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Investigation of Heat Transfer Coefficient in 'Square Shaped Pin-Fin'

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ABSTRACT

Pin-fin is one of the most convenient ways of heat transfer. Square shaped pin fin is a non-exposed analysis. In this paper we have done analysis of square shaped pin fin with and without hole. We used aluminium as a fin material. Analysis content observations and results with heat inputs 70, 90 and 120 volts.We compared the heat transfer coefficient of square shaped fin with and without hole. The result show heat transfer coefficient of with hole square shaped fin is higher than without hole square shaped fin.

Keywords- Pin Fin, Heat transfer coefficient, Square shaped

I.INTRODUCTION

Heat is a most well-known form of energy. Heat is being transferred by various ways. Convection heat transfer between a hot solid surface and the surrounding colder fluid is governed by the Newton's cooling law which states that "the rate of convection heat transfer is directly proportional to the temperature difference between the hot surface and the surrounding fluid and is also directly proportional to the- area of contact or exposure between them". By comparing the results of square shaped fin with and without hole we are going to show that whose coefficient is better.Gawaliet.al.[1]It is observed that for the same fin material, the trapezoidal fin experienced the least temperature drop over its length, the parabolic fin is the most efficient in dissipating heat to its surroundings, Due to their greater thermal conductivity, copper fins were, in general, more efficient than aluminium fins. Pin fins were, in general, more efficient than straight fins at dissipating heat. Yet, the latter were more preferred owing to the ease in manufacturing and the ease in clustering them over small areas. However, a recent paradigm shift indicates that designers were turning towards the greater heat dissipation potential offered by pin fins. Pin fins have found applications in fields where thermal dissipation plays a very crucial role.Saurabh Bahadure et al [2] have done theoretical and experimental study on thermal performance of pin fin with circular perforations. The results show that perforations increases heat transfer rate.Amol Dhumne et al [3] have done analysis on heat transfer enhancement by experimentation. In addition, analysis of pressure drop over a flat surface with cylindrical pin fin in rectangular channel was done. The performance parameters considered were Reynolds number and Nusselt number. The correlation equations for friction factor, heat transfer and enhancement efficiency were developed. The results shows that the cylindrical perforated pin fins have higher

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heat transfer rate than cylindrical fins. It was observed that efficiency of fins vary depending on the inter-fin spacing ratio and clearance ratio. A low inter-fin spacing ratio assured high heat transfer.Richard [4] from the experimental analysis in this project the enhancement of heat transfer of fin for different materials was analysedand it could be improve. Fin efficiencies of materials are 66%, 91%, 94% were achieved. And among these materials from the analysis that copper has high thermal conductivity than brass and aluminium. In this paper the system follows forced convection as the mode of heat transfer instead of it in future we can use natural convection as a mode of heat transfer.

There are various types of shapes of pin-fins available in to the market. Some of these are rectangular, cylindrical, annular, tapered. We have done analysis of square shaped fins and square shaped drilled pin-fins for heat transfer analysis with Aluminium with heat input of 70 volts, 90 volts and 120 volts. Analysis of elliptical, circular, porous and rectangular fins is available. But specific analysis of square shaped pin-fin with hole is not available till now.

1.1. Nomenclature

Q	Heat transfer rate
h	Convective heat transfer coefficient
P	Perimeter of fin
k	Thermal conductivity
$A_{c/s}$	Cross section area
L	Length of fin
T_{atm}	Atmospheric temperature
C_d	Coefficient of discharge
Tm	Mean film temperature
$T\infty$	Ambient temperature
Re	Reynolds number
d_h	Hydraulic diameter
Nu	Nusselt number
g	Gravitational acceleration
ΔT	Temperature difference between fin and ambient
ν	Kinematic viscosity
H_w	Water head

The heat transfer from pin fin by convection is expressed as:

$Q = \sqrt{hPKA} \times (T_b - T_\infty) \times \tanh(mL)$ (1)

Reynolds's number

$Re = V \times d/\upsilon$ (2)

Discharge of air through rectangular cross section

$Q = Cd \times \pi/4 \times d^2 \times \sqrt{2gh((\rho w/\rho a) - 1)}$ (3)

Nusselt Number

$Nu = 0.615 \times (Re) 0.456$ (4)

We have to calculate the temperatures theoretically,

$(T_1 - T_f) / (T_o - T_f) = \{\cosh[m \times (L-X)]\}/\cosh(m \times L)$ (5)

$h = Nu \times K_{air}/dh$ (6)

$m = \sqrt{hP/KAl \times Ac/s}$ (7)

Hydraulic Diameter

$D_h = 4A_{c/s}/P$ (8)

1.2 Experimental Setup

The experimental setup consists of heater to which test specimen is attached which is to be analysed. A blower is used as forced convection device whose inlet is connected to a rectangular duct and outlet is connected to flow control valve. To measure the supply to heater, a dimmer stat is provided. An ammeter and a voltmeter are also provided. For experimentation, the heater is switched on and the readings from the thermocouples are taken once the temperature is stabilized with help of temperature indicator. Five thermocouples are fitted along the length of the fin. First thermocouple is fitted at 10mm from the base surface. Second thermocouple is fitted at 30mm from the base surface. Third thermocouple is fitted at 50mm from the base surface. Fourth thermocouple is fitted at 70mm from the base surface. Fifth thermocouple is fitted at 90mm from the base surface.

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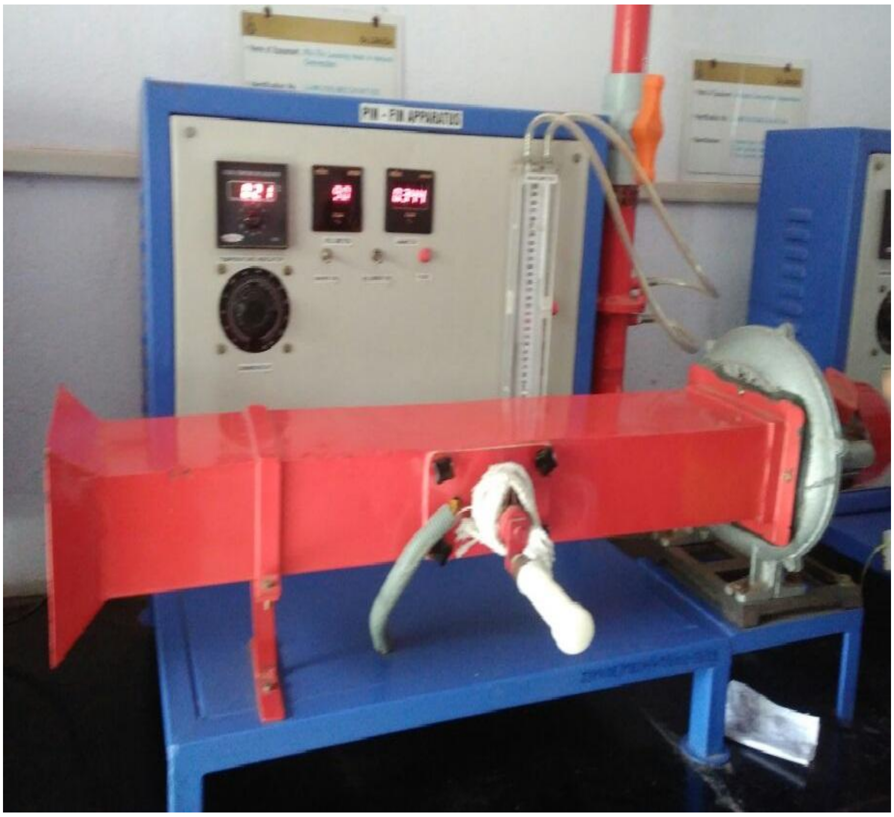

II. OBSERVATIONS AND CALCULATIONS-

ObservationNo 1:-

Material: Aluminium (without Hole) at 90V, 0.350A

Manometer Readings: 1. Full Flow- 185mm-100mm= 85mm

2. Partial Flow- 178mm-110mm= 68mm

3. Half Flow- 165mm-120mm= 45mm

Sr. No.	Flow Type	T_1 °c	T_2 °c	T_3 °c	T_4 °c	T_5 °c	T_{atp} °c
1	Full	47	44	44	41	41	27
2	Partial	47	44	44	44	41	27
3	Half	50	46	46	46	44	27

Table No-2.1Aluminium (without Hole) at 90V

Sample Calculations:

For Aluminium Rod Full Flow (without hole): - 90Volt

- $A_{c/s}$= 0.012×0.012 m^2

- $d_h = \frac{4\times0.012\times0.012T}{2(0.1+0.012)}$

  $= 2.5714\times10^{-3}$

- To find velocity:-

  $V = \frac{Q}{\text{Duct c/s area}}$

- $Q= Cd\times\pi/4\times d^2\times[2gh_w((\rho_w/\rho_a)-1)]^{1/2}$

  $= 0.64\times\pi/4\times0.027^2\times[2\times9.81\times0.085\times((1000/10225)-1)]^{1/2}$

  $=0.0135\ m^3/s$

- V= 0.0135/(0.15×0.1)

  =0.9 m/s

- Re= V×d/υ

  $= (0.9\times2.5714\times10^{-3})/15.89\times10^{-6}$

  = 145.6425

  Hence, 40< Re >4000

- $Nu= 0.615\times(Re)^{0.456}$

  $= 0.615\times (145.6425)^{0.456}$

  = 5.96

- $h= Nu\times K_{air}/d_h$

  $=5.96\times26.3\times10^{-3}/2.5714\times10^{-3}$

  $= 60.95\ W/m^2K$

- $m= [hP/K_{Al}\times A_{c/s}]^{1/2}$

  $= \{[60.95\times2(0.012+0.012)]/205\times0.012\times0.012\}^{1/2}$

  = 9.95Kg

- Now, we have to calculate the temperatures theoretically,

$(T_1-T_f) / (T_o-T_f) = \{\cosh [m\times (L-X)]\}/\cosh (m\times L)$

$(T_1-27) / (47-27) = \{\cosh [9.95\times (0.1-0.01)]\}/\cosh (9.95\times 0.1)$

$T_1=45.58^o c$

Similarly,

$(T_2-27) / (45.58-27) = \{\cosh [9.95\times (0.1-0.03)]\}/\cosh (9.95\times 0.1)$

$T_2=42.13^o c$

$(T_3-27) / (42.13-27) = \{\cosh [9.95\times (0.1-0.05)]\}/\cosh (9.95\times 0.1)$

$T_3=38.08^o c$

$(T_4-27) / (38.08-27) = \{\cosh [9.95\times (0.1-0.07)]\}/\cosh (9.95\times 0.1)$

$T_4=34.53^o c$

$(T_5-27) / (34.53-27) = \{\cosh [9.95\times (0.1-0.09)]\}/\cosh (9.95\times 01)$

$T_5=31.92^o c$

- $Q_{fin}=[hPKA_{c/s}]^{1/2}\times ø\times \tanh\times m\times L$

$= [60.95\times 2(0.012\times 0.012) \times 205\times 0.012\times 0.012]^{1/2} \times$

$(38.448\times -27)\times \tanh\times (9.95\times 0.1)$

$= 2.55W$

Now, put Q in above equation to find h,

- $2.55=[h\times 2(0.012+0.012)\times 205\times 0.012\times 0.012]^{1/2}\times (43.4-27)\times \tanh\times (9.95\times 0.1)$

$h = 29.57W/m^2K$

ObservationNo 2:-

Material: Aluminium (with Hole) at 90V, 0.346A

Manometer Readings: 1. Full Flow- 185mm-100mm= 85mm

2. Partial Flow- 178mm-110mm= 68mm

3. Half Flow- 165mm-120mm= 45mm

Sr. No.	Flow Type	T_1 °c	T_2 °c	T_3 °c	T_4 °c	T_5 °c	T_{atp} °c
1	Full	49	45	40	40	40	28
2	Partial	50	45	41	41	40	28
3	Half	51	47	42	42	42	28

Table No-2.2Aluminium (with Hole) at 90V

ObservationNo 3:-

Material: Aluminium (without Hole) at 70V, 0.271A

Manometer Readings: 1. Full Flow- 185mm-100mm= 85mm

2. Partial Flow- 178mm-110mm= 68mm

3. Half Flow- 165mm-120mm= 45mm

Sr. No.	Flow Type	T_1 °c	T_2 °c	T_3 °c	T_4 °c	T_5 °c	T_{atp} °c
1	Full	34	32	32	31	30	27
2	Partial	34	32	32	31	30	27
3	Half	35	32	32	32	31	27

Table No-2.3 Aluminium (without Hole) at 70V

ObservationNo 4:-

Material: Aluminium (without Hole) at 120V, 0.460A

Manometer Readings: 1. Full Flow- 185mm-100mm= 85mm

2. Partial Flow- 178mm-110mm= 68mm

3. Half Flow- 165mm-120mm= 45mm

Sr. No.	Flow Type	T_1 °c	T_2 °c	T_3 °c	T_4 °c	T_5 °c	T_{atp} °c
1	Full	76	70	70	69	66	27
2	Partial	78	72	72	71	68	27
73	Half	80	74	74	73	69	28

Table No 2.4 Aluminium (without Hole) at 120V

ObservationNo 5:-

Material: Aluminium (with Hole) at 70V, 0.271A

Manometer Readings: 1. Full Flow- 185mm-100mm= 85mm

2. Partial Flow- 178mm-110mm= 68mm

3. Half Flow- 165mm-120mm= 45mm

Sr. No.	Flow Type	T_1 °c	T_2 °c	T_3 °c	T_4 °c	T_5 °c	T_{atp} °c
1	Full	34	31	28	29	28	28
2	Partial	35	32	29	29	29	28
3	Half	37	33	30	31	30	28

Table No-2.5 Aluminium (with Hole) at 70V

Observation Table 6:-

Material: Aluminium (with Hole) at 120V, 0.460A

Manometer Readings: 1. Full Flow- 185mm-100mm= 85mm

2. Partial Flow- 178mm-110mm= 68mm

3. Half Flow- 165mm-120mm= 45mm

Sr. No.	Flow Type	T_1 °c	T_2 °c	T_3 °c	T_4 °c	T_5 °c	T_{atp} °c
1	Full	79	72	64	64	62	28
2	Partial	80	73	64	64	63	28
3	Half	83	76	67	67	66	28

Table No-2.6 Aluminium (with Hole) at 120V

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III. RESULTS TABLE

After processing on all the inputs, we get following outcomes

3.1: Aluminium (without hole)

Vtg.	Flow Type	Temp.(Expt) ^oc					Temp,(Thero) ^oc					Q (Exp) W	Q (Th) W	h (Exp)	h (Th)
		T_1	T_2	T_3	T_4	T_5	T_1	T_2	T_3	T_4	T_5				
70	Full	34	32	32	31	30	33.50	32.29	30.87	29.63	28.71	0.8927	16.31	42.31	60.95
	Parti.	34	32	32	31	30	33.52	32.35	30.97	29.74	28.82	0.8775	16.31	41.97	58.11
	Half	35	32	32	32	31	34.49	33.25	31.74	30.37	29.31	0.9604	16.31	42.09	52.57
90	Full	47	44	44	41	41	45.58	42.13	38.08	34.53	31.92	2.55	27.09	29.57	60.95
	Parti.	47	44	44	44	41	45.64	42.30	38.35	34.83	32.21	2.51	27.09	27.38	58.11
	Half	50	46	46	46	44	48.55	44.97	40.66	36.72	33.68	2.77	27.09	27.13	52.57
120	Full	76	70	70	69	66	72.53	64.09	54.17	45.46	39.07	6.26	47.47	23.49	60.95
	Parti.	78	72	72	71	68	74.52	66.02	55.93	46.97	40.28	6.43	47.47	25.42	58.11
	Half	80	74	74	73	69	76.65	68.41	58.46	49.39	42.41	6.37	47.47	24.46	52.57

Table No-3.1Aluminium (without hole)

3.2: Aluminium (with hole)

Vtg.	Flow Type	Temp.(Expt) °c					Temp,(Thero) °c					Q (Exp) W	Q (Th) W	h (Exp)	h (Th)
		T_1	T_2	T_3	T_4	T_5	T_1	T_2	T_3	T_4	T_5				
	Full	34	31	28	29	28	33.61	32.67	31.54	30.51	29.72	0.722	16.31	1725.83	53.06
	Parti.	35	32	29	29	29	34.57	33.51	32.23	31.05	30.13	0.824	16.31	118.47	50.29
70	Half	37	33	30	31	30	36.49	35.65	33.99	32.43	31.18	1.055	16.31	91.45	45.77
	Full	49	45	40	40	40	47.60	44.16	40.02	36.25	33.35	2.66	26.78	37.57	53.06
	Parti.	50	45	41	41	40	48.65	45.34	41.31	37.66	34.70	2.59	26.78	38.69	50.29
90	Half	51	47	42	42	42	49.69	46.45	42.46	38.71	35.70	2.59	26.78	34.44	45.77
	Full	79	72	64	64	62	75.76	67.79	58.19	49.44	42.72	6.158	47.47	23.96	53.06
120	Parti.	80	73	64	64	63	76.83	69.00	59.49	50.52	43.87	6.13	47.47	30.08	50.29
	Half	83	76	67	67	66	79.88	72.15	62.61	53.62	46.41	6.200	47.47	29.04	45.77

Table No- 3.2 Aluminium (with hole)

In this paper, the heat transfer rate of square shaped fin with and without hole is studied. The experimentation results show that with hole square shaped fin has higher heat transfer rate than without holesquare shaped fin.

IV. CONCLUSION

The objective of this paper was to investigate the heat transfer rate of the pin fin for Aluminium material using with and without hole square shaped fins. Temperature distribution along the length of fin for different base temperatures is studied.

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