Effect of Baffles in Enhancing the Heat Transfer Coefficient of a Shell and Tube Heat Exchanger

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***Abstract*: Heat exchanger is a device used to transfer heat between one or more fluids by direct or indirect contact. There are various type of heat exchanger in which Shell & Tube Heat Exchanger is one of them. A Shell and tube heat exchangers are widely used heat exchanger in many engineering process such as power plant, cement factory, food industry, oil & petrochemical application, pharmaceutical, electric power generation etc. There are various services and application provided by the shell and tube heat exchanger make this device an essential component which plays a crucial role in the industrial process. The main components of Shell and tube heat exchangers are Solid Shell, bundle of Tubes, Tubesheet, Baffles etc, within period of decades there are changes done in the design of shell and tube heat exchangers. The purpose of this research is to study about changing arrangement of baffles angle toanalyse reducing the shell side pressure drop and increase the heat transfer ratejust to increase efficiency of plant & industry. Improve the performance of shell and tube heat exchanger with suitable baffle spacing and baffle orientation angles and baffle inclination.**

***Index Terms:* Hear exchanger, Baffles, CFD**

INTRODUCTION

SHELL & TUBE HEAT EXCHANGER

The natural laws of Thermodynamic always allow the driving energy in a system to flow until equilibrium is reached. Heat leaves the hotter body or the hottest fluid, as long as there is a temperature difference, and will be transferred to the cold body to maintain equilibrium. With shell type heat exchanger, the heat penetrates the surface, which separates the hot medium from the cold one very easily. It is therefore possible to transfer heat or cool fluids which have different energy levels. Two fluids, having different initial temperatures, flow through the heat exchanger. One fluid flows from the tubes and the other flows from outside but inside the exchanger. Heat is transferred from one fluid to another (high temperature to low temperature)through the tube walls, either from shell side to tube side or vice versa. In order to transfer heat effectively, a large heat transfer area should be used so that's why we used many tubes. In this way, wastage of heat can be minimized& increase efficiency.

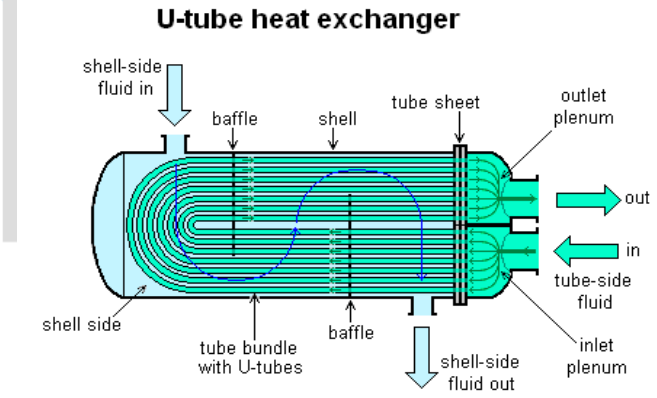

FIGURE 1: DIAGRAM OF SHELL & TUBE HEAT EXCHANGER

LITERATURE SURVEY

Recent work carried out for detail of work undertaken by different scientists and engineers in the field of heat transfer enhancement with the use of shell and tube type heat exchanger. The review includes numerical as well as the experimental work undertaken from time to time along with the development of the shell and tube type heat exchanger for enhancing the heat transfer rate–

Kevin M. Lunsford et al. [1] has analyzed to increase the efficiency & performance of heat exchanger and suggested increasing heat exchanger performance through a logical series of steps. The first step is considers if the exchanger is initially operating correctly and other step is to considers increasing pressure drop if available with single-phase heat transfer.
Rajagapal Thundil et al.[2] In the present study, investigate the impacts of various baffle inclination angles on fluid flow and the heat transfer characteristics of a shell-and-tube heat exchanger for different baffle inclination angles 0°, 10°,20°, 30°,40°. The result

of computer simulation for various STEH, one with segmental baffles perpendicular& one is inclined to the direction of fluid flow are compared for their performance. The Investigation is done by practically modelling a small shell-and-tube heat exchanger.

Chetan Namdeo Patil et al [3] practically investigated the effect of baffle cut on heat transfer coefficient and pressure drop with constant baffle spacing. They found that pressure drop is less in 30% baffle cut and heat transfer coefficient is almost same for 25% to 30% baffle cut.

B. Peng et al [4] investigated the effect of different baffles inclination angles & spacing on heat transfer coefficient keeping the pressure drop constant. They have found that for same pressure drop, shell and tube heat exchanger with segmental baffle has lower heat transfer coefficient as compared to shell and tube heat exchanger with helical baffles. They have also found the correlation between Nusselt number and Reynolds number as well as friction factor and Reynolds number.

Edward S. Gaddis et al [5] proposed a procedure to find the pressure drop. Their equation consists of correlation factor which is influenced by leakage and bypass stream. They compare their equation with experimental data to prove it.

Nikhil P. Talwekar.et.al [6] CFD analysis is carried on single pass, counter flow shell and tube heat exchanger containing Baffles at 0°,15°,30°, 45° inclination angle. The shell-side pressure drop is decreased with increase in baffle inclination angle from 0° to 45°.The baffle inclination angle more turbulence will be created across the shell side, because of this heat transfer coefficient is increases.

H. Li, V. Kottke. et.al [7] experiment with flowerbaffles, the angle of turn of the stream lines are reduced and minimise the pressure drop. The pressure is reduced by 25-35% which shows that Flower A Baffles are the most effective baffles as compared with Flower- B. Also Flower- A Baffles as they minimise the Pressure Drop as compares with Flower-B baffles but with a better thermal efficiency.

Vivekenand.et.al [8] Twisted elliptical tube with different structural parameter experimental investigated. They have found that there is pressure drop inside the tube. Larger tube and smallerl twist pitch result in high heat transfer.

Mahmoud Galal Yehia.et.al [9]. When using different number of swirl vanes at different locations along the pipe length to enhance the heat transfer rate there is definite an effect of friction.On experiment with the number of swirl vanes inserted into each tube is three swirl vanes and six swirl vanes distributed along the pipe length with variable diameter and different blade angle for each case. When we use case of six swirl vanes with 19 mm diameter and 45° blade angle gives the maximum heat transfer enhancement.

TYPES OF HEAT EXCHANGER

A Heat Exchanger is a device which is used to transfer thermal energy between two or more fluids inbetween a solid surface and a fluid, or inbetween solid particulates and a fluid, at variant temperatures and in different thermal contact. All the Heat exchangers operate under the same basic principles. However, Heat exchanger can be classified and categorized in several different ways i.e.

- Flow configuration
- Construction method
- Heat transfer mechanism

ON BASIS OF FLOW CONFIGURATION CONSTRUCTION METHOD

The flow configuration means flow arrangementof a heat exchanger based on the direction of movement of the fluids within the heat exchanger in relation to each other. There are four ways which flow fluids employed by heat exchangers:

- Cocurrent or Parallel flow (*the fluids move parallel to and in the same direction as each other.)*
- Countercurrent flow*(the fluids enter the exchanger from opposite ends)*
- Cross flow*(the fluids travel roughly perpendicular to one another through the exchanger)*
- Hybrid flow*(both counter flow and cross flowarrangements)*

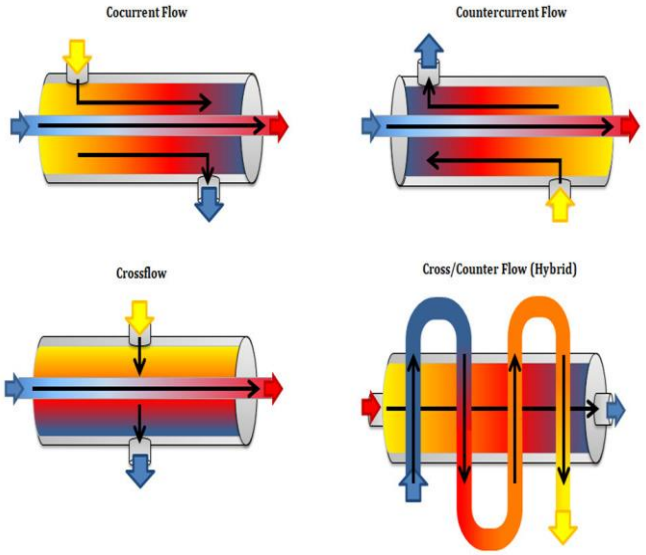

FIGURE 2: TYPES OF HEAT EXCHANGER ON BASIS OF FLOW

ON BASIS OF CONSTRUCTION METHOD

They are classified in construction characteristics include:

- Recuperative vs. regenerative
- Direct vs. indirect
- Static vs. dynamic

RECUPERATIVE VS. REGENEARTIVE

In Recuperative heat exchangers the fluid simultaneously flows through its own channel within the heat exchanger. On the other hand, regenerative heat exchangers, alternately allow warmer and cooler fluids to flow through the same channel.

Direct Vs Indirect

In direct contact heat exchangers, heat transfers from one fluid to another are done through direct contact(the fluids are not separated within the device) and On the other hand, In Indirect heat exchangers, the fluids separated from one another by some medium.

Static Vs. Dynamic

In static regenerators or fixed bed regenerators, the heat exchanger parts, structure and components remains stationary or fixed in a location as fluids flow through the device, while in dynamic regenerators the part of heat exchanger and their structure, components move throughout the heat transfer process.

ON THE BASIS OF HEAT TRANSFER MECHANISM

- Double pipe heat exchangers
- Plate heat exchangers
- Condensers, evaporators, and boilers
- Shell and tube heat exchangers

Double pipe heat exchangers

It is a form of shell and tube heat exchanger in which concentric tube are used. There are two pipes are used having different diameter. One pipe inside the other pipe. It is the simplest heat exchanger,. As per the design of all shell and tube heat exchangers, two different fluid having different temperature are passes with two different size of tubes (Diameter of one size is more than other one.)

Plate heat exchangers

Plate heat exchangers consists of various thin plate bundled together. Each pair of joined plates creates a duct through which one fluid can flow, and the pairs are stacked and attached with bolting, brazing or welding such that a second passage is created between pairs through which the other fluid can flow.

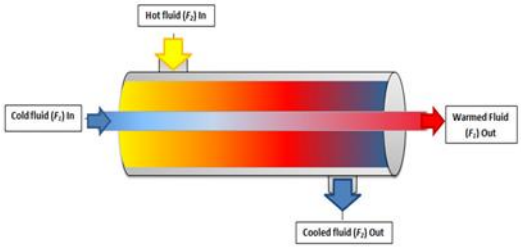

FIGURE 3: DOUBLE PIPE HEAT EXCHAGER

FIGURE 4: PLATE HEAT EXCHANGER

Condensers, evaporators, and boilers

Boilers, condensers, and evaporators are heat exchangers which are used to transfer heat between two phases of liquid, in two-phase heat exchangers one or more fluids undergo a phase change, during the heat transfer process, the temperature of hot fluid is exchange with cold fluid, due to this the phase change occurs.

Shell and tube heat exchangers

Shell and tube heat exchangers are the most common type of heat exchanger used in most of the industries, which consist bundles of tube enclosed within a sealed, cylindrical pressure vessel which is called shell. The fluid flows from the smaller tube, and the other fluid flows around its outside and between them within the sealed shell. Shell & Tube heat exchanger consist of finned tubes, single or two phase heat transfer, parallel flow, counter flow, or crossflow arrangements, and single, two, or multiple pass configurations. Some of the applications include preheating, oil cooling, and steam generation in various industries, Cooling of turbine, compressor, and engine.

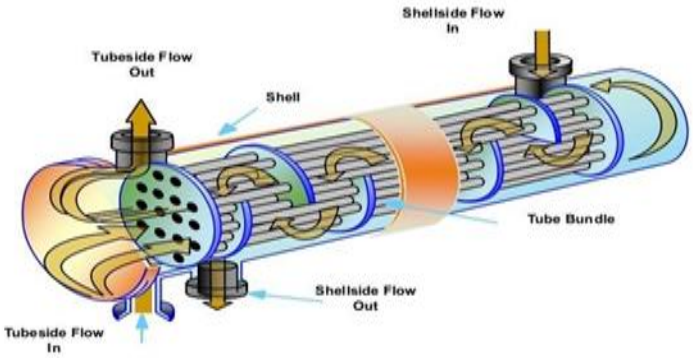

FIGURE 5: SHELL & TUBE HEAT EXCHANGER

TYPES OF SHELL & TUBE HEAT EXCHANGER

The manufacturing, design & maintaining standard, all are regulated by the TEMA i.e. Tubular Exchangers Manufacturers Association. They divided all heat exchanger designs into three main parts: - the shell, the rear end header and front end headerand designate all of them with letters.

There are three types are the U-tube, fixed tube sheet, and floating head heat exchangers.

U- TUBE SHELL & TUBE HEAT EXCHANGER

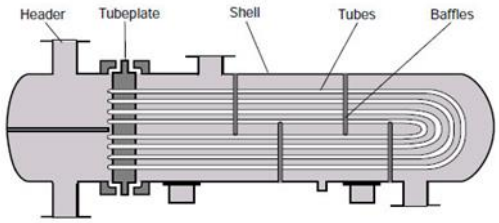

FIGURE 6: U-TUBE SHELL & TUBE HEAT EXCHANGER

From above figure its already shows where they get their name. The bundle of tubes are made of continuous tubes that bend into a U-shaped as seen in above figure, and are secured to the shell using one tubeplate (shown above). The low temperature fluids flows from the top half of the header, passes through the u-tubes, and then out the bottom half of the header, creating a multi-pass design. The main function of bend is to allow for thermal expansion without any rigid joint, as the bend side is free-floating in the shell and has room to expand and contract.

FIXED TUBE SHELL & TUBE HEAT EXCHANGER

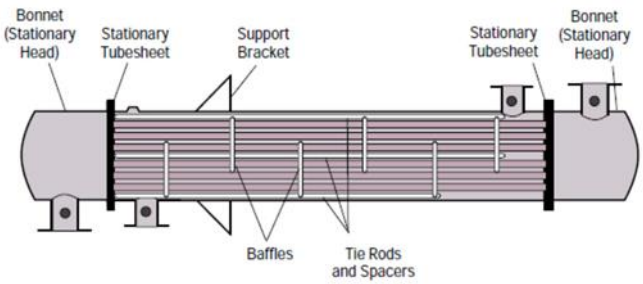

FIGURE 7: FIXED TUBE SHELL & TUBE HEAT EXCHANGER

The fixed tube sheet exchanger uses two stationary tube sheets as shown in above figure they are permanently joint by welding to the shell. They require minimum manufacturing cost & very easy to manufacture and works with highly efficient among all shell and tube design, to prevent expansion there are some gap or tolerance given between the tubes and sheet which are rigidly attached.

FLOATING HEAD HEAT EXCHANGER

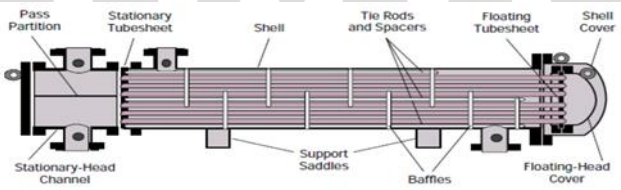

FIGURE 8: FIXED TUBE SHELL & TUBE HEAT EXCHANGER

Due to rigidity there are some problem occurring in contraction and expansion, to prevent this a hybridheat exchanger is used, named floating head exchanger which is combination of U- tube & Fixed type heat exchanger. In Floating Heat exchanger one end of the tubes is held stationary to the housing with a fixed tubesheet, but the other side is free to expand using a component known as afloating tubesheet. On increasing the temperature, this free part allows the tubes to expand without any bending.

BAFFLES IN SHELL AND TUBE HEAT EXHCHANGER

INTRODUCTION

Baffles are used to maintain flow of fluid inside the heat exchanger or in some industrial process, vanes or panels are used inin tanks such as shell and tube heat exchangers used in cement factories, power plant, chemical reactors, and static mixers. Baffles are an internal part of the shell and tube heat exchanger which is designed to support tube bundles and direct the flow of fluids with maximum efficiency.

USES OF BAFFLES

Themain function of a baffle in a shell and tube heat exchanger is to:

1. Hold tubes in position (preventing sagging), both in production and operation.
2. Prevent the effects of steam starvation, which is increased with both fluid velocity and the length of the exchange.

3. Direct shell-side fluid flow along tube field which increases velocity of fluid and alsoincreases the efficiency of heat Exchanger

TYPES OF BAFFLES

Implementation of baffles is decided on the basis of needs, size of exchanger, manufacturing cost, easily maintenance &their ability to support to the bundles of tubes. There are some types of baffle is used generally the follow are:-

1. Impingement Baffles (used for protecting bundle when entrance velocity is high)
2. Orifice Baffles
3. Single segmental
4. Double segmental
5. Support/Blanking baffles
6. De-resonating (detuning) baffles used to reduce tube vibration

Baffles play a crucial role in heat transfer, due to this if we change inclination angle, orientation angle and baffle spacing we get a different result for different value. With the study of this we enhance the efficiency of heat exchanger and reduce the cost.

For analysis of these i.e. baffle orientation and inclination angle on CFD with get an accurate result. Overall helpful for making a better heat exchanger with changes a minute angle of baffles.

If we Introducing baffle with appropriate orientation angles (45°, 60°, 90°, 120°& 180°) and baffle inclination angle (0°,10°,20°,30°,40°) in CFD and the result are compared with segmental baffle and alongwith segmental baffle orientation with inclination angle.

COMPUTATIONAL FLUID DYNAMICS (CFD)

Computational fluid dynamics (CFD) is a branch of fluid mechanics that uses numerical analysis and data structures to analyze and solve problems that involve fluid flows. A Computers software is used to perform the calculations required to simulate the free-stream flow of the fluid, and also the interaction between fluids (liquids and gases) with surfaces defined by boundary conditions. Once the Solid Works model has been created it is now fully adequate to the object, then, to solve the engineering problem with Flow Simulation. Once the model is created, the flow simulation project is to be set up. There are few step for setting up a Flow Simulation project in CFD, following are: choosing the analysis type, selecting a fluid and a solid and settings of wall condition and initial and ambient conditions. Any problem occurring in fluid mechanic is solved using this Flow Simulation which is categorized as either internal bounded or external unbounded flow. To analyzing Shell and tube heat exchanger, an effort is made to design and perform in the paper. The model of Shell & tube heat exchanger is created by using SOLIDWORKS2017.By applying boundary conditions, CFD analysis is carried out in ANSYS18.2.With the help of this software we study about changing arrangement of baffle analyses reducing the shell side pressure drop and increase the heat transfer rate. Improve the performance of shell and tube heat exchanger with suitable baffle spacing with different baffle orientation angles and baffle inclination angle.

CONCLUSION

Literature review reveals that,

1) Study of heat transfer of the heat exchanger at different flow rates
2) The output results coming out from heat exchanger having baffles situated at outer pipe are more efficient from heat exchanger without baffles.
3) if we change inclination angle, orientation angle and baffle spacing we get a different result for different value.
4) With the study of this we enhance the efficiency of heat exchanger and reduce the cost.
5) We get best result on comparing data of CFD & segmental baffles.

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