Indian Institute of Technology Gandhinagar

Design a simple system to demonstrate the heat transfer in agitated vessel and determine the overall heat transfer coefficient

CL 204 Heat Transfer
GROUP 5

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1 Introduction

1.1 Problem Statement

This study aims to determine the amount of heat transferred, the overall heat transfer coefficient, and the individual heat transfer coefficient of the inside tube in a heat exchanger system. The system consists of an Agitated Vessel where hot fluid is inside the vessel and transfers heat to a fluid at room temperature flowing inside the copper tube.

2 Objectives

To demonstrate heat transfer in an agitated vessel and determine the overall heat transfer coefficient for a copper coil system, a practical setup involves an agitated vessel with a heating/cooling system using a copper coil immersed in the fluid. By measuring temperatures at different points and varying agitator speeds (with or without baffles), you can analyze heat transfer rates and coefficients.

The system's design integrates a tank with a motor-driven agitator, a heating element, and a cooling copper coil submerged in the vessel. Inlet and outlet temperatures of the copper coil fluid are monitored, along with the vessel fluid temperature over time.

To determine the overall heat transfer coefficient (U) of the system, calculate the net heat transferred (Q) using:

$Q = U \times A \times \Delta T$.

A is the heat transfer surface area (copper coil), and ΔT is the logarithmic mean temperature difference.

3 Setup

3.1 Materials Used

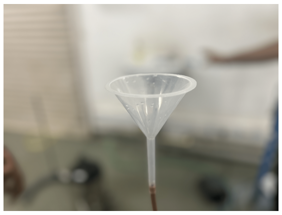
1. Copper Tube (Dimensions are given below)

2. Agitated Vessel (Thermally Insulated Vessel)

3. Impeller (Fan Blades)

4. Agitator Stand (For mounting the agitator)

5. Funnel (For easy passage of water in the coil)



6. Electric Kettle (For heating the water, putting in the vessel)

7. Thermocouple (Measuring the temperature)

3.2 Setup

Our setup includes a simple insulated vessel with hot water inside it and a copper coil that goes in and out of the vessel The copper tube is of length 10 feet and diameter 6.35 mm.

The water at room temperature is falling into the coil from a height of 1 m. The heating of water is done with the help of an Electric Heater.

4 Process, Methodology and Calculations

We first heated the water to high temperature which we measured using a thermocouple and put into the vessel.

Then, we took water at room temperature (again the temperature measured using a thermocouple) to pass it inside the coil from a height h (value given above).

Some of the data which we have calculated by measuring are as follows:

1. Velocity of water flowing inside the tube: 4.4 m/s
2. Mass Flow Rate of water flowing inside the tube: 0.025 kg/s These is the average readings taken after multiple readings.

4.1 Calculation of Mass Flow Rate

First we will calculate $\dot{m}$ using the formula $\dot{m}$ ={rho$v$ where $v = \sqrt{2gh + u^2}$.
On calculating $\dot{m}$ = 0.025 kg/s
Now, Heat transferred ($\dot{Q}$) = $\dot{m}$*C*$\Delta T where:$
$\Delta T = T_{in}$ - T_{out}
C_v = 4200 J/kgC

4.2 Calculation of Amount of Heat Transfer

Multiplying the Rate of Heat Transfer with the Time Interval (δt) will give us the total amount of heat transfer

4.3 Calculation of Overall Heat Transfer Coefficient

Also, we know $\dot{Q}$ = U*A*ΔT where U is overall Transfer coefficient and A is area of coil inside the water.

A = n* π * D where n in number of turns and D is diameter of coil circle in vessel
U = Overall heat transfer coefficient
$\Delta T_{lm} = \frac{(T_1-t_1)-(T_2-t_2)}{\ln\left(\frac{T_1-t_1}{T_2-t_2}\right)}$

Since we know $\dot{Q}$, A and ΔT, we can get:
U = $\frac{\dot{Q}}{A*\Delta T}$

On calculating, we can get the value of U.

4.4 Calculation of Inside and Outside Heat Transfer Coefficient

$\frac{1}{U} = \frac{1}{h_{water,vessel}} + \frac{1}{h_{Tube}} + \frac{1}{h_{water,tube}}$ –(1)
We already know U.

Calculating $h_{water,tube}$:
We know Re = $\frac{\rho VD}{\mu}$
where
ρ: Density of the fluid (kg/m^3)
v: Velocity of the fluid (m/s)
D: Characteristic length (m)
μ: Dynamic viscosity of the fluid (Pa·s) = 10^{-3}Pa
By calculating this, we can find the value of Re
Value of Pr taken from the internet.
Nu = 0.23*$Re^{0.8}$*$Pr^{0.4}$
This is the equation of Nu taken according to the conditions we have taken for this experiment.
We know $h_{water,tube} = \left(\frac{k}{L}\right) \times Nu$
Since the Agitator is off, we can use natural convection equations to calculate $h_{water,vessel}$. Gr = $\frac{\nu^2 g\beta(T_s-T_\infty)L^3}{\mu}$
where: g is the acceleration due to gravity (m/s^2)
β is the thermal expansion coefficient (1/K) = 17 × 10–6$/C$
T_s is the surface temperature (K)
T_∞ is the ambient temperature (K)
L is a characteristic length (m)
ν is the kinematic viscosity (m^2/s)

5 Our Case Studies

1. Experiment with Impeller Speed = 0 We first did the 3 experiments having the impeller speed zero and calculated the values of overall heat transfer coefficient and amount of heat transferred.

2. Agitator with multiple agitator speeds We then conducted further experiments along with agitator with multiple RPM Values - 810, 840 and 1500.

6 Results and Discussion

Here is a complete data of experiment we conducted above : DATA

Analysing the Data, we can see that the value of overall heat transfer coefficient increases as increase the speed of the impeller. The increase in the value can be seen the sheet shared above.

Also, we can say that if the mass flow rate is increases, the value of the overall heat transfer coefficent will be decreased.

Also, the values of the heat transfer coefficients inside the coil and outside the coil (inside the vessel) calculated manually are written in the sheet.

7 Conclusions

Concluding the experiment, we can say that by increasing the speed of the impeller (as we increases from 0 to 1500 RPM), the overall heat transfer coefficients increases. This brings changes in the values of h_i and h_o.

Also, by this experiment, we are able to justify the value of the thermal conductivity of copper.

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