Natural Convection Heat Transfer from Symmetrical Triangular Fin Arrays on Vertical Surface

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ABSTRACT

This paper deals with study of heat transfer characteristics of natural convection heat flow through vertical symmetrical triangular fin arrays. It was studied experimentally and its results were compared with equivalent rectangular fin arrays. In the experimental arrangement, spacing between fins was varied. Results were generated for $S^+ = 0.015, 0.03, 0.045$ & 0.105 and $Gr_H = 2*10^7$ to $5*10^7$. Average, base Nusselt number and Grashof number were calculated. It was observed that with increase in Grashof number, average and base Nusselt number increases. Similarly average Nusselt number increases with spacing whereas base Nusselt number increases to maximum value with spacing and then decreases [11].

Keywords: Fin arrays, Grashof number, Heat transfer, Natural convection, Spacing.

1. INTRODUCTION

Many proposed applications of electronic and thermo electric devices depend upon the feasibility of rejecting waste heat by economical, trouble free methods. For these applications better utilization of the available heat rejection area may be realized by the proper application of outstanding fins.

Fins are extended surfaces used to improve the overall heat transfer rate when it is limited by low rate between a solid surface and surrounding fluids. Fins provides larger surface area for heat dissipation. Fins are casted or fabricated by pressing, soldering or welding. Fins finds application in variety of fields of which some are-

(i)The heads and cylinders of the air cooled engines and compressors

(ii)Electronic components such as power diodes, transistors etc.

(iii)Tubes of various heat exchangers for example condenser tubes of domestic refrigerators, radiators of automobiles.

(iv)Outside surfaces of the cooling and dehumidifying coils in the air conditioning systems.

(v)Direct energy conversion devices.

(vi) Nuclear fuel modules.

(vii) Chemical and Cryogenic equipments.

(viii)Conventional furnaces and gas turbine

There are different types and shapes of fins used in practice. Fins are used on plane surfaces or cylindrical surfaces. Fins may be of having different cross sections. Depending on cross section we may have rectangular, parabolic or triangular fins.

The heat can be removed effectively if the fluid flow and the resulting flow pattern are capable of removing the heat efficiently. The heat dissipation from fins under natural convection condition depends on the geometry and orientation of finned surface.

The literature survey revealed that the problem of free convection heat transfer from vertical fin arrays has been investigated by a few investigators. Elenbass [1] had done extensive work on channels and parallel plates on experimental and semi-empirical basis. Starner and Mcmanus [2] presented free convection data for four rectangular arrays in three positions including vertical position for the fin base. Similarly experimental work for vertical fin arrays are carried out[3-8].Theoretical work on rectangular fin arrays for natural convection is also reported[9,10].

In the present work, experimental work on heat transfer in natural convection from symmetrical triangular fins on vertical surfaces was carried out. Then its comparison was done with equivalent

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rectangular fins arrays. In both cases spacing was the variable.

2. EXPERIMENTAL APPRATUS AND PROCEDURE

Natural convection heat transfer from the rectangular and triangular fin arrays is studied by varying the spacing and temperature difference for constant height and length of fins. It is seen from the literature review that spacing is a parameter of prime importance which affects the heat dissipation. Spacing ratio chosen for experimentation were 0.015,0.03,0.045 and 0.105 for symmetrical triangular and equivalent rectangular fin arrays. For carrying out experimental work, fin arrays were built by assembling separate spacer pieces and fin flats. Fin channels were formed by two fin flats separated by spacer.

2.1 Elements of fin array

The fin array was assembled by using following-

2.1.1 Fins

Fins were cut out a 3mm thick polished aluminum sheet. Holes were then drilled for cartridge heater and tie rods on the central rectangular portion. Fins of rectangular and symmetric triangular shape were cut.

2.1.2 Spacers

Spacers were also cut from aluminum sheet of 3mm thickness. Holes were drilled for the electrical cartridge heaters and tie rods. The dimensions of spacers were kept same as that of central rectangular portion fin. It forms the base.

2.1.3 Heaters

Cylindrical cartridge heaters of mild steel were used. The power output of one heater was 200 W at 230 V. Three such heaters were used for heating fin array.

2.2 Instrumentation

A.C. supply was used for the heater through a dimmer stat so that the input can be varied. The input was measured with the help of wattmeter. Four iron-constantan thermocouples were used to measure the temperature. Three thermocouples were connected at different points of fin array. Two ends of each thermocouple were connected to two opposite end of the tie rod to give average temperature. Fourth thermocouples were used for measuring the ambient temperature.

2.3 Procedure

Fin spacing and temperature differences were the parameters chosen. For a given spacing different temperature difference was obtained. For different spacing, heat input used was measured by wattmeter. All the readings were taken for the steady state. The performance of the symmetrical triangular fins was then compared with rectangular fin array of equivalent area.

3. DATA REDUCTION

The heat input to fin assembly is calculated by neglecting radiation losses and fin edge losses [6] with expression-

$$q = V*I$$

The heat transfer coefficient on the fin surface is determined by considering total fin area and projected base area -

$$h_a = q/(A_T*\Delta T)$$

$$h_b = q/(A_b*\Delta T)$$

The Nusselt number based on area is given by-

$$Nu_a = h_a *H /k$$

$$Nu_b = h_b * H /k$$

The Grashof number for air fin assembly is determined by-

$$Gr_H = (g* \beta*\Delta T * H^3) / \upsilon^2$$

4. EXPERIMENTAL RESULT AND DISSCUSSIONS

The experimental results are expressed in terms of average and base Nusselt number and their variation with fin spacing and Grashof number for studying the heat transfer characteristics for fin assembly..

4.1 Effect of Grashof Number Nu_a

Fig.1 represents the variation of average Nusselt number with Grashof number for vertical symmetrical triangular and rectangular fin arrays. It can be seen that with the increases in Grashof number, average Nusselt number increases for a given spacing. The increase in average Nusselt number for symmetrical triangular fin arrays is more than the equivalent rectangular fin array. It is also observed that value of average Nusselt number are higher for larger spacing ratio S^+.

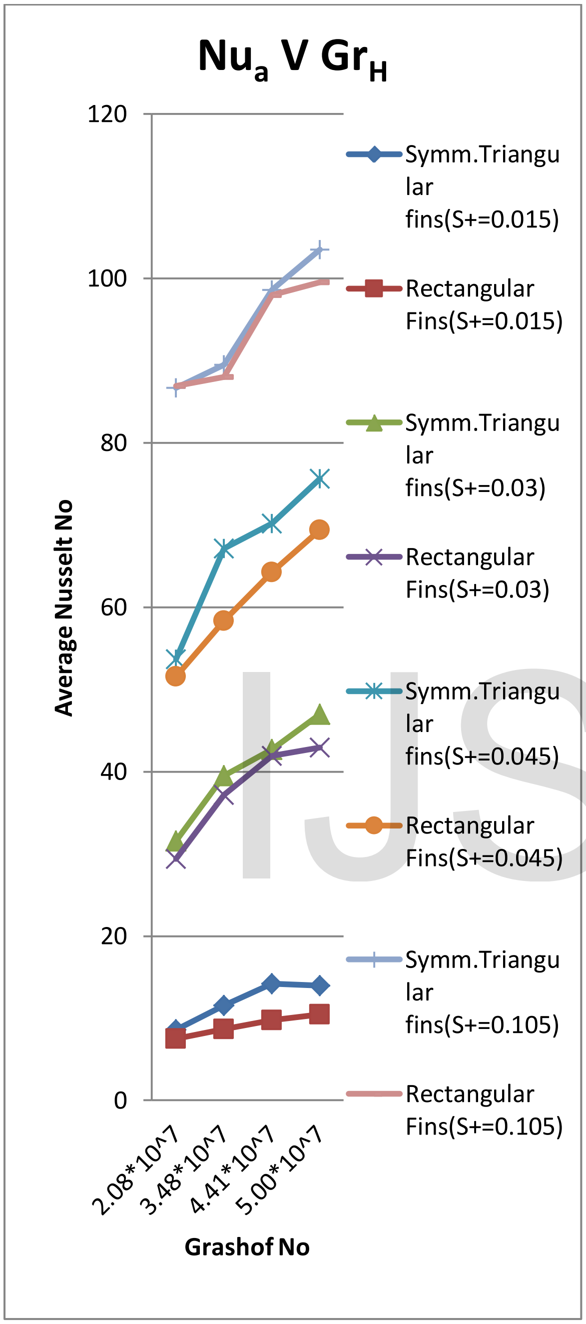

Fig.1 Variation of Average Nusselt number with Grashof number

4.2 Effect of fin spacing on Nu_a

For a given Grashof number variation of average Nusselt number with fin spacing for symmetrical triangular and rectangular fin arrays is shown in Fig.2.. It can be observed that average Nusselt number increases with fin spacing. The increase in average Nusselt number is more when fin spacing range is lower than when it is higher. Again symmetrical triangular fin arrays gives higher values of average Nusselt number than rectangular fin arrays.

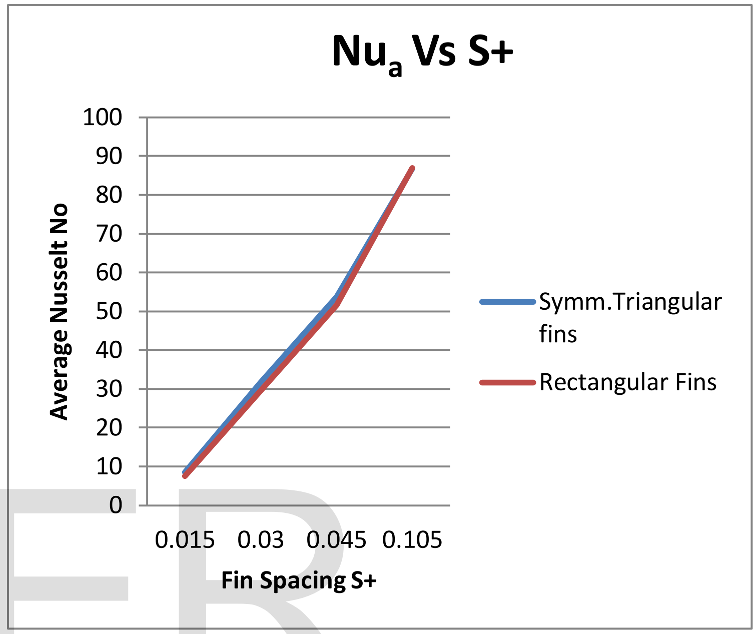

Fig.2 Variation of Average Nusselt number with Fin spacing for $Gr_H=2.08*10^7$

4.3 Effect of Grashof number on Nu_b

Fig.3 represents variation of base Nusselt number with Grashof number. Base Nusselt number increases with increase in Grashof number for both the type of fin arrays. The values of base Nusselt number are higher for symmetrical triangular fin arrays than rectangular fin arrays.

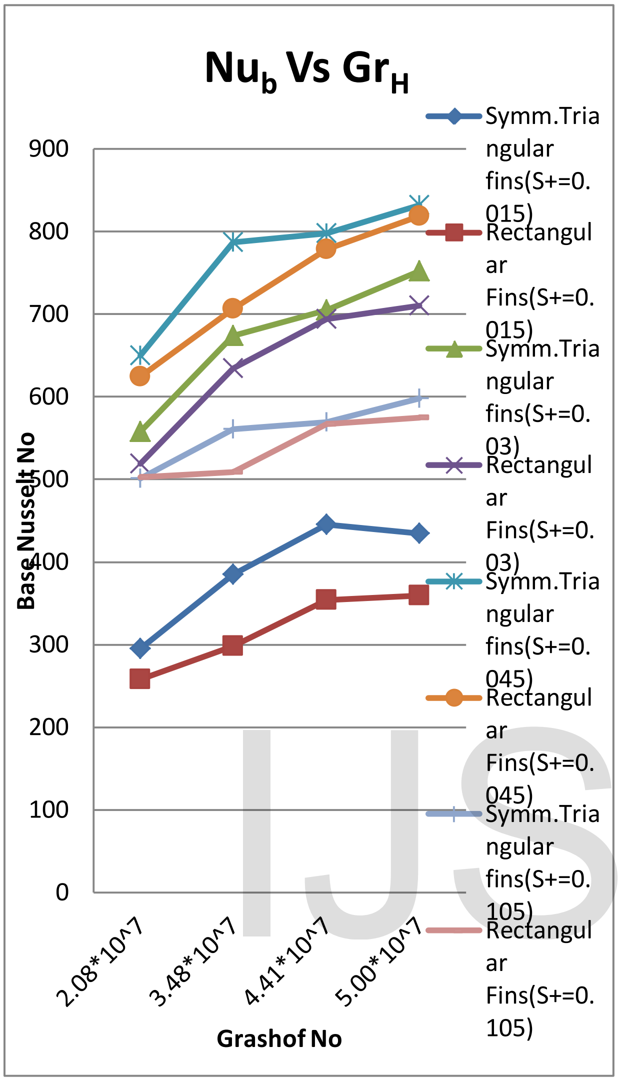

Fig.3 Variation of Base Nusselt number with Grashof number

4.4 Effect of fin spacing on Nu$_b$

Fig.4 represents variation of base Nusselt number with fin spacing for both type of fin arrays. It can be seen that as the fin spacing is increased, base Nusselt number increases for certain fin spacing range which is called as optimum fin spacing range. After optimum fin spacing range when fin spacing is further increased there is decrease in value of base Nusselt numbers. A symmetrical fin array provides better performance over equivalent rectangular fin arrays.

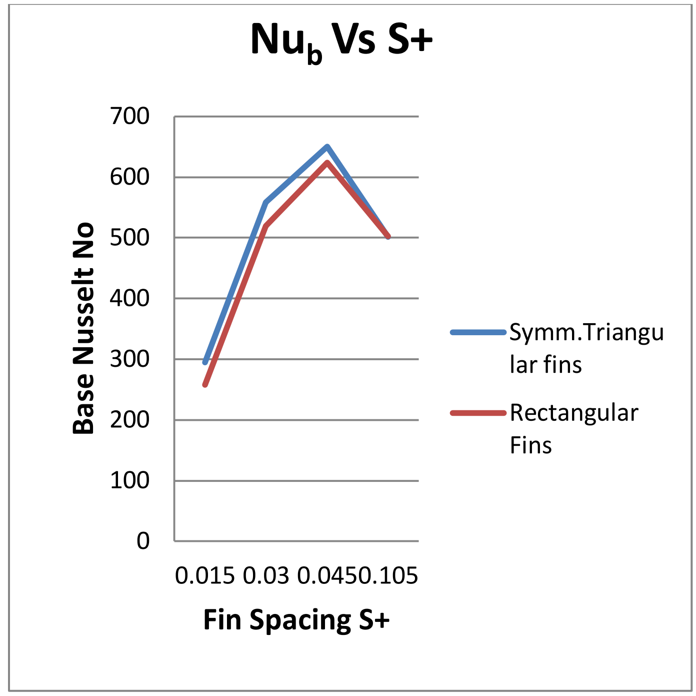

Fig.4 Variation of Base Nusselt number with Fin spacing for Gr$_H$=2.08*10^7

5. CONCLUSION

It is observed that parameters like spacing and Grashof number plays vital role in improving the heat transfer characteristics of fin arrays. Symmetrical triangular fin arrays on vertical surface has provided increased average and base Nusselt number over the equivalent rectangular fin arrays. Base Nusselt number increases with spacing for both triangular and equivalent rectangular fin arrays to a certain value called optimum spacing then there is drop in it for further increase in spacing. Overall heat transfer characteristics of symmetrical triangular fin arrays are better than rectangular fins.

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NOMENCLATURE

A Area,m^2

Gr_H Grashof number

g Acceleration due to gravity, m/s^2

h_a Average heat transfer coefficient/ m^2K

h_b Base heat transfer coefficient, W/ m^2K

I Current ,amp

K Thermal conductivity of the air, W/ m K

L Length of fins, m

L^+ L/H, length to height ratio

Nu_a Average Nusselt number

Nu_b Base Nusselt number

q Heat input, W

S^+ S/H, spacing to height ratio

S Spacing between the fins

ΔT Temperature Difference(T_m-T_{amb}),K

V Voltage, volts

Greek Symbols

β Volumetric expansion coefficient,K^{-1}

μ Dynamic viscosity of air, N-s/ m^2

ν Kinematic viscosity of air ,m^2/s

ρ Density of fluid air, kg/m^3

Superscripts/Subscripts

a Average value

amb Ambient value

b Base value

H Height of fins, m

m Mean film

T Total

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