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# Design and Comparative CFD Analysis of Shell and Tube Heat Exchanger

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*Abstract:* **Heat exchangers are one of the most important components of the processing industries and also power plants. The pressure drop and the temperature variation in them are altered based on the component design as per operating parameters. As an integral part of design, baffles which are part of the heat exchanger serve the purpose in altering the pressure drop. In order to reduce the flow induced vibrations and reduce pressure drop different types of baffles are being designed and used and one such baffle is helical baffle. Helical baffles forces the flow through the system be to be rotational and follow a helical path due to the geometry of the continuous helical baffles, which results in a significant increase in heat transfer coefficient per unit pressure drop in the heat exchanger. Besides this a properly designed continuous helical baffles can reduce fouling in the shell side and prevent the flow-induced vibration as well.**

**In the current study an attempt has been made to understand the influence of baffle design on the pressure drop in the heat exchanger. A comparison was made between a segmental baffled, helical baffled and a bafflesless heat exchanger by designing the baffles and performing CFD simulation using CATIA V5 and ANSYS 15.0. It was concluded from the results that helical baffles which are our primary interest of study showed an effective pressure drop of 0.17134Pa which varied slightly from the other two. Further the pressure drop can be improved by modifying the design of heat exchanger with helical baffles.**

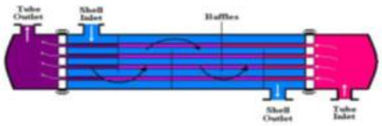
*Keywords:* **CFD Analysis; CATIA; ANSYS; Velocity;**

## I. INTRODUCTION

Heat exchangers are one of the normally used system in the system industries. Heat Exchangers are used to switch warmth between process streams. One can realize their utilization that any manner which involve cooling, heating, condensation, boiling or evaporation would require a heat exchanger for those motive. Process fluids, commonly are heated or cooled before the method or go through a section exchange. Different heat exchangers are named according to their application. For instance, warmth exchangers being used to condense are called condensers, in addition heat exchanger for boiling functions are referred to as boilers. Performance and performance of warmth exchangers are measured via the quantity of warmth transfer using least area of warmth switch and stress drop. A higher presentation of its performance is achieved by means of calculating over all heat switch coefficient. Pressure drop and place required for a positive amount of warmth switch, provides an perception about the capital fee and strength necessities (Running cost) of a warmth exchanger. Usually, there is a lot of literature and theories to design a heat exchanger consistent with the necessities.

**Shell-and-tube Heat exchanger:**

Shell-and-tube heat exchangers are built of round tubes mounted in large cylindrical shells with the tube axis parallel to that of the shell. These are commonly used as oil coolers, power condensers, preheaters and steam generators in both fossil fuel and nuclear-based energy production applications. They are also widely used in process applications and in the air conditioning and refrigeration industry. Although they are not specially compact, their robustness and shape make them well suited for high pressure operations. They have larger heat transfer surface area-to-volume ratios than the most of common types of heat exchangers, and they are manufactured easily for a large variety of sizes and flow configurations. They can operate at high pressures, and their construction facilitates disassembly for periodic maintenance and cleaning. The shell-and-tube heat exchangers consist of a bundle of tubes enclosed within a cylindrical shell. One fluid flows through the tubes and a second fluid flows within the space between the tubes and the shell. The simplest form of a horizontal shell-and-tube type condenser with various components is shown in fig (1.4). One fluid flows on the shell-side steam flows across between pair of baffles and then flows parallel to the tubes as it flows from one baffle compartment to the next. There are wide differences between shell-and-tube heat exchangers depending on the application. The most representative tube bundle types used in shell-and-tube heat exchangers are shown in figures,




Shell-and-tube heat exchanger

Double-pipe Hairpin Bare and Multi-tube (Table 1 & 2): These units are built using U shape tubes or pipe that are connected to two tubesheets and are loaded inner a hairpin shape shell.

**Baffle**

1) Segmental Baffle

Normal types of baffles are call as segmental baffles. It is apparent that higher heat transfer coefficient results when the liquid is maintained in the state of turbulence. To induce turbulence outside the tube it is customary to employ baffles, which cause the liquid to flow through the shell at right angles to the exit of the tubes. Baffles are used to support tubes, enable a desirable velocity to be maintained for the shell side fluid, and prevent failure of tubes due to flow-induced vibration.

2) Helical Baffle

A new type of baffle, called the helical baffle, provides further improvement. This type of baffle was first developed by Lutcha and Nemcansky. They investigated the flow field patterns produced by such helical baffle geometry with different helix angles. They found that these flow patterns were very close to the plug flow condition, which was expected to reduce shell-side pressure drop and to improve heat transfer performance. Stehlik et al. compared heat transfer and pressure drop correction factors for a heat exchanger with an optimized segmental baffle based on the Bell–Delaware method, with those for a heat exchanger with helical baffles. Kral et al. discussed the performance of heat exchangers with helical baffles based on test results of various baffles geometries. One of the most important Geometric factors of the STHXHB is the helix angle. Recently a comprehensive comparison between the test data of shell-side heat transfer coefficient versus shell-side pressure drop was provided for five helical baffles and one segmental baffle measured for oil-water heat exchanger. It is found that based on the heat transfer per unit shell-side fluid pumping power or unit shell-side fluid pressured drop, the case of 400 helix angle behaves the best. The flow pattern in the shell side of the heat exchanger with continuous helical baffles was forced to be rotational and helical due to the geometry of the continuous helical baffles, which results in a significant increase in heat transfer coefficient per unit pressure drop in the heat exchanger. Properly designed continuous helical baffles can reduce fouling in the shell side and prevent the flow-induced vibration as well. The performance of the proposed STHXs was studied experimentally in this work. The use of continuous helical baffles results in nearly 10% increase in heat transfer coefficient compared with that of conventional segmental baffles for the same shell-side pressure drop. Based on the experimental data, the non-dimensional correlations for heat transfer coefficient and pressure drop were developed for the proposed continuous helical baffle heat exchangers with different shell configurations, which might be useful for industrial applications and further study of continuous helical baffle heat exchangers.

## II. LITERATURE SURVEY

This chapter provides an overview of the literature on the works carried out in the analysis of Heat Exchangers, Shell and Tube Heat Exchanger simulation for CFD systems which are relevant for present studies

2.1 Shell and Tube Heat Exchanger

An extensive research work has been done till date on the Shell and Tube heat exchangers by changing different parameters to meet the industry requirements. Lunsford (1998) provided some methods for increasing shell- and-tube exchanger performance. The methods considered whether the exchanger is performing correctly to begin with, excess pressure drop capacity in existing exchangers, the re-evaluation of fouling factors and their effect on exchanger calculations, and the use of augmented surfaces and enhanced heat transfer. Sparrow and Reifschneider (1986) conducted experiments on the effect of inter baffle spacing on heat transfer. Huadong Li and Volker KottKe (1998) conducted experiments on the Effect of leakage on pressure drop and local heat transfer in shell and tube heat exchangers for staggered has slight contribution to the local heat transfer at the surfaces of the external tubes of the tube bundle, but reduces greatly the per-compartment average heat transfer. Morcos and Shafey (1995) carried out an experimental analysis to study the performance analysis of a plastic shell and tube heat exchanger. Qiao He and Wennan Zhang (2001) presented a theoretical analysis and an experimental test on a shell and tube latent heat storage exchanger. The prediction by the mathematical model on the performance of the heat storage exchanger is reasonable and in agreement with experimental measurements. Rozzi et al (2007) worked on convective heat transfer and friction losses in helically enhanced tubes for both Newtonian and non- Newtonian fluids. Four fluid foods, namely, whole milk, cloudy orange juice, apricot and apple puree, are tested in a shell and tube heat exchanger. Both fluid heating and cooling conditions are considered. The experimental outcome confirms that helically corrugated tubes are particularly effective in enhancing convective heat transfer for generalized Reynolds number ranging from about 800 to the limit of the transitional flow regime.

## INTRODUCTION TO CATIA

CATIA (Computer Aided Three-dimensional Interactive Application) is a multi-platform CAD/CAM/CAE commercial software suite developed by the French company Assault Systems. Written in the C++ programming language, CATIA is the cornerstone of the Assault Systems product lifecycle management software suite.

CATIA competes in the CAD/CAM/CAE market with Siemens NX, Pro/E, Autodesk Inventor, and Solid Edge as well as many others.

## INTRODUCTION TO FINITE ELEMENT METHOD

Finite Element Method (FEM) is also called as Finite Element Analysis (FEA). Finite Element Method is a basic analysis technique for resolving and substituting complicated problems by simpler ones, obtaining approximate solutions Finite element method being a flexible tool is used in various industries to solve several practical engineering problems. In finite element method it is feasible to generate the relative results.

### ANSYS Software:

ANSYS is an Engineering Simulation Software (computer aided Engineering). Its tools cover Thermal, Static, Dynamic, and Fatigue finite element analysis along with other tools all designed to help with the development of the product. The company was founded in 1970 by Dr. John A. Swanson as Swanson Analysis Systems, Inc. SASI. Its primary purpose was to develop and market finite element analysis software for structural physics that could simulate static (stationary), dynamic (moving) and heat transfer (thermal) problems. SASI developed its business in parallel with the growth in computer technology and engineering needs. The company grew by 10 percent to 20 percent each year, and in 1994 it was sold. The new owners took SASI's leading software, called ANSYS®, as their flagship product and designated ANSYS, Inc. as the new company name.

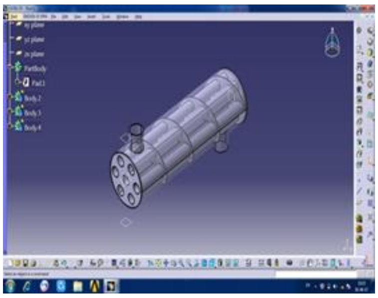
## MESHING & CFD ANALYSIS

### CFD

Computational fluid dynamics (CFD) study of the system starts with the construction of desired geometry and mesh for modeling the dominion. Generally, geometry is simplified for the CFD studies. Meshing is the discretization of the domain into small volumes where the equations are solved by the help of iterative methods. Modeling starts with the describing of the boundary and initial conditions for the dominion and leads to modeling of the entire system. Finally, it is followed by the analysis of the results, discussions and conclusions.

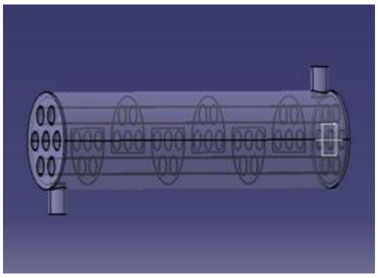
### Designed CATIA models

**1.STHX with Helical Baffle:**



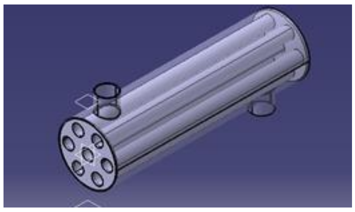
**STHX with Helical Baffle**

**2.STHX with segmental Baffle :**



**STHX with segmental Baffle**

**3. Simple STHX :**



**Simple Heat Exchanger**

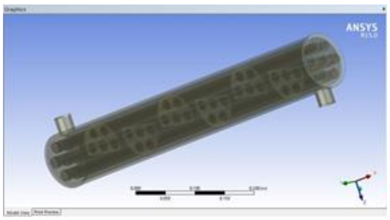
## CFD ANALYSIS OF HAIR PIN HEAT EXCHANGER

### Geometry

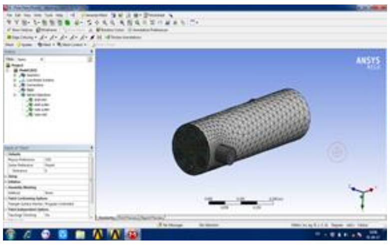
Heat exchanger is built in the ANSYS workbench design module. It is a counter-flow heat exchanger. First, the fluid flow (fluent) module from the workbench is selected. The design modeler opens as a new window as the geometry is double clicked.

**Imported model**



**5.3Meshing**

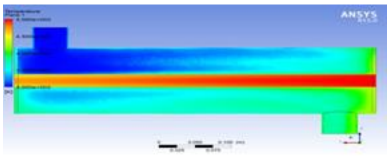
**Initially a relatively coarser mesh is generated. This mesh contains mixed cells (Tetra and Hexahedral cells) having both triangular and quadrilateral faces at the boundaries. Care is taken to use structured hexahedral cells as much as possible.**



**STHX model after Meshing**

**Temperature variation in simple HX**

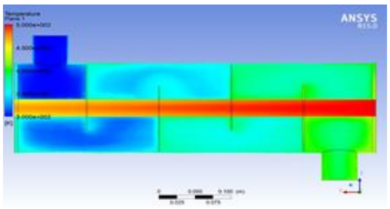
The simple heat exchanger is nothing but a heat exchanger having with out baffles.it is a very basic type shell and tube heat exchanger. It consisting only tubes and shell. There is no involvement of baffles. In this expiriment the inlet tempereture value of shell is 300 K and inlet tube temperature is 500 K .



Temperature variation in simple HX

**Temperature variation in HX with segmental baffles**

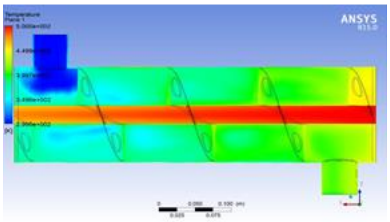
The segmental baffled HX is having the baffles in the shape of semicircle. In industries it is the one of the most common used HX. In this comparison we can see the temperature variations in the both cases like simple HX and in Heat Exchanger with segmental baffles.



Temperature variation in HX with segmental baffles

**Temperature variation in HX with helical baffles**

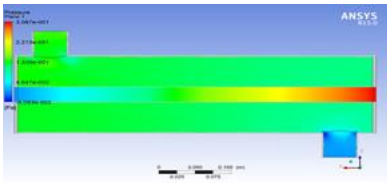
The helical baffle is the one type of most used heat exchanger in industries. In this case shows the temperature variation in the heat exchanger when he baffles are helical and the helix angle of the baffle varied from o0 to 200



**Variation of Pressure**

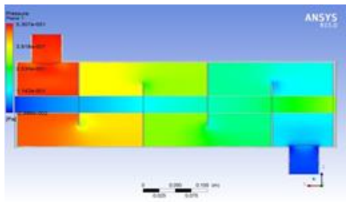
PressureDistribution across theshell andtube heat exchanger isgiven below in Figures .With the changing ofBaffle typepressuredrop inside theshell and tubesis changes. Pressurevaries

Largelyfrom inlet to outlet. The contours of staticpressureare shown in the entire figuretogive adetail idea about how the pressure varies from inlet to outlet.



Pressure variation in Simple Heat Exchanger

**Variation of pressure in Heat Exchanger with segmental baffle**

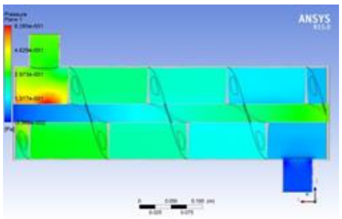


Variation of pressure in Heat Exchanger with segmental baffle

The pressure variation in the segmental baffled heat exchanger is shown in above diagram. At the inlet the pressure is maximum and at the outlet the pressure is minimum.

**Variation of pressure in Heat Exchanger with helical baffle**

The helical baffle is the one type of most used heat exchanger in industries. In this case shows the pressure variation in the heat exchanger when he baffles are helical and the helix angle of the baffle varied from $o^0$ to $20^0$. The inlet velocity of the tube is 0.01 m/s and the inlet velocity of shell is also 0.01 m/s.




Variation of pressure in Heat Exchanger with helical baffle

These are the pressure variation results obtained by the simulation of heat exchanger when the baffles are different types. The overall result of pressure variation in heat exchanger will be shown in the below table.

**RESULT TABLES**

| | Simple HX | Segmental baffle | Helical baffle |
|---|---|---|---|
| Shell inlet (K) | 300 | 300 | 300 |
| Shell outlet (K) | 396.47 | 408.637 | 410 |
| Tube inlet (K) | 500 | 500 | 500 |
| Tube outlet (K) | 463.57 | 459.11 | 461 |

**Temperature variation in HX with different baffles**

| | WITHOUT BAFFLE | SEGMENTAL BAFFLE | HELICAL BAFFLE |
|---|---|---|---|
| TUBE PRESSURE DROP (Pa) | 0.1470 | 0.2960 | 0.3474 |
| SHELL PRESSURE DROP (Pa) | 0.3041 | 0.5230 | 0.3298 |
| NET PRESURE DROP (Pa) | 0.1309 | 0.1786 | 0.17134 |

**Overall result of pressure variation**

## III. CONCLUSION

The temperature variation and Pressure Drop is discussed in detail and proposed model is compared with different baffles. In this experiment we are taking the inlet velocity of tubes as 0.01 m/s, the inlet velocity of shell also as 0.01 m/s, the inlet tube temperature as 500 k and the inlet shell temperature is as 300 k. The CFD results when compared with the results from different studies were well within the error limits. The assumption worked well in this geometry and meshing expects the outlet and inlet region where rapid mixing and change inflow direction takes place. Thus, improvement is expected if the helical baffle used in the model should have complete contact with the surface of the shell, it will help in more turbulence across shell side and the pressure drop will increase and also the temperature variation will increase compared to the remaining taken baffles and simple heat exchangers. More over the model has provided there liable results by considering the standard k-epsilon model. Furthermore, the enhance wall function are not use in this project, but they can be very useful. The pressure drop is poor in heat exchanger with helical baffles because most of the fluid passes without the interaction with baffles. Thus, the design of heat exchanger with helical baffles can be modified for better pressure drop in two ways either the decreasing the shell diameter, so that it will be propercontact with the helical baffle or by increasing the baffle so that baffles will be proper contact with the shell.

In this project we are calculate the pressure drop and temperature variation of Shell and Tube Heat Exchanger by varying different types of baffles (without baffle, segmental baffle and helical baffle). Among those, helical baffle gives effective pressure drop and temperature variation. The flow pattern in the shell side of the heat exchanger with continuous helical baffles was forced to be rotational and helical due to the geometry of the continuous helical baffles, which results in an effective pressure drop and temperature variation in the heat exchanger. So helical baffle is preferred in pressure drop conditions. And it is also preferred at the place which requires high temperature drop.

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