Review: Heat Transfer Coefficient in Pin-Fins

Kiran S. Koyale, Vikram D. Kudale, Vaibhav G. Talandage

Abstract: The development of technology with increase heat transfer coefficient rate stimulated extensive research throughout the world leading to the use increasing of heat flux and heat transfer areas. The present study is the review on heat transfer coefficient in pin fin. Pin fins are one of the parts to transfer heat from system to surrounding and vice versa. Review of investigation of heat transfer coefficient for variation of Reynolds number. Forced and natural convection is the major part of the analysis. It studied that future development of some technologies discussed.

Keywords: Pin-fin, Heat Transfer Coefficient, Reynolds number.

———————————— ◆ ————————————

1 Introduction:

A Pin-fin is an excellent heat exchanger. Heat transfer by convection between a surface and the fluid surrounding can be increased by attaching thin strips of metal is called pin-fin. One end of the pin-fin is attached to the primary surface and other end is exposed to air. Pin-fins are used to maintain the system in a steady state condition. The capacity of a surface to loose heat to the surrounding is not sufficient to maintain the surface at the optimum operating temperature, so to increase the rate of heat transfer pin-fins are use.Pin-fins can be of variety geometry plain, rectangular, tapered and cylindrical. Pin-fins are primarily used to increase the surface area and consequently to increase total rate of heat transfer. In addition, enhanced fin geometries also increase the transfer coefficient compared to that for a plain fin. Fins are attached to the primary surface by brazing, soldering, welding, adhesive bonding.

2 Literature Review:

There are several methods to investigation of heat transfer coefficient in pin-fin in different heat transfer mode. Heat transfer coefficient is a major parameter of heat transfer processes. In this review separate out three methods experimental, analytical and numerical to calculate heat transfer coefficient in pin-fin.

2.1 Experimental Investigation

Sahitiet. al. [1] studied heat transfer enhancement is an active and important field of engineering research since increases in the effectiveness of heat exchangers through suitable heat transfer augmentation techniques can be result in considerable technical advantages and saving of cost. This work was used small cylindrical pins on

• *Kiran S. Koyale, Vikram D. Kudale, U.G. Student, Mechanical Engineering Department, Dr.J.J. Magdum College of Engineering, Jaysingpur.*
E-mail: kirankoyale008@gmail.com
• *Vaibhav G. Talandage, Assistant Professor of Mechanical Engineering Department, Dr.J.J.Magdum College of Engineering, Jaysingpur.*

surface of heat exchangers. A partly quantitative theoretical treatment of the proposed method was presented.Asresults discuss the heat flux varies with the velocity approximately as $Q \approx u^{0.5}$ whereas the pressure drop varies as $\Delta p \approx u^2$. Thus due to an increased in velocity and Reynolds number the pressure losses would rise faster than the rise of heat flux.According to author, it will encourage the development of simple and cheap procedures to build pin fin heat exchanger for industrial application.

PaisarnNaphonet. al. [2] in this study, experimental and numerical result of the heat transfer characteristics of the in line and staggered tapper pin fin heat sink under constant heat flux conditions are presented. Experiment performed by various air Reynolds number in range of 1000-9000 and heat fluxes in range of 0.91-3.64 kW/m². A finite volume method with an unstructured non uniform grid system is employed for solving the model.It was found that when the inlet air temperature is kept constant the outlet air temperature decreases with increasing Reynolds number. Reasonable agreement is obtained from the comparison between the predicted result and the measured ones.
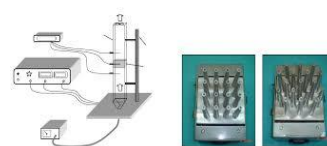

Fig 1Schematic diagram of experimental setup.

In this paper investigated Experimentally, Mathematically and Numerically.

Lawson etal. [4] Pin fin arrays increases heat transfer by increasing the flow turbulence and surface area of the air foil exposed to the coolant. This study experiments were conducted to determine the effects of pin spacing on heat transfer and pressure loss through pin fin arrays for a range of Reynolds number between 5000 to 30000.

Hafiz et al. [5] experimental data are reported for condensation of ethylene glycol at near atmospheric pressure and low velocity on 11 different 3- dimensional pin-fin tubes tested individually. The heat transfer

enhancement was approximately twice the active area enhancement was found to increase with increasing pin height and decrease circumferential pin spacing. This study experimental method was used to analyze problem.
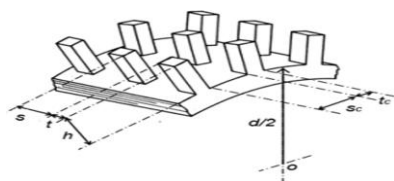

Fig 2 Idealized pin fin tube

Sahrayet.al. [6] studieddeeper understanding of heat transfer from horizontal-base pin-fin heat sinks with exposed edges in free convection of air. The effects of fin height and fin population density are studied experimentally and numerically. Result discussed by author that heat transfer enhancement due to the fins is not monotonic also analyzed the heat flux distribution at the edge and center of the sink.

U. V. Awasarmolet. al.[7] outcome of this paper based on experimental study is conducted to comparison of rate of heat transfer with solid and permeable fins and the effect of angle of inclination of fins. As compared to result the temperature of solid fins are more elevated to permeable fins. There was net increase in heat transfer rate of the block with permeable fins as compared to that of the fin block with solid fins.
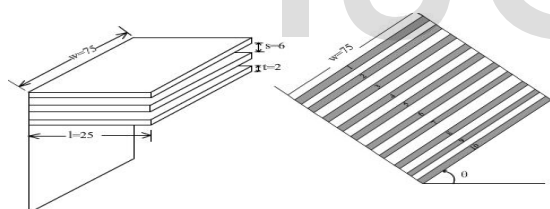

Fig 3 Schematic showing dimensions of fins (Left) and angle of inclination of fins (Right)

2.2 Analytical Investigation

Yang et.al. [8] the forced convective heat transfer in three –dimensional porous pin fin channels is numerically studied in this paper. TheForchheimer – Brinkman extended Darcy model and two equation energy models are adopted to describe the flow and heat transfer in porous media. Both air water are used as cold fluids and the effects of Reynolds number, density and pin fin form are investigated. The overall heat transfer efficiencies in porous pin fin channels are much higher than those in solid pin fin cannels which are 119.5% and 37.9% higher for air and water cases at Re = 229
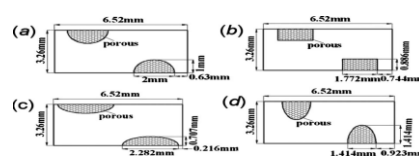

Fig 4 Different forms of porous pin fin cross-section

Kundu et al. [9] this Paper wants to express an analytical model for thermal performance and optimization of constructional fin subject to variable thermal conductivity of fin material and convective heat transfer coefficient over the fin surface. The new analytical method is based on the domaindecomposition method has been established for the solution process. A finite difference scheme has been adopted for the numerical result obtained through a numerical analysis
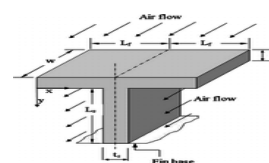

Fig 5 T-shaped fin

In this study literature was used T-shaped fin to variable thermal conductivity and convective heat transfer.

Mehdi Anbarloei et.al. [10] in this paper, the non-linear fin problem with temperature dependent thermal conductivity and heat transfer coefficient is restricted. It is show that governing non-linear differential equation is exactly solvable. They obtained three possible methods to solve this problem, but the solution is unique. They discussed the existence of domain of the solution and multiplicity of them. Also gave the some results about fin efficiency of non-linear problem.

Woodcock et.al.[11] in this study a comparative study of flow boiling in a micro channel with piranha pin fins. These piranha pin-fins are called as an advanced micro scale heat sink as per their research. These surface temperature, pressure drop, heat transfer coefficient and critical heat flux conditions were experimentally obtained and discussed. They concluded that heat transfer coefficient depends strongly on mass flux in both single phase and boiling regimes and critical heat flux varies with differential devices and different flow conditions. Critical heat flux under high pressure can be longer than under low pressure.
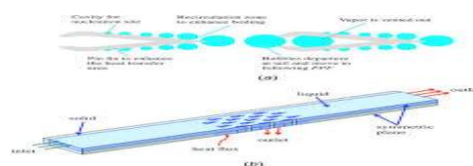

Fig 6 Schematic of microchannel with PPFs.

2.3 Numerical Investigation

Humid et.al. [12] a numerical analysis of forced convective heat transfer from an elliptical pin fin heat sink with and without metal foam inserts is conducted using three dimensional conjugate heat transfer model. This analysis was used elliptical fins. This numerical analysis was used Darcy-Brinkmun for chheimer and classical Navier-Stokes equation, together with corresponding energy equations are used of flow field and heat transfer in heat sink with and without metal foam inserts.to solving governing equation used Gauss-Seidel method.
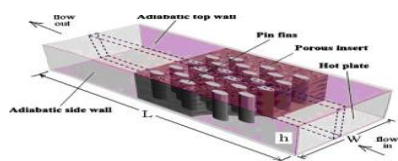

Fig 7 Elliptical pin fin heat sink

The effects of air flow Reynolds number and metal foam porosity and permeability on the overall Nusseltnumber.This numerical analysis consists of four parts in range of Reynolds number 126-630.

Wahan Yuan et.al.[13] the computational fluid dynamics software (Fluent) is used in assessing the electronics potential of a plate pin in heat sink, including the conjugate effects. This analysis used model development, computational domain, Mathematical model and experimental result. Thisanalysis goes through these parameters.
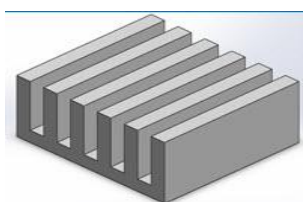

Fig 8 Plate fin heat sink

The simulations are validated with reported experimental data. This research was detail analysis on the influences of air velocity, pin diameter, pin array. All the processes carried out by using software.

Shih et.al. [14]this study used CFD tool for analysis. Heat transfer coefficients on surfaces exposed to convection environment are often measured by transient techniques. Such as thermo chromic liquid crystal or inferred as thermograph. Time-accurate CFD conjugate analyses were performed to examine possible errors in transient techniques used to measure the heat-transfer coefficient.

This technique the surface temperature was measured as a function of time.

Md.Farhad Ismail et.al.[15] numerical investigation is conducted in this study for three –dimensional fluid flow and convective heat transfer from an array of solid and perforated fins that are mounted on a flat plate. This analysis of flow field and convective heat transfer for conjugate problem was carried out for Re_L = 2×10⁴ to 3.9×10⁴, P_r = 0.71.it was found that when the inlet air temperature and the heat flux are kept constant, the thermal resistance decreases with increasing the Reynolds number. Author says the perforated fins have higher effectively than the solid fins. Generally optimization of fins focused on maximize heat dissipation rate and to minimize pressure drop for a given mass or volume of the heat sink perforated fins have higher than the solid fins.

Michael l.Seibertet.al.[16] this paper examined the augmentation of heat and mass transfer due to dual clearances on cylindrical Pin-Fins,relative to a channel between parallel plates, in mini/microchannel reactors at low Reynolds numbers. In this work diffusion limitation to heat and mass transfer in smooth-walled mini/microchannel reactors were investigated.

GazyF.Al-Sumailyet.al.[17]in this paper, thecharacteristics of fluid flow and forced convection heat transfer around a bank of four circular cylinders embedded in a metallic or non-metallic porous material have been investigated numerically. Both staggered and an in-line arrangement has been studied.

Yujie yang et.al. [18] the comparative analysis shows that the conventional fin efficiency and fin effectiveness. The fin performance of plain fins is analyzed by using CFD technique. The behavior of actual fin effectiveness for plain fins and offset strip fins is also discussed in detail.
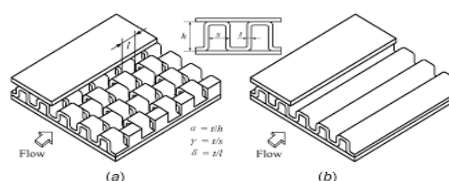

Fig 9 (a) Offset strip fin (b) plain fin

The actually efficiency physically represents the ratio of the heat flux over the secondary surface and that over the primary surface. The performance of OSE fins is higher than that of plain fin with same cross section.

Ali Mohammadi et.al. [19] this study present result on the hydrodynamic and thermal characteristics of single phase water flow inside microchannels with different micropin fin configuration. This study Reynolds number

was consideredin range of 20 to 160. As the Reynolds number increases, the pressure drops and Nusselt numbers increase as a result of extension of the wake region. Twofold increases in the Reynolds number result in a reduction of about 40% in the obtained friction factors. This study used numerical modeling to solve problem.

Fyrillas et.al. [20] author suggested of Critical Biot number of periodic array of rectangular fins. Numerical result suggested that the fins would enhance the heat transfer rate only if the Biot number is less than a critical value which is independent of the thickness of the wall. Author justified a critical Biot number as the local transport rate is proportional to the local surface area hence; we expected that an increase in the surface area would result in an increase the transport rate.

S. G. Khomane et.al[21] Numerical studies were conducted to analyze natural convection heat transfer from solid and discrete fin. This paper was numerical investigation made for three dimensional fluid flow and convective heat transfer from an array solid and discrete fins that were mounted on a flat plate. According to the author increasing the heat input Nusselt number increase. As author concluded that the base temperature of solid fins was more elevated as compared to discrete fins.
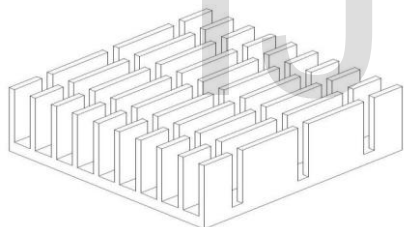

Fig 10 Physical model of discrete fin block

3 Conclusion

In this reviewa detailed investigation of the different calculation of heat transfer coefficient pin fin. Enhancement of heat transfer through the fin is carried important role main intension is that to identify easy way to enhance the heat transfer.

1) In experimental investigation used different type of models and type of fin to calculate heat transfer coefficient. According to the review experimental result having some approximation.
2) Analytical analysis is one of the methods to used behavior of pin fin. Better accuracy is given in this method.
3) It is used in latest trend to analyze the behavior of pin fin.Numerical analysis was used Darcy-Brinkman for

chheimer and classical Navior-strokes equation to calculate flow field.
4) According to review comparison of various method shown below
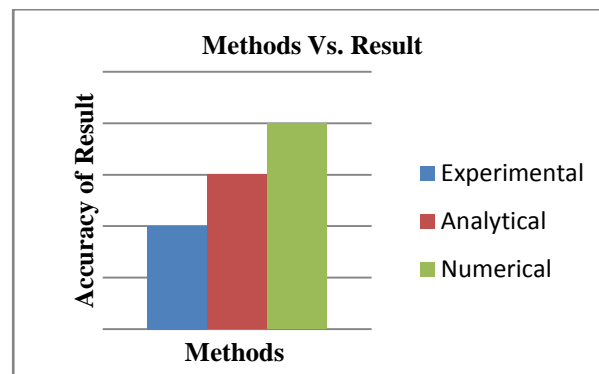
Graph No.1

5) According to the review of experimental analysis shows less accuracy because performing experiment facing some restriction and taking approximate value, manual error, environmental condition these factors are affecting to experimental investigation
6) Analytical and numerical investigation used standard parameters and conditions to solve problems comparatively results are approximately same in all methods.

References

[1] N.Sahiti et.al. , [2005], "Heat transfer enhancement by pin elements." International Journal of Heat and Mass Transfer, Vol. No. 48, pp. 4738-4747.

[2] PaisarnNaphon and AnusornSookkasem, [2007], "Investigation of heat transfer characteristics of tapered cylindrical pin fin heat sinks", International Journal of Heat and Mass Transfer, pp. 0196-8904.

[3] Yu Rao et.al.[2011], "spatially-resolve heat transfer characteristics in channels with pin fin and pin fin-dimple arrays." International Journal of heat and mass transfer, Vol.no.50, pp. 2277-2289.

[4] Seth A. Lawson et.al. [2011], "Heat transfer from multiple row arrays of low aspect ratio pin fins." International Journal of heat and mass transfer, Vol.no.54, pp. 4099-4109.

[5] Hafiz Muhammad Ali and Adrian Briggs [2012], "Enhanced condensation of ethylene glycol on single pin fin tubes: effect of pin geometry."Journal of heat transfer, Vol. no. 134, pp. 011503-8.

[6] D. Sahrayet. al. [2010], "Study and optimization of horizontal base pin fin heat sink in natural convection and radiation."Journal of heat transfer, Vol. no. 132 pp. 012503-13.

[7] U.V. Awasarmol et.al.[2011], "Experimental study of effect of angle of inclination of fins on natural convection heat transfer through permeable fins." Conference on thermal energy and environment.

[8] Jian Yang et.al.[2010], "Forced Convection Heat transfer enhancement by porous pin fins in rectangular channels", Journal of heat transfer, Vol. No. 132, pp. 051702-8.

[9]   B.Kundu and D.Bhanja [2010], "performance and optimization analysis of a consrtuctal T-shaped fin subject to variable thermal conductivity and convective heat transfer coefficient." International Journal of heat and mass transfer, Vol.no.53, pp. 254-267.

[10]   MahadiAnbarloei and ElyasShivanian [2016], "Exact closed-form solution of the Non-linear fin problem with temperature – Dependent thermal conductivity and heat transfer coefficient."Journal of heat transfer, Vol.no.138, pp. 114501-6.

[11]   C. Woodcock et.al.[2016], "A comparative study of flow boiling in a microchannel with piranha pin fins."Journal of heat transfer, Vol. no.138, pp. 111502-12.

[12]   Hamid Reza Seyf and Mohammad Layeghi [2010], "Numerical Analysis of convective heat transfer from an elliptic pin fin heat sink with and without metal foam insert.", Journal of Heat Transfer, Vol no. 132, pp.071401-9.

[13]   Wuhan Yuan et.al.[2012], "Numerical simulation of the thermal hydraulic performance of a plate pin fin heat sink." Applied Thermal Engineering, Vol.no.48, pp.81-88.

[14]   Tom I-P.Shih et.al.[2013], "Time-accurate CFD conjugate analysis of transient measurements of the heat transfer coefficient in a channel with pin fin.", propulsion and power Research, Vol.no.2, pp.10-19.

[15]   Md. Farhad Ismail et.al. [2013], "Numerical investigation of turbulent heat convection from solid and longitudinally perforated rectangular fins."International conference on thermal engineering, Vol.no.56, pp.497-502.

[16]   Michael L.Seibert, Neal Blackwell and DaneshK.Tafti [2014], "Effect of Pin tip dual clearance on flow Reynolds numbers", Journal of heat transfer, vol.136/071901-1

[17]   Gazy F. Al-Sumaily[2014], "Forced convection heat transfer from a bank of circular cylinders embedded in a porous medium", Journal of heat transfer, vol.136/042602-1.

[18]   Yujie Yang [2016], "Analysis of the fin performance of offset strip fins used in plate-fin heat exchangers."Journal of heat transfer, Vol. no.138, pp. 101801-9.

[19]   Ali Mohammad and Ali Kosar [2016], "Hydrodynamic and thermal performance of microchannels with different in-line arrangement of cylindrical micropin fins."Journal of heat transfer, Vol. no. 138, pp. 122403-17.

[20]   Marios M. Fyrillas [2016], "Critical Biot Number of a periodic Array of Rectangular Fins.", Journal of heat transfer, Vol.no. 138, pp. 024504

[21]   S. G. khomane [2015], "Enhancement of heat transfer by natural convection from discrete fins." International Engineering Research journal pp. 73-77