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Heat Transfer Enhancement Using Nanoparticles (Al_2o_3)

N. Mukilarasan[1], D.Vinoth[2], B.Yogesh[3], V. Vinith raj[4], B. Sivesh kumar[5]
[1]*Assistant Professor in Mechanical Engineering*
[2, 3, 4, 5]*Bachelor of Mechanical Engineering Jeppiaar SRR Engineering College*

Abstract: Performance is one of the great significance needs of many industries. However, low thermal conductivity is a primary limitation in developing energy-efficient heat transfer fluids that are required in many industrial applications. In order to avoid this limitation, "Nanofluid" (Heat transfer fluid + nano particle) which is engineered by suspending metallic nano particles in conventional heat transfer fluid. The resulting Nanofluid will exhibit high thermal conductivities when compared to those usually used heat transfer fluids. In this study it reveals that the currently used heat transfer fluid takes more time than the AL2O3 suspended Nanofluids. The time taken to reach 50°C for currently heat transfer fluid (Shell Thermia B) is 100 seconds, whereas for Nanofluid the same temperature is attained in less than 65 seconds. This shows that the Nanofluids have substantial higher thermal conductivity when compared to currently using heat transfer fluid.
Keywords: Heat transfer fluid, nanofluids ,shell thermia fluid, aluminium oxide

I. INTRODUCTION

Touloukian and Ho (1970) have proved experimentally that at room temperature, the thermal conductivity of Cu is 700 times more than that of water[1] and 3000 fold more than that of engine oil. Hamilton and Crosser (1962) and Wasp (1977) have developed a thermal conductivity models for two-phase mixture based on their theoretical study[2][6].Sohn and Chen (1984) investigated thermal conductivity property of solid-fluid mixture at low velocity. At higher 7 flow rate (higher peclet number), the Thermal conductivity was observed to be increasing with increase in the shear rate.Masuda et al. (1993) studied the possibility of altering the properties of conventional heat transfer fluids by suspending submicron particles of water based Al203and Ti02 and reported that the enhancement in the Effective thermal conductivities are about 32% and 11%,respectively for the nanofluids of 4.3% volume concentration.Choi (1995) is the first researcher who worked on nano particles at the Argonne National Laboratory, USA. He demonstrated that nanofluids exhibit an increased thermal conductivity compared to the host fluid[2]. Eastman et al.

(1997) observed that oxide nanoparticles, such as Al2O3and CuO have excellent dispersion properties in water, oil and ethylene glycol and form stable suspensions. Wang et al. (1999) employed a steady state parallel plate method to measure the effective thermal conductivity of nanofluids.

They tested two types of nanoparticles, Al2O3and CuO, dispersed in water, engine oil, and ethylene glycol. Experimental results indicated higher thermal conductivities in fluid mixture than those of the base fluids and the measured thermal conductivity values are higher for nanofluids and the mixture formula under predicted experimental thermal conductivity of the above nanofluids[7][8].Choi et al.

(2001) noticed that engine oil of carbon nanotubes and with 1.0% volume concentration exhibited 160% increment in thermal conductivity[2].Das et al. (2003) employed temperature oscillation technique to measure thermal conductivity of water based Al2O3and CuO nanofluids at different temperatures [5]and observed a 200% to 400% increase in the thermal conductivity of nanofluids[3]

In the temperature range of 210oC to 510oC.Xue and Xu (005) developed an effective thermal conductivity model for CuO/water and CuO/Ethylene glycol nanofluids [6] taking into account the thermal conductivity of the solid and liquid, their relative volume fraction, particle size and interfacial properties. From the above literature review ,the properties of nano sized aluminium oxide is well suited for increasing heat transfer rate as well as the limitations of low thermal conductivity is avoided.

II. DESIGN PARAMETER

The required design parameters for the experimental test rig is as shown below.

PARAMETERS	QUALITY/DIMENSIONS
TEST RIG	DIAMETER=345mm , LENGTH= 110mm .
HEATER	230 AC SUPPLY SINGLE PHASE,POWER=2Kw, 7 INCH NICHROME COIL
ALUMINIUM OXIDE NANOPARTICLES	SIZE= 30-50 nm, SHAPE= SPHERICAL, PURITY =99.9%
RUNNER WITH VENT HOLES ON TOP	LENGTH= 250mm ,DIAMETER=35mm ,VENT HOLE DIAMETER= 12mm .
DIGITAL THERMOMETER (PROBE)	PROBE LENGTH =10mm
VOLTMETER	0-300V
AMMETER	0-10 Amps
SHELL THERMIA B FLUID	3 LITRES

III. EXPERIMENTAL PROCEDURE

A. Case: 1 (without nanoparticles)

The tank is cleaned thoroughly and ensured that there is no any dust or other materials. Now, the thermicfluid is filled inside the tank and the tank is closed. The heater is switched on and the stop watch is started simultaneously. The time taken to reach 100^{o}C is noted with a regular interval of 5^{o}C. As soon as the temperature of oil inside the tank reaches 100^{o}C switch of the power supply The temperature is also noted at regular intervals from the digital thermometer. The readings are tabulated.

B. Case: 2 (with nano particles)

Now, the oil present inside the tank is drained after it has been cooled to room temperature. Then the tank is filled with thermicfluid which has nanoparticles dispersed in it. The heater is switched on and the stop watch is started simultaneously. The time taken to reach 100 ^{o}C is noted. As soon as the temperature of oil inside the tank reaches 100 ^{o}C the power should be cut off. The temperature is also noted at regular intervals from the digital thermometer. Thus, the time-temperature curve is drawn for the both cases and the graphs are compared. It is evident that the thermicfluid with nanoparticles dispersed took less time than that of the fluid without nanoparticles to reach the pre-set temperature of 100 ^{o}C. It is proved by the graph and time recorded. This shows that nanoparticles dispersion in the heat exchanging fluid enhances the heat transfer rate. This nanofluid synthesized can be used for various heat exchanging applications such as boilers, heaters, heat exchangers, boilers etc.

IV. EXPERIMENTAL SETUP

A. List Of Components

1) Shell Thermia B

Shell Heat Transfer Oil S2 is based on carefully selected, highly refined mineral oils chosen for their ability to provide superior performance in indirect closed fluid heat transfer systems. Enclosed circulated heat transfer systems for industrial applications such as process industry, chemical plants, textile producers etc. and in household equipment such as oil filled radiators. Shell Heat Transfer Oil S2 can be used in high temperature continuous heat transfer equipment with the following application limits:

a) S2 Max. film temperature 340°C

b) Max. bulk temperature 320°C

Extended maintenance intervals Shell Heat Transfer Oil S2 is based on carefully selected highly refined mineral oils and resists oil cracking, oxidation and thickening. This provides extended oil life, provided efficient fluid heating and good pump circulation is ensured, such that film temperatures on the heater surface do not exceed the limits above.

System efficiency Low viscosity enables excellent fluidity and heat transfer over a wide temperature range. Shell Heat Transfer Oil S2 also has a low vapour pressure so resists cracking. This minimizes the formation of volatile decomposition products; these would require recovery via expansion chamber and condensate collector .

2) Nanoparticle

a) Specifications

i) Material : aluminium oxide
ii) Size : 30-50 nm
iii) Shape : spherical
iv) Purity : 99.9%

Compounds of aluminium and oxygen are referred to as aluminium oxides (Al2O3), whereas compounds with hydroxyl groups are known as hydroxides. Alpha- Al2O3(corundum) is the most well-known and significant form of the existing Al2O3 modifications . Besides, there are further aluminium oxides of different structures called transition alumina. Corundum has a density of 3.98 g/cm³, a high hardness, a melting point of 2053 °C, and a high specific electrical resistance of approximately 1012 ohm m (at 20 °C). It is chemically very stable and is almost insoluble in water, acids, and bases. The transition aluminium oxide gamma- Al2O3, in contrast, dissolves in strong acids and in bases. Due to its high surface activity, gamma-aluminium oxide is used as an adsorbent and catalyst material. In addition to oxides of aluminium, there are different hydroxides, e.g. aluminium hydroxides [Al (OH)3] such as bayerite and gibbsite and the so-called aluminium oxy-hydroxides [Al(OH)] boehmite and diaspore. Gibbsite, boehmite, and diaspore are constituents of the technically important aluminium mineral bauxite. Aluminium (Al) Nanoparticles, nanodots or nanopowder are black spherical high surface area metal particles. Nanoscale Aluminium Particles are typically 10-30 nanometers (nm) with specific surface area (SSA) in the 30 - 70 m2/g range and also available in with an average particle size of 70 -100 nm range with a specific surface area of approximately 5 - 10 m2/g. Nano Aluminium Particles are also available in passivated and in ultra high purity and high purity, carbon-coated, and dispersed forms.

b) occurrence and production

Aluminium oxide is produced industrially from the mineral bauxite. The bauxite deposits are estimated at approximately 20 billion tons worldwide, the worldwide annual output amounts to about 100 million tons. Australia has the largest output and deposits. The sapphire, well-known as a precious stone, is a quite rare but at the same time the most beautiful modification of aluminium oxide. Aluminium and aluminium oxide are manufactured by means of the Bayer method: Bauxite is crushed, dried, and dissolved using concentrated sodium hydroxide solution. The impurities iron, silicon, and titanium are separated from the bauxite in the so-called red mud. Aluminium hydroxide is precipitated from the solution and calcinated at 1200-1300°C to form Al2O3. They are also available as dispersion through the AE Nanofluid production group. Nanofluids are generally defined as suspended nanoparticles in solution either using surfactant or surface charge technology. Nanofluid dispersion and coating selection technical guidance is also available.

3) Heater

a) Specifications

i) 230V AC supply single phase
ii) 2kW
iii) 7 inch nichrome coil with thermostat

Electric heating is a process in which electrical energy is converted to heat. Common applications include space heating, cooking, water heating and industrial processes. An electric heater is an electrical device that converts

electric current to heat. The heating element inside every electric heater is an electrical resistor, and works on the principle of Joule heating: an electric current passing through a resistor will convert that electrical energy into heat energy. Most modern electric heating devices use nichrome wire as the active element; the heating element, depicted on the right, uses nichrome wire supported by ceramic insulators.

4) Digital Thermometer

a) Specifications

i) Range : 15 – 115
ii) Wire with probe
iii) Digital thermometer

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A thermometer is an instrument designed to measure and indicates the temperature of a specific application or condition. The digital thermometer has a probe connected with the wire at one end and other end is to the display. when the probe is inserted on the liquid it will sense the temperature and resulting temperature will be shown.

5) Heat Exchanging Apparatus-Test Rig

This apparatus is designed and made as per the above said design parameter. It is then connected to the power supply via voltmeter, ammeter, auto transformer to vary current supply and to measure the heat input voltmeter and ammeter are used.

V. CALCULATIONS

A. Thermal Conductivity Of Nano Fluid

$$k_{nf} = \frac{k_p + 2k_{Bf} + 2\varphi\left(k_p - k_{BF}\right)}{k_p + 2k_{Bf} - \varphi\left(k_p - k_{BF}\right)} \text{ x } k_{BF}$$

Where

knf =Thermal conductivity of Nanofluid

kP =Thermal conductivity of particle

φ =Volume fraction

kBF =Thermal conductivity of Base fluid.

$$= \frac{40 + 2(0.127) + 2(0.2)(40 - 0.127)}{40 + 2(0.127) - (0.2)(40 - 0.127)} \text{ x } 0.127$$

$$= \frac{36.203}{32.284} \text{ x } 0.127$$

$$k_{nf} = 0.22109 \text{ W/mk.}$$

B. Volume Fraction

$$\phi = \left(\frac{\frac{m}{\rho_{np}}}{\frac{m}{\rho_{np}} + \frac{m_{bf}}{\rho_{bj}}} \right) \text{ x } 100$$

Where φ is volume fraction

m is mass of nano particle

ρnp is density of nano particle

ρbf is density of base fluid

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mbf is mass of base fluid

Assume φ = 0.2

$$0.2 = \left(\frac{\frac{m}{3.89}}{\frac{m}{3.89} + 3000} \right) \text{x } 100$$

$$m = 23.38 \text{ gm}$$

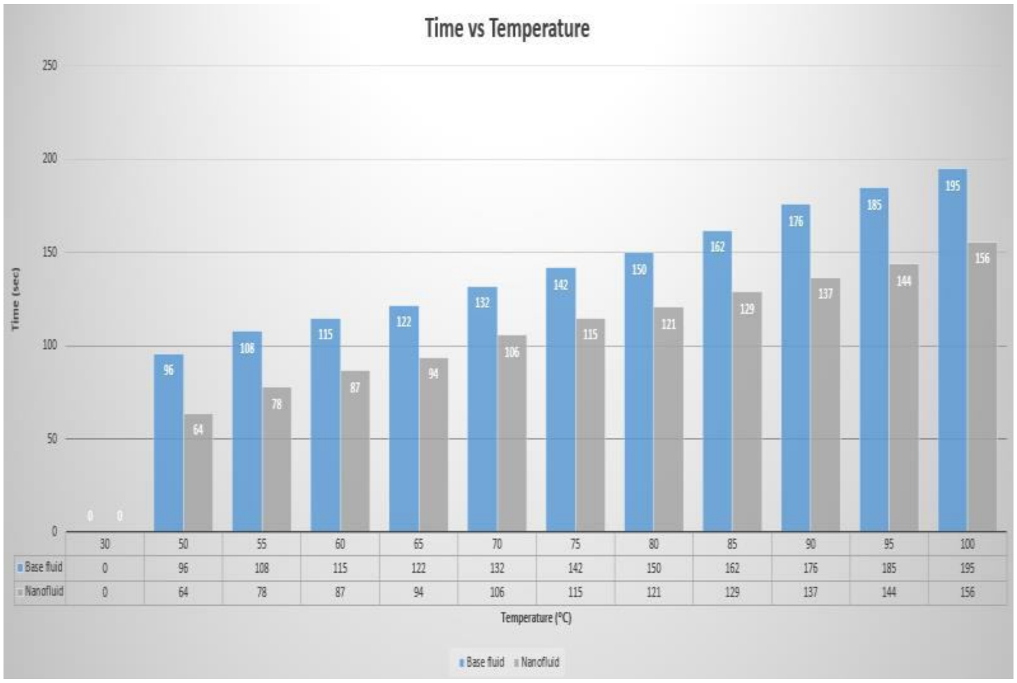
VI. RESULT AND DISCUSSION

A. Data: Without Nanoparticle

Time (sec)	Temperature (ºC)
0	30
96	50
108	55
115	60
122	65
132	70
142	75
150	80
162	85
176	90
185	95
195	100

B. Data: With Nanoparticle

Time (sec)	Temperature (ºC)
0	30
64	50
78	55
87	60
94	65
106	70
115	75
121	80
129	85
137	90
144	95
156	100



VII. CONCLUSION

Experiment concluded that the addition of nanoparticle to the base fluid alters the heat transfer coefficient and other physical properties such as density, viscosity. Here we found that the time taken to absorb the heat was less for the nanofluid when compared to base fluid. Variation in the properties of base fluid will depend upon the volume fraction of nanoparticle added. This obtained data can be simulated in computational fluid dynamics to determine the flow parameters. Hence by using nanoparticle the efficiency of heat transfer fluid used in the industry can be increased.

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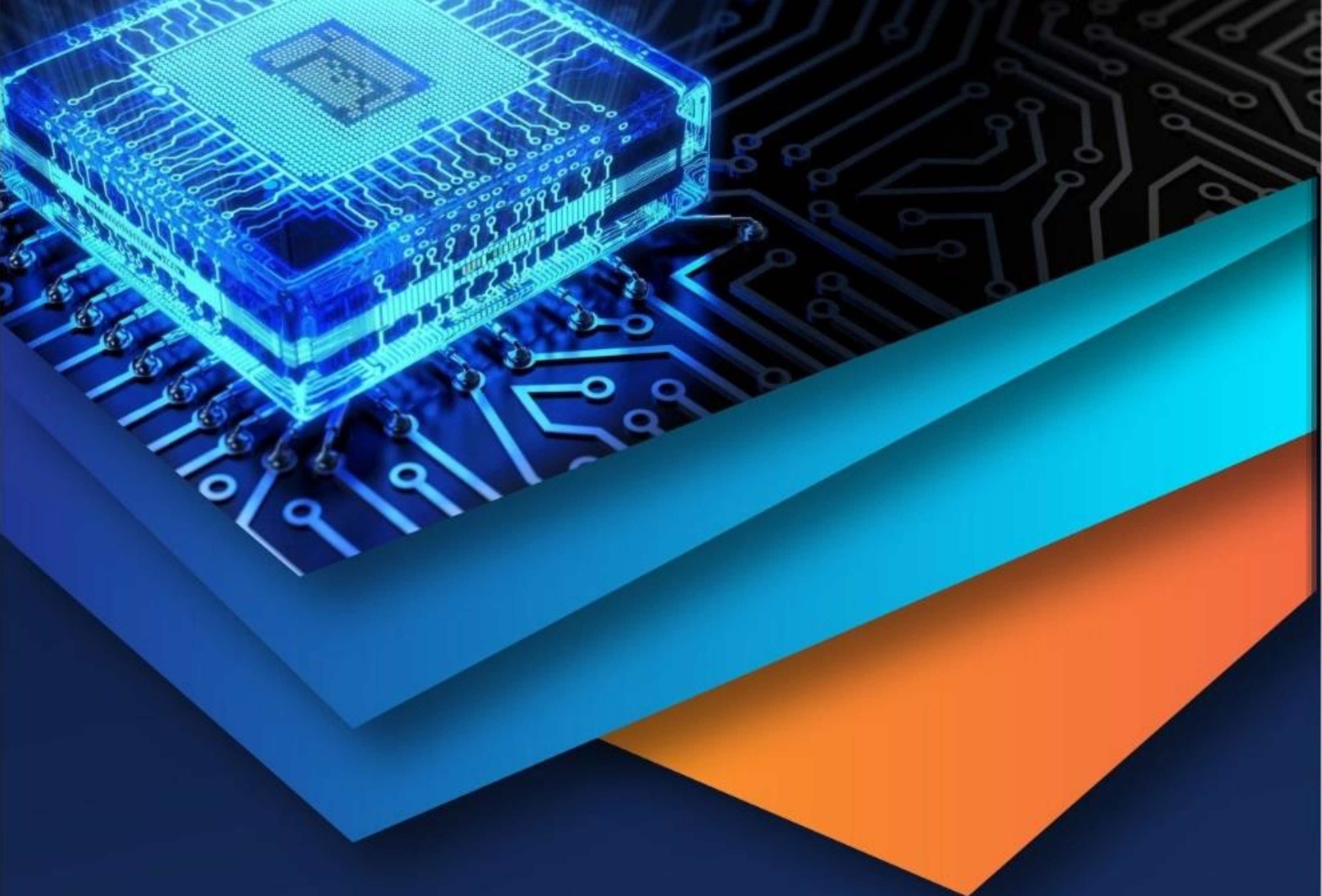

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