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HEAT TRANSFER ENHANCEMENT IN A DOUBLE PIPE HEAT EXCHANGER USING CFD

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Abstract - ***Higher rate of heat transfer and higher thermal efficiency are the main goals to improve the efficiency of heat exchanger. The present study investigates the effect of internal aluminium baffles on heat transfer enhancement and pressure drop in counter flow Double Pipe Heat Exchanger (DPHE) using computational fluid dynamic analysis (CFD). The baffles were taken in the form of semicircular and quarter-circular geometries arranged on inner pipe of DPHE. Heat transfer rate, overall heat transfer coefficient (HTC) and pressure drop are determined for fully developed condition for several Reynolds numbers based on the pipe diameter and flow mean velocity with water as working fluid. Comparative study were employed for heat exchanger without baffles and inner pipe equipped with semicircular and quarter-circular baffles, parameters such as total residence time, pressure drops, overall HTC and Heat transfer rate are investigated. At similar condition, the heat exchanger equipped with quarter-circular baffles on outer surface of inner pipe offered more heat transfer rate than heat exchanger equipped with semicircular baffles as well as heat exchanger without baffles as they stimulate more consistent turbulence inside annulus. This unveils that it is possible to derive compromise between enhanced heat transfer and optimum pressure drop by selecting the baffles with proper geometry.***

Key Words: *Heat exchanger, baffles, heat transfer enhancement, CFD, heat transfer coefficient, pressure drop, Reynolds number.*

1. INTRODUCTION

Heat exchanger is a device to facilitate to exchange heat between two fluids without mixing at different temperature. In heat exchanger two modes of heat transfer occurs such as convection and conduction. Usually convection occurs in both working fluids and conduction through walls of heat exchanger which separates the fluids. In the analysis of heat transfer overall HTC, surface area and logarithmic mean temperature difference plays an important role. The overall HTC, surface area is optimized by designing a compact heat exchanger, therefore for high performance applications it is needed to design a compact heat exchanger. To enhance heat transfer rate through a heat exchanger, there are three operational methods such as active method, passive method, and compound method are used. Passive technique is used to modify flow channel by incorporating inserts or additional devices. It includes surface coating, nanoscale coating, hydrodynamic cavitations, nanofluid, turbulence promoters and mixing promoters while Active technique requires external power input for enhancement of heat transfer rate. It includes electro hydrodynamic, jets, ultrasonic waves, sprays, and synthetic jet heat transfer and high amplitude vibratory motion. Compound technique is combination of both active and passive technique. Among them, utilising nanofluid, inserting fluid tabulators and roughening the heat exchanger surface these three passive techniques are effectively used for enhancing the heat transfer rate in heat exchanger.

The authors referred for this investigation of heat transfer enhancement in DPHE. It is found that, applications such as food and beverage industries require big instrumentation, so it has large mass flow rate as well as length to lower the process fluid temperature.

In present study the heat transfer enhancement is carried out through a DPHE by using computational fluid dynamics using different types of baffles such as Semi-circular and Quarter-circular baffles arranged on inner pipe surface which contains cold process fluid i.e. water. These baffles are arranged in such a manner that increases retention time of fluid, pressure drop and turbulence inside the annulus which contains hot process fluid i.e. water. Overall analysis is carried out by considering the system (DPHE) in a steady state condition.

Researchers are making sincere efforts to find out suitable alternatives for heat exchangers with different geometry and varying parameters which effects on performance of heat exchanger. Some of the attempts made by various researchers to increase heat transfer rate and decrease in pressure drop are listed below:

Saad A.EL. Sayed, Sayed A.EL Sayed and Mohamad M. Saadoun [1] Conducted experiment to enhance heat transfer by determining the detailed module by module pressure drop and HTC of turbulence flow inside a circular tube provided with longitudinal fin arranged in inline and continuous or staggered manner with number of fins (N =

6 and 12) and length equal to tube diameter (L = D = 30 mm).

P.Eiamsa-ard, N.Piriyarungroj, C.Thianpong, S.Eiamsa-ard [2] carried out experiment on concentric heat exchanger by using twisted tape geometries such as regularly-spaced twisted tape (RS-TT) with two different twist ratios (y = p/w = 6.0 and 8.0) and three space ratios (s = S/P = 1.0, 2.0 and 3.0), also they studied numerical solution for understanding physical behaviour of fluid flow, fluid temperature, and local Nusselt number characteristics of tube fitted with regularly spaced twisted, solved by simple technique with RNG k-ε turbulence model. Finally from that above investigations the heat transfer, friction factor and thermal performance factor enhanced with fully twisted tape and poor by use of different twist and space ratios and it induce more consistent swirling flow and turbulence.

M. Hatami n, D.D.Ganji, M.Gorji-Bandpy [3] studied numerical analysis of finned type heat exchanger for IC engine exhaust waste heat recovery. In this thesis they modelled heat exchanger numerically which are previously used by researchers for exhaust waste recovery from IC engines. They investigate two cases with the help of RNG k-ε and SST k-ω viscous model Case-1 Simple DPHE of length 70 cm with 12 cm inlet and 14 cm outlet diameter, water as a coolant is installed at exhaust of IC engine. In this case mass flow rate of water is 10-100 g/s and 30-60 g/s exhaust gas ranges in different engine operating condition, also temperature range for water is 10-25 and for exhaust gas 100-220 degree centigrade with different load and speeds. Case-2 is optimised design of finned type DPHE with mixture of 50% water and 50% ethylene glycol circulated around tube as a coolant to recover heat from exhaust gas which is flowing through pipe. It is analysed by using different engine speed and load.

N. K. Chavda1, Jay R. Patel, Hardik H. Patel, Atul P. Parmar [4] experimentation is carried out on DPHE by using 0.001% to 0.01% volume of nano particle concentration of Aluminium oxide in base fluid as water on cold side and water on hot side. They studied in this experiment to determine the effect of various concentration of aluminium oxide mixed with water as base fluid on overall HTC of DPHE for parallel and counter flow arrangement. From that experimentation they conclude that overall HTC increases with increase in volume concentration of nanoparticles and volume concentration of water up to 0.008%.

Snehal S. Pachegaonkar, Santosh G. Taji, Narayan Sane [5] studied heat transfer and pressure drop characteristic by experimentation done on DPHE with twisted tape inserted in annulus. The experimentation is performed on three set-up first plane DPHE used as reference and other two with different twist angle of twisted tape. The overall length, ID, OD of the heat exchanger tube 1500 mm, 16.5 mm and 21.5 mm respectively, ID and OD of outer pipe 42 mm and 48.5 mm. The M.S. twisted tape of length 1500 mm, width 10 mm and thickness 1.8 mm with varying twist ratios (y=6.7, y=10.7) and twist angle of 45^0 and 60^0 is wound by brazing on inner pipe. They compare both results and find out HTC and pressure drop in pipe with twisted tape is higher than that of plane heat exchanger at constant flow rate basis, constant pumping power, hot water flows though inner pipe and cold water flows through annulus.

H. Kahalerras, N. Targui [6] analysed DPHE numerically by attaching porous fin on the external surface of the inner pipe. In this investigation Brinkman-Forchheimer used extended Darcy model for solving differential equations subjected to numerical boundary conditions by using finite volume method. They use large range Darcy number ($10^{-6} \le Da \le 10^{-1}$), ratio of thermal conductivity ($1 \le R_k \le 100$), height of porous fin ($0 \le H_p \le 1$) and spacing ($0 \le L_f \le 39$) for numerical calculations and effect of these parameter are used to look properties of porous fin which are most important for optimal heat transfer enhancement in heat exchanger. They shows that in this investigation the flow pattern and geometry of porous fin are two important factors that directly effects on heat transfer rate, so that need to improve these factor by their thermo physical properties, permeability, spacing and height. Performance analysis shows that net energy gain is achieved by increasing ratio of thermal conductivity, Darcy number and height of porous fin.

N. Sahiti, F. Durst, A. Dewan [7] studied heat transfer enhancement by selecting optimal flow arrangement within heat exchanger in order to obtain maximum advantage apart from utilization of various surface element. In this experimental investigation heat transfer surfaces built with pin type element and inner one of copper and outer one of stainless steel. Mesh of copper wire providing pin like fin of diameter 0.7 mm, length 28.2 mm wrapped around copper pipe of pitch length 3.5 mm in stream wise direction, 6.5 mm in span-wise direction and mean diameter of 70.8 mm in staggered manner. This total investigation is carried out by supplying fluid with various flow rates through wind tunnel and arrangement of flow patterns such as parallel, counter and cross flow and concluded that heat transfer enhancement is depends on arrangement of pin fin, selection of pin height to pin diameter ratio and pin fin efficiency.

Sumit S. Kalmegh, Pawan A. Sawerkar, Pramod R. Pachghare [8] studied heat transfer augmentation is carried out in tube by using recent techniques. This recent techniques are useful to designer while implementing in heat exchanger. From that overall study they conclude that the passive technique is best technique used to increase heat transfer rate and it is easily implement in recent work without any external power source.

2. METHODOLOGY

2.1 Design of DPHE

DPHE design is normally based on correlations, among these; the Kern method is the most commonly used correlation. A Kern method is mostly used for preliminary design and provides conservative results. Table-1 shows problem description for present work. From Table-1 the DPHE is designed by using Kern method [11] and illustrated all design calculations such as mass flow rate, temperature, diameter, Reynolds number, heat transfer coefficient and length of DPHE in Table-2.

Table -1: Problem description

	Hot Side	Cold Side
Fluid	Water	Water
Mass flow rate	453.5920 kg/hr	907.1840 kg/hr
Fouling factor	0.001	0.001
Temperature	Inlet(T_1) = 82.22^{0}C Outlet(T_2) = 73.88^{0}C	Inlet(t_1) = 32.22^{0}C Outlet(t_2) = --^{0}C
IPS 3- by 2-inch	Area = 0.0018 m^2	Area = 0.0021 m^2

Table -2: Problem solution

Heat exchange length L = 1.905 m Hydrodynamic length L_h= 0.52425 m Overall HTC U_d= 275.6239 W/(m^2°C)		
	HOT SIDE (Annulus)	**COLD SIDE (Inner Pipe)**
Mass flow rate	m_h = 453.5920 kg/hr	m_c = 907.1840 kg/hr
Temperature	Inlet = 82.220°C Outlet= 73.880°C	Inlet = 32.220°C Outlet = 36.380°C
Diameter	D_1 = 0.06035 m D_2 = 0.07772 m	D = 0.052426 m
Reynolds number	R_e = 7400	R_e = 7800
Heat transfer coefficient	h_0=560.7924 $\frac{W}{m^2 °C}$	h_{io}=669.9658 $\frac{W}{m^2 °C}$
Velocity	V_h = 0.0583 m/s	V_c = 0.1167 m/s

The actual instrument parameters solving with the help of Computational Fluid Dynamics requires large computational time. Because of computational time limitation for this analysis we tend to reduced length of the heat exchanger. This is often done by scaling down temperatures similarly as mass flow rate.

2.2 DPHE Geometry and Baffle arrangement

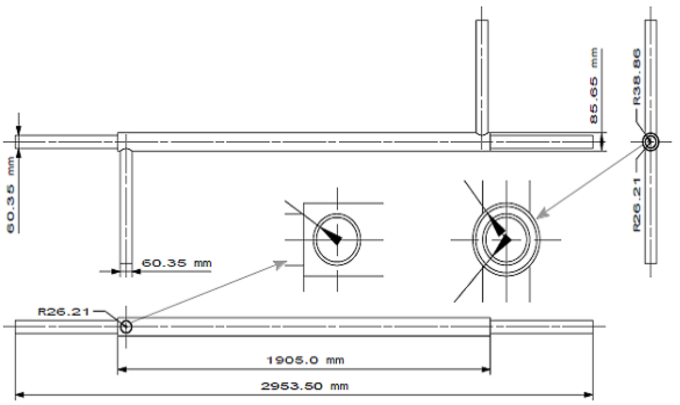
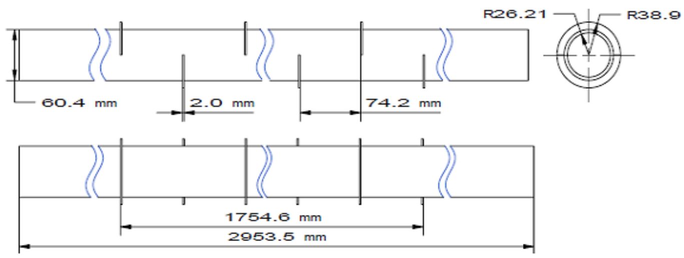
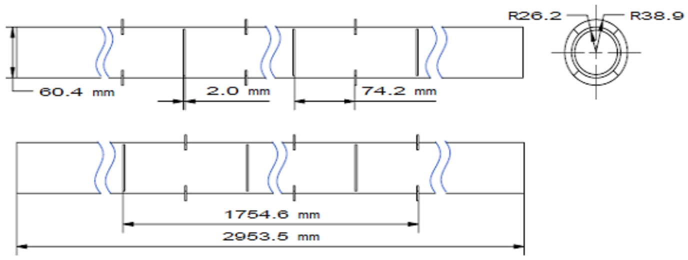


Fig-1: DPHE geometry

To enhance heat transfer rate in DPHE as shown in fig-1 some modification is required. This modification is done by inserting semi-circular and quarter-circular baffles of same surface area and distinct arrangement on surface of inner pipe shown in fig-2.



(a)



(b)

Fig-2: Inner pipe (a) Semi-circular baffles
(b) Quarter-circular baffles

2.2 Computational fluid dynamics procedure

2.2.1 Computational fluid domain

The computational domain of a DPHE designed with the help of geometry parameters which is calculated in section 2.1 and listed in table-2. The whole computational domain is bounded with inner pipe, annulus as solid domain and fluid flowing inside as liquid domain. The schematic diagram of computational fluid domain is as shown in fig-3

Fig-3: DPHE computational fluid domain

2.2.2 Grid generation

The Three-Dimensional model is divided into four components such as inner pipe, annulus, cold fluid and hot fluid, which is in the form of solid and liquid domain. The inner pipe and annulus which are included in solid domain and remaining two includes in liquid domain. These all four domains are decreased by using tetrahedral volumetric mesh element which is accurate and requires less computational effort. Fine mesh size are selected, in order to capture both thermal and velocity boundary layer with nodes of 64332 and 231004 elements shown in table-3.

Table-3: Nodes and Elements

Domain	Nodes	Elements
Cold Pipe	16500	49275
Cold Fluid	18139	81609
Hot Pipe	13486	40169
Hot Fluid	16207	59951
All Domains	64332	231004

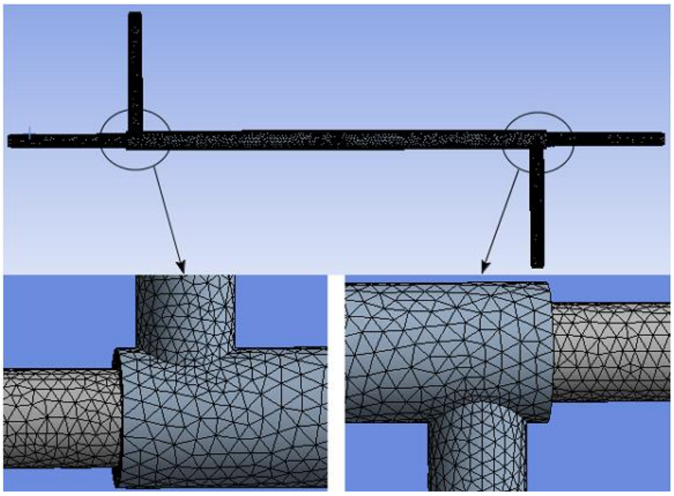


Fig-4: Discretized computational domain of DPHE with volumetric tetrahedral mesh

2.2.3 Mathematical foundation

The numerical model for fluid flow and heat transfer in DPHE was developed under following assumption.

- Steady three-dimensional fluid flow and heat transfer.
- The flow and heat transfer in DPHE are fully developed periodic.
- Fluid flow is turbulence and incompressible.
- Constant fluid properties.
- Fluid is in single phase.
- Body forces, viscous dissipation and radiation heat transfer are negligible.
- Outer wall of annulus is adiabatic.

On the basis of above assumptions, the fluid domain of DPHE is governed by continuity equation, the Navier-Stokes equations and energy equations.

The turbulence flows having characteristics, some characteristics are different from laminar flow. To Study of characteristics of flow, computational fluid dynamic contains turbulence models. In this present study to express the turbulence stresses and heat flux quantities of related physical phenomenon, the k-ε model is employed. The k-ε model having two equations, one is turbulent kinetic energy denoted as (k), other is rate of dissipation denoted as (ε). It is enforced in most general purpose CFD code and very popular in industrial applications due to its great convergence rate and relatively low memory requirement.

2.2.4 Setting up boundary conditions and solving

In this present study, the boundary conditions are specified on computational domain of DPHE as shown in fig-4 the walls of double pipe heat exchanger are set as no-slip condition. The inlet boundary condition of DPHE are defined as Cold fluid of 0.116 m/s velocity at 305.22K flowing though inner pipe and hot fluid of 0.0583 m/s velocity at 355.22K of flowing though annulus in counter clockwise direction. The outlet of both annulus and inner pipe are kept at atmospheric pressure.

Table-4: Boundary conditions

Quantities	Boundary Conditions	
Working fluid	Water	
Inner pipe (cold fluid)	Cold inlet	
	Velocity	Temperature
	0.1167 m/s	305.22K
Annulus (Hot fluid)	Hot inlet	
	Velocity	Temperature
	0.0583 m/s	355.22K
Heat flux	Zero w/m²	
Slip	No slip	

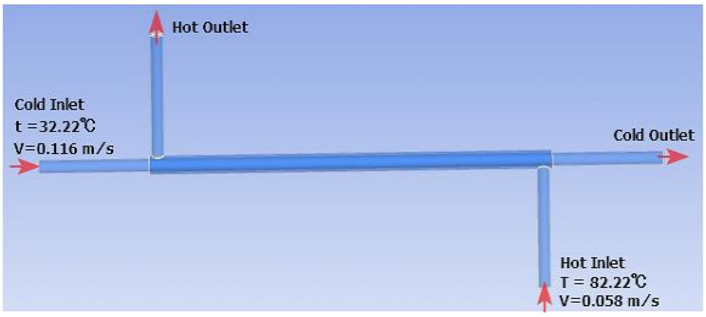


Fig-5: Boundary conditions

2.2.5 Post processing / analysing the result

The variables in DPHE such as temperature, velocity, pressure and heat transfer without baffles and with baffles are presented in the form of vectors and contours which extracted from post processing tool are discussed in following chapter.

3. RESULTS AND DISCUSSIONS

In this section, the heat transfer and flow characteristics of DPHE with and without baffles on the outer surface of inner tube are reported and compared with plane DPHE i.e. without baffles plates.

3.1 Verification of CFD facility

To provide substantiation of computational fluid dynamics facility, the benchmark test between the results of the present plane DPHE and those obtained from standard correlation as well as theoretical calculations of heat exchanger was performed. The standard correlations include Dittus-Boelter for fully developed turbulence flow in circular tube, as stated below.

Dittus-Boelter Correlation

$$Nu = 0.023R_e^{0.8}P_r^{0.3} \tag{3.1}$$

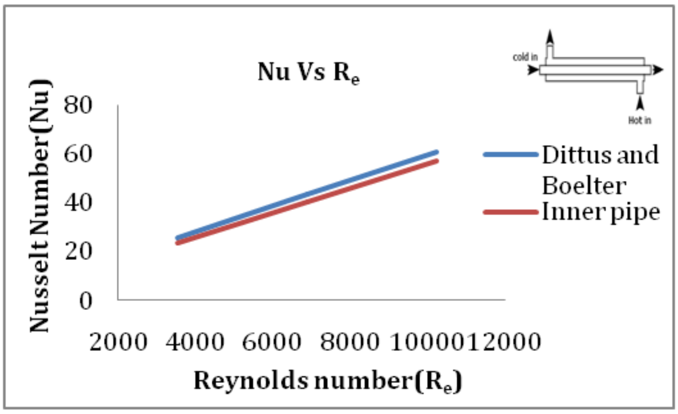


Fig-6: Data verification of Nusselt number for inner tube

The comparison between the computational fluid dynamic results of present work and those obtained from theoretical calculations as well as standard correlations are shown in table 4.1 and fig. 4.1. From table and figure it is observed that the deviation of hot and cold outlet temperature and Nusselt number obtained from computational fluid dynamic were within ±0.26, ±0.14 compared with theoretical results as well as ±9.237 compared with Dittus-Boelter correlation respectively.

3.2 Temperature distribution

The following contour map shows temperature distribution in DPHE across the cross section at heat exchanger including baffles and without baffles along the length by keeping 0.0583 m/s hot and 0.116 m/s cold fluid velocity. It will give an idea about variation of temperature along cold and hot side by keeping constant inlet temperature for both hot and cold side. These variations of temperature distinguish three geometries and elaborate with the help legend view on left hand side of contour map.

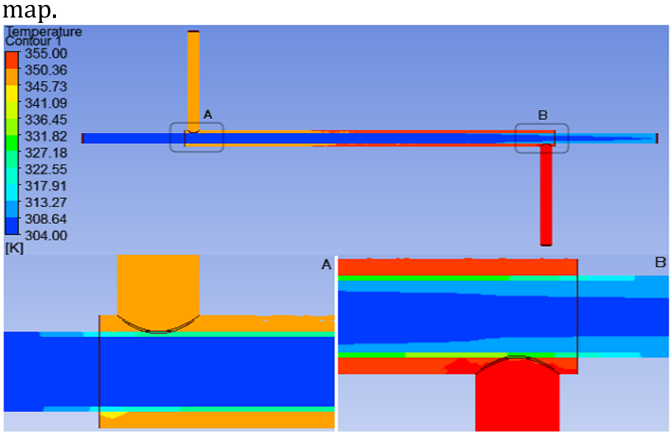


Fig-7: Temperature distribution for DPHE without baffles

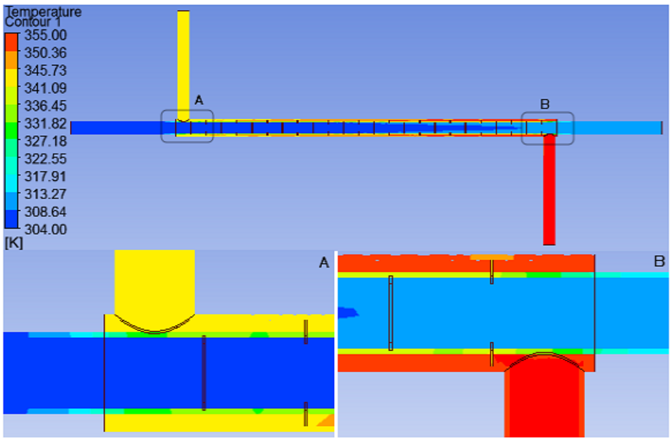


Fig-8: Temperature distribution for DPHE with QUARTER-CIRCULAR baffles

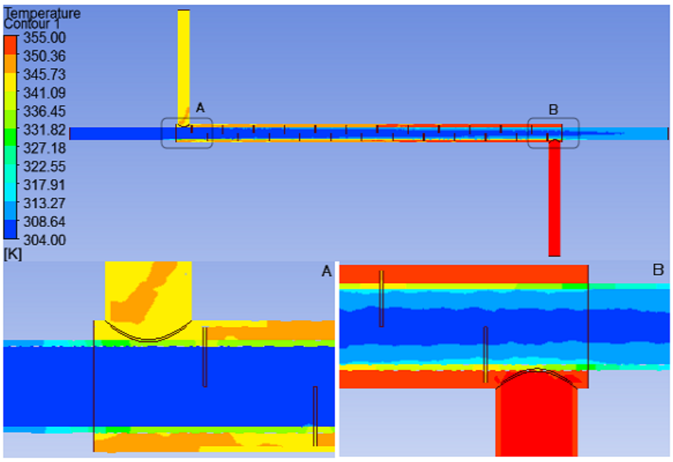


Fig-9: Temperature distribution for DPHE with SEMI-CIRCULAR baffles

Fig-7-9: Variation of temperature along length of DPHE for different baffles at $V_h = 0.0583$ m/s and $V_c = 0.1167$ m/s

From above Fig-7 to 9, it has been seen that the lower outlet temperature of hot fluid inside the annulus due to inserting semicircular and quarter-circular baffles inside annulus. It is obvious that by decreasing the hot fluid temperature, cold fluid outlet temperature increased due to increasing retention time, generating turbulence inside annulus.

3.2.1 Comparison of hot fluid outlet temperature for heat exchanger without baffles, with quarter-circular and semi-circular baffles.

3.2.1.1 Hot fluid velocity varied while cold fluid velocity constant

Fig-10 and 11 show comparison of hot fluid outlet temperature against velocity of hot & cold fluid for a DPHE without baffles, semi-circular baffles and quarter-circular baffles placed on outside surface of inner pipe. It is noticed

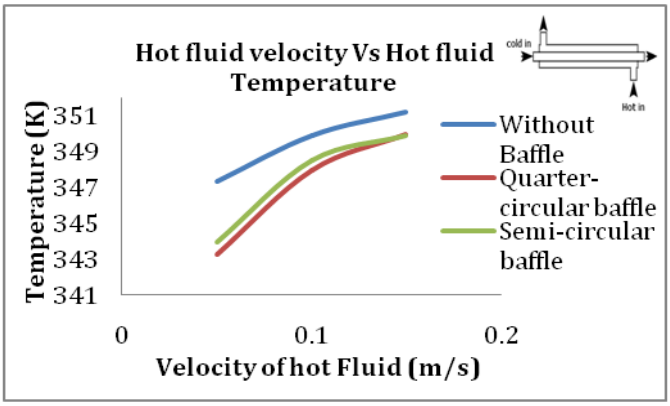


Fig-10: Effect of hot fluid velocity on hot fluid outlet temperature

3.2.1.2 Cold fluid velocity varied while hot fluid velocity constant

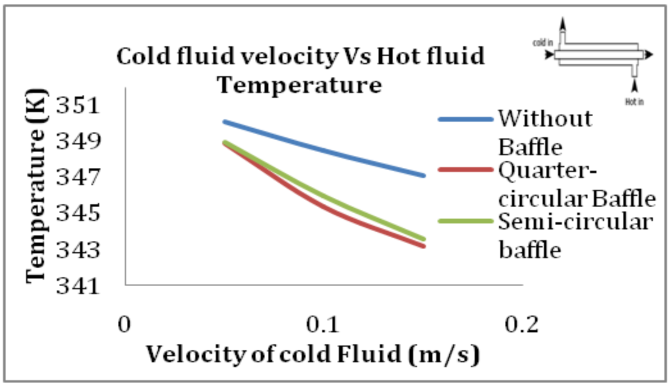


Fig-11: Effect of cold fluid velocity on hot fluid outlet temperature

that for all tested models, the outlet temperature of hot fluid decreases for heat exchanger without baffles to semi-circular and quarter-circular baffles at lower velocity of hot fluid and higher velocity of cold fluid. Also it has been observed that a much variations in the hot outlet temperature for without baffles and with baffles on the account of increased area available for friction, number of leading and trailing edges and also retention time increased by inserting 24 baffles of same surface area (0.046894 m^2), dissimilar geometry and arrangement with 74.2 mm pitch.

3.2.2 Comparison of cold fluid outlet temperature for heat exchanger without baffle, with quarter-circular and semi-circular baffles.

3.2.2.1 Hot fluid velocity varied while cold fluid velocity constant

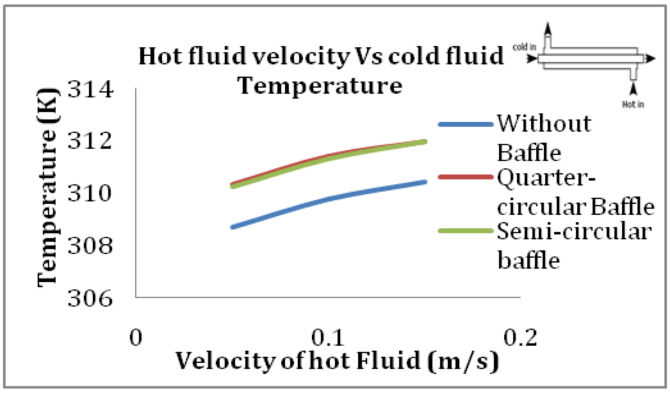


Fig-12: Effect of hot fluid velocity on cold fluid outlet temperature

3.2.2.2 Cold fluid velocity varied while hot fluid velocity constant

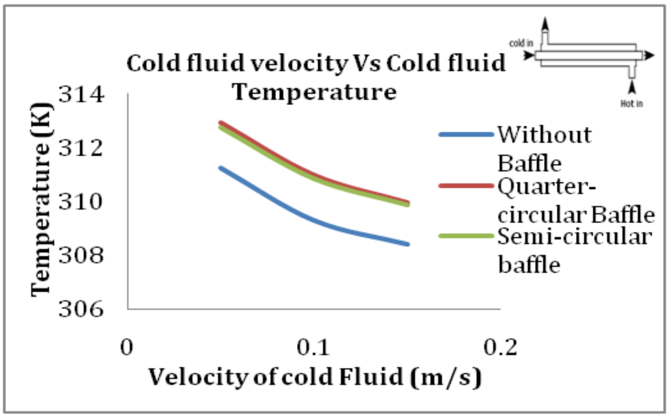


Fig-13: Effect of cold fluid velocity on cold fluid outlet temperature

Fig-12 and 13 illustrates effect of hot and cold velocity on cold outlet temperature by inserting two types of baffles. Higher temperature values for cold fluid are obtained by varying the velocity of hot fluid and keeping cold fluid constant with semi-circular and quarter-circular baffles.

3.3 Pressure distribution

The following figure shows pressure distribution across the cross-section of DPHE with the help of contour map. This contour map shows variation of pressure along length of the heat exchanger for all three cases. From figure-12 it is observed that low pressure at hot side inlet and gradually decreasing along the length at 0.0583 m/s velocity whereas high pressure at hot inlet in case of DPHE which has semicircular and quarter-circular baffles inside annulus observed in figure-13 and 14. The high pressure created at hot inlet due to baffles inside the annulus. This high pressure decreases alternatively on account of sudden variation of velocities across the baffles. The higher velocities across the baffles create pressure drop and disturb the entire flow field that leads to higher heat transfer rate.

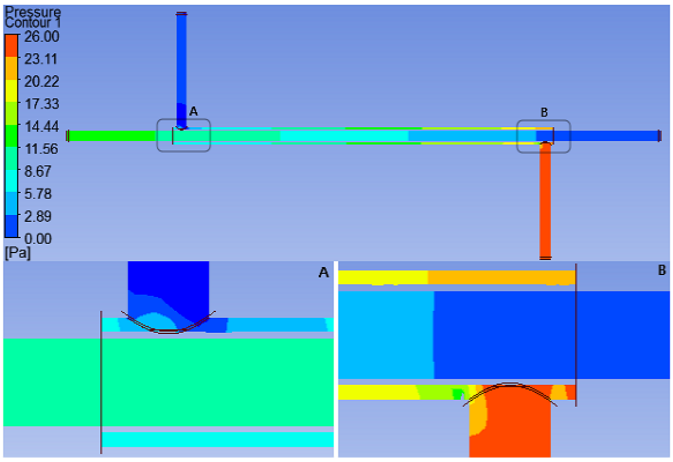


Fig-14: Pressure distribution for DPHE without Baffles

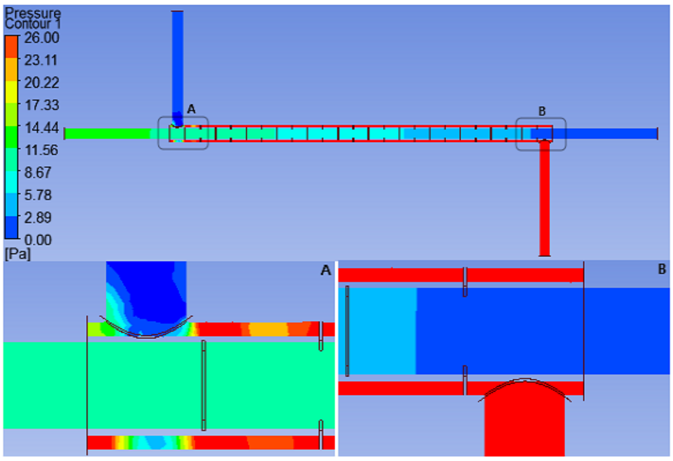


Fig-15: Pressure distribution for DPHE with QUARTER-CIRCULAR Baffles

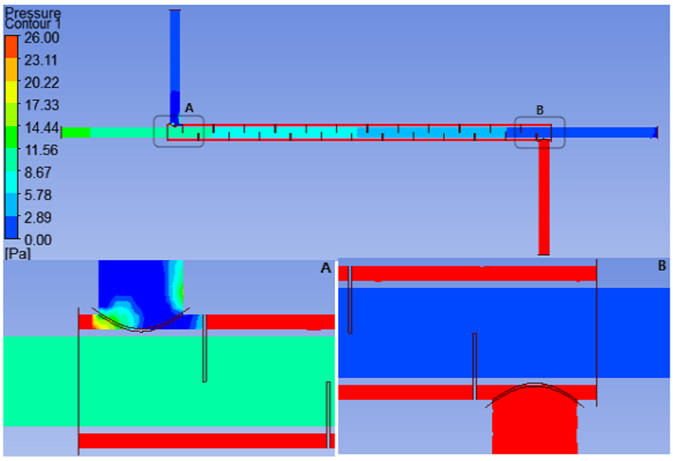


Fig-16: Pressure distribution for DPHE with SEMICIRCULAR Baffles

Fig-14 -16 Variation of pressure along length of DPHE for different baffles at $V_h = 0.0583$ m/s and $V_c = 0.1167$ m/s

3.3.1 Comparison of pressure drop for heat exchanger without baffles, with quarter-circular and semi-circular baffles.

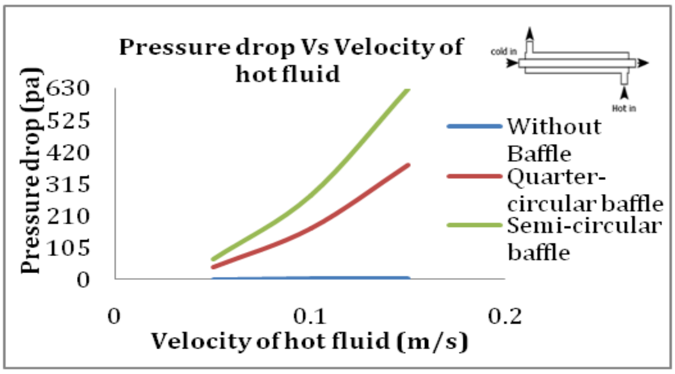
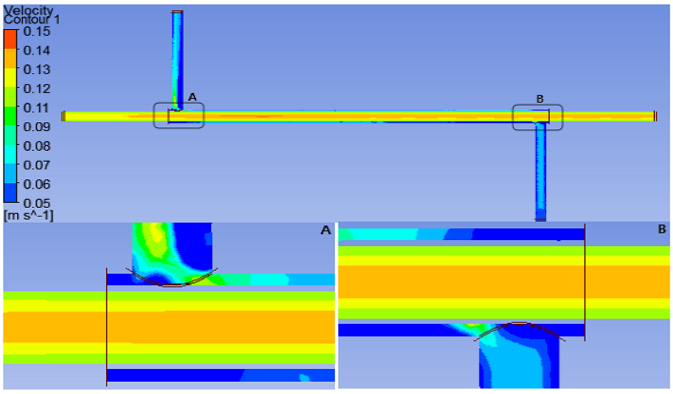


Fig-17: Effect of hot fluid velocity on hot side pressure drop

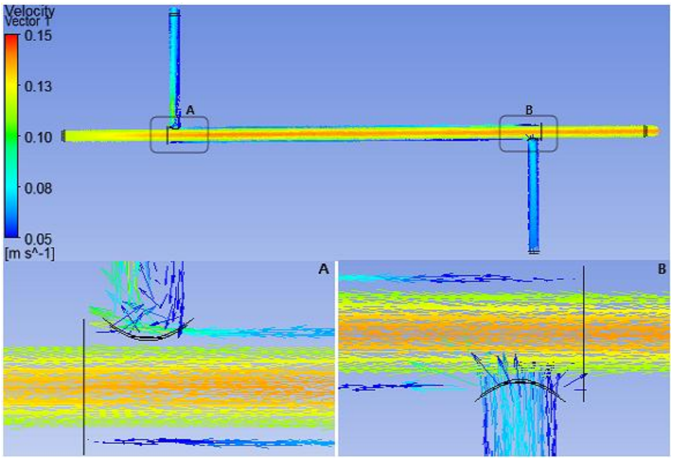
Fig-15 shows pressure drop inside annulus (hot side) of the concentric pipe heat exchanger by incorporating semi-circular and quarter-circular baffles against velocity of hot fluid. Pressure drop is increasing with increase in velocity of hot fluid for baffles have quarter-circular and semicircular cross-section. Heat exchanger without baffles there is a low pressure drop whereas higher pressure drop found in heat exchanger having semicircular baffles compared to quarter-circular baffles.

3.4 Velocity distribution

The following figures show velocity profile with the help of contours and vectors to understand flow distribution across the cross-section of DPHE. It is to be noticed from figure-16 to 18; the velocity profile varies along length from heat exchanger without baffles to heat exchanger with semicircular and quarter-circular baffles. The Higher velocity noticed in passage between two baffles in case of quarter-circular baffles due to staggered arrangement of baffles whereas lower in case of semicircular baffles. So, these higher velocities at the end of each baffle create more turbulence and better mixing of fluid for enhancement of heat transfer.

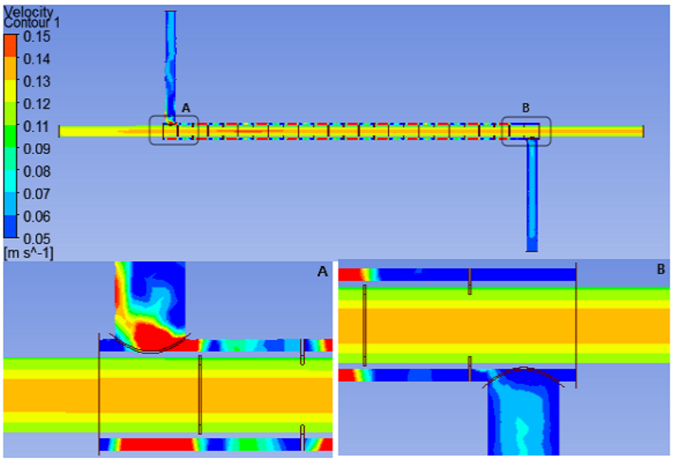


(a) Velocity contour

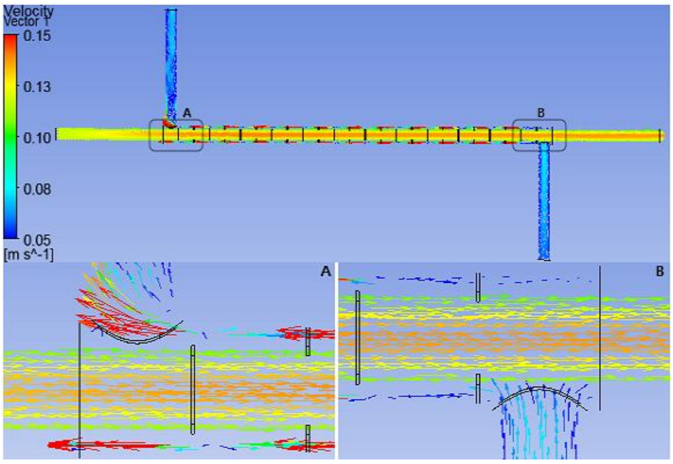


(b) Velocity vector

Fig-18: Velocity distribution for DPHE without Baffles

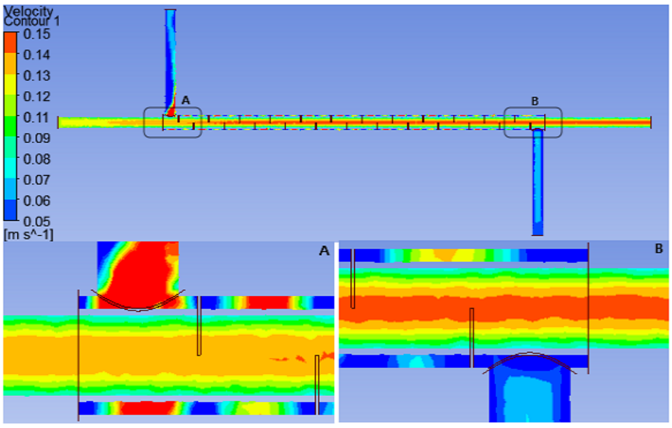


(a) Velocity contour

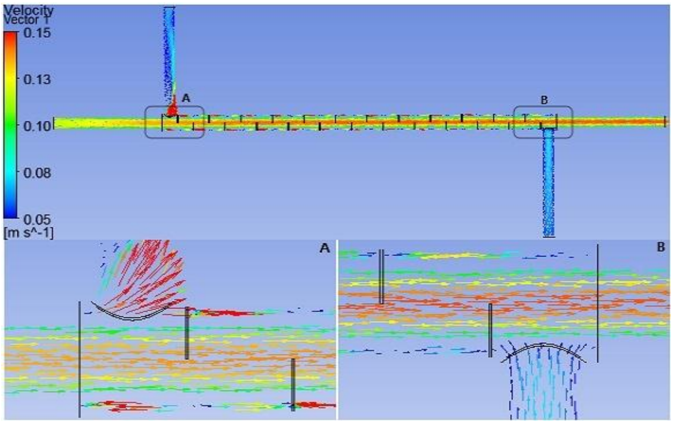


(b) Velocity vector

Fig-19: Velocity distribution for DPHE with QUARTER-CIRCULAR Baffles



(a) Velocity contour



(b) Velocity vector

Fig-20: Velocity distribution for DPHE with SEMICIRCULAR Baffles

Fig-18-20: Variation of velocity along length of DPHE for different baffles at $V_h = 0.0583\ m/s$ and $V_c = 0.1167\ m/s$

3.4.1 Comparison of Reynolds number along length for heat exchanger without baffles, with quarter-circular and semi-circular baffles

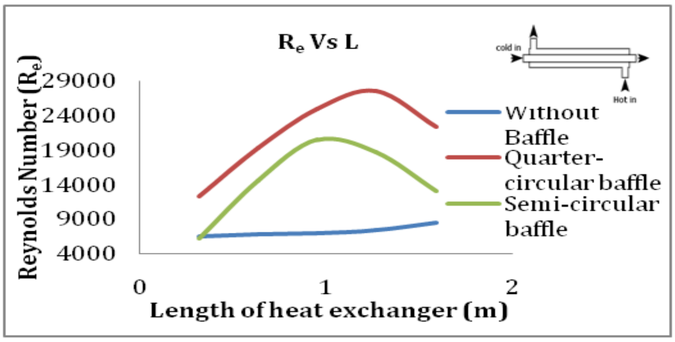


Fig-21: Variation of Reynolds number

Fig-21 shows variation of Reynolds number along length of heat exchanger for hot side by keeping inlet temperature of hot fluid as 0.0583m/s and demonstrates effect of Reynolds number on heat exchanger having semi-circular and quarter-circular baffles inside annulus. It has been observed that decrease in Reynolds number from hot side inlet to outlet due inserting baffles into flow channel whereas there is no variation in heat exchanger without baffles. As we know that for higher heat transfer through heat exchanger, it is required to change baffles arrangement for meeting higher frictional surface area, more retention time and high turbulence inside flow channel. In present study we observed variation of Reynolds number in three cases. From that observation it is noted that, high turbulence is generated which have quarter-circular baffles whereas low turbulence is observed which have semicircular baffles inside the annulus. This high and low generation of turbulence inside the heat exchanger is due their arrangement, geometry and number of baffles with same surface area. Therefore the selection of baffles is very important for enhancing heat transfer rate through DPHE.

3.5 Overall heat transfer coefficient

3.5.1 Comparison of overall HTC along length of heat exchanger

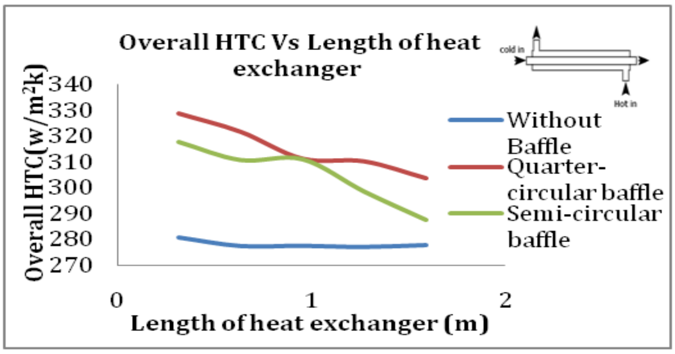


Fig-22: variation of overall HTC along length of DPHE

3.5.2 Comparison of overall HTC by varying cold fluid velocity

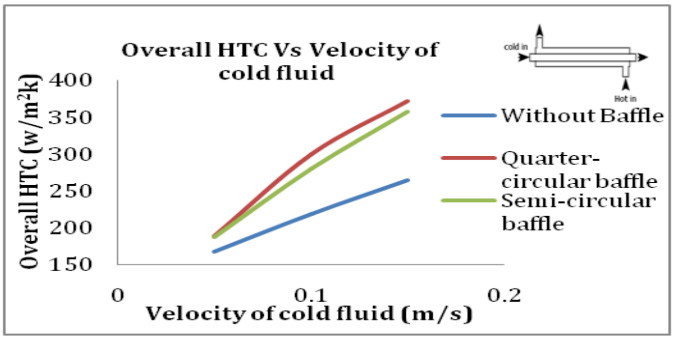


Fig-23: Effect of cold fluid velocity on overall HTC

Fig-22 shows variation of overall HTC along length of DPHE at 0.0583 m/s hot fluid velocity and 0.116 m/s cold fluid velocity and Fig-23 shows overall HTC against velocity of cold fluid by keeping hot velocity constant. It is observed that higher overall heat transfer rate obtained at high velocity of cold fluid. Further on comparing the values for heat exchanger without baffles, with semicircular and quarter-circular baffles, it has been seen that the overall HTC is higher for quarter-circular baffles than others at all cold fluid velocity. This is due to better mixing and creating more turbulence inside the flow channel. From figure the variations showed that mixing of fluid were induced due to presence of semi-circular and quarter-circular baffles. The low Reynolds number obtained by the use of semicircular baffles and it shows poorer generation of turbulence. Therefore it is seen that for low Reynolds number, the HTC shows poorer variations and thus lower heat transfer rate. On other side more consistent fluid mixing and high HTC due to higher turbulence present inside the annulus. From that above discussion one conflicting factor may be identified, which influence the variation of HTC inside the flow channel. This factor is resulting from baffles by baffle development of pattern of flow acceleration, shedding and impingement, which augment the heat transfer.

3.6 Comparison of Pipe material for Counter flow DPHE

3.6.1 Hot fluid velocity varied while cold fluid velocity constant

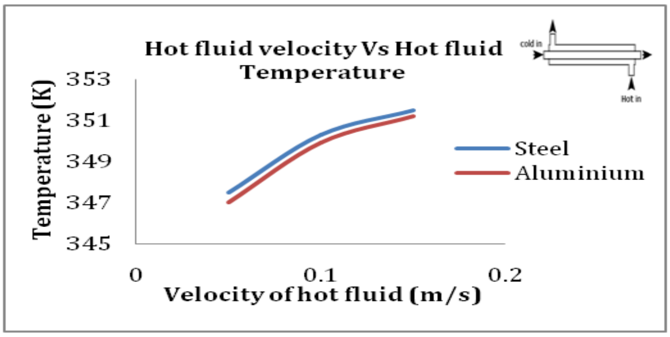


Fig-24: Effect of pipe material on hot fluid outlet temperature

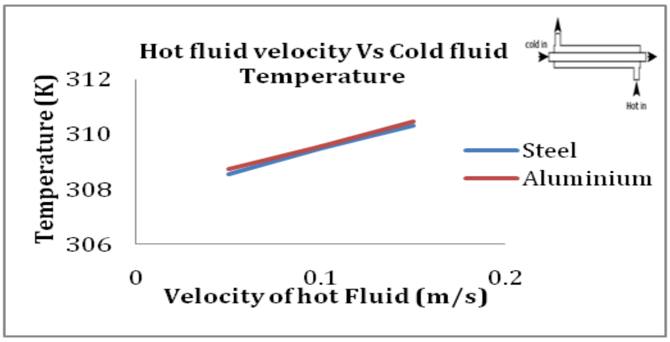


Fig-25: Effect of pipe material on cold fluid outlet temperature

3.6.2 Cold fluid velocity varied while hot fluid velocity constant

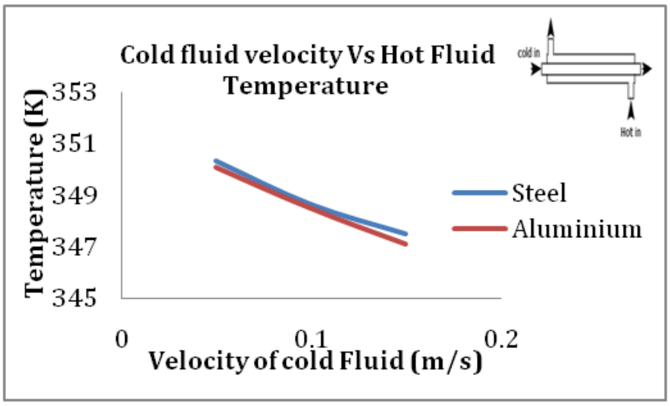


Fig-26: Effect of pipe material on hot fluid outlet temperature

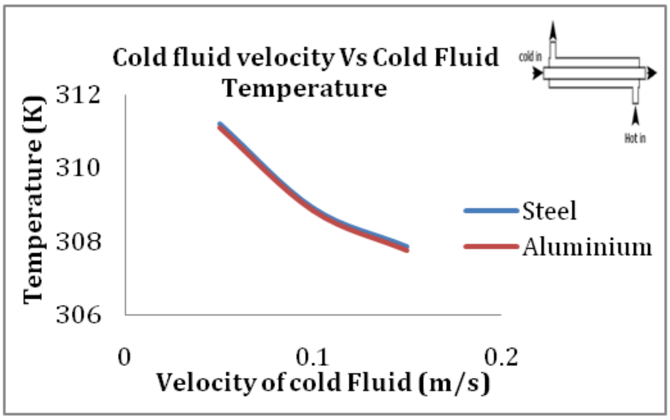


Fig-27: Effect of pipe material on Cold fluid outlet temperature

Fig-24 to 27 shows comparison of pipe materials for counter flow heat exchanger. This is represented with the help of cold and hot fluid outlet temperatures by varying hot and cold fluid velocities. From Fig-24 and Fig-26, it is observed that a slight variation occurs between two curves of hot outlet temperatures for all hot and cold velocities by utilising steel and aluminium materials whereas in Fig-25 and Fig-27 the curves of cold outlet temperatures for all cold velocities one curve extend over and cover a part of other curve. From above two conditions it can be say that there is no effect of material either change of material or not on hot and cold outlet temperature because of the all over analysis is carried out by using steady- state condition.

3.7 Effect of Pipe Thickness

Fig-28 and Fig-29 represents effect of pipe thickness on hot and cold outlet temperature. The analysis is carried out by varying thickness of pipe from 7.92 mm to 15.84 mm at 0.0583 m/s velocity of hot fluid and 0.116 m/s velocity of cold fluid.

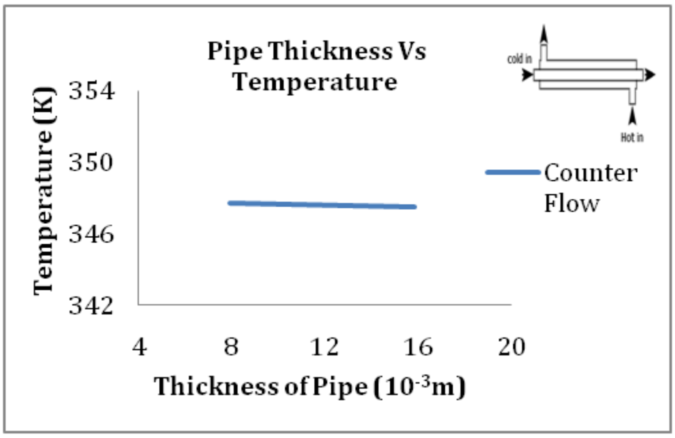


Fig-28: Effect of pipe thickness on hot fluid outlet temperature

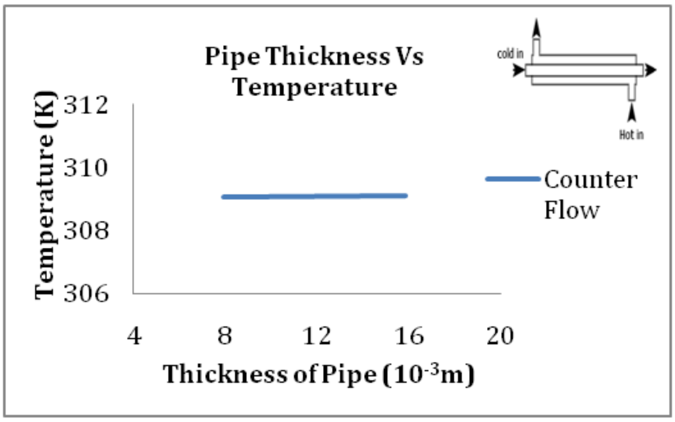


Fig-29: Effect of pipe thickness on cold fluid outlet temperature

From figure it is seen that the outlet temperature of cold and hot fluid are same at each thickness of pipe and shows flat curve parallel to x-axis. It is because of; the whole analysis of counter flow heat exchanger is carried out by assuming process is in steady state.

4. CONCLUSIONS

The heat transfer through DPHE with distinct arrangement of semicircular and quarter-circular baffles arrangement inside annulus is investigated using Computational Fluid Dynamic. The analysis is executed to examine detailed heat transfer characteristics and flow characteristics. As a result of present study, the following conclusions were derived:

- The analysis was carried out for a DPHE without baffles at 0.0583 m/s hot and 0.116 m/s cold velocities and was validated with analytical design. It was found that the temperature variation was$\leq$ 1%.
- Heat exchanger with quarter circular baffles arranged on outer surface of inner pipe resulted in an increase of heat transfer rate by 9.5% in comparison with no baffles. The surface area appears to have played an important role in the design of the DPHE.
- Quarter circular baffles placed in staggered arrangement induced better turbulence and resulted in 2.70 % more heat transfer rate as compared to semi-circular baffles.
- The performance of heat exchanger was increased by minimising hot fluid temperature and maximising cold fluid temperatures.
- The optimal heat transfer rate was achieved for quarter-circular baffles with lower pressure drop and higher turbulence at 0.0583 m/s velocity of hot fluid.
- The usage of different types of materials for DPHE will not make any impact on exit's hot and cold temperatures.

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