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EXPERIMENTAL INVESTIGATION & CHARACTERIZATION OF GRAPHENE COMPOSITE INK AS A THERMAL INTERFACE COATINGS FOR IMPROVED HEAT TRANSFER

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Abstract: Heat transfer rate in plate type heat exchanger was quite less. This problem could be solved by using graphene composite inks. Graphene ink has been prepared by using Graphite nano powder, epoxy resin, sodium silicate mixture of high thermal conductivity by stirring. The graphene composite ink was then coated on cast iron disc and allowed to dry. When composite ink used as a thermal interface on plate type heat exchanger increased the heat transfer efficiency.Graphene has received significant attention due to unique electrical, optical and thermal transport properties. The extremely high thermal conductivity and electrical conductivity may make graphite be used as fillers in porous ceramic matrix to provide enhanced thermal properties and replace metal or graphite parts in thermal management systems. The coated disc has been kept on magnetic stirrer with an constant temperature and then raise in temperature was noted for a period of time say five minutes and then heated composite ink coated cast iron was taken for the testing methods using infrared thermometer (IR Thermometer) to find the thermal conductivity of the different composition of graphene ink. Thus from the testing, thermal conductivity of the material has been found. To inspect thermal properties the model of plate type heat exchanger were designed using software (solid works) to simulate thermal conduction for the different types of graphene composite inks. The simulation result reveals the best composition and displays more efficient heat transfer rate as compared to others. As a result this work proves that the most improved and easiest way of heat transfer rate using the graphene composite ink benefiting practical application such as the plate type heat exchanger ,heat sinks etc.

Key Words- **Graphene Ink, Graphene Composite Inks , Heat Exchanger, Soild Works.**

I. INTRODUCTION

1.1 PLATE TYPE HEAT EXCHANGER

The system uses the metal plates to transfer heat between two fluids. the main advantage over conventional heat exchanger in that the fluids are exposed to much larger surface area because the fluids passes over the fluids thus provides the transfer of heat and greatly increases the temperature change. This type of heat type exchanger is now common and very small versions (mini model) were used in the hot-water sections of combination boilers. The small plate type heat exchanger has made a drastic impact in heating and hot-water. Where larger version of heat exchanger use gaskets between the plates, whereas smaller versions tend to be brazed.

1.2 DESIGN OF PLATE TYPE HEAT EXCHANGER

The plate type heat exchanger has specialized design to transfer heat between medium and low pressure fluids. Welded, semi-welded and brazed heat exchangers are used for heat exchange between high pressure fluids or where a more compact product is required. Stainless steel is a commonly used metal for the plates because of its ability to withstand high temperatures, its mechanical strength and its corrosion resistance.

The plates were spaced by rubber sealing gaskets which are cemented into a section around the edge of the plates. The plate consists of channel for the flow of water through the plates. These troughs are arranged so that they interlink with the other plates which forms the channel with gaps of 1.3-1.5mm between the plates.

1.3 GRAPHENE COMPOSITE INK

The composite inks were made using graphite nano powder, epoxy resin, sodium silicate. Graphite is a naturally occurring form of crystalline carbon it is mineral of extremes, extremely soft, high thermal conductive material, and high electrical property and has a very low specific gravity. Epoxy resin has low molecular weight pre-polymers or higher molecular weight polymers which normally contain at least two epoxies groups. The epoxy group is also sometimes referred to as a glycol or oxidant group .thus the little amount of graphite nano powder, epoxy resin, sodium silicate were taken together to make composite ink by stirring process. Epoxy resin was allowed to cure with the graphite powder and sodium silicate for a day to get a smooth surface.

II. MATERIALS & METHODS

Graphene is an allotrope (form) of carbon consisting of a single layer of carbon atoms arranged in a hexagonal lattice. Graphene can be considered as an indefinitely large aromatic molecule, the ultimate case of the family of flat polycyclic aromatic hydrocarbons. Graphite, the most common allotrope of carbon, is basically a stack of graphene layers held together with weak bonds. Fullerenes and carbon nano tubes, two other forms of carbon, have structures similar to that of graphene; which can also be viewed as a fullerene or nano tube of infinitely large size.

Table 2.1 Overview on the Materials needed for Fabrication of graphene composite inks

1.	Graphite nano powder	500g
2.	Epoxy resin	1000g
3.	Sodium silicate	1 kg
4.	Stirrer rod	1Nos
5.	Beaker	2Nos
6.	Cast iron	1Nos (circular plate100mm*15mm)
7.	Cost estimation	Rs. 4000-5000 INR

1.4 PREPARATION OF GRAPHENE INK

STIRRING is typically done to suspend coarse free-flowing solids, or to break up lumps of fine agglomerated solids. An example of the former is the mixing granulated sugar into water; an example of the latter is the mixing of flour or powdered milk into water. In the first case, the particles can be lifted into suspension (and separated from one another) by bulk motion of the fluid; in the second, the mixer itself (or the high shear field near it) must destabilize the lumps and cause them to disintegrate.

One example of a solid–liquid mixing process in industry is concrete mixing, where cement, sand, small stones or gravel and water are commingled to a homogeneous self-hardening mass, used in the construction industry.

Suspension of solids into a liquid is done to improve the rate of mass transfer between the solid and the liquid. Examples include dissolving a solid reactant into a solvent, or suspending catalyst particles in liquid to improve the flow of reactants and products to and from the particles. The associated eddy diffusion increases the rate of mass transfer within the bulk of the fluid, and the convection of material away from the particles decreases the size of the boundary layer, where most of the resistance to mass transfer occurs.

Axial-flow impellers are preferred for solid suspension, although radial-flow impellers can be used in a tank with baffles, which convert some of the rotational motion into vertical motion. When the solid is denser than the liquid (and therefore collects at the bottom of the tank), the impeller is rotated so that the fluid is pushed downwards; when the solid is less dense than the liquid (and therefore floats on top), the impeller is rotated so that the fluid is pushed upwards (though this is relatively rare).

The equipment preferred for solid suspension produces large volumetric flows but not necessarily high shear; high flow-number turbine impellers, such as hydrofoils, are typically used. Multiple turbines mounted on the same shaft can reduce power draw.The graphene composition ratio were calculated and coated on the cast iron plate the composition ratio and number of sample can be done.

2.2 METHOD OF FINDING THERMAL CONDUCTIVITY

These were the some of the methods to find thermal conductivity

1. Axial flow methods.
2. Absolute axial heat flow method.
3. Comparative cut bar method.
4. Guarded/Unguarded Heat Flow Meter Method.
5. Guarded Hot Plate Method.

Here we followed the convection method with one end heat flow.

The apparatus arrangement shows the working principle and construction of our project. By applying the principle of science, the value of thermal conductivity can be found out.

Fig. 2.1 Cast iron plate without graphite ink coating

Fig. 2.2 Coating of graphite composite ink on cast iron

Fig. 2.3 Measure the temperature of coating component

III. MODELLING AND ANALYSIS OF PLATE TYPE HEAT EXCHANGER

The model of the plate type heat exchanger were shown in the figure, the Specifications of plate type heat type exchanger were mentioned below

Dimensions - 110cm*200cm*1cm
Plate material - stainless steel
Cold water inlet - 20 degree
Celsius Cold water outlet - 32 Degree Celsius
Hot water inlet - 60 Degree Celsius
Hot water outlet - 50 Degree Celsius

Fig. 3.1 Plate type heat exchanger inlet pressure without graphene ink coating

Inlet velocity of cold water - 0.025 m/s Inlet velocity of hot water - 0.025 m/s

The model of plate type heat exchanger has shown below without applying the graphene ink coating.

The specifications were

Thickness of the plate - 2mm Gap between the plate - 10mm

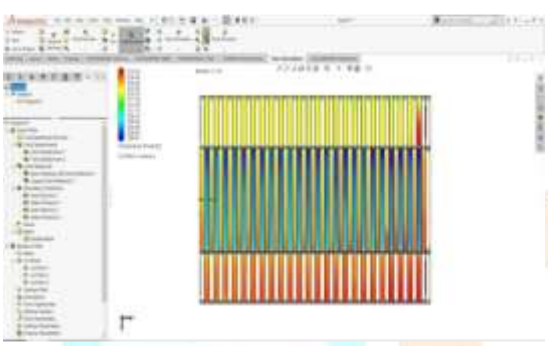

Fig. 3.2 Temperature result 1 without coating

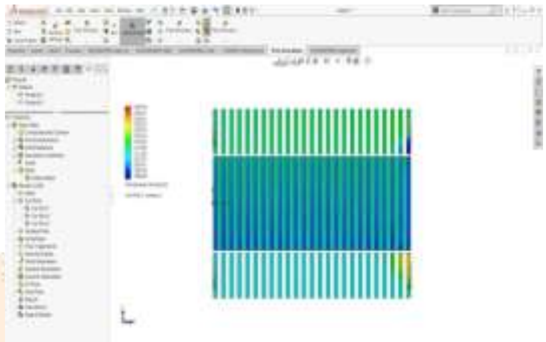

Fig. 3.3 Temperature result 1 with coating

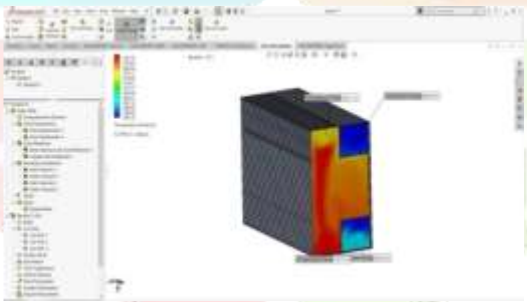

Fig. 3.4 Temperature result 2 without coating

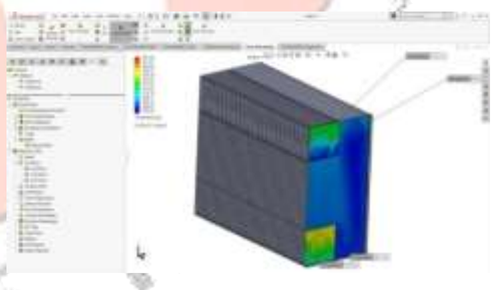

Fig. 3.5 Temperature result 2 with coating

IV. RESULTS AND DISCUSSION

Thus, the plate type heat exchanger shows the temperature results after graphene ink had been coated. The type of heat exchanger is counter flow type. From the simulation the results were compared with the experimental analysis. Temperature raises gradually compared without coating to with coating.

The graphene coated ink material was taken and conducted some test like thermal conductivity, electrical conductivity and SEM SPECTROSCOPY for the structure arrangement of graphene particles.

Thus, from the testing thermal conductivity of the material were found experimentally.

Following results were analysed

1) Thermal conductivity
2) Density
3) Specific gravity

From the experiment conducted and results were discussed below

Table 4.1 Temperature Observed from Sample no 1(GRAPHITE-40%, EPOXY-50%, SODIUM SILICATE-10%)

MINUTES	WITHOUT COATING	WITH COATING
0 min	$34.7^{0}c$	$34.7^{0}c$
1 min	$37.1^{0}c$	$37.4^{0}c$
2 min	$39.9^{0}c$	$40.9^{0}c$
3 min	$40.9^{0}c$	$43.8^{0}c$
4 min	$42.3^{0}c$	$46.9^{0}c$
5 min	$43.4^{0}c$	$49.9^{0}c$

From the experiment, temperature was observed and analysed the optimum coating should give for the plate type heat exchanger. Thus, from the results, coating given on the sample no 3 found to be best and efficient thermal conductive ink with the composition range of 10g of Graphite,7.5g of Epoxy resin,7.5 ml of sodium silicate (Na_2SiO_3).thus from the experiment the thermal conductivity of graphene composite ink for the given samples are listed below

Table 4.2 Experimental values of Thermal conductivity

SAMPLES	THERMAL CONDUCTIVITY K (W/Mk)
1	159.68
2	160.02
3	160.35
4	160.69
5	159.94
7	199.79
10	239.23

From the tabulation the thermal conductivity values were compared with the theoretical values.it found to be sample no 10 thermal conductivity value were high but the coating were not uniform so comparing the next sample, sample no 3 is found to be very effective and the coating were found to be uniform and efficient. Simulation results also helps to prove the sample no 3 composition is more effective when compared to other composition of graphene ink.

V. CONCLUSION

The following conclusions could be drawn from this successful demonstration.

- Increased thermal conductivity by 12%
- Improved heat transfer rate by $21.1^{0}c$
- Found thermal conductivity experimentally-160.35 W/mK

The heat transfer rate in the plate type heat exchanger can be improved by giving various composition mixture of graphene ink and various experimental test were carried out and from the results the efficient and optimum coating had been found out.

VI. SCOPE OF FUTURE WORK

The future research on this project may be performed in the following sectors.

- Plate type heat exchangers used in thermal power plant
- Heat sinks
- Solar power plant
- PCB circuits
- Thermal foils for mobile devices

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