ME341A-HEAT AND MASS TRANSFER

Experiment - 5

Heat Transfer through Extended Surface

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Group – G1(a)

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Objective:

1. Measuring the temperature distribution along an extended surface and comparing the result with a theoretical analysis
2. Calculating the heat transfer from an extended surface resulting from combined modes of free convection and radiation heat transfer and comparing the result with the theoretical analysis
3. Determining the thermal conductivity of the rod material

Experimental Procedure

<u>Equipment required</u>:
HT10X Heat Transfer Service Unit
HT15 Extended Surface Heat Transfer Accessory
PC with HT10X-90IFD Data Logging
<u>Equipment Set-up:</u>

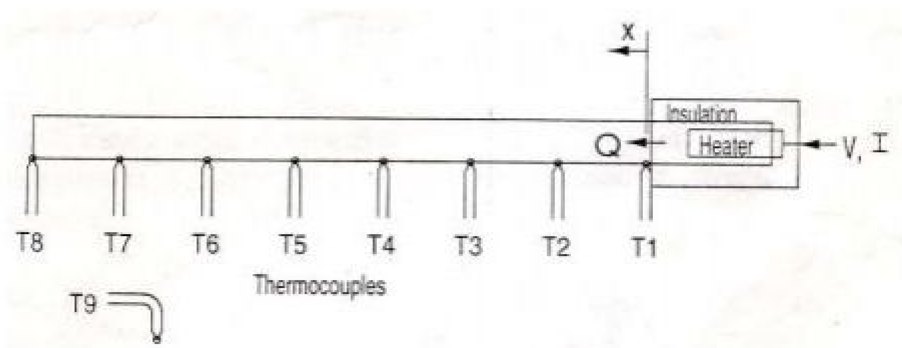


Figure : Schematic of experimental set up

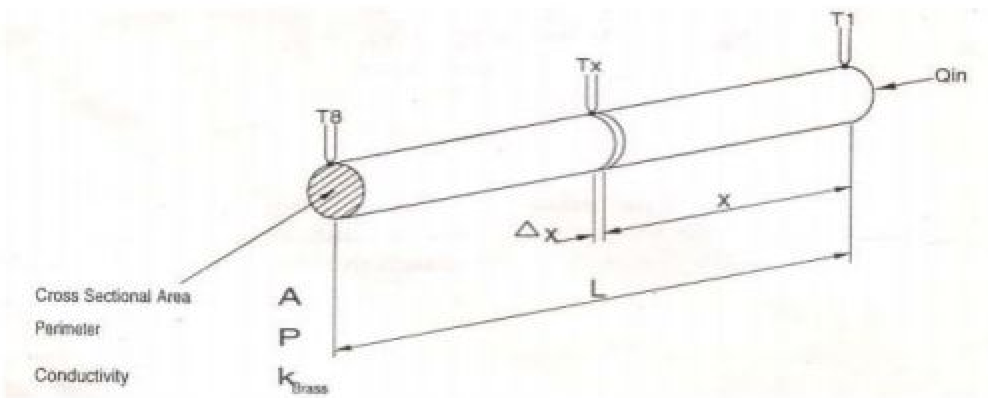
T1 to T9 there are nine thermocouples. Thermocouple 1 to 8 are situated on the specimen on certain interval of distance.
8 th Thermocouple is situated on stand measuring surrounding temperature.

<u>Steps involved in finding data</u>:

1. Connect heat transfer unit to heater and fix voltage and current. We fixed voltage at 7 V. Corresponding current was 0.21A.
2. Note the initial time and reading of thermometers.
3. Heat, generated by heater is conducted through the rod.
4. Note the reading of thermocouples after each 5 minutes. We get that reading is increasing.
5. When temperatures of all thermocouples become constant (increasing very very slowly), we assume it steady state.
6. Repeat same experiment for heater voltage 10V..

Theory

An extended surface is used to enhance the dissipation of heat. Here heat generated by the heater is conduct in the rod and radiated and convected in surrounding. To find out temperature distribution on rod we assume the steady state analysis. The temperature distribution along the fin or pin must be known to determine the heat transfer from the surface to its surroundings. Since radiation and natural convection from the surface occur simultaneously, both of these effects must also be included in the analysis. By considering the steady-state energy balance for an extended surface of uniform material and cross-sectional area, the following equation can be derived: $d^2\theta(x)/dx^2 - m^2\theta(x)=0$; where $m^2= HP/K_{brass}$; $\theta(x)= Tx-T\alpha$



Where N h=heat transfer coefficient combined of radiation and convection = hc + hr
A_s = total area of extended surface = πDL
L = 35 cm (length of the rod)
D= 1cm (Diameter of the rod)
Ts= average surface temperature
Tα= ambient air temperature

The average CHT Hc can be calculated from the formula given below (Fundamentals of heat transfer, Incropera and DeWitt):
$Nu_c= h_cD/k=C\ RaD^n$
Where $RaD= \beta g(Ts-T\alpha)D^3 /v\alpha$, and constants of above equation for natural/free convection on a horizontal circular cylinder are given in the table below.

Ra_D	C	N
10^{-10}- 10^{-2}	0.675	0.058
10^{-2}- 10^{2}	1.02	0.148
10^{2}- 10^{4}	0.850	0.188
10^{4}- 10^{7}	0.480	0.250
10^{7}- 10^{12}	0.125	0.333

The average radiative heat transfer coefficient hr can be calculated as follows:

$Hr = \sigma \epsilon F(Ts^4 - T\alpha^4)/(Ts - T\alpha)$
Where: σ= stefan Boltzmann constant=5.67x10-8 ($Wm^{-2} K^{-4}$)
ϵ= Emissivity of the surface =0.85
F=view factor=1
Part 3.
Thermal conductivity of the material: $K_{brass} = hP/m^2A$
Where P= perimeter of the pin =π D
A= cross section area of the pin =$\pi D^2/4$;

Calculations

Part 1.
Set 1 At voltage =7V
$(T_x - T_\alpha)/(T_1 - T_\alpha) = \cosh m(L-x)/\cosh mL$
Here
T_α= 26.2°C, T_1=36.2°C, L=35 cm
Using matlab we get value of m at position x as below:
X=5cm;
T2=32.7°C, we get m_2= 6.9992

	m_2	m_3	m_4	m_5	m_6	m_7	m_{avg}
Location(cm)	5	10	15	20	25	30	
At voltage 7V	6.9992	7.445	7.999	8.001	8.1022	8.3442	7.8151

Now to get theoretical value of temperature at given position, we have to solve the above equation with mavg as:
Set 1:
For T2; mavg =7.8151;
We get
T2= 32.33°C (using matlab)

Part 2
Set 1
Ts= average surface temperature=32.4875°C
Air properties:
β (Thermal expansion Coefficient) = 3.2817E-3 (1/K)
g (acceleration due to gravity) = 9.81 m/s^2
T_a (ambient temp.)= 26.6°C
D = 1cm
v= kinetic viscocity= 1.6183×10^{-5} m^2/s

α=thermal diffusivity= $2.2682x10^{-5}m^2/s$
K=0.026457 W/m.k
Ra_D= $3.2817x10^{-3}x9.81x(32.4875-26.6)x0.013/(2.2682x10^{-5}x1.6183x10^{-5})$=671.277
From the table of Ra values, we get
C=0.85; n=0.188;
From Nu= $C.Ra_D^n$= H_cD/k
n= h_cD/k
Nu= 2.8;
H_c=7.408 W/m2.k;
Now radiative coefficient:
$H_r= \sigma\epsilon F(T_s^4- T_\alpha^4)/(T_s-T_\alpha)$
Using
σ= 5.67x10-8 $(Wm^{-2}K^{-4})$
ϵ= 0.85
F =1
We get: H_r=5.018 $W/m^2.k$
H= H_c+ H_r=12.426 $W/m^2.k$
Qtotal= $A_SH(T_s-T_\alpha)$:
=πx0.01x.35x12.426 x(32.4875-26.6)
=0.8034 W;

Part 3:
Set 1
k_{brass1}= $hP/(m^2_{avg}.A)$
=12.426xπx0.01x4/(7.8151x7.8151xπx0.012)
=67.817 W/m.k

Uncertainty and error analysis

Error= $E_{observed}$- $E_{calculated}$;

	E_0	E_1	E_2	E_3	E_4	E_5	E_6	E_7	E_8	**Cumulative error**
Set 1	0	0.9678	0.4288	-0.0369	-0.0767	-0.6794	-0.6227	-0.5437	**0**	

Error in Q_{tot} with respect to Q_{in}

	Q_{in}	Q_{tot}	**Error %**
Set 1	1.47	0.8034	45.347

Result and discussion

Gradient : We find that gradient decreases with increasing x, this is consistent with the theory because heat dissipation in the surroundings due to radiation and convection, at steady state ΔT is fixed and heat conduction in rod is decreases. To ensure that it remains this way, gradient should decrease with increasing x.

Error in thermal conductivity: We get the thermal conductivity in set 1. This may be because conductivity is a function of temperature. In calculation of radiative heat conductivity coefficient, we use the T_∞ very close to the rod. Ideally, it should be far away from the the set-up.

Conclusion

A temperature gradient exists along each fin or pin due to combination of the conductivity of the material and heat loss in surroundings.

Precautions

1.Switch off the ceiling fan before giving supply to set-up. This ensures a natural heat transfer environment.
2.Ensure the that the labels on the thermocouples leads (T1-T9) match the label on sockets.
3.Keep dimmerstat to zero volt position and increase it slowly.