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Heat transfer enhancement from rectangular fin array using staggered perforations

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ABSTRACT

The efficiency of many devices greatly depends upon their ability to dissipate heat from their surfaces. Fins are extended surfaces used for dissipating heat from the hot surfaces. A number of experiments have been done in the field of enhancing heat transfer rate from hot surfaces. Present study deals with a new mechanism in which heat transfer rate in rectangular array is enhanced by means of staggered perforations.ANSYS Gambit 2.4 has been used for geometry creation and ANSYS Fluent 6.2.4 for simulation. The result shows that the fins with staggered holes possess increased heat transfer capacity

Index Terms: Fin, Extended surfaces staggered perforation

1. INTRODUCTION TO FIN ARRAY

The term extended surface is commonly used to depict an important special case involving heat transfer by conduction within a solid and heat transfer by convection from the boundaries of solid. Although there are many different situations that involve such combined conduction convection effects, the most frequent application is one in which an extended surface is used specially to enhance heat transfer rate from solid to adjacent fluid. There are mainly two methods through which the heat transfer rate can be increased- either by increasing convection heat transfer coefficient h or decreasing the fluid temperature $T\infty$. Sometimes increase in h value will not help to achieve the desired heat transfer rate.Reducing the value of $T\infty$ also becomes impractical. This situation can be overcome by increasing the surface area of the fin. In the case of fin array there exists one more option i.e. increasing turbulence between the fins.

A straight fin is an extended surface which is attached to a plane wall. The fin material is supposed to have higher thermal conductivity. This minimizes the temperature variation from base to

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tip.Notches are cuttings made on the surface of fin. These notches permit cold air to get in contact with adjacent fin arrays and hence ensure higher efficiency. Notching without material compensation may lead to poor efficiency. The problem can be overcome with the help of circular perforations. This paper focuses on increasing heat removal rate from rectangular fin by introducing staggered perforations on the surface

Guei-jangHuang et al [1] made experiments on enhancing natural convection heat transfer from horizontal rectangular fin arrays with perforations in base. Different perforation patterns were created and overall heat transfer coefficients were found out. Maximum enhancement factor of 2.77 was achieved at the end.

M.R. Shaeri et.al [2] conducted experiments on enhancing natural convection heat transfer from horizontal rectangular fin array with longitudinal perforations stream wise. Number of perforation was varied between 1 and 3 and overall heat transfer coefficient was found out. Following Enhancement factors were obtained.

Ashok TukaramPiseet.al [3] conducted experiment to compare the rate of heat transfer with solid and permeable fins. Engine cylinder block having solid and permeable fins were tested for different inputs (i.e. 75W, 60W, 45W, 30W). It was found that average heat transfer rate in permeable fins improves by about 5.63% and average heat transfer coefficient by 42.3% as compared with solid fins with reduction of cost material by 30%

UgurAkyol et.al [4] conducted experiments on heat transfer and friction loss characteristics of horizontal rectangular channel having rectangular fin array on its surface. Experiment was carried out for both straight line arrangement and staggered arrangement. Results concluded that staggered arrangement is having slightly increased heat transfer coefficient

In 2009 Khumbar D.G et.al [5] investigated heat transfer augmentation from a horizontal rectangular fin by triangular perforations using ANSYS. It was concluded that heat transfer rate increases with perforations compared with similar fins without perforations. The perforation of the fin not only enhances heat transfer rate but also reduces the material cost

In 2011 S Barhatteet. al[6]investigated natural convection heat transfer from vertical rectangular fin arrays with and without notch at the centre theoretically .He conducted experiment also. The fin flats were modified by removing the central fin portion cutting a notch

In 2011 M .Matkar et.al [7] calculated heat transfer rate from and the temperature behaviour of same object with different material. They have concluded that heat heat flow rate of copper fin is less than heat flow rate of aluminium fin.The copper gets stable at the lowest temperature and hence concluded that copper is more suitable material for fin than Aluminium

In 2012 G .Raju et.al [8] investigated the maximization of heat transfer through fin arrays of internal combustion engine cylinder under one dimensional steady state

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condition to obtain maximum heat transfer and their corresponding optimum dimensions. They concluded that heat transfer through triangular fin array per unit mass is more compared to rectangular fin array. Therefore triangular fin is preferred to rectangular fin for automobile applications where weight is main criteria

In 2013 N.G Narve [9] et.al studied heat transfer characteristics of natural convection from symmetrical triangular fin arrays. It was studied experimentally and comparison with rectangular fin array was done. In both the cases spacing was the variable. It was concluded that average and base nusselt number are higher for triangular fin array over the equivalent rectangular fin array. Overall heat transfer characteristics of symmetrical triangular fin array is better than rectangular fin array.

2. PROJECT METHODOLOGY

The steps in project methodology can be listed as follows

1. CFD Code validation
2. Creation of perforated rectangular fin in Gambit
3. Simulation of perforated geometry in Fluent
4. Optimization of hole diameter and orientation of hole using CFD softwares

3. PROBLEM DEFINITION

3.1 Problem specification

The study is about enhancement of natural convection heat transfer from large horizontal fin array by introducing holes arranged in staggered manner. Since such a method has not been reported in the literature, the aim of the work is to discuss on the enhancement mechanism and the effects of hole diameter and the hole orientation. Specifications of the fin are as follows: length L=380 mm fin height H =38 mm, fin thickness t_f=3mm, fin spacing S=10mm.The air flow in this study is assumed to be turbulent. Fin material is Aluminum with thermal conductivity 202 W/m. Each perforation has diameter 5 mm

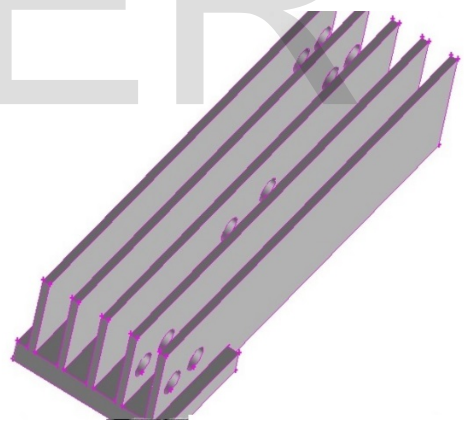

Fig 3.1 Array of fin with perforations (holes at center)

4. GOVERNING EQUATION

Continuity equation

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$$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}+\frac{\partial w}{\partial z}=0$$

Momentum equation

$$\left[\frac{\partial u}{\partial t}+u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}+w\frac{\partial u}{\partial z}\right]\times\rho=-\frac{\partial p}{\partial x}+\rho g_x+\mu\left[\frac{\partial^2 u}{\partial x^2}+\frac{\partial^2 u}{\partial y^2}\right.$$

$$\left[\frac{\partial v}{\partial t}+u\frac{\partial v}{\partial x}+v\frac{\partial v}{\partial y}+w\frac{\partial v}{\partial z}\right]\times\rho=-\frac{\partial p}{\partial y}+\rho g_y+\mu\left[\frac{\partial^2 v}{\partial x^2}+\frac{\partial^2 v}{\partial y^2}\right.$$

$$\left[\frac{\partial w}{\partial t}+u\frac{\partial w}{\partial x}+v\frac{\partial w}{\partial y}+w\frac{\partial w}{\partial z}\right]\times\rho=-\frac{\partial p}{\partial z}+\rho g_z+\mu\left[\frac{\partial^2 w}{\partial x^2}+\frac{\partial^2 w}{\partial y^2}\right.$$

5. COMPUTATIONAL DOMAIN

To make the analysis simple, an array of symmetrical fin is used. The domain consists of a solid phase to represent the fin plate and gas phase to represent the region of air flow.

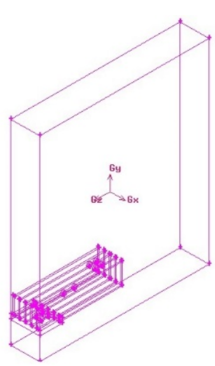

Fig5.1 Computational domain

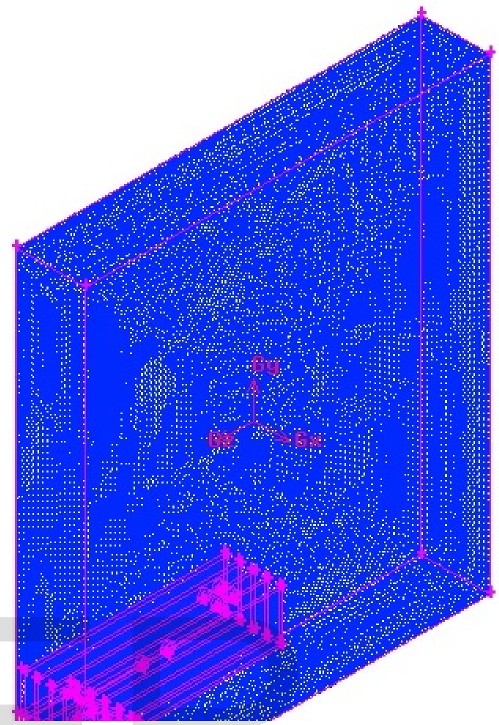

Fig 5.2 Meshed geometry

7. COMPUTATIONAL PROCEDURE

Using finite volume code, the governing equations are discretized. Velocity components are staggered using PISO algorithm with respect to the main control volume in this scheme. The first order upwind scheme is used to calculate velocity component, k and energy equations, In order to find out the flow field, computation is first started solving continuity, momentum, *k* and ε

6 RESULTS AND CONCLUSION

Analysis of flow field and heat transfer has been carried out for two different orientations It is observed that flow path lines around solid and perforated fin are different. From the analysis it is also concluded that when perforations in staggered manner are introduced on fin surface, the turbulent effect of air passing through the holes gets increased. This in turn enhances the heat carrying capacity of the perforated fins

Orientation of holes	h(w/m^2)
Without hole	3.35
Holes at center	3.9
Holes at L/4 length	4.1

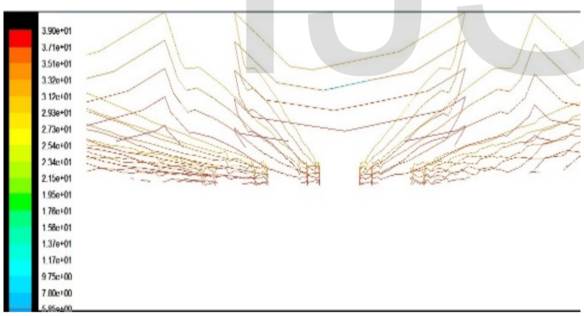

Fig 6.1 contour of heat transfer coefficient for holes at centre orientation

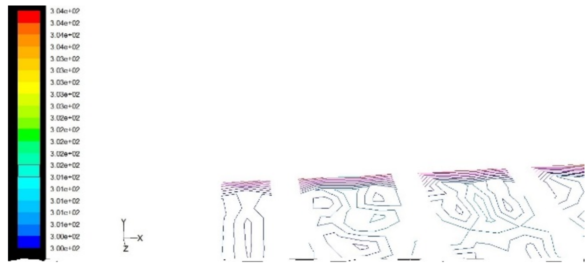

Fig.6.2 contour of heat transfer co efficient for holes at L/4 orientation

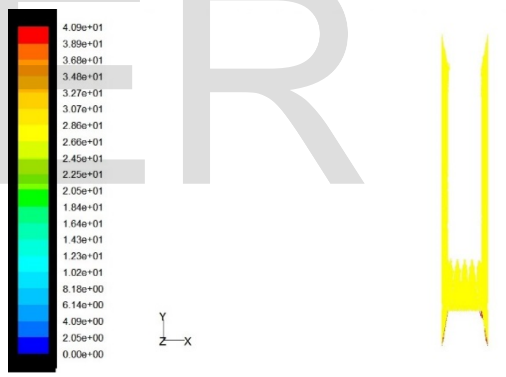

Fig 6.3 temperature contour for total temperature for holes at L/4 orientation

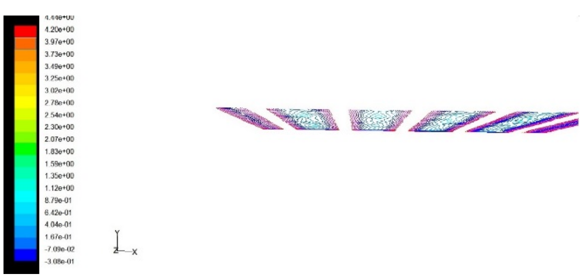

Fig 6.4 path lines for heat transfer coefficient for holes at center orientation

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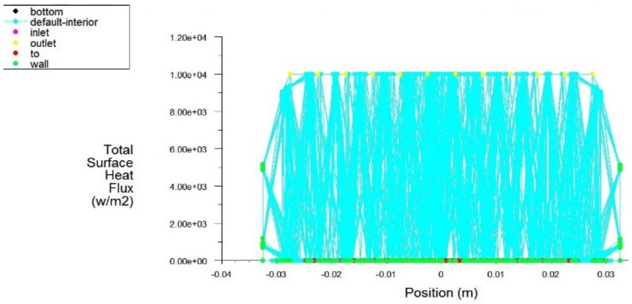

Fig6.5 total surface heat flux for holes at center orientation

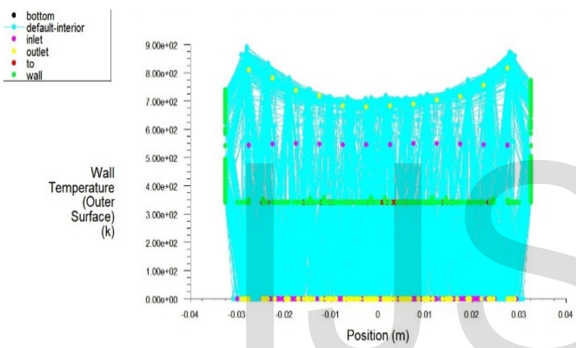

Fig 6.6 wall temperature for holes at center orientation

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