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Experimental Investigation and Comparison of Natural and Forced Convective Heat Transfer Enhancement Using Water -Cuo Nano Fluid

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Abstract
Free and forced convective heat transfer along a vertical cylinder immersed in water– CuO nanofluid for numerous concentrations (0, 0.05, 0.1, 0.15, 0.2vol %) below consistent heat flux circumstance turned into investigated experimentally with and without vibrations and compared the effects. The vibrational movement is acquired by way of placing vibratory motor beneath the experimental setup. The accelerometer is used to measure the vibration frequencies 100HZ-220HZ. Thermal stratification become discovered out of doors the boundary layer in the ambient fluid after steady-state condition is done as the fluid temperature is going on growing alongside the axial course. It is found that the temperatures of the cylinder and the fluid increases alongside the axial route and the fluid temperature decreases inside the radial route. Experiments had been conducted for various heat inputs (30 W, 40 W, 45 W and 50 W) and quantity concentrations and determined that the addition of Copper oxide nanoparticles as much as 0.15 vol. % complements the thermal overall performance and then the further addition of nanoparticles ends in deterioration. The most enhancement in the free convection (without vibration) i.e., the heat transfer coefficient is 478.4214 w/m^2 k at 0.15 vol. % and in forced convection (with vibration) i.e., the heat transfer coefficient is 489.4614 w/m^2 k at 0.15 vol. %. Thus it is observed that for the same heat input, the heat transfer enhancement is greater for forced convection in comparison to free convection due to vibratory impact.

***Key Words**: Free Convection, Forced Convection, Heat Transfer Enhancement, Constant Heat Flux, Thermal Stratification, Water-CuO, Vibratory Effect.*

Introduction:

Conventional heat transfer fluids including water, engine oil, kerosene, ethanol, transformer oil, ethylene glycol have lower thermal conductivity compared to solids. Lower thermal conductivity of fluid became an impediment to apply in specific packages. To triumph over this impediment, a new method which includes dispersing Nano sized solid debris within the base fluids, which enhance the thermal conductivity of the base fluids appreciably and it is known as as Nano fluids. It is a project to remove heat efficiently from rapid moving devices which include computers, strength electronics, vehicle engines, refrigerators, air conditioners, and so forth. But in Earlier, researchers dispersed the micro sized metallic particles (or) Nano particles into the base fluids to enhance the thermal properties of the base fluids but it has many drawbacks together with poor stability, erosion of the device, moderate enhancement. [1] The effect of oscillations upon the estimate of heat transfer by means of free convective heating surface may be studied analytically with various methods. In this primary approach, a surface is taken in static and vibrations impact within the neigh boring surface in a fluid medium. In this second method, oscillation movement impacted up on surface medium itself, its escape the fluid natural conditions. In this approach, the mechanical machine because of vibration at buoyant frequency and amplitude relies upon on it. Mechanical vibrations are utilized in one of a kind applications like commercial, area application and rocket propulsion vehicles, and so on. (Martinelli and Boelter 1938) one of the earliest analyses of the vibration effect on heat transfer was accomplished by using. They studied the impact of vibrations upon the heat transfer from a horizontal tube inside the water absorbed [2].Dispersed the Nano-sized particles of much less than a 100 nm size into the base fluid and prepared the nano fluids for the primary time and observed the development inside the thermal performance of it. Buoyancy triggered free convective heat transfer got a great deal interest these days in engineering applications together with electronic cooling, warmth ventilation and air conditioning, vapour absorption refrigeration, and nuclear reactor moderation. In order to increase the heat transfer overall performance of the fluid, nanoparticles in little quantity can be added to the base fluid. [3–9] Nano fluids consists of such particles suspended in liquids (typically conventional heat transfer liquids) have been shown to enhance the thermal conductivity and convective heat transfer performance of the base liquids. The thermal conductivities of the particle materials are commonly an order-of-magnitude higher than those of the base fluids consisting of water, ethylene, glycol, and mild oils, and nano fluids, even at low volume concentrations, resulting in tremendous increases in overall thermal performance.

Figure 1: Experimental setup

[10] Experimentally investigated the natural convection heat transfer behavior of Al_2O_3/water nanofluids with various volume fractions starting from 0 to 8%. In their study, test cellular is a 2D rectangularenclosure with heated vertical and cooled horizontal adiabatic partitions and finished the steady state and unsteady-state evaluation and observed that fashion of temperature profiles is similar for base fluid and nanofluid and also located theheat transfer enhancement for the smaller volume fractions$0.2\% \leq Ø \leq 2\%$ and the deterioration in the performance at better quantity fractions Ø>2%.[11] studied the thermo physical properties of the metallic oxide debris (Al_2O_3 and TiO_2) dispersed in water. The transient hot-wire methodturned into used for measuring the thermal conductivity of nanofluids. They said that the thermal conductivity of nanofluids wasextensively large than the base liquid. For example, the thermal conductivity of Al_2O_3-water nanofluids and TiO_2-water nanofluids at a 4.3vol% have been approximately32% and11% higher than that of base liquid, respectively. [12,13] formulated the water- based TiO2 nanofluids by dispersing the nano particlesinionized water and got the stable suspension with the help of high shear homogenizer and they test edit in the horizontal cylindrical enclosure for determining the natural convective heat transfer at various heat inputs andobserved the deterioration in the heattransfer performance in case of nanofluids.[14] conducted the experimentsto locate the natural convective heat transfer enhancement along a vertical cylinder immersed in transformer oil in addition to transformer oil+TiO_2 Nanofluid. [15] S.Ravibabu,G.Sambasivarao, Buoyancy Inducednatural convective heat transfer along a vertical cylinder beneath constant heat flux, int.J.Chem.Sci. 14(4), 2016, 2763-2774.

Experimental Setup

The test setup is having varioussegments such as test section, that is an Aluminum square prismatic enclosure, which incorporates the test liquid either base fluid or Nanofluid, Brass tube of 10.2mm diameter and 250mm length, a cartridge form of tubular heater that's having same length as brass tube, Outer galvanized iron shell with cooling water in and out arrangement, Cr–Al kind thermocouples of Teflon covered towithstand the temperature results, instrumentation panel with dimmer stat or variac to vary the heat input, voltmeter, ammeter, digital temperature indicator. Intervals and kept open at the identical heights in the liquid. A vibrator (single- phase vibrator) was bolted onthe rigid supporting frame and it’s tight . A 3 core cable connected vibrator to demonstrate and its frequency or amplitude ranges increase to decrease.An accelerometer become recycled to pick up a vibration indicator from the cylinder and switch the equal to avibration meter that can regulate amplitude, velocity or ace

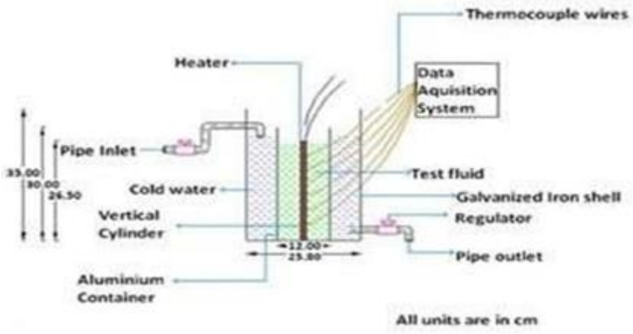

Figure 2: Line diagram of experimental setup

Experimental procedure

The experiments are conducted as per thefollowing manner.

1. Natural convection without vibration

2. Forced convection with vibration

In the first segment, a constant electrical input was given to the heater inside the cylinder. The water entered the cylinder surface is reaches to study state condition. When two consecutive readings of a thermocouple were the same, the outputs were reported. The thermocouple outputs were not found to be the same because of their different locations on the cylinder surface. An average value of the thermocouple outputs was assumed to represent the average temperature variation between the cylinder surface and the ambient. In the second segment, the electrical heater was given an arbitrary input. The dimmerstat was first set to power-on location - load location, thus vibration on the cylinder. The dynamo frequency was regulating to the desired equalize, the output from measure the accelerometer, which was mounted on the bracket carrying the cylinder. The power supply to the vibration meter on which amplitude, velocity or acceleration could be reached study state condition, the temperature difference, frequency; peak to peak values of amplitude, voltage, current electrical power, and the ambient temperature were recorded

Results and Discussion

Analysis to carry out at different heatinputs by regulate the voltage transfer with the help of distinct heat inputs given to the cylinder are 30W, 40W,50Wand60W.Theexteriortemperatures of the brassvertical cylinder are systematic with the use ofthermocouples in the axial direction forbase fluid medium increased for anyheat input, due to high local heat transfercoefficient so curing at the bottom location of the cylinder. All the thermo-physical plot of the analysis fluid iscalculated at the film temperature, whichis the standard exterior temperature ofthe cylinder and the bulk temperature ofthe fluid and is presented in equation.The bulk condition of the fluid mediumis calculated by using a natural convective with or without vibration effect. Take the average temperature of the fluid at the thermocouple locations(which are away from the boundary layer), which are exactly at the sameheight from the bottom wall of the container compared to the thermo couples attached to the vertical brass cylinder.

Film temperature= $(T_s+T_f)/ 2$

The Local heat transfer coefficients at various locations are calculated at the points where thermos couples are located. The local heat transfer coefficient iscalculated by using equation.

Local heat transfer coefficient =(h_x)

$h_x = Q/ (A_s*\Delta T_x)$

$h_{x1} = Q/ (A_{s1}*\Delta T_{x1})$

$h_{x2} = Q/ (A_{s2}*\Delta T_{x2})$

$h_{x2} = Q/ (A_{s3}*\Delta T_{x3})$…etc.

$\Delta T_x= (T_s – T_f)$

T_{s1}, T_{s2}, T_{s3}, T_{s4}, T_{s5}, T_{s6} are surfacetemperatures of the six thermocouple locations and T_{f1}, T_{f2}, T_{f3}, T_{f4}, T_{f5}, and $T_{f6}$are the temperatures of the fluid at the comparable height.

The local Nusselt number is

$Nu_x = (h_x*L_c)/K$

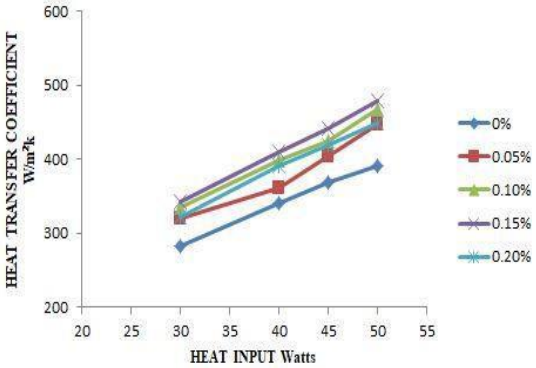

Chart-1: Variation of heat transfer coefficient with heat input various concentration of nano fluid without vibration effect

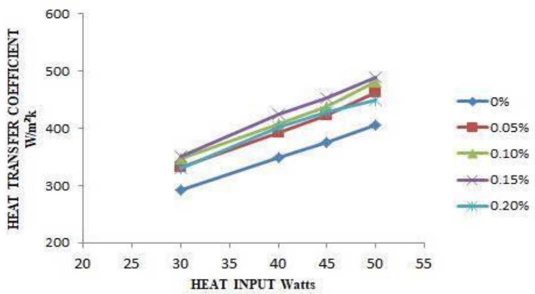

Chart-2: Variation of heat transfer coefficient with heat input various concentration of nanofluid with vibration effect

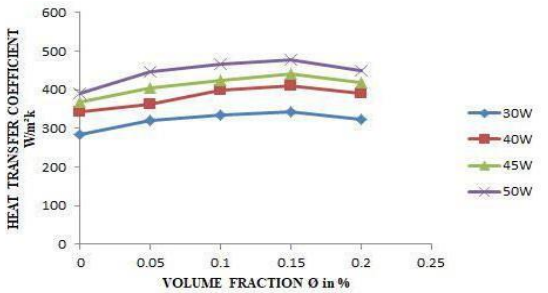

Chart-3: Various heat transfer coefficient with volume fraction of nano fluid for adifferent heat inputs without vibrationeffect

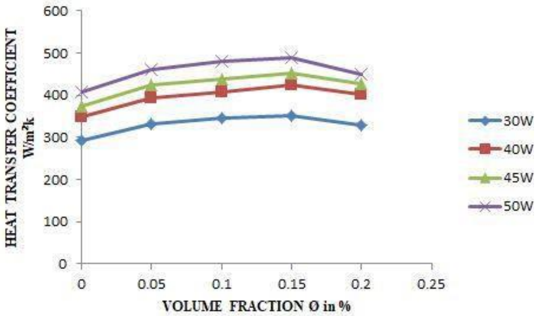

Chart-4: Various heat transfer coefficient with volume fraction of nano fluid for adifferent heat inputs with vibration effect

Conclusions

1. The effect of vibration upon the cylindrical brass surface the heat transfer rate increases with high frequency or amplitude and its small diameter.
2. The axial distance of the boundary layer bottom location to the top location increases lightly.
3. The natural convection of cylindrical surface decreases with increases in thetemperature variation.
4. The Study about this experiment cylindrical diameter decreases with vibration frequency increases and greatly increases temperature difference.
5. Natural and forced convective heat transfer performance is augmented up to 0.15 vol% concentration of CuO nanoparticles and then it is decreased after 0.15 vol% even it worse than the carrier fluid at higher concentrations.
6. The vibration effect on natural convective heat transfer is enhanced by using water at 50watts heat input and heat transfer coefficient is increased at 0.15 % volume fraction from 283.51 w/m^{2}k to 390.46 w/m^{2}k and in forced convection stage it has increased from 291.46w/m^{2}k to 406.25 w/m^{2}k
7. The vibration effect on natural convective heat transfer is enhanced by using water-Copper Oxide nano fluid at 50watts heat input and heattransfer coefficient is increased at 0.15% volume fraction from 342.42 w/m^{2}k to 478.42 w/m^2 k and in forced convection stage it has increased from 351.46w/m^{2}k to 489.46 w/m^{2}k

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