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Enhancement of Heat Transfer By Natural Convection from Discrete Fins

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ABSTRACT

Heat transfer enhancement in fins can be increased by using discrete fins. Numerical studies were conducted to analyzed natural convection heat transfer from solid and discrete fins. Numerical investigation was made for three-dimensional fluid flow and convective heat transfer from an array of solid and discrete fins that were mounted on a flat plate. Commercial computational fluid dynamics (CFD) code, Fluent was used to perform simulations. Incompressible air as working fluid was modeled using Navier–Stokes equations and standard based k-ε turbulent model was used to predict turbulent flow parameters. Temperature field inside the fins was obtained by solving Fourier's conduction equation. The conjugate differential equations for both solid and gas phase were solved simultaneously by finite volume procedure using SIMPLE algorithm.

Keywords: Heat transfer,convection,CFD,Navier-Stokes.

INTRODUCTION

Extended surfaces (fins) were frequently used in heat exchanging devices for the purpose of increasing the heat transfer between a primary surface and the surrounding fluid. Various types of heat exchanger fins, ranging from relatively simple shapes, such as rectangular, square, cylindrical, annular, tapered or pin fins, to a combination of different geometries,

have been used. The study of improving heat transfer performance was referred to as heat transfer augmentation or enhancement. The heat transfer augmentation was very important subject in industrial heat exchangers and other thermal application. There were many techniques which were available for augmentation for single or two-phase heat transfer in natural or forced convection.Akyol and Bilen [1] conducted an experiment on surface with hollow rectangular finned array with in line and staggered

arrangement. They found that the heat transfer significantly improves compared to surface without fin whereas staggered fin arrangement gives slightly better heat transfer than in line arrangement. Baskaya et al. [2] carried out parametric study of natural convection heat transfer from the horizontal rectangular fin arrays. They investigated the effects of a wide range of geometrical parameters like fin spacing, fin height, fin length and temperature difference between fin and surroundings; to the heat transfer from horizontal fin arrays. Bassam and Abu [3] numerically analysed heat transfer of permeable fins and resulted in significant enhancement 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. They used certain assumptions to make the analysis simple that the fins were made up of highly conducting material. Heat generation is happen through many engineering operations. This undesired by-product can cause overheating problems and also results in miscarriage of the system.So as to take care of the system at its predefined standard working temperatures, to function effective and reliable generation of heat in a system must be released to its surrounding. It is often most preferred in today's electronics devices, during which the cojuction in circuit are often dense. So to beat this issue, emitters as extended fins are beneficial. The best fusion of geometry and orientation of the surfaces of fins is required to have the appropriate rate of heat dissipation in minimum use of material. Rectangular fins are common among the geometrical variations because of their simple design, cheap price, and more effect of cooling. AlEssa et al [4] have examined the enhancement of natural convection heat transfer from a horizontal rectangular fin embedded with rectangular perforations of aspect ratio of two [5] and a fin by triangular perforations of bases parallel and toward its base by using finite element technique. Pise and Awasarmol [6] used permeable fins for augmentation of natural convection heat transfer from cylinder. The experiment was conducted to compare the rate of heat transfer from solid and permeable fin. Shaeri et al [7] they studies convective heat transfer from an array of solid and perforated fins that were mounted on a flat plate. They state that fins with longitudinal pores, have remarkable heat transfer enhancement in addition to the considerable reduction in weight by comparison with solid fins. Sandikar et al. [8] carried out numerical investigations of the heat transfer by natural convection from horizontal base with vertical fin array for solid and perforated fins. Base inclination and base temperature was varied as 00 to 900and 40 to 1000C respectively. Results show that fins with longitudinal perforations, have remarkable heat transfer enhancement and considerable reduction in weight in comparison with solid fins.

MATHEMATICAL MODELLING

A vertical fin array with solid and discrete fins is quantitatively studied for natural convection heat transfer.The fin array structure is created using suitable mesh and boundary conditions for solid and discrete fins. For incompressible ideal gas materials, the standard k-epsilon model is used to predict the turbulence caused by the buoyancy effect. Simultaneously, The SIMPLE algorithm of the finite volume scheme is used to rectify the conjugate differential equations for the gas and solid phases.. Attempting to solve Fourier's conduction equation yields the temperature distribution inside the fins. The amount of heat delivered at the base varies between 15 and 45 watts.

Assumptions

The following assumptions are used in the analysis:

1. The radiation is turned off.
2. For incompressible ideal gas materials, the standard k- epsilon turbulent model that can predict the turbulence caused by the buoyancy effect.
3. The gravity vector is examined, and the gravitational acceleration is determined to be -9.80665 m/s2 there in y direction.
4. The default fluid is air, which is stagnant.
5. The atmospheric temperature was maintained to 27°C,.
6. The steady-state method is to apply for solution.
7. The initial velocity condition is set to 1 m/s, while the initial temperature con is set to atmospheric temperature (27oC).
8. The ideal gas option is selected, and the operational pressure of 101325 N/m2 is chosen.
9. Surfaces are cosidered with a no-slip boundary condition.
10. There are no contact resistances.

Governing Equations

Commercial fluid dynamics (CFD) code, Fluent 2020 R2 supplied by ANSYS inc. is used to perform simulations. The governing equations used for simulations are listed below. The following are the basic equations that determine the mean flow quantities for the 3-d steady state incompressible turbulent flow: by implementing time-averaging processes to conservation equations.:

Equation of Continuity ∂ui∂Xi=0 (1)

Equation of Momentum ∂∂Xj(ρuj ui−τij) =−∂P∂Xi (2)

Equation of Energy $\rho Cp(uiT)\partial xi=\partial\partial xi[\partial T\partial xi(\lambda+\lambda t)]$ (3)

Fourier's equation is used to calculate heat conduction in the fin $\partial 2T\partial x2=0$ (4)

Fourier's equation for steady-state conduction of heat was solved, all while evaluating the temperature distribution in the fin's surfaces and perforation's walls using convection in the fluid.

The full buoyancy effect is predicted using the Standard k– epsilon model. The following transport equations yield the turbulence kinetic energy k as well as its dissipation rate: ∂∂Xi(ρkui)=∂∂Xj[(μ+μtσk)∂k∂Xj]+Gk+Gb−ρε (5) ∂∂Xi(ρεui)= ∂∂Xj[(μ+μtσϵ)∂ε∂Xj]+C1εεk(Gk+Gb)−C2ερε2k (6)

The creation of turbulent kinetic energy due to mean velocity gradients is denoted by G -k, which is calculated as,$G_k=\mu_t S^2$,

where, $S=\sqrt{2S_{ij}S_{ij}}$. $G_b$is the formation of turbulent kinetic energy because of buoyancy, given

$G_b= \beta g_i \frac{\mu_t}{Pr_T}\frac{\partial T}{\partial X_i}$ (4.7)

$C_{1\varepsilon}=1.44$, $C_{2\varepsilon} = 1.92$, $C_\mu = 0.09$, $\sigma_k= 1.0$, $\sigma_\varepsilon= 1.3$.

$C_{3\varepsilon} = 1$ for gravity-aligned flow direction

$C_{3\varepsilon} = 0$ for flow directions that are perpendicular to gravity's direction

RESULTS AND DISCUSSION

The numerical analysis is carried out for 37 different fin configurations, as discussed in the previous chapter. The effects of the base-to-ambient temperature difference on the steady-state heat transfer rate, as well as the results obtained with varying geometric parameters such as number of cuts and depth of cut. Natural convection is defined by these numerical data. Natural convection results are divided into two categories: flow and temperature field. The results are presented in figures so that each parameter's effect can be examined separately.

Result of Natural Convection

Variable parameters such as the number of cuts (3-5), depth of cut (1/4th depth-full depth), and width of cut (2 mm) with a constant fin thickness of 2 mm were used to analyse the problem. The heat input is varied between 15 and 45 W, which is typical for most applications. For inline fin arrays, the results were compared between solid fin and discrete fin.

- **Flow field**

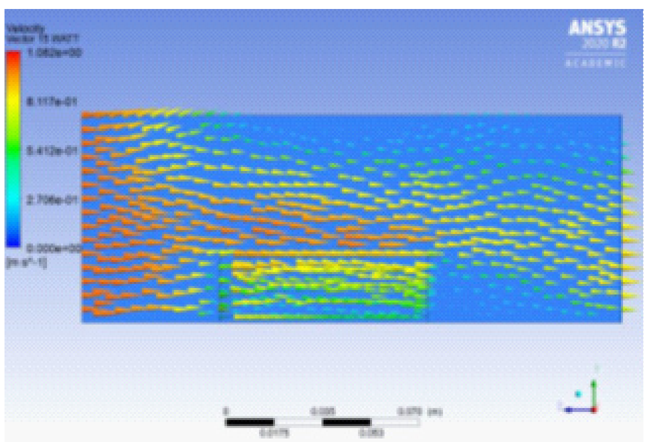

Figure1. Velocity vectors of solid fin at 15 W

The velocity vector for a solid fin is shown in Figure 5.1. The air appears to be moving upward due to the buoyancy phenomenon. As shown in the diagram, a counterflow of air is created. In comparison to the discrete fin, the solid fin has shown to have more restriction to the flow across the fin, causing the flow to diverge, as shown in the above figures.

Table1. Comparison of properties of solid and discrete fin

Properties	5 cut full depth	solid
Surface heat coefficient(w/m^2)	0.8553602	0.5765095
Mass(kg)	0.0203503	0.0228396
Volume(m^3)	7.48448*10^(-6)	8.4*10^6

CONCLUSION

From above discussion we get to the conclusion that,

1. By using discrete fins instead of solid, surface heat transfer coefficient increased by 48 %

2. Using discrete fins will save material upto 10.899 % of weight which will eventually turn into saving in cost.

3. Heat is effectively dissipiated in case of discrete fins than solid fins

4. Nusselt number keeps increasing with number of cut and amount of heat flux provided

5. Using discrete fin with 5 cut full depth saves volume upto 10% than solid fin

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