

PLATE TYPE HEAT EXCHANGER

AIM:

To determine the overall heat transfer coefficient in a plate type heat exchanger at different hot fluid flow rate

EXPERIMENTAL SETUP:

1. A Stainless-steel plate type heat exchanger with facility to measure hot and cold fluid temperature.
2. A stainless steel insulated tank with a heater to act as a reservoir for the hot fluid
3. Hot fluid circulation pump with a speed control potentiometer
4. Cold fluid inlet from the water supply taps
5. Thermocouples in order to sense the inlet and outlet temperature of hot as well as cold fluid
6. Rotameter

THEORY:

The plate heat exchanger normally consists of corrugated plates assembled into a frame. The hot fluid flows in one direction in alternating chambers while the cold fluid flows in true counter-current flow in the other alternating chambers. A schematic diagram of the flow is shown in Figure 1. The fluids are directed into their proper chambers either by a suitable gasket or a weld depending on the type of exchanger chosen. Plate heat exchangers are best known for having overall heat transfer coefficients (U-values) in excess of 3–5 times the U-value in a shell and tube designed for the same service.

Plate heat exchanger is an attractive option when more expensive materials of construction can be employed. The significantly higher U-value results in far less area for a given application. The higher U-values are obtained by inducing turbulence between the plate surfaces. Owing to this they are also known to minimize the fouling.

Heat Transfer Correlation:

Generally the heat transfer correlation for a fluid flow past a solid surface is expressed in a dimensionless form

$$Nu = Nu(\text{Re}, \text{Pr}) \quad (1)$$

where Nu is the non dimensionless Nusselt number expressed as

$$Nu = \frac{hD}{k} \quad (2)$$

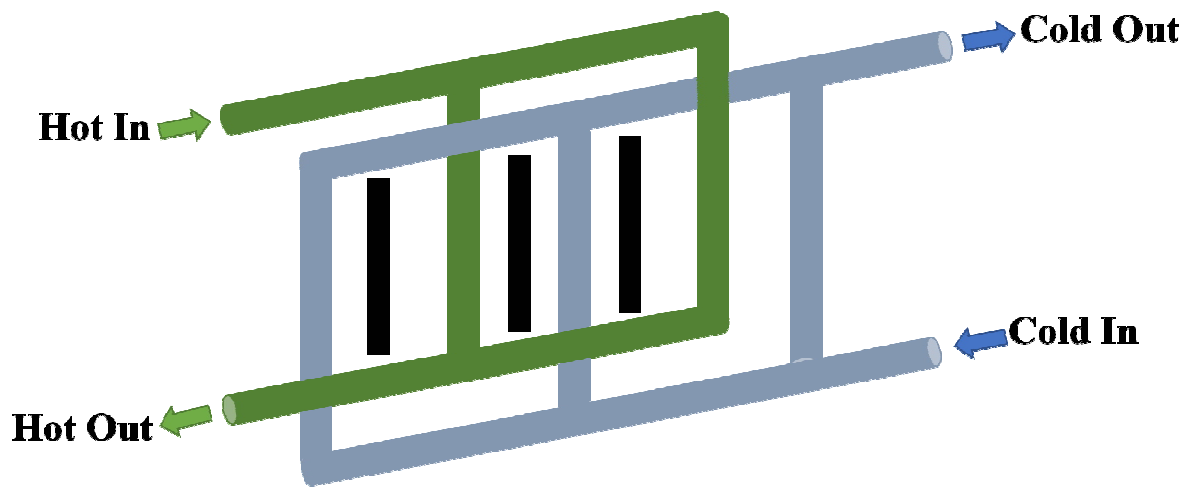


Figure 1: Schematics for Plate Type Heat Exchanger

For a heat transfer in a laminar fluidflow past a solid surface, with constant fluid properties, the steady state temperature profile is a function of Re , and Pr only.

For fully developed laminar flows (internal flows), we expect the Nusselt number Nu to be constant, however for a developing flow it is expressed as:

$$Nu = C_1 Re^\alpha Pr^\beta \quad (3)$$

The value of $\beta \approx 0.33$, $C = 0.664$. The value of α is found to be around 0.3 for developing laminar flow and around 0.5 for turbulent flow. The transition from laminar to turbulent region occurs between $2300 \leq Re \leq 4000$ for corrugated plates. It can be expected to be higher for plain plates. The heat transfer coefficient appearing in the Nusselt number can be calculated from the overall heat transfer coefficient U , which is given by

$$\frac{1}{U} = \frac{1}{h_h} + \frac{\Delta x}{K_p} + \frac{1}{h_o} \quad (4)$$

Where, h_h is the hot fluid heat transfer coefficient and h_o is the cold fluid heat transfer coefficient, K_p is the thermal conductivity of the metal plate and Δx is its thickness. Once the heat exchanger material and its geometry are fixed, then the metal wall resistance ($\Delta x/K_p$) becomes constant. Similarly, if the flow rate of cold fluid is fixed and its mean temperature does not differ much for different flow rates of hot fluid, then the resistance of the cold fluid will remain almost constant. Thus, the overall heat transfer coefficient will depend upon the value of the hot fluid heat transfer coefficient alone. If the bulk mean temperature does not differ much for different flow rates, then

all the physical properties will remain nearly the same and Eq. (4) can be re-written in combination with Eq. (3) as

$$\frac{1}{U} = \frac{1}{h_h} + C = \frac{m}{u^\alpha} + C \quad (5)$$

Where C is constant. h_h can therefore be evaluated from the intercept of the plot of $1/U$ vs. $1/u^\alpha$. Then a plot of $1/U$ vs. $1/u^\alpha$ will provide the intercept value C , which is then used to calculate the heat transfer coefficient from Eq. (5). The Nusselt number correlation can then be found. For the sake of simplicity, it is often assumed that $\alpha=0.5$. This can be verified if the plot of $1/U$ vs. $1/u^{0.5}$ is a straight line for a large range in the small limit.

PROCEDURE:

1. Set the pump to maximum hot fluid flow rate (≈ 550 lph), and measure the temperature difference between the outlet and inlet of the hot fluid.
2. Set the temperature of the inlet hot fluid in the dual temperature indicator cum controller. The setpoint should be set between 60 to 80°C .
3. Provide cooling water supply to the plate heat exchanger minimum as 100 LPH. This will ensure that the temperature difference is maintained at least $2-3^\circ\text{C}$. Keep this flow rate constant throughout the experiment.
4. Connect the 15 A and 5 A plug pins to a stable 230 V A.C. electric supply. Care should be taken to connect these two pins in different phases of the power supply. Switch on the heater power supply.
5. Adjust the flow rate of hot fluid through the heat exchanger by adjusting the speed of hot fluid circulation pump. This step should be done only when the steady state is reached.
6. To measure the oil flow rate, we have to close the valve beneath the fixed volume container for certain height. By measuring the time required for the hot fluid to achieve certain height, we can calculate the velocity and successively the volumetric flow rate of hot fluid.
7. Repeat step 6 at least for 10 different flow rates.

SPECIFICATION:

Height of the plate = 120 mm

Width of the plate = 65 mm

Gap between two plates = 1 mm

Number of plates = 7

Number of hot fluid chambers = 3

Number of cold fluid chambers = 4
 Zero error of hot fluid digital thermometers $\delta T =$
 Oil in tank = Servo Engine 32 Grade Oil
 Flash Point (COC) = 190°C
 Kinematic Viscosity = 32 cS @ 45°C, 5.4 cS @ 100°C.
 Density of Oil = 857 Kg/m³
 Diameter of flow measuring cylinder: 0.0762m
 Thermal conductivity of the hot fluid: 0.13W/mk
 Thermal conductivity of stainless steel 16 W/m.K

OBSERVATION TABLE:

Observation No.	Flow rate V lph	Hot fluid temperature (°C)		Cold fluid temperature (°C)	
		Inlet (T ₁)	Outlet (T ₂)	Inlet (t ₁)	Outlet (t ₂)
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					

CALCULATIONS

1. Total heat transfer area of heat exchanger

$A = NHW =$

2. Cup mean temperature (use any typical value)

$T_m = (T_1 + T_2) / 2 =$

3. Density of Oil

$\rho = 857 \text{ kg/m}^3$

4. Specific heat of Ethylene glycol at T_m $C_p =$

5. Viscosity of oil at T_m $\mu =$

6. Thermal conductivity of Ethylene glycol at T_m $K =$

7. Prandtl Number for hot fluid $Pr = \frac{C_p \mu}{K} =$

8. Equivalent diameter $De = \frac{2Wb}{W+b} =$

SAMPLE CALCULATIONS

1. Flow Rate $V =$

2. Velocity of hot fluid in a chamber $u = \frac{V}{WbN_h} =$

3. Total heat transferred $Q = \rho C_p V (T_1 - T_2) =$

4. Brinkman number $Br = \frac{\mu u^2}{K(T_1 - T_2)} =$

5. Log Mean Temperature Difference (LMTD) $\Delta T_{LMTD} = \frac{(T_1 - t_2) - (T_2 - t_1)}{\ln \left[\frac{(T_1 - t_2)}{(T_2 - t_1)} \right]} =$

6. Overall heat transfer coefficient $U = \frac{Q}{A \Delta T_{LM}} =$

7. Reynolds number $Re = \frac{D_e u \rho}{\mu} =$

8. Intercept of $1/U$ vs $1/u^{0.5}$ plot $C =$

$$\text{Here } C = \frac{1}{h_0} + \frac{\Delta x}{K}$$

9. Hot fluid heat transfer coefficient $\frac{1}{h_i} = \frac{1}{U} - C =$

10. Nusselt number $Nu = \frac{h_i D_e}{K}$

GRAPHS:

1. Plot of $1/U$ vs $1/u^{0.5}$
2. Plot of Nu number vs Reynolds number

CONCLUSION/DISCUSSION ON THE RESULT

1. Overall heat transfer coefficient and individual heat transfer coefficient in plate type heat exchanger was calculated.

FURTHER READING

G H Hewitt, G L Shires, and T R Bott, "Process Heat Transfer", CRC Press, NY, 1994

TEACHING ASSISTANT