Global Journal of Researches in Engineering: J
General Engineering
Volume 15 Issue 4 Version 1.0 Year 2015
Type: Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals Inc. (USA)
Online ISSN: 2249-4596 Print ISSN:0975-5861

Experimental Investigation & Modelling Studies for Different Tubes of Heat Exchanger using CFD

By Roshan. V. Marode & Ashok. J. Keche
MIT, India

Abstract- Shell and Tube Heat exchanger are the basic types of heat exchanger one of the fluids flow through a bundle of tubes enclosed by a shell. The outer fluid is forced through a shell and it flows over the outside surface of the tubes. Such an arrangement is employed where reliability and heat transfer effectiveness. In order to achieve the maximum heat transfer rate an analysis is made on single tube with two different fluids (Water and Al2O3-water based Nano fluid) in a shell and tube heat exchanger. With relate to same to have a maximum heat transfer rate this paper gives various optimal design solutions using computational techniques. To measure the performance of different designs, its model is suitably designed and fabricated so as to perform experimental tests. Thermal analysis has been carried out for different design with two fluids and on the basis of comparative results is made which one give the best heat transfer rates.

Keywords: heat exchanger, water, al2o3-water based,optimal design, thermal analysis, computational techniques.

GJRE-J Classification : FOR Code: 290901p

Experimental Investigation & Modelling Studies for Different Tubes of Heat Exchanger using CFD

Roshan. V. Marode [α] & Ashok. J. Keche [σ]

Abstract- Shell and Tube Heat exchanger are the basic types of heat exchanger one of the fluids flow through a bundle of tubes enclosed by a shell. The outer fluid is forced through a shell and it flows over the outside surface of the tubes. Such an arrangement is employed where reliability and heat transfer effectiveness. In order to achieve the maximum heat transfer rate an analysis is made on single tube with two different fluids (Water and Al2O3-water based Nano fluid) in a shell and tube heat exchanger. With relate to same to have a maximum heat transfer rate this paper gives various optimal design solutions using computational techniques. To measure the performance of different designs, its model is suitably designed and fabricated so as to perform experimental tests. Thermal analysis has been carried out for different design with two fluids and on the basis of comparative results is made which one give the best heat transfer rates.

Keywords: heat exchanger, water, al2o3-water based, optimal design, thermal analysis, computational techniques.

I. Introduction

In a Heat Exchanger, consists of bundle of tubes. One fluid flows through the tubes while the second fluid flows space between the tubes and shell. Tubes plays an important role while exchanging heat from hot fluid to cold fluid. Although they are not specially compact, their robustness and shape make them well suited for high pressure operations. They have larger heat transfer surface area to volume ratio than the most of common types of heat exchangers, and they are manufactured easily for a large variety of sizes and flow configurations. The main design objectives here are to accommodate thermal expansion, to furnish ease of cleaning, or to provide the least expensive construction.

To get robust, least expensive and technically sound design, we will be dealing with four different designs viz. “Circular Tube”, “Elliptical type(Oval)”, “Twisted type” and “Coil type” Along with construction issue we too come across the difficulties in improving heat transfer rates, which means to have high effectiveness, we were in flow to compromise the design and robustness. In order to achieve the maximum heat transfer rate an analysis is made on single tube for different designs with two different fluids (Water and Al2O3-water based Nano fluid) in a shell and tube heat exchanger. This paper shows how maximum heat transfer rate has been achieved by comparing four different designs and getting optimal design solutions using computational techniques. To measure the performance of different designs, its model is suitably designed and fabricated so as to perform experimental tests. Thermal analysis has been carried out for four different designs with two fluids and on the basis of comparative results is made which one give the best heat transfer rates. After the modification of design an experimental validation is carried out to validate the results from analysis.

Author α: Mechanical Engineering Department, MIT, Aurangabad (M.S), India. e-mail: roshan.marode@gmail.com
Author σ: Associate Professor, Mechanical Engineering Department, MIT, Aurangabad (M.S), India. e-mail: ashokkeche@gmail.com

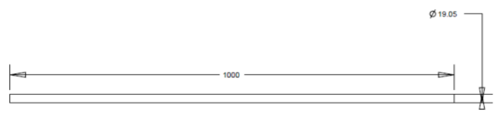
II. Literature Review

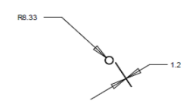
Ala Hasan [1] experimentally investigated five oval tubes and compared with that for a circular tube in a cross-flow way and concluded that oval tube gives higher heat transfer results. The outcome was taken for comparing results of oval and circular tubes which helped for optimized design. Abdul Kareem Abbas*et al* [2] shows heat transfer augmentation due to twisting parameter was investigated in a twisted tube of rectangular/square cross sectional area. Also swirling increases internal mixing process which enhances internal thermal equilibrium. The heat transfer coefficient also increases as Reynolds number increased as velocity components are increased. This relation shown was used as function and one of the parameter in design. Su Thet Mon Than *et al*[3]In this paper data is evaluated for heat transfer rate having spiral tubes and pressure drop and checking whether the assumed design satisfies all requirement or not by using computational techniques. Satisfied design found was used for coil type tubes for analysing the heat transfer rate.Jay J. Bhavsar*et al*[4]objective of this paper is to design and analyze of spiral tube heat exchanger. In this newly proposed design hot fluid flows in axial path while the cold fluid flows in a spiral path. The presented work was used in spiral tube designand has high heat transfer rate compared with helical coil heat exchanger and spiral plate heat exchanger.P. M. Deshpande *et al*[5]They studied horizontal spiral coil tube (HSTC) for various forces (viscous, buoyancy and centrifugal force) acting on fluid element in coil; of which the centrifugal force is predominant and results in secondary flow. This phenomenon also depends on the physical properties of fluid at a given temperature. They also concluded that as the coil diameter reduces the curvature ratio increase that increases the pressure drop. Relation was used for designing coil type tubes.

III. Design of Tubes

a) Circular type tube

D_i=16.65mm
D_o=19.05mm
Thickness=t=18BWG
Length= 1000mm





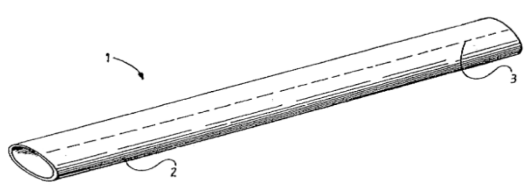
Source:

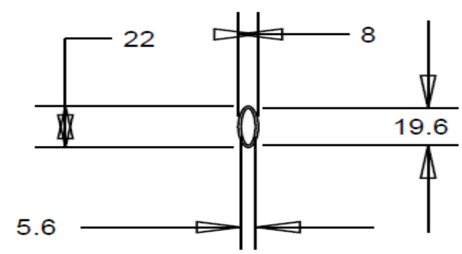
- Design of Heat Exchange equipment.
- Design shell and tube heat exchanger [Rajiv Mukherjee Engineers India Ltd.]
- Handbook of TEMA.

b) Elliptical Type Tube(Oval)

Source:

- Thermal-Hydraulic performance of oval tubes in a cross-flow air- *ALA-HASAN*
- Structural and Thermal Analysis of Heat Exchanger with Tubes of Elliptical Shape -Nawras H. Mostafa Qusay R. Al Hagag





c) Twisted Type Tube

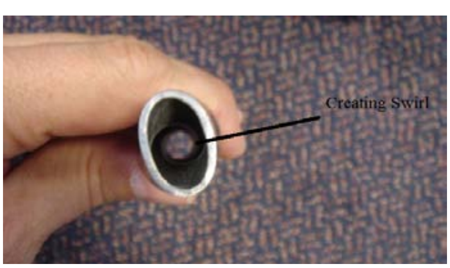
Length (L)=1000mm

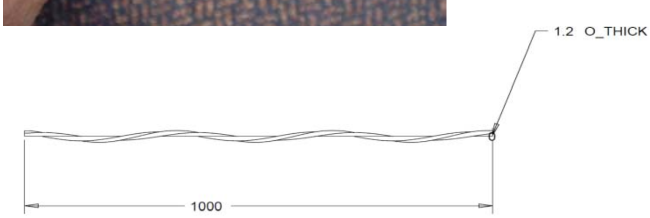
Thickness (t)=1.2mm

Breadth of rectangular tube (b)=22 mm

Depth of rectangular tube (d) =8mm

No. of twists (Nt)=05(Each at 200mm)





Source:

- Twisted Tube Heat Exchanger Technology-*R. Donald Morgan*
- Twist parameter influence on heat transfer coefficient augmentation for a square twisted tube- *A. Kareem*

d) Coil Type Tube

Diameter (D_0) =3/4"=19.05mm

Length(L)=1000mm

Number of turns(n)=6

Thickness(t)=1.2mm

Effective coil diameter (D)=52mm

Pitch (p) for helical it is taken as $1.5D_0$≡30mm

To know the unknown parameter, D (Coil Diameter)

Equation is given by,

$$L = N\sqrt{(2\pi R)2 + (p)2}$$

$$1000 = 6\sqrt{(2\pi R)2 + (1.5x19.05)2}$$

$$\frac{1000}{6} = \sqrt{(2\pi R)2 + (1.5x19.05)2}$$

$$\frac{1000}{6} = \sqrt{(2\pi R)2 + 816.53}$$

$$\frac{26961.24}{4x\pi^2} = R^2$$

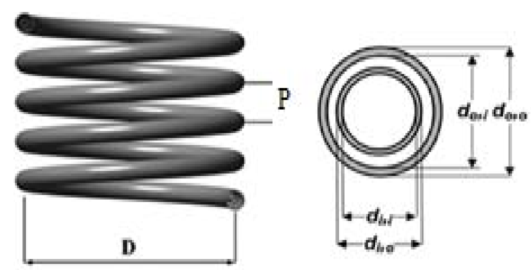
Therefore,

R = 26.13mm

D ≡ 52 mm

Source:

- ASME German AD-*Merkblatt*
- European pressure equipment directive (PED)
- Designing a helical-coil heat exchangers- *K. Ramchandra*



IV. Experimental Work

We achieved temperature range by placing thermocouple at 250 mm apart for four design tubes.

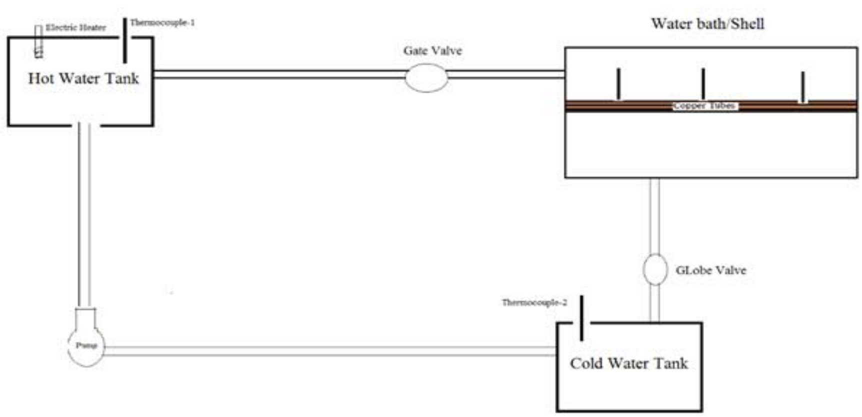
T_1 = Temperature at inlet of tube.

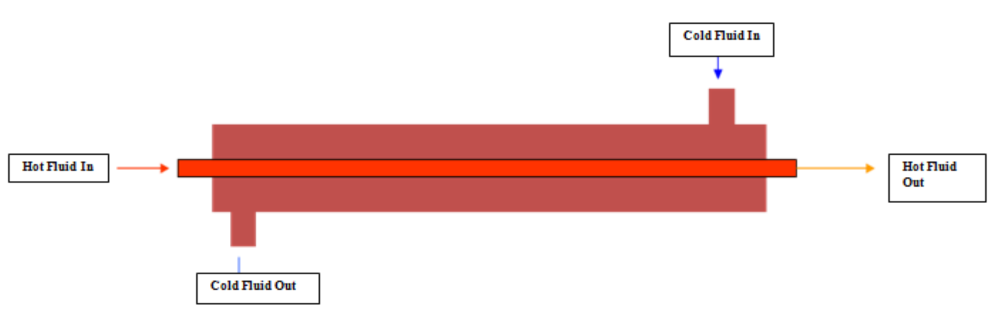
T_2=Temperature at a distance of 250mm from inlet.

T_3= Temperature at a distance of 500mm from inlet.

T_4= Temperature at a distance of 750mm from inlet.

T_5=Temperature at outlet of tube.





a) *For (Water –Water as a fluid)*

i. *For circular type*

Sr. No	Mass flow rate(Kg/sec)	Temperatures at different points of tube (^{0}C)				
		T1(At start 0mm)	T2(At 250 mm)	T3(At 500mm)	T4 (At 750mm)	T5(At 1000mm)
1	0.14	67	66.5	65.5	65	64
2	0.12	67	66.5	66.5	65	64
3	0.05	66.5	66	65	64.5	63.5

ii. *For Elliptical type*

Sr. No	Mass flow rate(Kg/sec)	Temperatures at different points of tube (^{0}C)				
		T1(At start 0mm)	T2(At 250 mm)	T3(At 500mm)	T4 (At 750mm)	T5(At 1000mm)
1	0.14	67.5	65	64.5	64	63.5
2	0.12	63	62.5	62	61	59.5
3	0.05	63	62	62	61.5	60

iii. *For Twisted type*

Sr. No	Mass flow rate(Kg/sec)	Temperatures at different points of tube (^{0}C)				
		T1(At start 0mm)	T2(At 250 mm)	T3(At 500mm)	T4 (At 750mm)	T5(At 1000mm)
1	0.14	64	62	60	58.5	56.5
2	0.12	56	54	53	52	51
3	0.05	58	57	56	54	53

iv. *For Coil type*

Sr. No	Mass flow rate(Kg/sec)	Temperatures at different points of tube (^{0}C)				
		T1(At start 0mm)	T2(At 250 mm)	T3(At 500mm)	T4 (At 750mm)	T5(At 1000mm)
1	0.14	68	68	67	65	63
2	0.12	65.5	65	64.5	62	58
3	0.05	61	60	60.5	58	56.5

V. Calculations for Heat Transfer Coefficient

a) *For case I(water-water)*

Fluid properties for water are:

μ=0.467xNs/

ρ=1000 kg/

Cp=4.18xJ/kg^{0}k

k_w=0.625w/m^{0}k

For Circular type:

$A_{c/s}$ = ($\pi[d_o^2-d_i^2]$

=($\pi[0.01905^2-0.01665^2]$

=$6.73x10^{-5}m^2$

As Reynolds number for circular tube is given by,

Re=ρvd/μ .... (1)

to find V,

We know continuity equation,

Q=AxV

As density = mass/volume (ρ=m/vol.)

Therefore, m= A x ρ x V (1a)

For mass flow rate =m=0.14kg/sec

0.14 = Vx1000x6.73x10^{-5}

V= = 2.08m/s

V= 2.08 m/s

So,

Re = 74158.45

From Reynolds number, flow is turbulent.(Re>2000)

Correlation used for turbulent flow is;

Nu= = CRe^aPr^{b-m} (1b)

where C = 0.021 for gases,

= 0.023 for non-viscous liquids,

= 0.027 for viscous liquids

Nu= = CRe^aPr^{b-m}

= $0.023xRe^{0.8}Pr^{(1/3)}$ x1

= $0.023x(74158.45)^{0.8}x(Pr)^{(1/3)}$ (1c)

Pr =μCp/k (Depend only on fluid properties)

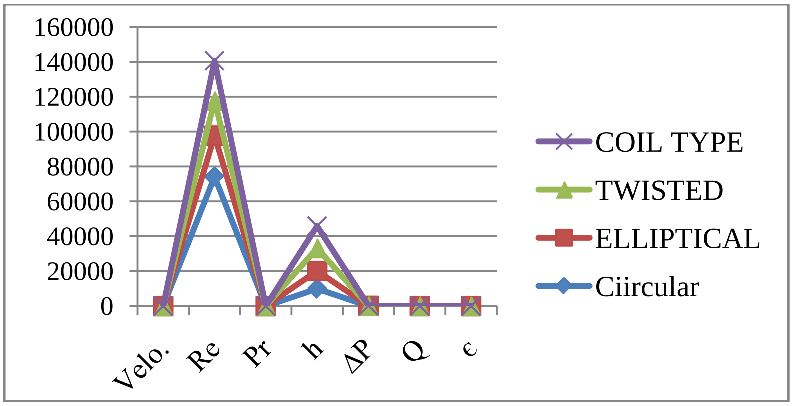
= 3.12

Equation 1c, → = 0.023 x $(74158.45)^{0.8}x(3.12)^{(1/3)}$

ȟ = 9932.08 w/m^{20}K

Likewise, calculated heat transfer rate for other three tubes are:

Sr. No.	Type of Design	V	Re	Pr	h	ΔP	Q	ϵ
1	Circular	2.08	74158.4	3.12	9932.08	31.18	19.6	0.35
2	Elliptical	1.7	23516.1	3.12	10213.7	54.91	19.22	0.24
3	Twisted	2.11	19952.4	3.12	13100.6	29.3	19.83	0.53
4	Coil	2.09	23032.5	3.12	12625.1	36.72	21.91	0.34

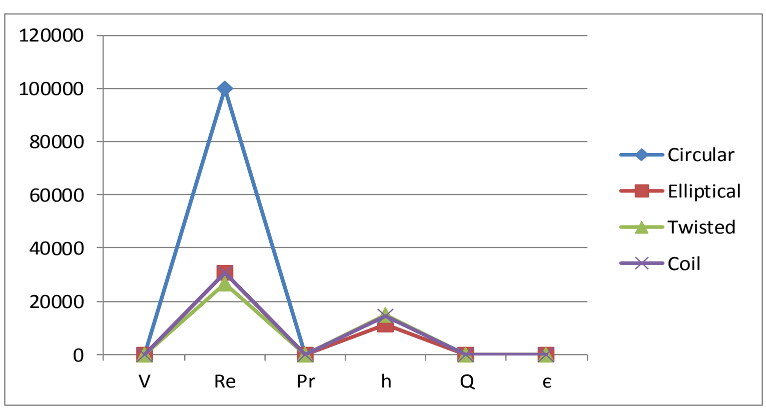


b) *Calculated outcome of Case-II (AL2O3-Water as a Nano fluid):*

Fluid properties for Al_2O_3- water (0.1 % concentration) are:
μ=0.35 cp=3.5xNs
ρ=1022 kg/
Cp=3.1xJ/kg^{0}k
k=0.72w/m^{0}k,

Prandtl number obtained from calculation is common for all type of deign as fluid properties are common, viz 1.5.

Sr. No.	Type of Design	V	Re	h	Q	ϵ
1	Circular	2.06	100153.08	11399.20	20.63	0.38
2	Elliptical	1.63	30761.90	11427.08	20.16	0.30
3	Twisted	2.07	26563.12	14864.54	23.18	0.60
4	Coil	2.04	30617.95	14307.87	24.01	0.40



VI. Thermal Analysis of Tubes with two Different Media

Thermal Analysis is made by using Computational Fluid Dynamics. In this a compromise between the computer time and accuracy of the analysis is made. The various parameters set in analysis are given below:

Thermal modelling

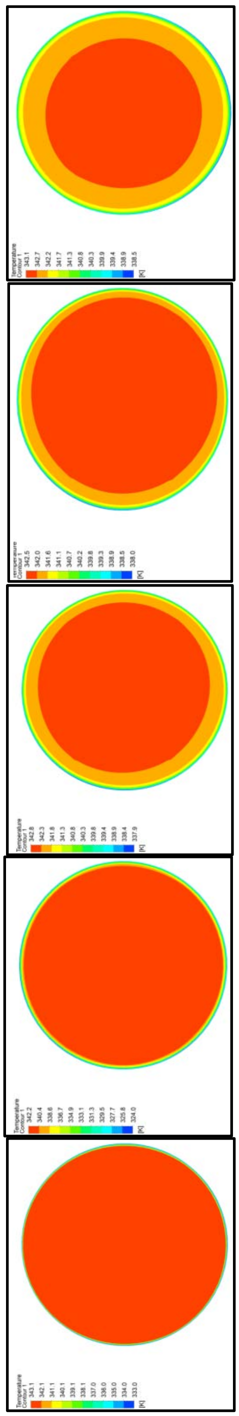
- Analysis type - Thermal h-method.
- Steady state or Transient State.

- Properties of the material
- Objective of analysis- to find out the temperature distribution in a tube at various cross sections for different design when the process of shell and tube is done.

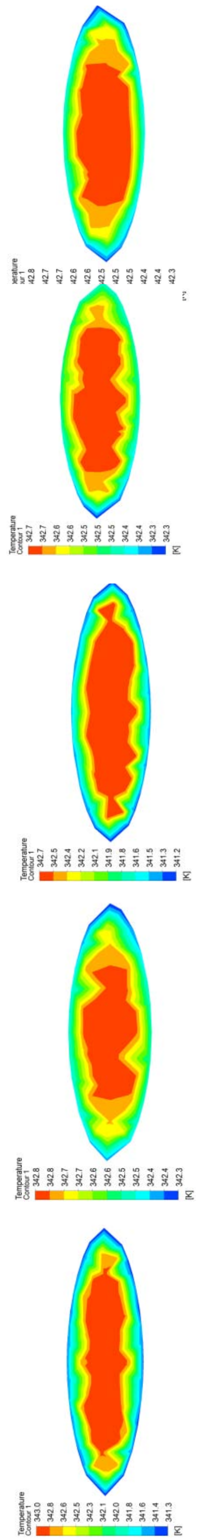
a) CFD-Results of Case-I

Mass flow rate: 0.14 kg/s

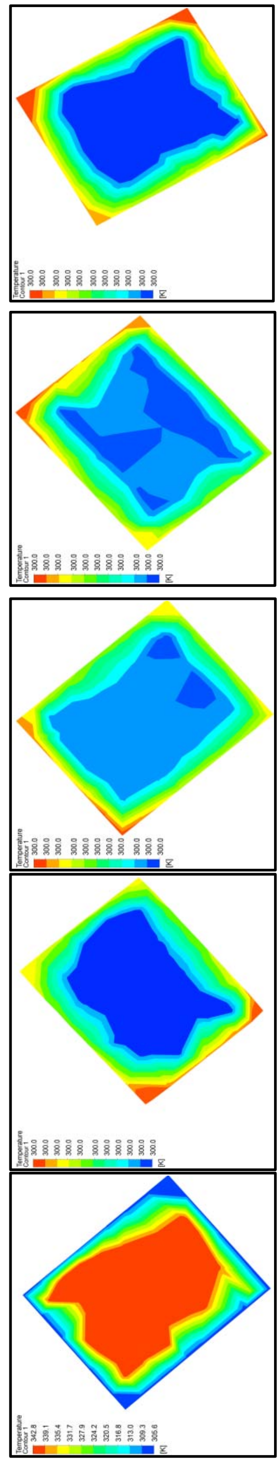
Temperature Contours



i. For Circular Tube



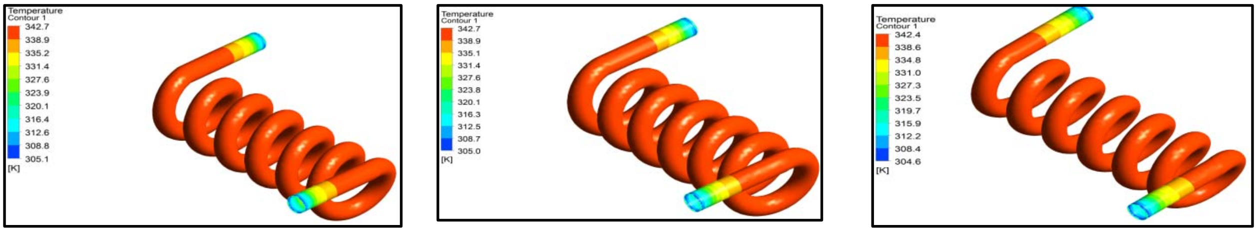
ii. Elliptical Tube



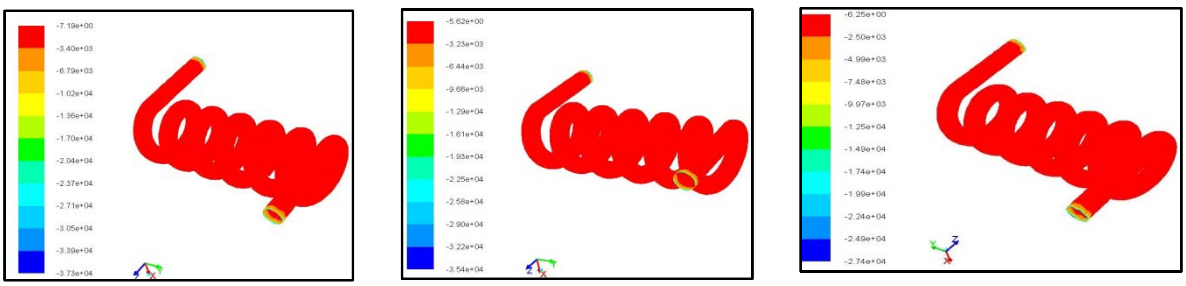
iii. Twisted Tube

iv. *Coil Tube: (For three planes)*

a. *Temperature Contours*

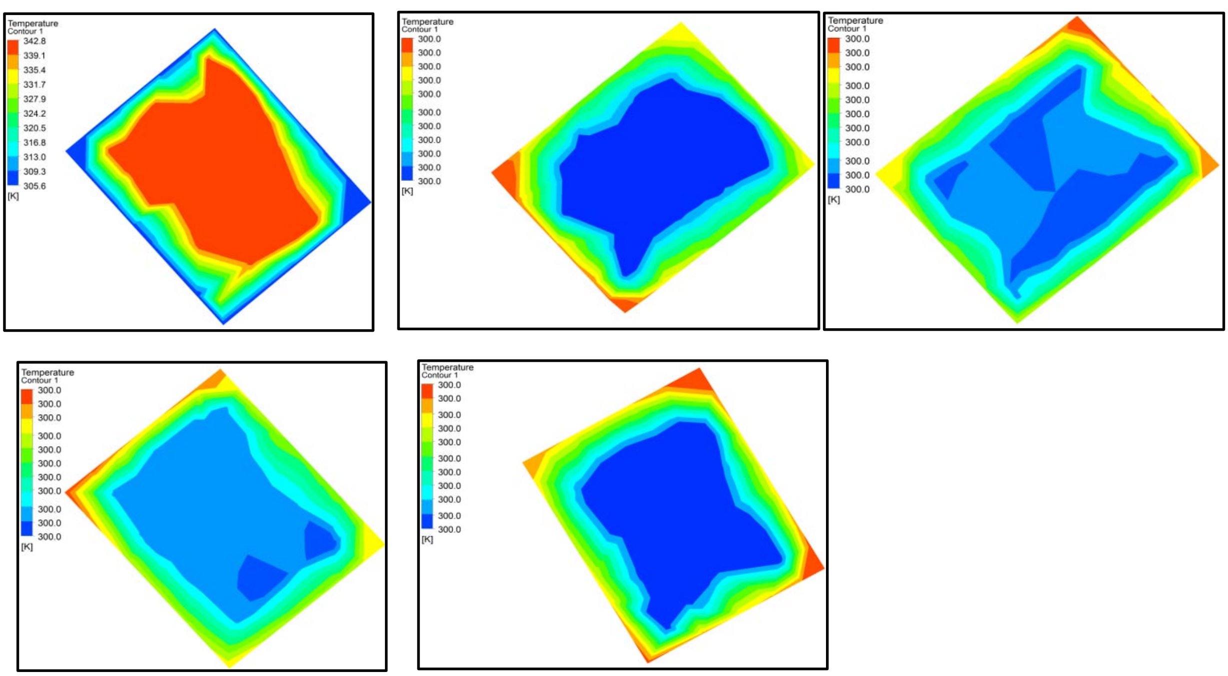


b. *h-Contours for inner wall*



b) *CFD-Results of Case-II(Al_2O_3 as a Nano fluid)*

We have focused only on twisted type tube as in above sequence of calculations we are getting high heat transfer rate and high effectiveness by calculation.



In above colourful diagram, if we compare d the twisted tube temperature contours with water as base fluid, an CFD analyst may observe that for 4^{th} and 5^{th} plane we are getting blue colour contours as compared to case 1, which directly shows the temperature gradient in above case is high along with effectiveness.

VII. Conclusion

This study shows the design and thermal analysis of different tubes. Experimentally, same designs are made and results are evaluated. With relate to same design tubes are thermally analysed in ANSYS software and compared both the results. After comparing the result for both water-water(Case-I) and water-Al2O3(Case-II) for four different tubes we are in conclusion that twisted type of tube is giving high heat transfer coefficient as compared to other i.e 1.14 more. Along with effectiveness, twisted tube is at higher side by 1.17.So according to my research one should go for twisted tube.

However, a good understanding of the underlying principles of exchanger design is needed to use this software effectively. The possibility to increase in these characteristics using the latest technology and various methods has raised application range of these designs. Modified design tubes are having great applications due to their large heat transfer area and high heat transfer coefficients. They are used in many industrial processes like waste water treatment, refrigeration, wine and beer making, petroleum refining.

References Références Referencias

1. Kotcherla Sriharsha, Venkata Ramesh Mamilla, 'Strength Analysis of Tube to Tube Sheet Joint in Shell and Tube Heat Exchanger', IJSETR Volume 1, Issue 4, October 2012.
2. Haran, Ravindra Reddy, 'Thermal Analysis of Shell and Tube Heat Ex-Changer Using C and Ansys', (IJCTT) – volume 4 Issue 7–July 2013.
3. Effectively Design Shell-and-Tube Heat Exchangers, CHEMICAL ENGINEERING PROGRESS FEBRUARY 1998.
4. Paresh Patel, Amiteshpaul, 'Thermal Analysis Of Tubular Heat Exchanger By Using Ansys', (IJERT) Vol. 1 Issue 8, October – 2012.
5. Vikil D. Malwe M. B. Mawale, 'Thermal Analysis of Heat Transferring Components in the Power Plant - A Review, (IJERT) Vol. 2 Issue 1, January- 2013 ISSN: 2278-0181.
6. TEMA, 1988 Standards of the Tubular Exchanger Manufacturers' Association, New York 7th ed.
7. Butterworth, D., Guy, A. R., and Welkey, J. J., Design and Application of Twisted Tube Heat Exchangers.
8. Small, W. M., and Young, R. K. 1979 Heat Transfer Engineering, Vol.1.
9. Paresh Patel, Amiteshpaul, "Thermal Analysis Of Tubular Heat Exchanger By Using Ansys", Proc. IJERT,Vol. 1, Issue 8, October 2012.
10. Gentry, C. C., Chem. Engng. Progress, Vol. 86, No. 7 pp 48-57.