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Experimental and Comparative Study of Thermal Conductivity and Mechanical Property of CNT Based Fly Ash Waste Composites

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ABSTRACT:

Carbon nanotubes (CNTs) reinforced industrial waste fly ash-based polymer nanocomposites are created in this study. The SEM approach revealed the strong interfacial adhesion between CNT-fly ash and epoxy. A 20 vol percent CNT reinforced nanocomposite sample has a low water absorption of about 0.17 percent. Due to the hydrophilic and polar properties of CNT, water absorption in fly ash-based nanocomposites increases slightly as CNT content increases. The flexural strength of nanocomposites increases as the number of carbon nanotubes increases. The great dispersion of CNT in epoxy polymer and the weakening of Vander Walls forces are responsible for the increased flexural strength. Due to the conducting nature of CNT, the material's thermal conductivity improves as well. In 3 percent of CNT reinforced in fly ash waste composites, high flexural strength was achieved, and in 4 percent of CNT reinforced in fly ash waste composites, high thermal conductivity was achieved. The conducting nature of CNT and the generation of space charge dispersion in polymer matrix was linked to this behavior. CNT is used to build vehicle body components, in the form of self-healing materials, and in electric work due to flame retardant qualities.

Introduction:

1.1 Fly ash:

Fly ash is a thin gray powder made up primarily of spherical, glassy particles that is a byproduct of coal-fired power plants. Pozzolanic qualities refer to the ability of fly ash to react with lime to generate cementitious compounds. A additional cementitious substance is what it's called.

Fly ash, flue ash, coal ash, or pulverized fuel ash (in the United Kingdom) — plural tantrum: coal combustion residuals (CCRs) – is a coal combustion product made up of particulates (fine particles of burned fuel) and flue gases that are expelled from coal-fired boilers. Bottom ash is ash that settles at the bottom of a boiler's combustion chamber (also known as a firebox). Fly ash is often caught by electrostatic precipitators or other particle filtration equipment before the flue gases reach the chimneys in modern coal-fired power plants. It's referred to as coal ash when it's combined with bottom ash scraped from the boiler's bottom.

The primary mineral components in coal-bearing rock layers are silicon dioxide ($SiO2$) (both amorphous and crystalline), aluminum oxide ($Al2O3$), and calcium oxide (CaO), which are all present in significant levels in fly ash.

Gallium, arsenic, beryllium, boron, cadmium, chromium, hexavalent chromium, cobalt, lead, manganese, mercury, molybdenum, selenium, strontium, thallium, and vanadium, as well as very small concentrations of dioxins and PAH compounds, are minor constituents of fly ash that depend on the specific coal bed composition. It also contains carbon that hasn't been burned.

Fly ash was once commonly thrown into the atmosphere, but new air pollution control regulations require it to be gathered first and then released using pollution control technology. Fly ash is often stockpiled at coal power plants or disposed of in landfills in the United States. About 43% of it is recycled, and it is frequently used as a pozzolan in the manufacture of hydraulic cement or hydraulic plaster, as well as a replacement or partial replacement for Portland cement in the construction of concrete. Pezzoli's ensures that concrete and plaster set properly and that concrete is more resistant to damp weather and chemical attack.

When fly (or bottom) ash is not made from coal, such as when solid waste is burnt to generate power at a waste-to-energy facility, the ash may include higher amounts of toxins than coal ash. The ash created in this situation is frequently designated as hazardous waste.

While suspended in the exhaust gases, fly ash material solidifies and is collected by electrostatic precipitators or filter bags. Fly ash particles are generally spherical in shape and range in size from 0.5 m to 300 m because they harden quickly while suspended in exhaust fumes. The quick cooling has the effect of allowing few minerals to form, resulting in mostly amorphous, quenched glass. Some refractory phases in pulverized coal, however, do not melt (completely) and remain crystalline. As a result, fly ash is a heterogeneous substance.

The main chemical components found in fly ashes are $SiO2$, $Al2O3$, $Fe2O3$, and, on rare occasions, CaO.

[needs citation] Fly ashes have a wide range of mineralogy. Glass, quartz, mullite, and the iron oxides hematite, magnetite, and/or maghemite are the most common phases found. Cristobalite, anhydrite, free lime, periclase, calcite, sylvite, halite, portlandite, rutile, and anatase are some of the other phases that are commonly found. Ca-rich fly ashes contain the calcium-bearing minerals anorthite, gehlenite, akermanite, as well as calcium silicates and calcium aluminates similar to those found in Portland cement. The mercury level in bituminous coal can exceed 1 ppm, however it is usually in the range of 0.01–1 ppm. Other trace element concentrations vary depending on the type of coal combusted to create it.

1.2 Types of Fly ash:

The American Society for Testing and Materials (ASTM) C618 divides fly ash into two categories: Class F and Class C. The amount of calcium, silica, alumina, and iron in the ash is the main distinction between these classes. The chemical composition of the coal burned has a significant impact on the chemical properties of the fly ash (i.e., anthracite, bituminous, and lignite).

Although this may not be necessary depending on the application, not all fly ashes meet ASTM C618 criteria. Although fly ash used as a cement substitute must meet high construction standards, there are currently no uniform environmental rules in effect in the United States. Seventy-five percent of the fly ash must be finer than 45 m and have a carbon concentration of less than 4 percent, as assessed by the loss on ignition (LOI). In the United States, the LOI must be less than 6%. Because of the fluctuating performance of coal mills and boilers, the particle size distribution of raw fly ash tends to shift constantly. This necessitates the employment of beneficiation processes such as mechanical air classification if fly ash is to be used effectively to substitute cement in concrete production. However, beneficiated fly ash with a higher LOI can be utilized as a filler to replace sand in concrete production. The continual quality assurance is very critical. This is mostly communicated through quality control seals such as the Bureau of Indian Standards mark or the Dubai Municipality's DCL mark.

Class "F"

Class F fly ash is produced by burning tougher, older anthracite and bituminous coal. This fly ash is pozzolanic in nature, with less than 7% lime content (CaO). Because Class F fly ash has pozzolanic qualities, it requires a cementing agent—such as Portland cement, quicklime, or hydrated lime—mixed with water to react and generate cementitious compounds. A geopolymer can also be formed by mixing a Class F ash with a chemical activator like sodium silicate (water glass).

.Class "C"

In addition to pozzolanic qualities, Class "C" fly ash formed from the combustion of younger lignite or sub-bituminous coal has some self-cementing properties. Class C fly ash hardens and becomes stronger over time when exposed to water. In most cases, Class C fly ash contains more than 20% lime (CaO). Self-cementing Class C fly ash does not require an activator, unlike Class F. Class C fly ashes have greater levels of alkali and sulfate (SO_4).

A fly ash brick containing up to 50% Class C fly ash has been announced by at least one US producer. The ASTM C 216 performance standards for typical clay bricks are met or exceeded in testing. It also falls within the ASTM C 55, Standard Specification for Concrete Building Brick, allowed shrinkage limitations for concrete brick. The production method employed in fly ash bricks is projected to lower the embodied energy of masonry construction by up to 90%. Before the end of 2009, commercial volumes of bricks and pavers were projected to be available.

1.3 Fly ash composition by coal type

Component	**Bituminous**	**Subbituminous**	**Lignite**
SiO_2 (%)	20–60	40–60	15–45
Al_2O_3 (%)	5–35	20–30	20–25
Fe_2O_3 (%)	10–40	4–10	4–15
CaO (%)	1–12	5–30	15–40
LOI (%)	0–15	0–3	0–5

2.Litrature Survey

[1] Liyuan Han et al. The structure, residual thermal stress development, and MSR of pure C/C and CNT-C/C composites at various heat treatment temperatures were comprehensively investigated in this study. The structure of PyC in composites gradually became optimal graphite structure after

heat treatment at 1600°C, 2100°C, and 2450°C, and the presence of CNT aided the process. The isotropic and ordered PyC owing to the CNT was attributed to the decreased residual thermal stress with uniform distribution in CNT-C/C composites, and heat treatment exacerbated the differences between pure C/C composites and CNT-C/C composites. The mechanical properties of the composites were influenced by the evolution of the structure and stress distribution throughout the heat treatment. After 2450 0C heat treatment, the MSR of ICS, OCS, and ISS in pure C/C composites was 53.07 percent, 45.27 percent, and 41.16 percent, respectively, whereas those in CNT-C/C composites were 69.69 percent, 66.33 percent, and 69.70 percent, respectively.

Carbon nanotubes reinforced fly ash polymer nanocomposites were synthesized by Ashish et al. [2] using a low-temperature compression molding process. CNT-filled nanocomposites were studied for their morphological and structural features. Before making the nanocomposites, the fly ash and CNT were dispersed in polar DMF solvent and the solution was ball milled. With varying CNT levels in epoxy polymer, the effect of CNT on water absorption, flexural strength, and dielectric characteristics was investigated. The pure fly ash/epoxy nanocomposite showed very low water absorption of 0.01 percent. Due to the hydrophilic and polar properties of CNT, a small increase in water absorption was observed in CNT reinforced fly ash polymer nanocomposites. CNT reinforcement enhanced the flexural strength of fly ash polymer nanocomposites. The increase in flexural strength in fly ash nanocomposites was studied in light of good CNT dispersion in the epoxy polymer/DMF, weakened Vander Walls forces, and the crystallization effect generated by CNTs. Furthermore, 20 percent CNT loaded fly ash polymer nanocomposites had a high dielectric constant of 38 and a low dissipation loss factor of 0.02. The CNT-filled nanocomposites' AC conductivity was also examined. CNT-fly ash reinforced nanocomposites with high dielectric constant, low water absorption, and high flexural strength have a wide range of applications as cost-effective and environmentally friendly construction and building materials.

[3] Wei Wang et al. The effect of high temperature and micro-environment relative humidity on the thermal conductivity of fly ash concrete is investigated in this work. The following conclusions are drawn from the test and analytical results:

(1) Both conventional concrete and fly ash concrete's compressive strength and thermal conductivity were significantly reduced after exposure to high temperatures, with compressive strength dropping by roughly 26% at 550 0C.

(2) The thermal conductivity of regular concrete and fly ash concrete rose with a rise in microenvironment relative humidity, with the thermal conductivity increasing by roughly 22% when the relative humidity reached 100%.

(3) The thermal conductivity of fly ash concrete with 30% replacement was lower than that of conventional concrete for a given exposure temperature and relative humidity in the microenvironment.

(4) The higher the program temperature (150 0C, 250 0C, 350 0C, 450 0C, 550 0C), the bigger the temperature gradient was, and the faster the concrete absorbed heat.

(5) With an increase in micro-environment relative humidity, the thermal conductivity difference between fly ash concrete and conventional concrete decreased after the same high temperature.

3. Materials Used:

3.1 Epoxy:

Epoxy resins are made up of a family of basic components and cured end products known as epoxy. Epoxy resins, also known as polyepoxides, are a type of epoxide-containing reactive prepolymers and polymers. Epoxy refers to the epoxide functional group as a whole. An oxirane is the IUPAC designation for an epoxide group.

Epoxy resins can be reacted (cross-linked) with a variety of co-reactants, including polyfunctional amines, acids (including acid anhydrides), phenols, alcohols, and thiols, by catalytic homopolymerisation (usually called mercaptans). The cross-linking reaction is generally referred to as curing, and the co-reactants are referred to as hardeners or curatives.

3.2 Hardener

Epoxy resin systems are divided into two sections: a "A" side and a "B" side. The epoxy curing agent is found on the B side, commonly known as the "hardener," and is responsible for reacting with the epoxy groups in the epoxy resin A side. Curing agents react with epoxy resins to produce rigid, thermoset materials.

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3.3 Flow chart of preparation of Hybrid composite

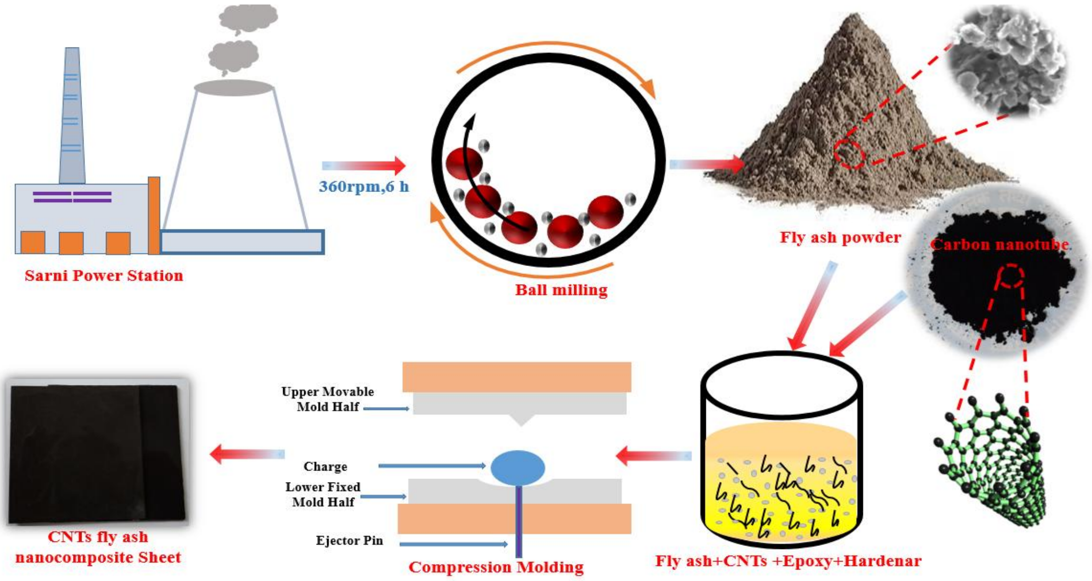

Fig 1: Schematic Diagram of preparation of CNT reinforced fly ash waste based hybrid composite sheet.

4.Experimental Instrumentation

4.1 Quick Thermal Conductivity Meter

There are several items all around us. Things that easily carry heat and those that do not, for example, are among them, and we choose the right materials for the job. The thermal conductivity rate of those materials is not only essential in science and engineering, but it is also a fundamental physical value with which we have a close link in our everyday lives

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Fig 2: Quick Thermal Conductivity meter equipment.

4.2 Flexural testing machine

The modulus of elasticity in bending is determined using the three-point bending flexural test. Ef flexural stress, flexural strain, and the material's flexural stress–strain response This test is done with a three-point or four-point bent fixture on a universal testing machine (tensile testing machine or tensile tester). The main benefit of a three-point flexural test is how simple it is to prepare and test the specimen. However, this method has several drawbacks: the testing method's results are susceptible to specimen and loading geometry, as well as strain rate.

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Fig 3 Flexural testing machine

4.3 Impact Testing Machine

Impact Testing is a type of nondestructive testing that uses generated waves into structures to assess the quality of building materials and find defects. The most basic method of impact testing is sounding. It's referred to as tapping on fragile materials like terra cotta. Sounding can also be done by dragging a chain or using a particular rotational percussion instrument in addition to utilizing a hammer. Materials that are in good shape will ping at their natural frequencies; materials that are in bad shape will thump at lower frequencies due to flexural vibrations.

Fig 4: Impact testing machine

5.Result and Discussion:

Mechanical Strength:

5.1.1 Fly ash waste based polymer Composite:

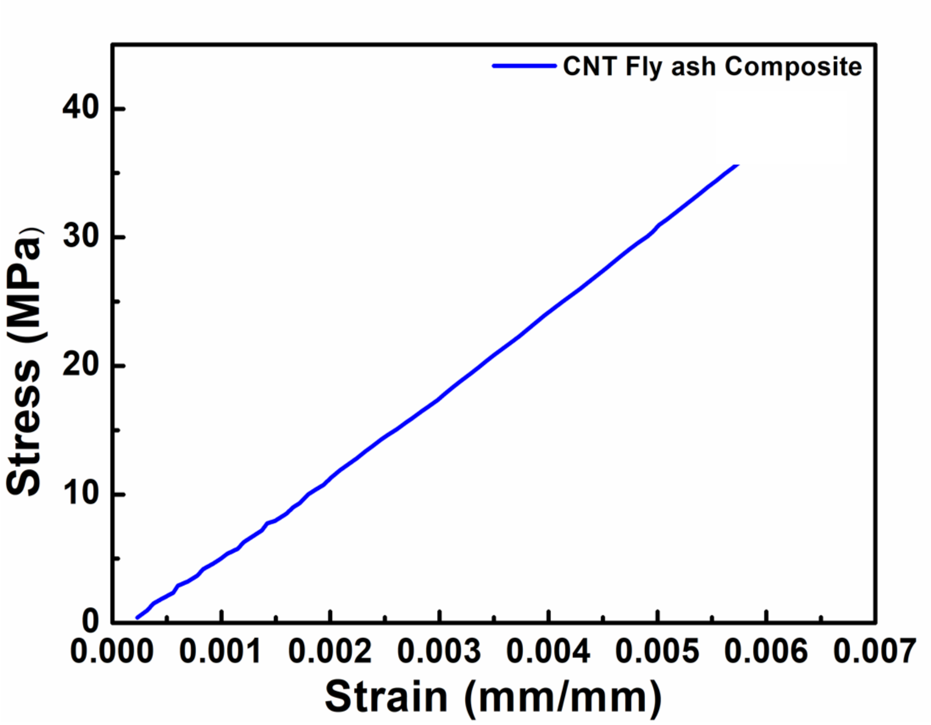

Fig 5 : Stress Strain diagram of fly ash epoxy based hybrid composite.

In above diagram the sample was tested by three bending test flexural machine and found the maximum strength of composites are 35Mpa

5.1.2 1% CNT reinforced Fly ash waste based polymer Composite:

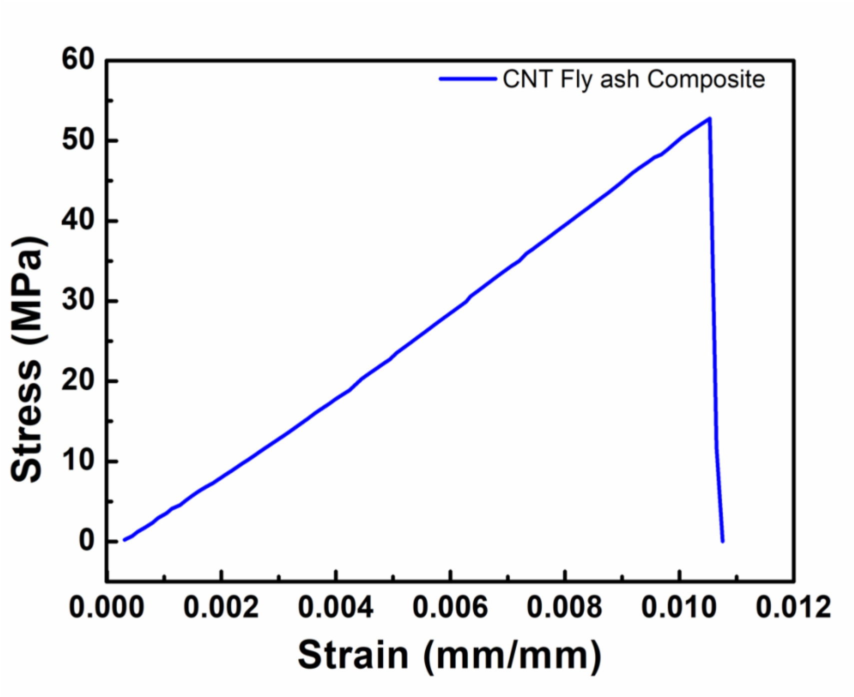

Fig 6 : Stress Strain diagram of fly ash 1% CNT reinforced epoxy based hybrid composite

In above diagram the sample was prepared with 1% of CNT reinforced with fly ash and then tested by three bending test flexural machine and found the maximum strength of composites are 55Mpa.

5.1.3 2% CNT reinforced Fly ash waste based polymer Composite:

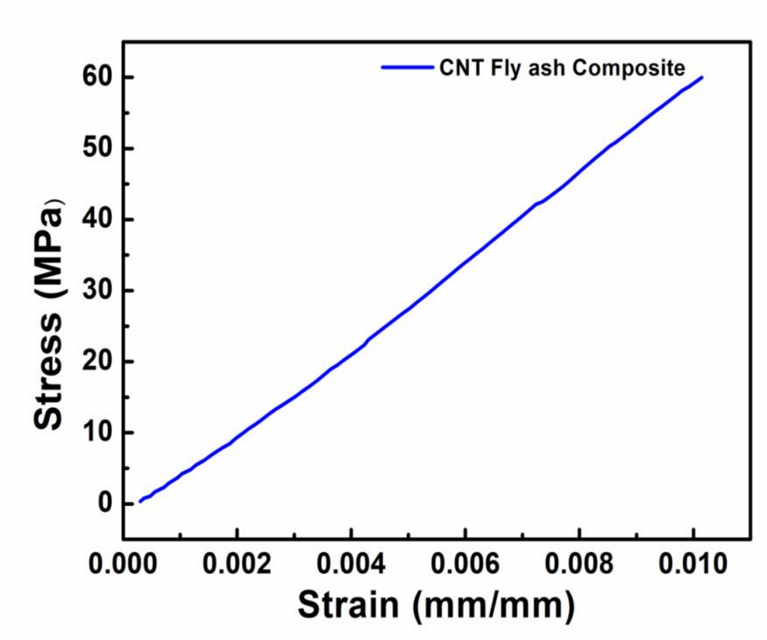

Fig7: Stress Strain diagram of fly ash 2% CNT reinforced epoxy based hybrid composite

In above diagram the sample was prepared with 2% of CNT reinforced with fly ash and then tested by three bending test flexural machine and found the maximum strength of composites are 62Mpa.

5.1.4 3% CNT reinforced Fly ash waste based polymer Composite:

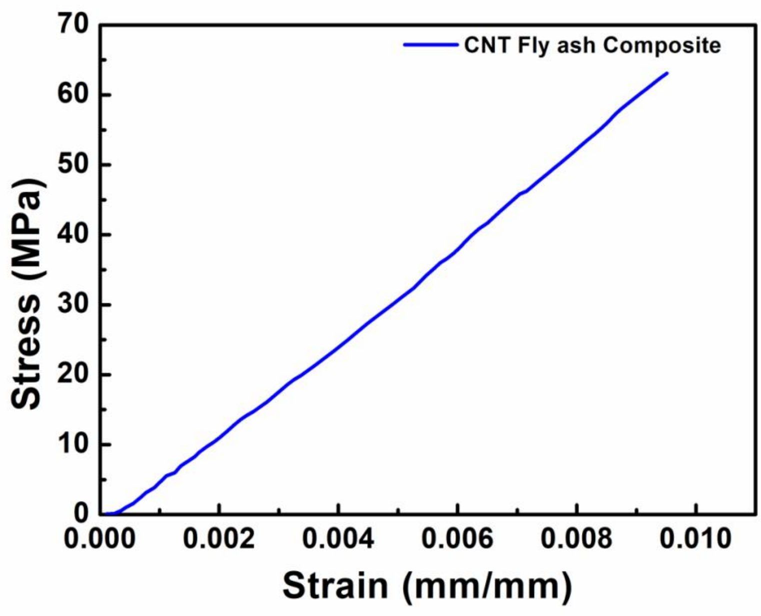

Fig 8: Stress Strain diagram of fly ash 3% CNT reinforced epoxy based hybrid composite

In above diagram the sample was prepared with 3% of CNT reinforced with fly ash and then tested by three bending test flexural machine and found the maximum strength of composites are 65 Mpa

5.1.5 3% CNT reinforced Fly ash waste based polymer Composite:

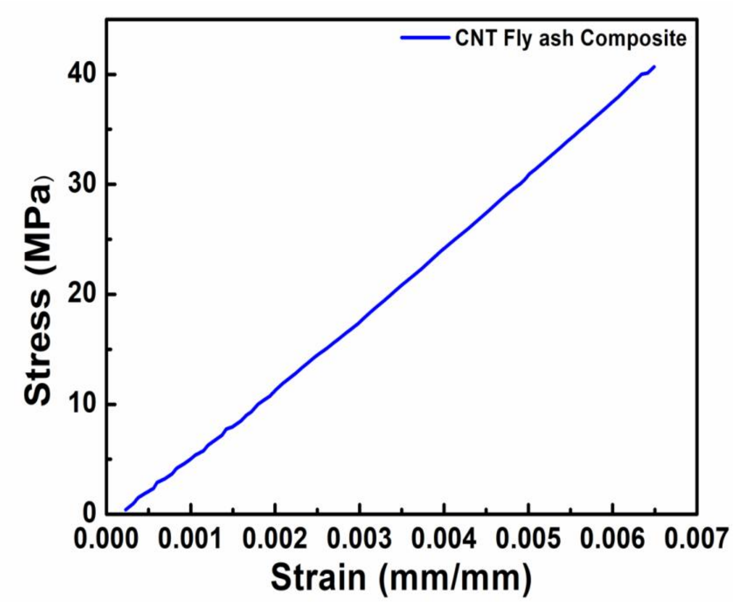

Fig 9: Stress Strain diagram of fly ash 4% CNT reinforced epoxy based hybrid composite.

In above diagram the sample was prepared with 4% of CNT reinforced with fly ash and then tested by three bending test flexural machine and found the maximum strength of composites are 40 Mpa. the strength decrease due to agglomeration of CNT.

5.2 Impact Strength:

Impact strength – also called impact toughness – is the amount of energy that a material can withstand when the said load is suddenly applied to it. It may also be defined as the threshold of force per unit area before the material undergoes fracture.

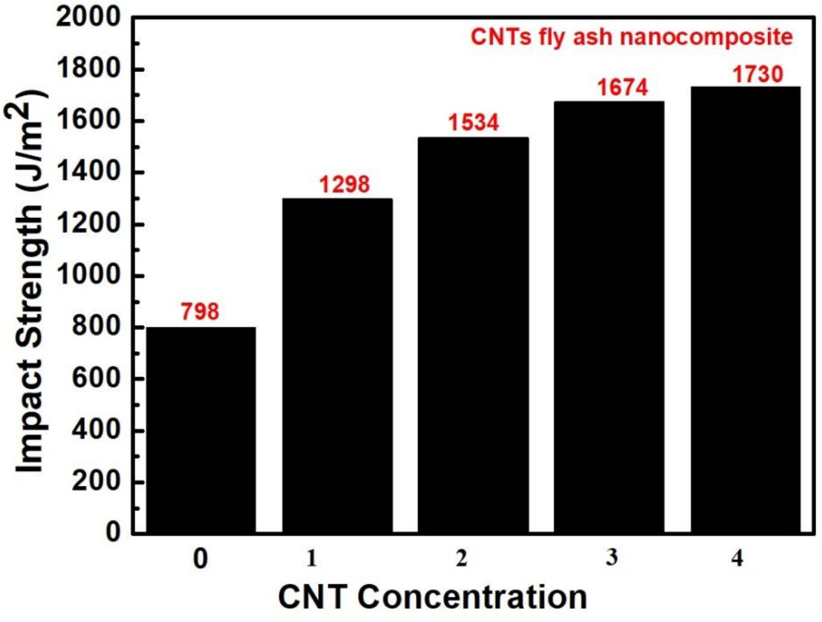

Fig 10: Impact strength of pristine fly ash and carbon Nano tube reinforced fly ash waste based hybrid composites.

5.3 Thermal Conductivity:

Thermal conductivity, thermal diffusivity and specific heat capacity define a material's ability to store and transfer heat. The precise and accurate measurement of these properties is critical for any process or material, which experiences a large or fast temperature gradient, or for which the tolerance for temperature change is exacting.

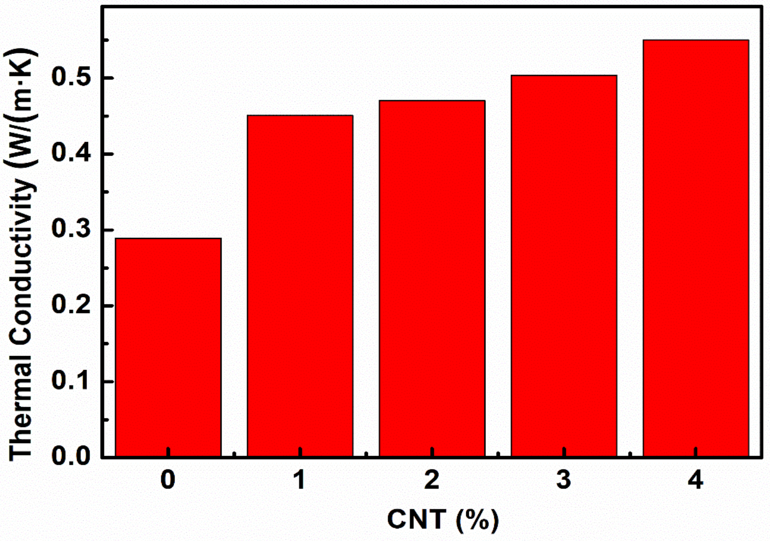

Fig 11: Thermal conductivity of pristine fly ash and carbon Nano tube reinforced fly ash waste based hybrid composites.

6.Conclusion:

After donethecalculationinthepreviouschapter,wecanseethattheresultsarequiteencouraging.The resultsaresummarizedunderthe followingpoints:

- In normal fly ash epoxy based composite represent the low thermal conductivity and low mechanical strength.
- In CNT reinforcing fly ash epoxy hybrid composite gives good results. With increment of CNT the thermal conductivity and mechanical strength are also increases till 3% CNT reinforcing.
- Due allgomarise of 4% CNT reinforcing hybrid composite gives decreasing thermal strength and increasing thermal conductivity.
- Due to outstanding property of carbon nano tube and good mechanical strength as well as electrical properties its reinforcing with fly ash and used in different designing auto parts, Body parts of air craft. And it's also used where risk for flame retardant.

7.Future Scope:

- In the place of fly ash take stone waste and same fining is done.
- Material selection and design as per requirement of society.
- To searching property of Carbon Nano tube and using as a flame retardant material.
- To study the effect of CNT in self-heling material.

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