Engineering Growth Connection

HEAT TRANSFER IN FORCED CONVECTION (HT-109)

HEAT TRANSFER IN FORCED CONVECTION

1. OBJECTIVE:

To study the heat transfer in forced convection.

2. AIM:

2.1 To calculate surface heat transfer coefficient for a pipe by forced convection.

2.2 To do comparison of heat transfer coefficient for different air flow rates and heat flow rates.

3. INTRODUCTION:

Convection is defined as process of heat transfer by combined action of heat conduction and mixing motion. Convection heat transfer is further classified as natural convection and forced convection. If the mixing motion takes place due to density difference caused by temperature gradient, then the process of heat transfer is known as natural or free convection. If the mixing motion is induced by some external means such as a pump or blower then the process of heat transfer is known as forced convention.

4. THEORY:

Air flowing into the heated pipe with very high flow rate the heat transfer rate increases. The temperature taken by the cold air from the bulk temperature and rises its temperature. Thus, heat flow rate by air is expressed in terms of temperature difference by inlet to outlet temperature of air.

$$q = \dot{m} C_P (T_2 - T_1)$$

Heat transfer coefficient can be calculated by following:

$$U = \frac{q}{A(T_s - T_a)}$$

Where T_a, T_s are surrounding temperature and surface temperature respectively. A is heat transfer area, q is heat flow rate and U is overall heat transfer coefficient.

$$F_x = 2\rho A V^2$$

5. DESCRIPTION:

The apparatus consists of blower unit fitted with the test pipe. The test section is surrounding by nichrome heater. Four temperature sensors are embedded on the test section and two temperature sensors are placed in the air stream at the entrance and exit of the test section. Test pipe is connected to the delivery side of the blower along with the orifice. Input to the heater is given through a dimmerstat and measured by volt meter & ampere meter. Digital temperature indicator is provided to measure temperature. Airflow is measured with the help of orifice meter and the water manometer fitted on the board. Control valve is provided to control the flow rate.

6. UTILITIES REQUIRED:

6.1 Electricity Supply: Single Phase, 220 V AC, 50 Hz, 5-15 Amp combined socket with earth connection.

6.2 Floor Area Required: 1.5 m x 0.5 m

7. EXPERIMENTAL PROCEDURE:

7.1 STARTING PROCEDURE:

7.1.1 Ensure that mains ON/OFF switch given on the panel is at OFF position & dimmer stat is at zero position.

7.1.2 Connect electric supply to the set up.

7.1.3 Fill water in manometer up to half of the scale, by opening PU pipe connection from the air flow pipe and connect the pipe back to its position after doing so.

7.1.4 Switch ON the mains ON / OFF switch.

7.1.5 Set the heater input by the dimmer stat, voltmeter in the range 40 to 100 volt.

7.1.6 Switch ON the blower.

7.1.7 Set the flow of air by operating the valve V_1.

7.1.8 After 0.5 hrs. note down the reading of voltmeter, ampere meter, manometer and temperature sensors at every 10 minutes interval (till observing change in consecutive readings of temperatures ±0.2 °C).

7.1.9 Repeat the experiment for different flow rate of air.

7.2 Closing Procedure:

7.2.1 When experiment is over set the dimmer stat to zero position.

7.2.2 Switch OFF the blower.

7.2.3 Switch OFF the mains ON/OFF switch.

7.2.4 Switch OFF the power supply to the set up.

8. Observation & Calculation:

8.1 Data:

Diameter of pipe d_p	= 0.028 m
Diameter of orifice d_o	= 0.014 m
Length of test section L	= 0.4 m
Coefficient of discharge C_o	= 0.64
Density of water ρ_w	= 1000 kg/m^3

8.2 Observation Table:

Sr. No.	V (volts)	I (amp)	T_1 (°C)	T_2 (°C)	T_3 (°C)	T_4 (°C)	T_5 (°C)	T_6 (°C)	h_1 (cm)	h_2 (cm)

8.3 Calculations:

$$T_a = \frac{T_1 + T_6}{2} \text{ (°C)}$$

Find the properties of air (ρ_a, C_p) at temperature T_a from data book

C_p = _____ (J/kg °C)

ρ_a = _____ (kg/m^3)

$$T_s = \frac{T_2 + T_3 + T_4 + T_5}{4} \ (^{\circ}C)$$

$$A = \pi d_p L \ (m^2)$$

$$\Delta H = \frac{h_1 - h_2}{100}\left(\frac{\rho_w}{\rho_a} - 1\right) \ (m)$$

$$a_o = \frac{\pi}{4} d_o^2 \ (m^2)$$

$$a_p = \frac{\pi}{4} d_p^2 \ (m^2)$$

$$Q = \frac{C_o a_p a_o \sqrt{2g\Delta H}}{\sqrt{a_p^{\,2} - a_o^{\,2}}} \ (m^3/sec)$$

$$M = Q \times \rho_a \ (kg/sec)$$

$$Q_a = M C_P (T_6 - T_1) \ (W)$$

$$U = \frac{Q_a}{A(T_s - T_a)} \ (W/m^2\ ^{\circ}C)$$

CALCULATION TABLE:

S.No.	Q (m^3/sec)	Q_a (W)	U ($W/m^2\ ^{\circ}C$)

9. NOMENCLATURE:

Nom	Column Heading	Units	Type
A	Heat transfer area	m^2	Calculated
a_o	Cross- sectional area of orifice	m^2	Calculated
a_p	Cross – sectional area of pipe	m^2	Calculated
C_o	Coefficient of discharge	*	Given
C_p	Specific heat of air	kJ/kg°C	Calculated

d_o	Diameter of orifice	m	Given
d_p	Diameter of pipe	m	Given
h_1-h_2	Manometer readings	cm	Measured
I	Ammeter reading	Amp	Measured
L	Length of test section	m	Given
M	Mass flow rate of air	kg/sec	Calculated
Q	Flow rate of air	m^3/sec	Calculated
Q_a	Heat taken by air	W	Calculated
T_1	Air inlet temperature	°C	Measured
T_2-T_5	Surface temperature of test section	°C	Measured
T_6	Air outlet temperature	°C	Measured
T_a	Average temperature of air	°C	Calculated
T_s	Average surface temp of test pipe	°C	Calculated
U	Heat transfer coefficient	W/m²°C	Calculated
V	Voltmeter reading	volt	Measured
ρ_a	Density of air	kg/m^3	Calculated
ρ_w	Density of water	kg/m^3	Given
ΔH	Head loss	m	Calculated

* Symbols represent unitless quantity.

10. Precaution & Maintenance Instructions:

10.1 Never run the apparatus if power supply is less than 200 volts and more than 230 volts.

10.2 Never switch ON mains power supply before ensuring that all the ON/OFF switches given on the panel are at OFF position.

10.3 Operate selector switch of temperature indicator gently.

10.4 Always keep the apparatus free from dust.

11. Troubleshooting:

11.1 If electric panel is not showing the input on the mains light, check the main supply.

11.2 Voltmeter showing the voltage given to heater but ampere meter does not, check the connection of heater in control panel.

13. Block Diagram: