# Experimental Investigation of Heat Transfer Analysis on Nano Graphene Coated Extended Surface

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**Abstract:** Finned surface has been extensively used for convective heat transfer of internal combustion engines and several electronic kits etc. Here cylindrical and square fin of copper and aluminum materials were preferred for analysis. Thermocouples were attached all over the surface of the fin in equal distances. The experiments were conducted to analyze the parameters such as heat transfer rate through fin, fin efficiency and effectiveness through free and forced convection heat transfer mode. The fins were coated with Nano graphene for all of the above cases and changes in heat transfer through the fin, fin efficiency and effectiveness were studied. It is found that there is a considerable increase in heat transfer and other parameters on Nano coating.

**Keywords:** Nano graphene coating, heat transfer rate through fin, fin efficiency

## 1. INTRODUCTION

In the study of heat transfer, a fin is a surface that extends from an object 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. The operation of many engineering systems involves heat generation. This may cause serious overheating problems and sometimes leads to failure of the system. The heat generated within a system must be dissipated to its surrounding in order to maintain the system operating. Fins are commonly used in many engineering applications to enhance heat transfer. A number of studies have been performed in order to increase the heat transfer effectiveness and to reduce the dimensions and weight of heat exchangers. The necessity to reduce the volume and weight of heat exchanger has become more important in many engineering applications like IC Engines, Heat exchangers, etc. Efficient design of fins can improve system performance considerably. Among several available techniques for augmentation of heat transfer in heat exchanger tubes, the use of internal fin appears to be very promising method as evident from the results of the past investigations. This is especially important in modern electronic systems, in which the packaging density of circuits is high. In order to overcome this problem, thermal systems with effective emitters as fins are desirable. In order to achieve the desired steady-state rate of heat dissipation, with the least.

Amount of material, the optimal combination of geometry and orientation of the finned surface is required. Among the all geometrical variations, rectangular fins are the most commonly encountered because of their simple construction, cheaper cost and effective cooling capability. Two common orientations of fin configurations, horizontally based vertical fins and vertically based vertical fins, have been widely used in the applications. However, the horizontal orientation is not preferable because of its relatively poor ability to dissipate heat. Compact heat exchangers have large surface-area-to-volume ratios.

Primarily through the use of finned surfaces. Since the use of extended surfaces is often more economical, convenient and trouble free, most proposed application of increasing surface area is adding fins to the surface in order to achieve required rate of heat transfer. However, the designer should optimize the spacing or the number of fins on base carefully; otherwise fin additions may cause the deterioration of the rate of heat transfer. Although adding numerous fins increase the surface area, they may resist the air flow and cause.

Boundary layer interferences which affect the heat transfer adversely. Today’s designer has available a very wide range of materials from which to choose. To determine the most cost-effective material for any application is no simple task when costs and performance are properly assessed. Aluminium and copper are ideally suited to the manufacture of many components because of the wide variety of forms and sizes available that minimize costs of machining to final dimensions. It has a unique combination of properties: strength, shock resistance, ductility and conductivity combined with good corrosion resistance and other attributes such as superb machinability. Other beneficial properties are good formability, good spark resistance, low magnetic permeability and toughness retained above and below ambient temperatures. As for handling the heat sink problem, the size of its outward design, the amount of fin flake, the gap of fin flake, the area of its outward surface all have an intimate relation on enhancing its convection effect and increasing its heat sink ability. The only controllable variable to enhance the convection heat transfer rate is the geometry of the fins. The designer must optimize the size and the spacing of the fin arrays otherwise; using fins can bring more disadvantages than its advantages to the design. Several studies of natural convection from rectangular fins were conducted previously proposed the Nano fluids are considered to offer important advantages over conventional heat transfer fluids. During the 2000s, researchers focused on measuring and modeling the effective thermal conductivity and viscosity of Nano fluids. In this heat transfer study, the performance of square and cylindrical fins of aluminum and copper materials were analysed for both with and without graphene coating over fins. Also In this study, the natural and forced convection heat transfer protruding from base is investigated experimentally.

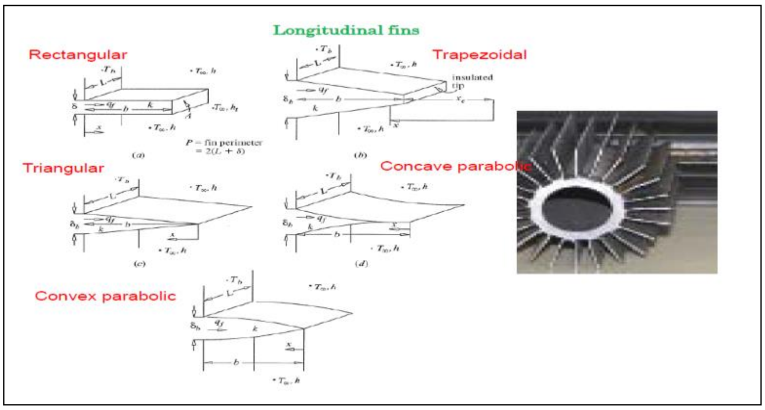


Fig. 2.1: Geometries of Fins

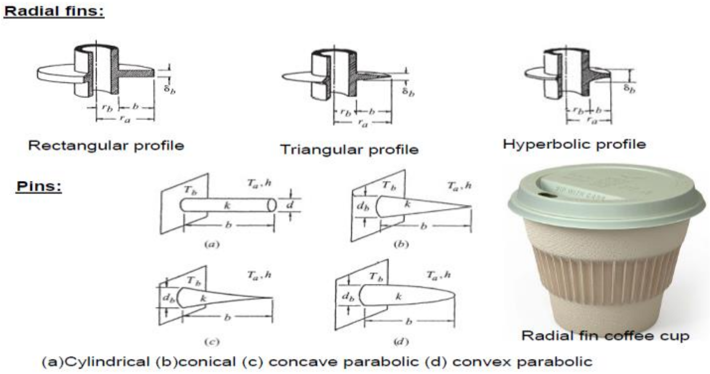


Figure 2.2: Radial Fins & Pins

## 2. HEAT TRANSFER THROUGH FINS

### 2.1 TYPES OF FINS:

Fins are used in a large number of applications to increase the heat transfer from surfaces. Typically, the fin material has a high thermal conductivity. The fin is exposed to a flowing fluid, which cools or heats it, with the high thermal conductivity allowing increased heat being conducted from the wall through the fin. The design of cooling fins is encountered in many situations and we thus examine heat transfer in a fin as a way of defining some criteria for design. Extended surfaces can be designed in different geometries like rectangular, Triangular, Trapezoidal and Parabolic shapes. The different shape of fins is shown in Figure 2.1.

Radial fins are used to enhance the heat transfer over the surfaces of like IC engine cylinders, heat exchanger tubes and Air Compressor cylinders etc. Radial fins may have the shape of rectangular, triangular or hyperbolic. In some of the engineering applications pin fins were used for better heat transfer rates. Figure 2.2. Shows the different types of fins.

## 2.2 HEAT TRANSFER THROUGH FINS

The heat transfer through fins is calculated by the principle of Newton’s law of cooling. The difference between the temperature at the tip of the fin and ambient temperature makes change significant effect on heat transfer through fin.

### 2.2.1. FIN EQUATION

The heat transfer equation for the fin is developed by considering the thermal conductivity of the fin material and heat transfer coefficient between the fin and ambient conditions as below.

### 2.2.2. BOUNDARY CONDITIONS:

There are different boundary conditions for the heat transfer calculations through fin as shown in Figure 2.3. Mathematical approach for simplifying the problems for above different boundary conditions gives the equations for temperature distribution and heat transfer through fin as shown in Table 2.1.

$$\frac{d^2\theta}{dx^2} - m^2\theta = 0$$

$$m^2 = \frac{hP}{kA_c}$$

$$\theta(x) \equiv T(x) - T_\infty$$

he general solution is of the form

$$\theta(x) = C_1 e^{mx} + C_2 e^{-mx}$$

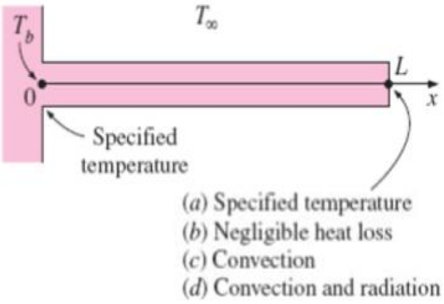
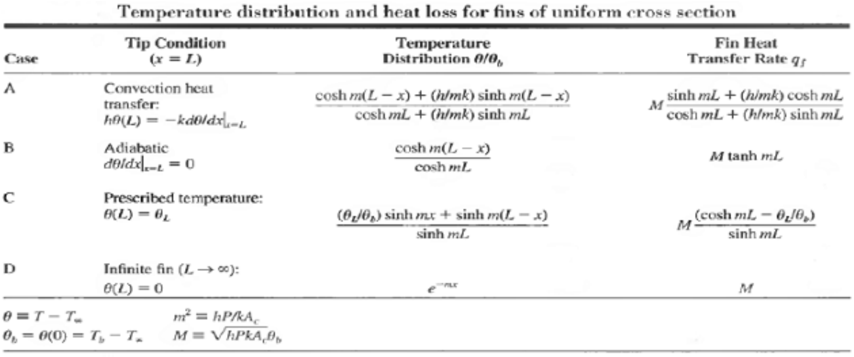


Fig 2.3: Boundary Conditions



Temperature distribution and heat loss for fins of uniform cross section

| Case | Tip Condition ($x = L$) | Temperature Distribution $\theta/\theta_b$ | Fin Heat Transfer Rate $q_f$ |
|---|---|---|---|
| A | Convection heat transfer:<br>$h\theta(L) = -kd\theta/dx\rvert_{x=L}$ | $\dfrac{\cosh m(L-x) + (h/mk)\sinh m(L-x)}{\cosh mL + (h/mk)\sinh mL}$ | $M\dfrac{\sinh mL + (h/mk)\cosh mL}{\cosh mL + (h/mk)\sinh mL}$ |
| B | Adiabatic<br>$d\theta/dx\rvert_{x=L} = 0$ | $\dfrac{\cosh m(L-x)}{\cosh mL}$ | $M \tanh mL$ |
| C | Prescribed temperature:<br>$\theta(L) = \theta_L$ | $\dfrac{(\theta_L/\theta_b)\sinh mx + \sinh m(L-x)}{\sinh mL}$ | $M\dfrac{(\cosh mL - \theta_L/\theta_b)}{\sinh mL}$ |
| D | Infinite fin ($L \to \infty$):<br>$\theta(L) = 0$ | $e^{-mx}$ | $M$ |

$\theta \equiv T - T_\infty$ $\quad m^2 \equiv hP/kA_c$

$\theta_b = \theta(0) = T_b - T_\infty$ $\quad M \equiv \sqrt{hPkA_c}\theta_b$

Table 2.1 Temperature distribution and heat loss through fins

## 2.3. FIN EFFICIENCY:

Fin efficiency is defined as the ratio of actual heat transferred by the fin to the Ideal heat transfer rate from the fin if fin area were at base temperature. This is illustrating in figure 2.4.

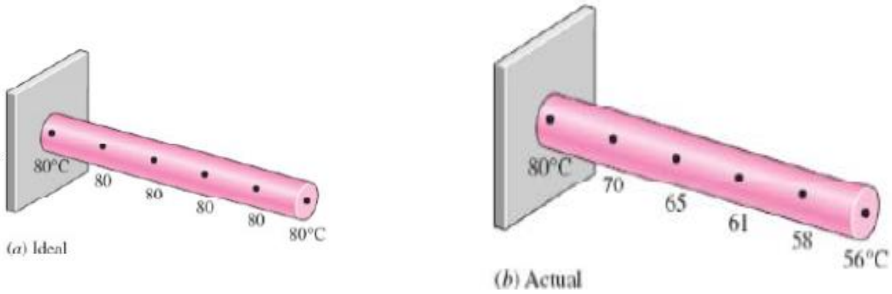


Figure 2.4: Fin Efficiency

$$\eta_{fin} = \frac{\dot{Q}_{fin}}{\dot{Q}_{fin,\max}} = \frac{\text{Actual heat transfer rate from the fin}}{\text{Ideal heat transfer rate from the fin if the entire fin were at base temperature}}$$

$$\dot{Q}_{fin} = \eta_{fin}\,\dot{Q}_{fin,\max} = \eta_{fin}\,hA_{fin}(T_b - T_\infty)$$

$$\eta_{insulatedt\ ip} = \frac{\dot{Q}_{fin}}{\dot{Q}_{fin,\max}} = \frac{\sqrt{hPkA_c}\,(T_b - T_\infty)\tanh mL}{hA_{fin}(T_b - T_\infty)} = \frac{\tanh mL}{mL}$$

h = Convective heat transfer coefficient (W/m$^2$.K)
P = Perimeter of the fin (m)
$A_c$=Cross sectional area of the fin (m$^2$)
K =Thermal conductivity of fin material (W/mk)
$T_b$ = Base Temperature (K)
T∞ = Ambient temperature (K)

### 2.4. FIN EFFECTIVENESS:

Fin effectiveness is defined as Heat transfer through fin to the heat transfer without fin from the base area.

$$\varepsilon_{fin} = \frac{\dot{Q}_{fin}}{\dot{Q}_{nofin}} = \frac{\dot{Q}_{fin}}{hA_b(T_b - T_\infty)} = \frac{\text{Heat transfer rate from the fin of base area } A_b}{\text{Heat transfer rate from the surface of area } A_b}$$

$\varepsilon_{fin} = 1$ Does not affect the heat transfer at all.
$\varepsilon_{fin} < 1$ Fin act as insulation (if low k material is used)
$\varepsilon_{fin} > 1$ Enhancing heat transfer (use of fins justified if $\varepsilon_{fin}$>2)

For better fin effectiveness ‘k’ and p/$A_c$ should be higher as possible. The fin is effective in application where ‘h’ is low. Use of fins justified if when the medium is gas and heat transfer is by natural convection. For this copper, aluminum and iron are preferred.

Fins with triangular and parabolic profiles contain less material are more efficient requiring minimum weight. An important consideration is the selection of the proper fin length L. Increasing the length of the fin beyond certain value cannot be justified unless the added benefits out weight the added cost. The efficiency of most fins used in practice is above 90%.

### 2.5 FIN MATERIALS :

Fins of higher thermal conductivity are preferred for application in engineering problems. Aluminium and copper having higher thermal conductivity are used for analysis in this context. The copper having thermal conductivity of 386 W/m.K and Aluminium having thermal conductivity of 204.2 W/m.K.

### 2.6 FIN SHAPE:

Considering the fin geometry and material the following test specimens were prepared for conducting the experiment.

Figure 2.5: Copper-square fin

Figure 2.6: Copper-pin fin

## 7 NATURAL AND FORCED CONVECTION:

To study the fins performance under varying air flow conditions natural and forced convection experiments were conducted over the above mentioned specimens. For forced convection an air flow at a velocity of 0.5 m/s is obtained through the blower over the fin surfaces. The apparatus used for conducting the experiment is shown in figure 2.8.

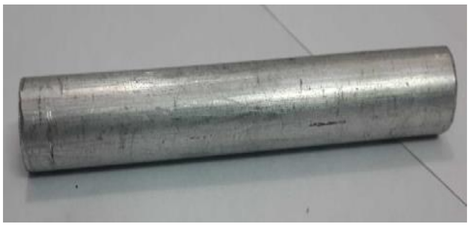


Figure 2.7: Aluminium - pin fin

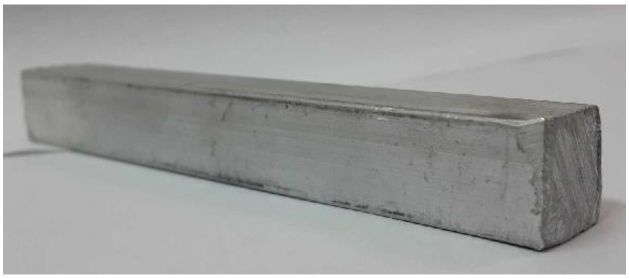


Figure 2.8. Aluminium - square fin

Figure 2.9. Pin fin apparatus

## 2.8 NANO COATING ON FIN MATERIALS:

As the nano materials having great thermal conductivity, they can be used as composite layers of fins for better performance characteristics. By physical vapor deposition (PVD) method the Nano graphene was coated to obtain required specimens.

### 2.8.1. PROPERTIES OF GRAPHENE:

The near-room temperature thermal conductivity of graphene was measured to be between (4.84±0.44) × $10^3$ to (5.30±0.48) × $10^3$ $W \cdot m^{-1} \cdot K^{-1}$. These measurements, made by a non-contact optical technique, are in excess of those measured for carbon nanotubes or diamonds. The isotopic composition, the ratio of $^{12}C$ to $^{13}C$, has a significant impact on thermal conductivity, where isotopically pure $^{12}C$ graphene has higher conductivity than either a 50:50 isotope ratio or the naturally occurring 99:1 ratio. It can be shown by using the Wiedemann–Franz law, that the thermal conduction is phonon-dominated. However, for a gated graphene strip, an applied gate bias causing a Fermi energy shift much larger than $k_BT$ can cause the electronic contribution to increase and dominate over the phonon contribution at low temperatures. The ballistic thermal conductance of graphene is isotropic.

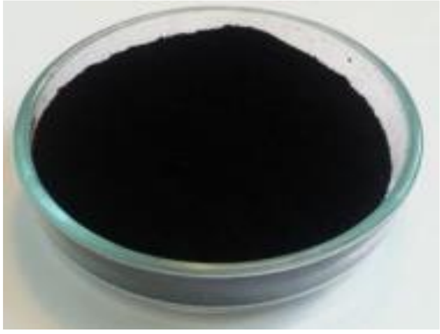


Figure 2.10. Nano grapheme

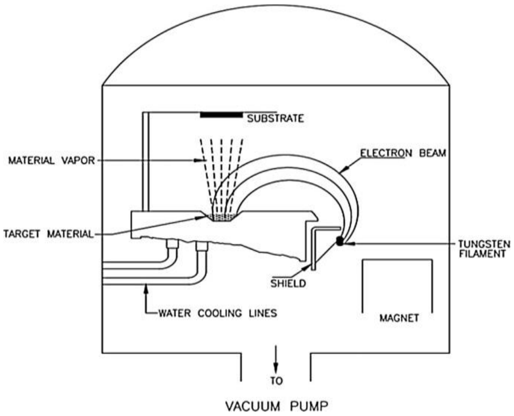


Figure 2.11. PVD process

Potential for this high conductivity can be seen by considering graphite, a 3D version of graphene that has basal plane thermal conductivity of over a 1000 $W \cdot m^{-1} \cdot K^{-1}$(comparable to diamond). In graphite, the c-axis (out of plane) thermal conductivity is over a factor of ~100 smaller due to the weak binding forces between basal planes as well as the larger lattice spacing. In addition, the ballistic thermal conductance of graphene is shown to give the lower limit of the ballistic thermal conductance, per unit circumference, length of carbon nanotubes. Despite its 2-D nature, graphene has 3 acoustic phonon modes. The two in-plane modes (LA, TA) have a linear dispersion relation, whereas the out of plane mode (ZA) has a quadratic dispersion relation. Due to this, the $T^2$ dependent thermal conductivity contribution of the linear modes is dominated at low temperatures by the $T^{1.5}$ contribution of the out of plane mode. Some graphene phonon bands display negative Grüneisen parameters. At low temperatures (where most optical modes with positive Grüneisen parameters are still not excited) the contribution from the negative Grüneisen parameters will be dominant and thermal expansion coefficient (which is directly proportional to Grüneisen parameters) negative. The lowest negative Grüneisen parameters correspond to the lowest transversal acoustic ZA modes. Phonon frequencies for such modes increase with the in-plane lattice parameter since atoms in the layer upon stretching will be less free to move in the z direction.

### 2.8.1. PHYSICAL VAPOUR DEPOSITION:

The fin is cleaned thoroughly before coating and placed inside the coating chamber. The pumping mechanism was started to create required vacuum levels inside the coating chamber (Fig. 3). The chamber will accommodate up to three ingots ranging in size from 49 to 68 mm in diameter and 450 mm long. The electron beam gun was switched on and the nitrogen gas supply was given to the chamber. The electron beam was focused on the fin surface and the graphene coating has been performed to the required thickness. After coating, the fins are going to be heated in a tray at a temperature of about 150 _C. Fins were heated continuously for span of 30min at the above set temperature. PVD is primarily a line of-sight process; therefore uniform coatings of complex parts (such as turbine blades) can be accomplished by continuously rotating the part during the coating process. The specimen were allowed to cool and taken out from the coating chamber. The PVD process offers many desirable characteristics such as relatively high deposition rates (upto150 urn/minute with an evaporation rate of app. 10e15 kg/h), dense coatings, controlled composition and microstructure, low contamination and high thermal efficiency. Coatings produced by the PVD process usually have a good surface finish and a uniform micro-structure. The microstructure and composition of the coating can be easily altered by manipulating the process parameters and ingot compositions.

## EXPERIMENTAL RESULTS

### 3.1. EXPERIMENT SETS:

The following table simplifies the experiments conducted on the above mentioned specimens for the heat transfer study through the fins.

| SHAPE | MATERIAL | SET UP | COATING |
|---|---|---|---|
| CYLINDER | COPPER | NATURAL | NON COATED |
| | | | NANO COATED |
| | | FORCED | NON COATED |
| | | | NANO COATED |
| | ALUMINIUM | NATURAL | NON COATED |
| | | | NANO COATED |
| | | FORCED | NON COATED |
| | | | NANO COATED |
| SQUARE | COPPER | NATURAL | NON COATED |
| | | | NANO COATED |
| | | FORCED | NON COATED |
| | | | NANO COATED |
| | ALUMINIUM | NATURAL | NON COATED |
| | | | NANO COATED |
| | | FORCED | NON COATED |
| | | | NANO COATED |

The selected two shapes of two materials were subjected to natural & forced convection experiment and non-coated and Nano coated trials. Hence there are 16 cases of experiments were conducted for this study.

### 3.2. EXPERIMENTAL INPUTS:

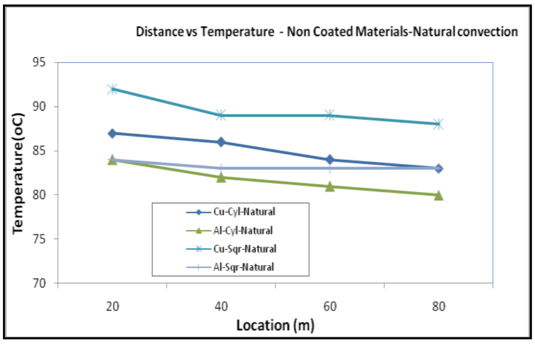
Fin diameter = 12 mm (Cylindrical)
Fin size = 12 mm (Square)
Fin length = 100 mm
Heat input = 130W
No of thermocouples on the fin surface = 4
Air speed for convection experiment = 0.5 m/s

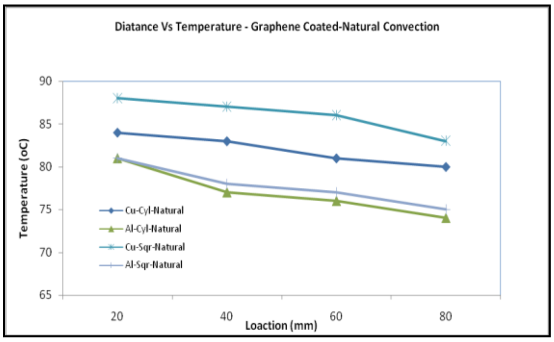
### 3.3. HEAT TRANSFER FORMULAE:

**Surface Temperature ($T_s$) $=T_1+T_2+T_3+T_4/4$**
$\Delta T = T_S - T_a$
**Thermal Conductivity (K) =W/M. K**
K =204.2 w/mk (aluminum) K =386 w/mk (copper)
**Cross Section Area Of The Fin (Ac)**
$A_c = \pi/4\ d^2$
**Heat Transfer Through Fin (Q) $=\Delta T/R$**
R $=1/2\pi l\ [k+1/H]$
**Coefficient Of Heat Transfer H=W/M2 K.**
Q fin $=\sqrt{}$ hp. k Ac m $= \sqrt{}$ hp / k Ac
**Fin Effectiveness ($\epsilon$) = Q Fin/H. $A_c$. $\Delta T$**
Q = -kA dt/dx.
**Fin Efficiency ($\eta$) = Q fin/h. $A_s$. $\Delta T$**

### 3.4.1 DISTANCE vs. TEMPERATURE - BARE MATERIALS-NATURAL CONVECTION [NON - COATED]

The comparison of experimental temperature distribution for nano coated fins was observed as follows: The surface temperature was increased for coated fin when it is compared to non-coated fined surfaces for various shapes of fins above. In this case we are using four materials and two shapes. They are as follows, copper cylinder, copper square, aluminum cylinder, aluminum square. The non-coated fins are less effective than the nano coated in efficient for transferring of heat. The thermo couple location at different heat inputs for non-coated fins are demonstrated and briefly described above the graph 3.5.0. The level of temperature for Aluminum cylinder at natural convection is low as shown in graph 3.5.0. This is low compared to nano coated may be due to their shapes or properties of the material of the fin. While it is compared to the square fin it experiences the high temperature from bottom to the top of the fin surfaces. That’s, what the major change in the temperature difference along the fin at four different places of the fin surface. The individual contribution of measured physical properties with uncertainties are described briefly





### 3.4.2. DISTANCE VS. TEMPERATURE- BARE MATERIALS - NATURAL CONVECTION [NANO - COATED]

The comparison of experimental temperature distribution for Nano coated fins for the following things was observed respectively. The surface temperature was increased for coated fin when it is compared to non-coated fined surfaces for various shapes of fins above. In this case we are using four materials and two shapes, they are as follows: Copper cylinder, coppersquare, aluminum cylinder, aluminum square. The Nano coated fins are less effective than then on coated fin efficiency for transferring of heat. The thermo couple location at different heat inputs for non-coated fins are demonstrated and briefly described above the graph 3.5.1. The level of temperature for Aluminum cylinder at natural convection is getting reduced from 80 degree to 75 degree as show in graph 3.5.1. This is very low may be due to their shapes or properties of the material of the fin. While it is compared to the square fin it experiences the high temperature from bottom to the top of the fin surfaces between 85 to 90 degree. The surface temperature should be raised as the efficiency will also be increased in order to perform high heat transfer. That’s, what the major change in the temperature difference along the fin at four different places of the fin surface. The individual contribution of measured physical properties with uncertainties is described briefly.

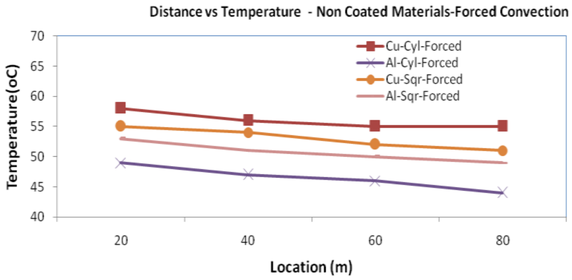
### 3.4.3 DISTANCE vs. TEMPERATURE MATERIAL FORCED CONVECTION [NON-COATED]

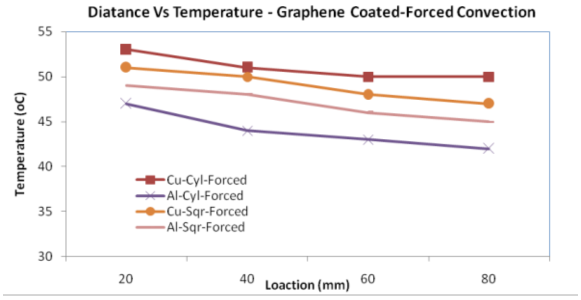
Here in the case of forced convection the amount of heat produced will be lower when it is compared to Natural non coated convective heat transfer. Comparing the amount of heat, the copper cylinder has the temperature of 60 degree from the base of the fin falling to 55 degree at the top of the fin. Obviously the square fin of the copper has 55 degree at the bottom of the which gets decreased step by step up to 50 degree at the of the fin respectively. While in case of the Aluminum square shape lies in between 52 degree and 50 degree. The last and the lowest heat produced at the Aluminum cylinder at the least temperature of 45 degree. On the overall heat transfer of fin, the heat produced in forced convection is less than that when compared to Natural convection.

### 3.4.4. DISTANCE vs. TEMPERATURE MATERIAL FORCED CONVECTION [NANO-COATED]

Here in the case of Nano coated forced convection the amount of heat produced will be lower when it is compared to Natural non coated convective heat transfer. Comparing the amount of heat, the copper cylinder has the temperature of 54 degree from the base of the fin falling to 50 degree at the top of the fin. Obviously the square fin of the copper has

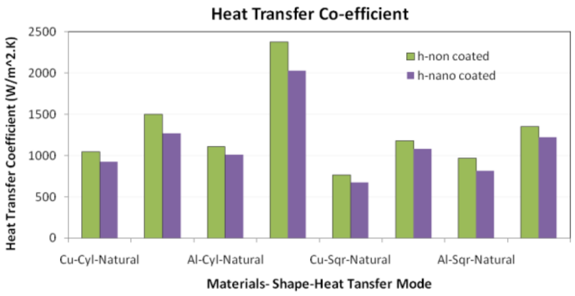
51 degree at the bottom of the which gets decreased step by step up to 48 degree at the of the fin respectively. While in case of the Aluminum square shape lies in between 49 degree and 46 degree. The last and the lowest heat produced at the Aluminum cylinder at the least temperature of 43 degree. On the overall heat transfer of fin, the heat produced in forced convection is less than that when compared to Natural convection.

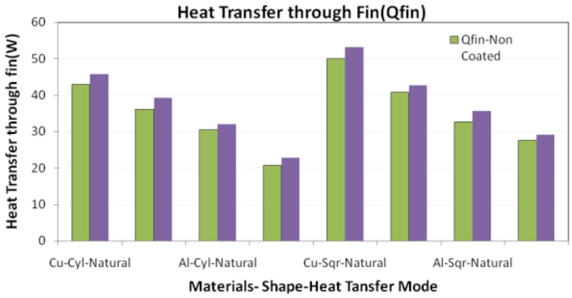




### 3.5.1 HEAT TRANSFER COEFFICIENT:

For copper cylinder, heat transfer co efficient in natural convection, shows the ration between coated and non-coated fins, i.e. the non-coated fin has high heat transfer co-efficient than the Nano coated fins. The heat transfer co-efficient for non- coated fins has 1000 w/m$^2$. K which is higher than the Nano coated fins. Comparatively for forced convection it has 1500 w/m$^2$.K for non- coated and 1200 w/m$^2$ K. for Nano coated. For aluminum cylinder, natural convection has 1500 w/m$^2$. K. For non-coated and below that the heat transfer co-efficient lies for Nano coated. In case of forced convection in overall heat transfer co-efficient aluminum cylinder experiences very high heat transfer co-efficient respectively. For copper square fin, the natural convection has very low heat transfer, for coated and non - coated in overall heat transfer co-efficient, between 500 to 1000 w/m$^2$. K. obviously in case of forced convection it raises higher than natural convection for both coated and non-coated extended surface. For aluminum square, the natural convection heat transfer co-efficient lies at 900 w/m$^2$. K. higher than Nano coated fins respectively. In case of forced convection heat transfer will be higher than the natural convection for both coated and non-coated surfaces like other cases.





### 3.5.2 HEAT TRANSFER THROUGH FIN :

The heat transfer through fin (Q fin) for four different heat transfer process. Similarly as above heat transfer co-efficient here also heat transfer through fin has some particular differences. Here, the copper square has maximum heat transfer in both coated and non-coated fins of 50W and 52W respectively. The other terminal aluminum cylinder has less heat transfer for fins at the rate of 20W and 22W comparatively. In case of forced convection, both fins have major difference in heat transfer, as shown above in the graph 3.5.2.

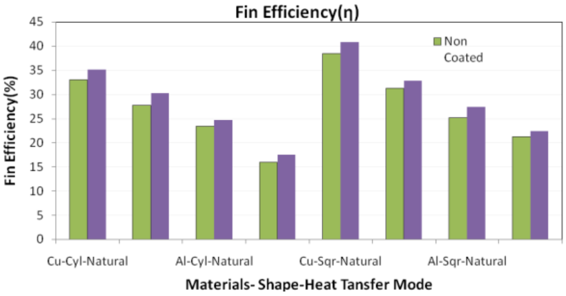
### FIN PERFORMANCE:

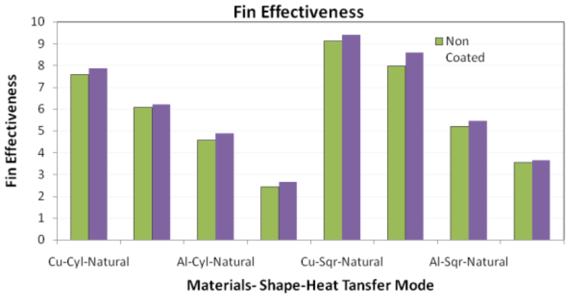
| SHAPE | MATERIAL | MODE | h (W/m$^2$.K) | | Qfin (W) | | Efficiency (%) | | Effectiveness | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | A | B | A | B | A | B | A | B |
| CYLINDER | COPPER | Cu-Cyl-Natural | 1045 | 928 | 43.05 | 45.692 | 33.11 | 35.14 | 7.588 | 7.85 |
| | | Cu-Cyl-Forced | 1500 | 1271 | 36.137 | 39.294 | 27.798 | 30.22 | 6.08 | 6.203 |
| | ALUMINIUM | Al-Cyl-Natural | 1112 | 1010 | 30.495 | 32.061 | 23.45 | 24.66 | 4.57 | 4.88 |
| | | Al-Cyl-Forced | 2378 | 2028 | 20.81 | 22.7 | 16.013 | 17.48 | 2.45 | 2.656 |
| SQUARE | COPPER | Cu-Sqr-Natural | 762 | 674 | 50.04 | 53.108 | 38.51 | 40.85 | 9.113 | 9.402 |
| | | Cu-Sqr-Forced | 1177 | 1078 | 40.767 | 42.683 | 31.35 | 32.83 | 7.98 | 8.58 |
| | ALUMINIUM | Al-Sqr-Natural | 967 | 817 | 32.715 | 35.615 | 25.16 | 27.39 | 5.21 | 5.45 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Al-Sqr-Forced | 1354 | 1225 | 27.65 | 29.1 | 21.26 | 22.39 | 3.545 | 3.635 |

**A = Non Coated** **B = Nano Coated**

### 3.5.3. FIN EFFICIENCY:

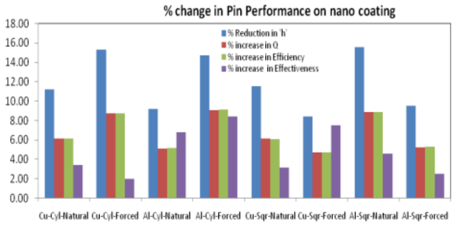




The comparison of heat transfer co-efficient and heat transfer through fin, the temperature difference for both coated and non-coated fins are explained above. This helps us to calculate the efficiency of the fin for all cases. Copper Square has higher fin efficiency in natural convection and less in aluminum cylinder. In case of forced convection, copper square has high fin efficiency and less in aluminum cylinder as shown in the graph 3.5.3.

### 3.5.4. FIN EFFECTIVENESS:

Like fin efficiency in fin effectiveness also copper cylinder's effectiveness is greater than the other fins. And aluminum cylinder is less effective compared to the other fins.



## 4. SCOPE FOR FURTHER WORK

The length of the fin could be changed it can be varied instead of using 100mm fin we can use 50 mm,60 mm etc.,. The height & width of the fin also could be changed as we had used 12mm here it could be kept differed in order to test the heat transfer along the length of the fin. We can also use other coating elements instead of Nano Graphene, such as Nano carbon, Iron, etc, in the form of nano powder or fluid regarding heat transfer analysis. The shapes of the fin could be replaced instead of using Square, cylindrical; we can use triangular fin, rectangular fin, etc. Thermo couples attached to the fin can be increased or reduced according to the shape of the fin, on the different spots of the fin. The inputs given to the Pin Fin Apparatus such as Voltmeter, Ammeter readings and rate of air could be adjusted through blower. We had used 130 volts and ammeter as 1 amp which could be changed upon the size of the fins. Thus these are some of the changes which could be executed upon the above factors.

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