International Journal of Technical Innovation in Modern Engineering & Science (IJTIMES)

Impact Factor: 5.858 (SJIF-2019), e-ISSN: 2455-2585

Volume 6 , Issue 11 , November -2020

CFD Analysis of Segmented Baffles Shell and Tube Heat Exchanger

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***Abstract—* A common technique to optimize the performance of shell and tube heat exchangers (STHE) is by redirecting the flow within the shell side with a series of baffles. A key aspect during this technique is to know the interaction of the fluid dynamics and transfer of heat. The objective of this work is CFD analysis for flow characteristics such as back pressure, velocity, turbulence kinetic energy in various geometrical modifications of Baffles in Shell and Tube Heat Exchanger and their impact on the performance has been collected and discussed and it is found that Triple Segmented Baffles Configuration exhibits best thermal characteristics and best flow characteristics.**

***Keywords—* baffle configurations, back pressure, turbulence energy, CFD**

I. Introduction

Heat Exchangers are devices that transfer energy, in the form of heat, from one working fluid to the next, whether that be liquids, or gases. These devices are essential for refrigeration, power generation, HVAC, and more, and are available in many shapes and sizes which will done both that is given heat or remove heat. Shell and tube heat exchanger is a simple device, it is used as a tool that puts two working fluids in thermal contact using tubes installed within an outer cylindrical shell. These two integral pathways are usually built out of thermally conductive metals that allow easy heat transfer those are steel, aluminium alloys, etc. The tubes carry a fluid from their inlet to their outlet the tube side flow, while the shell passes a separate fluid over these tubes the shell side flow. The number of tubes, known as the tube bundle will dictate how much surface area is exposed to the shell side flow, and therefore determines how much heat is transferred. These devices are among the foremost effective means of exchanging heat, as they're easily built, maintained, compact, and supply excellent heat transfer. They're commonly used in industry as condensers, turbine coolers, evaporators, feed water preheating, and more.

II. LITERATURE REVIEW

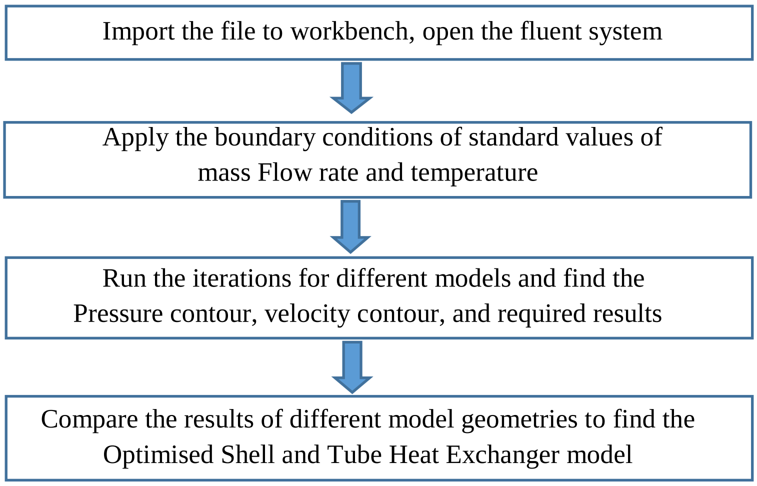
Akpa, J.G, et al (2011), Mathematical models that can be used to predict the transient behavior of heat exchangers in a Heat exchanger Network (HEN) has been developed. This analysis is aimed at predicting thermal transients in Heat Exchanger Networks due to temperature fluctuations of inlet streams. This model is used to predict thermal transient of the heat exchanger networks in the crude distillation unit of the New Port-Harcourt refinery. The response of heat exchangers in the entire network to transient input was investigated. A finite difference numerical scheme is used to develop a solution algorithm for solving the set of partial differential model equations. The results reveals the effect of inlet temperature change on the process streams and possible points where temperature control is required in the heat exchanger networks of the New Port Harcourt refinery.

Praful Date1, et al (2013), 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 design modifications which are implemented and studied numerically and experimentally is been discussed in the paper.

2.1.6 Taborek et. al., (1972) published an article entitled “Heat Transfer Fouling: The Major Unresolved Problem in Heat Transfer”. The article outlines ideas on the fouling problem through analyzing its stages and suggesting various predictive models. Afterwards many researchers such as Somerscales (1981), Watkinson (1988), Hewitt et al., (1994) and Zubair et al., (1999) categorized thermal fouling into six categories based on the dominant mechanism of fouling evolution. These are crystallization, solidification, particulate, corrosion, chemical reaction and biofouling. The classification of various aspects of fouling can be broken down according to the physical and chemical processes that occur.

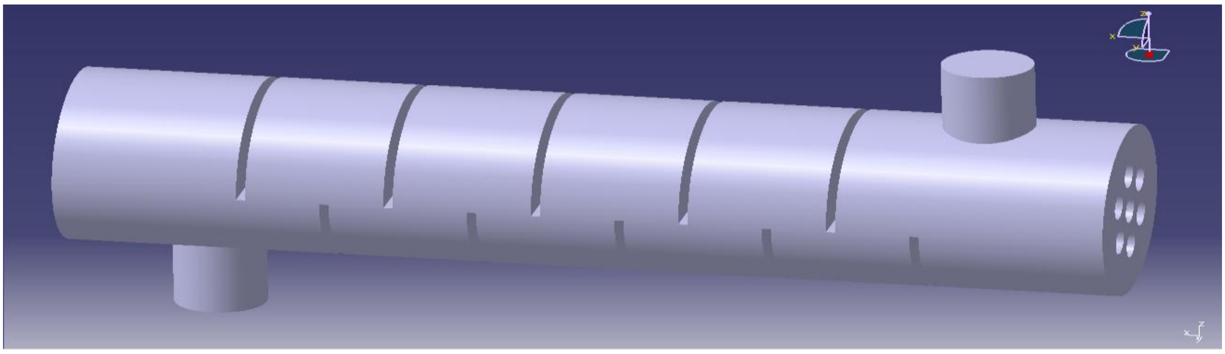
Chen Fang, et al (2010), Vapor-venting micro channel heat exchangers are promising because they address the problems of high pressure drop, flow instability, and local dry out that are common in conventional two-phase micro channel heat sinks. We present a 3D numerical simulation of the vapor-venting process in a rectangular micro channel bounded on one side by a hydrophobic porous membrane for phase-separation. The simulation is based on the volume of fluid (VOF) method together with models for inter phase mass transfer and capillary force. Simulation shows the vapor-venting mechanism can effectively mitigate the vapor accumulation issue, reduce the pressure drop, and suppress the local dry-out in the micro channel. Pressure surge is observed in the vapor-venting channel. The simulation provides some insight into the design and optimization of vapor-venting heat exchangers.

III PHASES OF WORK

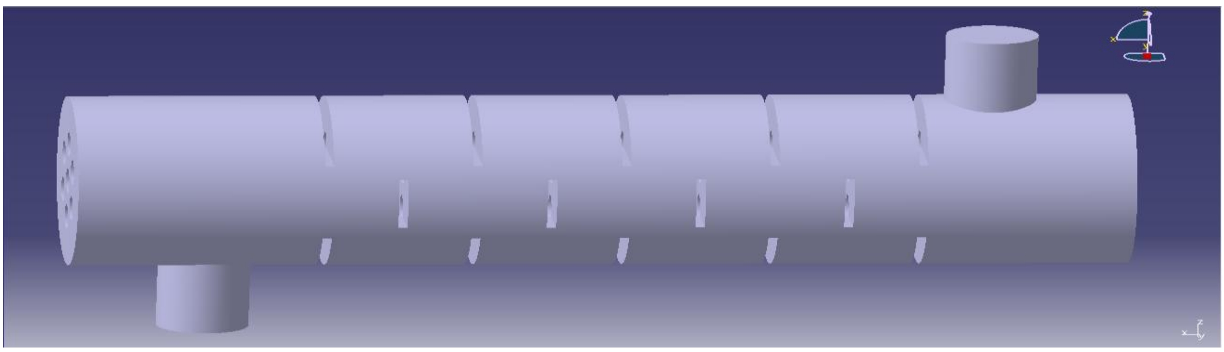


Baffle plates which are going to analysed are:

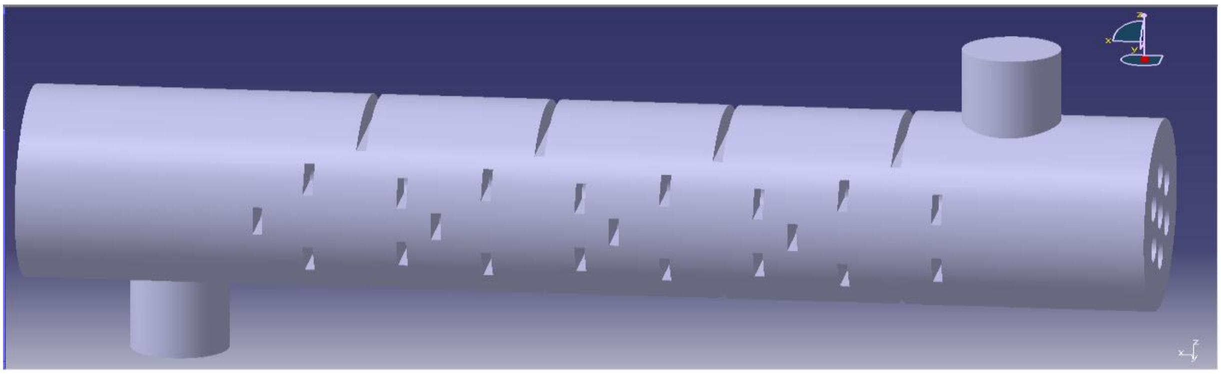
1. Single Segmented Baffles
2. Double Segmented Baffles
3. Triple Segmented Baffles



Single segmented baffle shell and tube heat exchanger



Double segmented baffle shell and tube heat exchanger



Triple segmented baffle shell and tube heat exchanger

IV CFD ANALYSIS

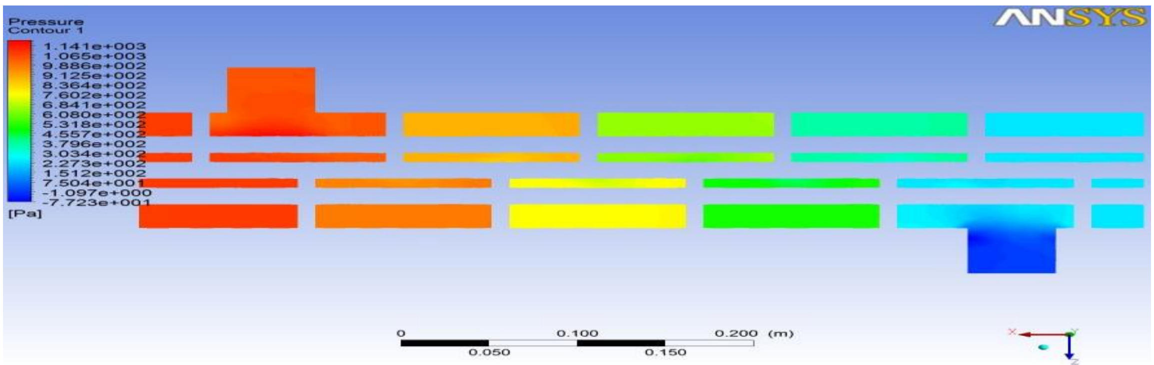
SIMULATION DETAILS:

- CFD software used : ANSYS-FLUENT
- Meshing done in : ICEM CFD
- Mesh : Tetrahedral
- Mesh quality : 0.25(industrial requirement is 0.25 to 0.3)
- Nodes : 10550
- No. of elements : 49087(tetrahedral)
- Type of cfd simulation : steady state
- Turbulence model : k-epsilon model
- No. of iterations : 1000
- Scheme used : high resolution
- Residual target : 10exp-4
- Reference pressure : 1 Pa
- Heat transfer coefficient : $45 W/m^2 k$
- Surface roughness : 0.00508mm
- Mass flow rate : 0.00188 Kg/s
- Temperature at inlet : $600\ ^{o}C$

V DISTRIBUTION ANALYSIS

1. SINGLE SEGMENTED BAFFLES

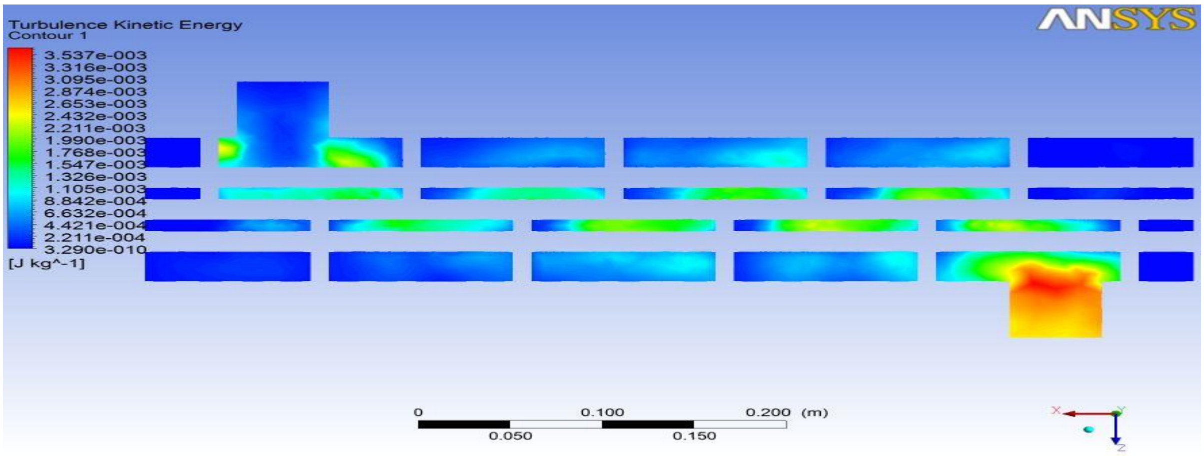
a. PRESSURE DISTRIBUTION



Single Segmented Baffle Pressure

From the above analysis, it is concluded that the pressure in the shell and tube heat exchanger varies from 1.141e+003 Pa to -7.723e+001 Pa and the back pressure at the inlet and outlets are found to be 7.504e+001 Pa and 1.141e+003 Pa.

b. TURBULENCE KINETIC ENERGY DISTRIBUTION



Single Segmented Baffle Turbulence Kinetic Energy

Turbulence kinetic energy at various positions from the figure are

Inlet: 4.421e-004 J/kg

Outlet: 3.095e-003 J/kg

c. VELOCITY STREAMLINE DISTRIBUTION

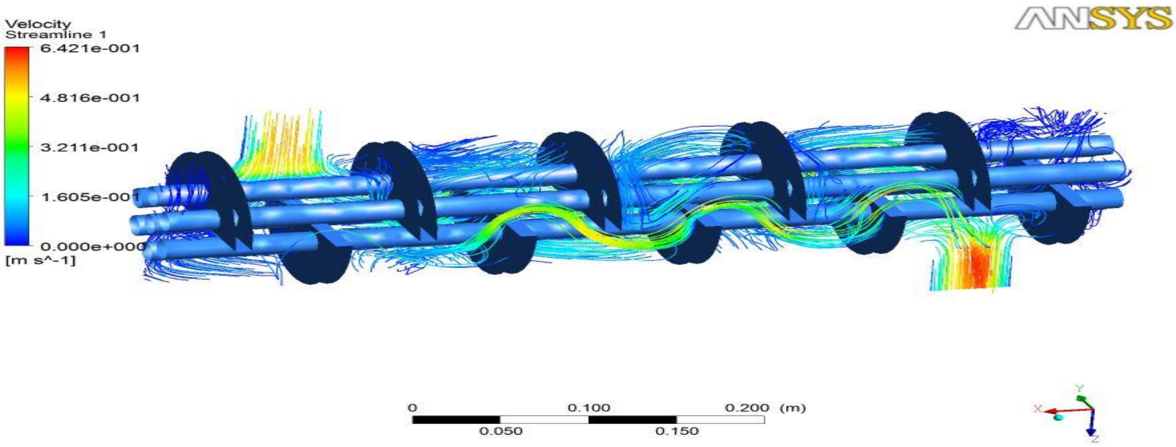


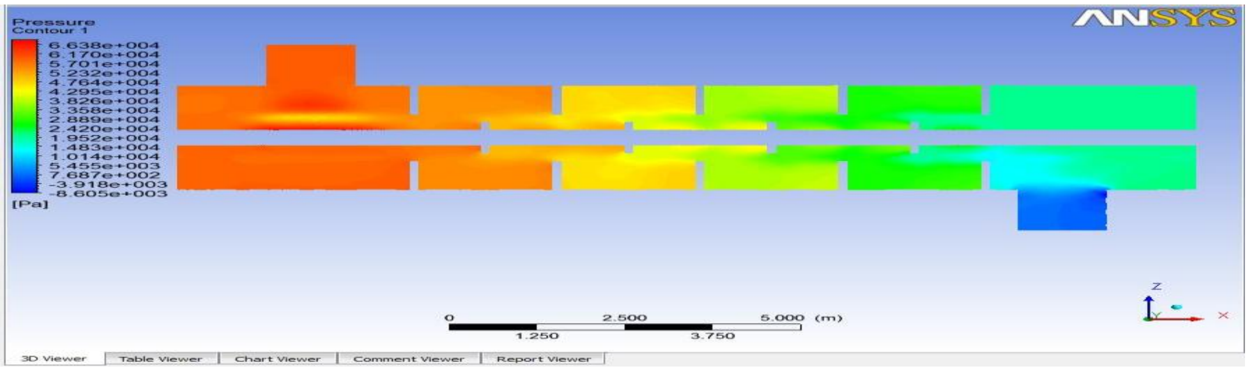
Fig: Single Segmented Baffle Velocity and Streamline

Velocity and Streamline at various positions from the fig are

Inlet: 4.816e-001 m/s

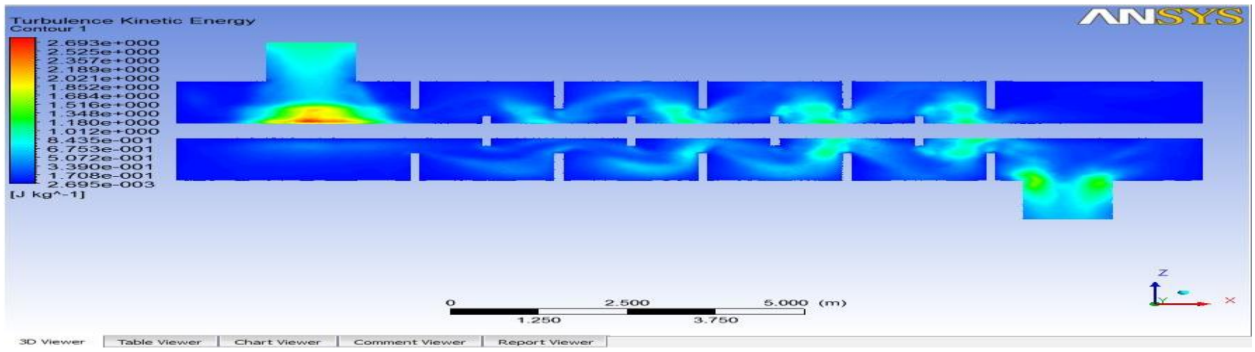
Outlet: 6.421e-001 m/s

2. DOUBLE SEGMENTED BAFFLES



a. PRESSURE DISTRIBUTION

From the above analysis, it is concluded that the pressure in the shell and tube heat exchanger varies from 6.638e+004 Pa to -8.605e+003 Pa and the back pressure at the inlet and outlets are found to be 7.687e+002 Pa and 5.232e+004 Pa.

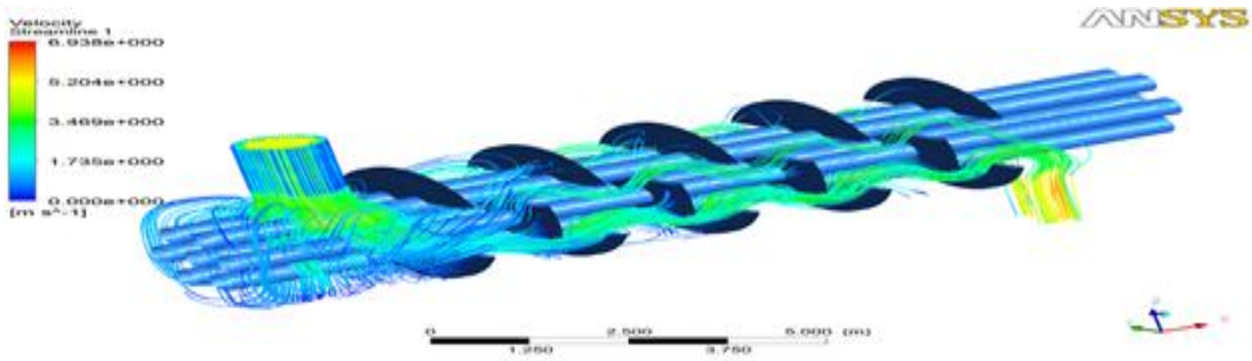


b. TURBULENCE KINETIC ENERGY DISTRIBUTION

Turbulence kinetic energy at various positions from the figure are

Inlet: 8.435e-001 J/kg
Outlet: 1.012e+000J/kg

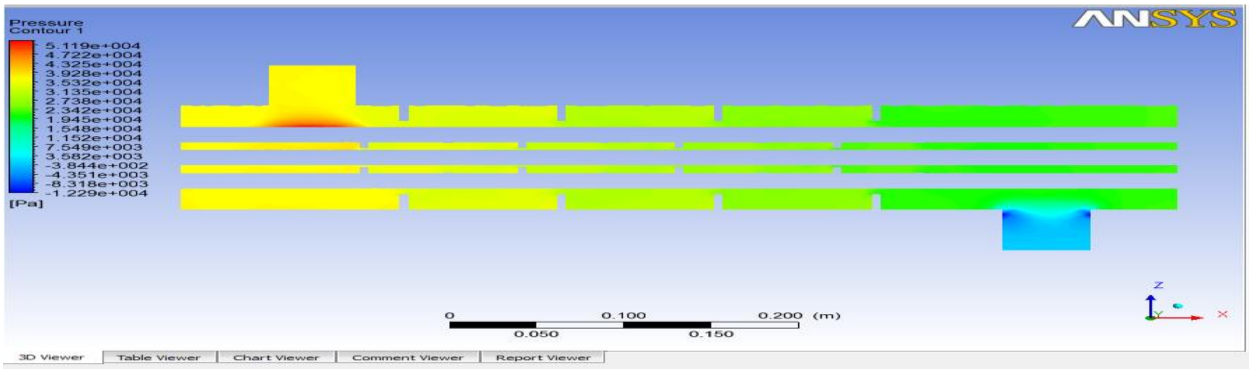
c. VELOCITY STREAM LINE DISTRIBUTION



Velocity and Streamline at various positions from the fig are

Inlet: 3.469e+000 m/s
Outlet: 5.204e+000 m/s

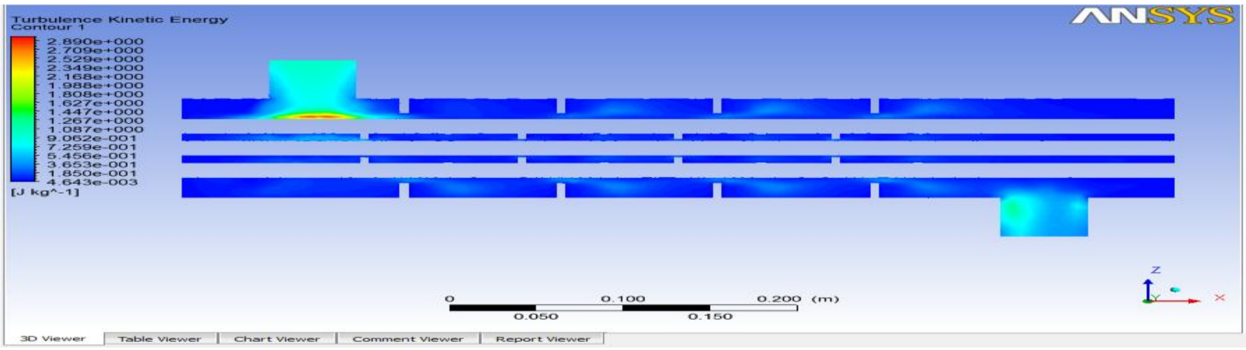
3 TRIPLE SEGMENTED BAFFLES



a. PRESSURE DISTRIBUTION

From the above analysis, it is concluded that the pressure in the shell and tube heat exchanger varies from 5.119e+004 Pa to -1.229e+004 Pa and the back pressure at the inlet and outlets are found to be 7.549e+003 Pa and 3.928e+004 Pa.

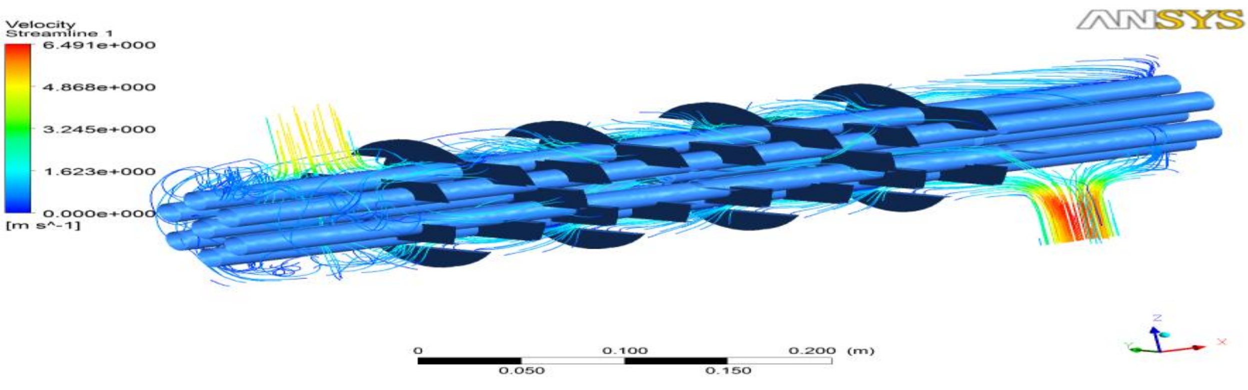
b. TURBULENCE KINETIC ENERGY DISTRIBUTION



Turbulence kinetic energy at various positions from the fig, are

Inlet: 9.062e-001 J/kg
Outlet: 1.087e+000 J/kg

c. VELOCITY STREAMLINE DISTRIBUTION



Velocity and Streamline at various positions from the fig are
Inlet: 4.868e+000 m/s
Outlet: 6.491e+000 m/s

VI RESULT ANALYSIS

PRESSURE

Sl. No	Type of Baffles	Inlet Pressure (Pa)	Outlet Pressure (Pa)
1	Single Segmented Baffles	7.504e+001	1.141e+003
2	Double Segmented Baffles	7.687e+002	1.141e+003
3	Triple Segmented Baffles	3.582e+003	3.928e+004

TURBULENCE KINETIC ENERGY

Sl. No	Type of Baffles	Inlet Turbulence kinetic energy (J/Kg)	Outlet Turbulence kinetic energy (J/Kg)
1	Single Segmented Baffles	4.421e-004	3.095e-003
2	Double Segmented Baffles	8.435e-001	1.012e+000
3	Triple Segmented Baffles	9.062e-001	1.087e+000

VELOCITY STREAMLINE

Sl. No	Type of Baffles	Inlet Velocity (m/s)	Outlet Velocity (m/s)
1	Single Segmented Baffles	4.816e-001	6.421e-001
2	Double Segmented Baffles	3.469e+000	5.204e+000
3	Triple Segmented Baffles	4.868e+000	6.491e+000

VII CONCLUSION

From the above CFD validation and comparing the results of the single segmented, Double Segmented and Triple segmented models in terms of pressure, turbulence kinetic energy and Velocity Streamlines. Triple segmented shell and tube heat exchanger gives good results than other models.

So the triple segmented Baffle shell and tube heat exchanger is considered to be optimised model.

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