Experimental Analysis of Cooling Fins

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Abstract - *Natural convection from vertical surfaces with large surface element is encountered in several technological applications of particular interest of heat dissipation in several forms. Natural convection represents an inherently reliable cooling process. The purpose of this project is to find out the best of different fin patterns by calculating the heat transfer rate. The considered fin pattern types are Parallel horizontal fin pattern, Parallel split pattern and V-fin array pattern. Project consists of self-made experimental setup having Nichrome wire is used for heating. It is supplied with the stabilized A.C. supply. The electrical heat input was controlled through Dimmer stat and measured with wattmeter. Different observation like temperature, heat input etc. is taken by performing experiment and these will be used to calculate heat transfer rate for every single fin pattern mentioned above. Result of this experiment is going to be used to determine the fin pattern with highest heat transfer rate, i.e. which fin will provide greater cooling effect. As not the all pattern with different fin height and pitch distance can be practically used for the experiment, so that analysis of these fins is also included as for the future aspects, in which fin dimension can be varied and further more pattern can be designed for more results.*

Keywords: Cooling fins, heat transfer coefficient, heat transfer rate, effectiveness thermocouples.

1. INTRODUCTION

In many cases fins (extended surface) is used to increase the rate of heat transfer to or from the environment by increasing convection. The amount of conduction, convection, or radiation of an object determines the amount of heat it transfers. Increasing the temperature difference between the object and the environment, increasing the convection heat transfer coefficient, or increasing the surface area of the object increases the heat transfer. Sometimes it is not economical or it is not feasible to change the first two options. Adding a fin to an object, however, increases the surface area and can sometimes be an economical solution to heat transfer problems. Use of fins to enhance convective heat transfer in a wide range of engineering applications, and offer a practical means for achieving a large total heat transfer surface area without the use of an excessive amount of primary surface area. Fins are commonly applied for heat management in electrical appliances such as computer power supplies or substation trans-formers. Other applications include Internal Combustion engine cooling, such as fins in a car radiator. It is important to predict the temperature distribution within the fin in order to choose the configuration that offers maximum effectiveness. Natural convection heat transfer is often increased by pro-vision of rectangular fins on horizontal or vertical surfaces in many electronic applications, motors and transformers. The current trend in the electronic industry is miniaturization, making the overheating problem more acute due to the reduction in surface area available for heat dissipation. Thus heat transfer from fin arrays has been studied extensively, both analytically and experimentally. Natural convection from vertical surfaces with large surface element is encountered in several technological applications of particular interest of heat dissipation from electronic circuit. Natural convection represents an inherently reliable cooling process. This heat transfer enhancing technique was investigated for natural convection adjacent to a vertical heated plate with a multiple v- type partition plates (fins) & also interrupted-plates (Split-fins) in ambient air surrounding and compared to conventional vertical fins. In order to enhance the heat transfer, different fin pattern with edges faced upstream were attached to the two the heater having Nichrome wire as heating element. It is supplied with stabilized A.C. supply. The electrical heat input was controlled through dimmer stat and measured using a Voltmeter and Ampere meter. Three types fin arrangement (parallel horizontal fin array, v-fin array, split fin array) were tried with two different values of heat input. Thermocouples are used to take readings and experiment analysis is done by manual calculation, to compare all three patterns of fins using effectiveness as the criteria and performance characteristics are observed.
There are some steps which had been followed to complete the project as mentioned below:
1. Study of cooling fins and its parameter with the search and studies done before.

2. Market survey of tools & equipment which are needed for making experimental setup and their studies.
3. Making of Different pattern of cooling fins.
4. Making of Experimental setup and its testing.
5. Preforming experimental setup and taking observation.
6. Calculation for obtaining parameters and conclusion.

2. LITERATURE REVIEW

Abdullah, H. Alessa et. al. [1] had studied the natural convection heat transfer enhancement from a horizontal rectangular fin embedded with equilateral triangular perforations. The heat dissipation rate from the perforated fin is compared to that of the equivalent solid one. he effect of geometrical dimensions of the perforated fin and thermal properties of the fin was studied in detail. They concluded that, For certain values of triangular dimensions, the perforated fin can result in heat transfer enhancement. The magnitude of enhancement is proportional to the fin thickness and its thermal conductivity. The perforation of fins enhances heat dissipation rates and at the same time decreases the expenditure of the fin material.

Golnoosh Mostafavi [2] had investigated the steady-state external natural convection heat transfer from vertically mounted rectangular interrupted finned heat sinks. After regenerating and validating the existing analytical results for continuous fins, a systematic numerical, experimental, and analytical study is conducted on the effect of the fin array and single wall interruption. FLUENT and COMSOL Multiphysics software are used in order to develop a two dimensional numerical model for investigation of fin interruption effects. Results show that adding interruptions to vertical rectangular fins enhances the thermal performance of fins and reduces the weight of the fin arrays, which in turn, can lead to lower manufacturing costs.

Sable, M.J. et. al. [3] had investigated for natural convection adjacent to a vertical heated plate with a multiple v- type partition plates (fins) in ambient air surrounding. As compared to conventional vertical fins, this v-type partition plate’s works not only as extended surface but also as flow turbulator. In order to enhance the heat transfer, V-shaped partition plates (fins) with edges faced upstream were attached to the two identical vertical plates. They jkl; observed that among the three different fin array configurations on vertical heated plate, V-type fin array design performs better than rectangular vertical fin array and V-fin array with bottom spacing design. The performance was observed to improve further, with increase in the height of the Vplates (fin height).

According to Yunus A. Çengel [4] in analysis of fins we consider steady operation with no heat generation in the fin & assume thermal conductivity of material is constant. The heat transfer coefficient is assumed to be constant over the entire surface of the fin. The value of h is much lower at the base than its tip because fluid is surrounded by the solid surface near its base. Hence adding too many fins on a surface decrease the overall heat transfer coefficient when the decrease in h offsets any gain resulting from the increase in the surface area.

Misumi and Kitamura [5] have reported an experimental work on enhancement of natural convection heat transfer from vertical plate having a horizontal partition plate and V-plates in the water ambience. They found that the heat transfer in the downstream region of the partition plate is markedly enhanced when the plate height 4 exceeds certain critical values because of the inflow of the low temperature fluid into the separation region. For vertical plate with V-shaped fins, Misumi and Kitamura obtained 40% higher heat transfer coefficient than the conventional vertical fins. From the results, authors observed that the ratio of the heat transfer enhancement exceeds the ratio of the surface enlargement.

Guillaum polidori and padet [6] studied natural convection on vertical ribbed wall experimentally with a wall boundary condition of uniform heat flux to get an idea about the roughness geometry influence on the heat transfer. Thus in the context of above work, it was decided to undertake experimental investigation on V-type fins, which seems to be more promising over conventional vertical fin arrays.

3. MANUFACTURING OF FIN PATTERNS

3.1 Material Selection

As Aluminium alloys are extensively used in making heat sink for computers, most of air cooled engines have cooling fins made of it. It is widely uses in Aerospace industry, automotive industry, marine industry etc. That is why material selected for making fin patterns is Aluminium 1100 (in the form of sheet having width of 3mm) ,belongs to aluminium-1000 series (1000 series are essentially pure aluminum with Aluminum 99% aluminium content by weight and can be work hardened.).Aluminium 1100 (3mm thickness)

3.2 Properties of Aluminum 1100

1100 Aluminum alloy is an Aluminum-based alloy in the "commercially pure" wrought family (1000 or 1xxx series). With a minimum of 99.0% aluminum, it is the most heavily alloyed of the 1000 series. It is also the mechanically strongest alloy in the series, and is the only 1000-series alloy commonly used in rivets. At the same time, it keeps the benefits of being relatively lightly alloyed (compared to other series of Aluminium).

The alloy composition of aluminium 1100 is:
1.Aluminium: 99.0-99.95%
2.Copper: 0.05-0.20%
3.Iron: 0.95% max
4.Manganese: 0.05% max
5.Silicon: 0.95% max
6.Zinc: 0.1% max
Residuals: 0.15% max

3.3 Fin patterns

There are three different patterns of fin which are used to perform experiment and calculating the effectiveness. From which conclusion will be made for the best fin pattern as per the value of effectiveness.
Three different patterns of fin which are used, mentioned below:
[1]Parallel horizontal fin pattern
[2]V fin pattern
[3]Split fin pattern

All three fins are made of Aluminium1100's sheet of width 3mm. Base plate dimension of cooling fin pattern are same is all pattern (i.e. 200mm×200mm). 'Parallel horizontal fin pattern' has 5 horizontal fins of dimension 200mm×40 welded by GTAW (Gas Tungsten Arc Welding) and arranged on the base plate with equal pith distance. 'V-fin pattern' are made by bending the 200mm×40mm Al-plate from center at an angle of 120o number of fins in this case is same as in parallel horizontal fin patter i.e. 5-fins on the base plate with equal pitch distance. For making 3rd patter 'Split fin pattern' fin of dimension 50mm×40mm is used and welded on the base plate actual pics of pattern are shone below:

Figure 1. Parallel Horizontal Fin Pattern

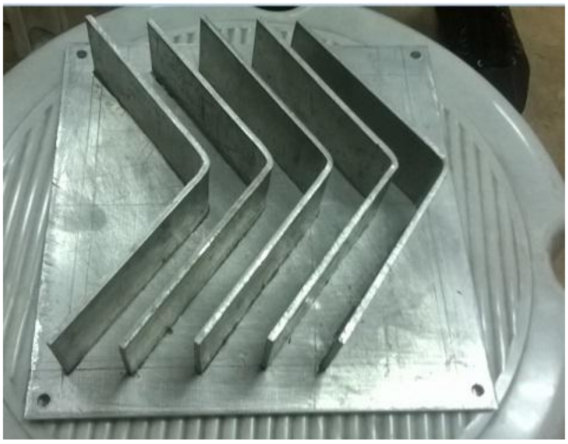

Figure 2. V-Fin Pattern

Figure 3. Split Fin Pattern

4. EXPERIMENTAL SETUP'S MANUFACTURING

Experimental setup is a heating arrangement, whose heat input is controlled by dimmerstat, and thermocouples are used to take reading, experimental setup is made in such a way that fin patterns are easily changeable with the help of nut-bolts, nichrome heating element is use for heating purpose. Basic connection of experimental setup is shown below.

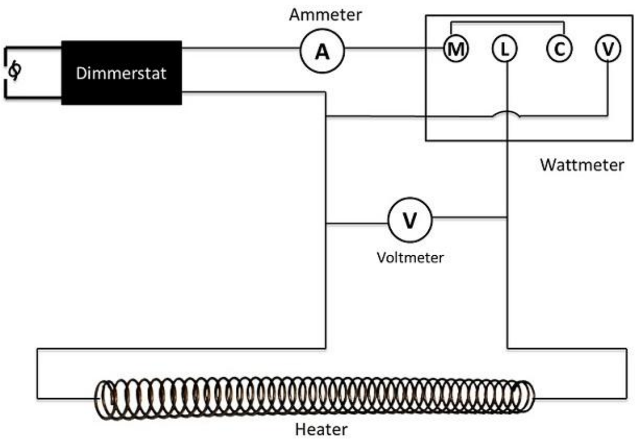

Figure 4. Basic connection of Experimental Setup

4.1 Requirements in making of experimental setup

It include apparatus as well as tools required to make the setup

1. Wooden base:
2. Dimmer stat
3. Voltmeter
4. Ammeter24
5. Connecting wire
6. Thermocouples
7. Nichrome Heating element
8. Tiles
9. Bolts & Nuts
10. Tile cutter
11. Temperature scanner

Other tools are also use which is mentioned above as in the making of fins.

4.1.1 Wooden base

Wood of dimension 30cm X 38cm X 4cm is used for making the base on which whole setup is arranged. Wooden cutter is used to cut the wood in dimension mentioned above strip wooden strip are used to make fin holding arrangements. Whole arrangement is a potable table arrangement so that it can be carried everywhere. Hammer, iron nails, hacksaw are also use in this process. Fin holding arrangement has the total height of 40 cm including the height of Nichrome heater equipped with nut-bots arrangement to assemble and disassemble the fin pattern as per the requirement. Wooden arrangement consist of two table one is equipped with electrical equipment and other with the fin holding arrangement which are connection to each other by means electrical wire to give electrical supply to the heater controlled by dimmerstat.

4.1.2 Heating arrangement

Heating arrangement uses a household wall tile to make a heater of Nichrome element. It uses a tile of having dimension similar to the base plate of Aluminium (i.e. 20cmX20cm). Strip of tile has been cut by tile cutter having height of 1cm to attach vertically on the tile base to make the groove. This groove made of tile act as the path for the heating element (Coil of Nichrome wire). High temperature sustainable epoxy is used to attach them as experiment is about heating of fin pattern. Nichrome coil is connected to the electrical supply coming from dimmerstat by means of electrical wire. This heating arrangement is attached to the fin holding base by wooden strips using bolts & nuts whole arrangement is made in such a way that assembly can be done or disassembled according to the need.

4.2. Study of Electrical Equipment

4.2.1 Dimmerstat

Another name of dimmerstat is Autotransformer, it is the most useful and effective device for stepless, brakeless and continuous control of a.c. voltage and therefore for control of various other parameter depending on a.c. voltage. The widely known as highly acclaimed product, introduced more than 35 year ago, it is an ideal controlling device for numerous application in laboratories and in industrial & commercial fields. The basic dimmerstat is meant for operation off a nominal voltage of 240V A.C. and can give output voltage anywhere between 0 to 240V, or output 270, by a simple transformer action.

4.2.2 Voltmeter

A voltmeter is an instrument used for measuring electrical potential difference between two points in an electric circuit. Analog voltmeters move a pointer across a scale in proportion to the voltage of the circuit; digital voltmeters give a numerical display of voltage by use of an analog to digital converter.

4.2.3 Ammeter

An ammeter is a measuring instrument used to measure the electric current in a circuit. Electric currents are measured in amperes (A), hence the name. Instruments used to measure smaller currents, in the milli-ampere or microampere range, are designated as milli-ammeters or micro-ammeters.

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4.2.4 Wattmeter

The wattmeter is an instrument for measuring the electric power (or the supply rate of electrical energy) in watts of any given circuit. Electromagnetic wattmeters are used for measurement of utility frequency and audio frequency power; other types are required for radio frequency measurements. the range of Dimmerstat is of range 1600W.

4.2.5 Thermocouple

A thermocouple is a temperature-measuring device consisting of two dissimilar conductors that contact each other at one or more spots, where a temperature differential is experienced by the different conductors (or semiconductors).

Seven thermocouples are used here to show the different value of temperature, thermocouples are marked as T1, T2, T3, T4, T4, T5, T6 and T7.

- Where, T1-T5 shows the temperature of the thermocouple attached to the fins.
- T6 shows the temperature of the base plate of the fin.
- T7 shows the ambient temperature.

4.2.6 Temperature scanner

A Temperature Scanner is a device that measures more than one temperature points or multi-channel. It is actually a multi-channel indicator that measures and displays signals of each channel one-by-one up to last channel and then returns to first channel and continues the process cyclically.

4.2.7 Connecting wire

A wire is a single, usually cylindrical, flexible strand or rod of metal. Wires are used to bear mechanical loads or electr*icity and* telecommunications signals. Wire is commonly formed by drawing the metal through a hole in a die or draw plate. Wire gauges come in various standard sizes, as expressed in terms of a gauge number. Here copper wire is used to connect the electrical equipment as it best electrical conductivity in its category and is easily available in the market

4.2.8 Nichrome wire

Nichrome is a non-magnetic alloy of nickel, chromium, and often iron, usually used as a resistance wire. A common alloy is 80% nickel and 20% chromium, by mass, but there are many others to accommodate various applications. It is silvery-grey in colour, is corrosion-resistant, and has a high melting point of about 1,400 °C (2,550 °F). Due to its resistance to oxidation and stability at high temperatures, it is widely used in electric heating elements, such as in appliances and tools. Typically, nichrome is wound in coils to a certain electrical resistance, and current is passed through it to produce heat.

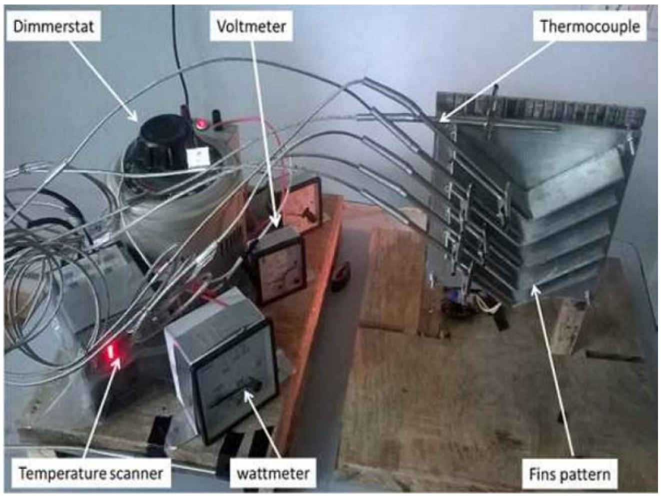

Figure 5 Experimental Setup with components

5. EXPERIMENT PROCEDURE

1. Ensure that main ON/OFF switch given on the panel is at OFF position & dimmerstat is at zero position.
2. Assemble the fin pattern (on which experiment has to experiment has to perform) to the heater assembly through bolts & nuts.37
3. Connect electrical supply to the setup.
4. Switch ON the main ON/OFF switch.
5.Set the heater input by the dimmerstat, voltmeter reading for 1st case is 80 volts, for 2nd case is 100V.
6.After1hr note down the reading of the voltmeter, ammeter & thermocouples (temperature scanners), in the observation table, and note down the temperature variation throughout the fin pattern.
7. After experiment is over set the dimmerstat at zero position
8. Switch OFF the main ON/OFF switch.
9. For the next fin patter disassemble the fin pattern from the heater assembly and assemble the new one.
10. Repeat step for the next fin from Step1-Step9.

5.1 Observation

Table 1, Voltage = 80V, Current = 6.5A

Temperature (On Sensors)	V – Fin Pattern	Parallel Fin Pattern	Split Fin Pattern	Without Fin Pattern
T 1	149	116	128	152
T 2	147	119	129	147
T 3	147	122	141	151
T 4	148	117	119	150
T 5	152	118	123	121
T 6	159	130	133	128
T 7	34	35	34	35

Table 2, Voltage = 100V, Current = 7.5A

Temperature (On Sensors)	V – Fin Pattern	Parallel Fin Pattern	Split Fin Pattern	Without Fin Pattern
T 1	193	168	139	188
T 2	192	167	142	185
T 3	192	172	151	190
T 4	193	167	139	191
T 5	196	175	140	165
T 6	202	181	154	190
T 7	34	35	34	35

6. CALCULATION

For case I

V = 80V
I = 6.5A

1. Parallel horizontal fin pattern
Mean temperature of fin, To = (T1+T2+T3+T4+T5+T6)/6
= 118.5 ^{0}C
Ta = 35^{0}C
ΔT = To-Ta = 83.5 ^{0}C

Now,
At = N.Af + Ab
Cross section area of fin, Acs = 20 × 0.3 = 6 cm^2 = 0.0006 m^2
Af = 5×[20×4×2 + 4×0.3×2] = 812 cm^2
Ab = 20×20 - 6×5 = 370 cm^2
At = 812+370 = 1182 cm2 = 0.1182 m^2
Q (heat supplied to fin) = Energy supplied to the heater (power)
= V×I = 6.5×80 = 520 W
Also, Q = h×At×ΔT
h = Q/At×ΔT= 520/0.1182×83.5 = 52.686505 W/m2.K
Effectiveness, Ef = Q/h×Acs×ΔT
= 520/5×52.68505×0.0006×83.5= 39.100506

2. V fin pattern
Mean temperature of fin, To = (T1+T2+T3+T4+T5+T6)/6
= 150.33^{0}C
Ta = 34 oC
ΔT = To-Ta = 116.33 ^{0}C
Now,
At = N.Af + Ab
Cross section area of fin, Acs = 2×[10 × 0.3] = 6 cm2 = 0.0006 m2
Af = 5×[2(10×4×2) + 4×0.3×2] = 812 cm^2
Ab = 20×20 - 6×5 = 370 cm^2
At = 812+370 = 1182 cm2 = 0.1182 m^2
Q (heat supplied to fin) = Energy supplied to the heater (power)
= V×I = 6.5×80 = 520 W
Also, Q = h×At×ΔT
h = Q/At×ΔT
= 520/0.1182×116.33
= 37.8176 W/m2.K
Effectiveness of fin, Ef = Q/h×Acs×ΔT
= 520/5×37.8176×0.0006×116.33
= 39.401128

3. Split fin pattern
Mean temperature of fin, To = (T1+T2+T3+T4+T5+T6)/6
= 142.35 ^{0}C
Ta = 34^{0}C
ΔT = To-Ta = 108.35 ^{0}C
Now,
At = N.Af + Ab
Cross section area of fin, Acs = 5 × 0.3 = 1.5 cm^2 = 0.00015 m2
Af = 15×2×[5×4 + 4×0.3] = 720 cm^2
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Ab = 20×20 – 1.5×15 = 377.5 cm^2
At = 720+377.5 = 10975 cm2 = 0.10975 m^2
Q (heat supplied to fin) = Energy supplied to the heater (power)
= V×I = 6.5×80 = 520 W
Also, Q = h×At×ΔT
h = Q/At×ΔT
= 520/0.10975×108.33
= 43.7371 W/m2.K
Effectiveness of fin, Ef = Q/h×Acs×ΔT
= 520/15×43.7371×0.00015×43.7371
= 48.777845

6.2 For case II

V = 100V
I = 7.5A

1. Parallel horizontal fin pattern
Mean temperature of fin, To = (T1+T2+T3+T4+T5+T6)/6
= 159.5 oC
Ta = 35 oC
ΔT = To-Ta = 124.5 oC
At = N.Af + Ab
Cross section area of fin, Acs = 20 × 0.3 = 6 cm2 = 0.0006 m2
Af = 5×[20×4×2 + 4×0.3×2] = 812 cm2
Ab = 20×20 - 6×5 = 370 cm2
At = 812+370 = 1182 cm2 = 0.1182 m2
Q (heat supplied to fin) = Energy supplied to the heater (power)
= V×I = 7.5×100 = 750 W
Also, Q = h×At×ΔT
h = Q/At×ΔT
= 750/0.1182×124.5
= 50.9652 W/m2.K
Effectiveness, Ef = Q/h×Acs×ΔT
= 750/5×50.9652×0.0006×124.5
= 39.40162

2. V fin pattern
Mean temperature of fin, To = (T1+T2+T3+T4+T5+T6)/6
= 194.66 oC
Ta = 34 oC
ΔT = To-Ta = 160.66 oC
At = N.Af + Ab
Cross section area of fin, Acs = 2×[10 × 0.3] = 6 cm2 = 0.0006 m2
Af = 5×[2(10×4×2) + 4×0.3×2] = 812 cm^2
Ab = 20×20 - 6×5 = 370 cm^2
At = 812+370 = 1182 cm2 = 0.1182 m^2
Q (heat supplied to fin) = Energy supplied to the heater (power)
= V×I = 7.5×100 = 750 W
Also, Q = h×At×ΔT
h = Q/At×ΔT
= 750/0.1182×160.66
= 39.4928 W/m2.K
Effectiveness of fin, Ef = Q/h×Acs×ΔT
= 750/5×39.4928×0.0006×160.66
= 39.40162

3. Split fin pattern
Mean temperature of fin, To = (T1+T2+T3+T4+T5+T6)/6
= 171.66^{0}C
Ta = 34 ^{0}C
ΔT = To-Ta = 137.66^{0}C
At = N.Af + Ab
Cross section area of fin, Acs = 5 × 0.3 = 1.5 cm2 = 0.00015 m2
Af = 15×2×[5×4 + 4×0.3] = 720 cm2
Ab = 20×20 – 1.5×15 = 377.5 cm2
At = 720+377.5 = 10975 cm2 = 0.10975 m2
Q (heat supplied to fin) = Energy supplied to the heater (power)
= V×I = 7.5×100 = 750 W
Also, Q = h×At×ΔT
h = Q/At×ΔT
= 520/0.10975×137.66
= 49.644196 W/m2.K
Effectiveness of fin, Ef = Q/h×Acs×ΔT
= 750/15×49.6442×0.00015×137.66
= 49.77894

Table 3, Comparison of Effectiveness for fin pattern for Q = 520W

S.no.	Fin pattern	Q(W)	E_f
1.	V-pattern	520	39.401128
2.	Split-pattern	520	48.777845
3.	Parallel horizontal-pattern	520	39.100506

Table 4, Comparison of Effectiveness for fin pattern for Q = 750W

Sno.	Fin pattern	Q(W)	E_f
1.	V-pattern	750	39.4016
2.	Split-pattern	750	48.77894
3.	Parallel horizontal-pattern	750	39.40162

7. CONCLUSION

1. According to the result obtained Split fin pattern out three pattern used where others are Parallel horizontal fin pattern and V fin pattern has best effectiveness value which show that heat enhanced by Split fin patter greater than other two patterns.
2. Surface area from which heat transfer take place plays an important role, As the area of Parallel horizontal fin pattern & V fin pattern same area which result in approximate similar values of effectiveness for both fin, whereas effectiveness of V fin pattern is slightly greater than parallel horizontal but in values of decimal.
3. In each case of fin tried in this project has effectiveness value greater than 1 which indicates that the fins are enhancing the heat transfer from the surface, where as if effectiveness has value equal to 1 than the fins to the surface do
not affect heat transfer at all.
4. Another important point that is observed in this project is that, design of fin pattern is also important for enhancing the heat transfer because the value of surface area from which heat transfer take place is minimum in case of Split fin pattern but it gives maximum value of effectiveness which means greater heat transfer.

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