MODIFIED DESIG OF SHELL AND TUBE HEAT EXCHANGER AND CFD ANALYSIS

J.Vijay Kumar[1], M.V.S.Pavan Kumar[2], J.Subash Kumar[3], T.N.V Ashok Kumar[4]
[1,2,3,4] Assistant Professor, Department of Mechanical Engineering,
Sasi Institute of Technology & Engineering, Tadepalligudem, A.P

ABSTRACT
The objective of this project is to design a heat exchanger with segmental baffles and to study the flow and temperatures inside the shell and tubes using Ansys software tool for the different baffles orientation also overall heat transfer is calculated for each design. This project compared both water and water & water and TiO_2, The heat exchanger having with six baffles is placed along the shell and tube heat exchanger angles and orientations with in order to create flow paths across tubes. The geometric model is compared by varying baffle inclination i.e 45^0, and 90^0. The process in solving simulation consists of modelling the basic geometry of heat exchanger using CFD package ansys 15.0.In this show the overall heat transfer, Temperature, Pressure, and Velocity varies in shell due to different baffles orientation.

Keywords: **Heat exchanger, Solid works, Ansys CFD Fluent, Segmental baffles, Pressure, Temperature, Velocity difference.**

I. INTRODUCTION

In this project heat exchanger contains designs for comparison and compared both water and water & water and TiO_2, In this study heat exchanger having with six baffles is placed along the shell in alternating orientations with cut facing up, cut facing down, etc., in order to create flow paths across tube bundle. The geometric model is compared by varying baffle inclination i.e 45^0, and 90^0. The heat exchanger contains seven tubes and 0.6m length and 0.09m shell diameterThe process in solving simulation consists of modelling the basic geometry of heat exchanger using CFD package Ansys 15.0.In simulation show the overall heat transfer, temperature, pressure, velocity varies in shell due to different baffles orientation.***A. Mohammed Irshad et.al [1]:*** The heat transfer and flow distribution is discussed in detail. From CFD simulation results, for fixed tube wall and shell inlet temperatures, shell side heat transfer coefficient, pressure drop and heat transfer rate values are obtained. From the CFD result it is observed that the heat exchanger without any short-circuited flow has the higher heat transfer coefficient than the heat exchanger with leakage. It’s found that the overall heat transfer coefficient increases by 18.89% if the sealers are installed inside the shell and tube heat exchanger. It is found that for 0.5 kg/s mass flow rate there is no much effect on outlet temperature of the tube even though the baffle inclination is increased from 0°to 40°. However the shell-side pressure difference is decreased with increase **in** baffle inclination angle i.e., as the inclination angle is increased from 0°to 40°. The pressure difference is decreased by 6%, for the heat exchanger with 20°baffle inclination angle and by 19.57% for the heat exchanger with 40°baffle inclination angle with 36% baffle cut. Baffle cut is reduced in order to provide proper support to the centre row of tubes. It is noticed that for the 36% baffle cut only 20°baffle inclination angle is maximum. If the angle is beyond 20°, the centre row of tubes is not supported. Hence the baffle cut can’t be used effectively. Also for the given geometry the mass flow rate must be below 2 kg/s, if it is increased beyond 2 kg/s the pressure drop increases rapidly with little variation in outlet temperature. Hence it can be concluded that shell and tube heat exchanger with 40°inclination angle and 25% baffle cut results in better performance compared to 0°, 20°and 30°inclination angle. ***B. Swapnil S. Kamthe et.al [2]:*** It can be concluded that due to addition of Nano fluid in base fluid will improve heat transfer characteristics of base fluid. Addition of Nano fluid increases heat transfer area compared with base fluid which directly increases heat transfer and indirectly heat coefficient of heat exchanger. Due to the presence of the Nano particle near the wall hence fast heat transfer takes place. Increase in Nano particle concentration increase thermal conductivity. Base fluid due to the availability of particle for energy exchange. Which also leads to increase turbulence level in fluid which directly speeds up energy exchange process? Pressure drop in laminar flow is less compared with turbulent flow. In laminar flow, less pressure drop occurs. For each type of Nano fluid there will be optimum concentration at which more heat transfer and less flow resistance occurs indifferent flow regions which depend on the properties of Nano fluid. ZnO –W (with polyvinyl pyrrolidone (PVP)) Nano fluid gives best performance among all Nano fluids considered in literature about an 35% compared with water (6 lpm tube side). Less optimum concentration found for particle having less mean diameter.

C. Rajagapal Thundil Karuppa Raj et.al [3]: The shell side of a small shell-and-tube heat exchanger is modeled with sufficient detail to resolve the flow and temperature fields. The shell side of a small shell-and-tube heat exchanger is modeled with sufficient detail to resolve the flow and temperature fields. For the given geometry the mass flow rate must be below 2 kg/s, if it is increased beyond 2 kg/s the pressure drop increases rapidly with little variation in outlet temperature. The pressure drop is decreased by 4%, for heat exchanger with 10° baffle inclination angle and by 16 %, for heat exchanger with 20° baffle inclination angle. The maximum baffle inclination angle can be 20°, if the angle is beyond 20°, the center row of tubes are not supported. Hence the baffle cannot be used effectively. Hence it can be concluded shell and tube heat exchanger with 20° baffle inclination angle results in better performance compared to 10° and 0° inclination angles.

II. MODELLING AND ANALYSIS

In this study shell and tube heat exchanger with six baffles are placed along the shell in alternating orientations with cut facing up, cut facing down, etc., in order to create flow paths across tube bundle. The geometric model is compared by varying baffle inclination i.e 45^0 and 90^0. The CFD analysis involves pre-processing, solving and post processing. The geometry modelling is done using software called Solid Works 15.0

S.No	Specifications	Dimensions
1.	Length of heat exchanger	600mm
2.	Shell diameter(Ds)	100mm
3.	Tube length (L)	600mm
4.	Tube outer diameter (d_0)	20mm
5.	No .of tubes(N_1)	7
6.	Baffle inclination(θ)	45°,90°
7.	Baffle cut	36%
8.	Baffle spacing	86mm
9.	Baffle thickness	3mm
10.	No .of baffles	6

Table.1.Geometric dimension

LMTD: The logarithmic mean temperature difference (also known as log mean temperature difference or simply by its LMTD) is used to determine the temperature driving force for heat transfer in flow systems, most notably in heat exchangers.

The LMTD is a logarithmic average of the temperature difference between the hot and cold fluids at each end of the shell and tube exchanger. The larger the LMTD, the more heat is transferred.

Counter flow:

$$(\Delta T)m = \frac{[(T1 - t1) - (T2 - t2)]}{ln \frac{[T1-t1]}{}}$$

Where

t_1 = Inlet temperature of cold fluid = 340K

T_1 = Outlet temperature of hot fluid = 300K

t_2 =Inlet temperature of cold fluid = 299K

T_2 = Outlet temperature of hot fluid = 340K

Boundary Conditions:

We must take same boundary conditions for the three types of shell and tube heat exchanger. At that boundary conditions, we want to found the effectiveness of the types.

For Hot Fluid:

Inlet temperature of hot fluid: -340K

Inlet velocity of hot fluid: 0.01m/s

Outlet velocity of hot fluid: -14.096 m/s

For Cold Fluid:

Inlet temperature of cold fluid: 299K

Inlet velocity of cold fluid: 0.01m/s

Outlet velocity of cold fluid: -14.096 m/s

LMTD with baffle angle 45°,

$$(\Delta T)_m = \frac{(300-340)-(340-299)}{\ln[(300-340)/(340-299)]}$$

$$(\Delta T)_m = 214.8\ K$$

LMTD with baffle angle 90°,

$$(\Delta T)_m = \frac{(300-340)-(340-298)}{\ln[(300-340)/(340-298)]}$$

$$(\Delta T)_m = 207.98K$$

TABLE 1: OUTLET TEMPERATURES OBTAINED FROM ANSYS-FLUENT ANALYSIS FOR WATER-WATER USED IN STHE

S.No	Type of heat exchanger	T_{hi} (K)	T_{ci} (K)	T_{ho} (K)	T_{co} (K)
1.	Shell and tube heat exchanger with baffle angle 45˚	340	297	300	340
2.	Shell and tube heat exchanger with baffle angle 90˚	340	302	300	340

TABLE 2: OUTLET TEMPERATURES OBTAINED FROM ANSYS-FLUENT ANALYSIS FOR WATER-TIO_2 USED IN STHE

S.No	Type of heat exchanger	T_{hi}(K)	T_{ci} (K)	T_{ho} (K)	T_{co}(K)
1.	Shell and tube heat exchanger with baffle angle 45˚	340	299	300	340
2.	Shell and tube heat exchanger with baffle angle 90˚	340	298	300	340

CALCULATIONS:

Over all heat transfer co-efficient,

$$Q = U.A.(\Delta T)m$$

$$U = \frac{Q}{A(\Delta T)m}$$

Where, Q =Heat Transfer Rate, W/S

U = Over all heat transfer co-efficient, W/m-K

$$A = \text{Area of the tube} = \frac{\pi}{4} \times D^2$$

Over all heat transfer co-efficient with baffle angle 45°,

$$Q = m_c\, c_{pc}\,(T_2 - T_1)$$

$$m_c = \rho W.\ A.V$$

$$= 1000 \times \frac{\pi}{4}(0.1)^2 \times 14.67$$

$$= 115.2 Kg/s$$

$Q = 115.2 \times 4.18 \times (340\text{-}298)$

$= 20224.5$ W/s

$$U = \frac{20224.5}{[\frac{\pi}{4} \times (0.1)^2 \times (58.2)]}$$

$= 4424.5$w/m-K

Over all heat transfer co-efficient with baffle angle 90°,

$Q = 115.2 \times 4.18 \times (340\text{-}299)$

$= 19746$W/s

$$U = \frac{19746}{[\frac{\pi}{4} \times (0.1)^2 \times (68.02)]}$$

$= 4424.5$w/m-K

For water and using Nano fluid (water- tio_2):

Over all heat transfer co-efficient with baffle angle 45°,

$Q = U.\ A.\ L.$

M

$$U = \frac{Q}{A(\Delta T)m}$$

$Q = m_c\, c_{pc}\,(T_2\text{-}T_1)$

$m_c = \rho\ W.\ A.V$

$= 4230 \times 7.85 \times 10^{-3} \times 14.67$

$= 487.37$ Kg/sec

$Q = 487.37 \times 4.18 \times (340\text{-}297)$

$= 87599$W/s

$$U = \frac{87599}{\frac{\pi}{4} \times 0.1^2 \times 608.33}$$

$= 18337$w/m-K

Overall heat transfer coefficient with baffle angle 90˚, $Q = mc\, c_{pa}\,(T_2 - T_1)$

$Q = 487.37 \times 4.18 \times (340\text{-}302)$

$= 77413$ W/s

$U = 77413/[(\pi/4) \times 0.1^2 \times 433.98]$

$= 22712$ w/m-K

III.RESULTS AND DISCUSSION

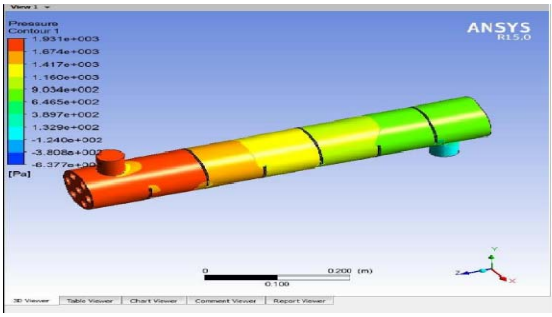

Fig.1. It shows the Heat Exchanger Pressure at the Baffle angle is placed in 90º

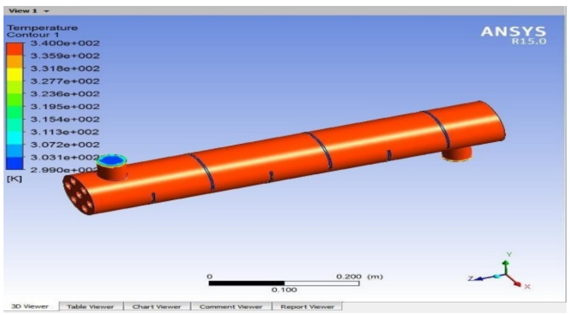

Fig.2. It shows the Heat Exchanger Pressure at the Baffle angle is placed in 90º

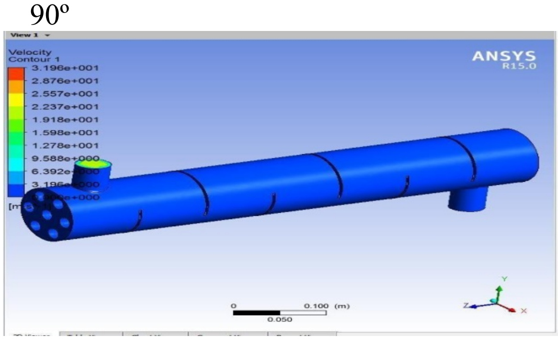

Fig.3. It shows the Heat Exchanger Velocity at the Baffle angle is placed in 90º

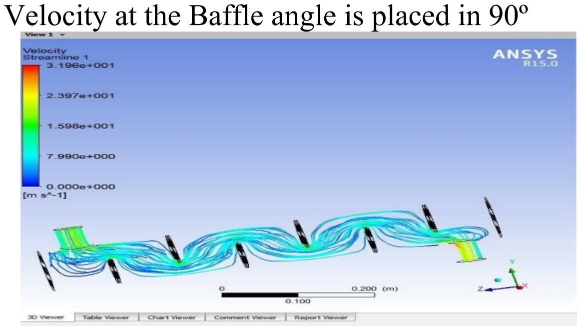

Fig.4. It shows the Heat Exchanger Fluid flow streamlines at the Baffle angle is placed in 90º

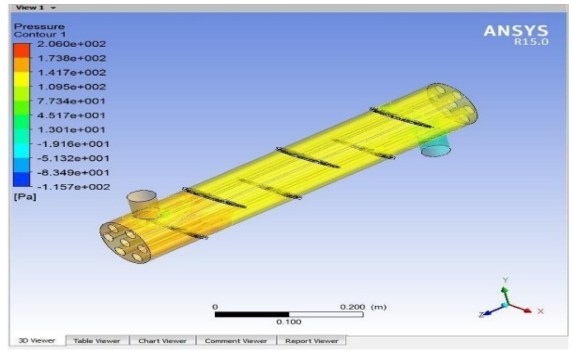

Fig.5. It shows the Heat Exchanger Temperature at the Baffle angle is placed in 45º

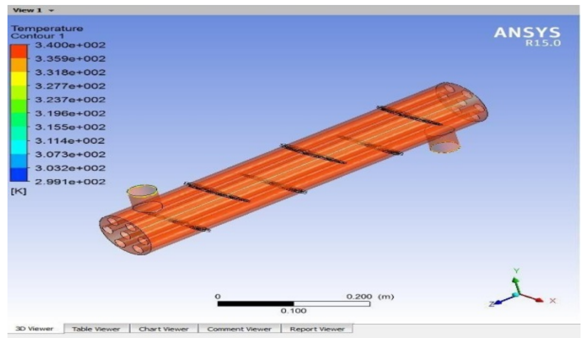

Fig.6. It shows the Heat Exchanger Pressure at the Baffle angle is placed in 45º

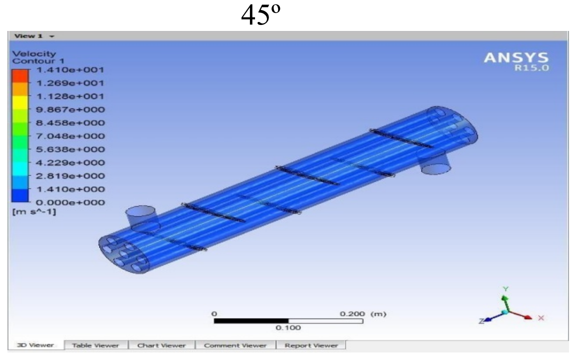

Fig.7. It shows the Heat Exchanger Velocity at the Baffle angle is placed in 45º

Temperature variations:

Table no.1. Temperature variations for water and water using STHE:

S.No	Baffle Angle(θ)	T_{hi} (K)	T_{ci} (K)	T_{ho} (K)	T_{co} (K)	Effectiveness (ε)
1.	45°	340	297	300	340	1
2.	90°	340	302	300	340	1

Table no.2. Temperature variations for water and Tio2 using STHE:

S. No	Baffle Angle(θ)	T_{hi} (K)	T_{ci} (K)	T_{ho} (K)	T_{co} (K)	Effectiveness(ε)
1.	45°	340	299	300	340	1
2.	90°	340	298	300	340	1

Pressure and velocity variations:

Table no.3. Pressure and velocity variations for water and water using STHE:

S.No	Baffle Angle (θ)	Pressure(pa)		Velocity(m/s)	
		Min	Max	Min	Max
1.	45°	-115.65	205.998	0	-14.096
2.	90°	-637.656	1930.72	0	31.959

Total Heat Transfer Rate Variations:

Table no .4. Total Heat transfer rate for water and water using STHE:

S. No	Baffert angle(θ)	Heat transfer rate Q (W/s)
1.	45°	20224.5
2.	90°	19746.1

Table no.5. Total Heat transfer rate for water and Tio2 using STHE:

S.No	Baffle angle(θ)	Heat transfer rate Q (W/s)
1.	45°	87599
2.	90°	77413

Logarithmic Mean Temperature Difference Variations:

Table no.6. LMTD for water and water using STHE:

S.No	Baffle angle(θ)	LMTD
1.	45°	58.2
2.	90°	65.02

Table no.7. LMTD for water and Tio2 using STHE:

S.No	Baffle angle(θ)	LMTD
1.	45°	608.35
2.	90°	433.98

Overall Heat Transfer Coefficient Variations:

Table no.8. Overall heat transfer coefficient for water and water using STHE:

S.No	Baffle angle (θ)	overall heat transfer coefficient (U)
1.	45°	4424.5
2.	90°	4424.5

Table no .9. Overall heat transfer coefficient for water and Tio2 using STHE:

S.No	Baffle angle(θ)	overall heat transfer coefficient (U)
1.	45°	18337
2.	90°	22712

COMPARISION OF TWO GRAPHS: The simulation results for 0.5 kg/s mass flow rate for models with 45°and 90°baffle inclination are obtained. It is seen that the temperature gradually increase from 300 k at the inlet to 340K at the outlet of the shell side. The average temperature at the outlet surface is nearly 330K. There is no much variation of temperature for two cases considered. The maximum pressure for models with 45°and 90° baffle inclination are 205.998 and 1930.72Pa respectively. The maximum velocity is nearly equal to 31.959 m/s for models at the inlet and exit surface and the velocity magnitude reduces to zero.

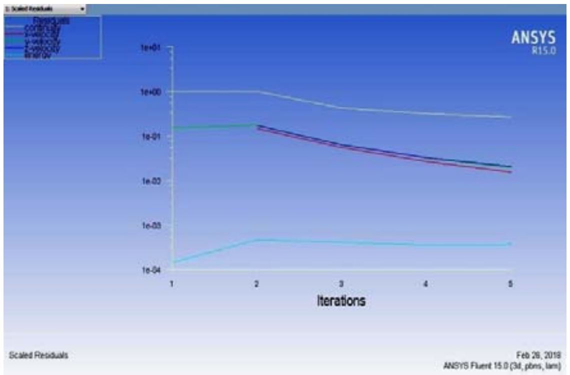

Fig.8.It shows the Heat Exchanger graph at the Baffle angle is placed in 90^0

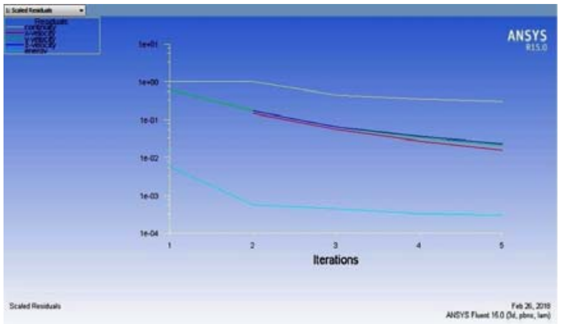

Fig.9. It shows the Heat Exchanger graph at the Baffle angle is placed in 45^o

IV. CONCLUSION

Heat transfer rate is increase drop and heat transfer rate values are obtained. From the CFD result it is observed that the heat exchanger without any short circuited flow has the higher heat transfer coefficient than the heat exchanger with leakage. It's found that the overall heat transfer coefficient increases by 24.12% for 45^o and 19.48% for 90^o. It is found that for 0.5 kg/s mass flow rate there is no much effect on outlet temperature of the tube even though the baffle inclination is increased from 45^o and 90^o. The pressure difference is 10.66%. Baffle cut is reduced in order to provide proper support to the centre row of tubes. Also for the given geometry the mass flow rate must be below 2 kg/s, if it is increased beyond 2 kg/s the pressure drop increases rapidly with little variation in outlet temperature. Hence it can be concluded that shell and tube heat exchanger with 90^o inclination angle and 25% baffle cut.

REFERENCES

[1] Digvendra Singh, Narayan Das Pal; "Designing and Performance Evaluation of a Shell and Tube Heat Exchanger using Ansys (Computational Fluid Dynamics)", International Journal of Scientific Engineering and Applied Science (IJSEAS) Volume2, Issue3 March 2016 e, ISSN: 2395- 3470

[2] R.Dharmalingam,K.K.Sivagnanaprabhu,J.Yogaraja,R.Mohan,S.Gunasekaran; "Experimental Investigation Of Heat Transfer Characteristics Of Nano fluid Using Parallel Flow, Counter Flow And Shell And Tube Heat Exchanger", Archive Of Mechanical Engineering Vol. LXII 2015 10.1515/Meceng-2015-0028.

[3] M.Thirumarimurugan, T.Kannadasan & E.Ramasamy, Performance and Analysis Of Shell And Tube Heat Exchanger Using Miscible System, American Journal Of Applied Sciences 5 (5): 548-552, 2008.

[4] Zarko Stevanovic, GradimirIlic, Design of Shell-And-Tube Heat Exchangers by Using CFD Technique, University Of Nis, Fr, 2002

[5] Huadong Li And Volker Kottke, Effect Of Baffle Spacing On Pressure Drop And Local Heat Transfer In Shell-And-Tube Heat Exchangers For Staggered Tube Arrangement, Inl.J. Heat Mass Transfer, Elsevier Science Ltd, 1998.

[6] Jian-Fei Zhang, Ya-Ling He, Wen-Quan Tao ; "A Design And Rating Method For Shell-And-Tube Heat Exchangers With Helical Baffles" Journal Of Heat Transfer, May 2010

[7] Khairun Hasmadi Othman, CFD Simulation Of Heat Transfer In Shell And Tube Heat Exchanger, University Malaysia Pahang, April 2009.

[8] K. Singh Defence Institute of Advanced Technology, Pune-411 025; "Thermal Conductivity of Nanofluids", Defence Science Journal, Vol. 58, No. 5, September 2008, pp. 600-607 Ó 2008.

[9] Abdul Razak Kaladgi, Sushma S, Faheem Akthar, Amjad Khan, Mohammed Rafeeq , Farooq Indikar and Mohammed Sami, " Heat Transport in High Heat Dissipating Electronic Devices." International Journal of Innovative Research in Science Engineering and Technology, Vol. 5, Issue 5, pp.7770-7775,2016.

[10]Amjad Khan, Abdul Razak Kaladgi, Sushma S, FaheemAkthar, Mohammed Rafeeq and Farooq Indikar, " Thermal Analysis of Heat Dissipating Electronic" International Journal of Innovative Research in Science Engineering and Technology, Vol. 5, Issue 5, pp. 7776-7781, 2016. DOI:10.15680/IJIRSET.2016.0505194.

[11]Hasibur Rahman Sardar, Abdul Razak Kaladgi, Forced Convection Heat Transfer Analysis through Dimpled Surfaces with Different Arrangements' American Journal of Energy Engineering, Vol. 3, No. 3, pp.37-45,2015.

[12]Shahrul, I. M., et al. "Effectiveness study of a shell and tube heat exchanger operated with nanofluids at different mass flow rates." Numerical Heat Transfer, Part A: Applications 65.7 (2014): 699-713.