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ANALYSIS OF SEGMENTAL AND COMBINATION OF VANE & SEGMENTAL BAFFLE IN SHELL AND TUBE HEAT EXCHANGER

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ABSTRACT

In this paper an analysis of two different types of baffle in a Shell and Tube Heat Exchanger is performed. Shell and tube heat exchanger are popularly used in many industrial applications such as power generation, Refrigeration and Environmental Protection and Chemical Engineering. Baffle is one of the components from the shell side of the STHE. The segmental baffle forces the liquid in a Zigzag flow and improving heat transfer and also increases the pressure drop and Combination of Vane & segmental decreasing the pressure drop, temperature distribution and exergy destruction

KEYWORDS: Baffle cut, heat exchanger, vane and segmental baffle, shell and tube heat exchanger.

INTRODUCTION

Heat transfer is one of the important and mostly applied in process industries and petroleum and oil refineries.A heat exchanger is a device that is used to transfer thermal energy (enthalpy) between two or more fluids, between a solid surface and a fluid, or between solid particulates and a fluid, at different temperatures and in thermal contact. Baffles are used to improve the heat transfer rate by increasing the velocity and turbulence of the shell side fluid. Baffles may be classified as transverse and longitudinal types. The purpose of longitudinal baffles is to control the overall flow direction of the shell fluid such that a desired overall flow arrangement of the two fluid streams is achieved. Transverse baffles may be classified as plate baffles and grid (rod, strip, and other axial-flow) baffles. Plate baffles increase the turbulence of the shell fluid and minimize tube-to-tube temperature differences and thermal stresses due to the cross-flow. The choice of baffle type, spacing, and cut is determined largely by flow rate, desired heat transfer rate, allowable pressure drop, tube support, and flow-induced vibrations. Single segmental baffle that is used in the present study is the most common baffle type. A comparison of segmental and segmental plate along with guide vane is presented here.

Exergy analysis is one of the powerful tools for the improvement of energy systems, with many possible applications in both conversion and utilization of energy. The previous researches done on heat exchangers by various researchers concluded that the exergy destruction in a heat exchanger can be separated into two components; one associated with the temperature differences and the other with the pressure drops. The thermal and pressure components of the dimensionless exergy destruction vary considerably with respect to baffle space[7]. The total exergy destruction rate and heat transfer rate are calculated to be functions of the effectiveness, pressure drop and specified inlet conditions[2]. For each of the geometrical parameters given, a set values of exergy destruction, exergy saving and annual total cost can be calculated by using the relevant equations.

GOVERNING EQUATIONS

The governing equations of the flow are modified according to the conditions of the simulated case. Since the problem is assumed to be steady, time dependent parameters are dropped from the equations.The resulting equations are:

Conservation of mass: $\nabla.\rho Vr = 0$

X-momentum:

$$\nabla.(\rho uVr) = -\frac{\partial p}{\partial x} + \frac{\partial \tau_{xx}}{\partial x} + \frac{\partial \tau_{yx}}{\partial y} + \frac{\partial \tau_{zx}}{\partial z} \_\_\_\_\_\_\_\_(1)$$

Y-momentum:

$$\nabla.(\rho vVr) = -\frac{\partial p}{\partial y} + \frac{\partial \tau_{xy}}{\partial x} + \frac{\partial \tau_{yy}}{\partial y} + \frac{\partial \tau_{zy}}{\partial z} + \rho g \_\_\_\_\_ (2)$$

Z-momentum:

$$\nabla.(\rho wVr) = -\frac{\partial p}{\partial z} + \frac{\partial \tau_{xz}}{\partial x} + \frac{\partial \tau_{yz}}{\partial y} + \frac{\partial \tau_{zz}}{\partial z} + \rho g \_\_\_\_\_(3)$$

Energy:

$$\nabla.(\rho eVr) = -p\nabla V^r + \nabla.(K\nabla T) + q + \emptyset \_\_\_\_\_\_(4)$$

In Eq. (4), $\emptyset$ is the dissipation function that can be calculated from

$$\emptyset = \mu\left[2\left[\left(\frac{\partial u}{\partial x}\right)^2 + \left(\frac{\partial v}{\partial y}\right)^2 + \left(\frac{\partial w}{\partial z}\right)^2\right] + \left(\frac{\partial u}{\partial y} + \frac{\partial v}{\partial x}\right)^2 + \left(\frac{\partial u}{\partial z} + \frac{\partial w}{\partial x}\right)^2 + \left(\frac{\partial v}{\partial z} + \frac{\partial w}{\partial y}\right)^2\right] + \gamma(\nabla.V^r)^2$$

The realizable k-ε model is a relatively recent development and differs from the standard k-ε model in two important ways:

- The realizable k-ε model contains a new formulation for the turbulent viscosity.
- A new transport equation for the dissipation rate, ε, has been derived from an exact equation for the transport of the mean-square vortices fluctuation.

Transport equations for the Realizable k-ε model

The modelled transport equations for k and ε in the realizable k-ε model are:

$$\frac{\partial}{\partial t}\rho k + \frac{\partial}{\partial x_j}(\rho k u_j) = \frac{\partial}{\partial x_j}[\left(\mu + \frac{\mu t}{\sigma k}\right)\frac{\partial k}{\partial x_j}] + G_k + G_b - \delta\varepsilon - Y_m + S_k$$

and

$$\frac{\partial}{\partial t}(\rho k) + \frac{\partial}{\partial x_j}(\rho\varepsilon u_j) = \frac{\partial}{\partial x_j}[\left(\mu + \frac{\mu t}{\sigma\varepsilon}\right)\frac{\partial \varepsilon}{\partial x_j}] + \rho C_1 C_s - \rho C_2 \frac{S^2}{K + \sqrt{VS}} + C_{1,s}\frac{S}{k}C_{1,s}G_b + S_g$$

Where, $C_1 = Max\left\{\left[0.43, \frac{n}{n+5}\right]\right\}, n = \frac{sk}{\varepsilon}$

MODELING OF SHELL AND TUBE HEAT EXCHANGER

Following data is used to generate the geometry of shell and tube heat exchanger using GAMBIT. The arrangement of the tube is square.

Table 1 Design Parameter of Shell and Tube Heat Exchanger

Heat Exchanger length, L	1500 mm
Shell diameter, D	254 mm
Tube diameter, d	25.4 mm
Number of tubes, N	33
Number of baffles	5
Baffle cut	20 - 25%

Shape of baffle	Segmental, Vane and Segmental

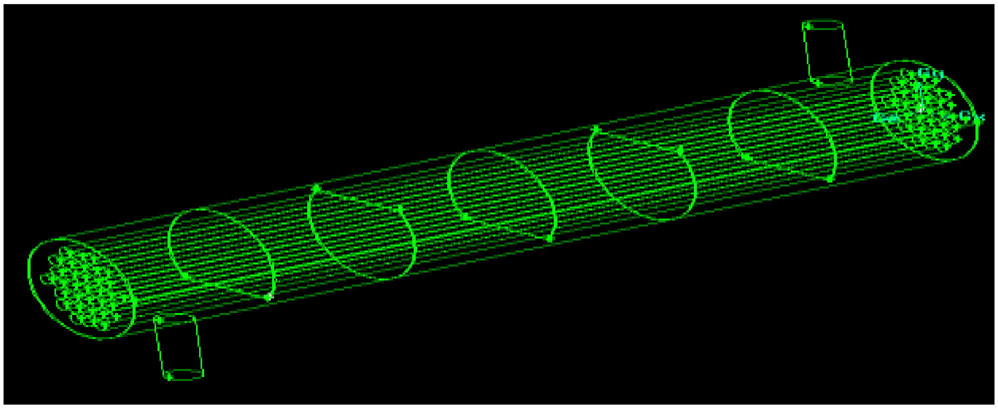

Figure 1 Geometry of segmental baffle heat exchanger

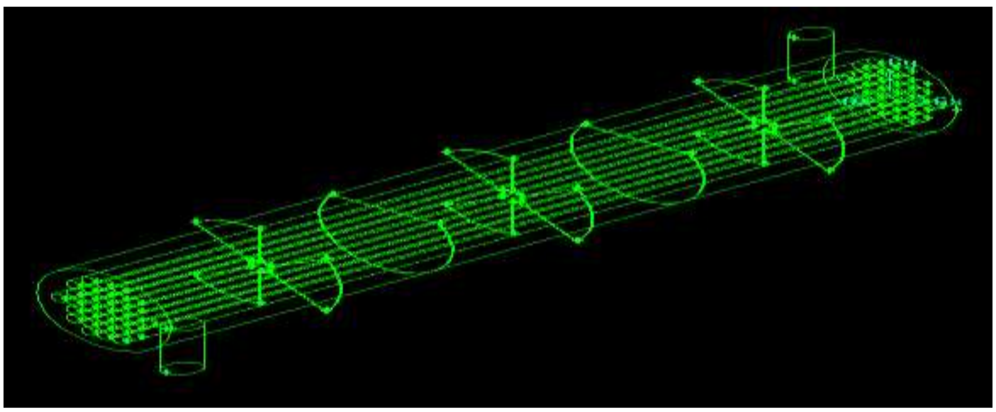

Figure 2 Geometry of vane & segmental baffle

MESH GENERATION

Meshing of this model is done in GAMBIT. The volume is meshed with tetragonal/T-grid. The volume mesh with approximately 686840 elements.

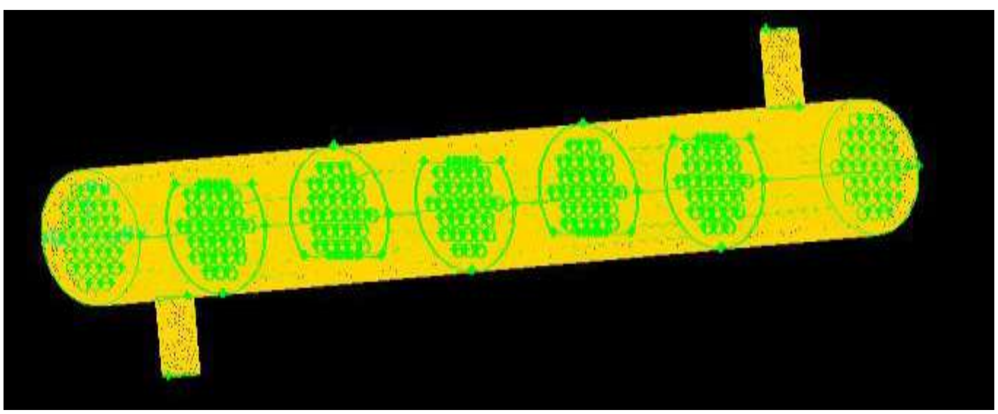

Figure 3 Meshing of segmental baffle heat exchanger

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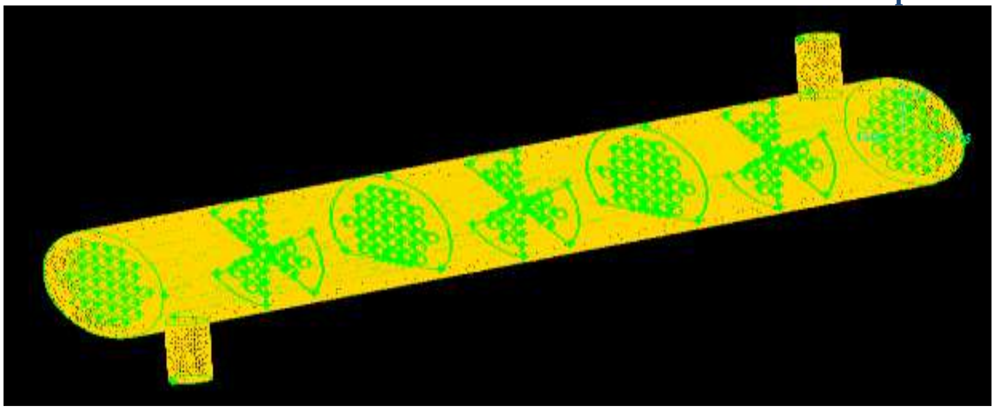

Figure 4 Meshing of vane and segmental heat exchanger

RESULTS AND DISCUSSION

[A] For Segmental baffle heat exchanger:

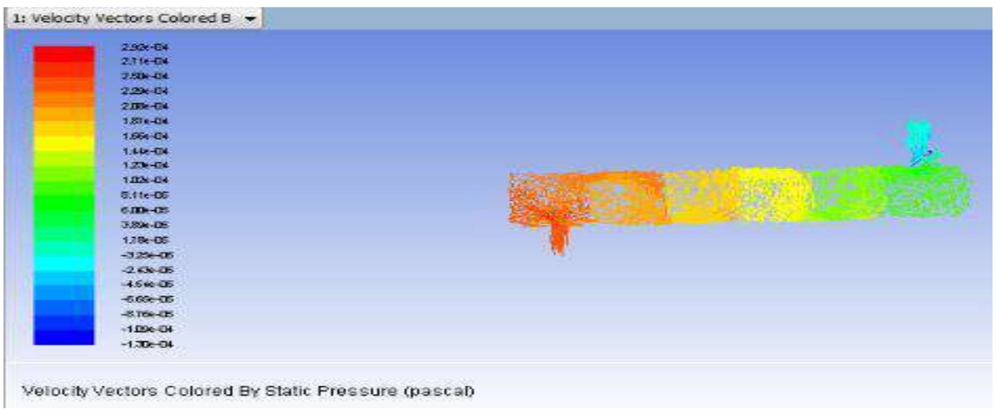

Figure 5 Pressure Vector

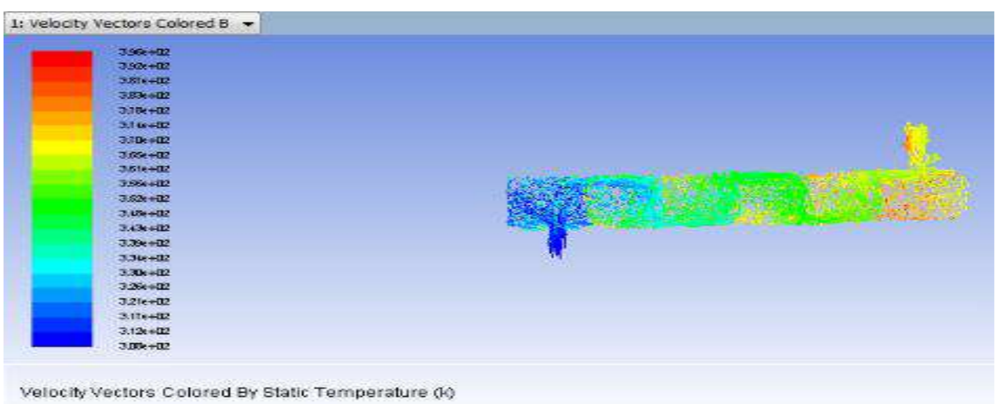

Figure 6 Temperature Vector

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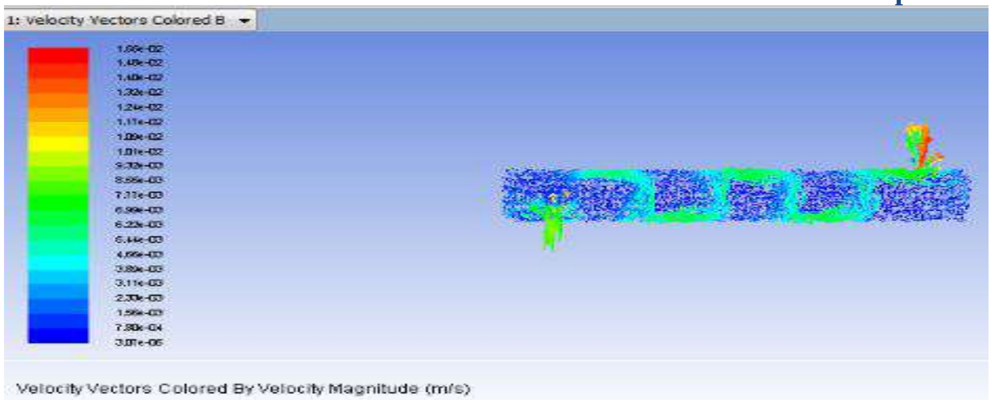

Figure 7 Velocity vector

[B] For vane and segmental baffle heat exchanger

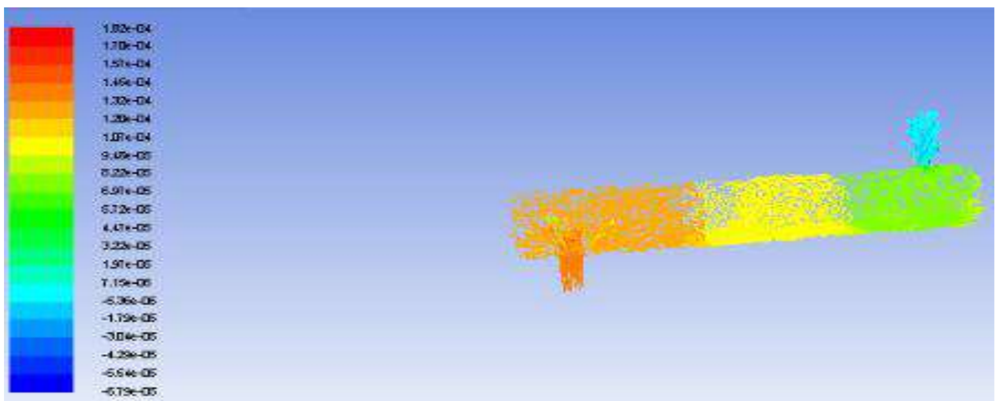

Figure 8 Pressure Vector

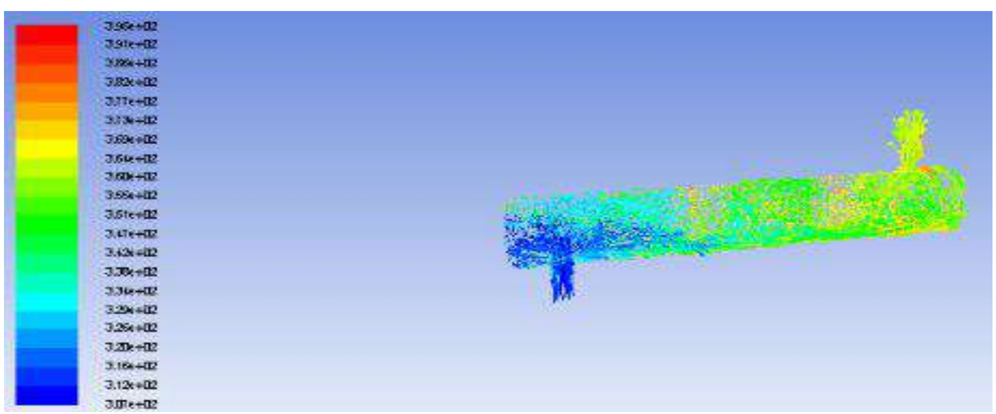

Figure 9 Temperature Vector

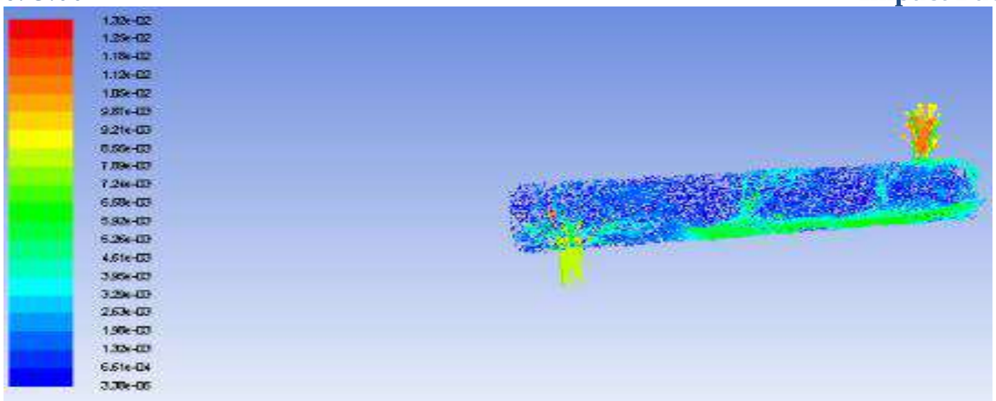

Figure 10 Velocity vector

Table 2 Comparison of Segmental and Combination of vane and segmental baffles

Shape of baffles	Mass flow rate (kg/s)	Outlet Temp (K)	Pressure Drop (Pa)	Velocity (m/sec)	Exergy Destruction
Segmental	28	392.88	2944	0.00100	65720
Combination of vane and segmental	28	392.78	1835	0.00099	61614

Ansys fluent is used for the analysis. The results obtained are displayed. Analysis on segmental baffle and combination of vane and segmental baffle are done, the results are graphically represented and optimum baffle spacing is derived.

CONCLUSION

In the above considered case, by varying the shape of baffles, the baffle cut value with 20-25% for 28kg/sec mass flow rate, the pressure drop and the temperature components are obtained in each case. The heat exchanger with segmental and vane combination has a very less pressure drop when compared to segmental baffles. Exergy destruction for the combination is comparatively less than that of the segmental baffles heat exchanger. Thus it can be concluded that the combination of vane and segmental baffles can have a less exergy destruction which can reduce the cost and save the energy.

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