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Comparison of Heat Transfer in Shell and Tube Heat Exchanger with Modified Baffles using Ansys Fluent

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***Abstract*— This study shows the difference in heat transfer inside a shell and tube heat exchanger while using segmented baffles and helical baffles to guide the shell side fluid. The variation in heat transfer surface area, velocity and turbulence affect the heat transfer rate. The change in baffle design, orientation and number of baffles gives slight differences in these parameters.**

***Keywords* —Helical Baffles, CFD Analysis, Shell and Tube, Effect of Turbulence.**

I. Introduction

A study of change in heat transfer due to baffle design is conducted here using CFD tool ANSYS Fluent. For this purpose a shell and tube heat exchanger with helical baffles and segmented baffles is designed for a refrigeration plant. The refrigeration plant selected is Kerala Refrigeration and Engineering Co Pvt Ltd[4] situated in Thrissur, Kerala. The refrigerant used is Ammonia. The heat exchanger is designed as a liquid vapour heat exchanger in order to increase the capacity of the plant without having major alterations [1].

II. SHELL AND TUBE HEAT EXCHANGER

A Shell and Tube Heat Exchanger having segmented baffles is designed using standard design procedure.[2] The refrigeration plant pressure and temperature requirements are taken into account. The same segmented baffles heat exchanger is modified into helical baffles using standard procedure. The angle of one baffle is selected as 15 degree in order to get more number of baffles.

A. Shell and Tube Heat Exchanger with Segmented Baffles

Number of tubes	: 14
Shell Inlet	: 4 cm
Shell Outlet	: 4 cm
Tube Inlet	: 4 cm
Tube Outlet	: 4cm
Number of Baffles	: 15

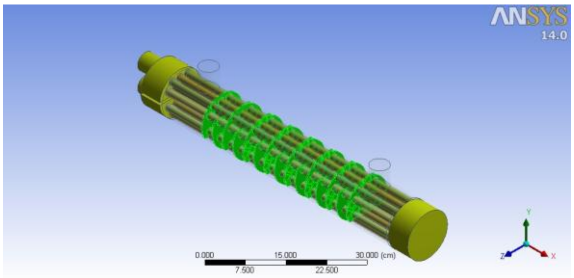

Fig. 1 Shell and Tube Heat Exchanger with Segmented Baffles

B. Shell and Tube Heat Exchanger with Segmented Baffles

Number of tubes	: 14
Shell Inlet	: 4 cm
Shell Outlet	: 4 cm
Tube Inlet	: 4 cm
Tube Outlet	: 4cm
Number of Baffles	: 5
Angle of Baffle	: 15°

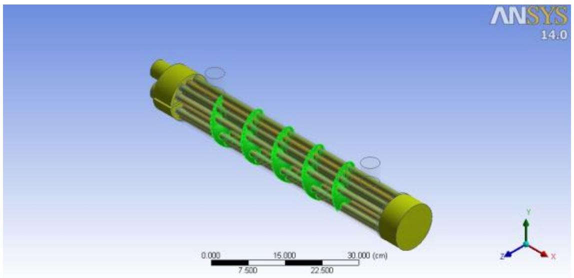

Fig. 2 Shell and Tube Heat Exchanger with Helical Baffles

III. CFD ANALYSIS USING ANSYS FLUENT

A. Modelling

Modelling is done using Design Modeller provided in ANSYS Fluent. Figure 1 and Figure 2 shows the modelled Shell and Tube heat Exchangers with segmented baffles and with helical baffles respectively.[6]

B. Meshing

Meshing is done using ANSYS ICEM CFD with a relevance of -80 in order to get a simpler mesh. For Shell and Tube Heat Exchanger with Segmented baffles, number of nodes is 271519 and number of elements is 1031836. For Shell and Tube Heat Exchanger with Helical Baffles, number of nodes is 225315 and number of elements is 1097149. Grid independency is checked and is positive. Figures show the mesh and named selections of Shell and Tube Heat Exchanger with Segmented Baffles and Helical Baffles respectively.

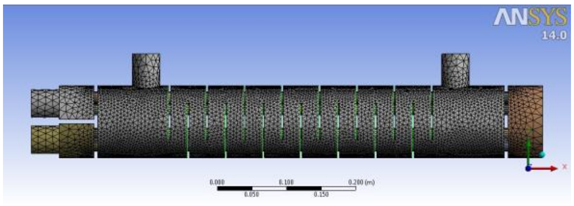

Fig. 3 Mesh of Shell and Tube Heat Exchanger with Segmented Baffles

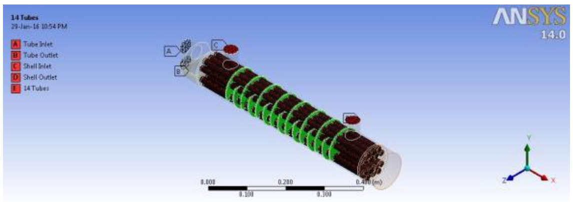

Fig. 4 Named Selections of Shell and Tube Heat Exchanger with Segmented Baffles

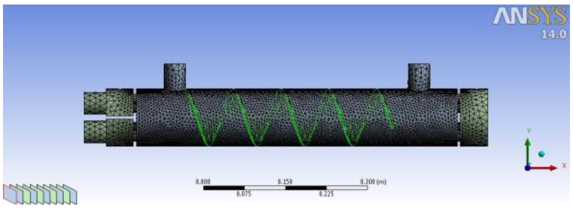

Fig. 5 Mesh of Shell and Tube Heat Exchanger with Helical Baffles

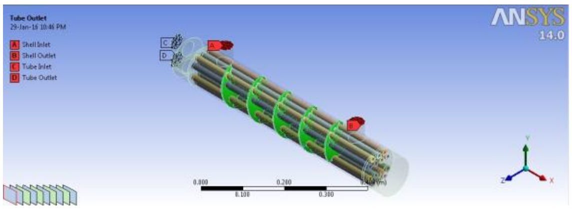

Fig. 6 Named Selections of Shell and Tube Heat Exchanger with Helical Baffles

C. Fluent

In Fluent the solver used is basic pressure based system. Acceleration due to gravity is set to 9.8 m/s^2 in negative y direction. Energy Equation turned on. Viscous model selected is k-ε standard. Radiation model considered is Discrete Ordinate. Materials properties of Ammonia Vapour, Ammonia Liquid and Steel are changed accordingly. Cell zone conditions are assigned as Ammonia Liquid as Shell side Fluid, Ammonia Vapour as Tube side fluid and 14 Tubes as Solid Steel.

Boundary Conditions are given below

1) Liquid inlet
   - Type-Velocity inlet
   - Velocity magnitude=-0.4511 m/s (Normal to boundary)
   - Initial gauge pressure=1275530 Pa
   - Turbulent intensity=0.04974%
   - Hydraulic Diameter=0.526 in
   - Temperature=310 K

2) Vapour Inlet
   - Type-Velocity inlet
   - Velocity magnitude=-101.48 m/s (Normal to boundary)
   - Initial gauge pressure=137890 Pa
   - Turbulent intensity=0.0284%
   - Hydraulic Diameter=3.068 in
   - Temperature=260 K

3) Outlets Type selected as Pressure Outlets

In solution methods Momentum, Turbulent Kinetic Energy and Turbulent Dissipation rate are set to Second Order Upwind in order to get accurate solution. Solution is initialised using Hybrid Initialisation Technique using specified inlet pressures. After 15623 iterations the solution is converged.[3][5]

D. Results

The area weighted average of temperature at the boundaries is as shown below.

Shell and Tube Heat Exchanger with Segmented Baffles

Shell Inlet Temperature	: 310 K
Shell Outlet Temperature	: 306. 35 K
Tube Inlet Temperature	: 260 K
Tube Outlet Temperature	: 287.5 K

Shell and Tube Heat Exchanger with Helical Baffles

Shell Inlet Temperature	: 310 K
Shell Outlet Temperature	: 306. 35 K
Tube Inlet Temperature	: 260 K
Tube Outlet Temperature	: 284.37 K

The figures show the contours of Temperature, Pressure, Turbulent Intensity and Velocity of Shell and Tube Heat Exchanger with Segmented Baffles and Shell and Tube Heat Exchanger with Helical Baffles respectively.

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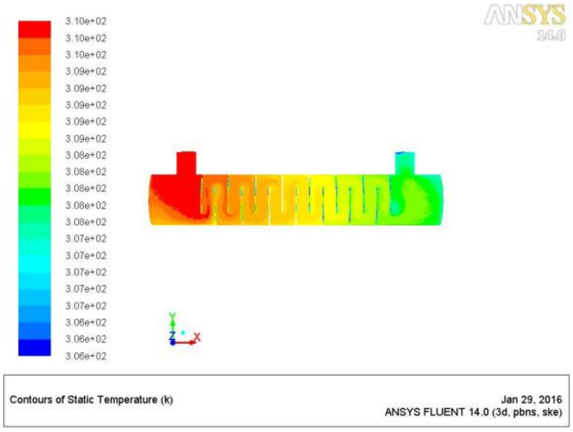

Fig. 7 Contours of Shell Side Fluid's Temperature of Shell and Tube Heat Exchanger with Segmented Baffles

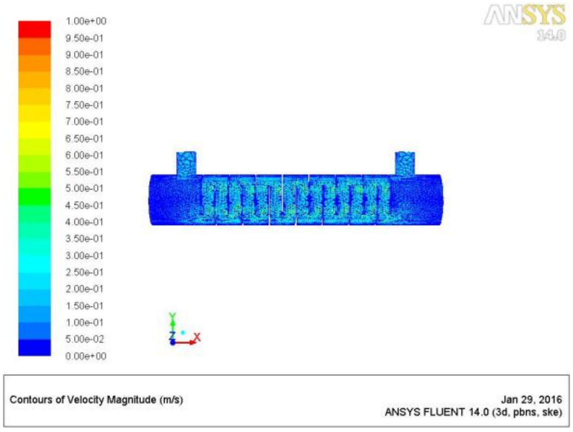

Fig. 9 Contours of Shell Side Fluid's Velocty of Shell and Tube Heat Exchanger with Segmented Baffles

Fig. 8 Contours of Shell Side Fluid's Pressure of Shell and Tube Heat Exchanger with Segmented Baffles

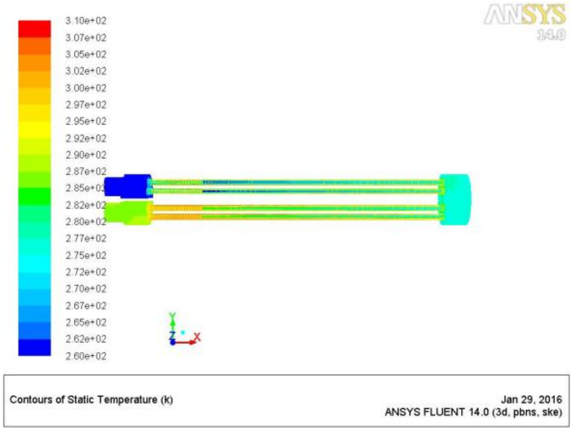

Fig. 8 Contours of Tube Side Fluid's Temperature of Shell and Tube Heat Exchanger with Segmented Baffles

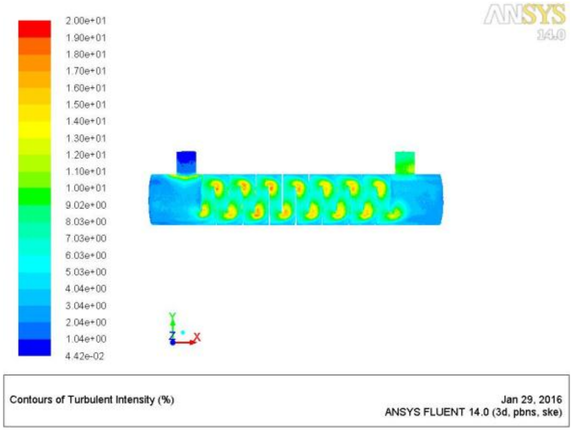

Fig. 9 Contours of Shell Side Fluid's Turbulent Intesity of Shell and Tube Heat Exchanger with Segmented Baffles

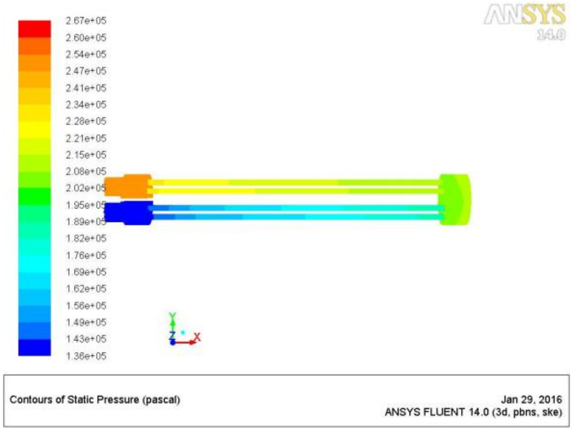

Fig. 8 Contours of Tube Side Fluid's Pressure of Shell and Tube Heat Exchanger with Segmented Baffles

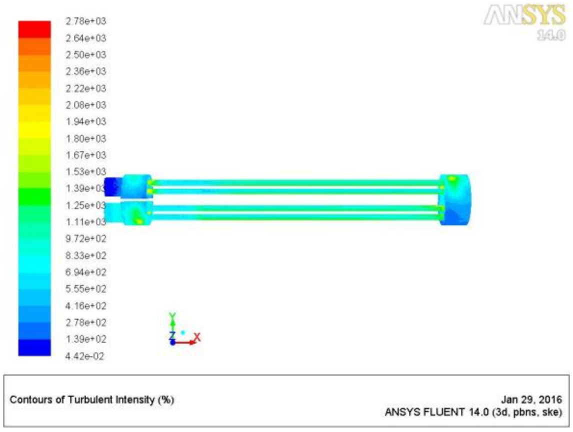

Fig. 8 Contours of Tube Side Fluid's Turbulent Intensity of Shell and Tube Heat Exchanger with Segmented Baffles

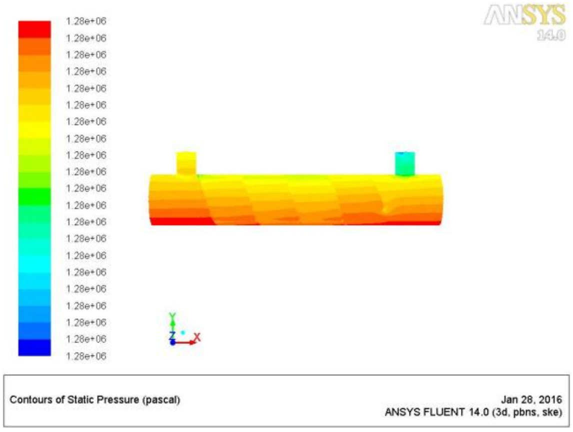

Fig. 8 Contours of Shell Side Fluid's Pressure of Shell and Tube Heat Exchanger with Helical Baffles

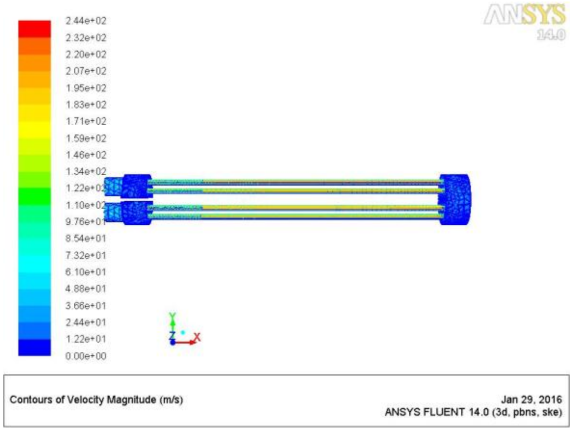

Fig. 8 Contours of Tube Side Fluid's Velocity of Shell and Tube Heat Exchanger with Segmented Baffles

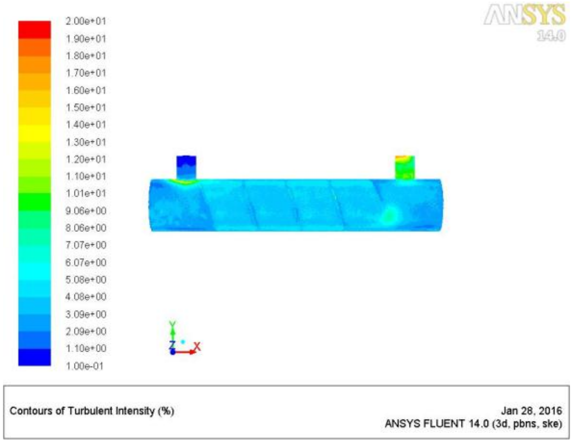

Fig. 8 Contours of Shell Side Fluid's Turbulent Intensity of Shell and Tube Heat Exchanger with Helical Baffles

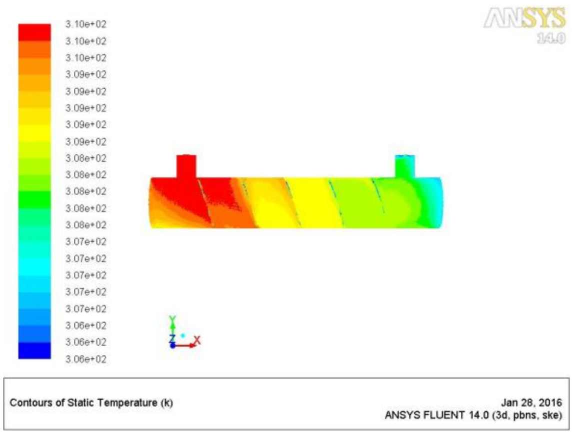

Fig. 8 Contours of Shell Side Fluid's Temperature of Shell and Tube Heat Exchanger with Helical Baffles

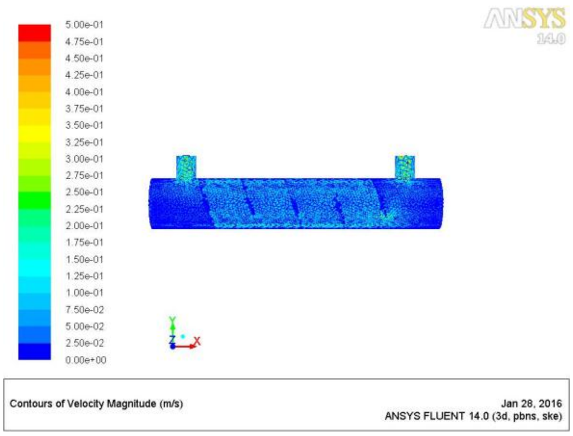

Fig. 8 Contours of Shell Side Fluid's Velocity of Shell and Tube Heat Exchanger with Helical Baffles

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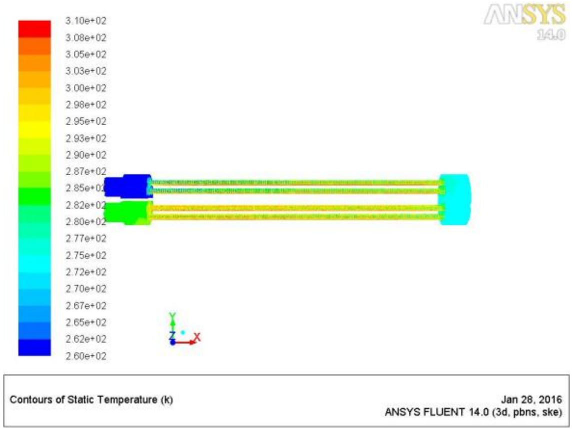

Fig. 8 Contours of Tube Side Fluid's Temperature of Shell and Tube Heat Exchanger with Helical Baffles

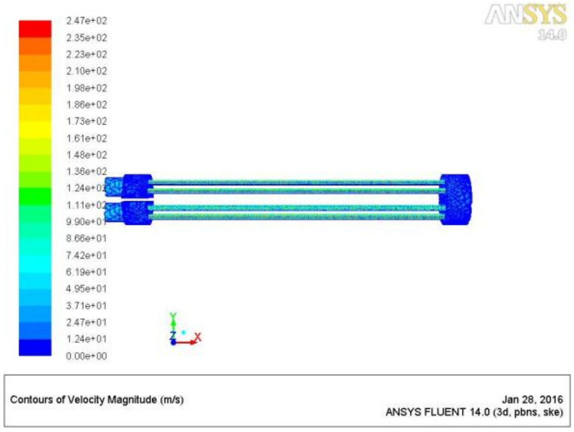

Fig. 8 Contours of Shell Side Fluid's Velocityof Shell and Tube Heat Exchanger with Helical Baffles

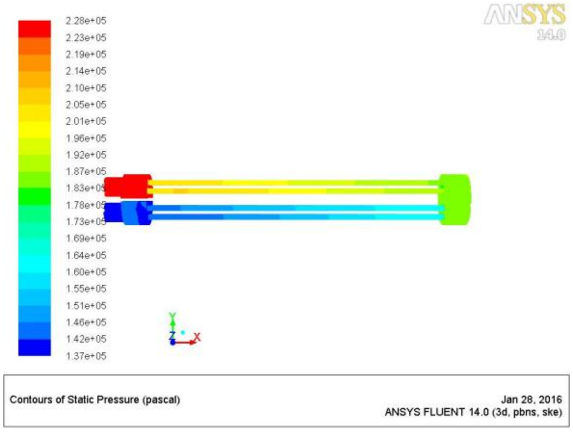

Fig. 8 Contours of Shell Side Fluid's Pressure of Shell and Tube Heat Exchanger with Helical Baffles

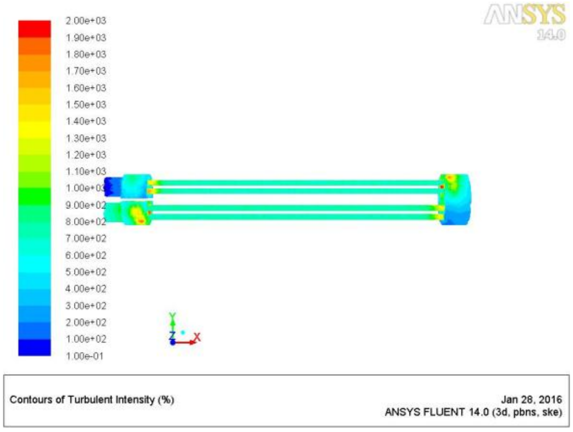

Fig. 8 Contours of Shell Side Fluid's Turbulent Intenisity of Shell and Tube Heat Exchanger with Helical Baffles

IV. CONCLUSIONS

While analyzing the temperature differences at the outlets, it can be seen that the temperature decrease of Ammonia Liquid is same in both cases and the increase of temperature of Ammonia Vapour is more in Segmented Baffles than in Helical baffles. This can be due to the difference in fluid mixing and turbulence during the flow of shell side fluid inside the shell. While examining the turbulent intensity contours, it is seen that the turbulent intensity has higher degree of variation while using segmented baffles. This effect made the heat transfer more efficient. So for a small size Shell and Tube Heat Exchanger, usage of segmented baffles is recommended. Helical baffles can be used in particular situations where a lesser increment of temperature in cold fluid is desired provided the size of the heat exchanger is not large.

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