Journal of Engineering and Applied Sciences 13 (17): 7298-7301, 2018
ISSN: 1816-949X

Natural Convection Heat Transfer from Extended Surfaces on Vertical Base

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Abstract: Numerical simulation of natural convection heat transfer for extended rectangular fins on vertical base is performed. A Computational Fluid Dynamics (CFD) Software Fluent is used to simulate a new computational model. The simulation model is developed by taking only two extended fins and vertical base instead of simulating the entire geometry. Heat transfer rate is predicted for different fin length, height and base temperature. The results of simulations show that the rate of heat transfer depends on base temperature and geometric parameters. The numerical simulation results compared with previous experimental results show very good agreement. Therefore, the accuracy of the new computational model is verified.

Key words: Computational, fins, heat transfer, model, natural convection, accuracy

INTRODUCTION

Heat transfer by natural convection from extended surfaces is vital in many industrial applications such as air conditioning, refrigerators, air cooled automotive engines and electronic equipments. Jones and Smith (1970) Presented free convection heat transfer coefficient for fins on horizontal surface. Experimental tests were carried out for a wide range of fin spacing. They suggested an optimum spacing to obtain a maximum heat transfer. Rao and Venkateshan (1996) investigated experimentally the natural convection heat transfer from horizontal fin arrays. Results were obtained from large number of experiments to show the effects of different parameters such as fin spacing, fin length and fin height on total heat transfer rate from the fin array. Yazicioglu and Yuncu investigated experimentally the heat transfer by natural convection from fin arrays. The effects of geometrical parameters on heat transfer performance were studied. They also obtained a correlation to estimate the optimum fin spacing for maximum heat transfer rates. Naidu *et al*. (2010) studied the effects of system parameters on the natural convection heat transfer rate from the fin array. It was found that the average Nusselt number is increased with increasing Rayleigh number and emissivity for all the fin lengths. Dogan *et al*. (2012) presented numerical study to find out the natural convection heat transfer from an annular fin on a horizontal cylinder and presented correlation for the optimum fin spacing depending on Rayleigh number and fin diameter. Ahmadi *et al*. (2014) studied experimentally and numerically natural convection heat transfer from vertical rectangular interrupted fins. They developed a two dimensional numerical model of fin interruption effects. An experimental numerical parametric study was performed to investigate the effects of fin spacing and fin disruption. They also proposed a new compact correlation for calculating the optimum interruption length. Awasarmol and Pise (2015) conducted experimental study of natural convection heat transfer for perforate fin array. The steady state heat transfer from the fins with different perforate diameter and different angle of inclination were measured. Chang *et al*. (2017) studied numerically the natural convection flow and heat transfer for a set of vertical fins with and without dimples. They analyzed the heat transfer performance for different Rayleigh numbers. It was found that the Nusselt number over each fin surface increases as Rayleigh number increases, especially for the dimpled fin arrays.

In this study, a new computational model is presented to study the natural convection heat transfer rate from fin arrays. The effect of different parameters like the fin height, fin length and base temperature on heat transfer rate is studied.

MATERIALS AND METHODS

The schematic diagram for the numerical model is shown in Fig. 1. The model consists of a vertical base and rectangular fins made of aluminium. The length and height of each fin are L and H, respectively. S is the fin spacing and t is the thickness of the fin. The dimensions of the geometry are listed in Table 1.

The simulation is performed considering only the vertical base and two fins, since, using the periodic boundary condition on the outside surface of each fin. The vertical base is at a temperature T_b which is greater than the ambient air temperature T_8. For this simulation, the flow is assumed to be laminar, steady state and three dimensional. Two modes of heat transfer are involved in

Table 1: Dimensions of the geometry

Dimensions	Values (mm)
Fin Length (L)	250 and 340
Fin thickness (t)	3
Fin Height (H)	5, 15 and 25
Fin Width (W)	180
Base thickness (d)	3

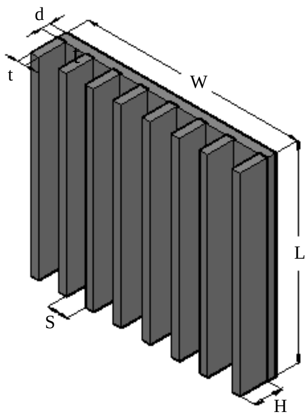

Fig. 1: Schematic diagram

this problem, conduction heat transfer from the base to the fins and natural convection from the fins to the ambient air.

The natural convection in the model can be described by the three dimensional governing equations with the Boussinesq approximation. Continuity Eq. 1:

$$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}+\frac{\partial w}{\partial z}=0 \quad (1)$$

x-momentum Eq. 2:

$$u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}+w\frac{\partial u}{\partial z}=-\frac{\partial P}{\partial x}+\frac{Pr}{Ra^{1/2}}\left(\frac{\partial^2 u}{\partial x^2}+\frac{\partial^2 u}{\partial y^2}+\frac{\partial^2 u}{\partial z^2}\right) \quad (2)$$

y-momentum Eq. 3:

$$u\frac{\partial v}{\partial x}+v\frac{\partial v}{\partial y}+w\frac{\partial v}{\partial z}=-\frac{\partial P}{\partial y}+\frac{Pr}{Ra^{1/2}}\left(\frac{\partial^2 v}{\partial x^2}+\frac{\partial^2 v}{\partial y^2}+\frac{\partial^2 v}{\partial z^2}\right)+Pr\,T \quad (3)$$

z-momentum Eq. 4:

$$u\frac{\partial w}{\partial x}+v\frac{\partial w}{\partial y}+w\frac{\partial w}{\partial z}=-\frac{\partial P}{\partial z}+\frac{Pr}{Ra^{1/2}}\left(\frac{\partial^2 w}{\partial x^2}+\frac{\partial^2 w}{\partial y^2}+\frac{\partial^2 w}{\partial z^2}\right) \quad (4)$$

Energy Eq. 5:

$$u\frac{\partial T}{\partial x}+v\frac{\partial T}{\partial y}+w\frac{\partial T}{\partial z}=\frac{1}{Ra^{1/2}}\left(\frac{\partial^2 T}{\partial x^2}+\frac{\partial^2 T}{\partial y^2}+\frac{\partial^2 T}{\partial z^2}\right) \quad (5)$$

where, the rayleigh number is defined as:

$$Ra=\frac{g\beta(T_b-T_a)L^3}{\nu\alpha} \quad (6)$$

And Prandtl number is given as:

$$Pr=\frac{\nu}{\alpha} \quad (7)$$

Energy equation for the solid phase is:

$$\frac{\partial^2 T}{\partial x^2}+\frac{\partial^2 T}{\partial y^2}+\frac{\partial^2 T}{\partial z^2}=0 \quad (8)$$

The governing equations are solved using finite volume method. Second order upwind scheme is used to discretize the convective term. Coupling between the velocity and pressure is made by simple algorithm.

RESULTS AND DISCUSSION

The simulation results are obtained from computational fluid dynamics Software Fluent for 16 rectangular fins extended from vertical base with different geometrical parameters by varying the base temperature. The predicted simulation results are compared with the experimental data of Yazicioglu and Yuncu (2007).

Figure 2 shows the variation of natural convection heat transfer rate (Q_c) with different base temperature of the vertical plate for fin spacing of S = 8.8 mm, length of L = 250 mm and height of H = 5 mm. It can be clearly seen from the figure that the natural convection heat transfer rate from the vertical fin arrays increases with base temperature. Figure 2 shows also comparison between the numerical simulation results from CFD Software Fluent and experimental values from literature. The comparison is in excellent agreement. Figure 3 plotted for fin arrays of height H = 15 mm and length and spacing same as pervious configuration. The predicted values from simulated model show a very good agreement with the data from experiment. In Fig. 4, the height of the fin is increased to 25 mm. It is seen that the natural convection heat transfer rate from the fins increases with fin height.

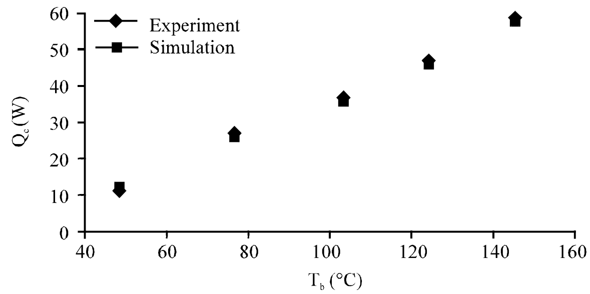

Fig. 2: Natural convection heat transfer for different base temperature at a fin length of L = 250 mm and a fin height of H = 5 mm

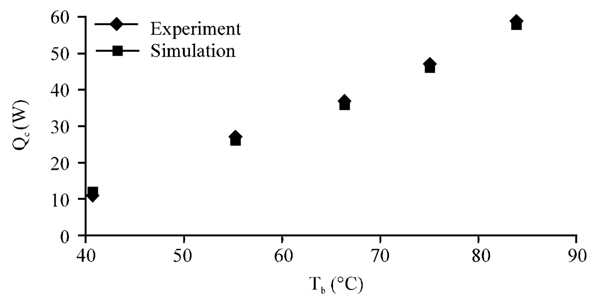

Fig. 3: Natural convection heat transfer for different base temperature at a fin length of L = 250 mm and a fin height of H = 15 mm

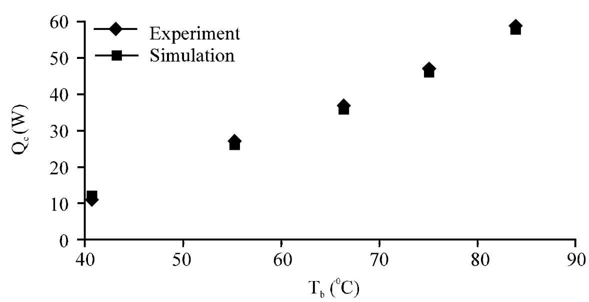

Fig. 4: Natural convection heat transfer for different base temperature at a fin length of L = 250 mm and a fin height of H = 25 mm

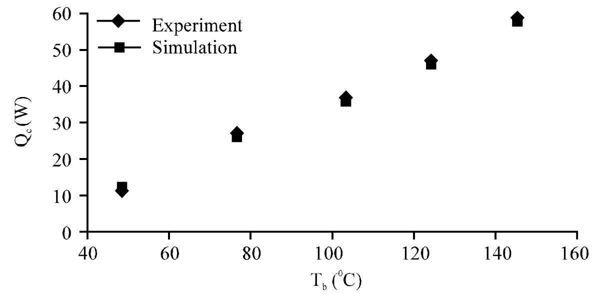

Fig. 5: Natural convection heat transfer for different base temperature at a fin length of L = 340 mm and a fin height of H = 5 mm

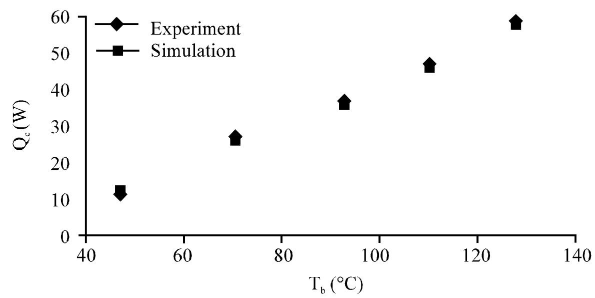

Fig. 6: Natural convection heat transfer for different base temperature at a fin length of L = 340 mm and a fin height of H = 15 mm:

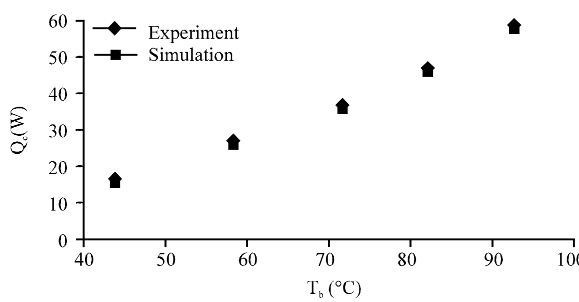

Fig. 7: Natural convection heat transfer for different base temperature at a fin length of L = 340 mm and a fin height of H = 25 mm

Figure 5-7 show the natural convection heat transfer rate for fin of length L = 430 mm, spacing of S = 8.8 mm, heights of H = 5 mm, H = 15 mm and H = 25 mm. Figures 5-7 show that the comparisons between the simulated results and the experimental values are in very good agreement. They also show that the convection heat transfer rate increases with fin height and base temperature. It is also seen that with extending the fin length from 250-430 mm the heat transfer rate is increased.

CONCLUSION

In this study, a new computational model for extended fins from vertical base was proposed. Fluent Software was used to predict the simulation results from different fin configurations. The heat transfer rate by natural convection was obtained for different base temperature. It was found that the heat transfer rate increases by increasing the base temperature. Also, the results show that increasing the height and the length of the fins will increase the rate of heat transfer. The obtained results were compared with experimental data and very good agreement was found. Therefore, the model produced was capable of predicting heat transfer rate accurately.

NOMENCLATURE

g = Acceleration due to gravity (m/sec^2)
L = Length (m)
P = Pressure (N/m^2)
Pr = Prandtl number
Ra = Rayleigh number
T_a = Air Temperature (°C)
T_b = Base plate Temperature (°C)
u = Horizontal velocity component (m/sec)
v = Vertical velocity component (m/sec)
w = Depth velocity component (m/sec)
x = Horizontal coordinate (m)
y = Vertical coordinate (m)
z = Depth coordinate (m)
v = kinematic viscosity (m^2/sec)
α = Thermal diffusivity (m^2/sec)
β = Volumetric thermal expansion coefficient (1/K)

REFERENCES

Ahmadi, M., G. Mostafavi and M. Bahrami, 2014. Natural convection from rectangular interrupted fins. Intl. J. Thermal Sci., 82: 62-71.

Awasarmol, U.V. and A.T. Pise, 2015. An experimental investigation of natural convection heat transfer enhancement from perforated rectangular fins array at different inclinations. Exp. Therm. Fluid Sci., 68: 145-154.

Chang, S.W., H.W. Wu, D.Y. Guo, J.J. Shi and T.H. Chen, 2017. Heat transfer enhancement of vertical dimpled fin array in natural convection. Intl. J. Heat Mass Transfer, 106: 781-792.

Dogan, A., S. Akkus and S. Baskaya, 2012. Numerical analysis of natural convection heat transfer from annular fins on a horizontal cylinder. J. Therm. Sci. Technol., 32: 31-41.

Jones, C.D. and L.F. Smith, 1970. Optimum arrangement of rectangular fins on horizontal surfaces for free-convection heat transfer. J. Heat Transfer, 92: 6-10.

Naidu, S.V., V.D. Rao, B.G. Rao, A. Sombabu and B. Sreenivasulu, 2010. Natural convection heat transfer from fin arrays experimental and theoretical study on effect of inclination of base on heat transfer. ARPN. J. Eng. Appl. Sci., 5: 7-15.

Rao, V.R. and S.P. Venkateshan, 1996. Experimental study of free convection and radiation in horizontal fin arrays. Intl. J. Heat Mass Transfer, 39: 779-789.

Yazicioglu, B. and H. Yuncu, 2007. Optimum fin spacing of rectangular fins on a vertical base in free convection heat transfer. Heat Mass Transfer, 44: 11-21.