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Analysis of an Elliptical Pin Fins Array for Further Improvement in Performance

L. Rajeshwar Rao[1], S. S. K. Deepak[2]

[1]M.Tech Student, Department of Mechanical Engineering, Rungta college of Engineering and Technology, Raipur, India

[2]Assistant Professor, Department of Mechanical Engineering, Rungta college of Engineering and Technology, Raipur, India

Abstract: ***In a gas turbine, airfoil cylindrical pin fin have been utilized extensively for internal cooling but in a past few decades, lots of efforts have been made by different researchers to study different fin array configurations. This research paper is about analysis of elliptical pin fins array for further improvement to perform. Heat transfer coefficient and flow resistance (pressure lose) are the important parameters which have been consider for any improvement in fin effectiveness. This paper is about review the previous research work on elliptical pin fins and also made some geometrical recommendation for the improvement of the fin overall effectiveness.***

Keywords: Elliptical pin fin, heat transfer coefficient, pressure loss, streamwise

1. Introduction

Staggered pin fins array are most commonly used in many thermal systems application to increase the heat transfer capacity at low pressure drop and thus to reduce the heat exchangers size. Fins are mostly used extended surfaces from an object to increase the heat transfer rate to or from the boundary by convection. The rate of heat transfer of an object can be determines by determining the rate of conduction, convection, or radiation. Fins increase the heat transfer rate by increasing the surface area of the object or by increasing the temperature gradient between the object and surrounding. Fins also increase the convective heat transfer coefficient. Now a day there is a need of small size, effective and energy efficient pin fin heat exchanger in electronics component for increase of heat production rate. The major factor which is considered during the designing of all type of heat exchanger is heat transfer and pressure loses.

Different techniques have been adopted by different researchers during the last few years to enhance convective heat transfer. Sparrow *et al.* [1] experimentally investigated the pressure drop characteristics of diamond shaped pin fin arrays, which were used on the space shuttle flight. Dewan *et al.*[2] showed the effect of pin fin spacing and material on performance of fin heat exchanger. Bergelin *et al.* [3] showed that in range 200 < Re < 5000, the flow which is selected should be considered in transition regime, while it is laminar below 200. Sahiti *et al.* [4] showed that the best fin configuration for the overall performance of the straight elliptical pin fin under the fully developed laminar flow conditions. Sahin *et al.* [5] experimentally studied the heat transfer enhancement and corresponding pressure drop over a flat surface equipped with circular cross section perforated pin fins in a rectangular channel. The rectangular channel with a cross section area of 100–250 mm2, for optimum design parameter Taguchi experimental design method was used. Results showed that the use of circular cross-section pin fins array may lead to increase of heat transfer and the optimum result were found for a Reynolds number of 42,000, fin height of 50 mm and streamwise distance between fins of 51mm.

Using the k–ε turbulence model, Yue-Tzu *et al.* [6] performed numerical simulation of a heat sink with fins of non-uniform height with a confined impingement cooling to examine the effects of the fin shape of the heat sink on the thermal performance. They considered *Re* of 15,000 and 25,000 and 12 non-uniform fin height designs. Their results showed that by increasing the fin height near the center of the heat sink the junction temperature can be reduce. Yang *et al.* [7] performed an experimental study of pin fin heat sinks having circular, elliptic and square cross-sections both for inline and staggered arrangements. In the staggered array geometry, by rise of fin density for all three configuration the heat transfer coefficient also increased. The elliptic pin fin showed the lowest pressure drops. For the same surface area at a fixed pumping power, the elliptic pin fin possessed the smallest thermal resistance for the staggered arrangement. The flow over tube banks with more than 16 rows is considered to be fully developed [8].

Moshfegh and Nyiredy [9] compared five different turbulence models for pin fin heat sinks, namely, the standard k-ε model, RNG k-ε model, the realizable k-ε model, the k-ω model, and the Reynolds stress transport model. Dewan *et al.* [10] compared the numerical results with the experimental data reported in the literature for circular pin fin heat exchanger and a good agreement was obtained using the RNG k-ε turbulence model with the standard wall functions. Elyyan *et al.* [11] performed a detailed computational investigation of heat transfer increase from dimpled fins using direct numerical and large eddy simulations over a wide range of Reynolds number covering laminar, transitional and turbulent flow regimes.

Experiments were carried by Uzol *et al.* [12] for investigation of the wall heat transfer enhancement and total pressure loss characteristics for two alternative elliptical pin fin arrays and the results were compared with the conventional circular pin fin arrays.

2. Experimental Setup and Technique

Q. Li, Z. Chen el al. [13] 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.

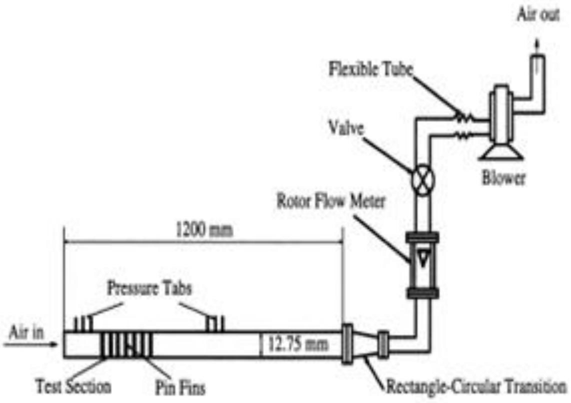

Fig. 1 Wind Tunnel System

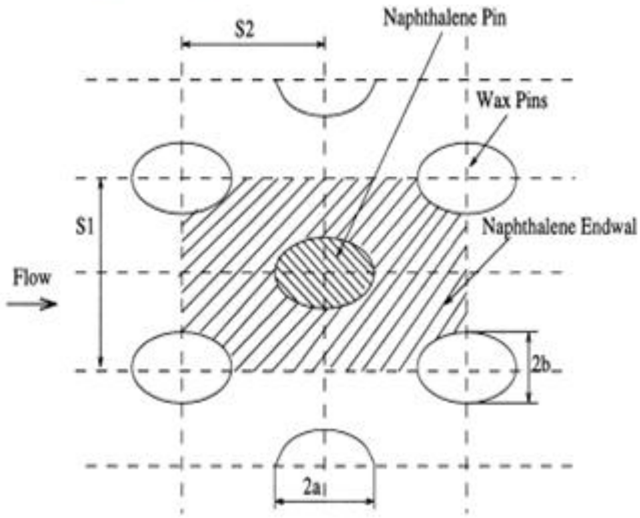

Fig. 2 Configuration of elliptical pin fin and their arrangement

The configuration for elliptical shaped fin are taken by the Q. Li, Z. Chen el al. [13] 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 technique only one pin fin is made of naphthalene and other are made of wax. In these experiment both either the naphthalene 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 micro-manometer 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.

3. Procedure

1) Q. Li, Z. Chen el al. [13] is employed the naphthalene sublimation technique in the research. In the naphthalene sublimation technique the pin made of naphthalene always placed in the middle of array of 10 row pin fin for every test run and pin fin are made of wax which is shown in fig. 2.
2) For manufacturing the pin fins, special designed steel mould has been used. In these mould melted analytical naphthalene (or wax) was poured that had been painstakingly fabricated in order to provide casting with very smooth surfaces.
3) After cooling down the pin fin specimens are formed. In this technique we are measuring the mass loss before and after a test run so that can achieve the mean heat transfer coefficients can be achieved by heat/mass transfer analogy. According to its symmetry, the local modeling method is adopted in the experiment and the mass transfer is confined to the oblique line area of Fig. 2.
4) So that these experimental results can only be used for fully developed flow cases and not for the arrays with only a few pin fin rows.

4. Experimental Result and Discussion

Result data taken from the Qingling el al. [13].The compact pin fin array ($S1/D\pi = S2/D\pi = 1.1$) has higher heat transfer coefficients than the other at the same Reynolds number. For the two arrangements, the experimental data in Reynolds number range from 1000 to 9000 can be well represented by two least squares fits. Nusselt number at pin finwall versus Reynold number shown in fig 3.

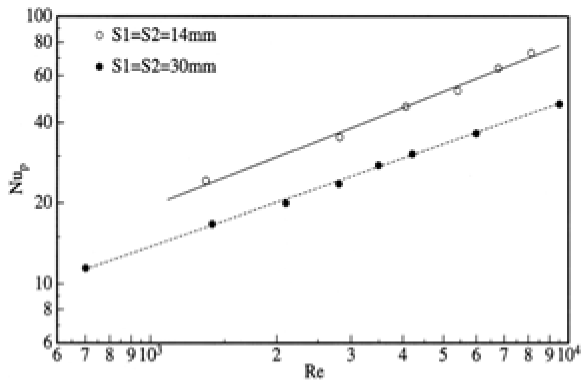

Fig. 3. Nu_p versus Re.

There is also the compression between Metzger et al. [14] cylindrical pin fin array and Q. Li, Z. Chen el al. [13] shown in fig 4. Which is shows that elliptical pin fin is higher heat transfer coefficient as compare to cylindrical pin fin array.

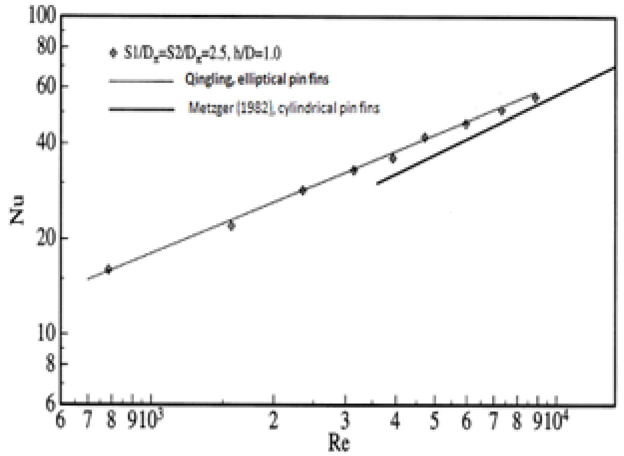

Fig. 4 Comparison of Nu with Metzger et al. (1982).

5. Conclusion

The configuration with elliptical channel shows the better heat transfer characters then the cylindrical channel in the same Reynolds number range. Over the whole Reynolds number range of interest, the elliptic pin fin channel has much lower flow resistance than that with circular pin fins. With the help of naphthalene sublimation technique we can easily find out the heat transfer characteristics for finwall and endwall separately. The arrangement of pin fins affects both heat transfer of pin fins and that of the endwall. The more compact pin fins arrays have higher heat transfer rate for the relative pitches investigated.

6. Recommendation

As we know that the heat transfer coefficient from finwall much higher then the endwall surfaces so by providing through hole in the elliptical fins the contact area between fluid flow and finwall will be increases. So that will increase the overall heat transfer coefficient. The other important factor for selection of any heat exchanger is pressure loss. With slotted elliptical pin fins resistant offering to fluid is decreases i.e. fluid can easily flow through fins and hence pressure loss decreases. Recommendation is that if use slotted elliptical pin fins in place of solid elliptical pin fin, the heat transfer coefficient increases and pressure loss decreases.

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