CFD analysis of Shell & Tube Type Heat Exchanger with Baffles

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***ABSTRACT*: In process industry, majority of heat exchangers are of shell and tube type heat exchangers. Shell and tube type heat exchangers are having different components, in which baffle is used to direct shell side fluid and to support the tubes. But use of segmental baffle produces problem of large pressure drop, flow induced vibration. To overcome these problems one way is to direct the flow as longitudinal on the shell side by use of a new baffle arrangement which will produce the longitudinal flow on the shell side. The baffle is called as Slotted baffle. Present work is focused on a detail description of the baffle geometry and arrangement of a new baffle.**

I. INTRODUCTION:-

Need of Analysis

When the **conventional baffles** are used in shell and tube type heat exchanger following problems were observed. High shell side pressure drop, Flow induced vibration, Formation of low flow areas, more fouling. Formation of dead zones. Mixture of counter current & co current flow. Due to pitting action, between baffle and tube, failure of tube due to crevice corrosion. More leakage areas. Hence in this paper we are focusing on the geometry of the baffles & their orientation to avoid above problems. A heat exchanger transfers energy from one fluid to another across a solid surface by convection and conduction.[1] Heat exchangers are used in power plants, nuclear reactors, refrigeration and air conditioning systems, automotive industries, heat recovery systems, chemical processing, and food industries.[3] The design of a new heat exchanger (HE) is referred to the (i) sizing crisis means it includes construction type, flow arrangement, tube and shell material, and physical size which has to meet the specified heat transfer and pressure drop.(ii) rating of existing heat exchanger.[1,4] Shell and tube heat exchanger design is based on correlations between the Kern method and Bell-Delaware method.[4,5] Kern method used for calculating shell-side pressure drop and heat transfer coefficient. And is restricted to a fixed baffle cut (25%) and cannot adequate for baffle-to-shell and tube to-baffle leakage. Kern method is not applicable in laminar flow region where shell-side Reynolds number is less than 2000. [4] Bell-Delaware method is more accurate method and can provide detailed results. It can predict and estimate pressure drop and heat transfer coefficient with better accuracy. The Bell-Delaware method is actually the rating method and it can suggest the weaknesses in the shell side deign but it cannot indicate where these weaknesses are. [5] The optimization of shell-and-tube heat exchangers requires a good knowledge of the local and average shell-side heat transfer coefficients which is complicated by a shell diameter, baffle cut, baffle spacing, tube diameter, pitch, arrangement and clearances or leakage paths. These leakages reduce the velocity in the tube bundle and, hence, the heat transfer coefficient and pressure drop. Recently, several models have been applied to analyze flow and thermal transfer but these models can only provide the integral heat transfer co-efficient. [6]

II. LITERATURE REVIEW

Žarko Stevanović, Gradimir Ilić, Design Of Shell-And-Tube Heat Exchangers By Using CFD Technique, University Of Niš, Fr, 2002. has developed an iterative procedure for sizing shell-and-tube heat Exchangers according to given pressure drop and the thermo-hydraulic calculation and the geometric optimization on the basis of CFD technique have been carried out. A numerical study of three-dimensional fluid flow and heat transfer is described. The baffle and tube bundle was modeled by the 'porous media' concept. Three turbulent models were used for the flow processes.

Koorosh Mohammadi*, Wolfgang Heidemann*,§ and Hans Müller-Steinhagen 2008 have published “EFFECT OF BAFFLE ORIENTATION ON HEAT TRANSFER AND PRESSURE DROPOF SHELL AND TUBE HEAT EXCHANGERS WITH AND WITHOUT LEAKAGEFLOWS”. It was found, that the horizontal baffle orientation produces up to 250% higher pressure drop compared to the pressure drop in vertical baffle orientation. The heat transfer coefficient is up to 20% higher than the heat transfer coefficient for vertical orientation. The local and overall behavior of the performance factor for liquids as shell side fluid is comparable and reaches a value of about 0.85 at high Reynolds numbers. With air as shell-side fluid a value of about 0.3 for the overall performance factor was obtained at high Reynolds numbers. The benefit of vertical baffle orientation over horizontal baffle orientation is more noticeable for gases since the dissipation rate in gases is much higher than in *liquids.*

Jian-Fei Zhang, Ya-Ling He, Wen-Quan Tao [7]
developed a method for design and rating of shell-and-tube heat exchanger with helical baffles based on the public literatures and the widely used Bell–Delaware method for shell-and-tube heat exchanger with segmental baffles (STHXSB). The accuracy of present method is validated with experimental data. Four design cases of replacing original STHXsSB by STHXsHB are taken. In case 1 comprehensive performance is greatly improved by using tube-core with 40 degree middle overlapped helical baffles, and

the pressure drop is 39% lower and 16% decrease in heat transfer area. In case 2 the usage of tube-core with 40 deg middle overlapped helical baffles can reduce the over-all pressure drop by 46% and the heat transfer area is 13% lower. In case 3 pressure drop of the heat exchanger with 40 deg middle-overlapped helical baffles is equivalent, the heat transfer area reduced by 33%. In case 4 20 deg middle-overlapped helical baffles were adopted and the pressure drop is 33% lower than that of the original unit with 10% decrease in heat transfer area. And comparison result shows that all shell and tube heat exchanger with helical baffles have better performance than the original heat exchanger with segmental baffles.

III. EXPERIMENTAL SETUP AND INSTRUMENTATION

On shell side, hot water is used as a working fluid. Hot water enters from the top into the shell and tube heat exchanger and leaves the shell from bottom. Hot water from the reservoir passes through the water pump; it is pumped towards the heat exchanger. Flow is controlled with the help of a ball valve; flow rate is measured through orifice. On shell side, thermostatically controlled heater is used to heat the water; it is clamped inside the reservoir.

It gives digital value of the temperature of water. The water can be heated up to 850C thermostatically and maintained at that temperature in reservoir on shell side. On tube side, cold water is used as a working fluid. Cold water at atmospheric temperature pumped on tube side from top of the rear head. On tube side flow rate is measured by orifice. From the rear head cold water passes into the tubes. Here heat exchange takes place. Then it flows into the front head and then leaves to the atmosphere.

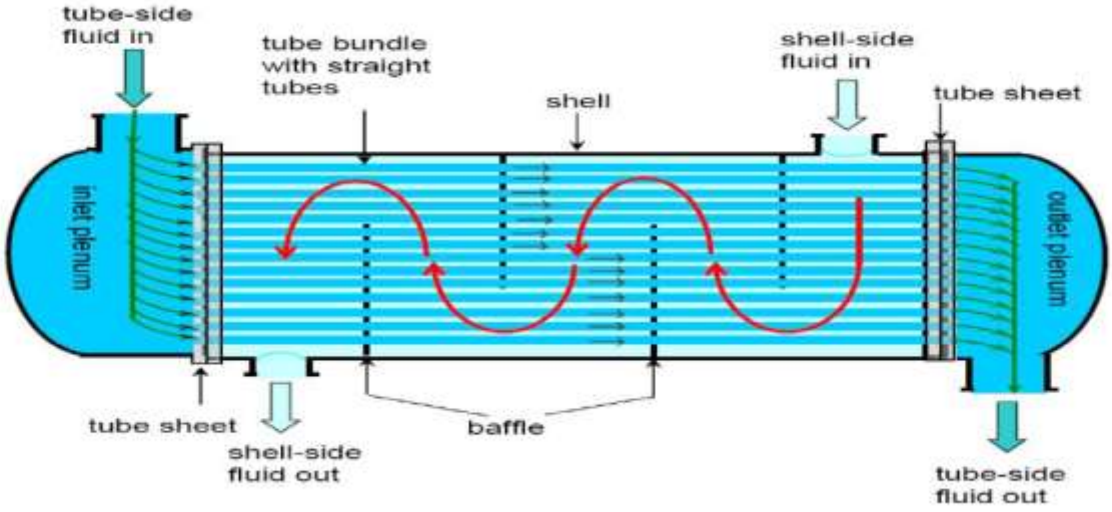
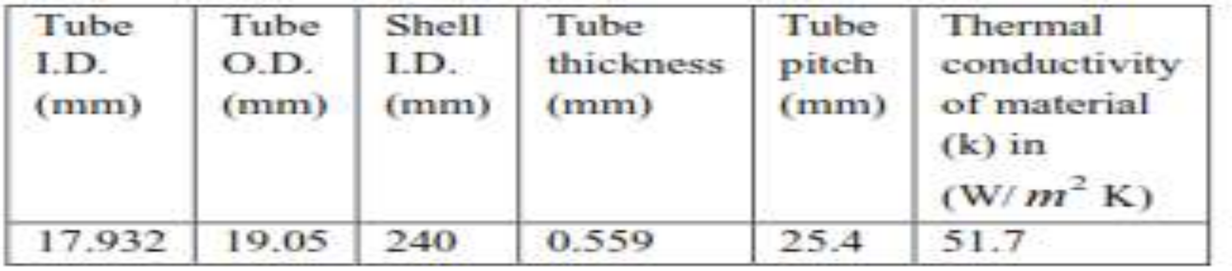


Table 1 Geometrical condition and physical properties



Tube I.D. (mm)	Tube O.D. (mm)	Shell I.D. (mm)	Tube thickness (mm)	Tube pitch (mm)	Thermal conductivity of material (k) in (W/ m^2 K)
17.932	19.05	240	0.559	25.4	51.7

Number of tubes 48
Number of baffles 3
Baffle spacing 250 mm.
Inlet /Outlet dia. for shell and tube 50.8 mm

SHELL AND TUBE TYPE OF HEAT EXCHANGERS

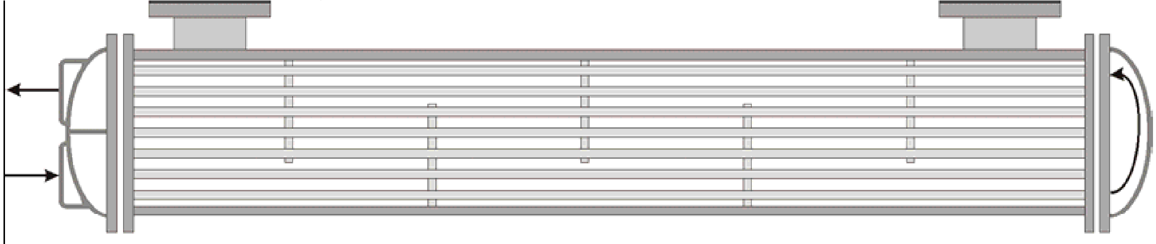
- **WHY SHELL AND TUBE HEAT EXCHANGER?**

Shell & tube heat exchangers in their various construction modifications are probably the most widespread & commonly used basic heat exchanger configuration in the process industries. The reasons for this general acceptance are several. The shell & tube heat exchanger provides a comparatively large ratio of heat transfer area to volume & weight .It provides this surface in a form which is relatively easy to construct in a wide range sizes & which is mechanically rugged enough to withstand normal shop fabrication stresses, shipping & field erection stresses, & normal operating condition. There are many modification of the basic configuration, which can be used to solve special problems. The shell & tube exchanger can be reasonable easily cleaned, & those components most subject to failure – gaskets & tube – can be easily replaced. Finally, good design methods exist, & the expertise & shop facilities for the successful design & construction of shell & tube exchangers are available throughout the world.

BASIC CONSTRUCTION OF SHELL AND TUBE HEAT EXCHANGER

Shell and tube heat exchangers represent the most widely used vehicle for the transfer of heat in industrial process applications. They are frequently selected for such duties as:

- Process liquid or gas cooling
- Process or refrigerant vapor or steam condensing
- Process liquid, steam or refrigerant evaporation
- Process heat removal and preheating of feed water
- Thermal energy conservation efforts, heat recovery
- Compressor, turbine and engine cooling, oil and jacket water
- Hydraulic and lube oil cooling
- Many other industrial applications



Fixed Tubesheet, 2-Pass Heat Exchanger

Shell and tube heat exchangers have the ability to transfer large amounts of heat in relatively low cost, serviceable designs. They can provide large amounts of effective tube surface while minimizing the requirements of floor space, liquid volume and weight. Shell and tube ex-changers are available in a wide range of sizes. They have been used in industry for over150 years, so the thermal technologies and manufacturing methods are well defined and applied by modern competitive manufacturers. Tube surfaces from standard to exotic metals with plain or enhanced surface characteristics are widely available. They can help provide the least costly mechanical design for the flows, liquids and temperatures involved.

BAFFLES

NEED OF BAFFLES

1. A baffle is designed to support tube bundles & reduce vibration of tube.

2. Direct shell-side fluid flow along tube field. This increases fluid velocity and the effective heat transfer co-efficient of the exchanger.

TYPE OF BAFFLES

Single Segmental Baffles
Single segmental baffles are used most frequently due to their ability to assist maximum heat transfer (due to a high-shell-side heat transfer coefficient) for a given pressure drop in a minimum amount of space

Double segmental Baffles Double-segmental baffles are used most frequently due to their ability to assist maximum heat transfer (due to a high-shell-side heat transfer coefficient) for a given pressure drop in a minimum amount of space

Doughnut & Disc Type of Baffles
Disk and doughnut baffles/ support plates are used primarily in nuclear heat exchangers. These baffles for nuclear exchangers have small perforations between tube holes to allow a combination of cross flow and longitudinal flow for lower shell-side pressure drop.

Disc and ring baffles are composed of alternating outer rings and inner discs, which direct the flow radially across the tube field.

1 The potential bundle-to-shell bypass stream is eliminated.

2 This baffle type is very effective in pressure drop to heat transfer conversion.

Longitudinal Baffles

The purpose of longitudinal baffles is to control overall flow direction of shell fluid such that a desired overall flow arrangement of the two fluid stream is achieved.

DISADVANTAGE OF CONVENTIONAL BAFFLES

1 High shell side pressure drop
2 Flow induced vibration
3 Formation of low flow areas
4 More fouling
5 Formation of dead zones
6 Mixture of counter current & co current flow
7 Due to pitting action, between baffle and tube, failure of tube due to crevice corrosion
8 More leakage areas

Shell Constructions

The most common TEMA shell type is the “E” shell as it is most suitable for most industrial process cooling applications. However, for certain applications, other shells offer distinct advantages. For example, the TEMA-F shell design provides for a longitudinal flow plate to be installed inside the tube bundle assembly. This plate causes the shell fluid to travel down one half of the tube bundle, then down the other half, in effect producing a countercurrent flow pattern which is best for heat transfer. This type of construction can be specified where a close approach temperature is required and when the flow rate permits the use of one half of the shell at a time. In heat recovery applications, or where the application calls for increased thermal length to achieve effective overall heat transfer, shells can be installed with the flows in series. Up to six shorter shells in series is common and results in countercurrent flow close to performance as if one long shell in a single pass design were used.

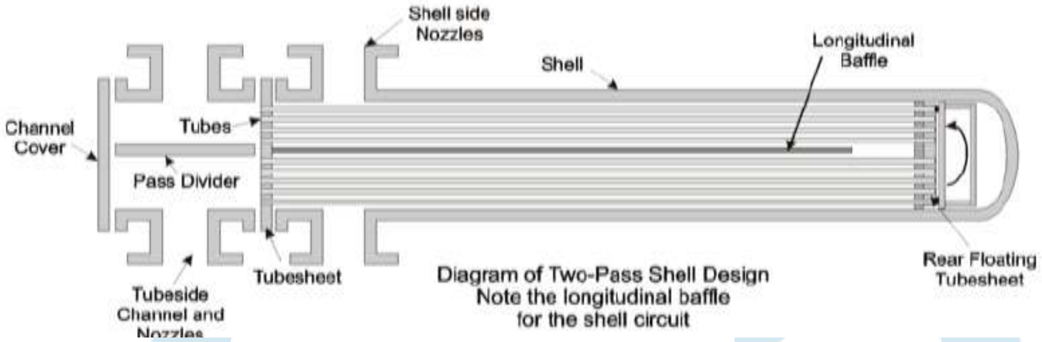


Fig. Two Pass Shell Design

Hence in this paper we are focusing on the geometry of the baffles & their orientation to avoid above problems. Conventional methods used for the design and development of Heat Exchangers are expensive. CFD provide alternative to cost effectiveness speedy solution to heat exchanger design and optimization.CFD results are the integral part of the design process and it have eliminated the need of prototype .due to the development of CFD models, the use of CFD is no longer a specialist activity. It is accessible to process engineers, plant operator and manager. Further study needs to be carried out for performance optimization of shell and tube heat exchanger by varying tube & shell diameter, no. of tubes, pitch and baffle angles.CFD is still a developing art in prediction of erosion/ corrosion due to lack of suitable mathematical models to represent physical process. New flow modeling strategies can be developed for flow simulation in shell and tube heat exchanger.

IV. CONCLUSION

As mass flow rate increases inside the shell side as well tube side, pressure drop also increases. The deference obtained in theoretical results and experimental results are significant because in tube side, pressure is calculated only between tube inlet and outlet, front and rear head pressure drop, nozzle pressure drops are not considered. In shell side pressure drop is calculated only between two baffles.

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