced bagasse ash composite and ascertain the suitability of the composite for engineering applications.
4. To conduct scanning electron microscopy analysis on epoxy –bagasse fly ash composite and study the impact of variation of bagasse ash volume fractions on the microstructure of composite.

1.2 Justification of the Study

This study is valuable in understanding the potentials of fly ash as filler in composite production and the behavior of Epoxy resins. The study is useful to engineers and researchers in the composite industry because it will help to suggest ways of improving the thermal properties of the epoxy reinforced fly ash composite. Proper understanding of the microstructure and mechanical and thermal properties of composites will help to ascertain the engineering application of composite in structures, industries, electronics, oil and gas, and other industrial production.

2. MATERIALS AND METHODOLOGY

2.1 Epoxy resin

It is a polymer or poly epoxide constitutes of two or more epoxy groups. It is a thermosetting polymer produced from the reaction of epoxide resin with a polyamine hardener. The resin used in the preparation of composites is Araldite LY 556 which is an unmodified liquid epoxy resin chemically belong to the epoxide family is used as the matrix phase.

The common name of matrix material (Araldite LY556) is Bisphenol-A-Diglycidyl-Ether. Epoxy resin and the corresponding hardener HY 951 (aliphatic primary amine) are blended in a ratio of 10:1 by weight as prescribed.

Along with Hardener HY 951 the matrix phase provides a low-viscosity, dissolvable free, room temperature curing.

2.2 Bagasse Fly Ash

Bagasse ash (BFA), a waste by-product is generated by combustion of sugar cane bagasse in thermal power stations. Typically, after the sugar cane is crushed in the sugar mills cane juice is separated and remaining is bagasse and this bagasse is dried under sun light and blown with air into the boiler's combustion chamber where it instantly gets ignites, generates heat and produces a molten mineral residue.

2.3 Preparation of Composite Mould

PVC pipes were cut and formed into various sizes that served as molds for the test samples. The testing techniques for the composite required that four sets of pattern (thermal conductivity, thermal expansion, specific heat) should be produced. The patterns were made according to the required dimensions of the test samples. The moulds were constructed to with + 5mm to give allowance for machining, and the surfaces were rubbed with wax releaser to ensure easy removal of the composite. Figure below shows the mould used for composite production.

Fig- 1: Mould used for specimen preparation

2.4 Composite Fabrication

Epoxy resin (LY556) and the corresponding hardener (HY951) are mixed in a ratio of 10:1 by weight as suggested. Bagasse ash is incorporated in epoxy resin (density 1.57 gm/cc) to prepare the composites. Composites of four different compositions (with 50, 60 and 70 vol % of epoxy respectively) are made. The composites are cast by traditionally hand-lay-up technique in order to obtain to get required specimen. The casted specimens are left to cure at room temperature for about 24 hours after which the pipes are broken and samples are released. Specimens of suitable dimension are machined to required dimensions for further physical characterization and thermal conductivity test.

Table-1: Composition of different composites

2	Ash Size	%by weight of epoxy	%by weight of ash
S1	-	100	0
S2	1-150μm	50	50
S3	1-150μm	60	40
S4	1-150μm	70	30
S5	150-325μm	50	50
S6	150-325μm	60	40
S7	150-325μm	70	30

3. EXPERIMENTAL WORK

3.1 Thermal conductivity

Thermal conductivity is defined as the ability of material to conduct heat. Many engineering situations involve the use of composite materials that consists of two or more materials of different thermal conductivity. Thermal conductivity measurements are carried out under steady state condition. According to ASTME1530 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.

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

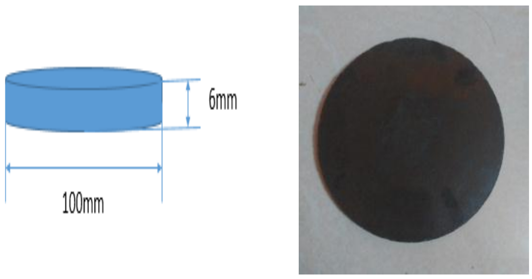

Fig- 2: Test specimen for thermal conductivity

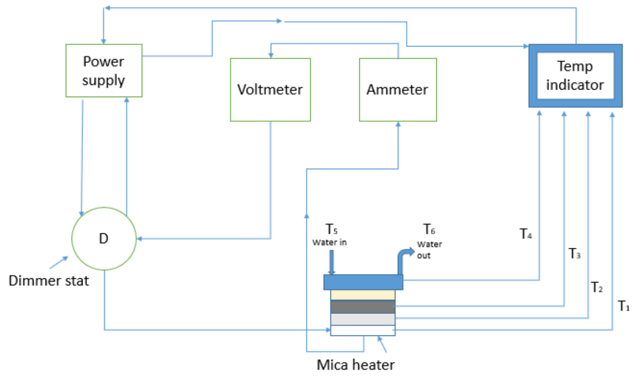

Fig-4: Electrical flow diagram of the thermal conductivity test setup

3.2 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 takes 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. Electrical flow diagram for the measurement of specific heat capacity is shown in below figure.

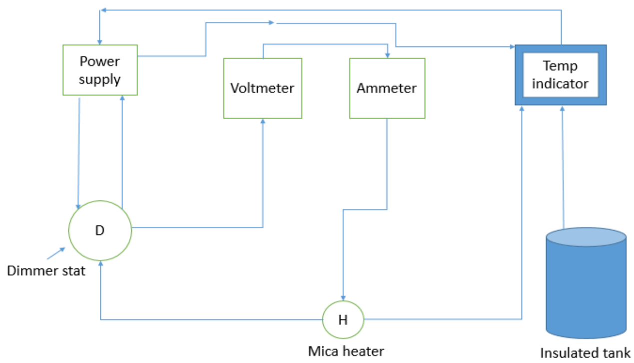

Fig- 5: Electric flow diagram of the specific heat test setup

3.3 Coefficient of thermal expansion

In simple terms it can be defined as change in measurements of the material per unit length. In other words it is also defied as the ratio of change in length to product of temperature change and original length.

CTE=ΔL/LΔT

Where ΔL = change in length

L = original length

ΔT = change in temperature

Apparatus which is used to measure the linear coefficient of thermal expansion is Dilatometer. Standard Specimen dimension required for experimental work is as follows

Diameter of specimen – 08mm

Length of specimen – 40mm

3.4 Thermal diffusivity

In heat transfer analysis, Thermal diffusivity of the material is defined as the thermal conductivity divided by density and specific heat capacity at constant pressure. It measures the capability of a material to transfer thermal energy relative to its capacity to withheld thermal energy. It has the SI unit of m^2/s. Thermal diffusivity is usually denoted by "α" or "D". The formula used to calculate thermal diffusivity is,

$\alpha = k/\rho C_p$

Where, K is thermal1conductivity, W/m-K

ρ is1density, kg/m^3

Cp is specific1heat capacity, J/kg-K

By using above formula the required thermal diffusivity for all the different fly ash epoxy composite can be calculated.

3.5 Finite element method (Analysis)

Some of the assumption are maid out in getting the results, are as fallows.

Both matrix and filler are homogeneous and isotropic.

- Thermal contact resistance between filler and matrix interface is very small.
- Composite laminate is free from voids.
- Heat loss due to radiation and convection effect is neglected.

In ANSYS methodology, the thermal analysis is selected in preferences .Next we select the proper element and in material properties isotropic analysis the material conductivity (k) (in W/m-^{0}C) is entered. In modelling stage the solid circular disc is made with required radius (mm) and extruded to its normal direction to attain its thickness. Meshing is considered as discretization of the specimen into elements of finite number and each element is solved and added to obtain temperature distribution results. By using two approaches we can get the temperature distribution across the composites. In first approach apply thermal loads in terms of temperature at both surfaces of circular disc and without considering air heat transfer coefficient (h). In second approach apply thermal loads in terms of temperature at single side with considering air heat transfer coefficient (h) and ambient air temperature. By using these two approaches we can get the temperature distribution across the composites.

4. RESULTS AND DISCUSSION

4.1Thermal conductivity of composite

The thermal conductivity of the composite material is influenced by its compositions and size of the ash. 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 below figures that the composition S5 shows maximum decrease of about 45% compared to pure epoxy this is due to decreasing percentage of epoxy and increasing percentage of fly ash.

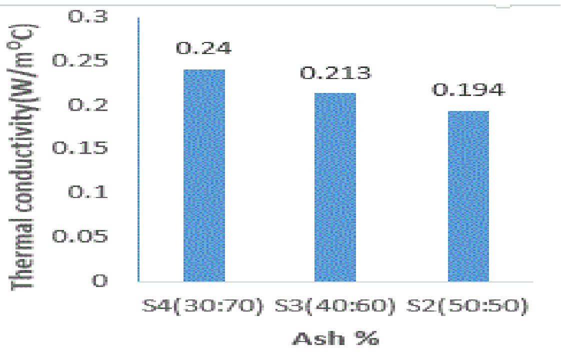

Fig-6: shows the variation of thermal conductivity For different composition of 1-150µm size ash

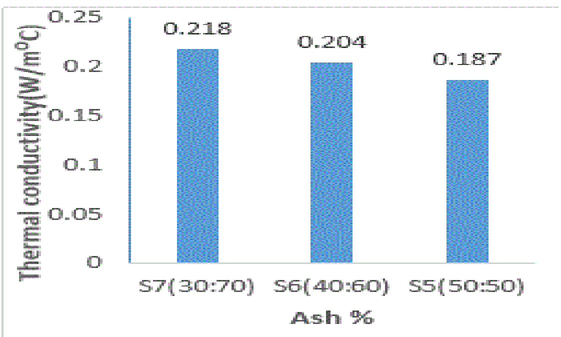

Fig-7: shows the variation of thermal conductivity For different composition of 150-325µm size ash

4.2 Specific heat capacity of composite

Fig 8 and fig 9 shows variation of specific heat capacity of composite with different weight fractions and size of bagasse ash. In this experimental work it is observed that specific heat capacity of Epoxy is 0.988J/g-°C. From the above graph it is observed that specific heat carrying capacity of composite is gradually increasing with increase in bagasse ash percentage. It is mainly due to the fact that bagasse ash particle exhibit higher specific heat capacity. As a result of this specific heat capacity of composite also increases. This enhanced specific heat capacity is most widely accepted in automobile and aerospace industries.

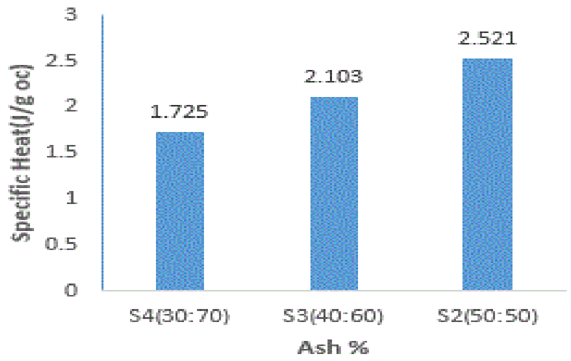

Fig-8: shows the variation of specific heat capacity for different composition of 1- 150µm size ash

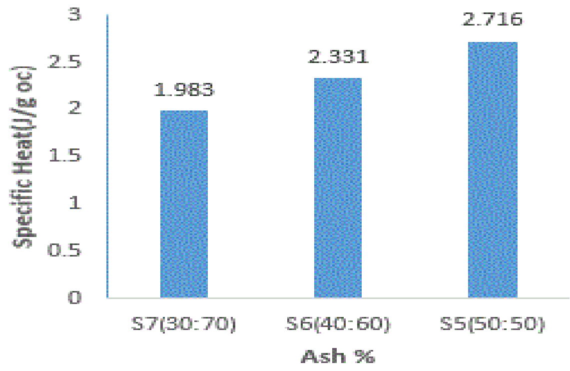

Fig-9:shows the variation of specific heat capacity for different composition of 150-325µm size ash

4.3 Thermal diffusivity of composite

It is measure of the capability of a material to conduct the thermal energy relative to its ability to store the thermal energy.

It is evident from the figure that the incorporation of fly ash particles significantly reduces thermal diffusivity. This is 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.

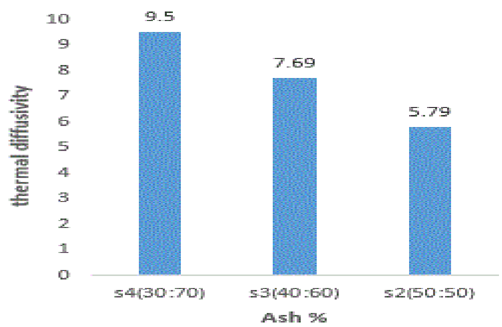

Fig-10: shows the variation of thermal diffusivity for different composition of 1- 150µm size ash

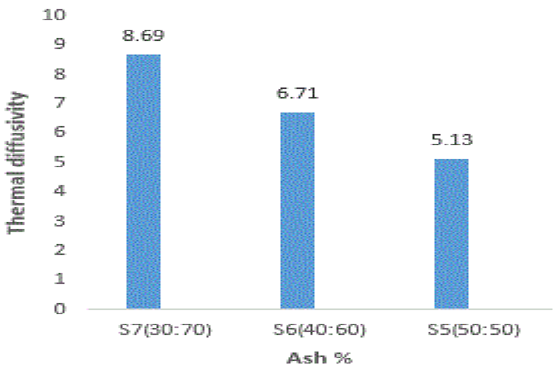

Fig-11:shows the variation of thermal diffusivity for different composition of 150-325µm size ash

4.4 Coefficient of thermal Expansion

It is observed from the figure 12 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 bagasse fly ash percentage and decreasing the epoxy percentage shows lower thermal expansion compared to that of pure epoxy.

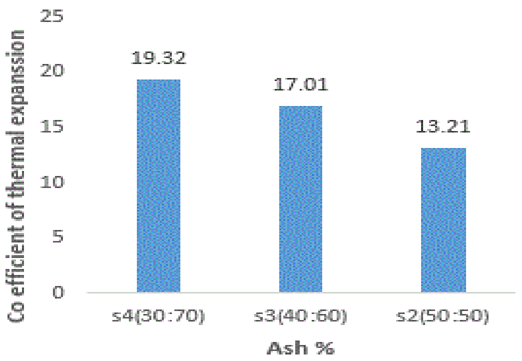

Fig-12: shows the variation of Co-efficient of thermal expansion of the composite material with different weight fractions of bagasse ash.

4.5 Finite element method (Analysis)

As we know that experimental method requires more time to attain steady state, and we cannot operate to extreme condition due to some reasons, and we cannot vary the material properties.

An alternate solution is the use of advanced computational tools such Finite Element Method (FEM). FEM's main advantage is that it produces a much more detailed set of results than experimental investigations and is often quicker and less expensive.

The advantages of FEM are

1. Safe simulation of potentially dangerous, destructive or impractical load conditions and failure modes.

2. The simultaneous calculation and visual representation of a wide variety of physical parameters such as temperature, enabling the designer to rapidly analyses performance and possible modifications.

3. Evaluation and optimization of different designs

4. Quick variants analysis of basic solutions

By absorbing both experimental and analytical results we can come to know that ANSYS gives ±2^0 temperature variation from experimental value

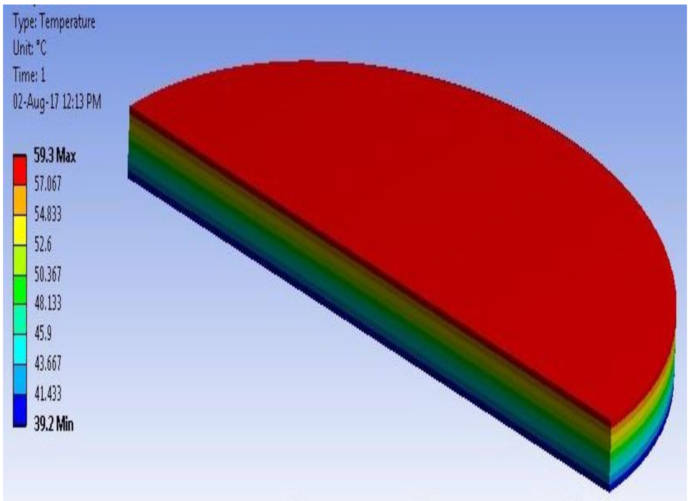

Fig-13; shows the contour plot temperature distribution along the composite (1-150µm size, 50BFA: 50 Epoxy) without considering convection effect

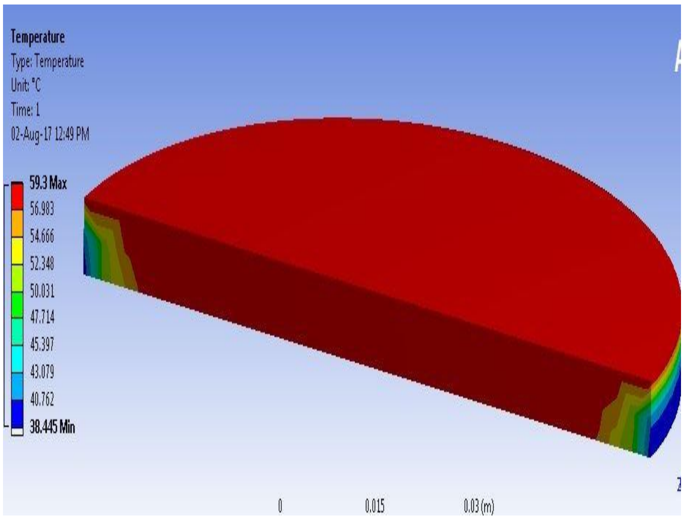

Fig-14:shows the contour plot temperature distribution along the composite(1-150µm size,50BFA:50 Epoxy) with considering convection effect

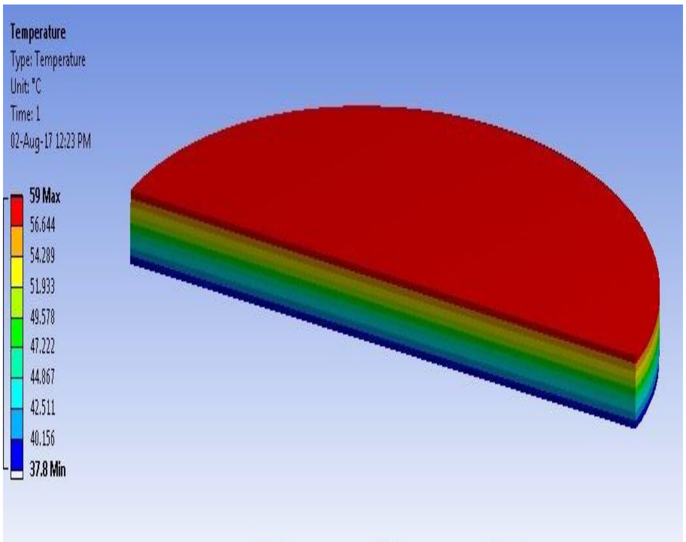

Fig-15:shows the contour plot temperature distribution along the composite(150-325μm size,50BFA:50 Epoxy) without considering convection effect

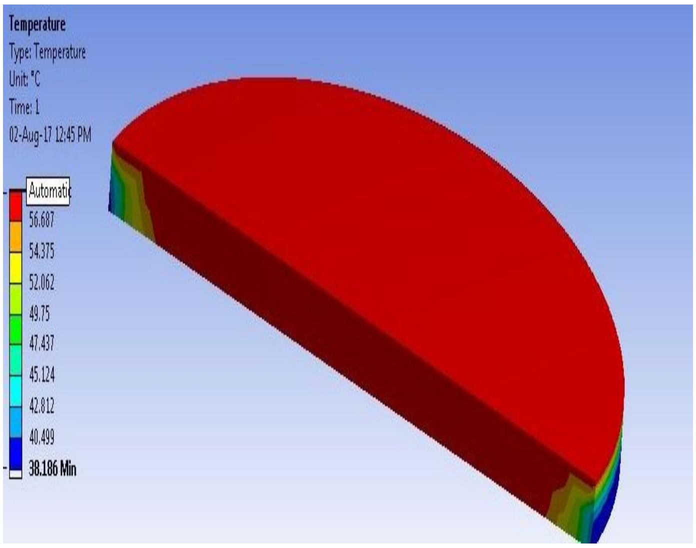

Fig-16:shows the contour plot temperature distribution along the composite (150-325μm size,50BFA:50 Epoxy) with considering convection effect

5. CONCLUSIONS

This experimental investigation of thermal properties of bagasse ash reinforced epoxy composite have led to the following conclusions

1. It is observed that the incorporation of bagasse fly ash particles results in decrease in the thermal conductivity compared to that of pure Epoxy. A maximum decrease of about 44.25% in thermal conductivity of epoxy is observed with 50%wt of bagasse fly ash in the composite there by improves its thermal insulation capability. This decrease in the thermal conductivity is widely accepted in the automobile and aerospace applications.

2. It is observed that the thermal expansion is greatly influenced with the addition of bagasse fly ash particles. Coefficient of thermal expansion of pure Epoxy is 23.23×10^{8} at temperature range of around 45-75 °C and for composite with 50% fly ash, thermal expansion is 13.21×10^{-8} /°C. In practice it shows that with increasing the bagasse 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.

3. The specific heat capacity of composite with bagasse fly ash particles exhibit higher specific heat carrying capacity than composite without fly ash. For pure epoxy it is around 1.000J/g°C and for epoxy with 50% weight fraction bagasse ash composite it is observed as 2.713J/g°C. Higher fly ash content in composite higher will be the heat carrying capacity of the composite.

4. Thermal diffusivity of composite with different weight fractions of fly ash is calculated. In this work thermal diffusivity of pure epoxy is observed as $3.324\times10^{-7} m^2/s$. Thermal diffusivity is decreased with addition of fly ash, thus its ability to store the thermal energy will be increases with increase in the bagasse ash percentage.

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