HEAT EXCHANGER

Heat exchange is an important unit operation that contributes to efficiency and safety of many processes. In this project you will evaluate performance of a shell and tube heat exchanger in which water flows through the tube side while steam flows through the shell side. This heat exchanger can be operated in both 1,2- and 1,4-pass configurations. Temperatures of inlet and outlet streams, as well as intermediate temperatures, are measured using K-type thermocouples and a digital thermometer.

Concepts to Review

- Shell and tube heat exchanger configurations (1,2-pass vs. 1,4-pass, co-current vs. countercurrent flow)
- NTU method for analysis of heat exchangers
- Heat transfer coefficients
- Reynolds number and Nusselt number
- Heat capacity/specific heat and heat of vaporization
- Thermal conductivity and film coefficients
- Material and energy balance closure

Degrees of Freedom

- Steam pressure
- Water flow-rate
- Heat Exchanger configuration (1,2-pass or 1,4-pass)

Consider effects of changes of these variables on key heat transfer performance indicators, such as heat transfer coefficient.
Theory

The heat exchanger can be modeled by the Effectiveness-NTU (number of transfer units) method. Effectiveness of a heat exchanger is defined as

\[ \varepsilon = \frac{q}{q_{\text{max}}} \quad (1) \]

Here, \( q_{\text{max}} \) is the maximum possible heat transfer rate for given inlet temperatures of the fluids and \( q \) is the actual heat transfer rate. NTU is defined as

\[ \text{NTU} = \frac{UA}{C_{\text{min}}} \quad (2) \]

Here, \( U \) is the overall heat transfer coefficient, \( A \) is the contact area, and

\[ C_{\text{min}} = \min(C_c, C_h), \quad (2) \]

where \( C_c \) and \( C_h \) are heat capacities of the cold and hot fluids, respectively.

Relationships between the effectiveness and the NTU have been established for a large variety of heat exchanger configurations. Therefore, the overall heat transfer coefficient can be obtained by experimentally measuring \( q \), computing \( \varepsilon \), and then computing NTU(\( \varepsilon \)) using an appropriate formula. Conversely, if the overall heat transfer coefficient is known, one can predict the heat transfer rate \( q \) for given inlet temperatures of the fluids; \( q \) can then be used to predict the outlet temperatures of the fluids.

The hot fluid in this experiment is steam which is nearly saturated. Therefore, a large fraction of the heat transfer involves steam condensation. In the first approximation, we can assume that the inlet hot fluid is saturated steam and the hot outlet fluid is saturated water.

Objectives

- Investigate effects of the control parameters (steam pressure and water flow rate)
- Check validity of the theoretical model. How good is the assumption that the heat exchange is dominated by condensation? You can check this assumption by computing the latent heat of condensation and the amount of heat transferred from the steam and hot water before and after the condensation took place.
- Determine the heat transfer coefficient in the 2-pass and 4-pass configurations and its variation with the Reynolds number.
- Compare your measured heat transfer coefficient with a theoretical calculation. Justify any assumptions and explain any differences.
- Investigate effects of the steam pressure on the rate of heat transfer.
- Investigate effects of the water flow rate on the rate of heat transfer.