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A STUDY ON CONVECTIVE HEAT TRANSFER ANALYSIS IN DROP SHAPED FINS

Dr. S.B.PRAKASH Mr. MANU.G.
Department of Thermal Power Engineering
VTU PG Studies, Mysuru-29 Karnataka

ABSTRACT: *This paper presents an experimental investigation on fluid flow and temperature distribution characteristic of drop shaped fins (solid and perforation) in a rectangular channel. Quite a few different geometries of arrangements are considered by changing the arrangement in transverse to air flow direction and it is compared with inline arrangement. The Reynolds number is varied by considering the obstruction along the air flow direction (hydraulic diameter). In the current experiment Reynolds number varied from* $30000 < Re < 60000$ *and the inter fin spacing ratio* $S_L/D=3.5$ *and* $S_T/D=1.7$*. The heat transfer rate in drop shaped fins is quite less as compare to cylindrical fins due to delay in boundary layer separation simultaneously the pressure drop is decreased due to more streamlined flow along the fins surface and avoid the formation of wakes at the trailing edge of the fins. The heat transfer enhancement in staggered arrangement is much better than inline arrangement. In terms of specific parameters the drop shaped fins are shows potential alternative to cylindrical fins.*

KEYWORDS: *Heat Transfer, Fins, Reynolds number,*

I. INTRODUCTION

Normally engineering devices produce the heat during operation, due to that the temperature of the device increase due to that overheating of the system takes place and efficiency of the device may got reduced or failure of the system takes place, in order to overcome this problem the heat should be rejected to surrounding atmosphere for the efficient function of the system. The convection method is commonly used in electronic devices in order to increase the heat dissipation heat transfer coefficient may increased or wetted surface area will be increased. Usually engineering solution concentrate to increase surface area of exposure in order to do that extended surfaces (Pin fins) are commonly used.

In current trends there has been great demand for high performance, lightweight, compact, and economical heat transfer components. The fins are recognized as one of the most effective means of increasing the heat dissipated. The design criteria of fins are different for various applications, but the primary concern is weight and cost. Therefore it is highly desirable to optimize the size of fins. The optimum dimensions are those for which maximum heat is dissipated for a given weight or mass of the fin.

Fins are extensively used in cooling of computer processors, air craft engines, air cooled automobile engines, cooling of generators, motors, transformers, refrigerators and other electronic devices etc. While selecting of fins geometry plays an important role in the dissipation of heat.

II EXPERIMENTAL METHODOLOGY

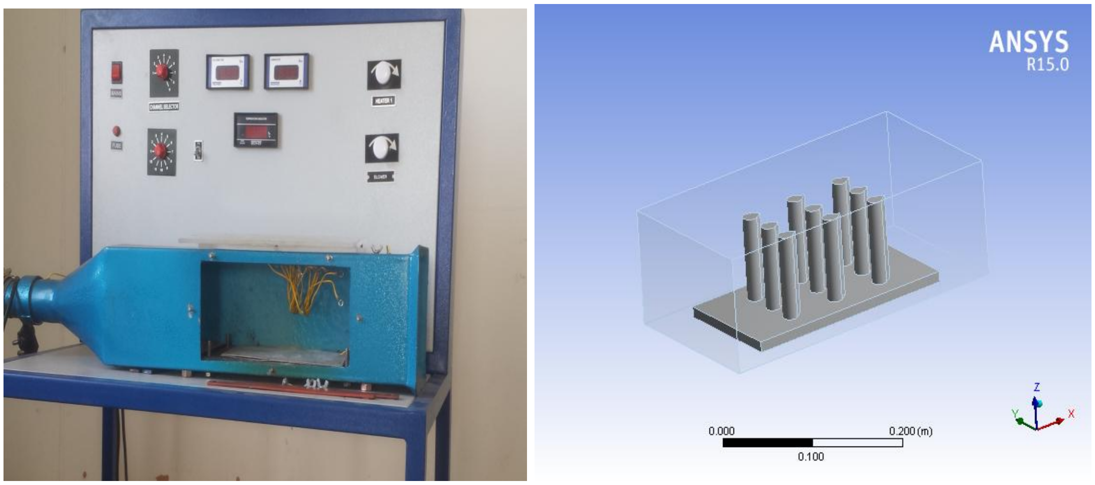


Figure 1: Experimental setup and fin model

Figure shows the experimental setup which comprises a blower, a rectangular channel with hydrodynamic developing section a test section and an exit section. Air is forced through the blower (velocity 3m/s to 5m/s and temperature 30^0c) and enters into the test section. The velocity of the air is measured by anemometer at the inlet section and simultaneously at the exit of the test section. The test section having rectangular cross section has a width of 150mm and a height of 150mm. The test section made up of 8mm thick transparent plate. It has a length of 600 mm to house three rows of pin fins set up with axes perpendicular to the direction of flow in a fixed inline and staggered array Figure 1. The stream wise and span wise pitches are S_L/D= 3.5mm and S_t/D=1.7mm, respectively. The pin fins are made of Aluminium 6063 has commercially available.

Two thin heater sheets with uniform resistance (100 mm wide, 100 mm long and 0.01 mm thick) covert each inner surface of two sidewalls. The pin fins are installed to be in contact with the heater sheet, with a thin mica sheet acting as an interface. Each heater sheet is equipped with two electrodes to provide controllable uniform heat flux. To reduce heat losses from the heater to the outside, the test section is insulated by a 20 mm thick asbestos shroud. The exit section length is 150 mm to allow free expansion of the flow and is insulated to reduce heat losses.

Twenty one thermocouples are mounted at the fin surface, base plate and inlet outlet of test section to measure the temperature distribution; because the properties of the fluid are taken to that temperature. The temperature could be considered to be practically uniform across the heating sheet thickness. These thermocouples are aligned in two rows.

III. RESULTS AND DISCUSSION

i). Flow of fluid on fin surface

The figure 1.2 shows the detailed velocity distribution on the fins in a rectangular channel, in cylindrical fins the early flow separation takes place due to adverse pressure gradient in the trailing edges of the fins, the separation of boundary layer is early in lower velocity, at higher velocity the delay in boundary layer separation because due to turbulent boundary layer processes a much greater momentum flow near the surface compared to the laminar boundary layer, the laminar boundary layer separates before equator of a cylinder ($\theta_{lam}=80^0$) and produce a wide wake, in turbulent flow the boundary layer separates downstream of the equator ($\theta_{tur}=140^0$) which is shown in the figure.

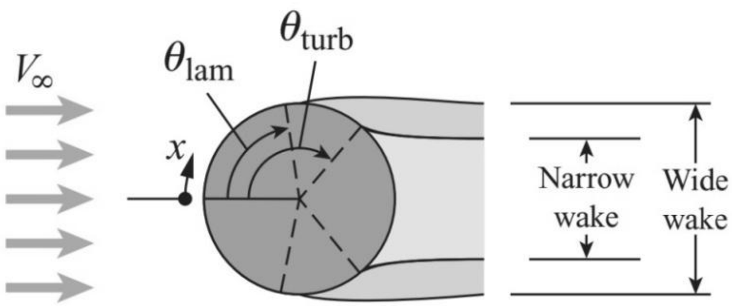


Figure 1.2: Boundary layer separation

ii).Flow Characteristic

Figure shows the detailed local vortices distributions on the mid-height plane of the flow channel for different pins. Two vertical structures dominated the vortices distribution: horseshoe and wake vortices. The occurrence of these vertical structures depends on the interaction of the primary flow and pin fins. Horseshoes are formed in the flow around a blunt body and roll up at the pin rim. Wakes are induced by flow separation when the windward flow is exposed to a blunt body and manifests near the trailing edge of a pin.

The horseshoe is a considerably smaller structure with a negligible effect on the aerodynamic penalty compared to wake vortices. As expected, the drop-shaped pin yields a reduced aerodynamic penalty compared to circular pins owing to its considerably weaker flow separation.

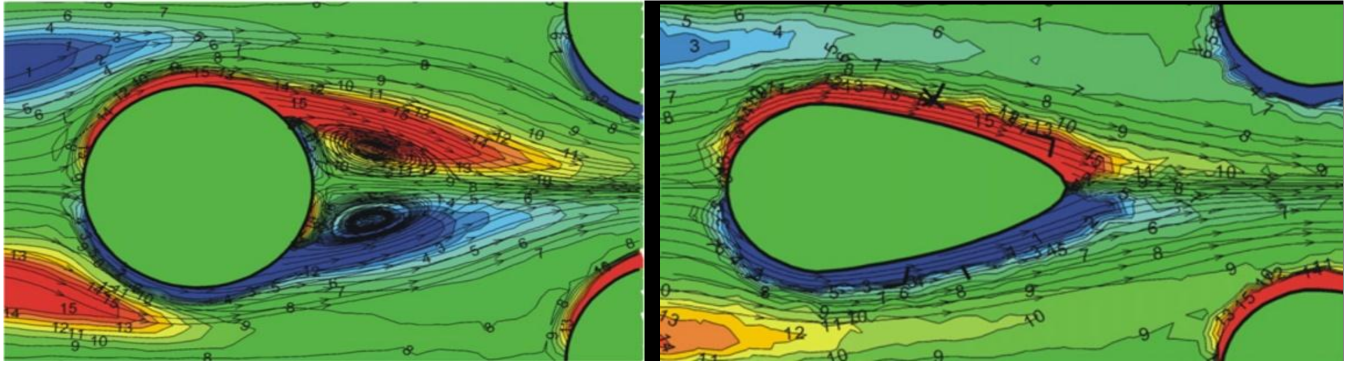
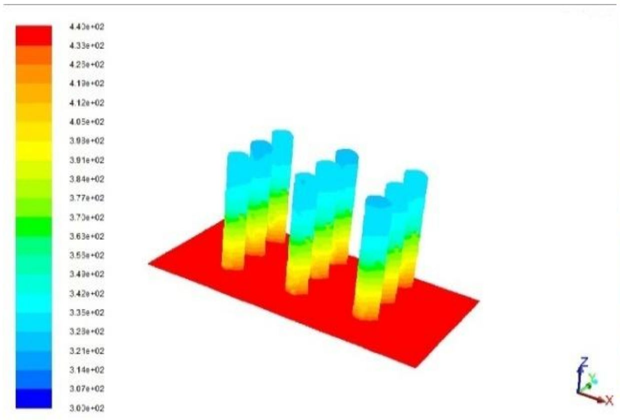
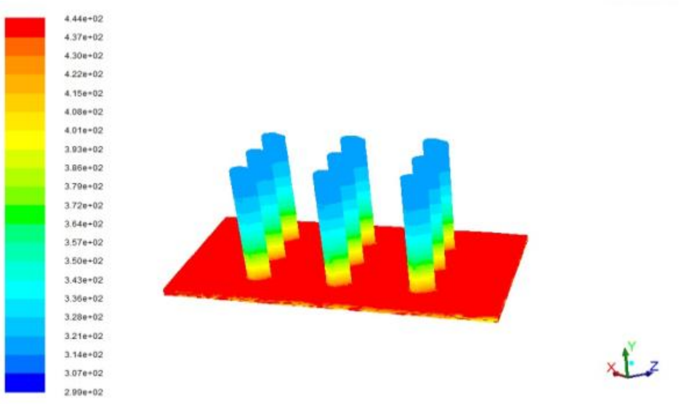


Figure 3: Boundary layer separation in Circular and Drop shaped structures

iii). Temperature contour plots:



a)



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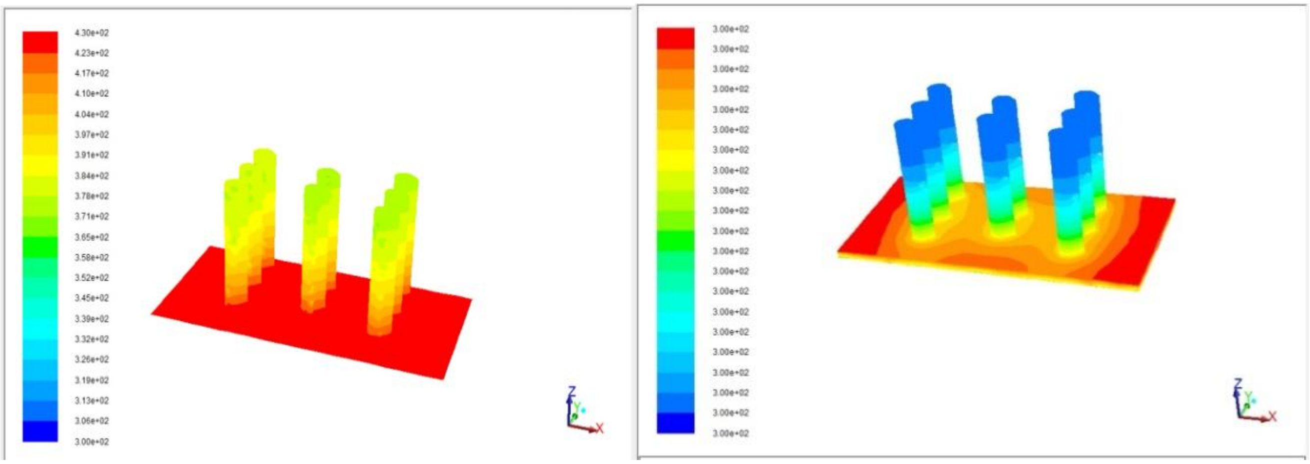

c) d)

Figure 1.3: Temperature contour plots of fin array. a) Solid fins with inline arrangement. b) Perforated fin With inline arrangement c) Solid fins staggered arrangement. d) Perforated fin with staggered arrangement.

Figure 1.3 shows Temperature contour plots of solid and perforated fins in inline and staggered

Arrangement done in ANSYS Workbench 15 CFD as a tool Solid fin shows higher temperature distribution as compare to perforated fins due to less contact surface area. In perforation fin with staggered fins gives best result of temperature drop along the fin length due to better circulation of air and delay in boundary layer separation.

iv). Heat Transfer

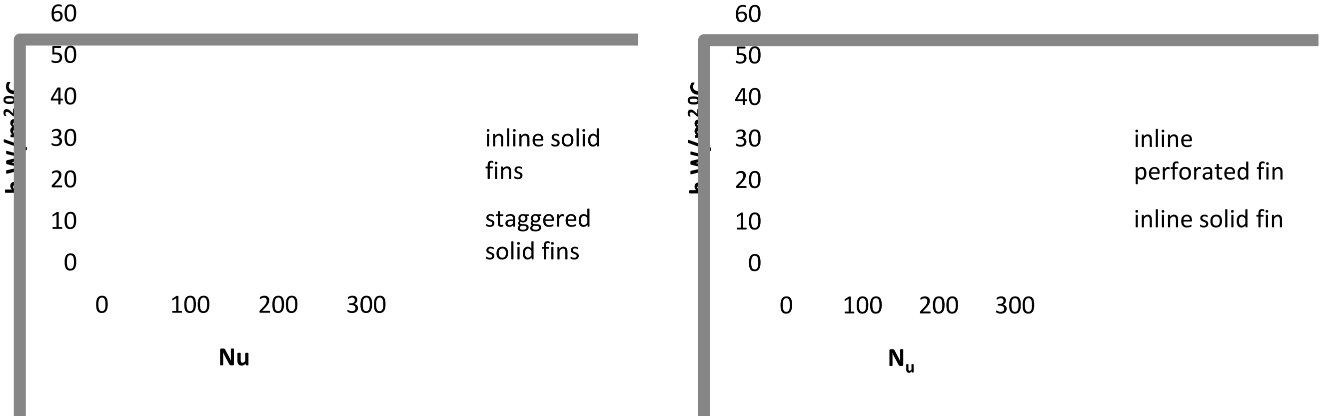

Figure 1.4: Relation between Heat transfer coefficient and Nusselt number

Figure 1.4: shows the relation between heat transfer coefficient and Nusselt number, solid fins with staggered arrangement shows better heat transfer compare to inline arrangement due to obstruction along the air flow in array of fins.

Fig 1.4 shows heat transfer coefficient and Nusselt number relationships in solid and perforated fins with inline arrangement. The perforated fins gives better heat transfer compare to solid fins due to increase in heat transfer area, so increase the number of perforation increase the heat transfer but it simultaneously increase the pressure drop.

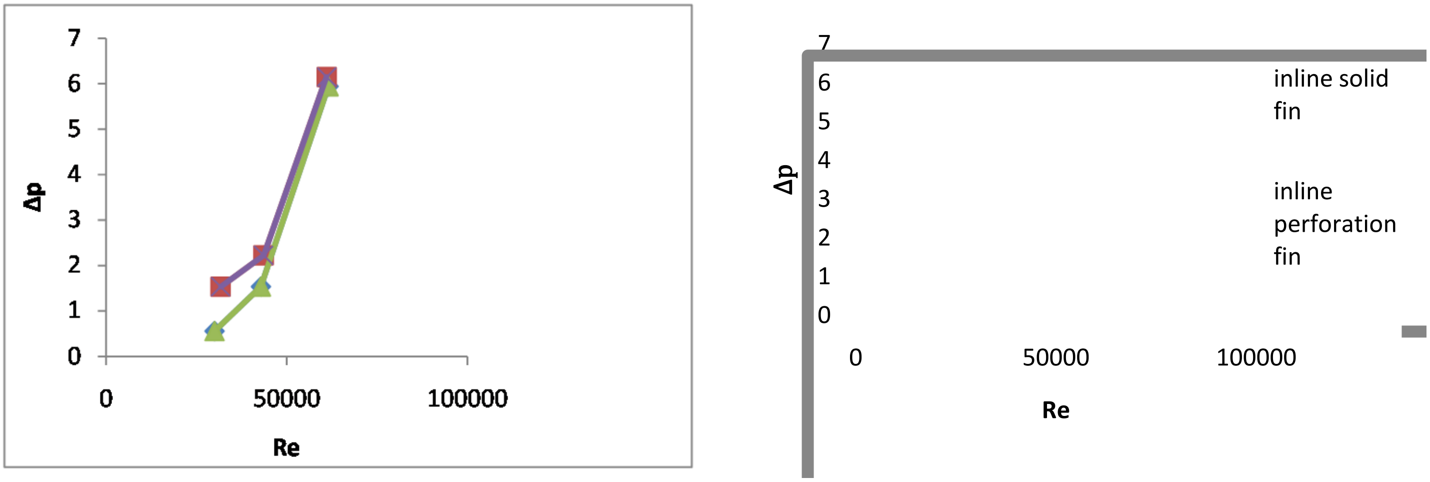

Figure 1.5: pressure drop V/s Reynolds number

Figure 1.5 shows the pressure drop across the fin array with Reynolds number in solid fin with inline arrangement shows less pressure drop compare to staggered arrangement due to streamlined flow across the pin fin array in inline arrangement.

Perforated fins having higher pressure drop along the fin array due obstruction in air flowing direction which enhance heat transfer but it increase the power density of the device

IV.CONCLUSION

This summarizes numerical and experimental results for research on the heat transfer and circulation of flow in a inline and staggered arrangement of fin array.

1) The more streamlined drop shape is delay in flow separation as compare to short trailing edge which reduces the aerodynamic penalty in the fin array which reduces the pressure drop along the streamlined direction.
2) The heat transfer in drop shape with perforation increase the heat transfer as compare to solid fins due to increase in surface area of contact region with air flowing media.
3) The friction loss around fin surface increased in perforated fins compare to solid surface due to obstruction in air flow in fin array.

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