Review of Heat Transfer Enhancement from Plate Fin Heat Sinks

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Abstract-Heat sinks are an extremely useful component that helps to lower maximum temperature of electronic devices resulting in an improvement in overall thermal efficiency and performance. Fins form an integral part of sinks. Geometry of fins plays a vital role in heat transfer from sinks. Researchers have studied effects of thermodynamic properties like heat input and base to ambient temperature difference. After experiments some investigators have also developed correlations .While optimising heat sink geometry aspect ratio needs to be also considered which has an important effect on heat transfer. Effect of very low aspect ratio needs to be determined.

Index Terms- *Aspect ratio, Fins, Heat sinks,*

I. REVIEW OF PREVIOUS WORK:

Wide review has been done in this paper beginning from pioneering work of Starner and McManus[1].They used four large rectangular fin arrays keeping base vertical, inclined at 45° and horizontal.Inter-fin separation distance(S) was 6.35 to 7.95 mm with fin heights 6.35,12.70,25.40 and 38.10 mm.Fin length(L),thickness(t) and width of base plate(w) was kept constant. They came to conclusion that vertical base orientation gave high heat transfer rate as compared to horizontal provided that geometric dimensions are kept constant.

In 1970 Kamal Eldin Hassan and Salah A. Mohamed determined local heat transfer coefficient using Boelter-Schmidt flux meter for a flat plate in natural convection. Experimentation for different plate inclinations was carried out by them. Their results show that flow separation takes place along trailing part at positive inclination angles.

In 1985 E.M.Sparrow and L.F.A.Azevedo experimentally and numerically studied the effect of interpolate spacing in open ended vertical channel. They made 50 times variation in channel wall spacing and used vertical plate to get infinite spacing limit.Flat plate heat transfer did not form an upper bound for channel heat transfer. Water (Pr≈5) was used for performing experiments.

Rong Hua Yeh,Shin Oin Liaw and Ming Chang theoretically determined optimum spacing of longitudinal fin arrays in forced convection. They used four different fins namely Rectangular,Convex-Parabolic,Triangular and Concave – Parabolic in analysis. They investigated aspect ratio, interfin spacing and heat transfer characteristics for given geometry of base plate, total fin volume and transverse Biot number. They came to conclusion that aspect ratio and spacing was largest for rectangular fins and least for concave parabolic.

Jian Li,D.B.Ingham and I.Pop developed numerical methods for natural convection over a flat plate kept vertical and having surface temperature oscillation. They obtained numerical results for Grashof number from 0 to 625 with an iterative approach. Perturbation method was used to validate results for small Grashof numbers. They constructed an unsteady numerical scheme for larger values of Grashof numbers. Their results show that unsteady solution approaches steady state for Grashof number up to 10000.

A.Giri,G.S.V.L Narasimham and M.V.Krishnamurthy developed mathematical formulation of natural convection heat and mass transfer over shrouded vertical fin array. They maintained base plate temperature well below dew point of surrounding moist air. They performed a numerical study by varying parameters. They found that local and average Nusselt number reduces in stream wise direction and tends to approach fully developed values for fin length with large values. Beyond certain stream wise distance more fin length does not improve sensible and latent heat transfer performance.

Ingrid Martorell,Joan Herrero and Francesc X. Graw carried out experimentation on Rectangular plates with aspect ratio between 0.036 to 0.43 and $290 \leq Raw \leq 3.3\times10^5$. They chose these values keeping in view of future applications for designing PCB's.Plates made of copper and steel were used. Surface temperature variations are observed along transverse direction for steel plates. Because of high thermal conductivity the surface of copper plate is almost isothermal.

They used three dimensional calculations at qualitative level to observe changes in flow structure due to finite length of plate. Thermal plume rising near plate centre is most relevant feature of natural convection flow.Nusselt number is found to depend on Ra_w^n with n=0.17.This low value is related to transverse condition of heat through air which becomes more significant as Ra_w tends to zero.

A.S.Krishnan,B.Premchandran,C.Balaji and S.P.Venkateshan carried out experimental and semi experimental investigation of steady laminar natural convection and surface radiation between three parallel vertical plates with black board paint on central hot plate and two side plates polished and unheated spaced symmetrically on each side and air as a medium.Radiosity-Irradiation method was used to calculate radiative heat transfer of hot surface and was deducted from input power of heater to get convective heat transfer rates and therefore Nusselt number. Six plate spacing's between 12.66 to 52.2 mm were used for experiments. Analysis shows importance of radiation heat transfer for low temperature of 310K.

S.A.M.Said,M.A.Habib,H.M.Badr and S.Anwar numerically investigated steady two dimensional turbulent natural convection between inclined isothermal plates. Calculations were done for single aspect ratio,L/b=24 for a range of modified Rayleigh number Ra',$10^4 \leq$ Ra'$\leq 10^6$ and inclination angle of $0° \leq \Theta \leq 90°$.Their results show that channel overall average Nusselt number reduces, rate of reduction increases with an increase in inclination angle. For horizontal channel (Θ=90°) results indicate that local Nusselt number along lower wall is higher than that along wall.

Giulio Lorenzini experimentally analysed flow field in air above flat metallic hot plate. Light coil is used as partial tracer of air flow field. Variation of angular velocity of coil with temperature variation of hot plate was measured. Tests showed that coil weight has an influence on angular velocity of system but an increase in weight does not lead to decrease in velocity.

S.A.Nada experimentally determined natural convection heat transfer and fluid flow characteristics in horizontal and vertical narrow enclosures at wide range of Rayleigh number(Ra) for different fin spacing's and lengths. Inserting fins enhances heat transfer rate as compared to bare base plate. Optimum fin spacing's for which Nusselt number(Nu) and finned surface effectiveness(ε) are maximum is obtained. They found that Nu and ε increases with increasing fin length. As Ra increases Nu also increases and for any fin array geometry as Ra increases ε reduces for Ra>10,000.

Hussam Jouhara and Brian P. Axcell analysed thermal conduction within a heat sink with rectangular fins cooled by laminar forced convection. Classical heat transfer theory and computational approach is used to model increase in air temperature through channels formed by adjacent fins.

Calculations show variation in heat transfer parameters along axial distance and more particularly rapid changes in heat transfer coefficient and fin efficiency near leading edges of cooling fins. Initially they obtained results for idealised fins which are 100% efficient.

Kamil Mert Cakar numerically investigated steady state natural convection from rectangular fins vertically placed by means of ICEPAK.Effect of geometric parameters on performance of heat dissipation from fin array was examined. Two sets were used and optimum fin spacing's was found numerically and experimentally. He found that convection heat transfer rate depends on fin height and fin length. For given fin spacing heat transfer rate increases with an increase in fin height. average temperature of fins reaches to minimum for specific fin spacing value.

M.Dogan and M.Sivrioglu investigated mixed convection heat transfer from longitudinal fins inside horizontal channel.Wide range of modified Rayleigh number and fin heights and spacing's was used. They also investigated optimum fin spacings to obtain maximum heat transfer. Air as a working fluid was used. Velocity of fluid was kept nearly constant ($0.15 \leq$Win≤ 0.16 m/s) with a flow rate control valve so that Reynolds number was always about Re=1500.Results obtained from experiments show that optimum fin spacing's which gives maximum heat transfer is S=8-9mm and depends on value of Ra.

Cheng-Hung Huang,Jon-Jer Lu and Herchang Ay examined a 3-D heat sink module to determine optimum design variables using Leveberg Marquardt Method (LMM).Three different heat sinks are designed with original fin arrays. Their objective was to minimize maximum temperature in fin array and get best shape of Sink. They concluded that optimum fin height tends to become higher and optimum fin thickness becomes thinner than original array resulting in an increase in fin pitch and base thickness. They measured temperature dfference for optimal heat sink by using thermal camera.

Dong Kwon Kim optimised thermal performance of vertical plate fin heat sink under natural convection with fin thickness varying in direction normal to fluid flow. For this air cooled heat sink ,thermal resistance reduces by upto 10% when fin thickness increases in direction normal to that of fluid flow. The difference between thermal resistances of heat sinks with uniform thickness and sinks with variable thickness reduces as height increases and as heat flux reduces.

Ilker Tari,Mehdi Mehrtash numerically investigated steady state natural convection from heat sinks with parallel arrangement of rectangular cross section plate fins on vertical base. Aluminium heat sinks with two different practical lengths are modelled. Finite volume CFD simulations are used to obtain natural convection and radiation heat transfer rates from heat Sinks. They suggested set of dimensionless correlations for convective heat transfer rates. They observed that convection heat transfer rates stay almost same for small inclinations. For inclination angles of ±4°,±10°,±20°,±30°,±45°,±60°,±75°,±80°,±90° extent of validity of obtained vertical case correlation is investigated by modifying Grashof Number.

Hung Yi Li,Shung-Ming Chao,Jing-Wei Chen,Jing-Tang yang experimentally studied thermal fluid characteristics of plate fin heat sinks cooled by piezoelectric fan. Experimental results show that when the piezoelectric fan is vertical thermal performance is best with tip of fan blade at centre of heat sink. When fan is horizontal there performance is best with fan tip blade at front edge

of heat sink. Vertical piezoelectric fan performs best with low fin height. For two fin heat sinks correlation with fin height depends on fin width. A thermal resistance reduces with fin width when piezoelectric fan is horizontal.

II. SUMMARY

Researchers have found that rectangular plate fin heat sinks are easy to manufacture. Heat transfer rate from rectangular plate heat sinks in vertical orientation is more as compared to horizontal one. Heat transfer rate from plate heat sinks depends on base-to-ambient temperature difference as well as fin geometry. Geometric parameters like fin length, fin height, thickness play a significant role on convective heat transfer. It is observed that with an increase in fin height, fin length and base-to-ambient temperature difference heat transfer rate increases proportionately. It is also found that optimum fin spacing depends on above mentioned parameters. Investigators have come to conclusion that optimum fin thickness depends on height, solid conductivity and conductivity of the surrounding fluid but is independent of Rayleigh number, fluid viscosity and length. Optimum fin spacing though differs for a difference in fin length and fin height this difference is not significant. It is proposed to investigate combined effect of low aspect ratio, variation in height and length as well as heat input on convective heat transfer and ultimately optimum fin spacing is to be achieved.Simultaneusly flow pattern of air on plate surfaces in various positions is to be studied.

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