Design, Analysis & Experimental investigation of a Shell and tube heat exchanger by varying the pitch

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ABSTRACT

The project has been undertaken to study the performance of Shell and Tube Heat Exchanger. Shell and Tube Heat Exchangers are one of the most commonly used in Industries. The effect of various parameters such as pitch and Baffle plate on Heat Exchangers is calculated. In this project design ,analysis & experimental investigation of helical baffle plate in shell and tube heat exchanger is done by using "Ansys Work bench 19.2(Fluent)". Baffle plate is an interval part of shell and tube heat exchanger which serves two major functions 1. To hold the tubes inside the shell.2. To direct the flow of fluid.3.Helical baffle design creates the swirl flow of fluid inside the shell.

Keyword:-*Specific heat, Turbulent, kinematic viscosity, Ratio of heat capacity*

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1. INTRODUCTION

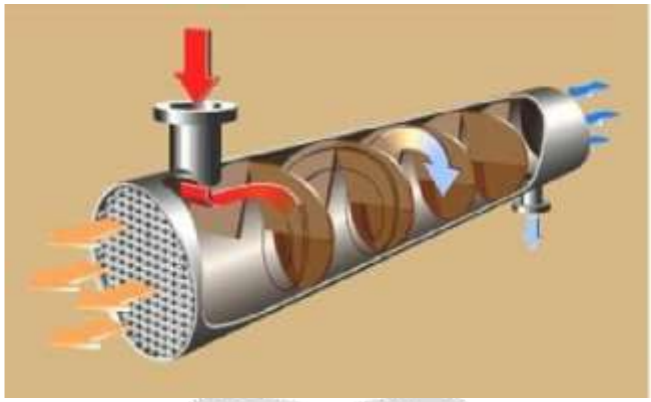
A heat exchanger is a piece of equipment built for efficient heat transfer from one medium to another. The media may be separated by a solid wall to prevent mixing or they may be in direct contact. They are widely used in space heating, refrigeration, air conditioning, power plants chemical plants, petrochemical plants, petroleum refineries, natural gas processing and sewage treatment The classic example of a heat exchanger is found in an internal combustion engine in which a circulating fluid known as engine coolant flows through radiator coils and airflows past the coils which cools the coolant and heats the incoming air.

1.1 Shell and Tube Exchanger:

A shell and tube heat exchanger is a class of heat exchanger designs. It is the most common type of heat exchanger in oil refineries and other large chemical processes, and is suited for higher-pressure applications. As its name implies, this type of heat exchanger consists of a shell (a large pressure vessel) with a bundle of tubes inside it. One fluid runs through the tubes, and another fluid flows over the tubes (through the shell) to transfer heat between the two fluids. The set of tubes is called a tube bundle, and may be composed of several types of tubes: plain, longitudinally finned, etc.

1.2 Shell and Tube Heat Exchanger design

There can be many variations on the shell and tube design. Typically, the ends of each tube are connected to plenums (sometimes called water boxes) through holes in tube sheets. The tubes may be straight or bent in the shape of a U, called U-tubes.



Shell and Tube Heat Exchanger with Helical Baffle

1.3 Selection of Tubes:

To be able to transfer heat well, the tube material should have good thermal conductivity because heat is transferred from a hot to a cold side through the tubes there is a temperature difference through the width of the tubes. Because of the tendency of the tube material to thermally expand differently at various temperatures thermal stress occurs during operation. This is in addition to any stress from high pressure from the fluids themselves. The tube material also should be compatible with both the shell and tube side fluids for long period under the operating conditions (temperatures, pressures, pH, etc.) to minimize deterioration such as corrosion. All of these requirements call for careful selection of strong, thermally-conductive, corrosion resistant, high quality tube materials, typically metals including aluminum, copper alloy stainless steel, carbon steel, non-ferrous copper alloy, Inconel, nickel, Hastelloy and titanium, fluoropolymer such as perfluoroalkyl alkane (PFA) and fluorinated Ethylene propylene (FEP) are also used to produce the tubing material due to their high resistance to extreme temperatures. Poor choice of tube material could result in a leak through a tube between the shell and tube sides causing fluid cross-contamination and possibly loss of pressure.

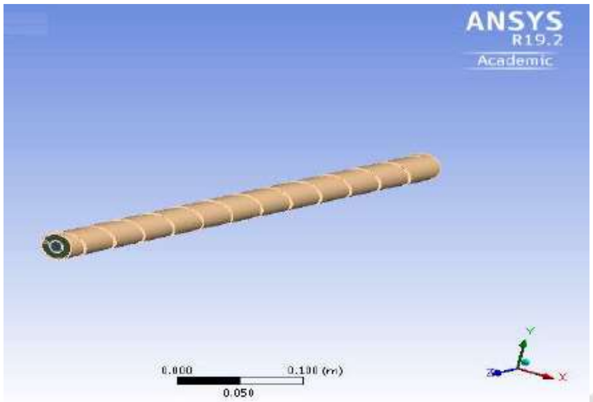
2. OBJECTIVE OF PRESENT WORK

The objective of the present work is to study the heat transfer characteristics of a Helical Baffle with the various pitches. This analysis has to be done for boundary conditions of zero at wall heat flux and coupled wall condition and also for flow condition i.e. laminar flow. This project deals with study and enhancement of shell and tube heat Exchanger parameters i.e, Design parameters straight curvature helical baffle with variation of pitch. Performance parameters Heat transfer rate, overall heat transfer coefficient and effectiveness. This project is done in “Ansys Work bench19.2” and analysis work is carried through fluid fluent. The variation design parameters i.e., baffle pitch are also following same criteria .The projects follows the simulation in case zero heat flux and coupled wall condition for walls of shell and tube heat Exchanger .This project work will give with which variation baffle pitch will give greater results by performing parameters.

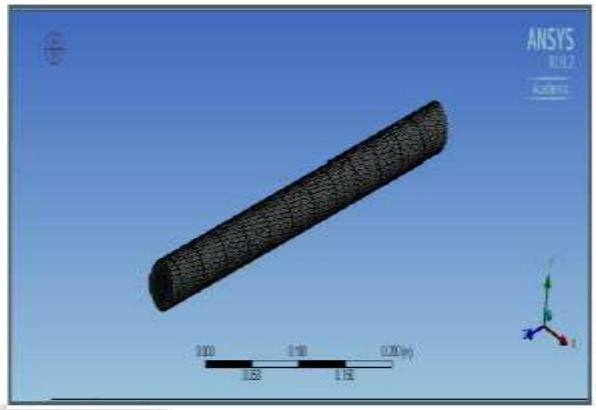
3. CFD PROCEDURE

For numerical analysis in CFD, it requires five stages such as:
1. Geometry creation
2. Mesh generation
3. Boundary conditions
4. Appling flow specification
5. Calculation and numerical solution
6. Results

3.1 Geometry creation & Meshing Generation

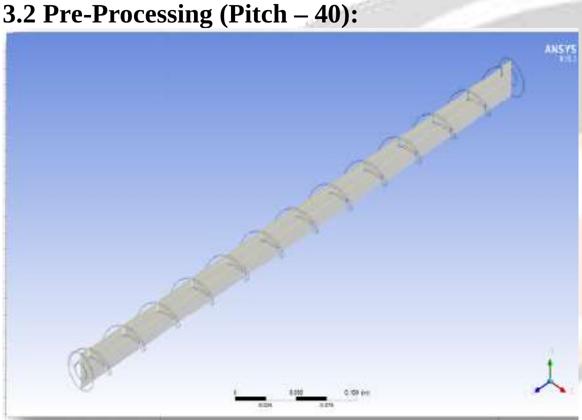


Geometry creation of Shell and Tube Heat Exchanger

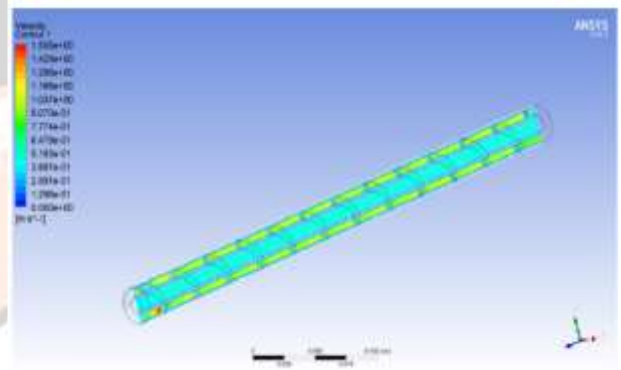


Creation of Meshing

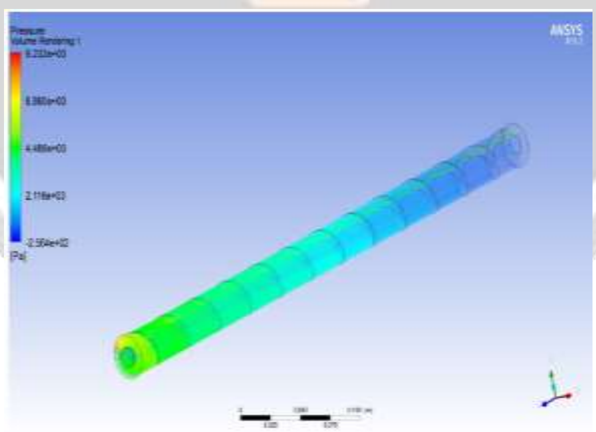
3.2 Pre-Processing (Pitch – 40):



View profile of create a plane on circular tube parallel Flow)

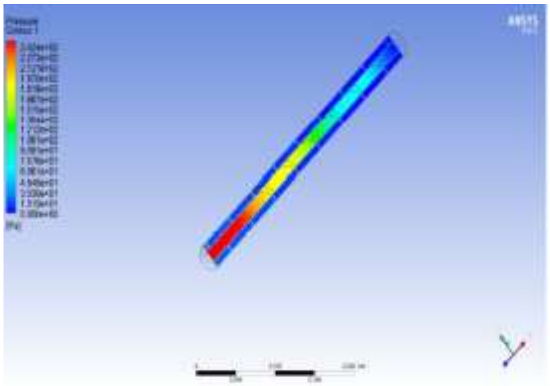


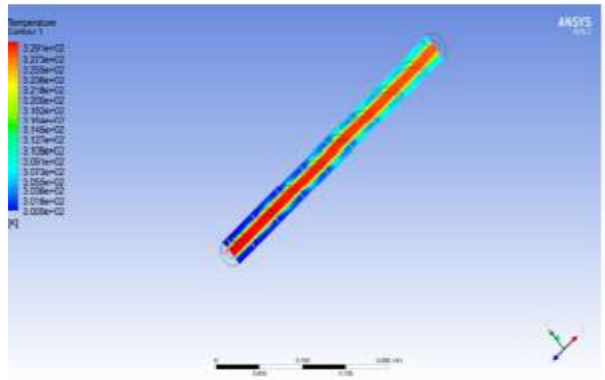
Contours of velocity of circular tube on plane 1 (



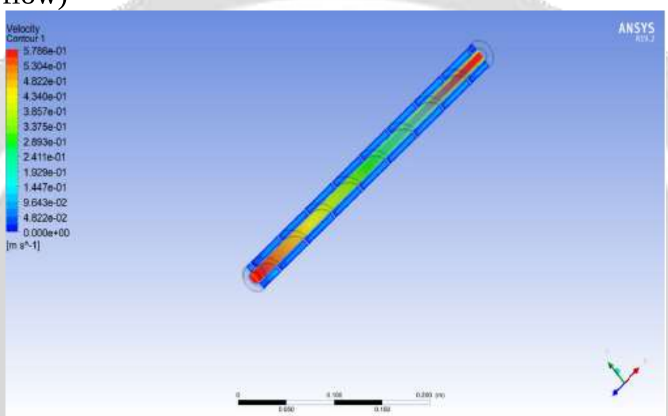
Contours of Pressure volume Rendering 1 of Circular tube(parallel flow)

3.3 Pre-Processing (Pitch – 60):



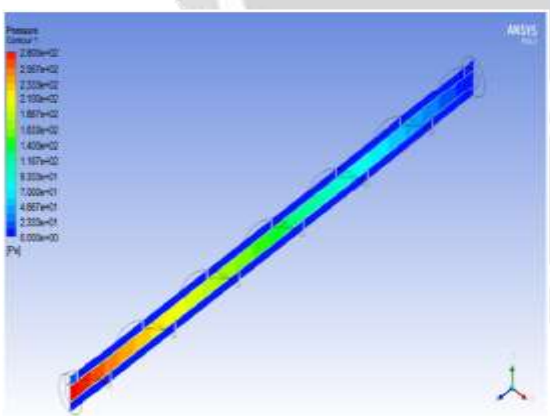


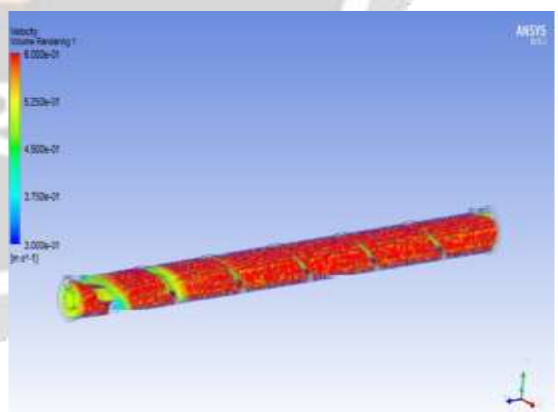
View profile of pressure contour 1 (parallel flow) Contours of static temperature 1 on circular tube for Velocity (0.5) (parallel flow)



Contours of velocity contour 1 on circular tube

3.4 Pre-Processing (Pitch – 80):





Contours of pressure contour 1 on circular tube (parallel flow) (0.5) Contours of Pressure volume Rendering 1(parallel flow)

4. Numerical calculations of shell and tube heat exchanger with Helical Baffle:

4.1 Pitch – 80:

Hot water inlet temperature = 330 K

Cold water inlet temperature = 300 K
Hot water outlet temperature = 325.619 K
Cold water outlet temperature = 301.11141 K
Specific heat of hot water C ph = 4178.75 J/kgK
Specific heat of cold water Cpc = 4178 J/kgK

Heat capacity rates:

C 1 = C pc × ṁc = 0.35 x 4178 = 1474.83

C 2 = C ph × ṁ h = 0.061 x 4178.5= 254.90

Ratio of heat capacity:

C r = Cmin/ Cmax=C1/C2

C r = 254.90/1474.83

Heat transfer rate from cold fluid:

Qc = ṁc Cpc x (Tco- Tci) = 0.353 x 4178 x (301.1141-300)= 1639.145 W

Heat transfer rate from hot fluid:

Qh= ṁh C ph (Thi - Tho) = 4178.750 x 0.061 (330 – 325.619)= 1116.69 W

Heat transfer rate, Q :

Q = (Qc + Qh) /2 = (1639.145 + 1116.69) / 2 = 1377.92 W

Logarithmic mean temperature difference (ΔTm):}

ΔTm = {(Thi – Thc) (Tho - Tco)}/ ln = {Th- Tci / Tho- TCO}

= (330-300) – (325.619- 301.11141)/ ln {330-300/325.619-301.1114} = 5.49/0.2022

Overall heat transfer coefficient:

Q = UA (ΔTm)

UA = Q/ ΔTm = 1377.92/27.175 = 50.70

Number of transfer units (NTU) :

NTU =UA/Cmin = 50.70/254.90 = 0.1989

Effectiveness (Ɛ) : Ɛ = 1- e-NTU (1+R) / 1+R

=1- e-(0.1989(1+0.172)) / 1+0.172

= 0.2079/1.172

=0.1774

4.2 Pitch – 60:

Hot water inlet temperature = 330 K
Cold water inlet temperature = 300 K
Hot water outlet temperature = 325.324 K
Cold water outlet temperature = 301.1813K
Specific heat of hot water C ph = 4178.75 J/kgK
Specific heat of cold water Cpc = 4178 J/kgK

Heat capacity rates:

C 1 = C pc × ṁc = 0.35 x 4178 = 1474.83

C 2 = C ph × ṁ h = 0.061 x 4178.5= 254.90

Ratio of heat capacity:

C r = Cmin / Cmax=C1/C2 C r = 254.90/1474.83 = 0.172

Heat transfer rate from cold fluid:

Qc = ṁc Cpc x (Tco- Tci)

= 0.353 x 4178 x (301.1813-300) = 1742.22 w

Heat transfer rate from hot fluid:

Qh= ṁh C ph (Thi - Tho)

= 0.061 x 4178.75 (330 – 325.329= 1190.65 W

Heat transfer rate, Q :

Q = Qc + Qh

=1190.65 + 1742.22/2= 1466.435 W

Logarithmic mean temperature difference (ΔTm):}

ΔTm = { (Thi – Thc) (Tho - Tco)}/ ln = {Th- Tci / Tho- TCO}

= (330-300) – (325.329- 301.1813)/ ln { 330-300/325.329-301.1813}

= 5.8523/0.208 = 26.968.

Overall heat transfer coefficient:

Q = UA (ΔTm)

UA = Q/ ΔTm

= 1466.435/26.968 = 54.376

Number of transfer units (NTU) :

NTU =UA/Cmin

= 54.376/254.90 = 0.2133

Effectiveness (Ɛ) :

Ɛ = 1- e-NTU (1+R) / 1+R

=1- e-(0.2133(1+0.172)) / 1+0.172 = 0.1887

4.3 Pitch – 40:

Hot water inlet temperature = 330 K
Cold water inlet temperature = 300K
Hot water outlet temperature = 324.936 K
Cold water outlet temperature = 301.469 K
Specific heat of hot water C ph = 4178.75 J/kgK
Specific heat of cold water Cpc = 4178J/kgK

Heat capacity rates:

C 1 = C pc × ṁc = 0.35 x 4178 = 1474.83

C 2 = C ph × ṁ h = 0.061 x 4178.5 = 254.90

Ratio of heat capacity:

C r = Cmin / Cmax=C1/C2 C r = 254.90/1474.83 = 0.172

Heat transfer rate from cold fluid:

Qc = ṁc Cpc x (Tco- Tci) = 0.353 x 4178 x (301.469-300) = 2166.53 W

Heat transfer rate from hot fluid:

Qh= ṁh C ph (Thi - Tho) = 4178.750 x 0.061 (330 – 324.936) = 1290.83 W

Heat transfer rate, Q :

Q = (Qc + Qh) /2 = (1290.83 + 2166.53) / 2 = 1728.68 W

Logarithmic mean temperature difference (ΔT_m):}

$\Delta Tm = \{(Thi – Thc) (Tho - Tco)\}/ \ln \{Th- Tci / Tho- TCO\}$

$=(330-300) – (324.936- 301.469)/ \ln \{330-300/324.963- 301.469\} = 6.533/0.245 = 26.6.$

Overall heat transfer coefficient:

$Q = UA (\Delta Tm) \; UA = Q/ \Delta Tm = 1728.68/26.60 = 64.98$

Number of transfer units (NTU) :

$NTU =UA/Cmin = 64.98/254.90 = 0.255$

Effectiveness (Ɛ) :

$\varepsilon = 1- e\text{-}NTU (1+R) / 1+R =1- e\text{-}(0.255(1+0.172)) / 1+0.172 = 0.2582/1.172 =0.2203$

5. Experimental Investigation

Experimental set up

S.no	Dimensions	Values
1	Length L	1.5mm
2	Inner tube Inner diameter di	1.2.5mm
3	Inner tube Outer diameter do	15.5mm
4	Outer inner tube Diameter D	42mm
5	Outer outer tube Diameter Do	45mm
6	Mass flow inlet of cold water mc	0.045m/sec
7	Mass flow inlet of hot water mh	0.05m/sec
8	Cold water inlet temperature Tc	298K
9	Hot water inlet temperature Th	316K

5.1 Calculations

Calculations:

Hot water inlet temperature T_{h_i} = 316 K

Cold water inlet temperature T_{c_i} = 298 K

Hot water outlet temperature T_{h_o} = 313 K

Cold water outlet temperature T_{c_o} = 304 K

$$Q_c = \dot{m}_c C_{pc}(T_{c_o} - T_{c_i})$$

$$Q_c = 0.045 \times 4178 \times (304 - 298) = 1128.06 \text{ W}$$

Heat transfer rate from hot fluid,

$$Q_h = \dot{m}_h C_{ph}(T_{h_i} - T_{h_o})$$

$$Q_h = 0.05 \times 4178.75 \times (316 - 313) = 626.7 \text{ W}$$

Heat transfer rate,

$$Q = \frac{Q_h + Q_c}{2}$$

$$Q = \frac{1128.06 + 626.7}{2}$$

$$= 877.38 \text{ W}$$

Logarithmic mean temperature difference (ΔT_m):

$$\Delta T_m = \frac{[(T_{h_i} - T_{c_i}) - (T_{h_o} - T_{c_o})]}{\ln\left[\frac{T_{h_i} - T_{c_i}}{T_{h_o} - T_{c_o}}\right]} \quad \text{(Parallel flow)}$$

$$\Delta T_m = \frac{(316-298)-(313-304)}{ln\left(\frac{18}{9}\right)}$$

$$= 12.98$$

Overall heat transfer coefficient,

$$Q = UA(\Delta T_m)$$

$$UA = \frac{Q}{\Delta T_m} = \frac{877.38}{12.98}$$

$$UA = 67.59 \text{ W/K}$$

Number of transfer units (NTU):

$$NTU = \frac{UA}{C_{min}} = \frac{67.59}{188.01}$$

$$NTU = 0.359$$

Effectiveness (ε):

$$\varepsilon = \frac{1-e^{-NTU(1+R)}}{1+R}$$

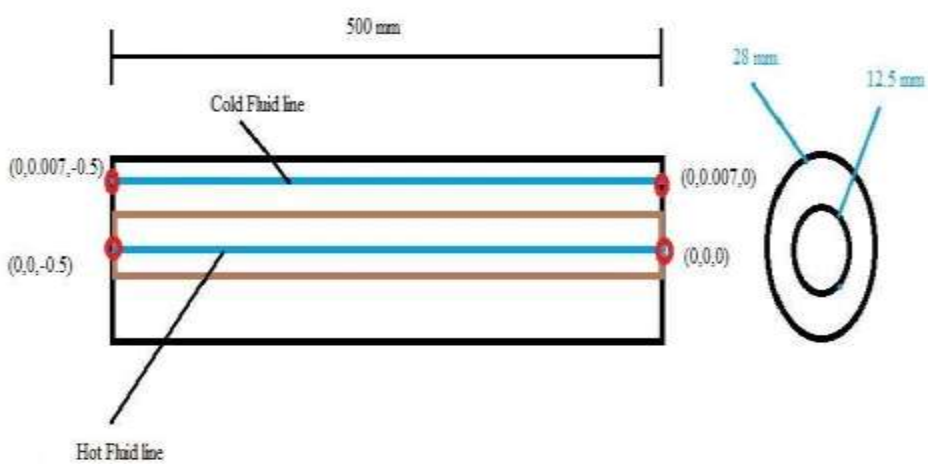
$$= \frac{1-e^{-0.359(1+0.9)}}{1+0.9}$$

$$\varepsilon = 0.26$$

6. Results & Discussions

The three dimensional flow and heat transfer characteristics of various configuration of heat exchanger. Results are described using plots, flow topologies of contours. They are discussed in following heads:

1. Comparing of numerical results with various configurations of heat exchanger.
2. Comparing effectiveness of various configurations.
3. Comparing of experimental results with CFD results.



Parallel flow arrangement for double pipe heat exchanger

HOT FLUID TEMPERATURE LINE

1= (0, 0, 0)

2= (0, 0,-0.5)

COLD FLUID TEMPERATURE LIN

3P= (0, 0.007, 0)

4P= (0,0.007 ,-0.5)

6.1 Graphs

Pitch-80:-

6.2 GRAPHS

PITCH -80:

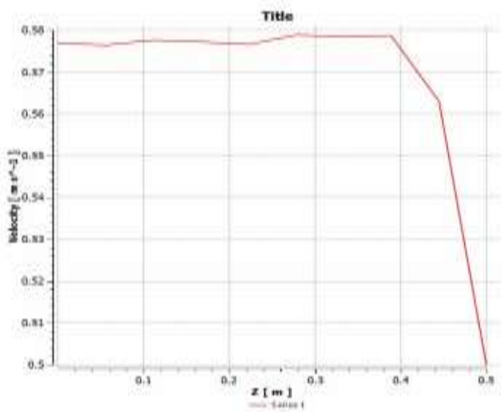


Fig 6.2.1Velocity Distribution of hot fliud

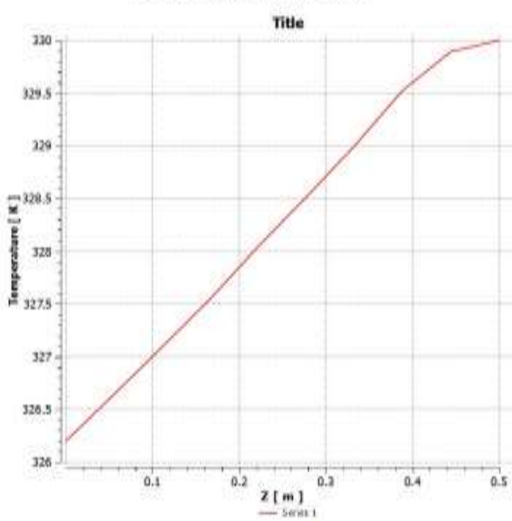


Fig 6.2.2 Temperature Distribution of hot fliud

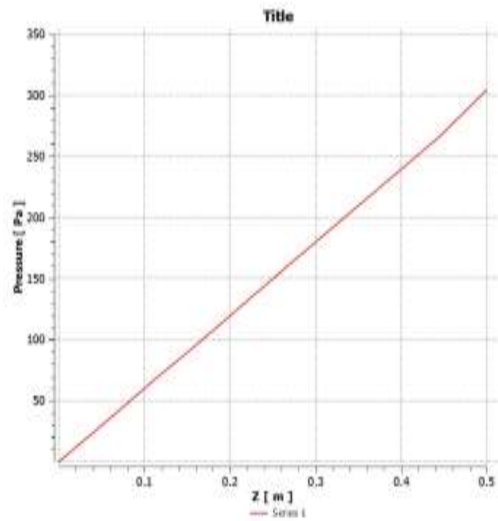


Fig 6.2.3 Pressure Distribution of hot fluid

PITCH – 60:

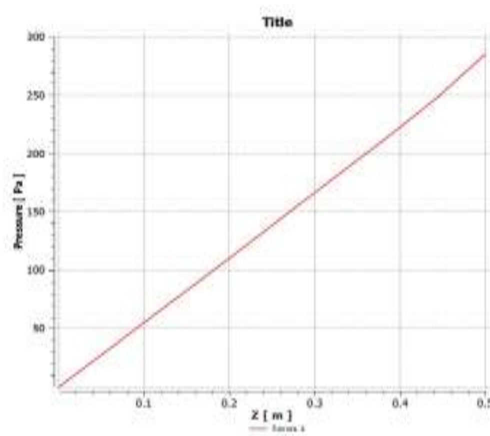


Fig 6.2.4 Pressure Distribution of hot fluid

Pitch-60:-

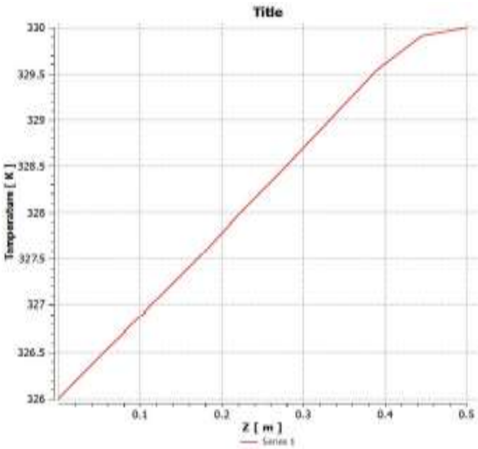


Fig 6.2.5 Temperature distribution 0.5

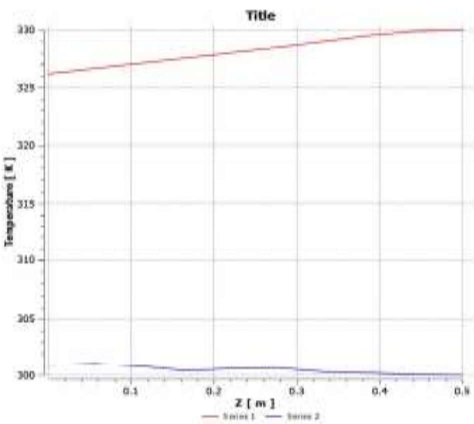


Fig 6.2.6 LMTD Graph of hot fluid

Pitch-40:-

PITCH 40 :

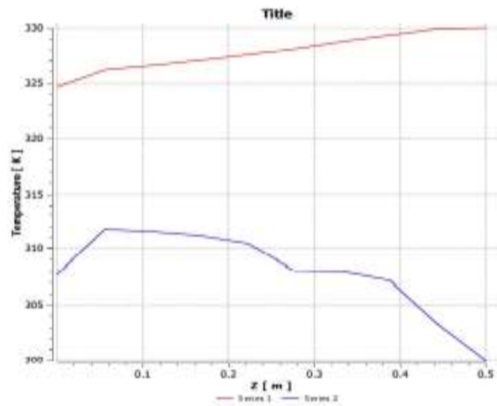


Fig6.2.7 Temperature Distribution of Hot fluid

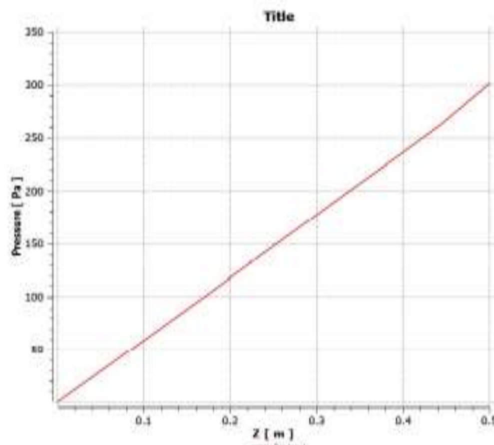


Fig 6.2.8 Pressure Distribution of Hot fluid

6.2 Theoretical & Experimental results Comparison Table

PITCH	T_h	T_C	Q_h	Q_c	Q_T	EFFECTI VENESS	COMPARSION
80	325.62	301.111	1116.69	1639.14	1377.92	0.1774	_
60	325.32	301.18	1190.65	1742.22	1466.43	0.1887	+6.37 %
40	324.93	301.46	1290.75	2166.53	1728.68	0.2203	+24.18 %

7. Conclusion

From the results of flow simulation of the Shell and Tube Heat Exchanger. It can be concluded that the simulation gives results close to the obtained results from the experimentation then that the overall heat transfer co-efficient increases and effectives also increases, because of we change the baffle structure and pitch layout
As per the design consideration we have pitch 40, pitch 60, and pitch 80. Here the main objective is to produce the better output that is better effectiveness.

As per the experimental work is conducted and finally compare to pitch 80 with pitch 60 Effectiveness increases by 6.37%.

The comparison of pitch 80 with pitch 40 Effectiveness increases by 24.18%.

Here the comparison of pitch 80 with pitch 40 the heat Transfer rate also increases by 25.45%.Thus pitch 40 has the greater flexibility to produce better efficiency

8. References

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