CFD Investigation of Influence of Tube Bundle Cross-Section over Pressure Drop and Heat Transfer Rate

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***Abstract*— In this paper, a study of different cross section bundle arrangements such as triangle, rectangular and round for a shell and tube heat exchanger computationally is presented. Ultimately, relationship between pressure drop and heat transfer is evolved for different cross section shape in a counter flow model shell and tube heat exchanger. The bundle cross section contribute towards pressure drop for same segmental baffle arrangement. This pressure drop can leads to structural damage of heat exchanger parts. The paper aims at understanding the effect of pressure drop caused due to three different bundle arrangements in shell and tube heat exchanger.**

Index Terms — **HX, CFD, Bundle Cross-section.**

I. Introduction

Shell and tube heat exchangers are widely used in heating, cooling and evaporation processes. It is required to enhance performance of heat exchanger to get maximum effectiveness possible. They are so many arrangements are used and studied in literatures to get better heat transfer rate such as baffle orientation, their types , fin and corrugation arrangement over tubes and threading inside of tube. These arrangements cause huge pressure drop shell side as well as tube side. It leads to structural damage of shell and tube, increasing more maintenance due to excessive scale and slug formation and overall running cost of heat exchanger. To avoid this, it requires concentrating on existing parameters of shell and tubes. Pressure drop increases more rapidly with increase in mass velocity. In most of the works the effect of tube bundle arrangement towards pressure drop is not discussed.

In this work, design of an experimental set up reassembles heat exchanger and a study with different cross-section of tube bundle such as *triangle, rectangle and round* experimentally and computationally is proposed. Ultimately, relationship between tube bundle cross-section shape and heat transfer, pressure drop is evolved.

II. LITERATURE REVIEW

Arjun K.S. et. al presented design of shell and tube heat exchanger using computational fluid dynamics tools. The simulation was converged at 160th iteration for zero degree baffle inclination. Simulation of ten degree baffle inclination was converged at 133rd iteration. Simulation of twenty degree baffle inclination was converged at 138th iteration. The velocity profile at inlet was same for all the three inclination of baffle angle i.e 1.44086m/s. The pressure decline inside the shell is decreased with the increase in baffle inclination angle. The pressure varies widely from inlet to outlet. Outlet temperature of shell side was much affected. This was because of decrease in shell side pressure decline[1].

Digvijay S.D. et. al presented heat transfer analysis of a cone shaped helical coil heat exchanger. In the present study an experimental investigation of heat transfer in cone shaped helical coil heat exchanger is reported for various Reynolds number. The purpose of this article is to compare the heat transfer in cone shaped helical coil and simple helical coil. The pitch, height and length of both the coils are kept same for comparative analysis. The calculations have been performed for the steady state condition and experiments were conducted for different flow rates in laminar and turbulent flow regime [2].

Date P. et. al presented heat transfer enhancement in fin and tube heat exchanger - a review. This paper proposed the novel approached toward the heat transfer enhancement of plate and fin heat exchanger using improved fin design facilitating the vortex generation. The vortex generator can be embedded in the plane fin and that too in a low cost with effect the original design and setup of the commonly used heat exchangers. The various designs modifications which are implemented and studied numerically and experimentally is been discussed in the paper [3].

Gowthaman P.S. et. al presented Analysis of Segmental and Helical Baffle in Shell and tube Heat Exchanger. In this project work the analyze of two different baffle in a Shell and Tube Heat Exchanger done by ANSYS FLUENT. Shell and tube heat exchanger has been widely used in many industrial applications such as electric power generation, Refrigeration and Environmental Protection and Chemical Engineering. Baffle is an shell side Component of shell and tube heat exchanger The segmental baffle forces the liquid in a Zigzag flow and improving heat transfer and a high pressure drop and increase the fouling resistance and Helical Baffle have a Effective Performance of increasing heat transfer performance. The desirable features of heat exchanger obtain a maximum heat transfer Coefficient and a lower pressure drop [4].

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Jadhav A.D. et. al presented CFD analysis of shell and tube heat exchanger to study the effect of baffle cut on the pressure drop. The shell side design of a shell and tube heat exchanger; in particular the baffle spacing, baffle cut and shell diameter dependencies of the heat transfer coefficient and the pressure drop are investigated by numerically modelling a small heat exchanger. The flow and temperature fields inside the shell are resolved using a commercial CFD package. A set of CFD simulations is performed for a single shell and single tube pass heat exchanger with a variable number of baffles and turbulent flow. The results are observed to be sensitive to the turbulence model selection [5].

Mohammadi K. et. al presented effect of baffle orientation on heat transfer and pressure drop of shell and tube heat exchangers with and without leakage flows. The effect of baffle orientation on the heat transfer and pressure drop of shell and tube heat exchangers in the domain of turbulent flow is investigated numerically using the commercial CFD code FLUENT. The segmental baffled shell and tube heat exchangers considered follow the TEMA standards and consist of 76 and 660 plain tubes respectively, with fixed outside diameter and arranged in a triangular layout[6].

Mohammadi K et. al presented simulation of turbulent flow and heat transfer through a duct with baffle plates. In this paper, a numerical study of the turbulent air flow and heat transfer through a duct with baffle plates is performed. The effect of baffles arrangement baffles number, baffle height and baffle thickness on the flow and heat transfer characteristics is investigated. The fully elliptic differential equations that describe the flow and heat transfer are integrated using the finite volume approach. The standard k-ϵ model with wall functions has been submitted to model the turbulence. The obtained computed results show that the boundary layer separation and recirculation regions are significantly affected with the height, thickness and arrangements of the baffle plates [7].

Ozden E. et. al presented shell side CFD analysis of a small shell-and-tube heat Exchanger. The shell side design of a shell-and-tube heat exchanger; in particular the baffle spacing, baffle cut and shell diameter dependencies of the heat transfer coefficient and the pressure drop are investigated by numerically modelling a small heat exchanger. The flow and temperature fields inside the shell are resolved using a commercial CFD package. A set of CFD simulations is performed for a single shell and single tube pass heat exchanger with a variable number of baffles and turbulent flow. The results are observed to be sensitive to the turbulence model selection [8].

Zhang J.F.et.al presented experimental performance comparison of shell-and-tube oil coolers with overlapped helical baffles and segmental baffles. Many research studies have been conducted on the performance of shell and tube heat exchanger with helical baffles because of its lower shell-side pressure drop, lower fouling resistance and lower operation and maintenance cost. But the extension of those studies into practical application is limited because of the additional effects caused by the small-size model [9]

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III. EXPERIMENTAL DESIGN

In this work, experimental investigation also is done. To reduce cost of experiment, the size of Heat exchanger should as small as possible. Based on this constrain, design is done.

Table 1 Fluid Properties and conditions

	Hot Fluid	Cold Fluid
Type	Hot water	Cold water
Inlet Temp	60°C	25°C
Outlet Temp	55°C	32°C
Specific heat Capacity	4120 J / Kg.K	4190 J / Kg.K
Mass Flow rates	0.146 Kg / s	0.106 Kg / s

For this requirement heat exchanger is designed.

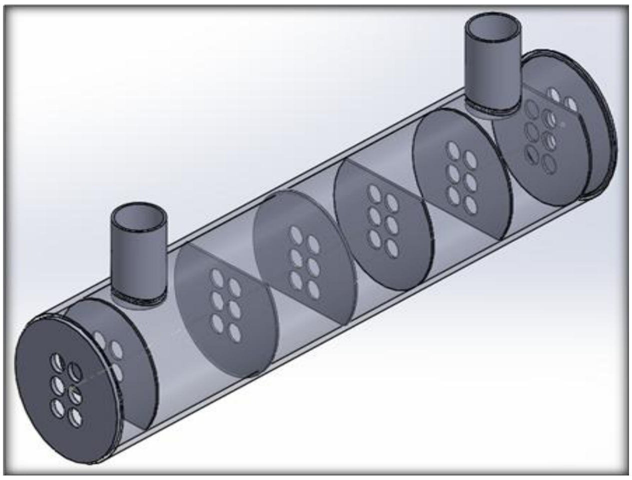

Fig. 1 Rectangular Cross-section Shell

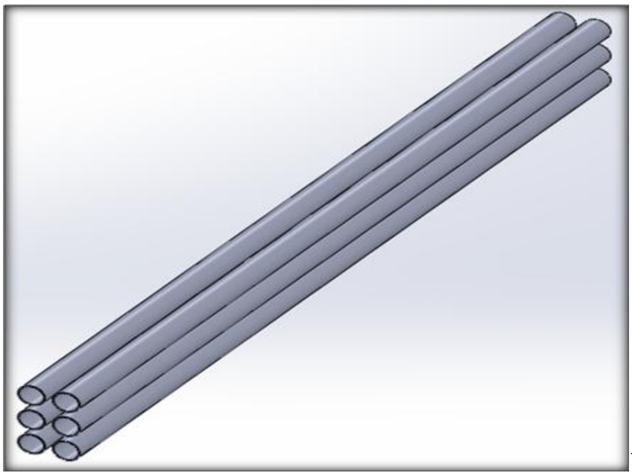

Fig. 2 Rectangular Tube Bundle

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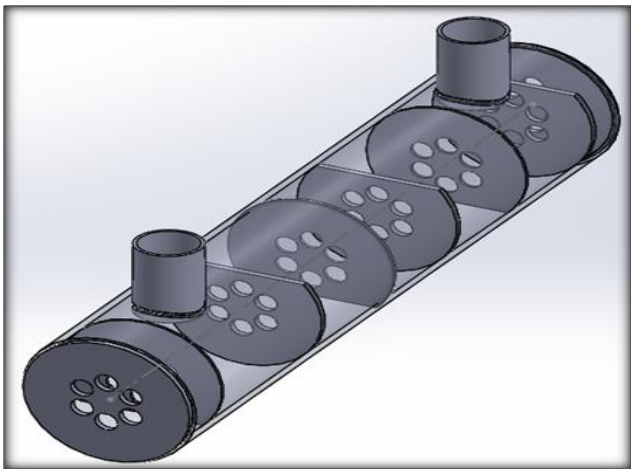

Fig. 3Round Cross-section Shell

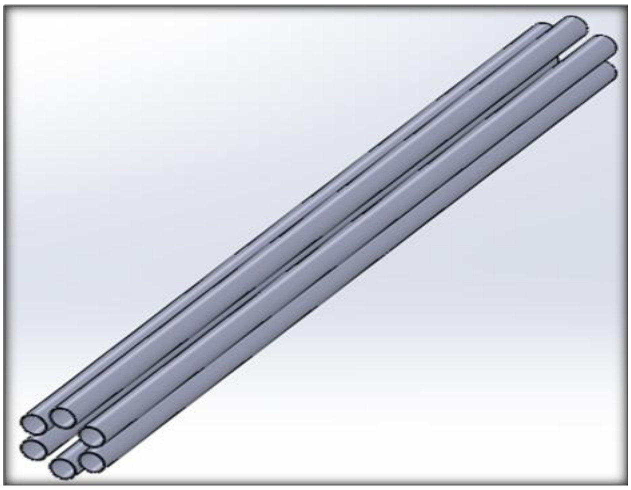

Fig. 4 Round Tube Bundle

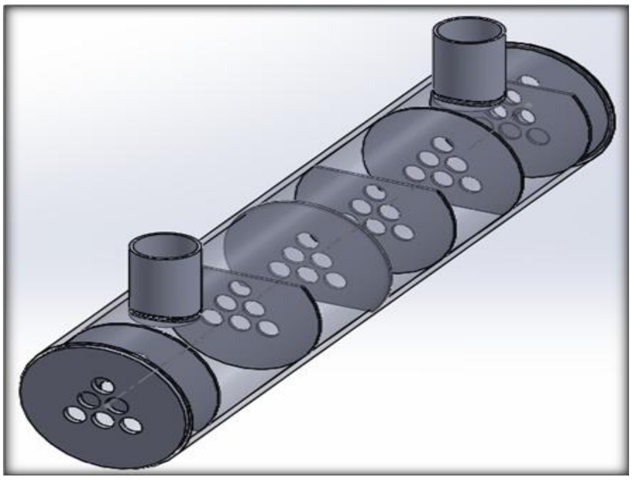

Fig.5Triangle Cross-section Shell

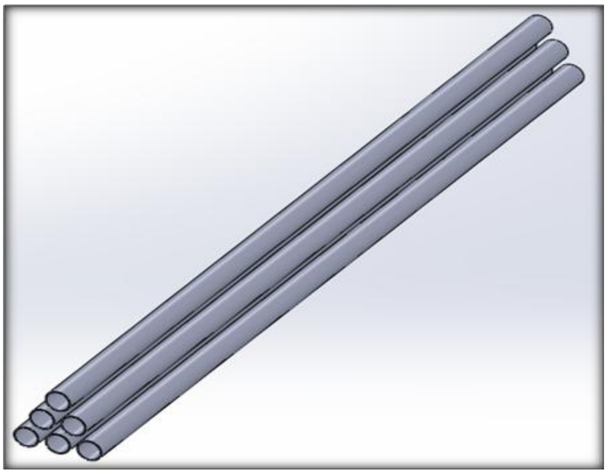

Fig. 6 Triangle Tube Bundle

IV. ANALYSIS

A. Details

Analysis Type- Internal Flow

Boundary condition (Shell):

Pressure Inlet – 4 bar, Temp – 333 K

Mass flow Outlet - 0.146 Kg/s

Boundary condition (Tube):

Mass flow Inlet – 0.018 Kg/ s (per tube), Temp – 298 K

Atmospheric Pressure - 1 bar, Temp – 305 K

B. Meshing

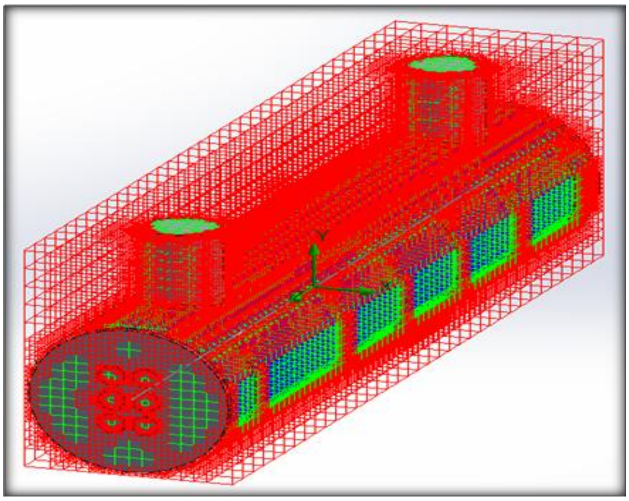

Fig. 7 Meshing of Rectangular CS assembly

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Fluid Cells - 36157
Solid Cells - 4040
Partial Cells - 49667

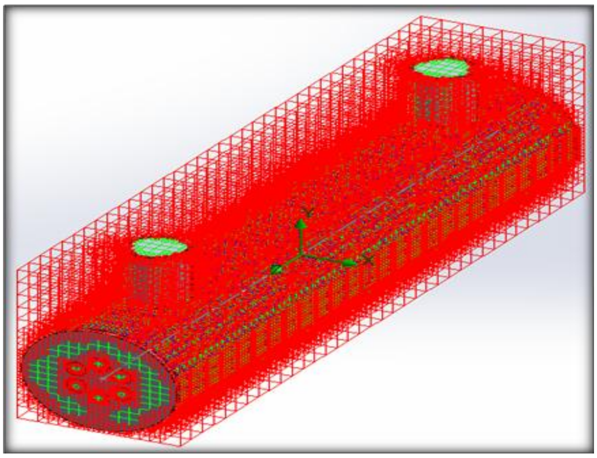

Fig. 8 Meshing of Round CS Assembly

Fluid Cells - 37748
Solid Cells - 4354
Partial Cells - 55119

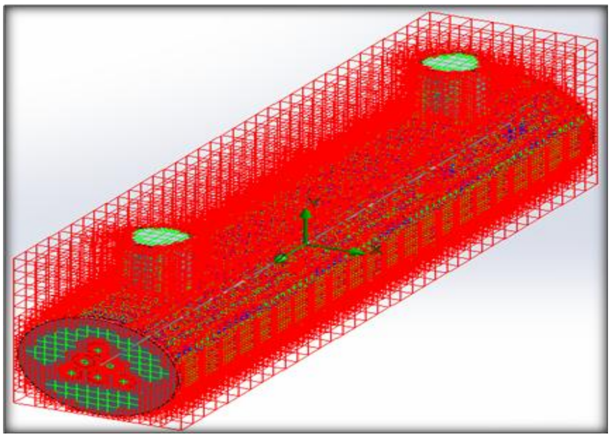

Fig. 9 Meshing of Triangle CS Assembly

Fluid Cells - 31748
Solid Cells - 3782
Partial Cells - 51352

C. Simulation Result

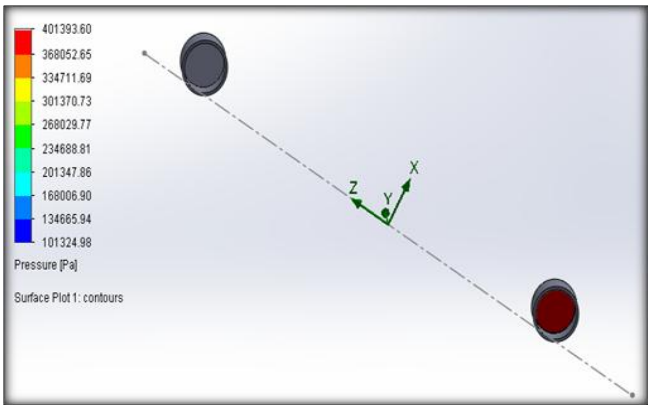

Fig. 10 Pressure at Shell Outlet (Rectangular)

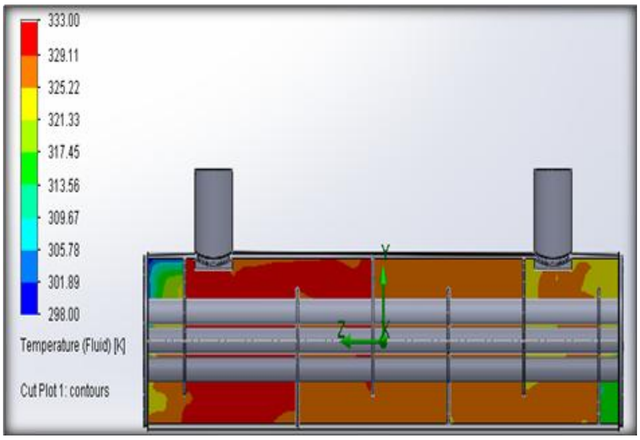

Fig. 11 Temperature Cut Plot (Rectangular)

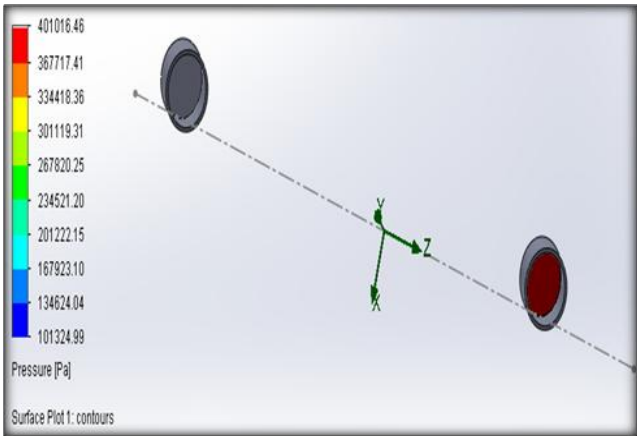

Fig. 12 Pressure at Shell Outlet (Round)

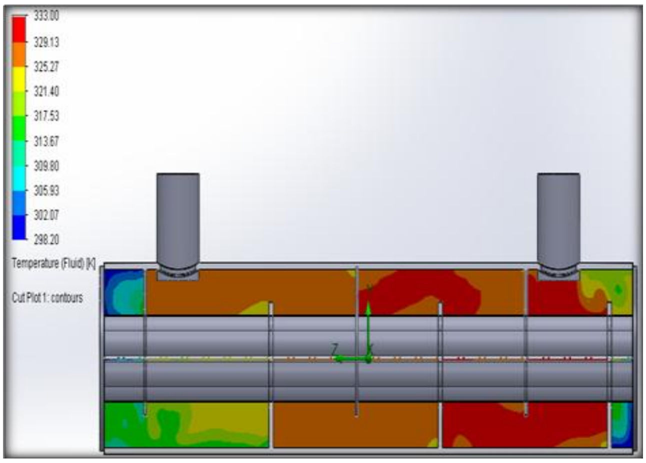

Fig. 13 Temperature Cut Plot (Round)

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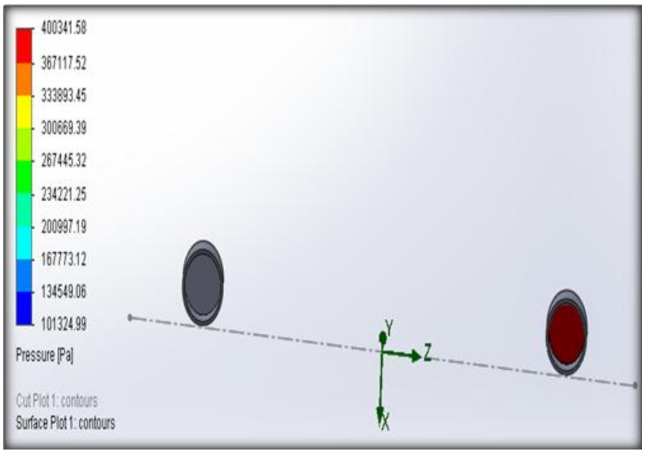

Fig. 14 Pressure at Shell Outlet (Triangle)

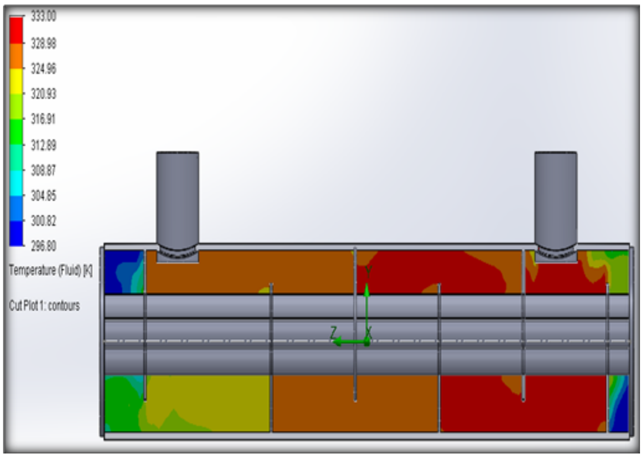

Fig. 15 Temperature Cut Plot (Triangle)

V. RESULTS

Table 2 Computational Vs Theoretical Results-Temperature

Sl.No.	Array	Shell outlet Temperature (K) (Analytical)	Shell outlet Temperature (K) (CFD)	Variation (%)
1	Rectangle	328	325.1	0.88
2	Round	328	325.5	0.77
3	Triangle	328	325.6	0.734

Table 3 Computational Vs Theoretical Results – Pressure

Sl.No.	Array	Shell inlet pressure (Pa)	Shell outlet pressure (Pa)	Pressure Drop (Pa)
1	Rectangle	401325	401174	151
2	Round	401325	400840	485
3	Triangle	401325	400459	866

VI. CONCLUSION

From computational results, it is concluded that there is slight variation in heat transfer performance between three cross-section configurations. Simulation results have good agreement with analytical results. Pressure drop variation between three configurations is more. This *variation will increases with increase in size of heat exchanger*. Therefore, from rectangular cross-section shape is good for tube bundle because it produces less pressure drop on shell side among three configurations. This work will carried to experimental investigation with rectangular configuration to compare experimental and CFD results.

VII. REFERENCES

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