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STUDY THE EFFECT OF LONGITUDINAL TAPERED FINS AND PINNED FINS IN A VERTICAL DUCT ON COOLING SURFACE TEMPERATURE

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ABSTRACT:

Heat is dissipated to the environment through heat sinks in electronic parts and fins in internal combustion engines, the extended surface plays a significant role in the heat transfer of many heat generation devices. Depending on the generation source, the extended surface can be used for cooling or heating. In the present study, three types of plates are used in vertical ducts (flat plate, tapered fin, and pinned fin heat sink) under differing power inputs (10 to 60 W) and varying air velocities, from 0 m/s for natural convection to 0.5–2.5 m/s for forced convection. Then study the temperature difference with the distance of the fins from the back plate. The experimental result shows a good temperature difference when we use tapered fins more than pinned fins, which in turn gives a lower temperature difference than the flat plate. Also, temperature will decrease when far from the back plate for the fin.

KEYWORDS: Cooling surface, Heat dissipation, Heat convection, Heat sink, Pin fin, Tapered Fin.

1. INTRODUCTION

Fins, or Extended Surfaces, are utilized in many engineering contexts to increase the efficiency of convective heat transmission without resorting to impractically enormous amounts of main surface area. Common uses of fins include cooling IC engines and automobile radiators, as well as heat management in various electrical devices including computer power supply and substation transformers. More length added to the fins increases their effective surface area. The rate at which heat is transferred from the base surface to the fluid rises as the fin's surface area grows due to the addition of extensions. One strategy for better heat transmission is based on the idea of using a perforated in fin array.

It is common practice to utilize extended surfaces in heat exchanging devices to boost heat transmission from a main surface to the surrounding fluid. Many varieties of heat exchanger fins have been employed, including combinations of geometry as well as more basic shapes like rectangles, cylinders, annuluses, tapered fins, and pin fins. These fins may extend from a square or a cylinder [1],[2],[3].

The pin fin is a kind of fin that is often seen in heat exchangers. An example of a pin fin is a cylinder or other shaped element mounted perpendicular to a wall, with the transfer fluid flowing over the element in a cross flow. Pin fins may be described by their form, height, diameter, height-to-diameter ratio, etc. Moreover, the pin fins may be arranged in arrays that are either offset or in-line with the flow direction [2]. In order to prevent premature failure, an ever-increasing

quantity of heat and heat flux must be dissipated at ever lower junction temperatures as power electronics perform more demanding tasks while the die size continues to decrease. As this is the case, proper thermal management is essential for the steady performance of power electronics [3],[4].

Depending on the material used, cooling techniques may be split into two distinct groups. There is the use of air as a cooling medium, and there is the use of liquids such as water or dielectric fluid. By fastening a forced-air-cooled heat sink to the housing of the electronic chip, ambient fluid may be used to efficiently cool the electronics at a low cost. Nevertheless, due to the poor heat transfer coefficient between the fin array and the air, the thermal resistance of such a design might be rather considerable, necessitating the need for heat transfer enhancement in air cooling. So, a great deal of effort has been put into developing strategies to improve heat transmission in an air-cooled heat sink. The electronic components are cooled by a forced air-cooled heat sink, and Wang [5] has

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published a comprehensive assessment of the methods that may be employed to do this.

Pin heat sinks are recommended as a means of halting the growth of the boundary layer and increasing the number of air disturbances necessary to increase the quantity of heat removed. The design of a pin fin is characterized by a grid of sharp nails that are joined in a straight line on the surface of the heat sink. Dissipation of energy results in the formation of heat as a secondary product, which may lead to the failure of the scheme in these apparatuses due to the very high temperatures present in a variety of industrial applications [6], [7], [8]. It is difficult to predict how well pin fin canals will operate in terms of heat transfer. Due to the challenging nature of flow distribution, a large number of researchers have participated in computational and empirical investigations of heat transmission using pin fins. The study was conducted to better understand how pin fins affect heat transfer and to improve it. Both experimental and numerical systems have been modified to examine the features of heat transfer for various configurations and investigate all the factors impacting the heat transmission processes.

The improvement of heat transfer provided by the use of fins has been explored experimentally as well as statistically using a variety of alternative designs for the fins. The flow structure, velocity vector, and temperature field are provided as the results of the experiment. According to the findings, the pace at which heat is transferred gets much more impressive when fins are used. It has also been discovered that an increase in the particle volume concentration as well as an increase in the Reynolds number leads to a greater augmentation of heat transfer [9],[10].

Slight pin fins in different configurations (ring, rhombus, and triangle) are subjected to an analysis by Guan et al. [11], who consider the impact of the heating load on the resistance and heat transmission characteristics of these components at a range of Reynolds numbers (10 to 10000). Pressure was observed to be reduced in the all-pin fin configuration. A larger effect is seen when the heating load increases, and the trigonometric fins experience a greater fall in pressure relative to other fins. Tiny pinned fins, including cylindrical, rectangular, and elliptical pin fins, were subjected to an experimental investigation by Ndao et al. [12] to determine the effect of pin fin form and arrangement on the single-phase heat transmission qualities of jet impingement. Depending on the conditions, the heat transmission coefficients of both rounded and square fins were found to be significantly greater.

The heat transmission performance of a tiny channel heat sink with fins of several shapes and sizes, such as triangular, circular, hexagonal, and pentagonal, was studied empirically and numerically by Yang et al. [13]. The triangle-shaped fins were shown to be associated with the greatest pressure reduction, while the circular fins were shown to be associated with the least. The effect of round and rectangular holes above panel fins on heat and turbulent air flow performance was implemented experimentally and computationally by Ismail et al. [14]. Perforated fins with both spherical and rectangular holes were found to have almost the same heat transfer rate, whereas the fin with spherical holes had a much lower pressure. increase the number of holes in a fin from two to three, the efficiency remains nearly the same, but the pressure reduces.

The impact of hole shapes on the hydraulic thermal efficiency of pin fins was studied statistically by Sallami et al. [15]. The results showed that the fins' thermal and hydraulic performances improved with a larger cross section of the punching region.

Fillet profile affects heat sink efficiency, which Wong et al. [16] empirically investigate. They found that by adding a fillet to the bottom of plate-finned heat sinks, they were able to boost their overall thermal performance by roughly 14 percent. Adjusting the Reynolds number affects the heat sink's performance by increasing the turbulent flow and decreasing boundary layer, which Li and Chao [17] study. Although the tallest fins have the best thermal performance for a certain fin width, the widest fins benefit the most from an increase in Reynolds number for a fixed fin height. Authors Chin et al. [18],[19] Studied the effects of forcing pregnancy through pierced fins on increasing convection. The pressure drop is 20% larger, and the number of nusselts increases by 55% for the pin fin that was perforated. Weak pin fins compared to the usual. It was hypothesized that when the hole count rose, the Nusselt number would rise and the pressure loss would be mitigated the rate of heat transmission was investigated by V. Karthikeyan et al. [20] for various types of extended surfaces. They developed and analyzed several fin extensions and perforation patterns, comparing their performance to that of standard fins. Consequently, heat transmission via a fin with a rectangular extension is enhanced compared to other types of extensions. The use of a fin with a rectangular extension achieved a heat transfer improvement of 13%–21%. In comparison to fins of varying lengths, those with a rectangular extension exhibited higher efficiency. Pardeep Singh, et al. [21] They have conducted research and analysis on the design of the heat transmission via the fins with extensions. As compared to a fin that does not have any extensions, the rate of heat transfer that occurs through a fin that has the same geometry but varying extensions results in an increase of anywhere from 5% to 13%. As compared to other types of extensions, the rate of heat transmission via a fin that has rectangular extensions is much greater. when compare the temperature at the end of a fin with rectangular extensions to the temperature at the end of a fin with other types of extensions, the difference is dramatic. The majority of heat exchanger designs utilize some kind of forced airflow across the exchanger; however, individual needs often dictate how different designs should be. These heat exchangers typically make use of fin-and-tube geometries and modified fin patterns in order to improve air-side heat transfer. This is done because the air-side heat transfer resistance is the primary factor that determines the level of performance that can be achieved. Several current heat exchanger designs have been designed with serpentine fins and flat tubes [22],[23], in contrast to the classic fin and tube heat exchangers, which have planar fins and circular tubes. Since there have been far fewer examinations of the flat-tube geometries, the performance differences between flat-tube heat exchangers with various fin shapes are not thoroughly known, according to the best knowledge of the authors. The aim of the present study was to investigate the heat transfer characteristics of different types of plates (flat plate, tapered fin, and pinned fin heat sink) used in vertical ducts. The study aimed to analyze the impact of varying power inputs and air velocities on heat transfer. Specifically, the focus was on examining the temperature difference as a function of the distance of the fins from the back plate. The experimental results aimed to compare the performance of tapered fins, pinned fins, and flat plates in terms of temperature difference. Additionally, the study aimed to observe the temperature variation as the fins moved away from the back plate.

2 EXPERIMENTAL WORKS

2.1 Experimental Apparatus

1. Set up a vertical duct unit with appropriate dimensions and insulation to minimize heat loss.
2. Install a heating element within the duct to generate controlled heat input.
3. Incorporate a fan on the top to control the air velocity within the duct.
4. Include temperature sensors at specific locations to measure temperature differences.

Instrumentation for monitoring and adjusting temperature, power, and fan speed may all be found in a separate console that can be set up on a workbench. Thermistor sensors that give a direct digital readout in degrees Celsius make it possible to keep an accurate eye on the temperature down to 0.1 degrees.

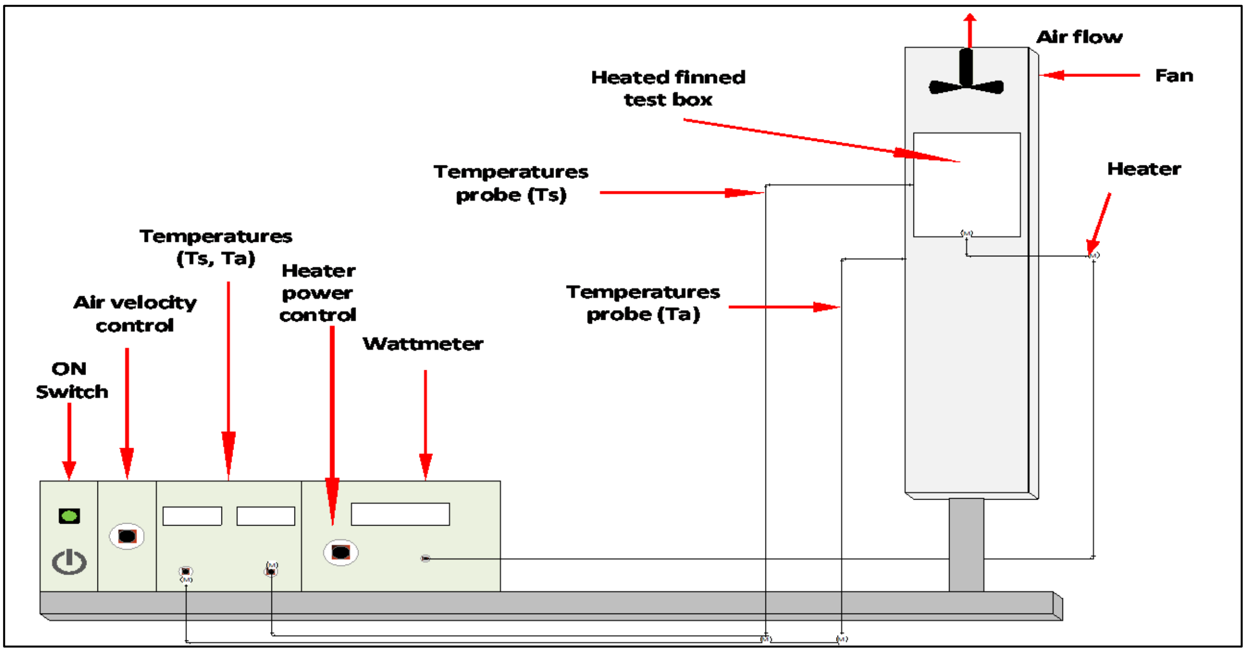

Fig.(1):-Experimental rig.

The experimental setup used in this work is shown in Fig 1. A portable anemometer (a Taiwanese Tenmars TM-4001 hot-wire anemometer), as shown in Fig. 2, is attached to the duct to monitor air velocity. The electrical output may be adjusted constantly between zero and one hundred watts according to the power control circuit.

Fig.(2):-Hot-wire anemometer.

The temperature was monitored until a steady state was attained. A log of each test's temperature was kept. Each experiment captured around 10 measurements, and each experiment was performed twice to reduce experimental uncertainties and collect enough data for statistical analysis.

2.2 Type of Plate

The material for a flat surface and extended surfaces made from Aluminum. In this experiment use the plate:

1. A flat surface
2. An array of cylinders (pinned fins) fig 3
3. An array of fins (tapered fins) fig 4

The dimension of duct and plat type listed in table 1:

Table (1): -Geometric Dimension of Samples

Geometric	Dimensions
Duct	Base dimension = 110 x 70 mm Height = 120 cm
Flat surface	Length = 110 mm Width = 100 mm Thickness = 2 mm
Pinned fins	Number of fins = 17 Diameter of fin = 12 mm Distance from back plate = 65 mm
Tapered fins	Number of fins = 9 Length of fin = 110 mm Distance from back plate = 65 mm base thickness of fin = 5 mm Top thickness of fin = 2 mm

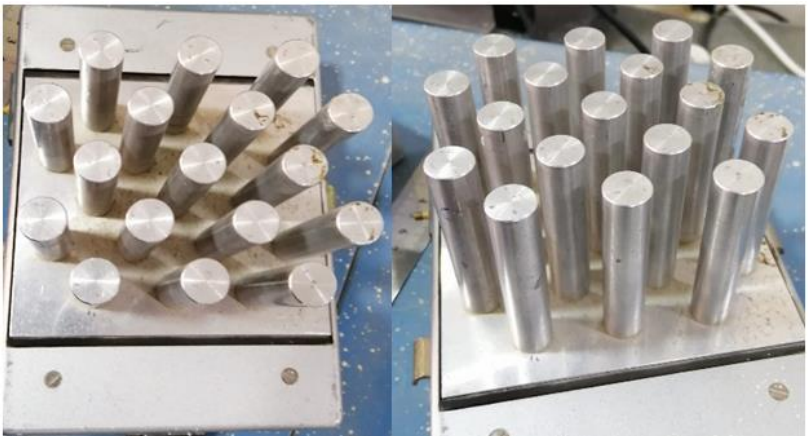

Fig.(3):-Pinned fins.

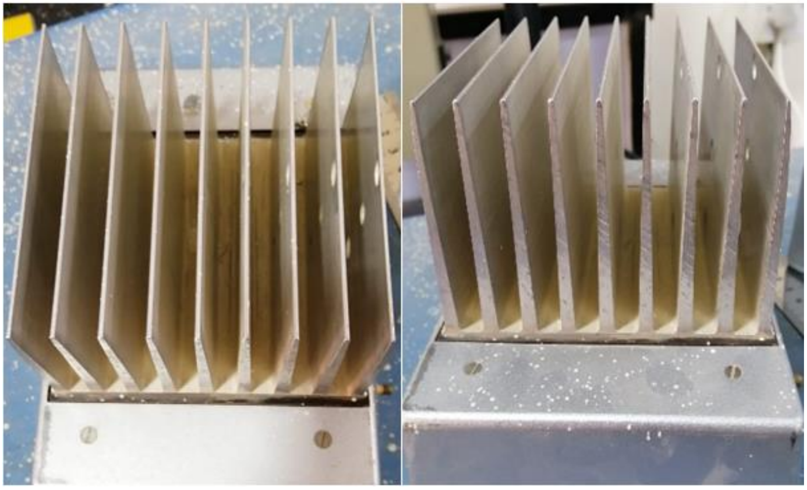

Fig.(4):-Tapered fins.

The surface area for each plate shown in table 2:

Table(2):- lists the surface area for each case

Geometry	Plate with a Flat surface	Plate with a Pinned fin surface	Plate with a Tapered fin surface
Surface area (m2)	0.011	0.05263	0.128

2.3 Power Input and Air Velocity Variation

1. Set a range of power inputs (e.g., 10 W, 20 W, 30 W, 40 W, 50 W, 60 W) for the heating element.

2. Adjust the air velocity within the duct by controlling the fan speed.

3. Select a range of air velocities (e.g., 0 m/s for natural convection, 0.5 m/s - 2.5 m/s for forced convection).

2.4 Experimental Procedure

Start with the flat plate fin configuration and measure the temperature differences at specific distances from the back plate for each power input and air velocity. Repeat the temperature measurements for the tapered fins and pinned fins configurations. Ensure sufficient time for temperature stabilization at each measurement point. With the flat surface tests, it may be hard to get stable temperatures because of thermal inertia and the naturally low convective temperature. Due to how delicate the heater's power control is, you have to be very careful if you want to keep the temperature steady.

2.5 The percentage of variation

The percentage of variation in each operational variable throughout the experiments is listed in Table 3. Mofat's [24],[25] approach for determining percentage deviation yielded the following formula:

$$\%deviation = \frac{x - x_{av}}{x_{av}} * 100 \tag{1}$$

where x is the measurement and x_{av} is the average of a series of measurements.

Table (3):- Experimental uncertainties expressed by average % deviation

Parameter	% Deviation
Surface Temperature	1.3 o C
Ambient Temperature	0.6 o C

3 .RESULTS AND DISCUSSION

It is possible to boost the rate of heat transfer from an item by expanding the surface area that is in contact with the air. In actuality, it may be tough to expand the size of the body to accommodate it. Under conditions such as these, the area of the surface that is in contact with the air may be expanded by the addition of fins or pins that are normal to the surface. Extended surfaces are another name for these types of characteristics. Fig 5. and Fig 6. show the temperature difference (between surface and ambient temperature) with air velocity. The effect of extended surfaces can be demonstrated by comparing (tapered) finned and pinned surfaces with a flat plate under the same conditions of power input (10 W) and (20 W) respectively. Both figures show a tapered fins give a good temperature for cooling temperature (give less temperature difference) when compare with pinned fin, which in turn gives a lower temperature difference than the flat plate. Temperature difference decreasing from 49 ºC for flat plate to 10 ºC for pinned fin and 6 ºC for tapered fin at air velocity 2.5 m/s and power 10 W, tapered fins offer better heat transfer characteristics than pinned fins due to their tapered shape, which enhances surface area and promotes improved airflow. This results in a more efficient heat dissipation process. On the other hand, pinned fins, while still contributing to increased surface area, may have higher resistance to airflow, limiting their heat transfer efficiency in comparison also the same result with increasing power to 20 W shown in fig 6 and this is in a good agreement with the literature [26].

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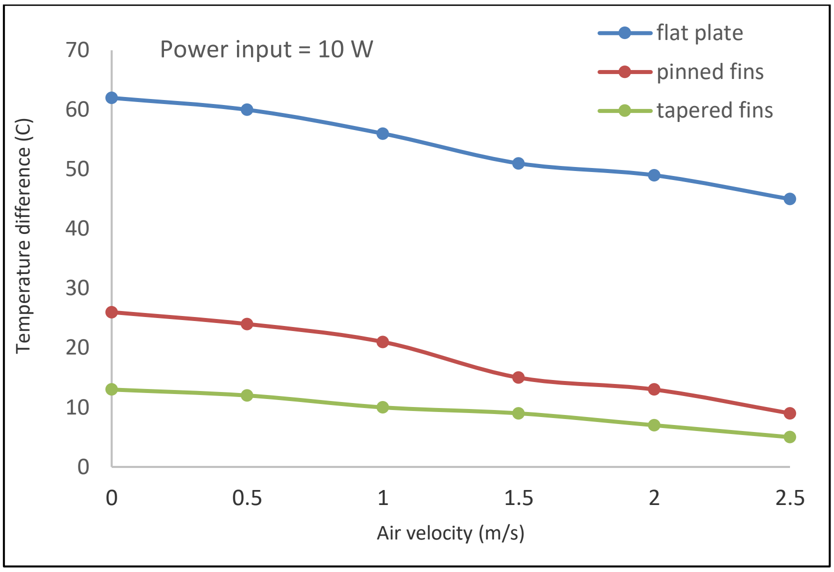

Fig.(5):-Temperature difference with air velocity at 10 W.

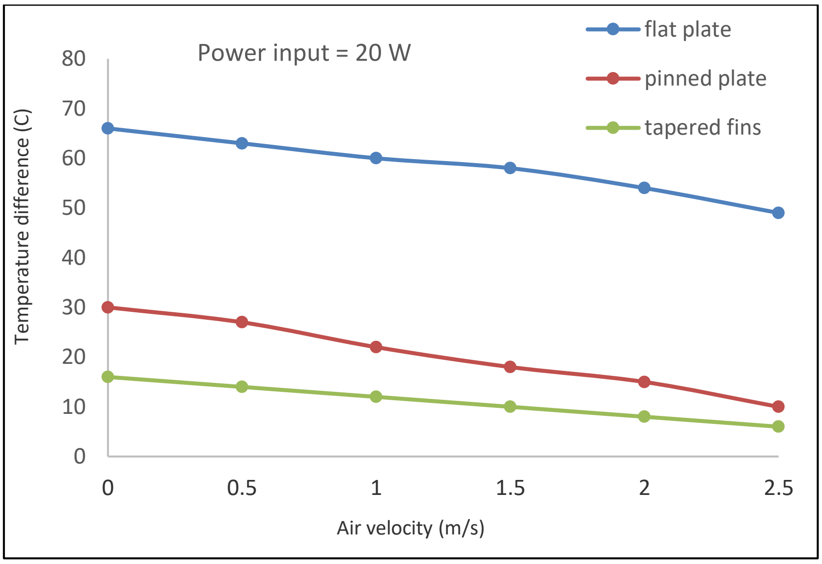

Fig.(6):-Temperature difference with air velocity at 20 W.

Fig 7. discuss the relation between temperature difference (surface – ambient temperature) with air velocity and different power input for tapered fin. Experiments show that a surface's temperature needs to go up for it to be easier for the extra power (between 10 and 60 W) that is added to the surface to get rid of itself. The term "convection" refers to the process by which heat is transferred away from a heated surface. The experiment does not take into account the effects of heat transfer through conduction and radiation, since these processes do not contribute to the loss of heat. The air that is in direct contact with the hot surface is heated by the surface, and as a result, the air is less dense and is able to ascend. Cooler air comes in and replaces the air that has been heated; this cooler air then gets heated by the surface and rises. Free convection is the term used to describe this phenomenon. The higher the temperature of the surface, the more powerful the convective currents, and the larger the amount of heat and electricity that will be lost. when increasing the power input from 10 to 60 W, the temperature difference will increase from 10 to 25 ^{o}C at air velocity 1 m/s and from 7 to 17 ^{o}C at air velocity = 2 m/s and this is in a good agreement with the literature [24], [27]. the combination of increased surface area, enhanced airflow, reduced boundary layer thickness, and minimized heat trapping makes tapered fins more favorable for heat transfer compared to other fin designs.

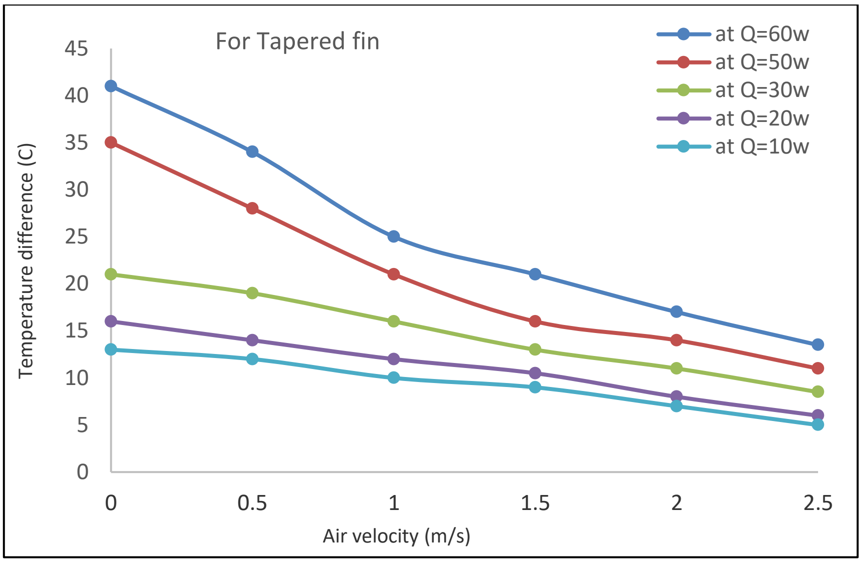

Fig.(7):-Temperature difference with air velocity for tapered fins at different power.

For a heat exchange to be as efficient as possible, its entire extended surface temperature must be the same as the temperature of the back plate. This, however, does not take place in reality due to the fact that heat must travel down a pin or fin through conduction, which results in a temperature gradient taking place. The gradient's steepness has a negative impact on the heat exchanger's overall efficiency. When comparing pinned and finned designs, for example, one must be careful not to mistake the efficiency with the surface area. In all actuality, the pin is the more efficient design; however, in this specific instance, the fin is marginally more efficient due to the fact that it has a larger surface area than the pinned exchanger and is therefore capable of dissipating more heat while maintaining the same surface temperature, this behavior showed clearly with fig 8., fig 9. and fig 10. when comparing the temperature difference against distance (mm) for air velocity (0 m/s) as free convection and air velocity (1-2 m/s) as Force convection respectively, Figures showed that the temperature decreases as the fin is farther from the surface [26], [27]. In the case of fin cooling, the temperature at the end of the fin exposed to heat is lower than the end connected to the hot end due to the process of heat transfer.

When a fin is exposed to a higher temperature at one end, heat flows from the hot end to the cooler end by conduction. The heat transfer rate is proportional to the temperature difference between the two ends of the fin. Therefore, the temperature at the hot end of the fin decreases as heat is transferred to the cooler end. When the cooler end of the fin is exposed to a cooling medium, such as air or water, heat is removed from the fin by convection. The rate of heat transfer from the fin to the cooling medium is proportional to the temperature difference between the fin and the cooling medium. As the temperature at the cooler end of the fin decreases, the temperature difference between the fin and the cooling medium increases, leading to a higher rate of heat transfer. Tapered fins are fins that gradually decrease in thickness or width along their length. This design allows for increased surface area as the fin extends outward, which enhances heat transfer. The tapering shape of the fin promotes better airflow and reduces the resistance to the flow of heat. As a result, tapered fins generally exhibit improved heat dissipation compared to other fin designs. In the context of the study, the experimental results showed that the temperature difference was more favorable when using tapered fins compared to pinned fins. This suggests that tapered fins were more effective in transferring heat away from the system. As a result, the temperature at the end of the fin exposed to heat is lower than the end connected to the hot end, because heat is transferred from the hot end to the cooler end, and then removed from the cooler end by convection with the cooling medium.

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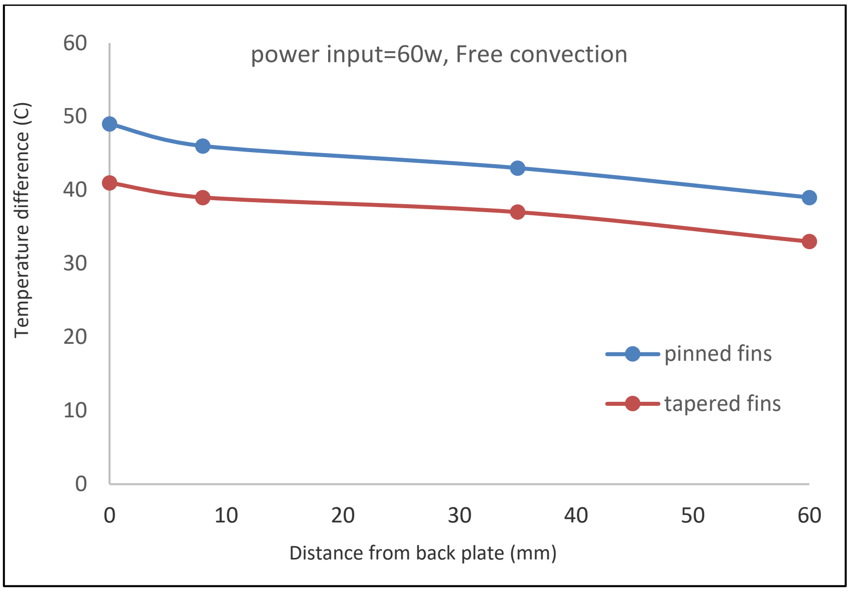

Fig.(8):-Temperature difference with distance from back plate at (Q=60 W, Free convection).

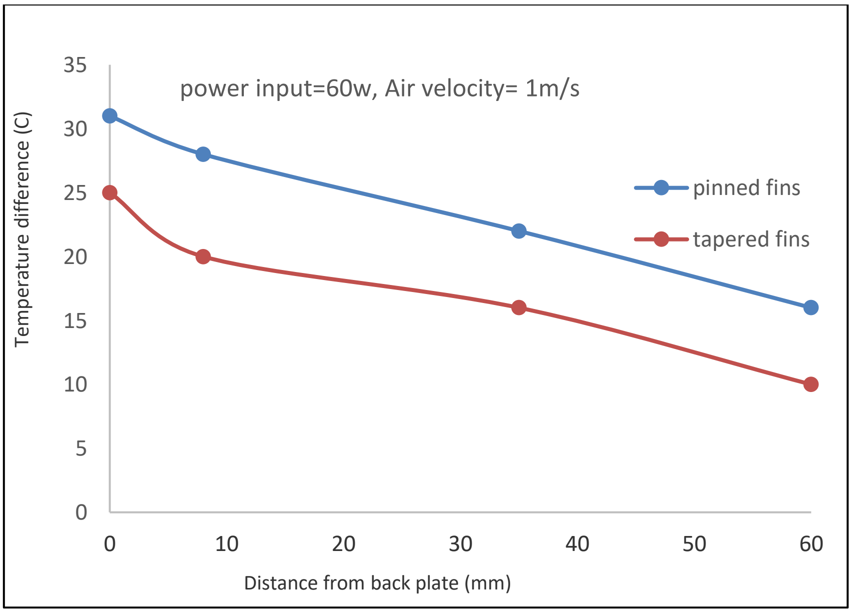

Fig.(9):-Temperature difference with distance from back plate at (Q=60 W, u=1 m/s).

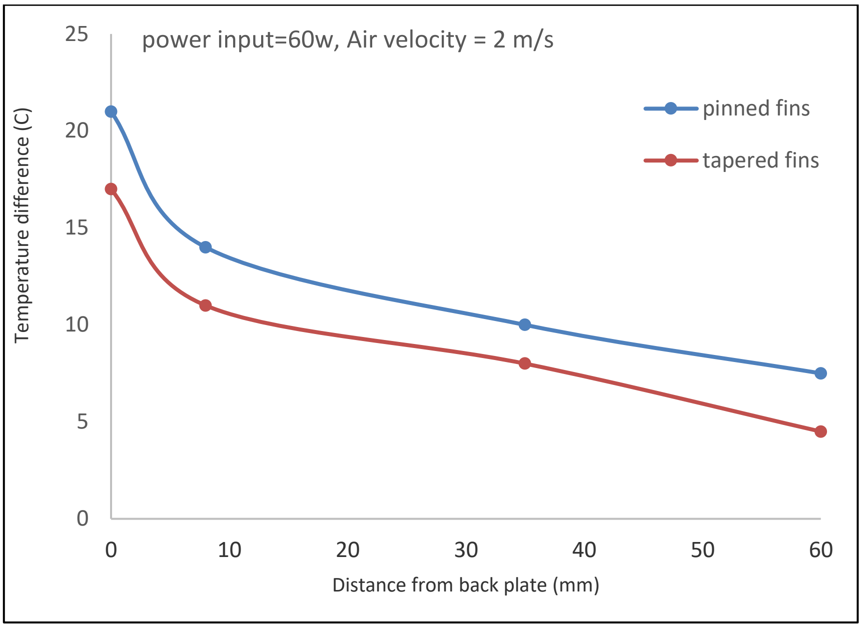

Fig.(10):-Temperature difference with distance from back plate at (Q=60 W, u=2 m/s).

4 .CONCLUSIONS

Through this research, it was found that the tapered fin has the biggest temperature loss compared to the pinned fin. This means that the tapered fin is better at cooling than the flat plate. Due to its greater surface area, a tapered fin dissipates heat more efficiently than a pinned fin; when increasing the power input from 10 to 60 W, the temperature difference will increase from 12 to 34 ºC at air velocity 0.5 m/s and from 5 to 14 ºC at air velocity 2.5 m/s. At the same air velocity and power input, the distance between the fin and the back plate is also shown, with a difference of 60 mm lowering the temperature to 8 mm.

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