ANALYSIS OF FLOW STRUCTURE IN HEAT EXCHANGERS

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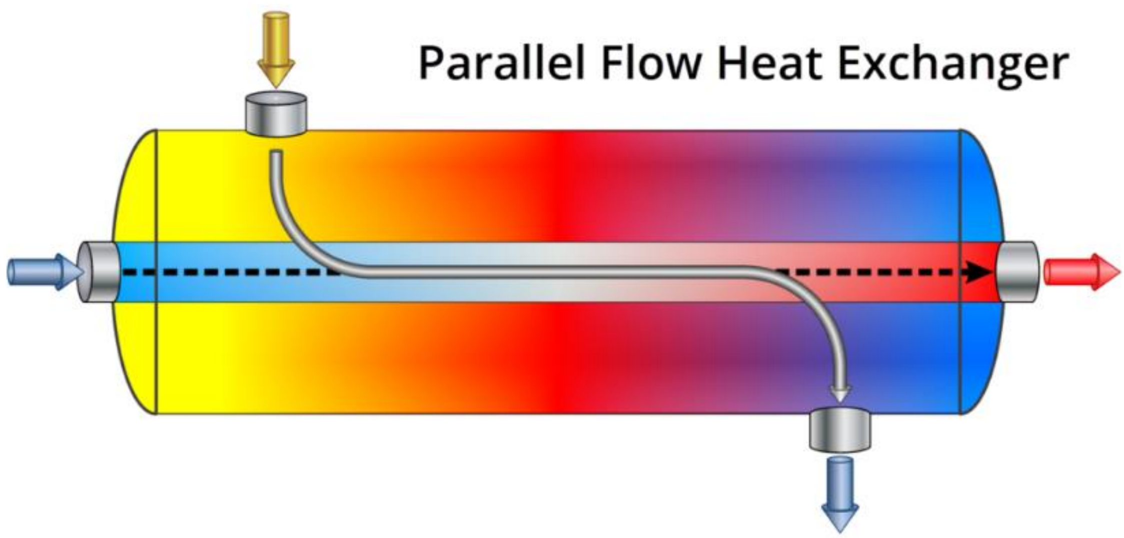
Abstract. *A heat exchanger is a system used to transfer heat between a source and a working fluid. Heat exchangers are used in both cooling and heating processes. The fluids may be separated by a solid wall to prevent mixing or they may be in direct contact. They are widely used in space heating, refrigeration, air conditioning, power stations, chemical plants, petrochemical plants, petroleum refineries, natural-gas processing, and sewage treatment. Shell and tube heat exchangers consist of a series of tubes which contain fluid that must be either heated or cooled. A second fluid runs over the tubes that are being heated or cooled so that it can either provide the heat or absorb the heat required. There are three primary classifications of heat exchangers according to their flow arrangement. In parallel-flow heat exchangers, the two fluids enter the exchanger at the same end, and travel in parallel to one another to the other side. In counter-flow heat exchangers the fluids enter the exchanger from opposite ends. The counter current design is the most efficient, in that it can transfer the most heat from the heat (transfer) medium per unit mass due to the fact that the average temperature difference along any unit length is higher. See countercurrent exchange. In a cross-flow heat exchanger, the fluids travel roughly perpendicular to one another through the exchanger.*

Key words: *heat exchanger, parallel-flow heat exchangers, counter-flow heat exchangers, cross-flow heat exchanger, temperature difference, flow resistance, flow speed.*

Introduction. As an important equipment in industrial cooling and heating process, shell and tube heat exchangers are widely used in refrigeration, chemical industry, air conditioning, petroleum, pharmaceutical industry, natural gas treatment and wastewater treatment because of their reliable operation, simple structure and easy maintenance. The baffle is a key structural part of heat exchangers. On the one hand, it can affect the flow resistance and heat transfer performance of the heat exchanger by changing the flow curve of shell side fluid. On the other hand, baffles can support the tube bundle and play a significant role in the stress and stability of the solid structure of a heat exchanger. Segmental baffle heat exchangers are the most adaptable and most widely used heat exchangers, which are simple in structure and convenient in manufacturing. However, it has shortcomings such as fouling, high pressure drop, large flow dead zone, and serious vibration caused by high-speed flow, which seriously affect its performance.

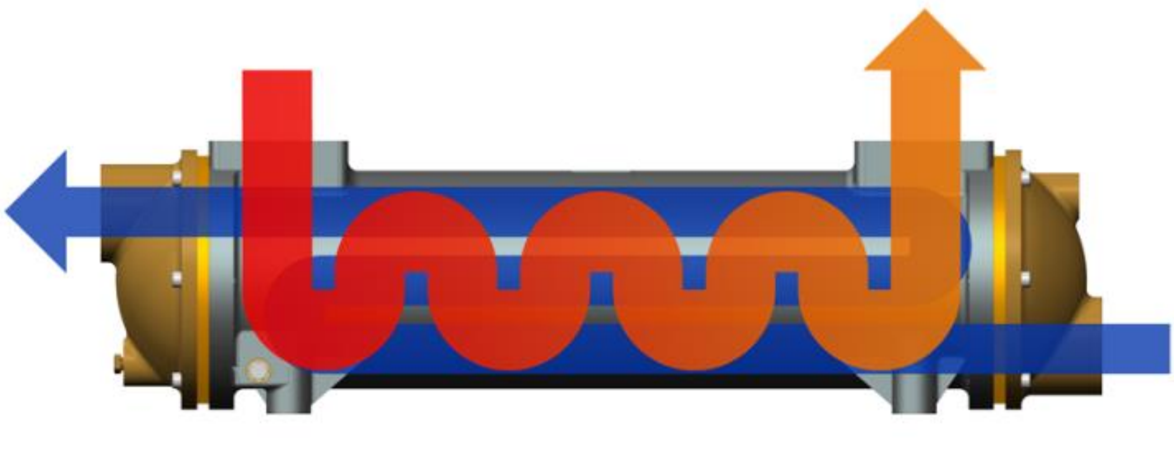
The purpose of a heat exchanger is to transfer heat energy from one fluid to another, with the two fluids existing initially at different energies and temperatures. What it means to be a parallel is that the two fluids enter and leave from the heat exhanger in the same directions. Heat exchangers are widely used across the world, from homes to giant industrial buildings, and as we will see parallel exchangers are not the only type, but are best for certain situations.

In its most basic form, a heat exchanger consists of tubes with one type of fluid moving through them, and a second fluid flowing around the outside of the tubes. The



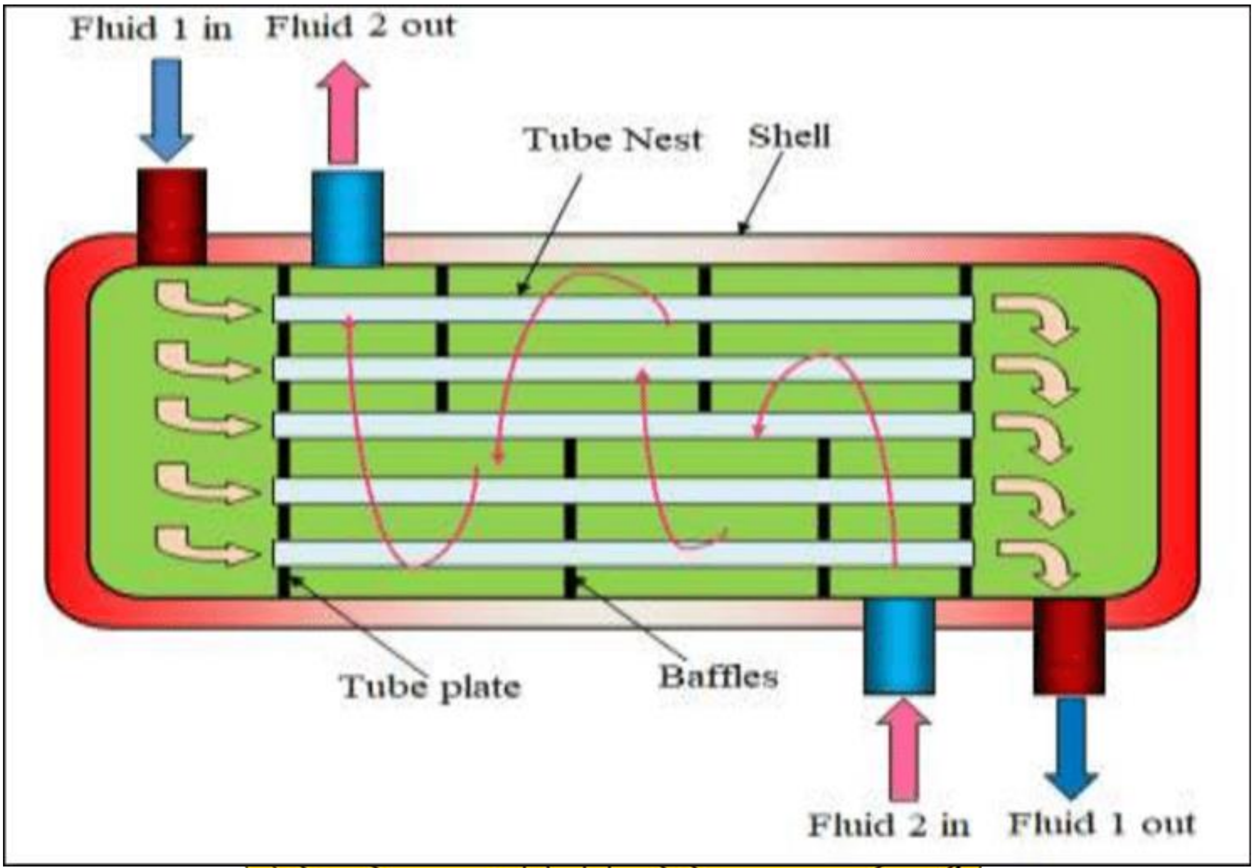
other main type of heat exchanger is called a counter-flow heat exchanger, in which the two fluids move in opposing directions.

Counter flow heat exchangers use flows in the opposite direction of each other. Shell and tube, and double pipes heat exchangers are examples of common exchangers using counter flow configurations. The best design for shell and tube and double-pipe exchanger is counter flow configuration, and the heat transfer between the fluid is the maximum. In counter flow, the efficiency is higher than the parallel, and temperature in the cooling fluid outlet can exceed the warmer fluid inlet temperature. In the figure below, we can see the position of inlets and outlets. As it is illustrated in the counter flow heat exchanger, the fluids flow in the opposite direction, and at the heads, there is a maximum temperature difference between them. We have an inlet for hot fluid and the exit pipes of cold fluid at the left head, while cold fluid inlets and the hot fluid



outlet are on the right head. For understanding what the counter flow is, we should know the differences between counter flow and parallel flow.

Counter flow heat exchangers have three noticeable advantages over parallel exchangers. As it is shown in the diagram, we have a uniform temperature difference



along the heat transfer area that minimizes the thermal stress in the system. The second one is the output temperature, which can have a higher value compared to the hot fluid. The final benefit of this type is uniform heat transfer between the fluids and larger LMTD (LMTD will be discussed in the next section). Whether we use parallel or counter flow heat exchanger, we have both convection and conduction. The heat transfer along the exchanger varies, and it is all because of the different temperatures at each point of view. Heat flows from the hot side to the cold side, and we have convection heat transfer between the fluids and the solid on both sides, while the heat transfer process is conduction in the solid part.

As can be seen in the figure, the temperature difference in counter flow is greater, and it causes a larger amount of heat transfer in the exchanger. The heat transfer can be calculated by the equation of $Q = UA\Delta T_{LM}$. it is the same for all the exchangers and the parameters are:

U = Average thermal transmittance from one fluid to the other one $(W \cdot m^{-2} \cdot K^{-1})$

A = Heat transfer area in the exchanger.

ΔT_{LM} = Logarithm mean temperature difference between fluids.

Logarithm mean temperature difference or LMTD can be calculated as below:

$$\Delta T_{LM} = \frac{\Delta T_A - \Delta T_{\boldsymbol{B}}}{L_N(\frac{\Delta T_A}{\Delta T_B})}$$

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