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A Review Performance of Different Shaped Fins Using In a Gas Turbine Airfoils

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Abstract - In a gas turbine airfoil cylindrical pin fin have been utilized extensively for internal cooling but in a past few decade lots of efforts have been made by different researchers to study different fin array configuration at different shapes, orientation and fin spacing. In this paper we are reviewing all the efforts made by different researchers to find out the heat transfer and pressure drop associated with different fin configuration. We also find out the heat transfer at the finwall and unfinned surfaces. All the study that have been made in this paper is to find out such type of fin configuration that increases the heat transfer and decreases the pressure drop.

Index Terms— finwall, unfinwall, heat transfer, pressure drop, circular pin fin, elliptical pin fin, straight rectangular fin

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1 Introduction

Fins are extended surfaces from an object to increase the heat transfer rate to or from the surrounding by convection. The rate of conduction, convection, or radiation determines the rate of heat is transfers from the object. Fins are increasing the temperature gradient between the object and the surrounding and also increasing the convective heat transfer coefficient , or by increasing the surface area of the object, increases the heat transfer. . Pin fin arrays are frequently used for cooling of electronic components such as - computer internal cooling, trailing edges of gas turbine blades and many other industrial applications.

Fins are mostly used as extended surfaces in compact heat exchangers to increase heat transfer rate and turbulence which help in to find a large total heat transfer surface area without using the large primary surface area. There is a need of compact and energy efficient pin fin heat exchanger for increase of heat production rate in electronics components. The two major factors that consider during the designing of any heat exchanger are heat transfer characteristics and pressures lose.

Staggered pin fins array are commonly used in many thermal systems to increase their heat transfer capacity at low pressure drop and thus to reduce the size of heat exchangers.

The objective of the present study is to investigate the heat Transfer and pressure drop characteristics in a different fin configuration like cylindrical, elliptical and rectangular fin. By means of the heat transfer analogy and the heat transfer coefficients on the endwall was measured separately in order to find outthe contribution of each of the total heat transfer of the finwall.

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2 Cylindrical pin fin

2.1 Background

In a past few years, arrays of intermediate length circular cylinders have been utilized extensively in internally cooled gas turbine engine airfoils. Theoclitus [1] measured array average heat transfer and flow friction characteristics for pin fin arrays with length-to-diameter ratios from 12 down to as short as 4. In general the average heat transfer rates reported are all lower than those expected for long cylinder arrays and are slightly lower for short pins *(HID* = 4) than for long *(HID* =12). Damerow et al., covers arrays in the range 2 < *HID* < 4, but the results are restricted to flow characteristics only. No consistent effect of *HID* on flow friction was observed in either [1] or [2]. A recent study by VanFossen presents heat transfer results for several staggered configurations of *HID* = 0.5 and 2.0 pin arrays similar to those used in the present study. All arrays in consist of four rows of pins in the streamwise direction, and only heat transfer rates averaged over the entire four row array were determind[3].

2.2 Review

Metzger et al. [4] measured the heat transfer and friction factor coefficient across an array of ten rows of short pin fin in a uniform channel. Row to row resolved the nusselt values were almost identical for maximum and minimum roughness value of the channel and no significant effect of roughness was reported. Two staggered array geometries were fabricated and tested: S/D = 2.5, X/D = 2.5, H/D = 0, and S/D = 2.5, X/D = 1.5, H/D = 1.0. Pin diameters were uniform for each ten row array at 0.508 cm for the X/D = 2.5 case and 0.846 cm for the X/D = 1.5 case.

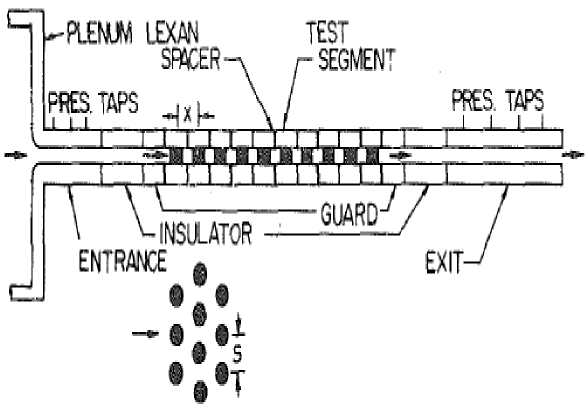

Fig. 1 Test section arrangement

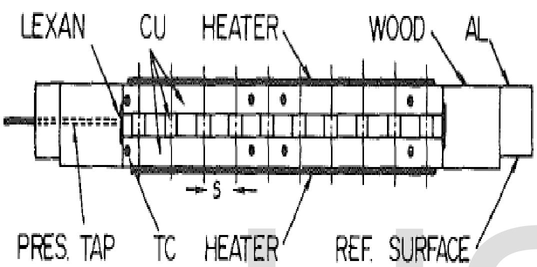

Fig. 2 Individual segment details

Metzger et. al. [4] used the experimental setup consists of an upper and lower copper bar with one row of pins connected by means of an interference fit. The enterence and exit length of uniform channel cross section of 12.7 cm and 7.6 respectively **are** not shown for the clerity of the figure. The approximately 10-cm thick balsa insulation placed around the segments to reduce heat loss to the laboratory. The top view and the front view of the experimental setup shown in the figs. 1 and 2 respectively.

2.3 Result

Sparrow For both the configuration initial increase in nusselt number for the first three to five row at all reynold number then there is gradual decline in following row.The heat transfer rate for small steamwise spacing is earlier as compared to larger steamwise spacing. Average Nusselt numbers encompassing the first four pinrows are in good agreement with the recent four row average measurements of [3].

3 Elliptical pin fin.

3.1 Background

The past few decade most of the work will be restricted to the pin fin with circular cross section. But few researchers are study pin fin with some other cross section Sparrow el al. [5] investigated experimentally the pressure drop characteristics of diamond-shaped pin fin arrays, which used in space shuttle flight STS-34. Ota et al. [6] studied the heat transfer and flow around an elliptic cylinder of axis ratio 1:3.They found from experimental setup that heat transfer coefficients of the elliptical shape cylinder is higher than that of a circular cylinder one with equal circumference and the pressure drag coefficients of the former are much lower than that of the latter.

3.2 Review

Qingling el al. [7] using naphthalene sublimation technique to find out the mass transfer before and after the test run the mean heat transfer coefficients can be achieved by heat/mass transfer analogy.

The configuration for elliptical shaped fin are taken by the Qingling el al. [7] are major axis length 2a =16 mm and the minor axis length 2b = 9 mm. Thus the equal-circumference-diameter of pin fin is $D\pi$ = 12.75mm. The height of pin fin is also 12.75 mm (equal to the height of the wind tunnel). The relative spanwise and streamwise pitches are $S1/D\pi$ = 1.10-3.00. In naphthalene sublimation techanique only one pin fin is made of naphthalene and other are made of wax. In these experiment both either the napathlene or wax pin fin are made by moulding.

The suction-mode wind tunnel used in this experiment is shown in Fig. 3. Rotameter is used to measure the flow velocity in the wind tunnel which is shown in Fig.3. By means of pressure tape together with micromanometer pressure drop has been find out through measuring the static pressure ahead of and behind the test section. An analytical balance was used to measure the mass loss during a test run and air temperature in the wind tunnel is measured both with thermocouples and with standard glass thermometers.

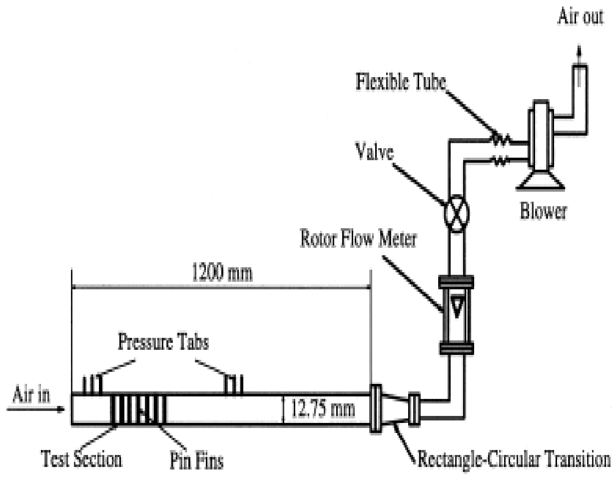

Fig.3. Wind tunnel system

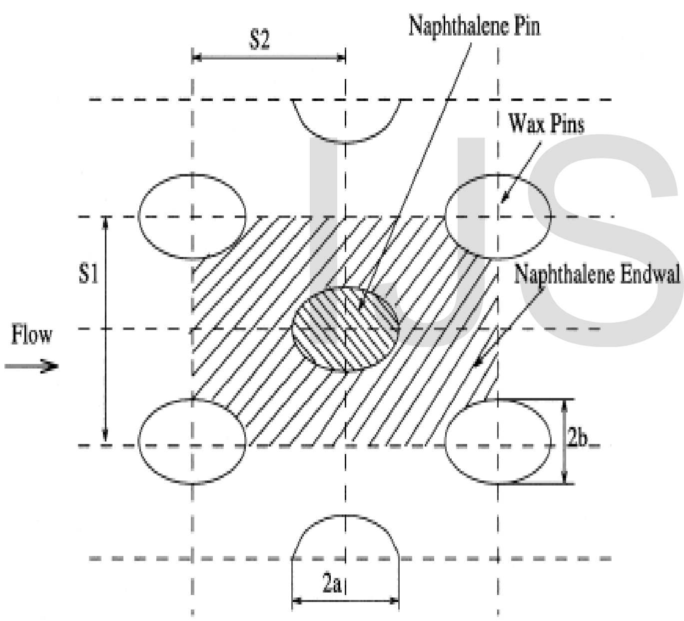

Fig. 4. Configuration of elliptical pin fin and their arrangement

3.3 Result

For both configuration, the heat transfer rate on the pin fin as compare to endwall is higher at the same Reynolds number. At the lower Reynolds numbers the difference is quite large but with the increase of Reynold number the difference decreases quickly. From the experiment it clearly seems that the heat transfer coefficients of ducts with elliptic pin fins are higher than those with circular shaped pin fin.

4 Straight Rectangular Fin

4.1 Backgrounds

It is known that fins with cross sections, like parabolic or triangular, can perform better than straight rectangular fins as far as the heat transfer rate per unit weight of the material is concerned.

Indeed, Eckert and Drake [8] told a technique to obtain a best fin shape that gives a optimum heat transfer rate for a given quantity of material. By gradually reduction of cross-section area the performance of these fins can be improved. As the fin is a coupled conduction-convection system, the solid material of the fin becomes increasingly redundant along its length [9].

4.2 Review

PRASAD el al.[10] study about the straight rectangular fin for reducing the weight of the fin by providing the semicircular cut at its tip. From the previous study we know that the performance of the straight rectangular fin can be increase by reducing the per unit weight so cut at its tip is provided to improve the heat transfer rate.

PRASAD el al. [10] using the The ANSYS 5.0 finite element package is used to obtain the temperature distribution and heat transfer values from the fin for both the uncut straight rectangular fin and the cut at the tip. Other input data taken in this study are the length of the fin l is arrived by choosing the values of heat transfer coefficient h, material thermal conductivity k, and thickness t. The width of the fin L can be chosen independently, whereas the diamcter of the semicircular cut can be varied fromzero to L. Thus the straight optimal or the conventional fin becomes a special case of the proposed configuration. However, in contrast to the predominantly one-dimensional nature of the temperature field in the straight fin, the semicircular cut at the tip is expected to render the temperature field three-dimensional. As the problem is mathematically more complex, a numerical approach is employed.

4.3 Result

By making a simple geometric modification by providing a semicircular cut at the tip of the fin is to improve the performance of the fin in terms of the heat transfer per unit weight. When the diameter of the cut is equal to the width of the fin the fin comparison factor (FCF) is maximum at the maximum size of the cut. Same result can be found even as the fin is arrangend in array. The Biot number does not have any significane influence on the fin comparison factor.

5 Conclusion

The channel with elliptic pin fin has better heat transfer than that with circular ones in the different Reynolds number range tested. Whole Reynolds number range of interest, the elliptic pin fin channel has much lower flow resistance as compared to the cylindrical pin fin. On the other hand straight rectangular fin transfer of heat much lower as compare to elliptical and cylindrical shape pin fin but the performance of straight rectangular fin can be improve by reducing the weight of the fin. By providing cut on the tip the heat transfer rate per unit weight is improved significantly. For the cylindrical pin fin For both the configuration initial increase in nusselt number for the first three to five row at all reynold number then there is gradual decline in following row.The heat transfer rate for small steamwise spacing is earlier as compared to larger steamwise spacing. For the elliptical pin fin both configuration the heat transfer rate on the pin fin as compare to endwall is higher at the same Reynolds number. At the lower Reynolds numbers the difference is quite large but with the increase of Reynold number the difference decreases quickly. From the experiment it clearly seems that the heat transfer coefficients of ducts with elliptic pin fins are higher than those with circular shaped pin fin. If we providing the additional cut or hole on the elliptical or cylindrical pin fin the heat transfer rate is increases due to the the reduction in per unit weight. There is also decrease in pressure drop due to less flow resistance.

5 References

[1] G. Theoclitus, "Heat Transfer and Flow Friction Characteristics of Nine Pin-Fin Surfaces," ASME JOURNAL OF HEAT TRANSFER, 1966, pp. 385-390. (Book style).

[2] W.P. Damerow, J.C. Murtaugh, and F. Burggraf, "Experimental and Analytical Investigation of the Coolant Flow Characteristics in Cooled Turbine Airfoils,"NASA CR-120883, 1972. (Book style).

[3] G.J. VanFossen, "Heat Transfer Coefficients for Staggered Arrays of Short Pin Fins," ASME Paper No. 81 -GT-75, Mar. 1981.

[4] D.E. Metzger, R.A. Berry, and J.P. Bronson, "Developing Heat Transfer in Rectangular Ducts with Staggered Arrays of Short Pin Fins," *ASME Journal of Heat Transfer, Vol. 104, 1982, pp. 700-706.*R.

[5] E.M .Sparrow, et al., 1991. Pressure drop characteristics of heat exchangers consisting of arrays of diamond-shaped pin fins, Int. J. Heat Mass Transfer 34, 589-600.

[6] T.Ota, .et al., 1984. Heat transfer and flow around an elliptic cylinder, Int. J. Heat Mass Transfer 27 (10), 1771-1779.

[7] Q. Li, Z. Chen, U. Flechtner, and H. J. Warnecke, "Heat transfer and pressure drop characteristics in rectangular channels with elliptic pin fins," *Int. J. Heat Fluid Flow*, vol. 19, no. 3, pp. 245–250, 1998.

[8] E.R.G.Eckert, and Drake, *8,* M., Jrr., ***Analysis of heat and mass transfer, pp. 82-90,*** McGraw Hill, New York, 1972.

[9] K.A. Gardner, Efficienq of Exteraded Surface, *Trans, ASME**, vale 63,* ***pp.*** *621-631, 1945*.

[10] B. V. S. S. S. PRASAD and A. V. S. S. K. S. GUPTA, "Note on the Performance of an Optimal Straight Rectangular Fin with a Semicircular Cut at the Tip," *Heat Transf. Eng.*, vol. 19, no. 1, pp. 53–58, 1998.