Design and Analysis of cylinder having longitudinal fins with rectangular notches

¹Kiran Beldar, ²Mr. Avinash Patil

¹PG Student, ²Assistant Professor Department of Mechanical Engineering, DYPSOEA, Ambi, Pune, India

Abstract— By construction of the cylindrical heat sink having rectangular notch fins the convective heat transfer coefficient is going to increase. The measuring parameter is convective heat transfer coefficient of fin with different notch size for the given fin branched angle of 15° using free convection heat transfer. By Ansys software steady thermal analysis is performed and by CFD software Air Flow analysis, pressure drop analysis had performed. The notch size is varies from 10%, 20% and 30% the heat input is varies from 25 watt, 45 watt and 65 watt.

IndexTerms—Analysis, Thermal, Cylinder, Notches.

I. INTRODUCTION

Fins are surfaces that extend from an object to increase the rate of heat transfer to or from the environment by increasing convection. Increasing the convection heat transfer coefficient or increasing the surface area of the object increases the heat transfer. Sometimes it is not feasible or economical to change the first two options. Thus, adding a fin to an object increases the surface area and can sometimes be an economical solution to heat transfer problems

Generally in natural convection heat transfer on horizontal fin array, we observe a chimney flow pattern which creates a stagnant zone near the central bottom portion of fin channel. This stagnant zone created becomes less effective or sometimes ineffective for heat transfer, because no air stream passes over this region. To optimize the fin geometry some portion of this stagnant zone is removed in various shapes and sizes and its effect on other parameters are studied in some experiments. Some of the material from that central portion is removed, and is added at the place where greater fresh air comes in the contact of the fin surface, it would increase overall heat transfer coefficient 'h'. [15] Hence it can be studied with various modes of heat transfer. Since heat transfer by convection depends on fluid flow, so we change the fluid flow by providing a notch. [5] By variation of heat input we can analyze the optimum notch size of fins for maximum heat transfer and natural convection air flow pattern around cylinder. Following is the diagram which shows the fin having notch by compensating area and without compensating area. [12]

In natural convection, fluid motion is caused by natural means such as buoyancy due to density variations resulting from temperature distribution. [4] Dr.M.K. Sinha determines of the optimum values of the design parameters in a cylindrical heat sink with branched fins. Investigations on the effect of the design parameters, such as the number of fins, length of fin, height of fin, and the outer diameter of the heat sink on heat transfer. [2]

Vijay Kumar experimental study deals with natural convection through vertical cylinder .The experimental set up is designed and used to study the natural convection phenomenon from vertical cylinder in terms of average heat transfer coefficient. Also practical local heat transfer coefficient along the length of cylinder is determined experimentally and is compared with theoretical value obtained by using appropriate governing equations [4] Shivdas S. Kharche Studied the natural convection heat transfer from vertical rectangular fin arrays with and without notch at the center have been investigated experimentally and theoretically. Moreover notches of different geometrical shapes have also been analyzed for the purpose of comparison and optimization.[13]



Fig. 1 Cylindrical Heat sink a) Plane fin b) 20% notch with area not compensated c) 20% notch with area compensated.

II. PROBLEM STATEMENT, OBJECTIVE AND METHODOLOGY OF THESIS:

A) Problem Statement

Heat transfer from the cylinder can be increase by making notch over the fin surface which change the flow pattern over the cylindrical heat sink. Comparing to the plate type of heat sink where notch is provided and same area is compensated over same fin heat transfer is increases. This concept is applied to cylindrical heat sink with same branch angle between consecutive fins the experimental thesis is made to increase the heat transfer from cylindrical heat sink. By variation of notch size with fix branched angle over cylindrical fin surface has its own way to vary pressure drop and flow pattern and thus vary heat transfer comparing to cylindrical heat sink of without notch size.

B) Objective of Thesis

The main objective of the project is to perform experiment on cylindrical heat sink having rectangular fins and to vary the geometry of fins by providing rectangular notch size of 10%, 20%, and 30% by area compensation and without area compensation. The variation of heat input is from 25 watt, 45 watt, 65watt. To validate the result by mathematical modeling so far to conclude optimum notch size having maximum heat transfer. Also analyzing temperature distribution. Pressure drop variation, air density variation, Air temperature variation and air velocity variation over cylindrical heat sink by performing steady thermal analysis in Ansys 15.0.and CFD analysis on Ansys fluent 15.0 respectively.

C) Methodology

Selection of problem statement by literature survey, Two dimensional and three dimensional modeling of 7 Cylindrical fin array, Mathematical modeling of cylindrical heat sink, Steady thermal analysis of 7 cylindrical fin array by Ansys 15.0, Interpretation of air flow pattern and pressure drop from 7 cylindrical fin array, Experimental validation by apparatus, Comparison of result for optimum fin configuration by graphs, CFD analysis of cylindrical heat sink., Calculation of radiation heat losses from each cylindrical fin array, Future scope and conclusion.

III. MATHEMATICAL AND CFD SIMULATION

A) Assumption made in the mathematical model

The cylindrical heat sink is composed of a cylindrical base and arrays of the branched fin which are arranged circularly at regular angular intervals. The computational domain of single-fin array is selected owing to the computational time and number of grids involvement. This domain is shown in Fig. The following assumptions made for this analysis are given. [2]

- 1) The flow is steady, laminar and three-dimensional.
- 2) All the fluid properties except the air density are constant.
- 3) The air density is obtained by the ideal gas law.

B) Governing Equations

Using the Boussinesq approximation for the buoyancy term, the governing equations of the present flow, which is assumed incompressible, steady, and laminar, can be written as follows.

- 1) Continuity equation: $\rho \nabla(\vec{V}) = 0$ (1)
- 2) Momentum equation:

$$\rho \nabla (u \vec{V}) = -\frac{\partial p}{\partial x} + \mu \nabla^2 u \tag{2}$$

$$\rho \nabla (v \vec{V}) = -\frac{\partial p}{\partial x} + \mu \nabla^2 v \tag{3}$$

$$\rho \nabla(w \vec{V}) = -\frac{\partial p}{\partial x} + \mu \nabla^2 w + (\rho - \rho_a)g$$
⁽⁴⁾

3) Energy equation of fluid:

$$C_{p} \frac{DT}{Dt} = \nabla .(k\nabla T) + \frac{DP}{Dt}$$
(5)

4) Energy equation of solid:

$$\nabla^2 \mathbf{T} = \mathbf{0} \tag{6}$$

C) Boundary Conditions and numerical details

All boundary conditions were implemented by the inclusion of additional source and sink terms in the finite volume equations for computational; cells at the boundaries. In natural convection flows there is no information regarding the velocity and temperature field before the start of calculations. Since governing equations are invariably coupled, the temperature field affects the temperature field with the promotion of convective heat transfer. The computational domain has been extended beyond the actual dimensions of the fin array.

ρ



Fig. 2 Computation Domain of cylindrical heat sink.

D) Convergence and Impendence

Due to the iterative process of the code, convergence was used as the monitor of achievement of the final solution. The criterion for convergence of numerical problems is determined by absolute value of normalized residual. Basically there are 5 residuals to be monitored x- velocity, y- velocity, z- velocity, continuity and energy. By default convergence is said to be occurred when these residuals become less than 10^{-3} for mass momentum and 10^{-6} foe energy. The principle of conservation of energy and mass and momentum provides checks for achievement of final solution. Grid impendency checks were made and it is found that coarser grid distributions were not able to give accurate results in agreement with experiments. The space between two adjacent fins is selected to be modeled as a symmetric unit. The size of computation domain determined as $r x \phi x z = 6H x \theta x 5L$, as shown in Fig. 2 The validation of computational domain indicates that the heat dissipation of 5L case shows no significant difference from that of 4L case. The grid number in space is $H x \theta x L = 0.03 x 15^{\circ} x 0.1$ the convergence is achieved when the relative residual of each velocity component is below 0.05%. To couple the velocity and pressure, the SIMPLE algorithm was used. The discretization scheme for pressure is Body-Force-Weighted. For momentum and energy, first-order upwind scheme was applied to the governing equations to yield an initial solution, after which a second-order upwind scheme was applied to improve accuracy. Weighted. For momentum and energy, first-order upwind scheme was applied to the governing equations to yield an initial solution, after which a second-order upwind scheme was applied to improve accuracy. From experimentation it is found that fresh air enters fin channel from bottom and moves up in vertical direction due to buoyancy force hence inlet boundary condition is assigned to bottom and outlet boundary condition is assigned to top of computational domain. Wall of cylinder is act as constant heat sink.

	Table 1 Fine meshing node and elemen	nts
Modifications of fins	Nodes	Elements
Plane Fin	108321	19890
10 % Notch AC	61406	31687
20% Notch AC	61431	31612
30% Notch AC	59013	30039
10% Notch ANC	63456	32832
20% Notch ANC	62232	32473
30% Notch ANC	58277	30387

Following images are the CFD analysis of natural convection flow where the flow velocity is 1 m/s. In cfd enclosure is made around cylinder of size x,y,z (80mm, 80mm, 400mm) at the inlet air flow is provided at1 m/s rate and the velocity pattern of natural convection is observed.

E) Experimental and Theoretical Calculation of Connective Heat Transfer Coefficient and Nusselt number

Experimental Calculation of Connective Heat Transfer Coefficient and Nusselt number

1) Heat loss by convection Q:

$$Q = h_{avg} x A_{Convection} x (T_{body} - T_{amb})$$
(7)

2) Average Heat transfer coefficient:

$$h_{avg} = \frac{Q_c}{A_{Convection} x (T_{body} - T_{amb})}$$
(8)

3) Mean Film temperature:

$$T_{\rm mf} = \frac{\left(T_{\rm body} + T_{\rm amb}\right)}{2} \tag{9}$$

4) Experimental Nusselt number:

$$Nu_{exp} = \frac{h_{avg} x L_c}{k}$$
(10)

Experimental and Theoretical Calculation of Connective Heat Transfer Coefficient and Nusselt number

1) To find average temperature of fins:

$$T_{avg.fin} = \frac{T_1 + T_2 + T_3 + T_4 + T_5}{5}$$
(11)

2) To find temperature of body:

$$T_{body} = \frac{T_{avg.fin} + T_{Base}}{2} \tag{12}$$

3) To find mean film temperature:

$$T_{mf} = \frac{T_{body} + T_{amb}}{2}$$
(13)

- 4) To find coefficient of volume expansion:
- 5) To find grashof's number:

$$Gr = \frac{g x \beta x \Delta T x L_c^3}{\left(\nu\right)^2}$$
(15)

- 6) To find Rayleigh number:
- 7) To find Nusselt number:

$$Ra = Gr \ x \ Pr$$
(16)

$$10^{4} < Gr \ x \ Pr < 10^{9}$$
(17)

$$Nu_{math} = 0.59 \ x \ Ra^{0.25}$$
(18)

8) To find heat transfer coefficient:

A) Connections of experimental set up

Our experimental set up consists of cylinder placed on the concrete block. We use 7 types cylindrical heat sink having without notch, 10% notch, 20% notch, 30% notch with and without area compensated. With the help of cartridge heater (275 watt capacity) we provide heat the inner surface of cylinder. 8 K- Type thermocouple wires are used to measure the temperature of the fins. Heater is connected through voltmeter and ammeter and dimmerstat to mains. Dimmer stat is used to give desired input to the heater. We had selected a room with no fans and windows or any other ventilation to avoid forced convection.

B) Apparatus required

Voltmeter (Range: 0- 500 volt), Dimmer stat (5 Amp), Thermocouple (k type butt type), Temperature indicator (digital indicator), Concrete block for sealing purpose, MCB fuse for safety.

C) Experimental Procedure

Connect the dimmer stat, voltmeter, ammeter to the heater by series circuit., Connect the probes of digital temperature indicator at different locations on the base of cylinder and on the fins as per requirement., Wait until the temperature indicated by digital temperature indicator becomes steady. It took us 90 mins to reach steady state., Once the steady state is reached, note down the temperatures at required locations Now conduct the same procedure for different set of fins at different wattage.

D) Overview of experimental set up

Heat inputs can be adjusted by a dimmer stat. The temperature of heat sink at different locations and ambient temperatures are recorded at time interval of 30 minutes till steady state is reached. Generally it takes around 90 mins to attain steady state

(14)

(19)

condition. Temperature variation of around 0.45° C is taken for steady state approximation. 8 thermocouples are used. 5 of them are attached to the over fin surface and one is kept suspended to record ambient temperature and 2 are attach to base of heat sink to record base temperature. Parameters used for study are as follows: Heat Input (Qin): 25W, 45W, 65 W and Fin Temperature: T₁, T₂, T₃, T₄, T₅, Base Temperature: T₆, T₇, Ambient Temperature: T₈.



Fig. 3 Experimental set up

V. STEADY THERMAL ANALYSIS BY ANSYS

Three dimensional and thermal analysis of cylindrical heat sink with 20% notch



Fig. 4 Three dimensional and thermal analysis of cylindrical heat sink with 20% notch

VI. EXPERIMENTAL AND ANALYTICAL RESULTS

A) Experimental Result for average convective heat transfer coefficients.

According to the Newton's law of cooling we get coefficient of convective heat transfer and Nusselt number experimentally.

Notch	25 W	45 W	25 W	45 W
variation	h	h	Nu	Nu
Plane Fin	7.14391	8.041641	7.908388	8.902185
10% AC	6.528056	7.679201	6.528056	8.50096
10% ANC	7.245656	8.160272	8.021022	9.033512
20% AC	7.281293	8.186535	8.060472	9.062585
20% ANC	7.397336	8.338815	8.188932	9.23116
30% AC	6.336858	7.530708	7.014972	8.336577
30% ANC	6.953556	7.995571	7.697663	8.851185

Table 2 Experimental Result for convective heat transfer coefficients

B) Analytical Results for average convective heat transfer coefficients.

By using the Ansys result and mathematical correlations we get following results.

	able 57 marytical fo		fieur transfer eberner	ents
Notch	25 W	45 W	25 W	45 W
variation	h	h	Nu	Nu
Plane Fin	8.260629	9.367157	9.144607	10.36955
10% AC	8.228981	9.332945	9.109574	10.33167
10% ANC	8.390394	9.509008	9.288259	10.52658
20% AC	8.439747	9.553133	9.342893	10.57542
20% ANC	8.563208	9.698606	9.479565	10.73646
30% AC	8.220757	9.383127	9.100469	10.31051
30% ANC	8.232942	9.351468	9.113958	10.35218

Table 3 Analytical Result for convective heat transfer coefficients

Table 4 Percentage increase of heat transfer comparing to plane fin array								
Notch variation	25 W	45 W	65 W					
10% ANC Experiment	1.4648	1.4752	1.6956					
10% ANC Theoretical	1.5708	1.5143	1.7545					
20% AC Experiment	1.9638	1.8018	2.2959					
20% AC Theoretical	2.1683	1.9662	2.3259					
20% ANC Experiment	3.5889	3.6954	3.7895					
20% ANC Theoretical	3.6629	3.5384	3.6625					

C) Experimental and Theoretical Distribution of Local convective heat transfer coefficients.

From base temperature to tip temperature on fin K-type thermocouple is located like,T5 located at 0.5 cm from based,T4 Located at 1 cm from base and Ttip is average temperature of T1, T2, T3.

"h"	Plane Exp.	Plane Theo.	10% ANC Exp.	10% ANC Theo.	20% AC Exp.	20% AC Theo.	20% ANC Exp.	20% ANC Theo.
T _{base}	7.3678	9.3530	6.9900	9.4968	7.5725	9.5345	7.8623	9.6855
Т5	8.0179	9.3579	7.3678	9.5095	8.2609	9.5514	8.0540	9.7010

T4	8.2609	9.3652	8.0179	9.5125	8.5191	9.5581	8.4671	9.7030
T _{tip}	9.4004	9.3778	9.1891	9.5154	9.2935	9.5635	9.3457	9.7050

Table 6 Tabular representation of Distribution of Local Nusselt along the length of fin at 45 Watt.

"h"	Plane Exp.	Plane Theo.	10% ANC Exp.	10% ANC Theo.	20% AC Exp.	20% AC Theo.	20% ANC Exp.	20% ANC Theo.
T _{base}	8.15632	10.3538	7.54460	10.5131	8.38289	10.5548	8.70366	10.7220
Т5	8.87600	10.3594	8.15632	10.5271	9.14497	10.5735	8.91595	10.7391
T4	9.14497	10.3674	8.62240	10.5304	9.43075	10.5809	9.37317	10.7413
T _{tip}	10.4063	10.3813	9.63140	10.5337	10.2880	10.5869	10.3458	10.7435

VII. GRAPHICAL RESULT VALIDATION

Experimental and analytical readings are plotted on graphs, by Fig. 5 the Average convective heat transfer coefficient is increases for 10% and 20% of notch size. Further it is validated that the 20% of notch size with and without area compensation has highest capacity to increase the heat transfer comparing to plane fin array. Fig. 7 shows the distribution of local heat transfer coefficients over fin surface from base of the fin to tip of the fin. It shows the convective heat transfer coefficient is increases from base of the fin to the tip of the fin.



Fig. 5 Heat Input V/S Variation of Notch in terms of Average convective heat transfer coefficients.







Fig. 7 Percentage increase of convective heat transfer coefficient comparing to plane fin.



Fig. 8 Local convective heat transfer coefficients distribution over Fin Surface.



VIII. AIR VELOCITY, AIR DENSITY, AIR TEMPERATURE AND PRESSURE DROP ANALYSIS BY CFD

According to the inlet boundary condition with the speed of 1m/sec the air is flowing from bottom to top. When air is flowing across the channel the profile of notch creates the disturbance to the air flow thus the slight turbulence is created near the notch profile. According to the Fig. 10 pressure is higher near the notch profile and pressure is lower at the tip of the fin. Thus the air flows from the lower notch profile to the tip of the fin as the air always flow from high pressure to low pressure. Maximum value of increase in air velocity is 1.76 m/sec at the top of the fin.



Fig. 10 Air velocity variation over cylindrical heat sink at 20% fin array.



Fig 11 Air velocity variation for different notch size over cylindrical fin array.

As the heat is give to inner surface of cylinder that heat is travels across the fin surfaces, when the air is enters from the sides and bottom into the heat sink, air touches the surface of the cylindrical heat sink get heated first and density of that air is increase that air is travels from the bottom of the fin to top of the fin and also from bottom of the cylinder to top of the cylinder. The value of density increases from 1.125 Kg/m3 to 1.23 Kg/m3



Fig. 12 Air density variation over cylindrical heat sink at 20% AC fin array.

As the air enters from the side and bottom of the cylindrical heat sink as soon as air enters across the channel between two fins of fix spacing it starts absorbing the heat and get heated. The air very close to the cylinder base and surface of the fins has higher temperature and air somewhat above the metal surface has lower temperature. This change of temperature forms the boundary layer near the base surface of cylinder and side walls of cylinder. As the notch size is varies corresponding temperature distribution is also varies thus affect the formation of thermal boundary layer. The air temperature varies from 307.60 K to 320.20 K.



Fig. 14 Air Temperature variation for different notch size over cylindrical fin array.

According to the graphs its shows the 10% and 20% notch size have constant pressure distribution with variation of heat inputs, the value of pressure drop is increased for 10% Area not compensated, 20% Area compensated and 20% Area not compensated respectively. With increased in the value of pressure drop for above selected fins the rate of air flow is also increase its leads to high heat transfer.



Fig. 15 Pressure range over cylindrical heat sink at 20% AC fin array.



Fig. 16 Pressure drop variation for different notch size over cylindrical fin array.

IX. HEAT LOSSES IN CYLINDRICAL HEAT SINK

It is found that in experimental apparatus there are some losses like radiation losses, improper insulation of cylindrical fin array, the heat carried by atmospheric humidity and dust particle. Out of these radiation losses are dominant. 30% of Notch size has higher radiation losses comparing to other fin array.

Table 7 Radiation Losses From cylindrical heat sink.								
Notch variation	25 Exp.	45 Exp.	65 Exp.					
Plane fin	4.538776	7.715851	9.401989					
10% AC	5.015244	8.142256	9.485911					
10% ANC	4.943217	8.357719	10.2797					
20% AC	4.233721	7.47863	9.15153					
20% ANC	5.135726	8.62918	10.80028					
30% AC	5.184072	8.330703	9.457913					
30% ANC	6.573899	9.73898	11.89566					



Fig. 17 Heat input V/S Notch Variation in terms of radiation losses

X. FUTURE SCOPE OF THESIS

Provision of different sizes of notches over the plate type of heat sink it is possible to increase the heat transfer. Similar concept is also applicable for the cylindrical type of heat sink but only some sort of proper notch combination have an ability to improve the heat transfer from the surface by increasing the convective heat transfer coefficient from the fin surface by varying the flow pattern of air over the surface. Generally in two wheeler engine because of less space is available the natural air cooling is used to bring down the cylindrical engine surface temperature as early as possible.

To cool engine surface radial type of fin surfaces are use which consumes the more material as well as the engine block weight is also going to increase. Also according to research it found that the central portion of the fin surface is not having effective contribution towards heat transfer mostly the stagnant zones are occurs near the central portion of the fins. So there is alternative to this is longitudinal fins over cylindrical surface of engine. By area compensation method we exposes the unused central fin material to fresh air convective heat transfer will increase leads to increase in heat transfer. By without area compensation method we remove central material of fin, especially in 10% and 20% notch size of fin by without area compensation heat transfer will going to increase. So that by provision of notches by area compensation method and area without compensation method there is wide scope in automotive industry to used this concept so that is less consumption of material, less space, less weight and new attractive agronomics of two wheeler engine to improve the heat transfer by natural cooling.

By changing the position of the notch at different location of the fin surface have different identity of heat transfer. As heat transfer is also get affected by the optimum fin spacing so by changing the fin spacing and changing the Branched angle of fin heat transfer may increase in certain proportion.

XI. CONCLUSIONS

After design and fabrication of cylindrical fin array and validation of results it is observe that convective heat transfer coefficient and Nusselt no. is increased comparing to fin without notches.

- 4) In area not compensated fin array though area of fin will decrease still heat transfer increase.
- 5) Second case with compensation fin array the central material of fin is exposed to fresh cold air again it is found that heat transfer is increasing.
- 6) 10% of notch size Area without compensation and 20% of Notch size area with or without compensation has higher convective heat transfer coefficient that leads to increase in heat transfer of cylindrical heat sink from 1.5% to 3.65% comparing to the fin array without notches.
- 7) After provision of notch at the central portion of fin leads to change of flow pattern of natural air, increase in the air velocity across channel, Variation of air pressure across channel and increase of air temperature in cylindrical heat sink.
- 8) By experimental and CFD result it found that 20% of Rectangular Notch size of longitudinal fin is the optimum notch size which has the higher heat transfer comparing to the other fin array.

XII. ACKNOWLEDGEMENT

I feel immense pleasure in expressing our deepest sense of gratitude to my guide Assist. Prof. Avinash Patil, Department of Mechanical Engineering, DR. D.Y.Patil School of engineering academy, Ambi, Patil. His valuable guidance, constant encouragement and made it to partially complete this paper. His appreciative suggestion always motivated me for putting most willing efforts on my study during project.

REFERENCES

[1] Qie Shen, Daming Sun, Ya Xu, Tao Jin, Xu Zhao, Ning Zhang, Ke Wu, Zhiyi Huang, "Natural convection heat transfer along vertical cylinder heat sinks with longitudinal fins", International Journal of Thermal Sciences. 1-8, 2015.

[2] Krishna Kumar Singh, Dr.M.K. Sinha, "Parametric Effects on a Heat Sink with Branched Fins under Natural Convection", International Journal of Scientific & Engineering Research. Volume 7, 229 ,ISSN 2229-5518, 2016.

[3] Ayla Dogan, Sinan Akkus and Senol Baskaya, "numerical analysis of natural convection heat transfer from annular fins on a horizontal cylinder", Journal of Thermal Science and Technology ISSN 1300-3615, 2014.

[4] Nilesh B.Totala, Mayur V.Shimpi, Nanasaheb L.Shete, Vijay S.Bhopate, "Natural Convection Characteristics in Vertical Cylinder", International Journal Of Engineering And Science. Vol.3, PP 27-31 Issn(e): 2278-4721, Issn(p):2319-6483, 2016.

[5] S. V. Kadbhane and D. D. Palande, "Experimental Study of Natural Convective Heat Transfer from Vertical Rectangular Fin Array at Different Angle of Inclination", International Journal of Current Engineering and Technology E-ISSN 2277 – 4106, P-ISSN 2347 – 5161, 2016.

[6] S.D.Ratnakar, D.D.Palande, "Enhancement of heat transfer from plate fine heat sink", International Journal of Advance Research In Science And Engineering IJARSE, Vol. No.4, Issue 04, April 2015.

[7] P. Lohar, Dr. S. G. Taji, "Experimental Investigation for Optimizing Fin Spacing in Horizontal Rectangular Fin Array for Maximizing the Heat Transfer under a Natural and Forced Convection", International Journal of Engineering Research & Technology (IJERT) ISSN: 2278-0181 Vol. 3 Issue 7, July - 2014.

[8] S. D. Wankhede, S. G. Taji, V. M. Suryawanshi, "Experimental Investigation of Heat Transfer from Inverted Notch Fin Arrays (INFA) Under Natural and Forced Convection", IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) ISSN(e) : 2278-1684, ISSN(p) : 2320–334X, PP : 14-22, 2014.

[9] Aniket H. Kawade, "Experimental and numerical analysis of convective heat transfer from notched fin arrays with pin fins", ASME International Mechanical Engineering Congress and Exposition November 15-21, 2013.

[10] Vishal Hegana, P.R. Kulkarn, "Experimental Analysis of Natural Convection Heat Transfer from Horizontal Rectangular Fin Arrays with a Semi Circular Profiled Notch at the Center", International Research Journal of Engineering and Technology (IRJET). Vol.3, 2014.

[11] V.Sivaprakasam, J. Kalil Basha, R.Udhayarasu, D. Siva, "Experimental investigation on the performance of longitudinal fins with different notches using mixed convection heat transfer", IJRAME, ISSN: 2321-3051 Vol.3 Issue.6, Pgs: 12-20, June 2015.

[12] S.C. Haldar, G.S. Kochhar and K. Manohar, "Numerical Study of Laminar Free Convection About a Horizontal Cylinder with Longitudinal Fins of Finite Thickness" International Journal of Thermal Sciences.volume.3, 2015.

[13] Shivdas S. Kharche, Hemant S. Farkade, "Heat Transfer Analysis through Fin Array by Using Natural Convection" International Journal of Emerging Technology and Advanced Engineering, ISSN 2250-2459, Volume 2, 2014.

[14] D GKumbhar, "Analysis of Heat Transfer From Horizontal Rectangular (Square Notched) Fin Arrays by Natural Convection", International Journal of Engineering Innovation & Research, ISSN: 2277 - 5668, Volume 4, 2014.

[15] Mr. Ram Bakale, Mr. Kaushik Baheti, "Experimental Analysis of Natural Convection Heat Transfer from Notched Fin", Imperial Journal of Interdisciplinary Research (IJIR) Vol-2, Issue-6, 2016, ISSN: 2454-1362, 2015...

[16] V.sivaprakasam, j. kalil basha, r.udhayarasu, d. siva, "experimental investigation on the performance of longitudinal fins with different notches using mixed convection heat transfer", International journal of research in aeronautical and mechanical engineering issn (online): 2321-3051, Vol.3, 2014.

[17] S.H. Barhattel, M. R. Chopade2, V. N. Kapatkar, "experimental and computational analysis and optimization for heat transfer through fins with different types of notch", Journal of Engineering Research and Studies E-ISSN 0976-7916, 2014. [18] V.Achuth kumar reddy,SK subhani basha, "Effective cooling of ic engine by using various fin configurations and

materials", International journal of professional engineering studies ,Volume 6, 2014.