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Experimental Investigation on Natural Convection Heat Transfer Augmentation with Vibration Effect

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Abstract - *The usual conventional fluids like H_2O, engine oil, kerosene, ethanol, and ethylene glycol have lower thermal potential analyze to solids. Lower melting conductivity of fluid became an obstacle to use in distinctive utilization. The observations were carried out to obtain the increase in heat transfer rates as an outcome of mechanical vibrations enforced to a horizontal cylinder. The two cylindrical diameters are one in which external diameter 25cm and internal diameter is 12cm is heated inside the brass cylindrical surfaces. A Thermal layer was recognized outside the boundary layer in the ambient fluid later the study-state condition is obtain as the fluid temperature goes on increasing along an axial direction with Temperature variation of the cylinder along an axial direction. Preliminary carried out different heat inputs 30w, 40w, 50w, 60w and an interrelationship between the Nusselt numbers (Nu) for perpetual heat flux. The cylindrical surface is various vibrating frequencies 190 Hz, 160 Hz, 130 Hz, and 100 Hz. A range of amplitude, frequency, temperature difference and it is observed that amplitude length 0.5 amps. The vibration local heat transfer coefficient increases with linearly and Nusselt number increases from the bottom location to the top location.*

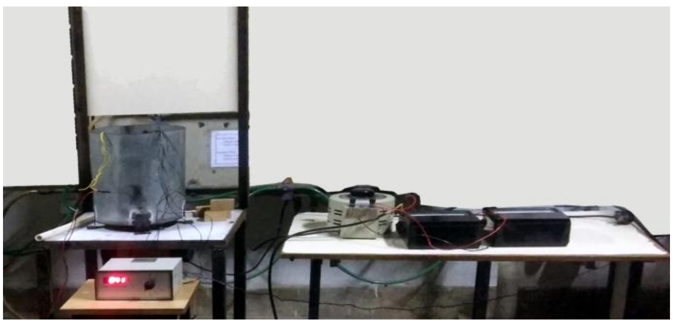
Key Words: Natural Convection, Heat Transfer, Constant Heat Flux, boundary layer, Vibration, amplitude, frequency.

1. INTRODUCTION

The effect of oscillations upon the estimate of heat transfer by free convective heating surface can be studied analytically with two various methods. In this first method, a surface is taken in static and vibrations effect in the neighbouring surface in a fluid medium. In this second method, oscillation motion impacted up on surface medium itself, its escape the fluid natural conditions. In this method, the mechanical system caused by vibration at buoyant frequency and amplitude depends on it. Mechanical vibrations are used in different applications like industrial, space program and rocket propulsion motors, etc. (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 [1].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 [2]. 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 [3].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 (0^o, 30^o, 45^o, 60^o, 90^o). 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 (0^o, 30^o, 45^o, 60^o, 90^o), and reaches a maximum ratio of (13.3%) in the horizontal state, except at the vertical state ($\theta = 90^o$) the heat transfer coefficient decreases as the excitation increases and the maximum decrease ratio occurs at (7.65 %) [4].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 [5].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 the acoustic cycle, the fluid is alternately hotter and colder than the wall. In combination with the reciprocating flow, substantial axial heat transport results [6].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 [7].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 [8]. 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 [9].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 [10].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 [11].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 [12].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."[13].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 [14].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 [15].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 [16].

2. EXPERIMENTAL SETUP

The experimental setup as shown in fig. a vibrator (single-phase vibrator) was bolted on the rigid supporting frame and it's tight. The outer galvanized iron cylindrical container consists of L*H*D (265mm*350mm*258mm) and its cylinder fixed at both ends was carried on brackets seated on the vibrating strip and receiving vibrations through it. The inner aluminium square enclosure consists of l*b (120mm*120mm) and t*h (4mm*300mm) respectively. The cylindrical heater road coated with brass material it consists of D*l (18.5mm*250mm) and its surface placed on six K-type thermocouples and its each thermocouple distance is 33.3mm. The 6 point temperature indicator 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.



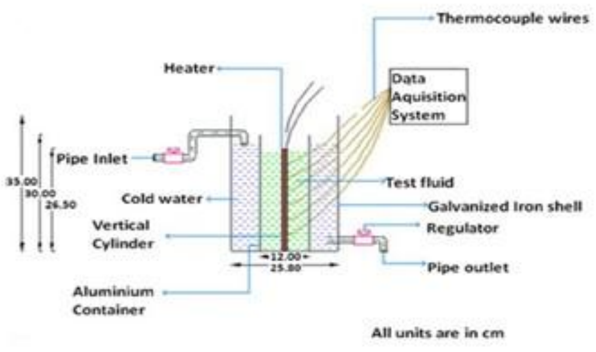


Fig.1: Experimental setup (17)

3. Experimental procedure

The experiments are conducted as per the following manner.

1. Natural convection without vibration
2. Natural 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 dimmer stat was first set to power-on location and varying to power-load location, thus starts the 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.

4. RESULTS AND DISCUSSION

Analysis to carry out at different heat inputs by regulate the voltage transfer with the help of distinct Heat inputs given to the cylinder are 30W, 40W, 50W and 60W. The exterior temperatures of the brass vertical cylinder are systematic with the use of thermocouples in the axial direction for base fluid medium increased for any heat input, due to high local heat transfer coefficients occurring at the bottom location of the cylinder. All the thermo-physical plot of the analysis fluid is calculated at the film temperature, which is the standard exterior temperature of the cylinder and the bulk temperature of the fluid and is presented in equation. The bulk condition of the fluid medium is 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 same height from the bottom wall of the container compared to the thermocouples attached to the vertical brass cylinder.

Film temperature $=(Ts+Tf)/2$

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

$$hx = Q/(A\,\Delta Tx)$$

Local heat transfer coefficient

$h_{x1} = Q/ As\,(T_{S1}-T_{F1})$, $h_{x2} = Q/As\,(T_{S2}-T_{F2})$ Etc….

Ts1, Ts2, Ts3, Ts4, Ts5, Ts6 are surface temperatures of the six thermocouple locations and Tf1, Tf2, Tf3, Tf4, Tf5, and Tf6 are the temperatures of the fluid at the comparable height.

The local Nusselt number is

$$Nu_x = h_x\, l_c / k$$

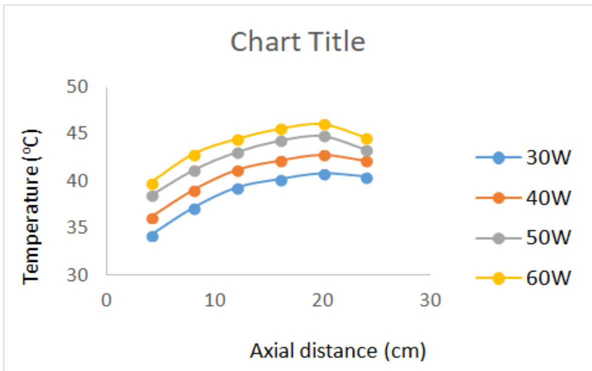


Chart-1: Surface temperature of the vertical cylinder along axial distance for without vibrations in the base fluid.

The change of temperature in the axial distance is shown in **Chart-1**: It is understood that the temperature is increases at the bottom and it is decreases at the top of the cylinder. As the boundary thickness is very less in the bottom portion of the axial distance, the temperature will be increases and as it goes ahead to top portion.

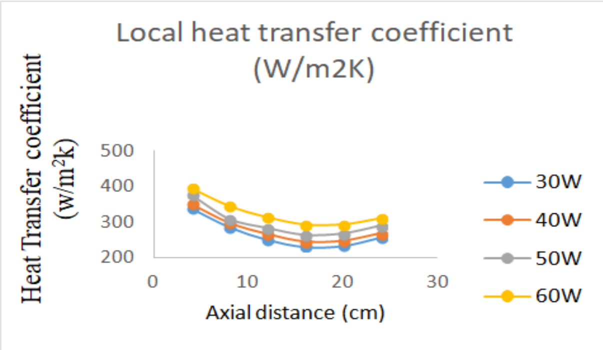


Chart -2: Variation of heat transfer coefficient with axial distance various heat input

The change of local heat transfer coefficients in the axial distance is shown in **Chart -2**. It is recognized that the local heat transfer coefficient is higher at the bottom and it is lower at the top of the cylinder. As the boundary layer thickness is very less in the bottom location of the axial distance, the local heat transfer coefficient will be higher and as it goes ahead to top location, the thickness of the boundary layer will be more; because of this, lesser heat transfer coefficients might be seen there. Local Nusselt number is calculated from Eq. The variation of local Nusselt number along the axial direction is illustrated.

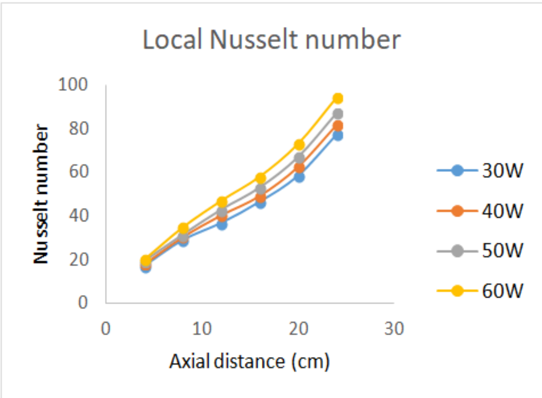


Chart -3: Variation of local Nusselt number with axial distance various heats input

Chart -3: It is determined that the local Nusselt number reinforce as the space increases and for all the heat improvement to a detail of water medium. The thermal layer is recognized in the mass liquid as the temperature of the liquid at a point which is far from the boundary layer and continues increasing from base part to the top location.

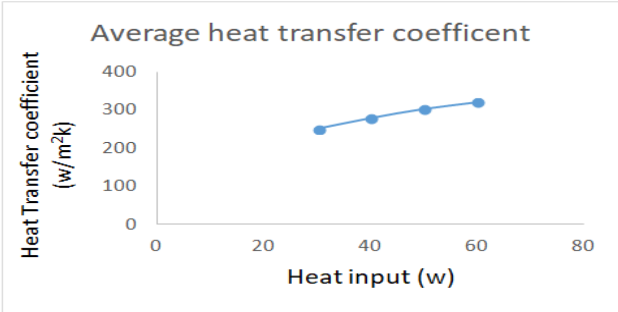


Chart-4: Variation of heat transfer coefficient with heat input

Chart-4: it is observed that different heat inputs (30W, 40W, 50W, 60W) with average heat transfer coefficient increases by the bottom portion to the top portion with linearly.

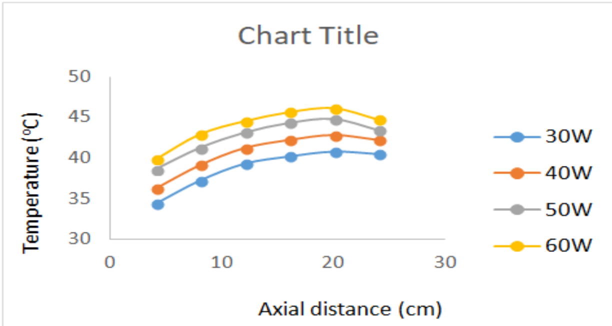


Chart-5: Surface temperature of the vertical cylinder along axial distance for with vibrations in the base fluid.

The variation of temperature in the axial distance is shown in **Chart-5**: It is observed that the temperature is increases at the bottom and it is decreases at the top of cylinder. As the boundary thickness is very less in the bottom location of the axial distance, the temperature will be increases and as it goes ahead to top location. The vibration effect on the surface of the fluid temperature increases to better than to it's without vibration.

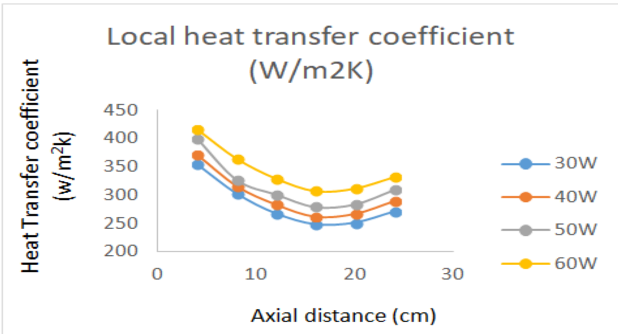


Chart-6: Variation of heat transfer coefficient with axial distance various heat input with vibration effect

The change of local heat transfer coefficients with axial distance is shown in **Chart-6**: It is understood that heat transfer coefficient is increases at the bottom and it is slightly decreases at the top of the portion. As the boundary thickness is very less in the bottom portion of the axial distance, the local heat transfer coefficient will be higher and as it goes ahead to top location, the thickness layer will be more, because of this, lesser heat transfer coefficients might be seen there. Local Nusselt number is calculated from Eq. The deviation of local Nusselt number onward the axial direction is representing.

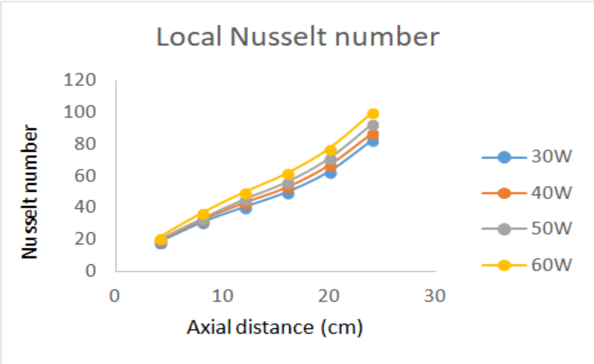


Chart-7: Variation of local Nusselt number with axial distance various heat input

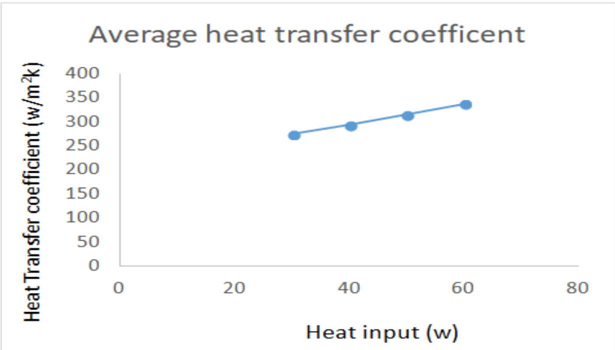


Chart-8: Variation of local Nusselt number with axial distance various heat input

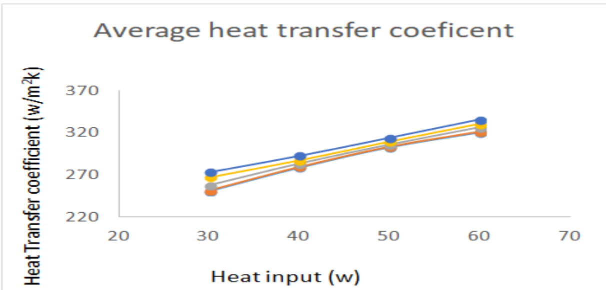


Chart-9: Variation of Average heat transfer coefficient with heat input

It is observed that the local heat transfer coefficient with heat input increases with a linearly bottom portion to the top portion. This graph observed to compare with or without vibration in the bottom portion to increases linearly in the top portion. The effect of vibration up on the fluid medium temperature increases more than that of without vibration effect.

Rayleigh number $Ra_L = Gr. Pr = g\beta l^3 \Delta T / v^{2. \mu c_{p}} {}_{/k}$

Nusselt number $Nu = 0.287 (Ra_L)^{0.287}$

Local Nusselt number $Nu_L = h x/k$

5. 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 slightly.
3. The natural convection of cylindrical surface decreases with increases in the temperature variation.
4. The vibration Reynolds number has riches effects on the heat transfer from the cylinder. The free convection term (Gr. Pr) has a bad effect on the vibration heat transfer.
5. The Study about this experiment cylindrical diameter decreases with vibration frequency increases and greatly increases temperature difference.
6. The vibration effect on natural convective heat transfer is enhanced by water at 60w heat input has heat transfer coefficient is increased 321 w/m^2k to 336 w/m^2k.

Nomenclature

Ra_L= Rayleigh number

Gr = Grashof number

Pr = Prandtl number

g = acceleration due to gravity (m/s^2)

β = coefficient of thermal expansion (K^{-1})

L = length of the cylinder (m)

ΔT=temperature difference (°c)

V=volume of the fluid (m^3)

μ = kinematic viscosity

c_p=specific heat (J/kg k)

k=thermal conductivity

Nu=Nusselt number

X=axial distance (cm)

Subscripts

B_f = *base fluid*

Film= film temperature

f = fluid

s = surface

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