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Experimental Investigation of Natural Convection over Notched FinArrays on Horizontal Plate

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Abstract- *Natural convective phenomenon of heat transfer over heated horizontal and vertical surfaces occurred by keeping it directly exposed into air with extended surface attached to a surface. The extended surfaces (fins) areused to increase the heat transfer rate so that it givean easy and trouble free solution in many situations required for natural convection heat transfer. Geometry and orientation plays an important role in natural convection heat transfer. Fin arrays on horizontal and vertical surfaces are used in variety of engineering applications to dissipate heat to the surroundings.*

For horizontal rectangular fin array a chimney flow pattern is developed due to density difference. This flow can be of single flow or multi flow type. The heat transfer can be enhanced by using both the methods. Many researchers have been studied the heat transfer rate through without notch and notched fins for single chimney flow, hence the present work is done on the multiple chimney flow for the enhancement of natural convective heat transfer.

Keywords*: Convection, Natural Convection, Notched fin, Heat Transfer Enhancement.*

1. INTRODUCTION

Fins are generally used to enhance heat transfer such as convection in an engineering applications and also gives a practical means for getting a large total heat transfer surface area without the use of an excessive amount of primary surface area. Fins are commonly helpful for management of heat in electrical base equipments which are getting heated after their use such as computer power supplies or substation transformers. Another very important application where natural convective heat transfer occurs which is the cooling of Internal Combustion engine, such as fins used in automobile radiator. Hence it is necessary to predict the distribution of temperature within the fin in order to choose the right configuration that delivers maximum effectiveness. Natural convection heat transfer is often increased by providing of different shapes of fins on horizontal or vertical surfaces in many electronic applications, motors and transformers. In current days in the electronic based industry is working heavily on the overheating problem due to the reduction in surface area available for heat dissipation.

Thus extensive study has made analytically and experimentally over heat transfer from fin arrays. Baskaya et al (2000) [1] carried out parametric study of natural convection heat transfer from the horizontal rectangular fin arrays. This study did on the effects of a various geometrical parameters on the heat transfer from horizontal fin arrays like fin length, fin height, fin spacing and variation of temperaturebetween fin and surroundings. However, it was not possible to make clear conclusions due to the various parameters involved in their work. Finally it was concluded that, by only concentrating on one or two parameters, it is not possible to get a optimum performance in terms of overall heat transfer. So the relation between among all the design parameters must be considered. This research has also shown that each variable makesan effect on the overall heat transfer. As a whole, it can be concluded that the overall heat transfer is enhanced with the increase in the height (H), of the fin and decrease in the length (L) the fin.

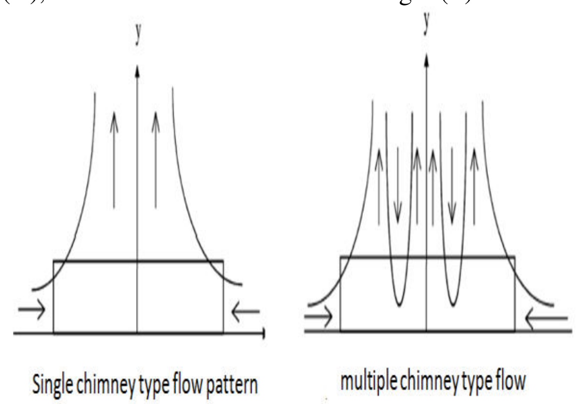

Fig.1. Different Flow Patterns [1]

Fins are generally used to increase the heat transfer rate from the surface. According to YunusA. Çengel [9] in a study of fins considered steady operation assume thermal conductivity of material is constant along with no heat generation in the fin. Over the entire surface of the fin the heat transfer coefficient is assumed to be constant. The value of h is much higher at the tip than its base. Because fluid is surrounded by the solid surface near its base, hence adding too many fins on a surface will decrease the overall heat transfer coefficient when the decrease in h offsets any addition resulting from the increased surface area.

From the early research work it was clear that, there is establishment of single chimney pattern for lengthwise short fins and multiple chimney flow for lengthy fins. In case of natural convection cooling of vertical fin array, there was sidewise entry of air. The air coming gets heated andit rises due to decrease in densityas well as it moves towards the centre of the fin. So, the central portion of the fin becomes ineffective because heated air-stream passes over that part and therefore there is less possibility of large heat transfer through that portion. So, if some of the material from that central portion was removed, and was added at the place where greater fresh air comes in the contact of the fin surface, it would increase overall heat transfer coefficient h. This has been confirmed experimentally by previous researcher.From the past studies it was found that lots of experimental work carried over single chimney pattern and less work on experimental study of multiple chimney flow.It is also found that if the length of fin is more so require to the more area removed for notch will cause increase in height that makes object in convenient in structure. Hence the present work will be done by considering multiple chimney flow pattern.

1.1 Extended surfaces.

Heat transfer inside the solid to the solid takes place by the phenomenon of conduction and from the particular surface to another medium that is surroundings takes place by convection. Convective heat transfer may be occurred by natural convection or by forced convection. The rate of heat transfer from a surface at a temperature (T_a) to the surrounding medium at T_b is given by the Newton's law of cooling as: $Q = h\,As\,(T_a - T_b)$ where As – is surface area of heat transfer and h is the convection heat transfer coefficient.
When the temperatures T_a and T_b are fixed by design considerations, as in general, there are two ways to increase heat transfer rates:
(1) By increasing convection average heat transfer coefficient [h] &
(2) By increasing the surface area [As].
There is having alternative option to increase the surface area by attaching to the extended surfaces called fins to the geometry which are made up of highly conductive materials. The main purpose of extended surfaces is to increase the heat transfer rate.

1.2 Materials Used For Fins.

Generally there are two most common types of materials used for fins aluminum and copper. The aluminium having thermal conductivity of225 W/mK where as that of copper is having 385 W/mK. Pure aluminum looks silvery in color and it also gives the greater resistance to corrosion. It is used in deoxidizing molten irons and steel as well as to prepare the metals from their oxides by heating a mixture of powdered aluminum and the oxides of the metal to be reduced. It has electrical resistivity around 2.669 micro ohms/cm. The material used for current study is aluminium.Copper looks reddish brown in color. When the copper is in the blister stage refining of the metal is usually considered to begin, the surfaces of the cast material being irregular and blistered due to the generation of gases during cooling. This results a copper that is of around 99% pure and then it is further refined in the furnace with oxidation process which helps to removes sulphur and other impurities present in it. The excess of oxygen present in is removed from the metal by poling operation. Copper is having an electrical resistivity around 1.682 micro ohms/cm.

1.3Fins Shapes Used For Heat Transfer

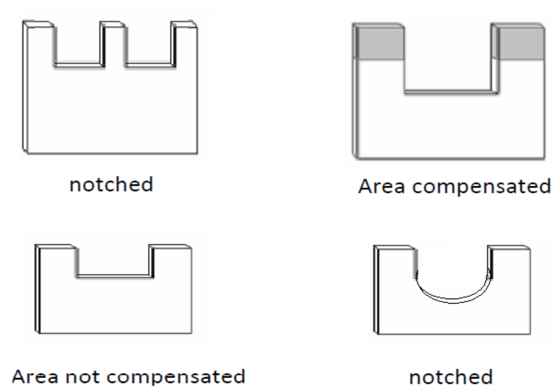

Fig.2.Configuration of Fin Arrays

Different types of fins were used to increase the heat transfer rate. The fin shapes used was rectangular, circular, triangular, V-shapes and trapezoidal. Some researchers were used without notch fins and some uses notched fins. They were also used different shapes of notches such as rectangular; V-shapes, triangular and they have found that the heat transfer rate through notched fins was more than without notched fins.

Earlier researcher use material for fin was aluminum and copper as well and studied each of the variables of fin spacing, height, and length and temperature difference produces an effect on the overall heat transfer.

2. EXPERIMENTAL SET-UP:

Proposed experimental set-up designed for determination of convective heat transfer coefficient of air flowing over a horizontal plate with rectangular fins attached to plate as shown in block diagram. It consists of control system that includes the temperature indicator, heater input, temperature selector switch, fuse, dimmer stat. From the control panel thermocouples are attached to the plate. The plate is kept in direct environment and it is enclosed by enclosure. The different shapes of fins are mounted on plate to enhance the heat transfer. The 100 w heater is use to give a temperature variation in the plate in order to get the various operating conditions as the results will take for 20w, 40w and 60w heat input conditions.

Table 2 Fin characteristics.

Fin dimensions	Values
Length of fin (mm)	200
Height of fin (mm)	70
Fin thickness (mm)	6
Fin spacing (mm)	8
Number of fins	6
Fin material	Aluminum
Base plate thickness(mm)	5

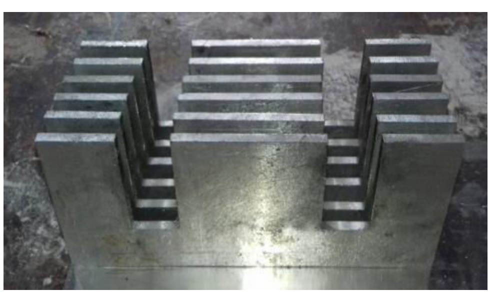

Fig 3a- fin configuration used in set up

In this set-up there will use of six-eight thermocouples placed at equal distance on the surface of plate. Heat input can be set with the help of variance provided on control panel and same can be show out digitally with the help of ammeter and voltmeter. The current experimental set up is under manufacturing stage.

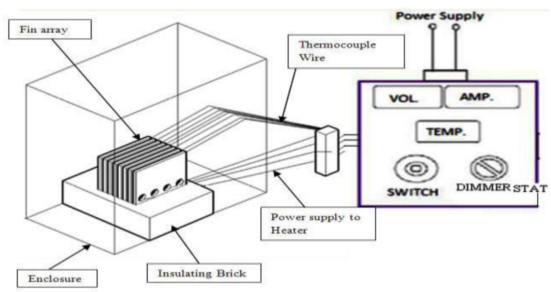

Fig.3b-Experimental set-up

3. FINITE ELEMENT ANALYSIS

The CAD model of the HRFA is prepared in Catia V5 modeling environment as shown in Fig-2 and Ansys Fluent 16.0 simulation tool is used for the FE analysis. Generally fins are made of copper and aluminium alloys. The material used in current work is aluminium. The material properties adopted for analysis are listed in Table 1.

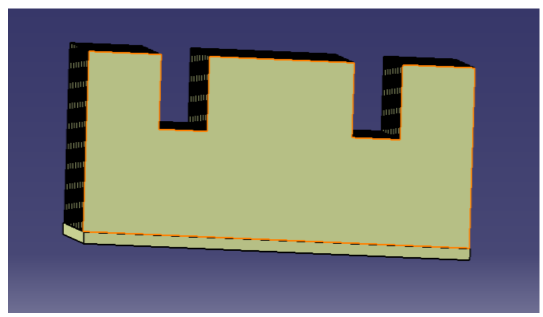

Fig 4- CAD model of HRFA

Table 1 properties of aluminium

Properties	Values
Thermal conductivity (W/mK)	202.4
Density (kg/ m^3)	2719
Specific heat (J/ KgK)	871
Melting point (^{0}C)	658
Boiling point (^{0} C)	2057

A. Description

Ansys Fluent-16.0 software is used for Computational fluid dynamic analysis.A sourceis assumed as the fin surfaces, with base, kept at uniform temperature. The mechanism consider for heat transfer from the fin array is Laminar natural convection. The losses due to Radiation heat loss is considered as zero. ANSYS-Workbenchis used to Geometry creation and meshing. The 3D geometric model of fin with notch and without notch fin array is created in ANSYS Workbench consisting the fin array assembly over a horizontal base plate and enclosure for natural convection condition.

The meshing of the geometry has been done in ANSYS ICEM tool. The meshing procedure and different meshing elements type are given below.

Tetra- The ANSYS ICEM CFD Tetra mesh takes full use of object-oriented unstructured meshing technology. With no requirement of tedious up-front triangular surface meshing required to provide well-balanced initial meshes, ANSYS ICEM CFD Tetra works directly from the CAD surfaces and fills the volume with tetrahedral elements using the Corte approach. This is powerful smoothing algorithm that provides the element quality. There are lots of options available for automatically refinement and coarsen the mesh both within the volume and over the geometry.To create tetras from an existing surface mesh and also to give a smoother transition in the volume element size a Delaunay algorithm is also included.

Prism- ANSYS ICEM CFD Prism createshybrid tetrahedral grids including of layers of prism elements near the boundary surfaces and tetrahedral elements in the interior for better modeling of near- wall physics of the flow field. Compare to pure tetrahedral grids, this results in smaller analysis models, better convergence of the solution and better analysis results.

Shell Meshing-the methods for faster generation ofsurface meshes an ANSYS ICEM CFD software provides best option.

The process typically involves the following:

1. Firstly using the diagnostic checks available the mesh is checked for various problems present in it this problem are holes, gaps, overlapping elements. Then Fix the problems using the available methods either automatic or manual repair.

2. Check the elements for bad quality and use smoothing to improve the mesh quality.

3. When the mesh quality is getting poor, the geometry may be get fixed appropriately or there is need to recreate the mesh using more accurate size parameters or use of a different meshing method.

B.Boundary conditions

A top surface is designated pressure inlet from where air enters and all the remaining boundaries are designated as pressure outlet where air leaves the channel at the surrounding temperature. Here the stagnation boundary conditionused as the ambient pressure with the incoming mass having the ambient temperature. It is assumed that the static pressure is equal to the pressure of surrounding atmosphere.

CFD-POST is used for seeing results and plots. Temperatures at various surfaces are viewed fromgraphics and animation contours. In this work the temperature distribution profile on the fin is obtained which was used to calculate the heat transfer coefficient using formulas.

4. RESULTS

A. Temperature Contours

Due to the creation of notches of different area height of fin increased for 10 %, 15 % and 20 % notch fins. By clear observation available from temperature contours that as there is increase in height top tip temperature goes on reducing for 10 %, 15 % and for 20 % notched fin arrays than without notch fin array as shown in following figures.

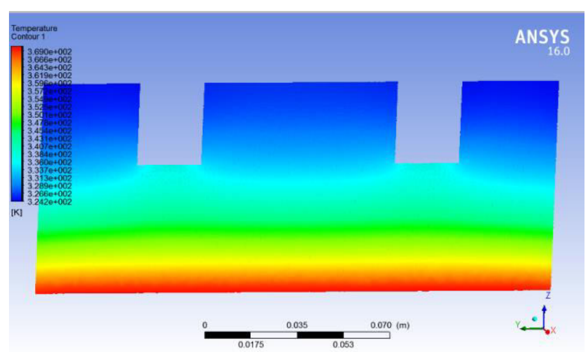

Fig 5-Temperature Contour for Fin with 10 % notch

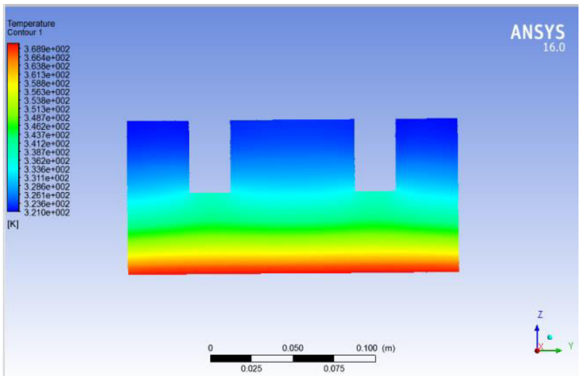

Fig 6- Temperature Contour for Fin with 15 % notch

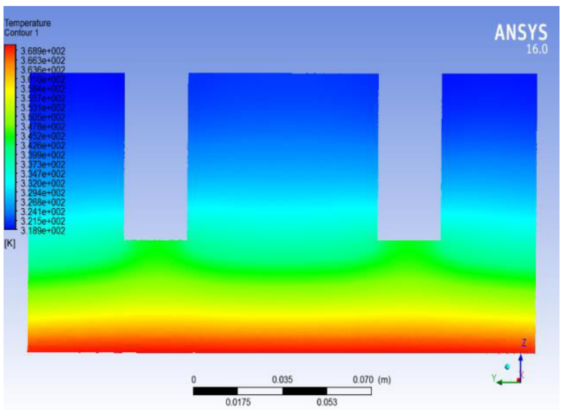

Fig 7-Temperature Contour for Fin with 20 % notch

5. CONCLUSION

In this analytical research work is carried out to found out effect of extensions of different shapes and perforation of different sizes on the heat transfer in Natural convection by using CFD. Analytical Investigation of fin arrays with perforation and fin arrays with extensions under Natural Convection conditions is carried out. In this work different variants with extensions and perforations are tested and results are presented by using CFD Post. The conclusions made in this study are presented below:

1. It is observed in this study that the shape fin extensions have a positive effect on the heat transfer through fin array. The fin extensions of rectangular shape are the best shapes to provide heat transfer enhancement. It is observed by using CFD results when increases the rectangular notch area then increases the heat transfer rate.

2. Due to the creation of notches of different area height of fin increased for 10 %, 15 % and 20 % notch fins. It is observed from temperature contours that as there is increase in height top tip temperature goes on reducing for 10 %, 15 % and for 20 % notched fin arrays than without notch fin array.

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