Ministry of Higher Education and Scientific Research
Al-Mustansiriayah University
College of Engineering
Material Engineering Department

وزارةالتعليم العالي والبحث العلمي
الجامعة المستنصرية
كلية الهندسة
قسم الهندسة المواد.

مختبر

انتقال الحرارة

إعداد

مهندس: دلمن ياسين طه

إشراف

أ.م.د. عامر حميد مجيد

م.م. أسماعيل ابراهيم مرهون

2015

2016

Experiment No. (4)

a. Name of Experiment:

Forced Convection

b. Purposes of Experiment:

1. To find the values of heat transfer coefficient for different velocities forced convection for closed, half open and fall open duct (different velocities).
2. Obtain an experimental relation for a transient condition data and compare it with experimental published data.

Theory of Experiment:

In convection heat transfer, there is a flow of fluid associated with heat transfer and the energy such as a fan or pump or due to atmospheric disturbances, the resulting heat transfer is known as forced convection heat transfer whereas a hot plate simply hung in air will lose heat by natural convection for the purpose of analysis we quantify the preceding statement by a dimensionless group called, Reynolds number which is defined as follows:

$$Re = \frac{\rho u d}{\mu}$$

u Mean velocity of flow, m/s
ρ Density of fluid, kg/m^3
μ Dynamic viscosity of fluid, kg/m. s
d Diameter of pipe, m

If Reynolds number is below a certain value, as determined by experiments, the flow is laminar; the fluid layers move parallel to each other in an orderly manner. As the velocity of flow increases; as the value of Reynolds number increases, there is more disorder in the fluid flow becomes turbulent fluid move at random and obviously the heat transfer increases. Transition from laminar to turbulent flow occurs not at fixed value of Reynolds number, but occurs in arrange of Reynolds numbers.

Steady state heat transfer means: the temperature of the solid was only a function of position and did not depend on time. However, all the process equipment’s used in engineering practice, such as boilers, heat exchangers, regenerators, have to pass through an unsteady state in the beginning when the process is started and they reach a steady state after sufficient time has elapsed. Conduction heat transfer in such an unsteady state (transient heat conduction), or time dependent conduction, in transient conduction, temperature depends not only on position in the solid, but also on time.

Consider for example, a small body loses heat to the medium. Heat flows by conduction from within the body to the surface and then, by convection to the medium. When the body is high or when the thermal conductivity of the material of the body is very large, temperature gradients within the body will be very small and may be neglected. In such a case, temperature within the body is only a function of time and is independent of spatial coordinates then the whole body acts as lump and temperatures of all points within the body decrease (or increase if the object is being heated) uniformly.

Heat transfer process from the body, in this case is controlled by the convection resistance at the surface rather than by the conduction resistance in the body.

In lumped system analysis, the internal conduction resistance of the body to heat flow $\left(\frac{L}{k.A}\right)$is negligible compared to the convective resistance $\frac{1}{(h.A)}$ at the surface. So, the temperature of the body, no doubt, varies with time, but at any given instant, the temperature within the body is uniform and is independent of position, T=f(t) only. Practical examples of such cases are: heat treatment of small metal pieces, measurement of temerture with a thermocouple or thermometer, where the internal resistance of the object for heat conduction may be considered as negligible.

Consider a solid body of arbitrary shape, volume v, mass m, density ρ, surface area A and specific heat cp.

With boundary conditions:

At t=0 ; $T= T_i$

At t>0 ; T=T

So that the solution to energy balance eq.

$$\frac{T-T_\infty}{T_i-T_\infty}=e^{-\frac{hA}{\rho C_p V}t} \qquad \text{.....................................} \qquad (1)$$

We have already noted that the Lumped- capacity type of analysis assumes a uniform temperature distribution throughout the solid body and that the assumption is equivalent to saying that "**the surface- convection resistance is large compared**

with the internal – conduction resistance". Such an analysis may be expected to yield reasonable estimates when the following condition is met:

$$Bi = \frac{h(V/A)}{k} < 0.1 \quad \text{..........................} \quad (2)$$

Where

Bi: Biot number (dimensionless number)

C. Description of Instrument:

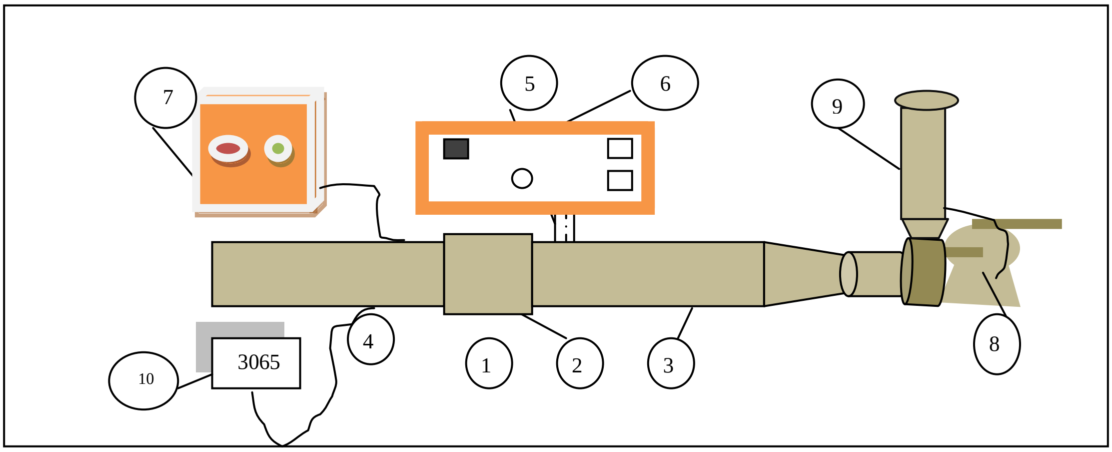


Fig (1) Forced Convection instrument

1. Heater.
2. Specimen metal.
3. Horizontal duct.
4. Thermocouple.
5. Differential gauge Pressure.
6. Electrical control system
7. On- off switch.
8. Blower
9. Vertical duct (for variables velocities)
10. Digital screen

d. Procedure:

1. Heating the specimen (cylinder) to 80 °C.
2. Put the specimen in the tunnel of experiment and recording the decrease in temperature with time.
3. Repeat the above steps with half open and fall open duct.

e. Readings:

(1)		**(2)**		**(3)**	
closed		**Half open**		**Fall open**	
V=		**V=**		**V=**	
T °C	t (s)	T °C	t(s)	T °C	t(s)
80	0	80	0	80	0
70		70		70	
60		60		60	
50		50		50	
40		40		40	
30		30		30	

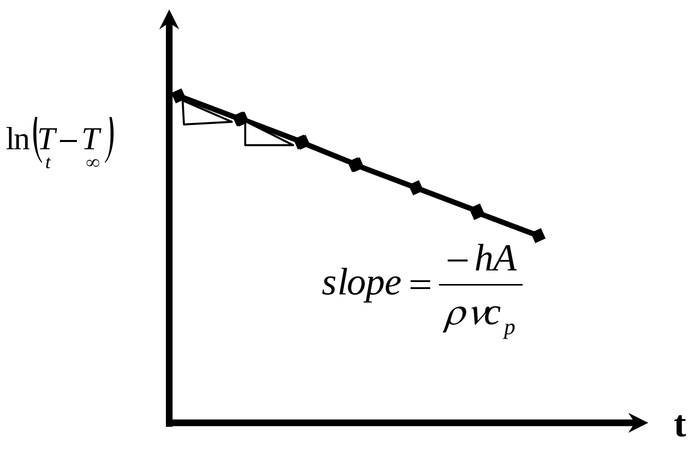
f. Calculations:

1. To find the convection coefficient, take ln to eq (1), so it becomes as line eq.

$$\frac{T - T_\infty}{T_i - T_\infty} = e^{-\frac{hA}{\rho C_p V}t}$$

$$\ln\left(T_t - T_\infty\right) = -\frac{hA}{\rho C_p V} t + \ln\left(T_i - T_\infty\right)$$

Y = m X + b



So we can determine h_1, h_2 , h_3………

2. Determine Nusselt no. (Dimensionless number).

$$Nu = \frac{hD}{k_f}$$

k_f= we can find it from properties of air at T_f

$$T_f = \frac{T_s + T_\infty}{2}$$, simply may be taken as T_{air}

3.determine the Reynolds number (used for forced convection)

$$\text{Re} = \frac{\rho u d}{\mu}$$

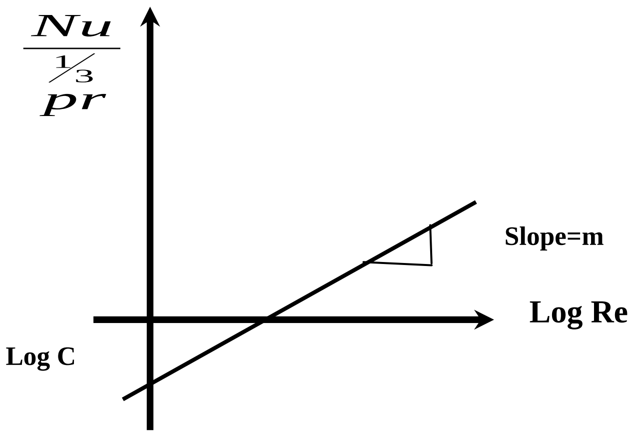
Take ρ µ from properties tables of air at T_f.

4. Find the constant C, m and compare it with the theoretical eq. What are the causes of this contrast?

$$\because Nu = c \, \text{Re}^{m} \, pr^{1/3}$$

Take log for two sides

$$Log \frac{Nu}{pr^{1/3}} = LogC + mLog\,\text{Re}$$



D	1cm
$C_{p\ AL}$	0.896 kJ/kg.°C
ρ_{AL}	2707 kg/m^3
T_∞	20°C