Effect of Fin Array Parameters on Variation in Heat Transfer Coefficient for Natural Convection in Fin

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Abstract:- Fins are usually analyzed by assuming uniform heat transfer coefficient model on its surface. However, studies by various investigators revealed that it is not constant but varies along the fin length. It is mainly because of non-uniform resistance experienced by the fluid flow in the inter fin region. Obviously, this variation is functions of fin array parameters such as inter fin spacing (S), fin height (Hf) & fin tip clearance (C) as they largely influence the resistance to the fluid flow. The objective of the present work is to establish experimental relationship between the variations in the heat transfer coefficient along the fin height (Length) with respect to the fin array parameters fin spacing (S), fin height (Hf) & fin tip clearance (C). Experiments were performed for five different values of inter fin spacing (S) and tip clearance(C) and best fit curve of the type $h = ax^n$ was obtained. The values of 'a' and 'n' were then correlated with the appropriate dimensionless fin array parameters thus variation in the heat transfer coefficient with respect to the fin array parameters is obtained It is found that average heat transfer coefficient varies hyperbolically (for constant clearance C= 6) with respect to S/Hf Also the value of n is fairly constant at 0.065 while value of a is decreasing as (S) inter-fin spacing is increasing indicating that the average value of 'h'also decreases with increase in 'S'. It is found that average heat transfer coefficient varies parabolically (for constant inert-fin spacing S= 5.5cm) with respect to C/S with minima occurring around C/S =0.55 Also the value of n is decreasing with increasing clearance and at C=6it again increases indicating rise in heat transfer coefficient

Keywords: Fin array, heat transfer coefficient, clearance, inter fin spacing

1 Introduction

Fins are commonly used for enhancing the value of heat transfer from a surface to the surrounding fluid .They is usually analyzed assuming uniform heat transfer coefficient (h) along its length. However studies by different investigators [1, 2, 3] indicate that heat transfer coefficient is not constant but varies along the fin length. Typical variation is as shown in figure 1 .It can be seen from the figure that the value of heat transfer coefficient is low at the fin base and increases towards the fin tip .This variation is mainly because the fluid experiences more resistance near the fin base region than near the fin tip .thereby causing low fluid velocity in fin base region as compared to the tip region .obviously the nature of variation is a function of fin parameters such as inter fin spacing (S) ,fin height (H_f) and fin tip clearance (C).However in literature survey ,the dependence of the variation in the heat transfer coefficient with respect to these parameters have not been reported so far .Hence the work is undertaken

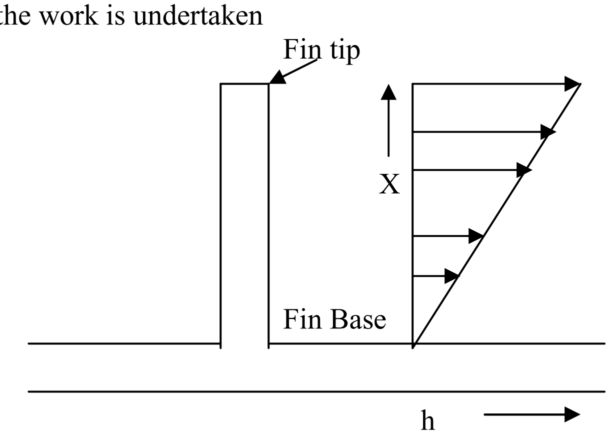

Fig.1 Variation in 'h' along the fin length

2 Problem Formulation

It is proposed to establish experimentally expression for variation in the heat transfer coefficient along the fin length with respect to fin array parameters for natural convection mode of heat transfer. An experimental set up was fabricated for the purpose Air was working fluid and variation in the heat transfer coefficient was found to be of the type $h= ax^n$ where a and n are constants and are found out from the best fit curve .

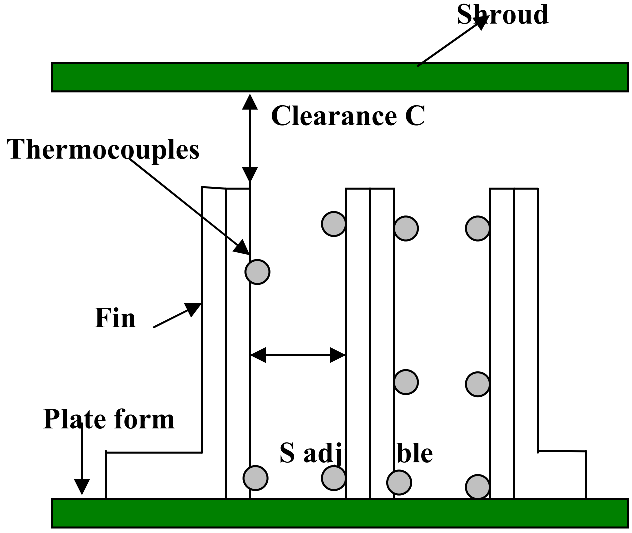

Fig. 2 (a) Experimental set up (schematic)

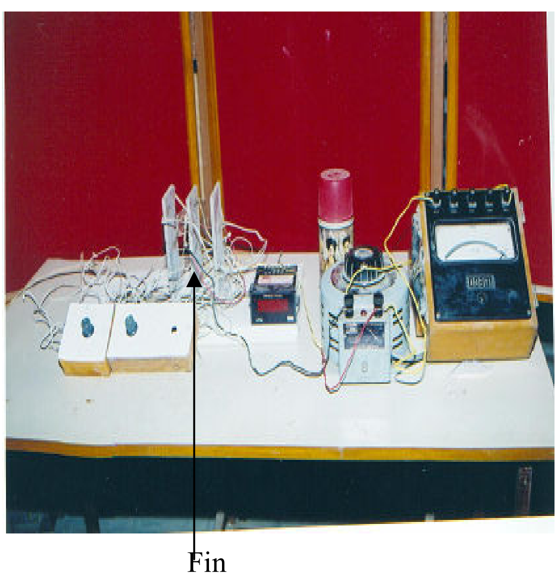

Fig.2 (b) Photograph of Experimental set up

3. Experimental Set Up

The experimental set up (see fig.2 (b)) comprise of rectangular fin array assembled appropriately to vary the spacing between them. They are embedded with electric heaters and designed to produce uniform heat flux condition on its surface .Thermocouples are mounted the fin surface to measure temperatures at five different locations along the plate height Air is working fluid and plates are dissipating heat by natural convection dimensional details of set up are as below.

3.1 Fin structure

Fin is basically consisting of Al plates, mica cover sheet with electric heater riveted together at four corners of the plates as shown in fig.3.

There are 3 such fins in experimental set up. Grooves were cut on Al plate on the external side along width of the plate for thermocouple mounting regulated electric supply was given to the fin and hence constant heat flux condition is achieved

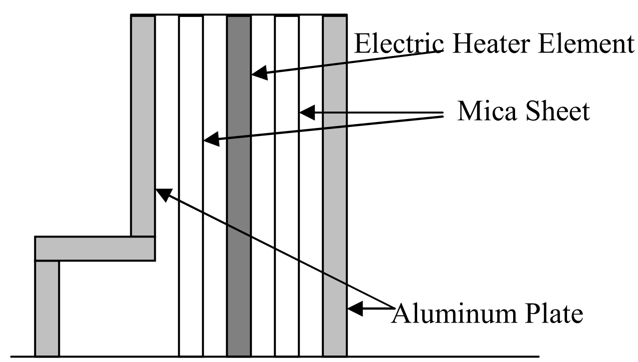

Fig.3 Fin Structure

4 Experimental Methodology

The procedure consists of first fixing up the spacing between the fins and supplying a stabilized power input to the fins. The radiative heat exchange between fins will raise the temperature and build up the natural convection boundary layer on the surface of fins whose strength depend strongly on emissivity of fin and to a smaller extent emissivity of surrounding fins. These in turn affect the radiative heat transfer rate between the tins. Thus making the problem conjugate one. The measurements will be done when steady state is reached. Experiment will be repeated for a different power input i.e. for different temperature. Here the experimentally determined values of heat transfer coefficients found will

be compared with those predicted by correlation. Experiments will be performed for different values of interfin spacing (S) and the tip clearance (C). For a given value of Sand C and under steady state condition, local heat transfer coefficient at five different location will be calculated and best fit curve of type $h = ax^n$ is expected to be obtained. The values of the constant 'a' decides the magnitude of heat transfer coefficient and are expected to be different for different fluids whereas the constant' n' decides the nature of variation in the heat transfer coefficient on the fin surface and is expected to remain same for all fluids. The values of 'a' and 'n' will be correlated with the appropriate dimensionless fin array parameters, thus variation in the
heat transfer coefficient with respect to the fin array will be analyzed

5 Data Reduction

Heat loss by natural convection is given by
$Q = hj\ Aj\ (\Delta T)j$
$(Q/A)\ j = hj\ ((\Delta T)\ j$

hj = experimental heat transfer coefficient
Where Q= Heat supplied W watt (a measured parameter)
(ΔT) j= temperature location j on the fin and the corresponding temperature in the inter fin spacing (a measured parameter)

Knowing Q ΔT, A we can find out
$hj = [(Q/A)/(\Delta T)]j$ Characteristic curve between hj vs x is drawn and the best fit curve of the type h j vs. a x^n

Theoretical Heat Transfer Coefficient h is estimated using corerelation for contant heat flux condition:-
$Nu = 0.60\ (Gr\ Pr)^{1/5}$ $\quad 10^5 < Gr\ Pr < 10^{11}$
$Gr^* = Gr\ Pr$
$h_{th} = Nu * K/L$

Heat transfer coefficient theoretically and experimentally were found comparable and set up is validated

6 Results and Discussion

Table 1 Variation in heat transfer coefficient for C= ∞ and different interfin spacing

Interfin spacing (S)	C	S/H_f	h experimental = ax^n
2.5 cm	∞	0.154	$h = 20.4\ x^{0.066}$
3.4 cm	∞	0.209	$h = 14.41\ x^{0.0652}$
5.5 cm	∞	0.339	$h = 11.25\ x^{0.0652}$
6.5 cm	∞	0.4612	$h = 10.48\ x^{0.04}$

for C=∞ and S = 2.5cm, 3.4 cm, 5.5 cm, 6.5 cm .It can be seen that variation in heat transfer coefficient is similar in all cases and is parabolic over the fin surface length .
The best fit curve for each of the spacing is given in Table 1

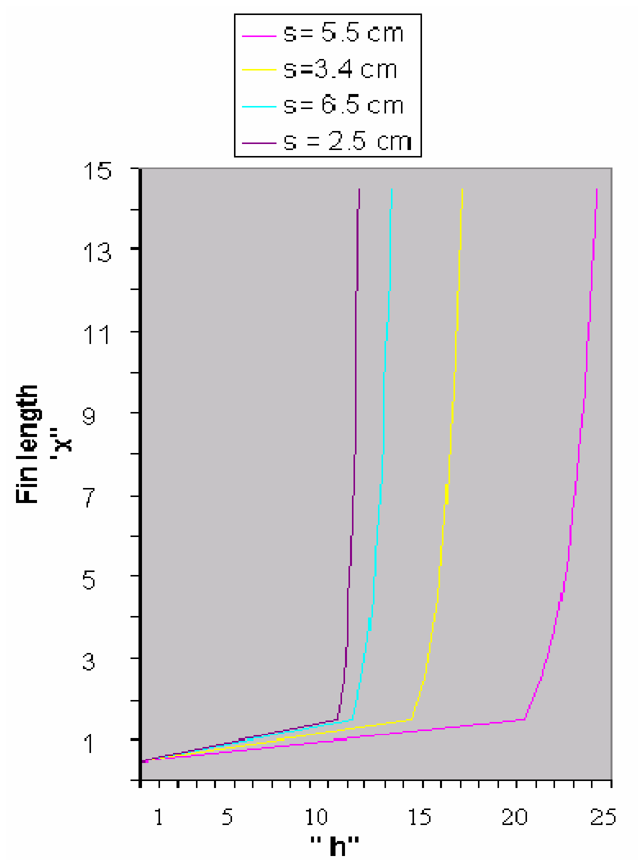

Fig. 4 Variation in “h” along fin length for different Inter-fin Spacing (For C= ∞)

Table 2 Variation in heat transfer coefficient for S= 5.5cm and different clearance

Clearance C	**Interfin spacing (S)**	**C/S**	**h experimental = ax^n**
0	**5.5 cm**	**0**	**h= $7.788\ x^{0.0655}$**
1 cm	**5.5 cm**	**0.1818**	**h= $1.537\ x^{0.06149}$**
2cm	**5.5 cm**	**0.363**	**h= $0.95\ x^{0.0449}$**
3 cm	**5.5 cm**	**0.547**	**h= $0.865\ x^{0.037}$**
∞cm	**5.5 cm**	∞	**h= $11.25\ x^{0.065}$**

for S=5.5 cm and C= 0 cm, 1 cm, 2 cm,3 cm &∞ .It can be seen that variation in heat transfer coefficient is similar in all cases and is parabolic over the fin surface length .

The best fit curve for each of the spacing is given in table 2

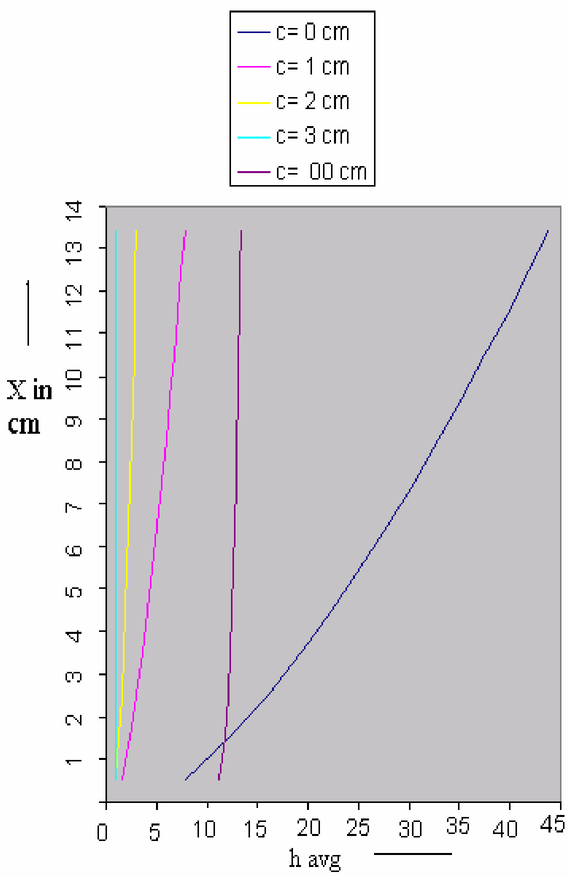

Fig 5 Variation in "h" along fin length for different clearance

The constants of the best fit curve reported in the table 1 and 2 (multiplier (a) and exponent (x)) are correlated with dimensionless parameters and the resulting relation ship is found as below: -

a= f(C/S)(S/ H_f)

n = f(C/S) (S/H_f)

For C= ∞.

a= $0.007(S/H_f)^{-3.33}$

n= $0.063\ (S/H_f)^{-0.020}$

For S= 5.5cm.

a= 4.335,n= 0.872

Fig. 5 shows variation in heat transfer coefficient along the fine length

Fig 6 and 7 (shown below) states the parametric dependence of average heat transfer coefficient with respect to fin array parameter C/S,S/H_f respectively. It can be seen (refer fig6) that average heat transfer coefficient varies hyperbolically (for constant clearance C= ∞) with respect to S/H_f Also the value of n is fairly constant at 0.065 while value of a is decreasing as (S) interfin spacing is increasing indicating that the average value of 'h'also decreases with increase in 'S'.

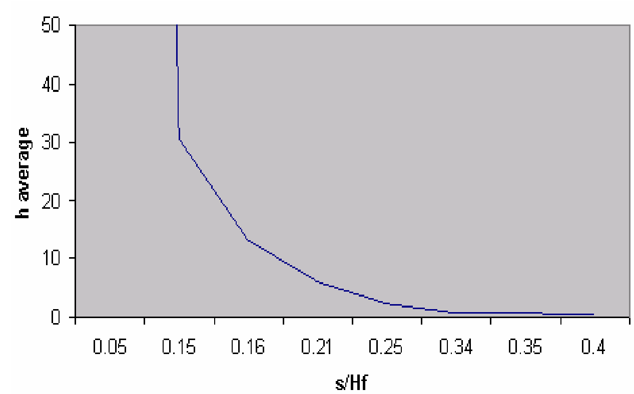

Fig. 6 Variation in havg Vs S/H_f for constant clearance

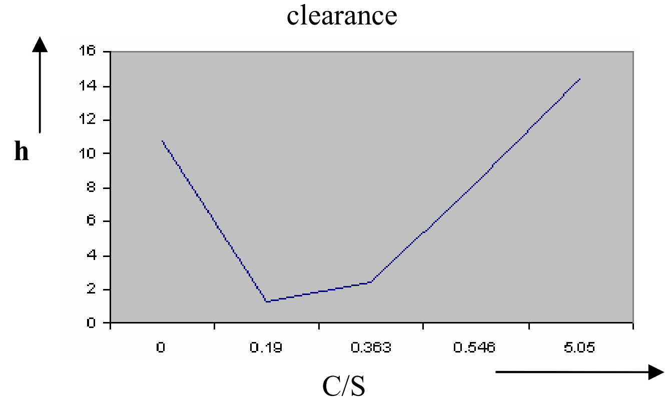

Fig. 7 Variations in h avg C/S for constant interfin spacing

It can be seen (refer fig 7) that average heat transfer coefficient varies parabolically (for constant inetrfin spacing S= 5.5cm) with respect to C/S with minima occurring around C/S =0.55 Also the value of n is decreasing with increasing clearance and at C=∞it again increases indicating rise in heat transfer coefficient

6 Conclusion

Experiments were performed to study the variation in the heat transfer coefficient along a fin length dissipating heat by natural convection. Experimental setup is designed, fabricated and validated for the purpose & required data is generated. The variation in the heat transfer coefficient along the0 fin length is expected to be parabolic on the fin surface. Suitable correlation in terms of fin array is suggested

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Symbols used

H_f= height of fin
S= intefin Spacing
h = heat transfer coefficient
x= fin length
T = Temparature
C= Clearence
Nu = Nusselt No.
Pr= Prandtl No.
ΔT= temperature difference
Q – Heat transferred
A – Area of fin Surface
K – Conductivity
L- Length