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The Effect of Vibration on the heat transfer from a vertical plate: A Review

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Abstract - *The influence of free or forced convection heat transfer becomes an essential element in laminar and turbulent flows. There have been numerical and experimental methods introduced in studying the convection in (tubes or plates) with different angular positions for conditions such as temperature-dependent fluid density, constant wall temperature, and parabolic profile axial velocity at (tubes or plates) entrance. In all cases, heating and cooling have been considered. The current research is an extension to free or forced convection, where it unravels the effect of Vibration on heat transfer performance of free or forced convection. This section presents the literature review to observe possible gaps in the literature concerning the topic under discussion, which informs further research***.**

Keywords - *forced convection, natural convection, vibration effect, heat transfer from the vertical plate.*

INTRODUCTION

Although we seldom notice the presence of heat, the changes it makes, and how it is transmitted, it surrounds us and is present in most of our daily lives. Convection is the dominant heat transfer system for liquids and gases and occurs when hotter gas and liquid layers travel to the more relaxed layers[1]. The convection is separated into two sections (Natural Convection). That is what happens without interference by humans. The hot gasses decrease in density and thus rise to the top and are replaced by cold gasses, such as carrying air to heat from the hot spot to the cold spot as it moves due to differing density. And (Forced Convection) In this case, the fluid is forced to run using a pump, fan, or another mechanical device in which the minutes of the heat transfer fluid shift by force, as if caused by currents produced by industrial devices that operate to find a difference in pressure between two fluid areas[2].

Techniques for enhancement heat transfer:

1. Active technique: This method is more complicated from use and design as the method requires some external power input to change the system and improve heat transfer purposes. Along with mechanical supports, various active ways, stream vibration, surface vibration, and jet impingement. Vibration and oscillation phenomena in industrial equipment such as fluctuating fluid flow and Vibration occurring in mechanical and spacecraft applications, as the vibrations caused by the sound and the vibrations caused by the ultrasonic effect may fail due to the pressures resulting from the Vibration of the component materials [3-4]. Vibration is one of the researchers' successful ways of enhancing heat transfer. Vibration increases the severity of the layer turbulence adjacent to the fluid and expands the confusion between the particles in the fluid layer, which increases the heat transfer rate [5]. Studying the effect of Vibration on hot surfaces in two ways, the researchers continued. The first approach involved putting the seductive body in a fluid medium and emphasizing the hot surface's fluid with the sound vibrations. In contrast, the second method applies Vibration to the hot surface itself. This approach provides a mechanical mechanism that moves at a particular frequency or is forced to vibrate, and the type of Vibration used is sinusoidal vibration [6].
2. Passive technique: this method is popularly geometric to the flow channel surface by incorporating inserts (or) to add devices. Extended surface, rough surface, and the treated surface will complete heat transfer. Extended characters, known as fins, are used to improve heat transfer in many industries where heat exchanger devices' performance can be increased by applying extended surface [7]—using fins as ample surface increases the weight and size of the device and also increases the production cost. As a result, in recent years,' attention has been paid to improving fin geometry

[8]. Therefore, fins as heat-transfer devices are becoming very popular. As extended surfaces' technology continues to grow, new design ideas are emerging, including fins made of anisotropic compounds, porous media, and perforated and cut boards [9]. Due to the requirements of lightweight, compact and economical fins, improving the size of fins is essential.

Consequently, the fins should be designed to maximize heat removal with the minimal material expense and ensure that fin manufacturing is facilitated [10]. Several studies have been done to improve fins. Suppose other studies have made shape changes by removing some materials from the fins to form cavities, holes, grooves, or channels through the fin body to increase the area of heat transfer and increase the coefficient of heat transfer. The use of cut or perforated surfaces in various configurations is a standard heat transfer magnification technique where the cavity aims to promote surface turbulence, aiming to increase the heat transfer coefficient in the surface area [11]. Theoretically analyzed a horizontal rectangular fin's thermal performance with a uniform cross-sectional area combined with four vertical body piercing patterns that spanned through the fin. Probe patterns included triple, square, circular, and rectangular holes. Natural Convection was used using finite element technology to analyze these patterns. The analysis showed that perforated fins' thermal transfer was greater than that of non-perforated fins [12].

3. Compound technique: are a summation of two or more individual active and passive techniques.

II. APPLICATIONS FREE CONVECTION

Jalil (2012) [13] investigated the effect of different parameters on the heat transfer ratio (hv/ho), where it was found out that the percentage of heat transfer increases at high frequency and small diameter. The vibration Reynolds number was also found out to have a good effect on the heat transfer ratio. On the other hand, (Gr.Pr) has a lousy indication of heat transfer ratio at high-temperature difference or high heat flow. Therefore, the researcher concluded that the vibration intensity has a good influence on the transfer of heat. In a related experiment, Kadhim & Nasif (2016) [14] investigated the effect of vertical oscillation on the finned aluminum tube's heat transfer coefficient. The impact of the frequency of vibration frequency ranged from 2-16 Hz with various heat fluxes ranging from 500 to 1500 W/m2. The results showed that the relation between heat transfer and the vibration amplitude increased for all inclination angles (00- 450). In contrast, the increment of the inclination angle decreases the values of the convection heat transfer coefficient. The results portrayed that the heat transfer coefficient ratio (hv/ho) of longitudinally finned cylinders in (00) angle was (8%) and (30% greater as compared to those for the (300) and (450) respectively.

Theoretically, the heat generated electrically in the cylinder is transferred to the ambient through radiation and convection due to variation in temperature between the cylinder surface and the ambient, For free convection.

According to the studies conducted by Nag & Bhattacharya (1982) [15], it was discovered that up to some level of the threshold value of the product of amplified and frequency (15mm/s), the imparting of the Vibration had no significant impact on the transfer of heat from the fin array. The researchers involved conducting extensive experiments on natural convection heat transfer. This study indicates no change in the heat transfer rate from vertical fin array with the effects of the imparting of Vibration of the low intensity below the threshold. Another study supported this result by Eid, E. I., & Gomaa, M. E. (2009) [6].

The researchers were investigating Vibration's influence in the enhancement of the heat transfer from thin planner fins. According to the results of this study, it was discovered that the normal Vibration is capable of enhancing the heat transfer rate for the case study by approximately 85% instead of the steady flow case if there is the same average velocity in both cases.

According to the findings of the research carried out by Park et al. 2014 [16], the Nusselt number of the vibrating fin, when normalized to its value for this statutory fin, is impacted strongly by the ration of the speed of Vibration and the velocity of the buoyancy-driven flow. According to this finding, the study proposed a correlation that can apply to velocity ratios of 0-20 and the vibration frequencies of 29 to 59 Hz. The researchers focused on investigating how the oscillatory motion affects heat transfer on the vertical flat surfaces.

According to these researchers, the average time of heat transfer rate could be estimated as per the time average of the oscillatory Reynolds number. It was also shown by the results of this research that the enhancement of the modest heat transfer because of the oscillatory motion is associated with the small convective term in the energy equation. The study's result indicated that the oscillatory motion enhances the transfer of heat at vertical surfaces, increasing the highest frequencies and amplitude of the oscillation. In 2006 Fu, W. S., & Huan, C. P. [7] conducted another study to investigate the effects of vibrational heat surface on the convection in a vertical channel flow. The scientists performed a numerical simulation to study the impacts of vibrational heat surface to develop the findings. The researchers took into consideration the frequency, the Rayleigh number, and natural convection. The results indicated that the natural convection of the Rayleigh number's vibration heat with some combination of frequency and amplitude tends to be smaller than that of the stationary state. Pilli et al. [24] agreed with this finding on their computational analysis of fluid dynamics and heat transfer characteristics of the vibrating heated plates. The results of this study were supported the work of Fu, W. S., & Huang, C. by emphasizing the fact that the induction of vibrations to a horizontal plate can result in the induction of the turbulence in the flow field adjacent to the plate under the combination of amplitude and frequency. It was discovered in a related study that the wall shear stress increases with the increase of the frequency and amplitude of Vibration.

III. APPLICATIONS OF FORCED CONVECTION

Sarhan et al. (2019) [18] recently conducted another research on the impacts of vertical Vibration on the thermal performance of the rectangular flat surface. According to the results of this study, it was evident that the increase of the oscillation frequencies resulted in the rise of the average heat transfer coefficient as well as the maximum increase obtained in the horizontal position and higher frequencies. The researchers also found a decline in the intermediate heat transfer with the increased vibration frequencies when the plate was placed in a vertical position.

In 2007, Kim et al.[19] conducted a study to investigate mechanical Vibration on critical heat flux in the vertical annulus tube. During this research, there was an increase in the heating rod's Vibration as the flow regime changed from the subcooled region to the bubbly area. Mechanical Vibration increased the CHF to 16.4%. The researchers discovered that vibration amplitude was one of the parameters found to be the most effective in the enhancement of the CHF. The study concluded that a Vibration is a practical approach to the enhancement of heat transfer and CHF. Moreover, these results can conclude that the Vibration of heated surfaces tends to give rise to turbulence flow and enhance bubbles' movement from one place to another. The CHF was enhanced by the heater's Vibration, indicating that Vibration's reinforced turbulent mixing effect is associated with CHF enhancement. Therefore, it is essential to conclude from these studies that mechanical Vibration tends to increase heat transfer and CHF.

Hussain, Amori & Mutasher (2013) [20] carried out the experimental investigation of the heat transfer characteristics in a plate-fin having a built-in piezoelectric actuator that had been mounted on the substrate or the base plate. The single element of the plate and triple fins is based on the geometric configuration considered, while air acts as the working fluid. The researchers observed an increase in the heat transfer with the subsequent rise in the frequency and Reynolds number. Moreover, the triple fins with 50mm height and 3mm distance between fins were better than other cases. The study supports evidence showing that when mounted on the rectangular piezoelectric actuator gives excellent promise for enhancing heat transfer rate.

To find out the relationship between critical heat flux (CHF) and flow-induced Vibration (FIV), Lee et a. (2003) [21] used the vertical round tube in the atmosphere. The researchers showed that in both departure conditions from nucleate boiling and liquid film dry-out, CHF was found to increase by 12.6% with vibration intensity represented by the vibrational Reynolds number (Rev). The critical heat influx enhancement by cylindrical Vibration emanates from the reinforced flow turbulent mixing and the rise in the deposition of the droplet into the liquid film. The results show that Vibration is an effective method of heat transfer enhancement and CHF.

The current experimental results have

presented the impacts of low-frequency vibrations in a horizontal heat pipe. Alaei, Kafshgari & Atashi (2012) [22] showed that the temperature between the evaporator and the heat pipe's condenser could be measured under different heat transfer rates, filling ratios, and frequencies. The researchers concluded that the vibrations of low frequency imposed a significant effect on the thermal performance. The best performance was achieved with the thermal resistance of 0.05 K/W within the 25Hz frequency. The influence of horizontal longitudinal vibrations and the condensation section temperature on a heat pipe's heat transfer has also been widely examined. By setting the condensation section temperatures at 20, 30, and 400C, Chen, Lin & Lai (2013) [23] tested the longitudinal vibrations having frequencies of 3,4,5,6 and 9Hs with subsequent amplitudes of 2.8, 5, 10, 15, and 25mm that were considered to give accelerations in the range of 0.1-1.01. The results showed that horizontal Vibration of the heat pipe in the longitudinal direction led to an increase in the heat transfer of the heat pipe, which was directly proportional to the input vibration energy below 500 mm3 Hz2.

VI. CONCLUSIONS

The current research has analyzed the effects of vibrational heat surface on the convection in different channel flows based on either forced or free convection. There are common contention points among researchers, with most of the findings showing a relation between the heat transfer coefficient and the amplitude of Vibration, where it increases for all angles of inclination. That indicates that Vibration can increase the steady heat transfer rate. The increase in the oscillation frequencies is observed to increase the average heat transfer coefficient and the maximum increase obtained in the horizontal position and higher frequencies. The researchers' other consensus is that there is a decrease in the average heat transfer with the increasing rate of vibration frequencies whenever the plate's position is vertical. Other results show that under normal oscillation conditions, the flow and thermal fields experience boundary problems.

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