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# The Effects of Baffle's Design on Shell and Tube Heat Exchanger's Performance

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***Abstract:*** **The purpose of this article is to observe the effects of baffles' design in shell and tube heat exchanger on pressure drop and thermal performance at various mass flow rates. The pressure drop and heat transfer depend on the baffles design so here different baffles are simulated to evaluate the performance and find the best and suitable baffle at high mass flow rate in shell and tube heat exchanger. In this study shell side flow is focused and simulated because turbulence in shell side flow is high and baffles are also installed there. Four different types of baffles are modeled and simulated including single segmental, double segmental, helical and single segmental plus helical. These baffles are modeled and simulated on solidworks CAD software. Simulated results has shown that the single segmental baffle has more pressure drop and less heat transfer rate but new design single segmental plus helical baffle has less pressure drop and more heat transfer rate even at high mass flow arte.**

***Index Terms—*** **Shell and tube heat exchanger, CFD, baffle design, pressure drop, thermal performance.**

## I. INTRODUCTION

To transfer thermal energy between various fluids and solid at different temperature heat exchangers are used. Basically, Heat exchanger transfer heat energy without mixing of two fluids having different temperatures. Unlike Boiler, no interaction of external thermal energy; however, Heat exchanger exchange heat due to temperature difference of fluids. Mainly, in Heat exchanger Heat transfer take place due to conduction and convention. Shell and tube heat exchanger is one of the major classes of heat exchangers. The shell & tube heat exchanger gives high heat transfer rate. A lot of changes have been carried out to get solution of required problems. Heat exchanger design is a dynamic area discovering modern technologies.

Baffles of heat exchanger support its tubes to maintain required velocity for the shell side fluid, prevent tubes vibration and for transferring heat. In side of shell baffles guide the stream across the tube field. In shell and tube heat exchanger various baffle plates are used it may segmental baffles or helical baffles .the major factors are being considered in shell-tube heat exchangers are pressure drop & Thermal performance. These factors are affected by the baffles orientation and design.

Different variable can easily be designed and simulated with help of CFD [1] ]Heat exchangers are classified on the basis of different characteristics such as flow arrangements, number of fluids transfer process, heat transfer mechanism and construction futures [2].comparatively other types of heat exchangers shell & tube heat exchanger mostly used in large chemical processes and high pressure applications [3]. Also this type of heat exchanger is simple to design for the large temperature differences [4]. It has been recommended for high performance pressure drop should be low and high heat transfer coefficient. Moreover, the turbulence created by baffles also effects heat transfer performance.

There has been given several geometries of baffles in literature. Likewise, segmental, doughnut & helical types. Huge pumping power is needed to offset high pressure drop when baffles having segmental geometries use in shell & tube heat exchangers. [5]. ABB Lummus had manufactured commercially [6]. Lei et al had given heat transfer in heat exchanger [7] numerical investigation carried out to get the impact of heat transfer due to inclination of various angels of baffles. It was concluded that the best-integrated 45° helix angle gives best performance. Gaddis and Gnielinsk [8] two types of flow array categorized: parallel or co-current & counter flow or concurrent. In a counter-flow two fluids parallel flow but opposite in direction .It was found that the counter-flow array carry higher thermal energy than others flow array. It gives higher thermal efficiency.

Furthermore, it had been proved that at same structure and mass flow helical baffles are most effective for heat transfer than other geometries of baffles. Wang et al [9]. Different types of baffles were proposed to decrease the pressure drop inside the shell [10].According to requirement to support the tubes maximum space between the baffles is limited. The unsupported maximum tubes distance in inches equal to $74d^{0.75}$ (where d indicates outer diameter of tube in inches ) [11]. Most favorable value for the overall coefficient of heat transfer is within 5-10%. However, some authors also mentioned a range within 2-5% [12] Two fluids flow at different temperatures: One of these flows internal of the tubes other external of the tubes. Heat is transfer take place between these fluids through the wall of tubes. It has been found that more than 30% shell and tube types of heat exchangers are currently being used [13].

## II. Computational Fluid Dynamics

### A. *Physical modeling*

In Solidworks CAD software, model of a shell and tube Heat Exchanger is created and specifications for modeling geometry are.

TABLE I: Model dimension of heat exchanger

| Specification | Dimensions |
|---|---|
| Heat Exchangers' length , L | 600 mm |
| Inside Diameter of Shell, DS | 90 mm |
| Length of Tube, l | 600 mm |
| Outside Diameter of Tube, Do | 20 mm |
| No. of tubes, Nt | 07 |
| Baffle Designs | 1. Single segmental<br>2. double segmental<br>3. Helical<br>4. single segmental + helical baffle |
| Baffle spacing, ΔBt | 86 mm |
| Baffles thickness, t | 03 mm |
| No. of baffles Nb | 6 |

Figure 1.Shows four types of baffles that are used and equal spacing is given for all types of baffles and other parameters are kept constant. This indicates to a comparison between the four different types of baffle types. Inside the shell working fluid is water having specific heat 4185 J/kg K. Water is incompressible fluid and Newtonian as its thermo physical properties does not change at required temperature range. It is supposed that the new Heat Exchanger to be constructed and the leakage between the contacts of the parts is very minor and negligible fouling resistance.

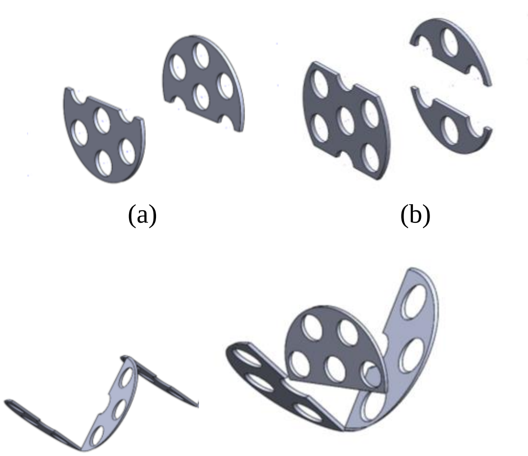


Fig. 1. Types of baffles (a) single segmental (b) Double segmental (c) Helical segmental (d) Single +helical segmental

### B. *Mathematical modeling*

With the help of CAE software various physical problems can be resolved and transformed in mathematical domain i.e. fluent and solidworks CAD simulation. These are established on Numerical approaches and these are solved both empirical relations and iteratively. In such a way, these complex systems are being modelled into mathematical equations and are solved respectively. CFD (Computational Fluid Dynamics) is a simulation technique including flow simulation, thermal analysis, and structural analysis and associated phenomena such as heat transfer due to difference of temperature between two fluids with the help of Computer. CFD helps to shows behavior of fluid flow in various conditions and pressure drop effects and thermal performance Computational Fluid Dynamics use an equation of Navier-Stokes that is shown as:

$$\left(\frac{\partial \rho\phi}{\partial t}\right) + \left(\frac{\partial \rho u\phi}{\partial x} + \frac{\partial \rho v\phi}{\partial y} + \frac{\partial \rho\phi}{\partial x}\right) = \Gamma\left(\frac{\partial^2\phi}{\partial x^2} + \frac{\partial^2\phi}{\partial x^2} + \frac{\partial^2\phi}{\partial x^2}\right) + S(\phi) \quad (1)$$

where, $\phi$= 1, V (u, v, w), T mass, momentum and energy. Basically, the conservation of energy ,mass and momentum for the given system these equtions are used.

### C. *Boundary conditions*

The Shell and Tube heat exchanger using four types baffle is modeled .shell side study is focused and the coarse type mesh is generated using Solidworks tool. It is also observed the highly turbulent fluid flow inside the Heat Exchanger.In shell side cold water is passed and tube side hot water passed the heat transfer take place due to conduction. Shell inlet is fixed as inlet mass flow rate and that ranged 0.03863765kg/s to 0.08 kg/s and outlet of shell is set pressure outlet.

TABLE II: Boundary conditions

| Physical Parameter | Shell Side | Tube Side |
|---|---|---|
| Fluid | cold water | Hot water |
| Inlet Mass Flow | 0.03863765 ,0.04, 0.05 ,0.06, 0.07, 0.08 kg/s | 0.78441kg/s is kept constant |
| Outlet pressure | Atmospheric pressure | Atmospheric pressure |
| Inlet Temperature | 300K | 340K |
| Area of inlet | 0.000490874m$^2$ | 0.000490874m$^2$ |

## III. Results and discussions

Flow trajectory path lines show the path fallowed by fluid and the path lines also depends on orientation of baffles' design. The single segmental baffle Fig. 2(a) shows it fallow zigzag array that create back mixing and dead zones of fluid particles and eddy formation this lead the result less effectively heat transfer and more pressure drop and reduce the performance of heat exchanger. It is important that more the pressure drop more the power required to the pump. In double segmental as shown in Fig. 2 (b) (DSG-STHX) the improvement of in reduction of dead zones which effects the reduction of pressure drop and increase the thermal performance. Fig.2(c) shows Helical baffles (H-STHX), The fluid fallow the path is helical and has very less dead zones that effects the reduction of pressure drop and increase of thermal performance. In a novel design of this research shown in fig.2 (d) a new type of baffles named single segmental +helical baffle is designed which eliminate the dead zones and increases the much thermal performance reduce much more pressure drop respectively than others baffles available.

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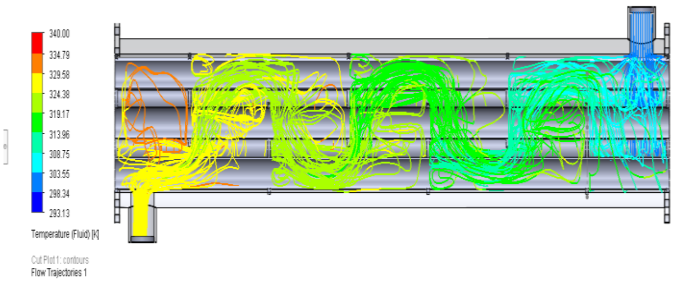
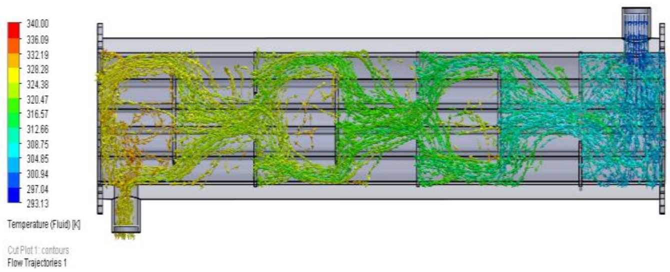
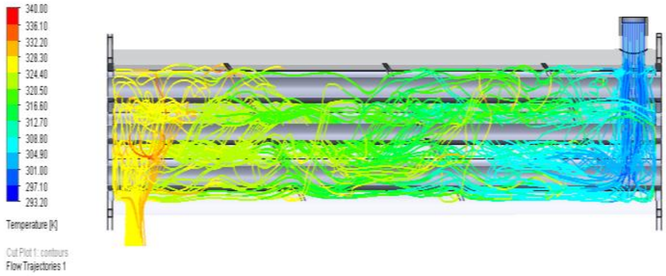



(a)




(b)

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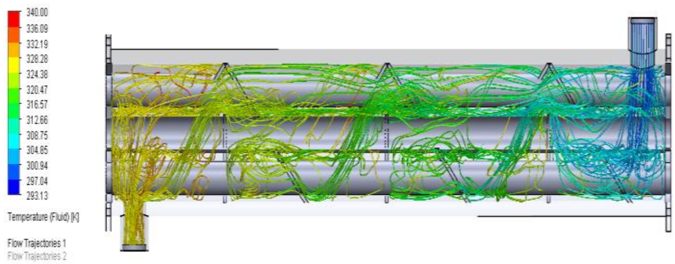
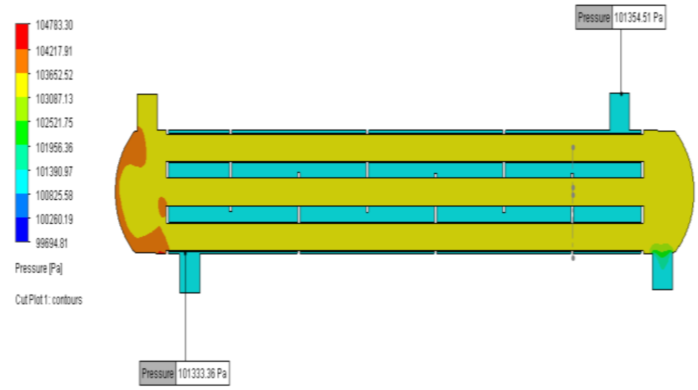



(d)

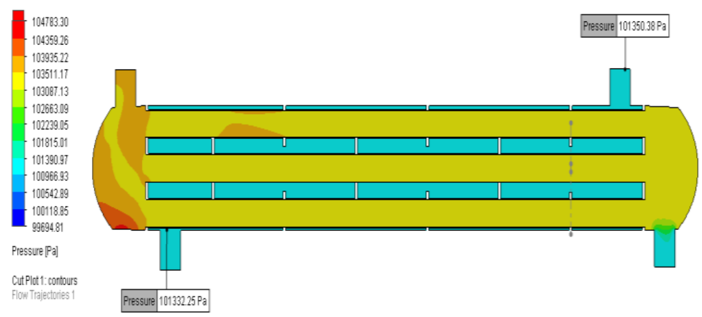
Fig. 2. Path lines flow trajectory of fluid of (a) Segmental baffle (b) Double segmental baffle (c) Helical baffle (d) single segmental +helical baffle

## A. *Pressure drop*

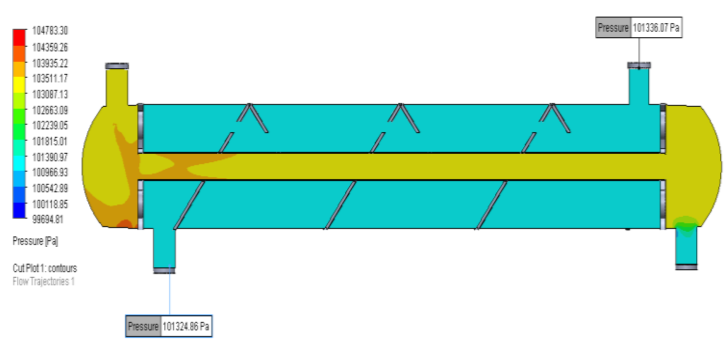
Pressure drops directly affects the performance, efficiency and operating cost of heat exchanger. More the pressure drop more the power consumed by pump and reduce the overall efficiency. from these simulation it is observe fig 3(a) single segmental baffle has more pressure drop where as in double segmental baffle shown fig 3(b) pressure drop reduce as compared single segmental moreover in helical type baffle shown fig 3(c) pressure drop is lower than both single segmental and double segmental . also it can be observed from simulated result the novel design of single segmental +Helical baffle shown fig 3(d) the pressure drop is lower than respective other baffles used in simulation and due to less pressure drop this type of baffle give more thermal performance.



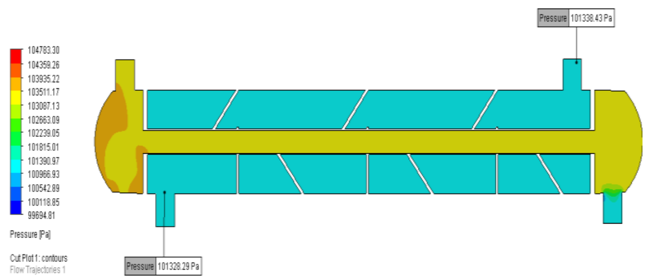

(a)




(b)




(c)



(d)

Fig. 3. Result of pressure simulation (a) Segmental baffle (b) Double segmental baffles (c) Helical baffle (d) Single segmental + helical segmental

*B. Effect on Shell side Pressure Drop*

Pressure drop graph fig.4 shows that the mass flow rate flow varies (0.0383 to 0.08) kg/s and it can be observed by changing mass flow rate pressure drop also changes. It can be observed that at low mass flow rate for all types of baffles pressure drop is low.

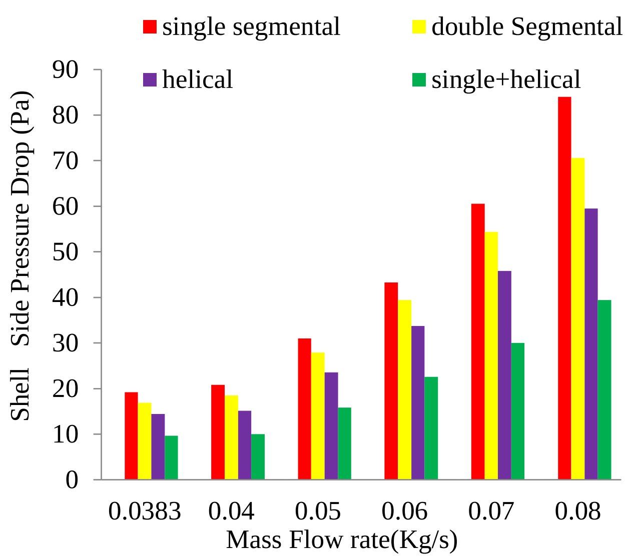



Fig. 4. Comparison of pressure drop for different types of baffle design

It can be observed from pressure drop chart shown in figure 4. Increase mass flow shell side increases pressure drop and also can be observed pressure drop in different types of baffles used in Heat exchanger. Likewise, It can be noted that the pressure drop high in single segmental and low in novel design single segmental+ helical baffle . it is recommended that new design single segmental+ helical baffle has very less pressure drop and can be used at high mass flow arte to get maximum performance.

## IV. Conclusion

In this work, a CFD model is used to compare and compute effects of baffles' designs on the performance shell and tube heat exchanger. These four baffle including, 1.single segmental baffle, 2.double segmental baffle, 3.helical baffle and 4.single + helical segmental baffle were simulated to see the effects of baffles' design on the pressure drop and thermal performance. Pressure drop effects if the number of baffles are increased. Due to change of the baffles' design and keeping the other parameters same It is found that single segmental baffle give high pressure drop however, new design single segmental+ helical baffle give very less pressure drop comparatively all these baffle were simulated in this study .It was also concluded The formation of dead zones in single segmental baffle occurs whereas low heat transfer takes place. This issue is overcome by using double segmental baffles. Similarly it lower the vibrational damage related to single segmental baffle .However ,using single segmental + helical baffle as compared others baffle it lowers the pressure drop that helps to increased efficiency of overall system. So it is concluded that new design single segmental + helical baffle is more efficient than other three design of baffle.

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