Experiment 2 Forced convection heat transfer through pin fin

1. Objective

I. To obtain the variation of temperature along the length of a pin fin under forced convection from the experiment.

II. To determine the value of heat transfer coefficient under forced convection from the experiment.

III. To evaluate :

   a. Theoretical values of temperature along the length of the fin.

   b. Effectiveness and efficiency of the fin.

2. Theory

The heat transfer in convection is given by Newton's law of cooling q = h.A.ΔT where q is the heat transfer rate, h is the heat transfer coefficient and ΔT is the temperature difference, A is the surface area through which transfer occurs. To increase the heat transfer rate q, whether increase the surface A or increase the heat transfer coefficient h. But in some case it is not possible to increase h, in that case the only way is increase the surface area, the surface area is increased by attaching some extra material in the form of rod (circular or rectangular) on the surface where higher heat transfer rate is required. That extra material attached to the surface is called the surface or fins.

The fins are called plane surface fins if they are attached to plane surface, circumferential fins if attached to cylindrical surface. The cross-section of fin may be circular, rectangular, triangular or parabolic.

- *Temperature distribution and heat transfer from a fin of finite length with insulated tip:*

Temperature distribution along the length of the fin is:

$$\frac{\theta}{\theta_0} = \frac{T - T_\infty}{T_1 - T_\infty} = \frac{\cosh m(L - x)}{\cosh mL}$$

T = Temperature at any distance x from the base

T_∞ = Ambient temperature, T_1 = Base Temperature/ or at thermocouple 1.

L = length of the fin = 200mm

Where h is the heat transfer coefficient; $m = \sqrt{\frac{hP}{kA}}$

P = Perimeter of the fin

A = Area of the fin

K = Thermal conductivity of the fin material = 110 W/m-K

Heat transfer rate $q = \theta_0 \sqrt{hPkA}$

- *Fin effectiveness*

Effectiveness of a fin is defined as the ratio of the heat transfer with fin to heat transfer from the surface without fin. For insulted tip effectiveness of the fin:

$$\varepsilon = \sqrt{\frac{P.k}{h.A}}\tanh mL$$

- *Fin efficiency*

The efficiency of a fin is defined as the ratio of the actual heat transferred by the fin to the maximum heat transferred to the fin if the entire tin area is at the same temperature. Efficiency of the fin:

$$\eta = \frac{\tanh mL}{mL}$$

3. Procedure

- Connect the equipment to electric power supply.
- Keep the thermocouple selector switch to zero position.
- Switch on the blower.
- Turn the dimmer stat knob clockwise and adjust the power input to the heater to the desired value.
- Allow the unit to stabilize; approximate waiting time is 40-50 minutes.
- Turn the thermocouple selector clockwise and note down the temperature T_1 to T_6.
- Note down the difference in the level of the manometer.
- Repeat the experiment for different power input to the heater.

4. Precautions

- Switch on the blower before turning on the heater.
- When the experiment is complete, first turn off the heater then some time turn off the blower.
- Do not stop the blower in between the testing period.

5. Observation Table

Sr. No.	Time (min)	Heat Input (W)	Pressure drop h (cm)	Temperatures (°C)					
				T_1	T_2	T_3	T_4	T_5	T_6
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									

6. Results and calculations

i. Average surface temperature of fin is given by

$T_s = (T_1 + T_2 + T_3 + T_4 + T_5)/5$

T_6 = ambient temperature

T_m = mean temperature = $(T_s + T_6)/2$

ii. Properties of air are evaluated at T_m

a) Kinematic viscosity (ν) = ……….. m^2/s

b) Prandtl no. (Pr) = ………….

c) Thermal conductivity of air (K_a) = …………W/mK

iii. Velocity at orifice (V_0) = $C_d\left(\sqrt{2gh.\frac{\rho_w - \rho_a}{\rho_a}}\right).(1-\beta^4)^{-0.5}$

Where $\beta = 0.52$

Coefficient of discharge (C) = 0.85

Density of manometric fluid (ρ_w) = 1000 Kg/m^3

Density of air (ρ_a) = 1.17 Kg/m^3

iv. Velocity of air in the duct (V) = $\frac{\text{(Velocity at orifice)}\times\text{(Cross−sectional area of orifice)}}{\text{(Cross−sectional area of duct)}}$

$$V_a = V_0.\left(\frac{\frac{\pi}{4}d_0^2}{WxB}\right)$$

Where d_0 is the diameter of orifice = 0.02m

W = width of the duct = 0.15m

B = Breadth of the duct = 0.1m

v. Nusselt no. (Nu) = C $Re^n.Pr^{1/3}$

$Nu = \frac{hD}{k_f}$ where h is heat transfer coefficient.

Reynolds Number (Re) = $(D.V_a)/\nu$

C is a constant and n is index values, which are given in table below for different ranges of Reynolds number.

Reynolds No.	**C**	**n**
0.4-40	0.989	0.33
4-40	0.911	0.385
40-4000	0.683	0.466
4000-40000	0.293	0.618
40000-400000	0.27	0.805

- *Specifications*
  - Length of the fin L= 150mm
  - Diameter of the fin (D) = 12mm
  - Thermal conductivity of the fin material (brass) = 110 W/m-K
  - Diameter of the orifice (d_0) = 20
  - Width of the duct W = 15 cm
  - Breadth of the duct B = 10 cm
  - Coefficient of discharge of the orifice = 0.85
  - Density of manometric fluid water = 1000Kg/m^3
- *Properties of air at mean temperature*

Temp (K)	ρ (kg/m^3)	C_p (kJ/kg-K))	μ($x10^7$) (Ns/m^2)	ν($x10^6$) (m^2/s)	K_a($x10^3$) (W/m-K)	α (m^2/s)	Pr
250	1.3947	1.006	159.6	11.44	22.3	15.9	0.720
300	1.1614	1.007	184.6	15.89	26.3	22.5	0.707
350	0.9950	1.009	209.2	20.92	30.0	29.0	0.700
400	0.8711	1.014	230.1	26.41	33.8	38.3	0.690

7. Discussion on results

Discuss about your findings in the results and explain/ provide reasons for deviations of the experimental results with the theoretical/analytical solution/s.

8. Conclusions

Conclude the experimental results obtained in the experiments.