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An investigation into the potential of CuO nanofluid for improving heat transfer efficiency

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Abstract:

An ordinary fluid containing nanoparticles floating in it is called a nanofluid. A novel class of heat transfer coolants called nanofluids has evolved from the field of nanotechnology. When compared to more conventional coolants, these fluids have much larger thermal properties. One possible future heat transfer fluid is the nanofluid, due to the exciting new possibilities it offers for improving heat transfer performance compared to pure liquids. Even when using particles the size of micrometres in particle-fluid suspensions, no such noticeable enhancement is seen. Nanofluids are expected to outperform conventional heat transfer fluids and those with micro-sized metallic particles. Using nanoparticles, which have a much larger relative surface area than ordinary particles, greatly improves the solution's stability and heat transfer capabilities.

KEYWORDS: GFRP, TAGUCHI method and parameters.

INTRODUCTION

The creation of nanofluids was driven by the need to reduce the size of heat transfer equipment by improving the heat transfer coefficient. One potential use of these fluids is as thermal fluids in heat exchangers. Thermal energy and heat exchanger materials may be better conserved with the use of nanofluids. Nanofluids' thermal conductivity, viscosity, specific heat, and density are crucial elements that impact their heat transfer qualities. The operating temperature of nanofluids is also a determinant of their thermophysical characteristics. Therefore, it is crucial to accurately quantify the temperature dependent characteristics of nanofluids. It is not possible to estimate the heat transfer coefficient or the Nusselt number without first knowing the thermophysical characteristics of the nanofluids. Colloidal suspensions of designed nanoparticles in a base fluid are known as nano fluids. Nanoparticles typically range in size from one millimetre to one hundred nanometers. If the base fluid needs a certain quality improved, the kind of nano particle employed to do so will be different. There is a crucial length scale for every physical mechanism, and at this scale, materials' physical characteristics vary. Hence, the characteristics of particles smaller than 100 nm differ significantly from those of typical solids. Due to the high concentration of component atoms at grain boundaries, nano phase materials have a comparatively high surface area to volume ratio, which gives them their noble characteristics. Nano phase materials have better electrical, thermal, mechanical, optical, and magnetic capabilities than traditional materials with larger grain sizes.



fig1 Photographic view of CuO nanoparticles

PREPARATION METHODS FOR NANOFLUIDS

Classification of Methods of preparation of Nano Fluid

Two -Step Method

Nanofluids are most often prepared using a two-step process. Before using this technology, the nanomaterials (nanoparticles, nanofibers, nanotubes, etc.) are first created as dry powders using physical or chemical processes. The second phase of processing involves dispersing the nanosized powder into a fluid using a combination of ultrasonic agitation, homogenising, high-shear mixing, intense magnetic force agitation, and ball milling. The two-step process is the most cost-effective way to make nanofluids on a big scale, as nanopowder synthesis methods are already at an industrial level of production. Nanoparticles are prone to high-surface-area and surface-activity-related all things. The use of surfactants is a crucial strategy for improving the stability of nanoparticles in fluids. One major issue, particularly for high-temperature uses, is the surfactants' functionality at such conditions.

Single-Step Method

The nanoparticles are made and distributed into the base fluid all at once in the one-step process. Blending commercially available nano particles derived from various mechanical, physical, and chemical processes—including milling, grinding, sol-gel, and vapour phase methods—with base fluids is a common two-step preparation procedure for synthesising nanofluids. For the most part, when mixing nanopowders with host fluids, an ultrasonic vibrator or other higher shear mixing device is used. Reduce particle agglomeration by often using ultra sonication or stirring. Alumina nano fluids were produced using a two-step process by Eastman et al., Lee et al., and Wang et al. Using the same procedure, Murshed et al. created a TiO₂-water nano suspension. Xuan et al. synthesised water and transformer oil nanofluids using commercially accessible Cu nanoparticles. Nanofluids of CuO dispersed in ethylene glycol were prepared in two steps by Kim et al. using sonication and no stabilisers. Nanofluids based on carbon nanotubes may also be synthesised using a two-step process. After being created via the pyrolysis process, carbon nanotubes with one or

more walls are suspended in base fluids, either with or without surfactants. Nanofluids containing oxide nanoparticles, according to some writers, are better prepared using a two-step technique than nanofluids including metallic nanoparticles. Because of the high van der Waals force among nanoparticles, powders readily agglomerate, making stability a major concern intrinsic to this process. The most cost-effective method for producing nano fluids, this technology continues to be popular despite these drawbacks.

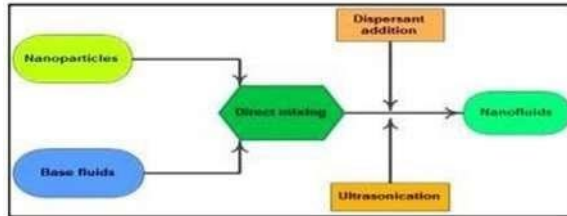


fig2StepPreparationforNanoFluids

1. LITERATURE REVIEW

The thermal performances of the nanofluids are one-of-a-kind. Compared to more traditional heat transfer fluids, nanofluids have unique characteristics. A faster heat transfer rate is anticipated in nanofluids due to the increased overall surface area that nanoparticles provide. Thermophysical characteristics of conventional thermal fluids improved when nanoparticles are included, according to many studies. A higher heat transfer rate and lower specific heats are anticipated from nanofluids compared to ordinary fluids, according to experimental investigations on the topic. Erosion of pipe materials, obstruction of flow passageways, and sedimentation owing to gravity are typical outcomes of particles suspended in fluids with a diameter of millimetres or micrometres. Macroscopically under stationary settings, studies on the effective heat transfer coefficient of nanofluids were conducted by S.U.S. Choi (1995), Masuda et al. (1993), Eastman et al. (1996), Wang et al. (1999), and Lee et al. (1999). Eastman et al. (2001), Xuan and Li (2000), Keblinski et al. (2002), Xie et al. (2002), and Wang et al. (2003) are all mentioned. Research on the real-world applications of slurry hydrodynamics and heat transmission was conducted by Ahuja (1975) and Liu et al. (1988). Nanofluids were developed at Argonne National Laboratory and proof tests were performed by Eastman et al. (1995). Modern technology allows for the production, processing, and characterization of materials with an average crystalline size below 100 nm. Nanoparticles of Al_2O_3 and CuO materials dispersed in mixes of glycols, oils, and water have shown an enhanced heat transfer coefficient and great dispersion quality. It is believed that the increased properties of nanofluids are due to the particles' Brownian motion and their huge surface area. Nanofluids with an average crystalline size of less than 100 nm were manufactured at Argonne National Laboratory and then tested by Eastman et al. (1995) to determine the heat transfer rate. Nanoparticles of Al_2O_3 and CuO materials dispersed in mixes of glycols, oils, and water have shown an enhanced heat transfer coefficient and great dispersion quality. Nanofluids are thought to have an improved heat transfer coefficient due to the particles' Brownian motion and their enormous surface area. Lee et al. (1999) measured the thermal conductivity of Al_2O_3 and CuO particles in ethylene glycol and water base fluids in great detail. The transient hot wire technique is used to determine the heat transfer rate of nanofluids. Researchers are encouraged to conduct heat transfer experiments on various nanofluids due to the notable improvement in heat transmission seen with these materials. A stable fluid may be produced by particles as big as 100 nm, according to a recent research by Xuan and Li (2000). A little quantity of laurite salt can be added to the base fluids for this purpose. However, what happened was experimental investigations have also shown that these dispersants impact the beneficial characteristics of nanofluids.

2. NANOFLUID PREPARATION USING CuO NANO PARTICLES

The CuO nano particles having an average size of 50nm and density of 6.3 gm/cm³ is procured from a India based company (Nano Partech Chemicals Private Ltd) and is used for investigation in the present experimental work. The photographic view of the nanoparticles as seen by the naked eyes is shown in the plate..1.



Fig3 Photographic view of CuO nanoparticles

The distribution of CuO nanoparticles at Nano scale can be observed under a Scanning electron microscope (SEM). The SEM images of CuO nanoparticles at 1 mm magnification is shown in Plate.3.2(a) and SEM image of CuO nanoparticle on a 500 nm scale is shown in Plate.3.2(b). Preparation of Nanofluids is an important stage and Nanofluids are prepared in a systematic and careful manner. A stable Nanofluid with uniform particle dispersion is required and the same is used for measuring the thermo physical properties of Nanofluids.

SEM images of CuO nano particles on 1000 nm and 500 nm scales.

In the present work, water-Propylene glycol mixture 80:20 by volume is taken as the base fluid for preparation of CuO Nanofluids. Basically three different methods are available for preparation of stable Nanofluids and are listed below.

By mixing of nano powder in the base liquid

In this method, the nanoparticles are directly mixed in the base liquid and thoroughly stirred. Nanofluids prepared in this method give poor suspension stability, because the nanoparticles settle down due to gravity, after a few minutes of Nanofluid preparation. The time of particle settlement depends on the type of nanoparticles used, density and viscosity properties of the host fluids.

By acid treatment of base fluids

The PH value of the base fluid can be lowered by adding a suitable acid to it. A stable Nanofluid with uniform particle dispersion can be prepared by mixing nanoparticles in an acid-treated base fluid. But acid-treated Nanofluids may cause corrosion on the pipe wall material with prolonged usage of Nanofluids. Hence acid-treated base fluids are not preferred for preparation of Nanofluids even though formation of stable Nanofluids is possible with such base fluids.

By adding surfactant to the base fluid

In this method a small amount of suitable surfactant, generally one tenth of mass of nanoparticles, is added to the base fluid and stirred continuously for few hours. Nanofluids prepared using surfactants will give a stable suspension with uniform particle dispersion in the host liquid. Then the nanoparticles remain in suspension state for a long time without settling down at the bottom of the container.



The CuO Nanofluids samples thus prepared are kept for observation and no particle settlement was observed at the bottom of the flask containing CuO Nanofluid even after four hours.

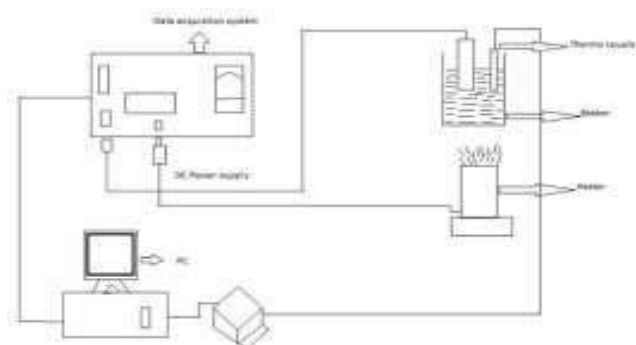
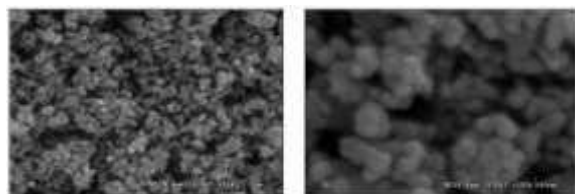


Fig: The photographic view of CuO Nanofluid suspension prepared after magnetic stirring process

In the current study, surfactants were not added to the CuO nanofluids since the time needed to finish the experiment for property assessment was shorter than the time needed for the first sedimentation to occur. It is presumed that the created CuO nanofluids behave in a uniform and consistent manner throughout the fluid sample, and that they are isentropic and Newtonian in nature.

Determination Of CuO Nano Fluid Properties

Nanofluid density, heat transfer coefficient, viscosity, and specific heat are the four most critical characteristics for estimating the convective heat transfer coefficient. The experimental estimates of CuO nanofluids' thermo-properties are compared with the theoretical equations that predict these characteristics, and the findings are obtained for all concentrations.

Experimental Set Up For Heat Transfer Coefficient Measurement Using Transient Heat Conduction Apparatus

Fig. shows a schematic representation of the experimental setup used to assess the heat transfer coefficient of nanofluids. On the plate, you can see an image of the experimental setup. our current project The transient heat conduction device is used to test the heat transfer rate of CuO nanofluids.

Fig: Schematic diagram of the Heat transfer coefficient measuring experimental setup



Procedure to Perform the Experiment

Measure out 1000 millilitres of base fluid. 2. Separate the 1000 millilitres of nano solution into a heating and cooling portion.

Turn the power on and turn on the heater. To avoid water splashing, turn on the stirrer and adjust the speed. Take note of the test cylinder's temperature once you take it out of the bath. To.

- Set the temperature controller to a value between 0 and 70 °C.
 - Adjust the screw to the temperature you want by pressing the button. As soon as the button is let go, the controller will display the bath temperature.
- Insert the cylinder into the bath and start a stop clock at the same time when the water temperature reaches the desired level. Keep track of how long it took the test cylinder to get to the desired steady state temperature (T).
- Base fluid and copper nanoparticles must be mixed thoroughly by using the appropriate stirring technique.
 - After that, dip the copper cylinder into the cooled cuO solution and record the results in the same way.

Keep doing this until the temperature reaches 70 °C, 60 °C, or 50 °C.

- Repeat steps 0.05%, 0.1%, 0.15%, and 2% in the same manner.

Nanofluids containing distilled water, 20% ethylene glycol, and CuO nanoparticles at concentrations of 0.05%, 0.1%, 0.15%, and 2% should be prepared in the same way.

SpecificationsOfExperimentalSetup

The dimensions of the copper cylinder are as follows: • 20 mm for diameter; • 70 mm for length; • 0.00439 m² for area.

- 0.00002199 m³ is the cylinder's volume.

The density of a cubic metre of copper is 8954 kg/m³.

- Copper's specific heat is 0.381 kJ/kg-k.

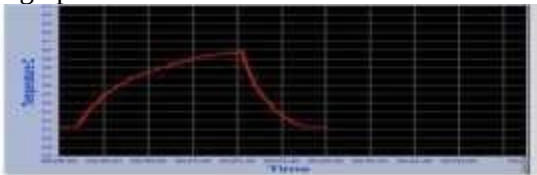
The temperature of the copper cylinder at the beginning is T_o , the temperature at the end is T , and the temperature of the water bath, whether hot or cold, is T_{∞} .

- The number of seconds it takes for the cylinder to travel from point A to point T One way to get the heat transfer coefficient is by using the following formula:

GRAPHS

GraphswereObtainedonthePcduringtheExperiment,thegraphsareplottedTime(t)vsTemperature(T)

Thegraphsareasfollowsas:-



HEATING COOLING $T_{\infty} = 40.4^{\circ}\text{C}$ $T_{\infty} = 31.3^{\circ}\text{C}$ $T_o = 31.3^{\circ}\text{C}$
 $T_o = 39.9^{\circ}\text{C}$

$t = 104 \text{ sec}$

$t = 44 \text{ sec}$

$T = 40.1^{\circ}\text{C}$

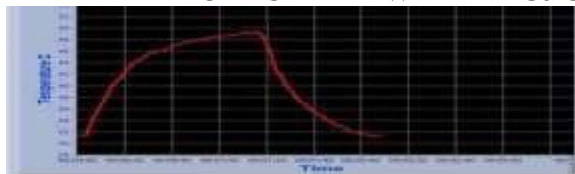
$T = 31.8^{\circ}\text{C}$

$h = 0.5627 \text{ kW/m}^2 \text{ }^{\circ}\text{C}$

$h = 1.10903 \text{ kW/m}^2 \text{ }^{\circ}\text{C}$ TRANSIENT HEAT

CONDUCTION

OF DISTILLED WATER AT 50°C



HEATING COOLING $T_{\infty} = 51.4^{\circ}\text{C}$ $T_{\infty} = 31.3^{\circ}\text{C}$ $T_o = 31.3^{\circ}\text{C}$
 $T_o = 48.5^{\circ}\text{C}$

$t = 89 \text{ sec}$

$t = 61 \text{ sec}$

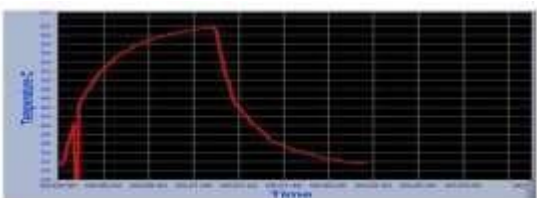
$T = 49.4^{\circ}\text{C}$

$T = 31.6^{\circ}\text{C}$

$h = 0.4447 \text{ kW/m}^2 \text{ }^{\circ}\text{C}$

$h = 1.1384 \text{ kW/m}^2 \text{ }^{\circ}\text{C}$

TRANSIENT HEAT CONDUCTION OF DISTILLED WATER AT 60°C



HEATING COOLING
 $T_{\infty} = 62^{\circ}\text{C}$ $T_{\infty} = 31.7^{\circ}\text{C}$ $T_o = 31.4^{\circ}\text{C}$ $T_o = 60.9^{\circ}\text{C}$

t= 79 sec t=81sec
T=61.7°C T=32°C
h=0.4980kW/m² °C h=0.9711kW/m² °C

Results and Discussions

The Column Chart Shows Temperature vs Heat Transfer Coefficient During Heating.

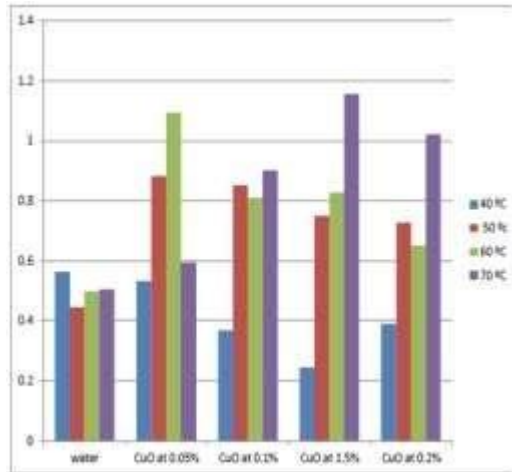


Fig11

From the above chart it has been observed that by comparing Water, CuO at 0.05%, CuO at 0.1%, CuO at 0.15% and CuO at 0.2% During Heating Heat Transfer Coefficient is high at CuO of 0.15% concentration at 70 °C with a value of $h = 1.1554 \text{ kW/m}^2 \text{ }^\circ\text{C}$

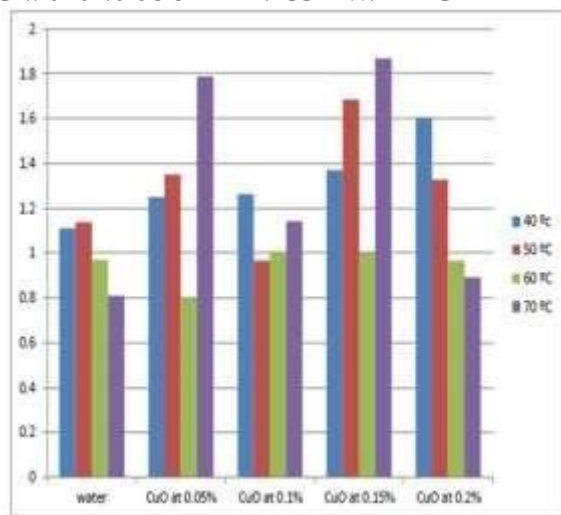
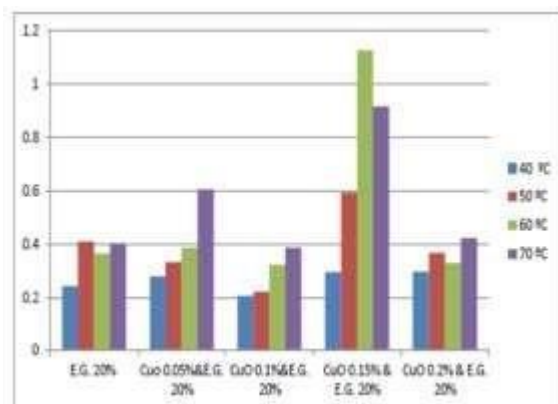


Fig12

From the above chart it has been observed that by comparing Water, CuO at 0.05%, CuO at 0.1%, CuO at 0.15% and CuO at 0.2% During Cooling Heat Transfer Coefficient is high at CuO of 0.15% concentration at 70 °C with a value of $h = 1.8674 \text{ kW/m}^2 \text{ }^\circ\text{C}$.

The Column Chart Shows Temperature vs Heat Transfer Coefficient During Heating.



From the above chart it has been observed that by comparing Ethyl Glycol of 20% and Water, Ethyl Glycol of 20% and CuO at 0.05%, Ethyl Glycol of 20% and CuO at 0.15% and Ethyl Glycol of 20% and CuO at 0.2%. During Heating Heat Transfer Coefficient is high at CuO of 0.15% concentration at 60 °C with a value of

$$h = 1.1671 \text{ kW/m}^2 \text{ } ^\circ\text{C}$$

CONCLUSIONS

Nanofluids have been shown to have much higher heat transfer coefficients and thermal conductivities than regular fluids.

Through contrasting the HSCoV of nanofluid copper oxide with that of base fluids such as distilled water and

The copper oxide nano fluid has a high heat transfer coefficient when heated and cooled, and it also has an ethyl glycol component. Using distilled water as a base fluid, heating and cooling copper oxide at a concentration of 0.15% CuO nano particles at 70 °C results in a high heat transfer rate. When we push it to even higher temperatures, it could show a far wider spectrum of heat transmission than regular fluids. At a concentration of 0.15% CuO nanoparticles in an ethyl glycol base fluid, the heat transfer rate is high during heating and cooling at 60 °C; additional increases in temperature result in an even greater removal of fluid heat. The versatility of CuO Nano fluids makes them useful in several fields, including heat transmission and detergency, among others. The biomedical profession has long made use of colloids, which are also CuO nanofluids, and this application will only increase. It has also been shown that CuO Nano fluids may be used as smart fluids. It is essential that the applications thoroughly investigate the issues of nanoparticle aggregation, settling, and erosion potential. For experimental study using CuO Nano fluids to provide the most relevant findings, it is crucial to have well-characterized fluids in terms of particle size, size distribution, form, and clustering. There will be a plethora of uses for CuO nano fluids once their engineering and science are completely understood, allowing for their mass production. Biomedical engineers and scientists will make more use of colloids, which are also CuO nano fluids. To make CuO nano fluids work as intended, further study into their production and potential uses is required. Despite this, a lot has been found out about the properties of CuO nano fluids in the studied uses, and we are getting closer to creating smaller, more efficient systems that will make the environment cleaner and healthier.

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