LITERATURE REVIEW ON HEAT SINKS UNDER NATURAL CONVECTION HEAT TRANSFER MECHANISM

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Abstract: Natural convection heat transfer mechanism is widely used for removing the heat from a high temperature heat source without requiring any additional components. Fins attached to a hot surface in a vertical orientation evokes the natural convection heat transfer between the high temperature fin surfaces and the surrounding cold atmosphere. There have been numerous research – experimental, analytical and computational - had been conducted over the years in designing and analyzing the heat sinks. A detailed study on existing research work would help to identify the critical factors such as fin shape, fin size, fin positioning etc. and their influence on heat transfer rate. In this journal, a review of the existing literature on natural convection heat transfer from the heat sink and maximizing the heat transfer rate had been discussed.

Keywords: Fins, CFD, Heat Sinks, Natural Convection, Raleigh Number.

I.INTRODUCTION

Natural convection heat transfer mechanism is widely used for removing the heat from a high temperature heat source without requiring any additional components. Typically, the fins are attached on a hot surface, such as electronic component, in a cold atmosphere surrounding. The temperature difference between the hot surface and the surroundings evokes the heat transfer. With this heat transfer, the electronic components will be maintained at the desirable temperature range.

Recent research had been focused on enhancing this heat transfer rate so that more heat could be removed from the electronic components. This would help in higher performance of the electronic components as well as the extended life for the components. This journal discusses the latest research on natural convection heat transfer from the heat sinks.

II.LITERATURE SURVEY:

Aishwarya A Patil [1] had investigated the impact of introducing the fin splits for the pin-fins on a vertically placed heat sink. In their study, the pin-fins were split to form semi-cylindrical shaped fins and the distance between these semi-cylindrical fins were varied to study the impact on the heat transfer rate. The authors had conducted experimental and numerical simulations in their work. Based on the obtained results, they had concluded that the fin-splitting resulted in higher heat transfer rate as compared to the solid pin-fins. Also, as the fin split distance was increased, increase in heat transfer rate was observed in their studies.

In the numerical simulation study conducted by **Hakan F Oztop** [2], natural convection in a partially open enclosure was studied for entropy generation. The authors had studied for various geometrical parameters such as opening ratio (0.25 to 0.75) and the center of opening (0.25 to 0.75). The flow conditions for their study was corresponding to $10^3 \leq Ra \leq 10^5$. From their simulations, they had observed that the entropy generation due to heat transfer is largely concentrated near the domain opening.

Application of natural convection heat transfer in micro-scale components such as Micro Electro Mechanical Systems (MEMS) was investigated by **S Mahmoud** [3]. In their study, a square horizontal heat sink (31.75 mm X 31.75 mm) with fin heights varying from 0.25 to 1.0 mm and fin spacing varying from 0.5 to 1.0 mm was considered. The steady state laminar CFD simulations were conducted for heat loads of 0.25, 0.5, 1.0 and 1.25 W by the authors along with the experimental studies to validate the results. Their CFD simulations were conducted using ANSYS CFX with the inclusion of radiation effects. Based on their results, the authors had observed that the increase in fin spacing resulted in high heat transfer coefficient while the increase in fin height resulted in reduction in heat transfer coefficient.

Iman Jafari [4] had applied lattice Boltzmann method to study the heat transfer characteristics for the radial fins. In their study, the number of fins as well as the arrangement of the fins were varied (number of fins 2 to 8). The fins were attached externally to the horizontal cylinders. In the streamlines plotted for the low Raleigh number conditions, the shape of isotherms resemble the cylinders, indicating that the conduction heat transfer was dominant. This pattern was changed as the Rayleigh number was increased since the convection effects becomes dominant. Extending the same analogy, the isotherms were more pronounced as the number of fins were increased. This shows influence of number of fins on the natural convection heat transfer rate.

Shankar Durgam [5] had conducted numerical and experimental investigation to estimate the optimal positioning of heat source. Their study was performed for both the natural and forced convection operating conditions. For defining the heat source positioning, the author had introduced a variable λ defined based on the sum of square of distance from the each heat source centroid to the centroid of the particular configuration. The 3-dimensional CFD simulations were performed using COMSOL Multiphysics. In their simulations, the air density changes were modeled using Boussinesq approximation while the radiation effects were neglected due to the lower temperature conditions in the heat sink.

A.Giri [6] had developed mathematical model for the natural convection heat and mass transfer from air-conditioning system's vertical fin array. Their study focused on sensible as well as latent heat transfer from the heat sink for various fin spacing. The heat sink plate considered by the author was maintained below the dew point temperature of the moist air in the surrounding. This resulted in condensation and hence the mass transfer. In their CFD simulations, SIMLPER algorithm was applied for pressure-velocity coupling. From their research work, the authors had estimated nearly 50% less heat transfer predictions for wet fins if they were modeled as dry fins approach.

An analytical mathematical model for annular fins under natural convection heat transfer was developed by **C.S Wang** [7]. Their mathematical model classifies the fin surfaces as internal and external surfaces. With this classification, the respective heat transfer mechanism – thin boundary layer convection, fully developed flow, transitional regime and external natural convection – shall be applied to estimate the heat transfer rate. The results obtained from this mathematical model in terms of Ra vs Nu graphs were compared against the experimental data and it was found to in good agreement.

Natural convection heat transfer from a vertical cylinder was numerically studied by **Ashsihman Kar** [8] using ANSYS Work Bench. The author had studied four configuration – pipe without fins, pipe with conical fins, pipe with trapezoidal fins and pipe with cylindrical fins – for a wall temperature of 380 K. With the surround air at 300 K, the heat transfer rate from all these four geometrical configurations were estimated and the authors had concluded that the trapezoidal shaped fins provided higher heat transfer rate as compared to other configurations.

In another analytical solution method for natural convection from fins, developed by **Avram Bar-Cohen** [9], optimization of fin spacing between the printed circuit boards (PCBs) was performed. Their model included four boundary conditions – Symmetrically Isothermal channel, Asymmetrically Isothermal Channel, Symmetrically Isoflux Channel, and Asymmetrically Isoflux Channel – to optimize the spacing between vertical heat dissipating plates, which are typically encountered in densely packaged printed circuit boards.

Heat transfer characteristics of a single tube heat exchanger under natural convection was studied **Han-Taw Chen** [10] by numerical simulations and experimental methods. The steady state 3-D incompressible flow simulations were performed in ANSYS FLUENT using three approaches – Laminar, Zero equation and RNG k-ε turbulence model – by the authors. The heat exchanger tube diameter was varied 3 mm and 27 mm in their study. They had applied symmetry model in their simulations to reduce the computational time. From the results, it had been observed that the prediction from the Zero equation turbulence model were in close agreement to the experimental heat transfer coefficient values (for Ra = 12).

Dhanunjay S Boyalakuntla [11] had analyzed the natural convection heat transfer mechanism on the laptop display panel with the pin-fins. The pin-fin diameter was 2 mm and of the height of 2 cm. They had investigated for two kind of thermal conditions – constant heat flux (1020 W/m^2) as well as constant wall temperature. In their simulations, the authors had applied the periodicity concepts to reduce the computational domain. Unstructured based polyhedral type elements were used for domain discretization and the simulations were performed using ANSYS FLUENT. From their studies, they found that heat transfer rate increases nearly 20% for the finned configurations as against non-finned configurations.

Application of natural convection heat transfer for the computer heat sink cooling was studied experimentally by **Mahdi Fahimina** [12]**.** They had developed six types of heat sinks based on fin height variations as well as on gap. The authors had defined coefficient of enhancement (COE) as the ratio of Nusselt number between the base model and the modified model to quantify the performance of the heat sink design. **Mehran Ahmadi** [13] had conducted heat sink optimization by introducing interruptions on the continuous plate fins. The authors had studied for various interruption distance for the natural convection heat transfer mechanism with experimental and numerical simulations. For the CFD simulations on ANSYS FLUENT, they had used 2-Dimensional approach in their studies and found that the heat transfer rate estimation was in agreement with the experiments.

In a 2-Dimensional numerical investigations by **Gi Su Mun** [14], natural convection heat transfer in a cold enclosure that contained four cylinders of high temperature. The study was conducted for the operating conditions corresponding to 103 ≤ Ra ≤ 106. The position of the cylinders were also varied to predict the impact on the heat transfer rate. In their study, the variation of Raleigh number influenced the flow and thermal field change from steady to transient pattern.

On a heat sink of 250 mm X 250 mm, **H. R. Goshayeshi** [15] had studied various fin channel orientation – vertical, horizontal – along with varying fin spacing. In this study, the authors had included the fin tip radiation by specifying emissivity in the CFD simulations. In their study, the vertical fin channel provided higher heat transfer rate as compared to the horizontal fin channel. The authors had observed in heat transfer rate increase as the fin spacing was increased. Much of the literature on natural convection are based on steady state simulations. However, **F. Xu** [16] had conducted transient simulation approach to estimate the natural convection heat transfer from a cavity that are differentially heated. In their study, fin was placed in the surrounding of water. The 2-Dimensional laminar flow simulations was performed with the Boussinesq approximation.

A finite element based solver, Acusolve, was employed by **Bhupender Kumar Bharti** [17] for estimating the natural convection heat transfer rate from a vertically placed tubes with fin various – no fins, conical fins, trapezoidal fins. The author had estimated the optimal fin length based on analytical calculations. Trapezoidal shaped fins resulted in higher heat transfer rate as compared to the other two configurations. The impact of inclination angle over the natural convection heat transfer rate from the heat sinks was experimentally investigated by **A. A. Walunj** [18]. The authors had also varied the fin height as well as heat sink aspect ratio. Their study was conducted for multiple thermal operating conditions. Fin inclination 0° means vertical and 90° being horizontal in their study, it was observed that the heat transfer rate reduced as the inclination angle was increased.

Application of heat transfer enhancement on a cylindrical heat sink (LEDs) with the help of fins was studied by **Krishna Kumar Singh** [19]. In their analysis to estimate the optimum number fins required, the results were plotted as thermal resistance against the number of fins. It had been shown that thermal resistance was found to be reducing as the number of fins were increased (till 36 fins) and then the resistance was increasing for any further increase in the number of fins. Triangular shaped fins in a rectangular enclosure was investigated experimentally by **Gaurav Kumar** [20]. The authors had conducted this parametric study for Rayleigh number (to define the thermal operating conditions), fin height and fin spacing. They had estimated the fin effectiveness, defined as the ratio between the heat transfer rate with fins and without fins, to identify the optimal fin design.

III.OBSERVATIONS:

From these available literature on heat transfer enhancement using natural convection heat transfer mechanism, the following observations could be noted.

1. If the temperature range for the natural convection heat transfer field is lower, the radiation effects could be neglected [5]
2. Higher fin spacing increases the heat transfer rate from the heat sinks till optimum fin spacing [15]
3. The shape of the fins plays crucial role in natural convection heat transfer enhancement [17]
4. Optimum number fins needed for a heat can be concluded based on the thermal resistance [19]

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