Journal of Advances in Science and Technology
Vol. 13, Issue No. 1, (Special Issue) March-2017, ISSN 2230-9659

Experimental Investigation of Effects of Angle of inclination on Convective Heat Transfer through Permeable Fins in Natural Convection

A. S. Pendse[1]*, S. U. Mayekar[2], S. A. Pashte[3]

Finolex Academy of Management & Technology, Ratnagiri, Maharashtra

Abstract – Fins are generally used to enhance the heat transfer rate in many industrial applications. In this study solid and permeable fins are compared for various heat inputs and at different angle of inclinations under natural convection mode. Heat input was given to fins by using heating element at base, fitted inside heat resisting casing so as to achieve unidirectional flow of heat towards base of fins. Permeable fins were made by drilling holes on plane surface of solid fins. Experimentation was carried out for five different arrangements of holes. Fins with three inline holes, five diagonal and zigzag holes, six inline holes and eight inline holes were the different arrangements used for the experimentation. Heat input was varied from 10W to 25W and angle of inclination was varied from $0^0$to 90^0.It was found that convective heat transfer rate was increased up to 21% by using permeable fins. Also maximum heat transfer rate was found for vertical fins arrangement. Heat transfer coefficient increases by increasing no. of holes or by increasing angle of inclination for natural convection.

Keywords- Permeable Fins, Angle of inclination, Natural Convection, Heat Input, Base Temperature.

---------------------------♦-----------------------------

1. INTRODUCTION

Many Engineering devices produce heat during their operations. And this heat is required to remove rapidly to avoid serious overheating problems. Fins are the best solution because of their less cost and trouble free operation. It is generally a flat surface extended from heat sink surface used for augmentation in heat transfer to and from environment by increasing the convection heat transfer surface area [1].Fins are extensively used in cooling of computer processors, air craft engines, air cooled automobile engines, cooling of generators, motors, transformers, refrigerators and other electronic devices etc. They are very important aspect in geometry of heat sinks. Fins come in various shapes; such as rectangular, circular, triangular etc. Rectangular fins are the most popular type because of their low production costs and high thermal effectiveness. Fins can also be divided on the basis of their convective properties at the end, like fins with insulated tip and fins with convective tip. The different materials like Mild steel, Stainless Steel, Aluminium, Silver and Copper etc. are used for making fins. In order to get lightweight, compact, and economical fins, the optimization of fin size is of great importance. Therefore, fins must be designed to achieve maximum heat removal with minimum material expenditure taking into account the ease of the fin manufacturing.

2. LITERATURE SURVEY

Al-Essa and Al-Hussien [2] numerically investigated natural convection heat transfer from a horizontal rectangular fin with square perforation with two orientations. They found that square perforations increase surface area and heat removal rate. They concluded that square perforations of inclined type were best for low fin thickness and parallel type for high fin thickness. Ashok Tukaram Pise and Umesh Vandeorao Awasarmol [3] used the original engine block for experimentation work. They modified the solid rectangular fins into permeable fins by drilling three inline holes per fins. They observed heat transfer rate, heat transfer coefficient and percentage saving of material. The experiment showed that the heat transfer rate improves with the use of permeable fins. Kumbhar D.G, Dr. N.K. Sane and Chavan S. T [4] investigated the effect of triangular perforations on rectangular fin .The analysis was done numerically and followed by experimentation. It was observed that heat transfer rate increases with perforations as compared to fins of similar dimensions without perforations. They also concluded that heat transfer rate was different for different materials. Bassam and Abu [5] numerically analysed heat transfer through permeable fins and quoted significant enhancement in heat transfer over solid fins. They stated that under no condition did the increase of number of permeable fins result in decrease in Nusselt number as opposite to solid fins. Al-Essa and Al-Widyan [6] studied the natural convection heat transfer augmentation from horizontal rectangular fin embedded with triangular perforations. They found that temperature drop along the perforated fin length was consistently larger than that on equivalent solid fin. U. V. Awasarmol and Dr. A. T. Pise [7] found that heat transfer rate is improved and convective heat transfer coefficient increases by about 20% as compared to solid fins with reduction in cost of the material of 30%. Also, they observed that heat transfer rate is maximum for vertically placed fins for natural convection.

After going through the literature survey one can conclude that definitely heat transfer coefficient gets improved for permeable fin as compared to solid fin. Hence in present work total five different arrangements of holes of permeable fins are experimentally tested under natural convection conditions. Also efforts have been taken to relate heat transfer coefficient with angle of inclination.

A. Optimal Area Condition

The best comparison between solid and permeable fins is possible if surface area and surrounding temperature remain same. To have equal surface area one mathematical relation was developed as follows,

Area removed= Area added

$2\pi r^2 = \pi dt$

$r = t$

Where,

d = diameter of hole drilled = 2r,

t = thickness of fin.

Using above mathematical relation perforation size can be justified from fin thickness. Using the hole diameter twice that of the thickness the area will remain constant irrespective of no. of holes drilled. Hence, this condition can be treated as *"optimal area condition"* while making perforations.

DATA REDUCTION

The models used for study were taken with finite length and the convection takes place along the surfaces as well as at the end. Hence, relation for heat transfer by fins with convection off the end was used.

$$Q_{fin} = \sqrt{hpkAc}(t_0 - t_a)\frac{\tan h(ml) + \frac{h}{km}}{1 + \frac{h}{km}\tan h(ml)}$$

................[8]

Where, $m = \sqrt{\frac{hp}{kAc}}$

h = coefficient of convective heat transfer (W/m^2-K)

k = thermal conductivity (w/m-K)

A_c = c/s area of fin

p = perimeter of fin

t_o= base temperature

t_a= Atmospheric temperature

EXPERIMENTAL SETUP AND PROCEDURE

Setup used for experimentation is shown in Fig.1. It consisted of arrangement for holding the model of fins, heating coil, voltmeter, ammeter, dimmer stat and temperature display.Each model had three equally spaced fins. Permeable fins were created by drilling holes on solid fins. The diameter of hole was 4mm. Fins with three inline holes, five diagonal and zigzag holes, six inline holes and eight inline holes were the different arrangements used for the experimentation.

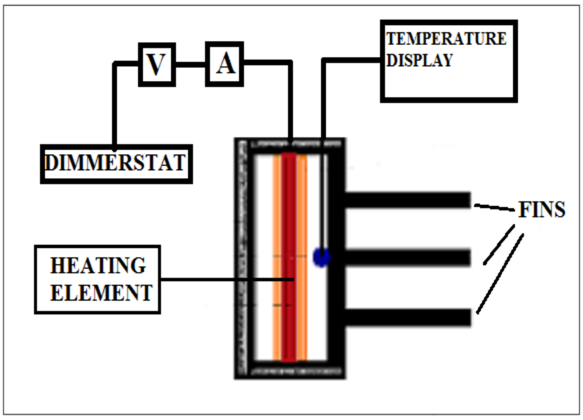

Fig.1 Schematic of Setup

Heating coil (450W) was inserted at the base of model. An enclosed box was formed with asbestos, mica and plywood to make unidirectional heat flow at base without loss of heat. Electric supply was given to the coils through a dimmer stat so as to vary the input power. To calculate actual heat supplied, ammeter and voltmeter were connected at output of the dimmer stat. Base temperature of each fin was measured by k-type thermocouple. Tests were taken by varying the input supplied to the heating coils.10W, 15W, 20W, 25W were the heat inputs. To analyse the effect of angle of inclination on heat transfer coefficient same models were tested at 0^0, 30^0, 45^0, 60^0 and 90^0.Few models are shown below-

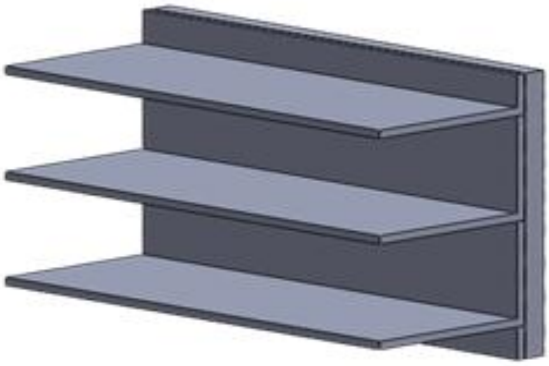

Fig.2 Solid Fins

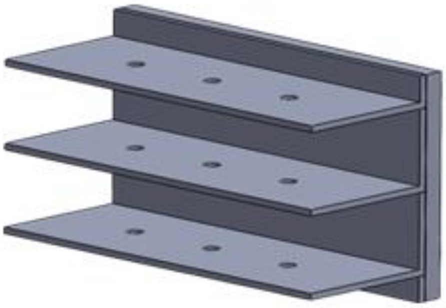

Fig.3 Model with 3 inline holes

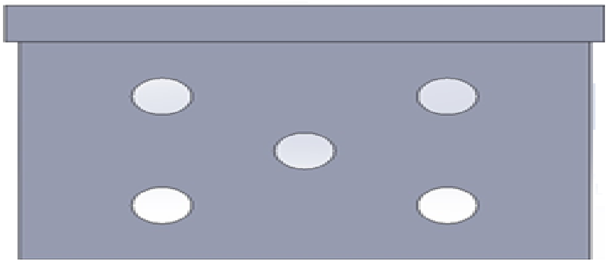

Fig.4 Model with 5-holes (diagonal)

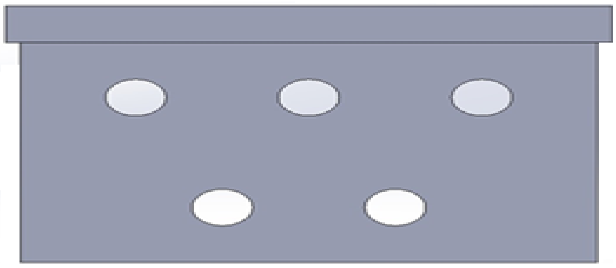

Fig.5 Model with 5 zigzag holes

The heat input was adjusted by adjusting the values of voltage and current. After achieving the steady state the base temperature was recorded.

RESULTS AND VALIDATION

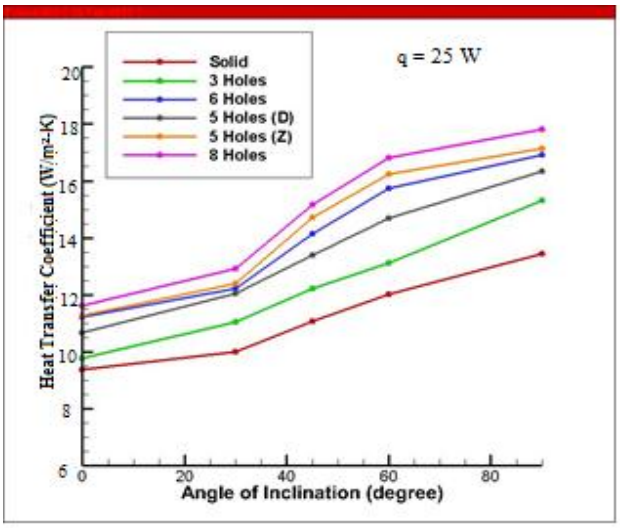

Fig. 7 Comparison of various models at different inclinations

From above graph it can be concluded that permeable fins have better heat transfer coefficient than solid fins. For models of 3 inline holes, 5 holes (diagonal), 6 inline holes, 5 holes (zigzag) and 8 inline holes arrangements, average increase in heat transfer coefficient was found to be 10%, 18%, 24%, 26% and 40% respectively. It is due to the fact that perforations provided on fins disrupt the thermal boundary layer growth along the fins. Also due to these perforations more amount of air comes in contact with fins. In addition to this, provision of perforations reduces the weight and leads to lower production cost. It can be seen from graph that heat transfer coefficient increases with no. of holes. But, for 5-holes (zigzag) model thermal boundary layer gets broken 5 times while for 5 holes (diagonal) and 6 holes models it gets broken only 3 times. Hence, 5-holes (zigzag) model shows higher value of heat transfer coefficient than that of 5-holes (diagonal) and 6-holes model.

When air comes in contact with hot fins, temperature of air increases and hence its density decreases. In horizontally placed fins this hot air remains trapped between fins and natural flow due to density difference does not get developed properly. Whereas in case of vertically placed fins, air which comes in contact with fins when gets heated up moves upwards and more dense cold air comes in contact with fins. Hence, natural flow of air due to density difference is developed. Therefore, for vertically placed fins heat transfer coefficient is better than for any other angle of inclination for respective model. For horizontally placed fins up to 21% increase in heat transfer was obtained using permeable fins, while for vertically placed fins up to 50% increase was achieved.

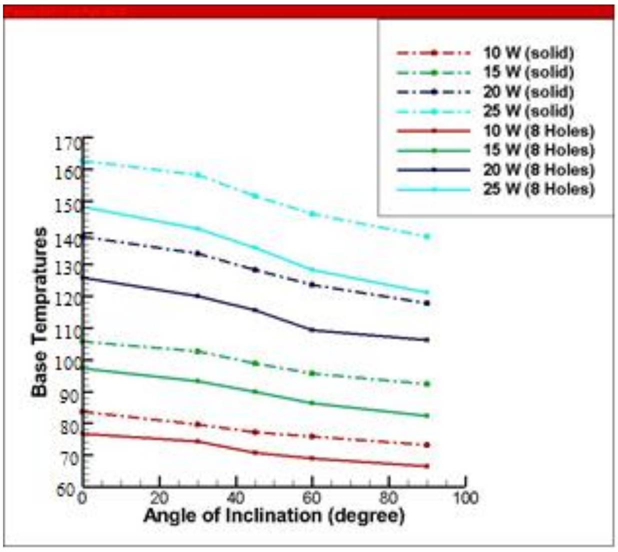

Fig. 5 Base temperature profile for various models

It can be seen that the base temperature gets reduced with increase in no. of holes. Also, when angle of inclination increases base temperature decreases. It is very significant to have low temperature to avoid thermal stresses.

CONCLUSIONS

1. For same heat input permeable fins have better heat transfer coefficient than that of solid fins.

2. Heat transfer coefficient increases with increase in no. of holes, but it is also dependent on arrangement of holes.

3. Maximum heat transfer from permeable fins occurs for vertical position in natural convection.

4. Overall weight of the component is reduced significantly by 10-15 %.

REFERENCES

[1] Vipin and Udhishter Saini, "Natural Convection Heat Transfer Augmentation from Heat Sinks using Perforated Fins: A Review", JMSME Print ISSN: 2339-9095; Online ISSN: 2393-9109; Volume 2, Number 6; April – June 2015.

[2] Abdullah H. Al-Essa, et.al. (2004), "The effect of orientation of square perforations on the heat transfer enhancement from a fin subjected to natural convection", Heat and Mass Transfer, 40, 509-515.

[3] A.T. Pise, U.V. Awasarmol "Investigation of Enhancement of Natural Convection Heat Transfer from Engine Cylinder with Permeable Fins", IJMET ISSN 0976 – 6340(Print) ISSN 0976 – 6359(Online) Volume 1 Number 1.

[4] D. G. Kumbhar, et al. "Finite Element Analysis and Experimental Study of Convective Heat Transfer Augmentation from Horizontal rectangular Fin by Triangular Perforations", Proceedings of the International Conference on Advances in Mechanical Engineering (2009).

[5] Bassam A/K Abu-Hijleh, 2010, 'Enhanced Forced Convection Heat Transfer from a Cylinder using Permeable Fins', Journal of Heat Transfer. [DOI: 10.1115/1.1599371].

[6] Abdullah H. Al Essa, et.al. (2008). Enhancement of natural convection heat transfer from a fin by triangular perforation of bases parallel and towards its tip. Applied Mathematics and Mechanics, 1033-1044.

[7] U. V. Awasarmol and Dr. A. T. Pise, "Experimental Study of Effect of Angle of Inclination of Fins on Natural Convection Heat Transfer through Permeable Fins", Proceedings on International Conference on "Thermal Energy and Environment (INCOTEE 2011).

[8] R K Rajput, "Heat and Mass Transfer", S. CHAND publications 2008.

Corresponding Author

A. S. Pendse*

Finolex Academy of Management & Technology, Ratnagiri, Maharashtra

E-Mail – aniketpendse2001@gmail.com