Investigation of Thermal Performance in Natural Convection from Rectangular Interrupted Fins-A Review

Wankhade Sachin D [1], Bhor S.K [2],Nagraj A.M[3]

P.G. Student, Department of Mechanical Engineering, Dr.D.Y.Patil SOEA, Ambi, Maharashtra, India[1]

Assistant Professor, Department of Mechanical Engineering, Dr.D.Y.Patil IET, Ambi, Maharashtra, India[2]

Professor, Department of Mechanical Engineering, Dr.D.Y.Patil SOEA, Ambi, Maharashtra, India[3]

ABSTRACT: This paper presents a review of investigation of thermal performance in natural convection from different geometrical fins. There are many methods for investigation of thermal performance of fins with different geometrical parameters. The thermal performance in natural convection from different geometrical fins being reviewed includes analysing the natural convective heat transfer from vertical fins, also similarity solutions for boundary layer equations for the cases of uniform surface heat flux, analytical work on vertical channels, an analytical study to investigate the natural convective heat transfer from two parallel plates, correlated the Nusselt number based on the squared root of the wetted area for the three dimensional bodies, a numerical approach to investigate the developing flow in the channel and the heat transfer between symmetrically heated, isothermal plates, the heat transfer from inclined interrupted fin channels, calculated natural heat transfer coefficients for four different fin arrays and three different base plates, the natural convection and radiation heat transfer From twelve large vertically based fin arrays also naturally cooled vertical shrouded fins. This present paper can be used as the first guideline for the researcher for changing different orientation of the interrupted fins for 3-D analysis by using FLUENT software also numerical model for investigation of interruption effects

KEYWORDS: Thermal Performance, Interrupted fin, Natural Convection.

I. INTRODUCTION

Thermal processes have practical importance in the heat exchangers from the heat transfer point of view. For the application of heating and cooling widely used are Heat exchangers. For designing the heat exchangers Heat transfer, pressure losses, weight and price should be taken into account. Obtaining high heat transfer rates through various enhancement techniques can lead to substantial energy savings. I*n* a heat exchanger Heat transfer processes are mainly improved by turbulence promoters via providing suitable optimum flow condition having different geometrical features as well as orientations. The heat transfer process are closely related to the performance the effects of the sizes and orientations of these geometries.The High power density electronics requirements design of efficient cooling strategies is essential for reliable performance. Many of a failure mechanism in electronic devices, such as inter-metallic growth, metal migration, and void formation, are closely related to thermal effects.

Now a day, the thermal losses of power electronic devices are rapidly increasing. At the same time, decreasing their sizes .As we know, heat sinks have to be dissipating higher heat fluxes in every new design. Therefore, devising efficient cooling solutions is to meet these challenges is of paramount importance as well as it has direct impacts on the performance and reliability of the electronic and power electronic devices.

Fins are come in various forms of shapes; such as rectangular, circular, pin fin rectangular, pin fin triangular, etc., shown in Fig.1, depending upon the application. Out of these Rectangular fins is the most popular fin type because of their low production costs as well as it high thermal effectiveness.

Fig.1.Different fin types, a) rectangular b) radial c) pin fins.

Natural convective heat transfer from vertical rectangular fins, is as shown in Fig .1.2, and from pin fins is a well studied subject in the literature review. It has been investigated analytically, numerically also experimentally. The following paragraphs provide to an overview on the mention literature of the subject. The previous studies are grouped into analytical, numerical, also experimental works, more detailed reviews can be found elsewhere, see for example [1].

Fig.1.2 Heatsink with continuous rectangular fins.

The main focus of this study is on natural convection heat transfer from an interruption, vertical and rectangular fins. However, a more general overview on these literatures in the area of natural heat transfer from fins is provided in this section. A number of varieties of theoretical expressions, graphical correlations also empirical equations have been developed to represent the coefficients for natural convection heat transfer from vertical plates and the vertical channels. These studies are mostly focused on geometrical parameters of the heatsinks as well as fins, such as fin spacing, fin height, fin length, as well as, fin directions also. Following study shows a summary of the literature review as it pertains to analytical, numerical or experimental type of work.

Three dimensionless numbers are important in natural convection heat transfer: the Nusselt (*Nu*) number, the Prandtl (*Pr*) number and Rayleigh number (*Ra*). These three non-dimensional numbers are used extensively in the heat transfer literature for analytical purposes only. These Number explain as, The Nusselt number is the ratio of convection heat transfer to the fluid conduction heat transfer under the same conditions.

1.1 Vertical walls:

By assuming vertical wall geometrical parameters are shown in Fig.1.3.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

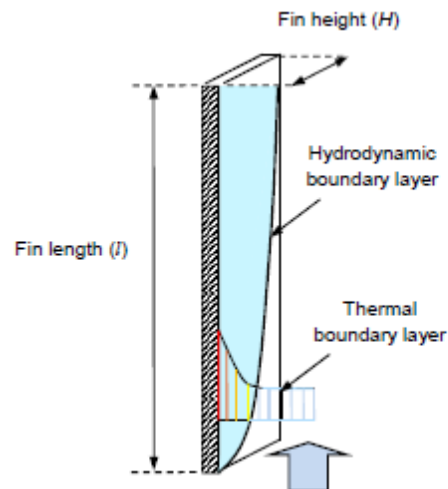**Vol. 4, Issue 1, January 2015**

Fig .1.3 Geometrical parameters and boundary layers of a vertical wall.

An important contribution on analysing the natural convective heat transfer from vertical fins had been made by Ostrach [2] . He was analytically solved laminar boundary layer equations by using similarity methods for keeping uniform wall temperature condition also developed a relationship for the Nusselt number for different values of Prandtl number. As well, Sparrow and Gregg [3] used similarity solutions for boundary layer equations for the cases of the uniform surface heat flux condition.As study previous Churchil and Chu [4] also developed an expression for Nusselt number for all ranges of the *Ra,* and *Pr* numbers,

1.2 Vertical rectangular fin arrays:

A schematic of a vertical rectangular fin array and its geometrical parameters along with the thermal and hydrodynamic boundary layers are shown in Fig.1.4
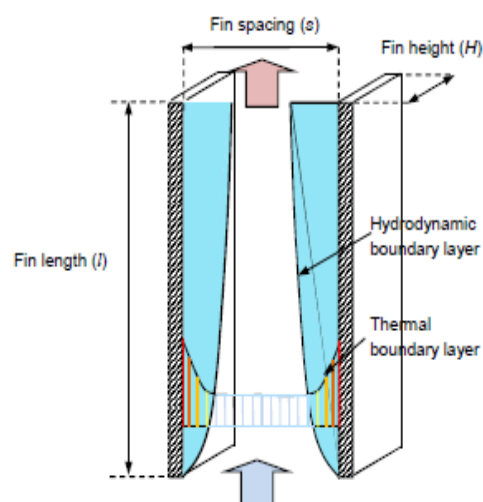

Fig 1.4. geometrical parameters and schematic thermal and hydrodynamic boundary layers on vertical fin array.

Similarly analytical work on vertical channels was carried out by Elenbaas [5]. He investigated analytically and experimentally the isothermal finned heatsinks. And also developed an expression for Nusselt number and the Ra_s where s is the spacing between two fins are as follow,

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 1, January 2015

$$Nu_s = \frac{1}{24} Ra_s \left[1 - \exp\left(\frac{-35}{Ra_s} \right) \right]^{\frac{3}{4}}$$

The BarCohen and Rohsenow [6] were made for The analytical study resulted in general relations for natural convective heat transfer from vertical rectangular fins. Bar- also performed an analytical study to investigate the natural convective heat transfer from two parallel plates. They are developed relationship in between Nusselt number and the Rayleigh number Ra number for both, isothermal and isoflux plate cases and reported a correlation for the optimum fin spacing showing following equation.

$$Nu_s = \frac{hs}{k} = \left[\frac{576}{\left(\frac{Ra_s s}{L} \right)^2} + \frac{2.873}{\left(\frac{Ra_s s}{L} \right)^{0.5}} \right]^{-0.5}$$

where Ra_s is the Rayleigh number, which is mainly based on fin spacing between two adjacent fins, s, L is fins length also h is the convective heat transfer coefficient, and k is the fluid thermal conductivity, respectively. These aforementioned coefficients are mostly shown in Fig.1.2.

For the three dimensional bodies [7] and [8], the Culham *et al.* [9] correlated the Nusselt number with characteristic length scale based on the squared root of the wetted area. The wetted area of a fin is that surface that is exposed to the air flow. Another numerical approach was to investigate the developing flow in the channel as well as the heat transfer between symmetrically heated, isothermal plates by Bodoia and Osterle [10] . They made aimed to predict the channel length required to attain a fully developed flow as a function of the channel width as well as wall temperature. A finite element method used by, Ofi and Hetherington [11] were to study the natural convective heat transfer from open vertical channels with uniform wall temperature. They also observed that fluid velocity may be vertical alone. Culham *et al.* [9] also used META, a numerical code, to simulate the natural convective heat transfer from a vertical fin array, also compared their results to their experimental data and the three dimensional models of [8] and [8] as mentioned in the previous section of review.

Several researchers were to be studied the natural convection heat transfer in vertical channels experimentally. Fujii [12] studied the heat transfer from inclined interrupted fin channels systems. In this study, it was examined that the thermal boundary layers were interrupted by the fins, a correlation developed, as shown following Eq., was fitted to be an experimental results. . Fig.1.5 shows the Fujii was used by these fin geometry.

$$Nu_s = \frac{1}{24} Ra_s \cdot \left(\frac{s}{l} \right) \left\{ 1 - e^{-12.5 \Big/ \left[Ra_s \cdot \left(\frac{s}{l} \right) \right]^{\frac{3}{4}}} \right\}$$
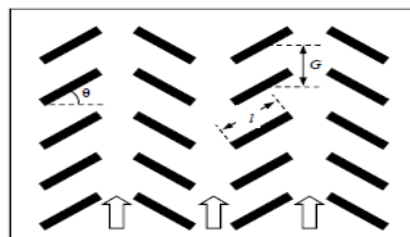

Fig.1.5 Fujii's [12] considered geometry for inclined interrupted fins.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 1, January 2015

natural heat transfer coefficients for four different fin arrays also with three different base plates was calculated by Starner and McManus [13]. Flow patterns for each of these cases were observed by using new smoke filaments. Parameters which were varied in their study were the fin spacing as well as the height, respectively. Welling and Wooldridge [14], who was investigated large arrays with comparable fin heights, confirmed the findings of [13] for the vertically based fin array orientation of the geometry. The natural convection as well as radiation heat transfer from twelve large vertically based fin arrays was investigated by the Chaddock [15].

Another study by Aihara [16, 17] investigated the natural convection as well as radiation heat transfer from an eleven large vertically based fin arrays. In the former work [16], He was to be conducted an experimental study of the heat transfer from the base plate in experiments. The effect of fin geometry and temperature on the average heat transfer coefficient has been studied and an empirical correlation was to be obtained. In their latter work [17], a series of experiments were focused on heat transfer from the fins reported. Based on their experimental data, they finding a correlated average Nusselt number

Leung *et al*. [18, 19, 20, 21, and 22] and Van de Pol and Tierney [23] were investigated mostly focused on the effects of varying fin geometrical parameters, mainly, the array, and base plate orientation. They finding a relationship for the Nusselt number based on the fin spacing for different ranges of Rayleigh number *Ra* .

An important role plays in the heat transfer from fin arrays mainly in Radiation heat transfer. This has been shown by Edwards and Chaddock [24], for different value of Rayleigh number *Ra* as shown in following equation,

$$\text{Nu}_L = 0.59 \, Ra_L^{\frac{1}{4}}$$

Chaddock [15], Sparrow and Acharya [25] a correlation developed, as shown following Eqation between Nusselt number and the Rayleigh number Ra, Saikhedkar and Sukhatme [26], Sparrow and Vemuri [27, 28], The common conclusion of the aforementioned studies was that the radiation heat transfer contributes between 25–40% to the total heat transfer from fin arrays in naturally cooled heatsinks.

$$\text{Nu}_s = 6.7 \times 10^{-4} \, Ra_s \left[1 - \exp\left(\frac{7460}{Ra_s} \right)^{0.44} \right]^{1.7}$$

Objectives

1. The goal of this study is to investigate the effects of fin interruption in natural convection.
2. Determining an optimum value for different geometrical parameters of vertical fin arrays, mainly the length of fin interruption.

II. METHODOLOGY AND MODELING

Problem statement:

A schematic of the considered fin geometry with their salient geometric parameters is shown in Fig.2.1. When the heatsink is heated, the buoyancy force causes the surrounding fluid to start moving therfor as a result thermal boundary layers start to develop at the bottom edges of the fins. the boundary layers mostly merge if the fins/channels are sufficiently long(continuous), creating a fully developed channel flow [2]. Interrupted fins, therefore, disrupt the thermal boundary layer growth also maintaining a thermally developing flow regime, which can lead to a higher natural heat transfer coefficient.
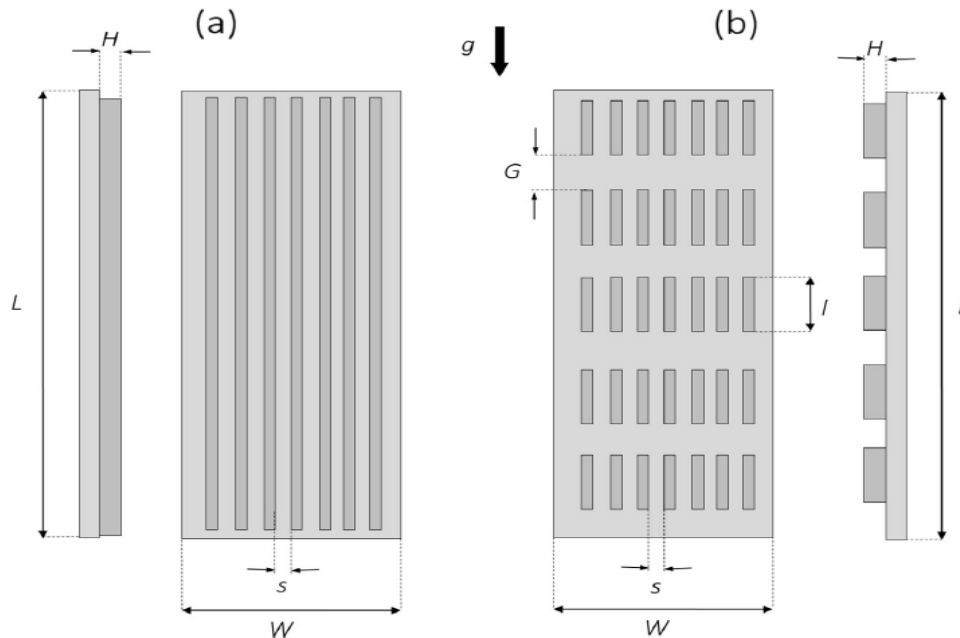
Fig. 2.1. Schematic of the considered heatsink geometry, a) continuous rectangular fin heatsink; b) interrupted rectangular fin heatsink

To investigate the effects of fin interruption in 3-D and to determine an optimum fin length to interruption ratio, we started by using the existing analytical models of [3] to calculate the optimum fin spacing, s. The idea is to be decouple the effect of fin spacing from the fin interruption. As such, the fin spacing will be kept constant at its optimum value proposed by RohsenoweBar-Cohen model [4] throughout the analysis. We also independently investigated the effect of fin spacing experimentally.

III. EXPERIMENTAL SETUP

The experimental study is to investigate the effects of fin interruption length as well as fin spacing on the natural convection heat transfer from the considered rectangular vertical fins. To enable this investigation, two new custom-made test bed were designed. A number of heatsinks and single wall samples, with various geometrical parameters, were prepared. In total, two series of tests were undertaken. The first series of tests was designed to investigate the effect of interruptions in 3-D and their comparison to the non-interrupted (continuous) 3-D channels (shown in fig 2.3 a for continuous and b for interrupted model). The second series of tests were undertaken to validate the numerical data used for calculating the Nusselt number for the vertical fins.

A new testbed has been designed for measuring natural convection heat transfer from the finned heatsinks, as shown in Fig. 2.2 . The set-up included an enclosure made of poly(methyl)methacrylate (PMMA) which was insulated by a layer of foam with a thickness of 10 mm. The testbed also included 20 cm long Chromalox strip heaters (120 V, 150 W) , which were attached to 37 the backside of the fins base-plate, and a data acquisition system (DAQ).

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

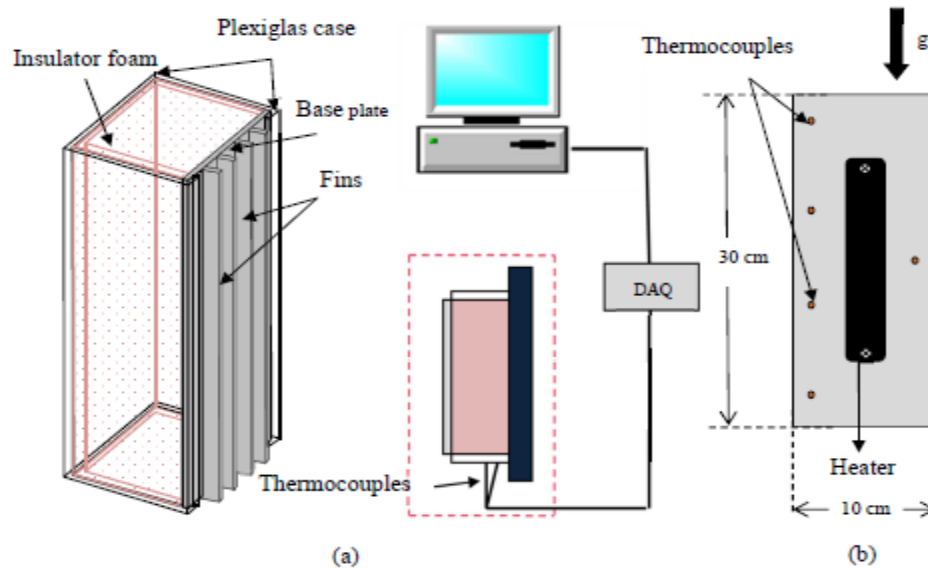**Vol. 4, Issue 1, January 2015**

Fig 2.2. Experimental setup

Fig.2.3 shows the 3-D model of rectangular interrupted fin (continuous and interrupted)which are used for analysing by using fluent software in CFD compared the result with respect to rectangular interrupted fin in 2-D.
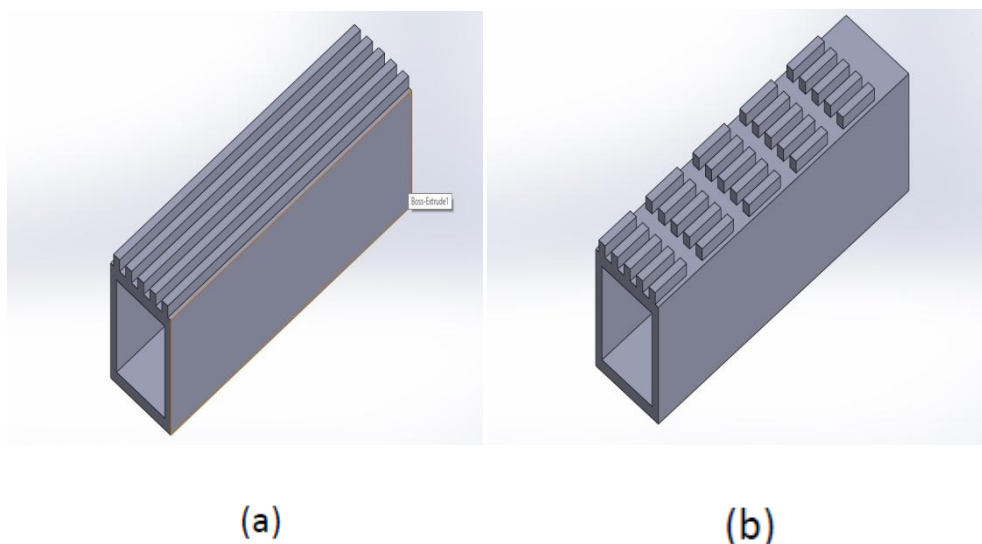

Fig 2.3. Schematic of the considered heatsink geometry in 3-D, a) continuous rectangular fin 3-D heatsink; b) interrupted rectangular fin 3-Dheatsink

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

IV.CONCLUSION

The present study provides a survey about Investigation of thermal performance in natural convection from rectangular interrupted fins where both the continuous and interrupted must be keeping into account simultaneously. It is conclude from these an important contribution on analysing the natural convective heat transfer from vertical fins with similarity solutions for boundary layer equations for the cases of uniform surface heat flux. The effect of an analytical study on the two parallel plates by natural convective. The three dimensional bodies based on the squared root of the wetted area correlated the Nusselt numbe.The effect on the heat transfer from inclined interrupted fin channels which improve natural convection heat transfer which are applicable in a variety of electronics, power electronics as well in telecom application.

REFERENCES

1.   S. Anandan and V. Ramalingam, " Thermal management of electronics: a review of literature.," vol. 2, 2008.
2.   S. Ostrach, "An analysis of free convection flow and heat transfer about a flat plate parallel to the direction of the generating of the body force," NACA, 1953.
3.   E. Sparrow and J. L. Gregg, "Laminar free convection from a vertical flat plate," *ASME,* vol. 80, pp. 435-440 , 1956.
4.   S. Churchill and H. Chu, "Correlating equations for laminar and turbulent free convection from a vertical plate," *International journal of heat and mass transfer,* vol. 18, no. 11, pp. 1323-1329, 1975.
5.   W. Elenbaas, "Heat dissipation of parallel plates by free convection," *Journal of Physica,* vol. 9, no. 1, pp. 1-28, 1942.
6.   Bar-Cohen and W. Rohsenow, "Thermally optimum spacing of vertical, natural convection cooled, parallel plates," *Journal of heat transfer,* vol. 106, no. 1, pp. 116-124, 1984.
7.   . Y. M., "Natural convection from isothermal spheroids in the conductive to laminar flow regimes," in *AIAA Thermophysics conference*, Honolulu, 1987
8.   M. Yovanovich, "On the effect of shape, aspect ration and orientation upon natural convection from isothermal bodies," in *ASME*, Boston, 1987.
9.   J. Culham, M. M. Yovanovich and S. Lee, "Thermal modeling of isothermal cuboids and rectangular heat sinks cooled by natural convection," *IEEE transaction on components, packaging and manufacturing technology,* vol. 18, no. 3, pp. 559-566, 1995
10. J. Bodoia and J. Osterle, "The development of free convection betwen heated vertical plates," *Journal of heat transfer,* vol. 84, pp. 40-44, 1962.
11. O. Olusoji and H. Hetherington, "Application of the finite element method to natural convection heat transfer from the open vertical channel," *International journal of heat and mass transfer,* vol. 20, no. 11, pp. 1195-1204, 1977.
12. M. Fujii, "Enhancement of natural convection heat transfer from a vertical heated plate using inclined fins," *Heat Transfer—Asian Research,* vol. 36, no. 6, pp. 334-344, 2007.
13. K. Starner and H. N. McManus, "An experimental investigation of free-convection heat transfer from rectangular-fin arrays," *Journal of heat tranfer,* vol. 85, no. 3, pp. 273-278, 1963. J. Welling and C. Wooldridge, "Free convection heat transfer coefficients from rectangular vertical fins," *Journal of heat transfer,* vol. 87, no. 4, pp. 439-445, 1965.
14. Chaddock, "Free convection heat transfer from vertical rectangular fin arrays," *ASHRAE journal,* vol. 12, pp. 53-60, 1970.
15. T. Alhara, "Natural convection heat transfer from vertical rectangular-fin arrays: Part 2, heat transfer from fin-edges," *Bulletin of the JSME,* pp. 1182-1120, 1970.
16. T. Alhara, "Convection heat transfer from vertical rectangular-fin arrays (part 3, heat transfer from fin-flats)," *Bulletin of JSME,* pp. 1192-, 1970.
17. Leung and S. Probert, "Heat exchanger performance: effect of orientation," *Journal of applied energy,* vol. 33, no. 4, pp. 235-252, 1989.
18. Leung and S. Probert, "Natural-convective heat exchanger with vertical rectangular fins and base: design criteria," *Journal of mechanical engineering science,* vol. 201, no. 5, pp. 365-372, 1987.
19. C. Leung, S. Probert and M. Shilston, "Heat exchanger design: Optimal uniform separation between rectangular fins protruding from a vertical rectangular base," *Journal of applied energy,* vol. 19, no. 4, pp. 287-299, 1985.
20. C. Leung, S. Probert and M. Shilston, "Heat exchanger design: Thermal performances of rectangular fins protruding from vertical or horizontal rectangular bases," *Journal of applied energy,* vol. 20, no. 2, pp. 123-140, 1985.
21. C. Leung, S. Probert and M. Shilston, "Heat transfer performance of vertical rectangular fins protruding from bases: effect of fin length," *Journal of applied energy,* vol. 22, no. 4, pp. 313-318, 1986.
22. Van de Pol, "Free convective heat transfer from vertical fin arrays," *IEEE transaction on parts, hybrids and packaging,* vol. 10, no. 4, pp. 267-271, 1974.
23. J. Edwards and J. Chaddock, "An experimental investigation of the radiation and free convection heat transfer from a cylindrical disk extended surface," *ASHRAE transactions,* vol. 69, pp. 313-322, 1963.
24. Sparrow and S. Acharya, "A natural convection fin with a solution-determined nonmonotonically varying heat transfer coefficient," *Journal of heat transfer,* vol. 103, no. 2, pp. 218-226, 1981.
25. N. Saikhedkar and S. Sukhatme, "Heat transfer from rectangular cross-sectioned vertical fin arrays," in *Proceedings of the sixth national heat and mass transfer conference, India*, 1981.
26. E. Sparrow and S. Vemuri, "Natural convection/radiation heat transfer from highly populated pin fin arrays," *Journal of heat transfer,* vol. 107, no. 1, pp. 190-198, 1985.
27. E. Sparrow and S. Vemuri, "Orientation effects on natural convection/radiation heat transfer from pin-fin arrays," *International journal of heat and mass transfer,* vol. 29, no. 3, pp. 359368, 1986.
28. Azarkish, S. Sarvari and A. Behzadmehr, "Optimum geometry design of a longitudinal fin with volumetric heat generation under the influences of natural convection and radiation," *Journal of energy conversion and management,* vol. 51, no. 10, pp. 1938-1946, 2010.