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Review Article

A review on the effect of shape on performance of pin fins

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Abstract

Pin fins are extended surfaces protruding from heat sinks in a perpendicular direction. The heat transfer flow flows in cross direction to the pin fin. The use of pin fins results in higher heat transfer coefficients.From the literature it is clear that pin fins offer the highest heat transfer coefficient amongst all other types of fins. But along with the increased heat transfer rate the higher pressure drops associated with the pin fins reduce the overall performance of the pin fins. Hence a lot of research is being carried out to reduce the pressure drop. This paper focuses on the effect of the shape on the performance of the pin fins. Due to the more streamlined shape the wake region is reduced which results in reduction in the pressure drop.

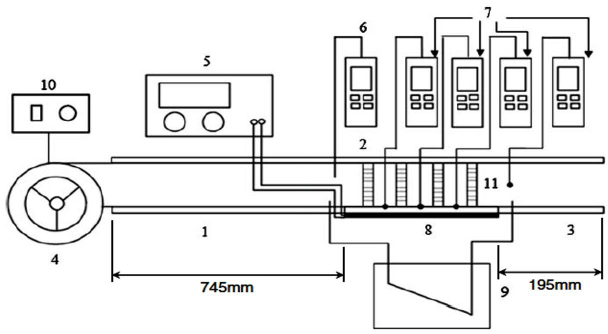
Keywords: *Convection, Reynolds number, Heat transfer coefficient, Pressure drop, Drag coefficient.*

1. Introduction

Modern heat exchangers are required to be designed in such a way that their size is reduced and more compactness is achieved. For achieving this the heat transfer coefficient must be increased. When gases are used to transfer heat high attention must be given to the surface which transfers heat as gases have very low Cp. Liquids have heat transfer coefficients 100 times higher than that of the gases. The use of highly effective fins increases the heat transfer surface area, which leads to substantial increase in the heat transfer rate.

When the pin height to pin diameter ratio is less than four these are called short pin fin arrays. Applications like turbine blade trailing edges, compact heat exchangers, electronics heat sinks, etc require high heat flux removal rates, hence short pin fin arrays are of great use in such applications. The short pin fin arrays placed inside the flow channel develop turbulence which enhances the convective heat transfer rate. Due to this the pin fin material of low thermal conductivity can also be selected. For such high heat dissipating applications mostly inline and staggered arrays of short circular pin fins are considered. Circular pin fins face the limitation of early separation of flow over the fin, increasing the the total pressure drop across the channel. Hence to improve the integrated heat transfer rate using pin fins the pressure drop associated with the fins must be reduced. One such method to reduce the pressure drop is to use different shape for the pin fins and check its effect on the overall heat transfer rate. The objective of this study is to review the literature regarding various pin fin shapes used and to find out the most optimum shape amongst them.

The following setup was used to test the performance of the specimens under forced convection-



1. Channel Entrance 2. Test Section 3. Channel Exit 4. Blower 5. AC Power Supply 6. Hot Wire Anemometer 7. K-type Thermocouples 8. Thermo foil Heater 9. Inclined Pressure Manometer 10. Speed Regulator 11. Pin Fin Array

Fig.1 forced convection experimental setup

Hongxia Zhao, Zhigang Liu, Chengwu Zhang, Ning Guan, Honghua Zhao (2016)

The heat transfer rate due to convection can be given by Newton's law of cooling as, the product of the temperature difference between the surface and the ambient temperature, the surface area exposed to the fluid and the convective heat transfer coefficient. The temperature difference between wall and the fluid depends on the ambient conditions and hence cannot

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used for increasing the heat transfer rate. Therefore for increasing the heat transfer rate research is focused on increasing the heat transfer surface area and and the heat transfer coefficient by various means.

The main resistance to heat transfer from a solid surface to a contact fluid is formation of the velocity boundary layer. The turbulent or the transition flow regime is of most importancefrom the point of view of the heat transfer coefficient, in the boundary layer such as for a laminar boundary layer over a flat plate $h \approx u^{0.5}$in a turbulent boundary layer $h \approx u^{0.8}$and in the transition boundary layer $h \approx u^{1.4}$ (Zukauskas and Karni, 1989). Turbulence is created at high velocities which also induces increase in hydraulic drag as $\Delta p \approx u^2$. Therefore measures for creating artificial turbulent boundary layers or reducing the thickness by breaking the boundary layer are more effective in increasing the heat transfer coefficient.

The assessment of fin performance depend on the parameter *ml*. Obviously, this parameter which accounts for the fluid dynamic and thermal flow patterns around the fins, fin cross-section, fin length and fin material, determines the final fin performance. The large number of variables influencing the parameter *ml* and hence the fin performance make the fin design an open-ended optimization problem.

2. Heat transfer enhancement using various shapes for pin fin cross section

In a study conducted by W. A. Khan, J. R. Culham and M. M. Yovanovich(2006)analysis was done to find out the effect ofdifferent fin geometries on overall thermal/fluid performance. The analysis was done on rectangular, elliptical, circular and square pin fins.The parameters for the comparison of the different fin shapes were the heat transfer coefficient and coefficient of friction also by varying the axis ratio, aspect ratio, and Reynolds number. The experimental results were as follows.

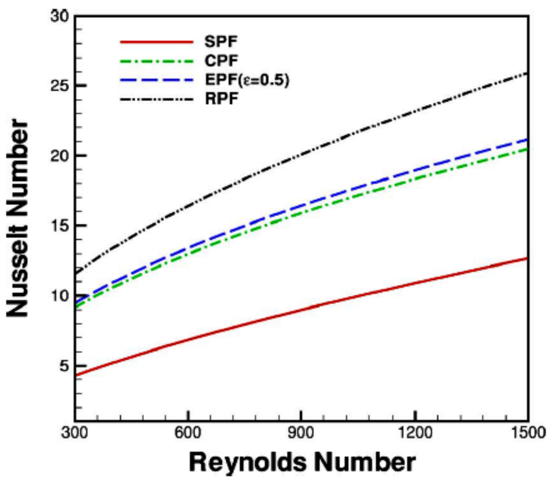

Fig. 2 Effect of the Reynolds number on heat transfer coefficients.W. A. Khan, J. R. Culham, M. M. Yovanovich (2006)

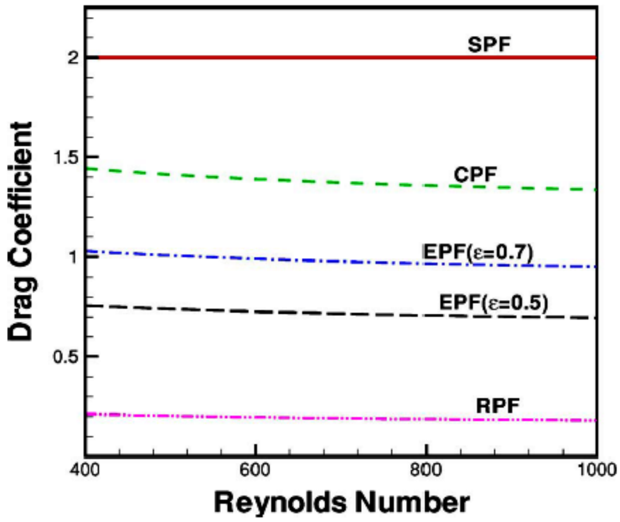

Fig. 3 Effect of the Reynolds number on drag coefficients W. A. Khan, J. R. Culham, M. M. Yovanovich (2006)

He drew the following conclusions from the results The Figs. 3 and 4 show the effect of varying Reynolds number on the heat transfer coefficient and the drag coefficient. The increase in Nusselt number with increasing Reynolds number is shown in figure 3. Figure 4 shows the hydraulic performance of each pin fin. Keeping the perimeter same for each shape the following conclusions were drawn -

1) The square pin fin shows least heat transfer rate while it increases from the circular pin fin to the rectangular pin fin.
2) The square pin fin shows the highest drag coefficient and the rectangular pin fin shows the least.
3) The drag coefficient reduces with the decreasing axis ratio

The overall performance of the pin fin is greatly affected due the pressure drop associated with it. To check how the shape of pin cross-section affects the pressure drop and heat transfer performance, six forms of pin cross-section were investigated by N.Sahiti (2005). The fins were compared on the basis of two geometrical parameters. Staggered and inline pin fin configurations were studied during this study. The heat transfer and pressure drop characteristics were presented in terms of Nusselt number and Euler number. The final judgment of the performance of the pin fin cross-section was performed based on the heat exchanger performance plot. He observed that the elliptic profile offers the highest heat transfer rate for a given base area and for the same energy input.

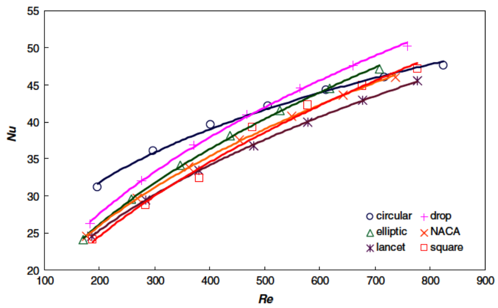

Fig.4 Pin fin array Nu as a function of Re.N. Sahiti, A. Lemouedda, D. Stojkovic, F. Durst, E. Franz (2006)

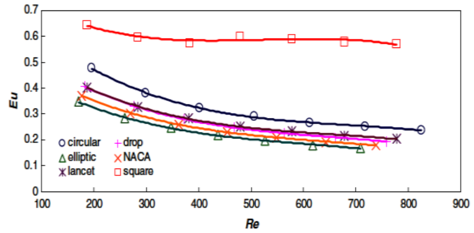

Fig. 5 Pin fin Eu as function of Re.N. Sahiti, A. Lemouedda, D. Stojkovic, F. Durst, E. Franz (2006)

The results of the simulation of six different pin cross-sections show that elliptical profile transfers maximum heat and also the pressure drop is minimum for the elliptical profile.

In this study conducted by JaideepPandit, Megan Thompson, Srinath V. Ekkad, Scott.T.Huxtable(2014) experiments were carried out to find out the most efficient shape of the pin fin for transferring heatfrom the hot side of a TEG system. TEG systems are used to generate power from waste heat. In this case waste heat in automobile exhaust gases was used. Pin fin arrays of circular, triangular, hexagonal, and diamond shapes were mounted on the walls of a rectangular channel which represented the hot side of the TEG. The effect of the pin fin height to channel height ratio was studied by varying the channel heights while keeping the pin fin height constant.

Two factors affecting the fin performance were evaluated during this study. First the most efficient shape was found out amongst the four shapes then the effect of the distance between pin fin and the channel was studied. The hydraulic diameter to pin fin height ratio was kept constant.

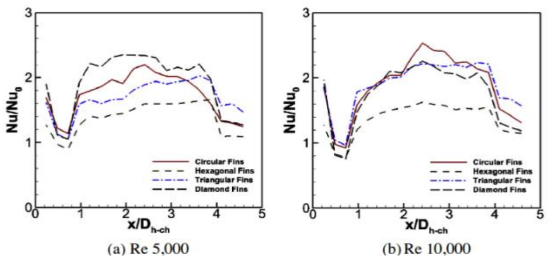

Fig .6 Spanwise area averaged normalized Nusselt numbers for Reynolds numbers.JaideepPandit, Megan Thompson, Srinath V. Ekkad, Scott T. Huxtable (2014)

The diamond shaped fin performs the best at Reynolds number 5000. But as the Reynolds number increases the performance of other fins is similar to the diamond shape. Lower channel heights that cause pin fins to block 50% of the channel provide significantly higher heat transfer coefficients.

Hongxia Zhao, Zhigang Liu, Chengwu Zhang, Ning Guan, HonghuaZhao(2016) performed an experiment in which the working fluid used was de-ionised water.The fluid was allowed to flow over the staggered mini pin fins. The height and transverse spacing was kept same but they varied the pin density and considered different shapes of fin like circular, elliptical, square, diamond and triangle, which wereplaced in a rectangular channel. The flow properties required were mass flow rate, pressure difference between inlet and outlet and temperature at the inlet and outlet. The Reynolds number (Re) was varied in the range of 50–1800 to obtain the friction factor. The results showed that the friction factor for all the fins decreased with the increase of Re.

In the laminar flow regime the triangular shape with minimum fin density showed the minimum pressure drop while the elliptical shape with highest fin density had the maximum pressure drop. Whereas in the turbulent flow the elliptical shape fins had the minimum pressure drop and the triangular shaped fins had the maximum pressure drop.

In a similar study Shrenikkumar Oswal, Hemant Jagtap & Ajit Mane (2015) studied the various factors affecting on heat transfer characteristics of the pin fins. Inline, staggered and radial pin fin arrays were compared. Along with the different configurations of arrays six different shapes of the pin fin were also compared. The effect of the different shapes and arrangements were studied by observing the parameters like maximum temperature, pressure and velocity. Results showed that elliptical fins give higher overall performance than other shape pin fins.

Fengming Wang, Jingzhou Zhang &SuofangWang (2014) numerically and experimentally simulated the flow and heat transfer characteristics of differently shaped pin fins.The fins were of circular, elliptical, and drop-shaped shape with the same cross-sectional areas were compared by placing them in a staggered arrangement. The pin fins were embedded in a rectangular box in a staggered arrangement.

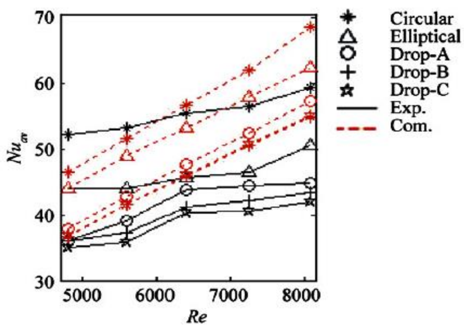

Fig.7 Thermal performance of the pin fins.

Naturally the more streamlined drop-shaped pin fins had the minimum pressure drop by delaying or suppressing separation of the flow passing through them. This decreased the aerodynamic penalty compared to circular pin fins. But the heat transfer rate of the drop shaped fin was less than the circular pin fin as the drop shaped fins develop very less or no turbulence in the fluid. Thus considering the overall performance the elliptical pin fin shows optimum performance.

P.A. Deshmukh& R.M. Warkhedkar (2013)studied the thermal performance of the elliptical pin fin numerically and also experimentally. They studied the combined effects of forced and natural convection to find out the optimum design for the elliptical pin fin. They compared theheat transfer rate and pressure drop across the circular and elliptical profiled pin fin heat sinks. The effect of various design parameters like spacing along the x and y directions,pin fin aspect ratio, configuration (inline and staggered), air flow and the orientation on the performance of the pin fin were studied. This study gives the optimum design parameters for the elliptical pin fin.

Conclusions

- The heat transfer rate is highest for the circular pin fin. The elliptical fin is second in considering the heat transfer rate. While the square fins transfer least heat.
- Reynolds number plays an important role in selection of the fin shape. Because at high Reynolds number the heat transfer rate is similar for circular and elliptical shape.
- Considering the pressure drop the drop shape due to its aerodynamic advantage shows least pressure drop. The elliptical pin causes slight more pressure drop than the drop shaped fins.
- Hence we can conclude that the elliptical pin fin gives highest overall performance.

References

W. A. Khan, J. R. Culham, M. M. Yovanovich (2006) The Role of Fin Geometry in Heat Sink Performance,*Journal of electronic packaging.* vol. 128.

N. Sahiti, A. Lemouedda, D. Stojkovic, F. Durst, E. Franz(2006) Performance comparison of pin fin in-duct flow arrays with various pin cross-sections, *Applied Thermal Engineering* 26, pp. 1176–1192.

JaideepPandit, Megan Thompson, Srinath V. Ekkad, Scott T. Huxtable(2014) Effect of pin fin to channel height ratio and pin fin geometry on heat transfer performance for flow in rectangular channels, *International Journal of Heat and Mass Transfer* 77 ,pp. 359–368.

P.A. Deshmukh, R.M. Warkhedkar(2013) Thermal performance of elliptical pin fin heat sink under combined natural and forced convection, *Experimental Thermal and Fluid Science* 50 pp. 61–68.

Hongxia Zhao, Zhigang Liu, Chengwu Zhang, Ning Guan, Honghua Zhao(2016) Pressure drop and friction factor of a rectangular channel with staggered mini pin fins of different shapes, *Experimental Thermal and Fluid Science* 71, pp. 57–69.

Fengming Wang, JingzhouZhang, SuofangWang (2012) Investigation on flow and heat transfer characteristics in rectangular channel with drop-shaped pin fins, *Propulsion and Power Research*;1(1): pp. 64–70.

Shrenikkumar Oswal1, Hemant Jagtap, Ajit Mane (2015) Factors Affecting on Thermal Performance of Fins & Analysis of Fins, *International Journal of Innovative Research in Science, Engineering and Technology*, Vol. 4,.

M. K. Chyu, Y. C. Hsing, T. I.-P. Shih, Heat Transfer Contributions of Pins and Endwall in Pin-Fin Arrays: Effects of Thermal Boundary Condition Modeling, *International Gas Turbine and Aeroengine Congress and Exhibition*, Stockholm, Sweden, June 2-5, 1998. Paper No. 98-GT-175.

Phd dissertation, Thermal and Fluid Dynamic Performance of Pin Fin Heat Transfer Surfaces, *University of Erlangen-Nurnberg*, 27 January2006.