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Research Article

Buoyancy Induced Natural Convective Heat Transfer In Prismatic Container Filled With Transformer Oil - Tio2 by Vibration Effect on the Cylindrical Surface

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ABSTRACT

The main aims of the buoyancy induced natural convection of the heat transfer in a vertical brass cylindrical surface by using fluids Such as the water, engine oil, ethylene, ethylene glycol, and transformer oil have a lower thermal conductivity of fluid compared to the solid brass cylindrical rod. The fluid maintains the uniform heat flux condition observed in experimentally. The different volume fractions are 0, 0.05, 0.15, 0.2% of volume fractions with various heat inputs 30W, 40W, 50W and 60W. The thermal conduction was observed in Tio2 Nano fluids with transformer oil after the study state condition of Nano fluid and SDS solution is mixed into the Nano fluid and it is avoided into the sedimentation of Nanoparticles in the bottom surface will be increased in temperature of the Nano fluid onward the axial direction to the outside surface of the boundary layer. The temperature increases in both the axial direction and radial direction as shown in the graph. It is recognized that the increases in temperature along the axial direction and decrease the temperature in the radial direction. Its final thermal conduction is obtained. Experimentally gives to various heat inputs 30W, 40W, 50W, 60W, and its correlated by Nusselt number (Nu) and Rayleigh number (Ra) at uniform heat flux. Experimentally observed that the vibrator is placed on the cylindrical surface temperature is higher at The bottom portion of the cylinder and it goes on the top portion and fluid maintain at Study condition and its given frequency ranges are 100Hz-190Hz.

Keyword: Natural convection, Heat transfer, Digital thermometer, Constant heat flux, Boundary theory layer, Newtonian fluid, vibrator, dimmer start, voltmeter, ammeter.

INTRODUCTION

Many research papers are studied both theoretical as well as experimental on the cooling of the equipment like electrical devices, defense, biomedical, radiator, etc... the natural convection of the heat transfer in the literature. The temperature is observed in the study state condition. The vibrators are placed in a vertical cylindrical surface and its help full to use heat transfer increases than without vibration. The applications of vibrators are rocket propulsion jet used. The Nano-sized solid particles are mixed into base fluid then thermal properties increases and also thermal conductivity increases. The Nano fluids are used to cooling applications like cooling electrical chips, computers, automobiles and biomedical applications, etc...

[1]Dispersed the Nano-sized metallic particles of less than 100 nm size into the base fluid and prepared the Nano fluids for the first time and observed the improvement in the thermal performance of it. Buoyancy-induced free convective heat transfer got much interest these days in engineering applications such as electronic cooling, heat ventilation and air conditioning, vapour absorption refrigeration, and nuclear reactor moderation. In order to increase the heat transfer performance of the fluid, nanoparticles in little quantity will be added to the carrier fluid. [2–9] Nano fluids consisting of such particles suspended in liquids (typically conventional heat transfer liquids) have been shown to enhance the thermal conductivity

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and convective heat transfer performance of the base liquids. The thermal conductivities of the particle materials are typically an order-of-magnitude higher than those of the base fluids such as water, ethylene glycol, and light oils, and Nano fluids, even at low volume concentrations, resulting in significant increases in thermal performance. [10] Experimentally investigated the natural convection heat transfer behavior of Al_2O_3/water Nanofluids with various volume fractions ranging from 0 to 8%. In their study, test cell is a 2D rectangular enclosure with heated vertical and cooled horizontal adiabatic walls and performed the steady-state and unsteady-state analysis and observed that trend of temperature profiles is similar for base fluid and nanofluid and also observed the heat transfer enhancement for the smaller volume fractions0.2% ≤ Ø ≤ 2% and the deterioration in the performance at higher volume fractions Ø>2%.[11] studied the thermo physical properties of the metallic oxide particles (Al_2O_3 and TiO_2) dispersed in water. The transient hot-wire method was used for measuring the thermal conductivity of nanofluids. They reported that the thermal conductivity of nanofluids was significantly larger than the base liquid. For example, the thermal conductivity of Al_2O_3-water nanofluids and TiO_2-water nanofluids at a 4.3vol% were approximately32% and11% higher than that of base liquid, respectively. [12,13] formulated the water-based TiO_2 nanofluids by dispersing the nanoparticles in de-ionized water and got the stable suspension with the help of high shear homogenizer and they tested it in the horizontal cylindrical enclosure for determining the natural convective heat transfer at various heat inputs and observed the deterioration in the heat transfer performance in case of nanofluids . [14] Experimentally investigated the natural convection heat transfer performance of water-based Nano-fluids and a dimensionless equation based on the experimental data is suggested for the calculation of Nusselt number with respect to Rayleigh number. [15] performed a study on turbulent natural convection heat transfer in an enclosure for various aspect ratios from 0.3 to 2.5 using Al_2O_3/ water nanofluids and it is observed that the augmentation at lower con-cent rations and deterioration at higher concentrations of nanoparticles. [16] performed the characterization and stability analysis of alumina/water Nano fluid and experimentally invest- gated the natural convective heat transfer at various volume con- cent rations of Nanofluid in a rectangular cavity, which is differentially heated the vertical walls opposite each other and observed an enhancement in the heat transfer up to 15% compared to water at 0.1% volume concentration and after that addition of nanoparticles decreases the performance. [17] To estimate the natural convective heat transfer performance using Cu–water Nanofluid in an annulus and results show that the Nusselt number increases with increase in aspect ratio. [18] Numerically investigated the natural convection heat transfer in a horizontal cylinder filled with Al_2O_3–water Nanofluid in the range of 1–4% volume concentrations and observed the increment in Nusselt number for higher Rayleigh number. [19] Simulated the natural convection heat transfer in a con- centric horizontal annulus using SiO_2 Nanofluid, investigated the effect of Rayleigh number and hydraulic radius, and observed that the average Nusselt number increases with Rayleigh number and hydraulic radius ratio as well. [20] Conducted the experiments to find the natural convective heat transfer enhancement along a vertical cylinder immersed in transformer oil as well as transformer oil +TiO_2 Nanofluid.

[21] (Martinelli and Boelter 1938) one of the earliest analyses of the vibration effect on heat transfer was done by. They studied the effect of vibrations upon the heat transfer from a horizontal tube in the water absorbed. [22] The influence of vibration on the convective heat transfer which has been investigated in the past studies for cylinders, flat plate, and other geometries and has carried out for different directions of applied vibration relative to these surfaces and various ranges of applied frequency and amplitude and different thermal boundary conditions. The results of these investigations show that the vibration gives a large increase to none increase or even a decrease in the heat transfer rate. [23] One of the practical problems, which originally inspired interest in the effect of vibration on heat transfer, was encountered in rocket propulsion motors. As combustion instability of high amplitude occurred in such motors, the local heat transfer to the motor walls drastically increased and the wall temperature rose to the point where the motor was destroyed. The vibrating either the surface of the liquid contents of an extraction column to improve its efficiency. This is the principle of pulsed columns which is widely applied in the nuclear field. [24] Abdel amid R. S. performs an experimental study for the effect of forced vertical vibrations on free convection heat transfer coefficient, from a flat plate made of aluminum with dimension (300 mm length, 100 mm width, and 3 mm thickness). It has been heated under a constant heat flux of (250-1500 W/m2) in an upward direction. The flat plate was located horizontally or inclined in multiple angles at a range of (0o, 30o, 45o, 60o, 90o). The experimental study is carried out at a range of frequency (2-16 Hz) and the amplitude at the range of (1.63-7.16 mm). The results of this study show that the relation between the heat transfer coefficient and the amplitude of vibration is incrementally for inclination angles from (0o, 30o, 45o, 60o, 90o), and reaches a maximum ratio of (13.3%) in the horizontal state, except at the vertical state (θ = 90o) the heat transfer coefficient decreases as the excitation increases and the maximum decrease ratio occurs at (7.65 %). [25] In the current study, a detailed effort has been under taken to develop correlations for heat transfer from a cylinder in a low-amplitude zero-mean oscillatory flow. The cylinder is representative of a heat exchanger tube while the oscillatory flow is typical of the acoustic field in a thermo acoustic engine. The low- amplitude feature refers to oscillatory flow displacement amplitudes being small on the scale of the characteristic body dimension, i.e. the cylinder diameter. The various dimensionless parameters of importance in this range have been identified and systematically covered. [26]Besides acoustic streaming, other acoustic mechanisms can transport heat. Greatly enhanced heat transport down a temperature gradient can be obtained using large amplitude oscillating flows without recourse to the streaming effect. The large particle velocity creates a thin boundary layer between the bulk of the fluid and an adjacent wall containing a large temperature gradient normal to the wall. Because the fluid and wall temperatures differ substantially, and because the boundary layer is thin, enormous radial heats flux

results. On opposite halves of theacoustic cycle, the fluid is alternately hotter and colder than the wall. In combination with the reciprocating flow, substantial axial heat transport results. [27] The left wall of the enclosure is modelled as a rigid boundary that vibrates harmonically in time representing the motion of a loudspeaker diaphragm or vibration of a commercial ultrasonic mixer probe. The vibrating boundary is the acoustic source in this geometry and a sound field in the enclosure is created by this source. We are able to model the physical processes including the compression of the fluid and the generation of the wave, acoustic boundary layer development, and finally the interaction of the wave field with viscous effects and the formation of streaming structures. [28] Acoustic streaming induced by sonic longitudinal vibration is investigated. Acoustic streaming induced by ultrasonic flexural travelling waves is studied for a micro pump application and the negligible heat transfer capability of acoustic streaming is reported Nguyen and White. [29] Mozurkewich presented the results of an experimental investigation of heat transfer from a cylinder in an acoustic standing wave generated in a free stream. He established that for a cylinder of fixed diameter and a fixed acoustic frequency, the Nusselt number showed a distinctive variation with acoustic amplitude. At high amplitude, the Nusselt number followed a steady-flow, forced-convection correlation (time-averaged over an acoustic cycle) while at low amplitude, the Nusselt number had a constant value determined by natural convection. [30] The acoustic field in a fluid with attenuation, due to viscosity and thermal conduction, is always accompanied by the unidirectional flow called acoustic streaming. Bradley and Nyborg. [31] Considered a problem in which a steady-state sonic wave propagates in a longitudinal direction in a fluid enclosed between two horizontal parallel plates. In this theoretical study, an acoustic Peclet number was defined. The results obtained demonstrated that acoustic streaming results in the enhancement of heat transfer between the plates. Thermo acoustic streaming in a resonant channel driven by a transducer was studied theoretically by Gopinath et al. [32] Richardson analytically studied the effect of sound on natural convection from a horizontal cylinder subjected to transverse relative to the fluid in which it is immersed. [33] A investigators have used the term “acoustic streaming” for either Eulerian or Lagrangian mean velocity fields interchangeably, others only attribute acoustic streaming to the mean particle velocity.3 Lighthill4 showed that the difference between Lagrangian and Eulerian mean velocities is proportional to the mean acoustic intensity, and indicated that “in typical cases of acoustic streaming both the Lagrangian and Eulerian mean motions vastly exceed this difference.”. [34] Acoustic streaming is a vortex-type airflow caused by a high-intensity sound wave. Two factors have been known to induce Acoustic streaming: spatial attenuation of a wave in free space and the friction between a medium and a vibrating object.1−3 the absorption and scattering of the sound wave result in the attenuation of the sound wave in the process of the propagation. This attenuation is in general considered negligible, but the propagation of a high, intensity sound wave causes the attenuation of pressure significant enough to create steady bulk airflow. This type of streaming usually occurs in a medium of high viscosity. The other type of acoustic streaming is attributable to the friction between a medium and a solid wall when the former is vibrating in contact with the latter. [35] The investigation of a related phenomenon, the inner streaming vortices produced by oscillatory flow near cylinders. In these studies, the inner vortices were comparable in thickness to the cylinder radii, and consequently, they were easily observed in experiments. This series of Thermal effects on streaming was first considered by Rott.3 His result, also restricted to wide channels, includes the effects of heat conduction and dependence of the viscosity on the temperature in a gas, as well as the effect of a mean temperature gradient imposed along the channel walls. The inclusion of a temperature gradient was motivated by an interest in processes that occur in thermo acoustic engines. His result reveals that in the absence of an imposed temperature gradient, thermal effects alter the streaming velocity in wide channels by only a few percents. [36] Perlin and Schultz reviewed the study of the capillary effect on the surface waves, including the hysteresis due to the pressure-saturation relationship. The hysteretic phenomena are also reported in the study of bio fluids due to the nonlinear stress-strain relationship [37].

SYNTHSIS & CHARACTERIZATION OF NANOFLUIDS

A two-step technique is hired for preparing the titanium Nanofluids. TiO_2 nanoparticles (99.9% purity) were procured from Nano Labs, India and the manufacturer stated that the purchased alumina particles with average size 30- 50 nm were having a specific surface area of 200-220 m2/g, bulk density of 0.15-0.25 g/cm3, and true density of 4.01 g/cm3. Titanium oxide nanoparticles were flowed into the transformer oil in the authorized extent comparing to the volume division of a nanofluid and played out the attractive mixing. The amount of the nanoparticles to be titanium oxide nanoparticles were flowed into the transformer oil in the authorized extent comparing to the volume division of a nanofluid and played out the attractive mixing20 kHz frequency for an optimized sonication time span of 3 h to get the stable suspension.

Volume fraction % = $(m_n/\rho_n)/(m_n/\rho_n+m_f/\rho_f)$

Fig: TEM Of Tio2 Nano particle

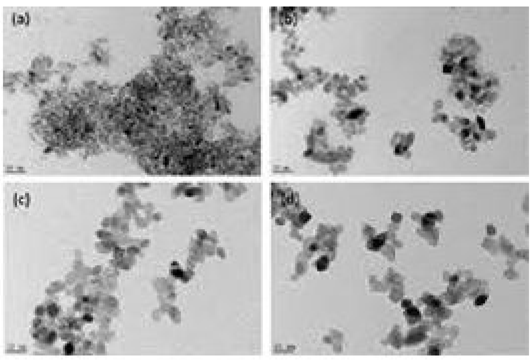
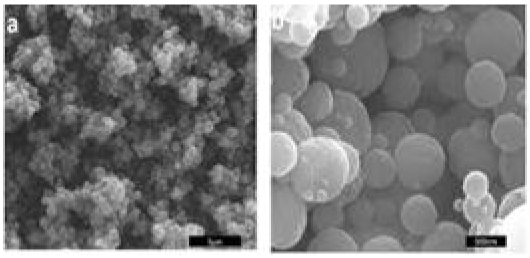


Fig: SEM Of Tio2 Nano particle



DIGITAL BALANCE

The digital mass balance is a sensitive instrument it is used for measuring the weight of a substance to the milligram (0.001g) level. Its surface area will be clean and draft shielded glass will be closed on each side. The press-button switch on to adjustable then to measure the weight of Tio2 nanoparticle(1gram) at room temperature condition.

Fig: Digital balance

MAGNETIC STERLING

Magnetic sterling is the process in which stir the combinations of base fluid of transformer oil and Tio2 Nanoparticles are mixed into a glass jar is a 500 Ml of combination fluid is also called as Nanofluid. It is sterling the Nanofluid in 1 hour at a time of stir the fluid.

Fig: magnetic sterling

ULTRA SONICATOR PROCESS

The ultrasonic electronic generator transforms AC line power to high-frequency electrical energy. The generator futures a keypad or buttons which allow to the user control the ultra-sonication parameters. The generator provides the high-intensity pulses of vitality at a frequency of 20KHZ that runs a piezoelectric convector. The convector is a cylindrical device which is connected to the generator by a high voltage cable the convector transforms electrical energy mechanical vibration due to the crystals. The vibration is amplified and transmitted down the length of the probe/horn. Probes have threaded ends and attach them to the convector. During operation, the probes tip longitudinally increase and contracts. Amplitude is the tip travels and is reliant on the amplitude setting selected by the users.

Fig: Oscar Ultrasonic sonicator,Pr-1000

Fig: UV-Vis spectrophotometer reading of TiO_2 nanoparticles

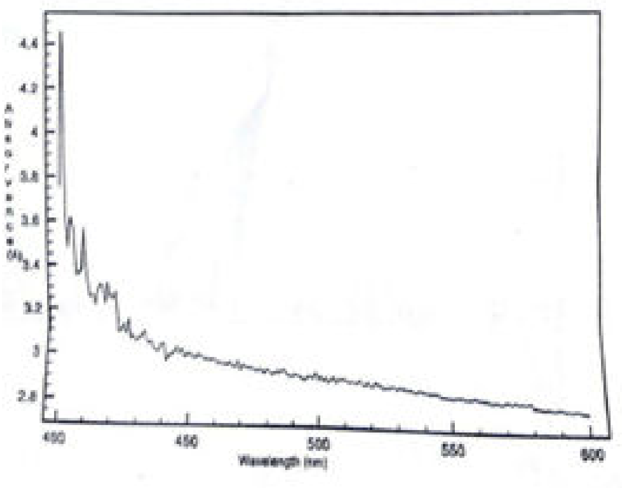
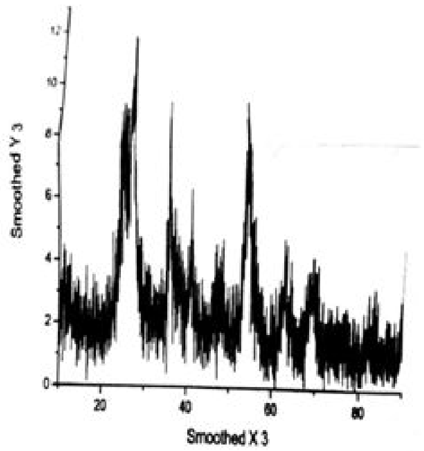


Fig: XRD analysis of TiO_2 nanoparticles



EXPERIMENTAL SETUP

The experimental setup consists of an aluminium square prismatic container which contains the testing liquid, a brass tube of 1.27cm diameter and 25 cm length, a cartridge type tubular heater outer shell with cooling water in and out an arrangement, chrome-Al type thermocouples of Teflon coated to resist the temperature effects, instrumentation panel with dimmer start or vary to vary the heat absorption, voltmeter, ammeter, and digital temperature indicator. All the thermocouples were calibrated with a constant temperature bath at various temperatures and obtained the error < 0.1oC. In order to reduce the loss of heat and to conduct the full amount of heat from the heater to the brass tube, the Nanofluid is filled till the vertical brass tube is completely immersed in it. The outside water is a study state in condition. The heater road surface is located on six K-type thermocouples and each thermocouple distance is 33.3mm. The 6 point temperature indicator is connected to the k-type thermocouples and its temperature recorded. A 3 core cable connected vibrator to demonstrate and its frequency or amplitude ranges increase to decrease. An accelerometer was recycled to pick up a vibration indicator from the cylinder and transfer the same to a vibration meter which could regulate amplitude, velocity, or acceleration. The same, as well as the vibrator placed on the vertical cylindrical surface and its different concentrations, are observed than its local heat transfer coefficient increases.

Fig -3: Experimental setup

Experimental method

The exploratory technique might be partitioned into

1. Common convection without vibration

2. Normal convection with vibration

The common convection without vibration in electrical enter is given to the warmer in the chamber. The water went into the chamber floor compasses to look at the realm condition. The thermocouples situated on the radiator surface and it's associated with the data procured a gadget. The two progressive readings of thermocouples were indistinguishable, yield readings are recorded.

The convection with vibration in an electrical radiator became given arbitrary info. The evil spirit detail transformed into the principal set to control the position and shifting to vitality load work, in this way starting the vibration of the chamber.

The dynamo recurrence was acclimated to the supported degree. The accelerometer is utilized to gauge the frequencies which had been set up at the section conveying the chamber.

After the ordinary realm becomes reached, the temperature differentiation, recurrence, top to top estimations of sufficiency, voltage, current electrical vitality, and the encompassing temperature was recorded top to the base segment.

RESULTS AND DISCUSSION

Experimental gives in various heat inputs 30W, 40W, 50W, and 60W.and its temperature various with regulating the voltage supply with the help of variance.

The surface temperature of the brass vertical cylinder in an axial direction for the base fluid of transformer oil as mediums is depicted.

It is observed that the temperature increases axially maintain at constant heat flux then increases local heat transfer increases the below portion of the cylinder

The properties of the fluid can be calculated by the film temperature that means the average temperature of the cylinder and the bulk temperature of the fluid is calculated by using equation (1).

Film temperature = $Tw+T\infty/2$

Fig: variation of surface temperature of vertical cylinder in axial direction for transformer oil medium.

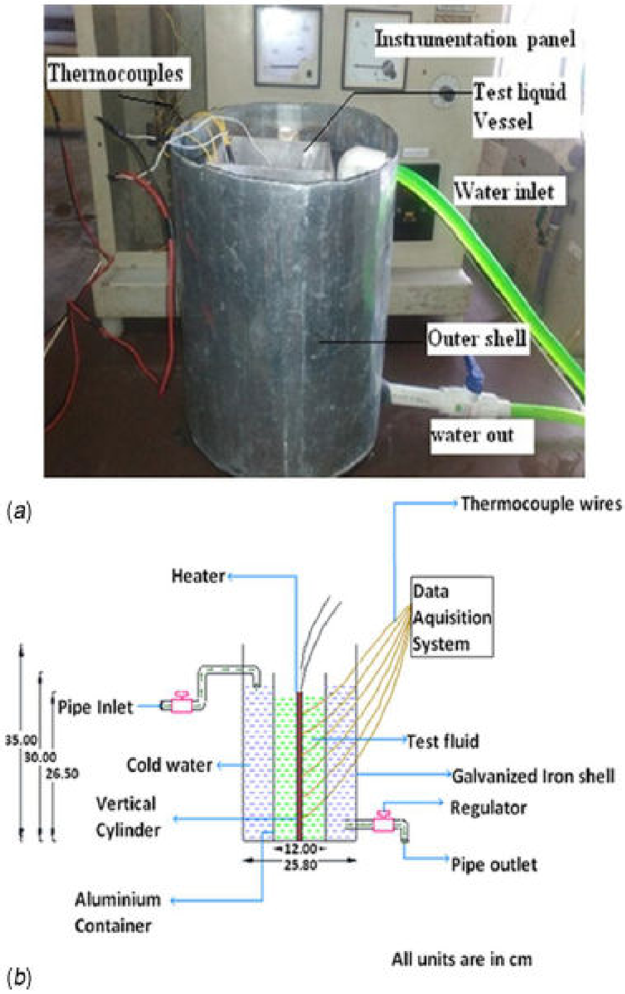
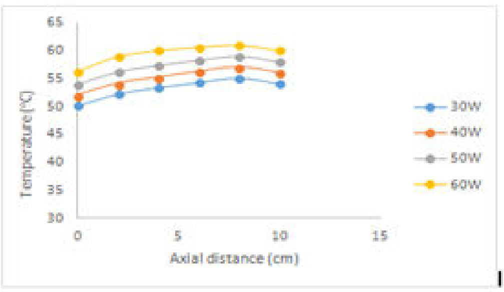


Fig: vibration effect on variation of surface temperature of vertical cylinder in axial direction for transformer oil medium



The Local heat transfer coefficients at various portions are calculated at the points where thermocouples are located. The local heat transfer coefficient is calculated by using equation (2). The various local heat transfer coefficient in the axial direction

Local heat transfer coefficients hx =

Fig: variation of local heat transfer coefficient with axial distance for transformer oil medium

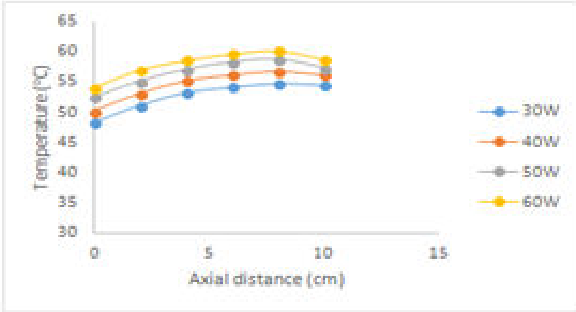
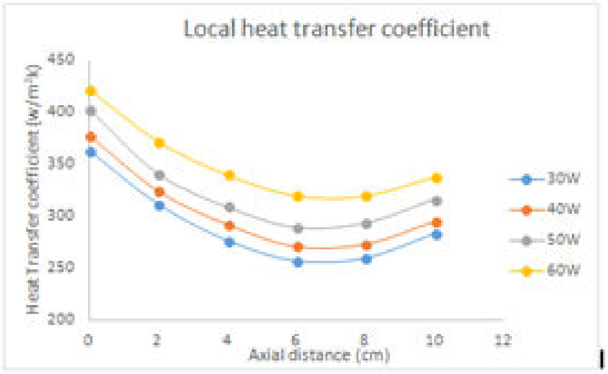


Fig: vibration effect on variation of local heat transfer coefficient with axial direction for transformer oil medium.



Practically observed that the local heat transfer is high at the bottom portion and low at the top portion of the cylinder because of boundary layer thickness is very less in bottom portion of the local heat transfer coefficient is higher and its goes on top portion of cylinder

Nusselt number Nux =

Rayleigh number RaL = Gr. Pr = gβl3ΔT/v2. µcp /k

Fig: variation of local Nusselt number with axial distance for transformer oil medium.

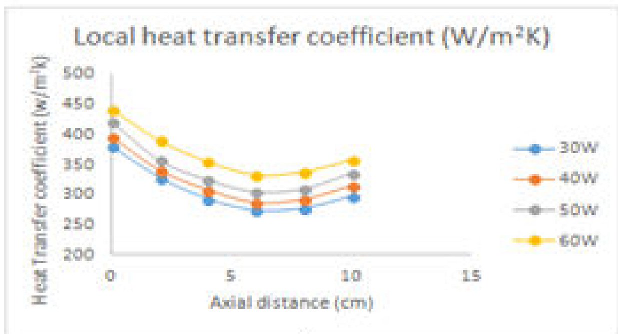
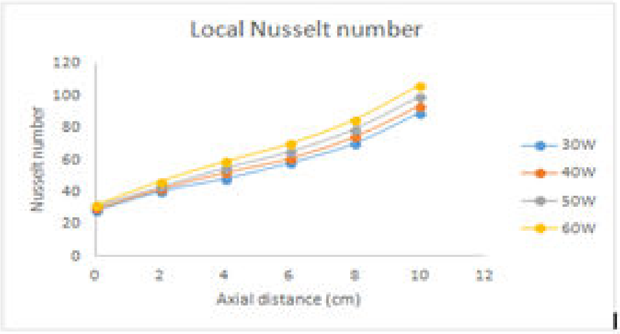


Fig: vibration effect on variation of local Nusselt number with axial direction for transformer oil medium.



It is recognize that the average heat transfer coefficient higher at bottom portion to goes on top portion of cylinder.

Fig: variation of local Average heat transfer coefficient with Heat transfer for transformer oil medium.

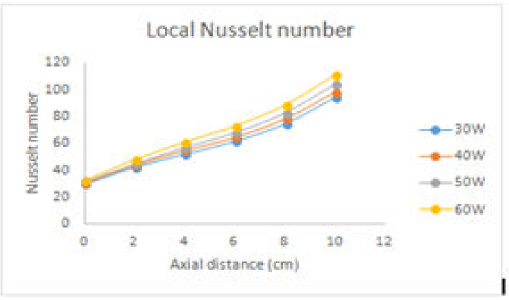


Fig: vibration effect on variation of local Average heat transfer coefficient with Heat transfer for transformer oil medium.

It is observed that the vibration effect on cylindrical surface given to the difference frequencies 0Hz, 100Hz, 130Hz, 160Hz and 190Hz the experimentally observed that given heat input to surface and its heat transfer coefficient increases randomly.

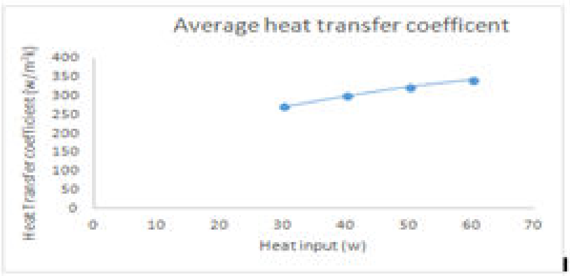
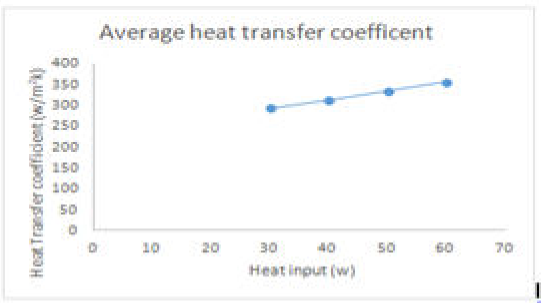
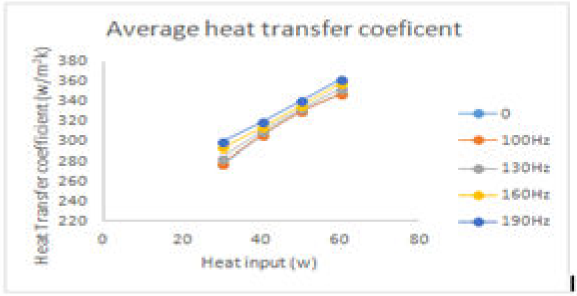


Fig: variation of with and without vibration effect Average heat transfer coefficient with Heat input for transformer oil medium.



Calculated by using the Mathematical equations are used to calculating the density of Nanofluid, specific heat, dynamic viscosity and thermal conductivity etc...



CONCULSION

The study state of buoyancy induced natural convection of a heat transfer of a brass vertical cylinder heat is uniformly has been observed and various heat fluxes. The temperature difference from cylinder along axial direction in case of base fluid of transformer oil

Experimentally observed that in case of transformer oil, the surface temperatures is recorded 6 to 8% higher than in case of transformer oil

Local heat transfer coefficient, nusselt number and Rayleigh numbers are determined at different portion of the vertical cylinder are graphically represented

A correlation between the non-dimensional nusselt number and Rayleigh number

The vibration heat transfer is enhanced by 15.8% at 0.1 vol% concentration compared to water at 60W heat input as heat transfer coefficient is increased from 325.334 w/m2k to 350.419 w/m2k.

0, 0.05, 0.1, 0.15 and 0.2% volume fractions require 1 hour of magnetic stirring to get stable suspension during the experiment.

0, 0.05, 0.1, 0.15 and 0.2% volume reactions require 30min of ultr-sonication to get stable suspension during the experiment.

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