SIMPLE SYSTEM TO DEMONSTRATE THE HEAT TRANSFER IN AGITATED VESSEL

CL 204: HEAT TRANSFER

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1 Problem Statement

This project delves into the fascinating world of heat transfer within agitated vessels. Through meticulous design, construction, and experimentation, we aim to not only demonstrate this fundamental principle but also quantify the key parameters involved: the overall heat transfer coefficient, individual heat transfer coefficient of the inner tube, and the total heat transferred during the process. Our proposed design leverages a well-insulated vessel, a U-shaped copper tube for heat exchange, and a combination of hot and cold water circulation to achieve this objective.

2 Theoretical Background

Agitation is not same as Mixing. Agitation refers to the induced Motion of a material in a specific way, usually in a circulatory pattern inside some sort of container whereas on the other hand Mixing refers to the random distribution into and through one another of two or more initially separate phases. In case of Agitation the composition remains the same, but in case of Mixing the composition is random and not the same throughout the mixture.

Agitated vessels are used in carrying out many operations involving heat transfer. Both, mixing and heat transfer, are major prerequisites for safe and reliable operation in chemical reaction.

Heat transfer in agitated vessels can be carried out either through an external jacket on the vessel or by internal coils. Whether to use internal coils or an exterior jacket requires careful consideration. When it comes to large-scale reactors that are involved in exothermic processes, the use of jacketed vessels presents a significant disadvantage. This is due to the negative correlation that has been found between the area-to-volume ratio decreasing and scale incrementation, which undermines the overall effectiveness of heat transmission mechanisms.

When the traditional methods of using jackets or internal coils cannot supply the necessary surface area, a wise solution would be to incorporate a recirculation loop with an external heat exchanger. This tactical enhancement successfully overcomes fundamental limitations linked to conventional jacketed vessels or internal coils, enabling more flexibility to different sizes and the demands of exothermic processes. The careful choice of jacketed vessels, internal coils, or recirculation loops emphasizes how important it is to customize heat transfer techniques to unique operating requirements, especially regarding large-scale, exothermic reaction scenarios in agitated vessels.

Some of the industrial applications where agitated vessels are used are:

1. Agitation of fluid to increase heat transfer between the fluid and a coil in the vessel wall.

2. Liquid-liquid Dispersion, i.e. Dispersion of Pigments in solvents.

3. Dispersing a gas in a liquid as fine bubbles, such as oxygen from air in a suspension of microorganisms.

Not going into the advanced designs for an agitated vessel, the basic design of an Agitated Vessel includes the below-mentioned factors that have to be kept in mind:

- The shape at the bottom of the vessel should be rounded to eliminate sharp corners or regions into which fluid current would penetrate.

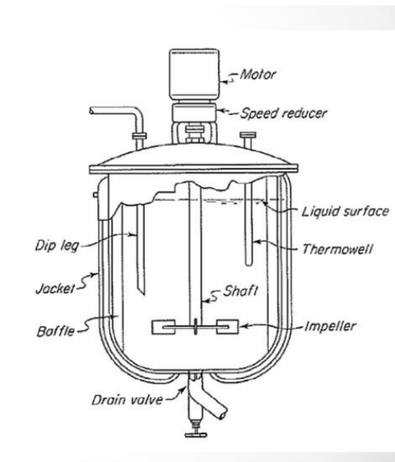

Figure 1: Basic Agitated Vessel

- The major influencing factors are:
  1. Dimensions of the liquid content of the vessel.
  2. Arrangements of the Impellers.

3 Proposed Work Plan

3.1 System Design and Construction

3.1.1 Agitated Vessel

The foundation of our system lies in a well-insulated, thick vessel. Jacketed glass reactors or insulated metal containers offer excellent options to minimize heat loss to the surroundings. Choose a vessel with sufficient volume to accommodate the inner tube and allow for proper fluid mixing during agitation.

3.1.2 Stirrer

The heart of the agitation process, the stirrer (impeller or propeller), plays a crucial role in generating sufficient flow within the vessel. Consider factors like power requirements and potential impact on the uniformity of heat transfer when selecting the stirrer.

3.1.3 Inner Tube

Fabricate a U-shaped copper tube with known dimensions and material properties. Ensure smooth bends and leak-proof connections for accurate measurements. Calculate the tube's surface area beforehand, as it will be crucial for later calculations.

3.1.4 Heat Source and Cooling System

Utilize hot water as the heat source, preparing a system capable of heating and maintaining the desired temperature throughout the experiment. For the cooling system, implement a siphon arrangement to circulate cold water through the inner tube. Ensure steady flow and measure both the inlet and outlet temperatures of the cooling water.

3.1.5 Temperature Measurement

Install thermocouples at strategic locations to capture vital temperature data. These include the bulk inner fluid, multiple points along the length of the inner tube wall, the bulk outer fluid, and optionally, the vessel wall.

3.1.6 Data Acquisition

Set up a robust data acquisition system to record temperature data from all thermocouples at regular intervals. This data will be the lifeblood of our analysis and calculations.

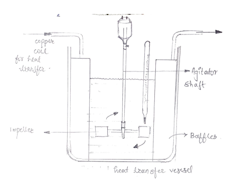

Figure 2: Rough Design of Agitated Vessel

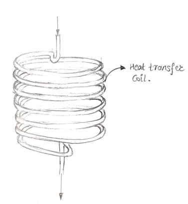

Figure 3: Rough Design of Coil

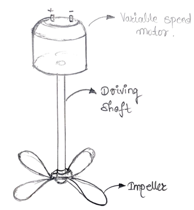

Figure 4: Impeller and Shaft

3.2 Experimental Procedure

1. Fill the vessel with water up to a suitable level.
2. Preheat the hot water to the designated temperature and ensure it stays consistent throughout the experiment.
3. Set the desired agitation speed using the stirrer and initiate data recording from all thermocouples.
4. Once steady-state conditions are achieved, marked by constant temperature readings, continue recording data for a sufficient duration to ensure accurate calculations.
5. To analyze the influence of various parameters, repeat the experiment with different agitation speeds and/or hot water temperatures.

3.3 Data Analysis and Calculations

1. Mass flow rate of water: $\dot{m} = \chi \times \rho_{water}$
2. Amount of heat transferred:

$$Q = \dot{m} \cdot C_p \cdot (t_2 - t_1)$$

3. Overall heat transfer coefficient

$$U = \frac{Q}{A_i \cdot \Delta T_{lm}}$$

   We shall also use Reynolds Number and Prandtl Number if necessary.

4. Reynolds number of water through tube

$$Re = \frac{d_i \cdot u \cdot \rho}{\dot{m}}$$

5. Prandtl number of water:
$$Pr = \frac{C_p \cdot \mu}{\kappa}$$

3.4 Additional Considerations

We can make some additional considerations and optimize the results.

- Prioritize safety by adhering to proper precautions when handling hot water and electrical equipment.
- Maintain consistent experimental conditions throughout, including factors like ambient temperature.
- For improved accuracy, consider using control valves or feedback systems to regulate the hot and cold water temperatures.
- Explore alternative data acquisition methods like wireless sensors for increased flexibility and ease of operation.

3.5 Procurement of Items

Table 1: Example Table

Equipment	Cost	Links
Stainless Steel Vessel	1336Rs	Link
Copper Coil - Hollow (Fluid has to flow inside)	1500Rs	Link
Agitator (Variable speed Agitator motor)	1400rs	Link
Something to heat the fluid 1	800rs	Link

4 References

1. https://www.linkedin.com/pulse/heat-transfer-agitated-vessels-ekato-corporation-2/