CFD Analysis of Heat Transfer in A Double Pipe Heat Exchanger Using Fluent

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ABSTRACT: Numerical analysis of 3-d incompressible flow is done for concentric tubular heat exchanger type of domain; this is basically water to water heat exchanger. Analysis is done for both parallel flow and counter flow with different mass flow rate and when we compare the efficiency, efficiency is higher for counter flow and less for the parallel flow because in counter flow we have highest heat transfer area than in parallel flow. Calculation are done for the cross cheq. Ansys Fluent is used for the analysis of double pipe heat exchanger or analysis software. Ansys design modler is used as input CAD package to the FLUENT. Pressure correction technique is used for solving governing equation. Flow is basically simulated at higher Reynolds no., because when we increases the turbulence, efficiency of heat exchanger is also increases, analysis is done in ansys workbench 12.1 and various contour plots and vector plots are presented.

Key words: CFD, HE, CAD, Ansys, Parallel flow, counter flow

I. INTRODUCTION

Heat exchange between flowing fluids is one of the most important physical process of concern, and a variety of heat exchangers are used in different type of installations, as in process industries, power plants, food processing, refrigeration, etc. The purpose of constructing a heat exchanger is to get an efficient method of heat transfer from one fluid to another, by direct contact or by indirect contact. The heat transfer occurs by three principles: conduction, convection and radiation. In a heat exchanger the heat transfer through radiation is not taken into account as it is negligible in comparison to conduction and convection. Conduction takes place when the heat from the high temperature fluid flows through the surrounding solid wall. The conductive heat transfer can be maximized by selecting a minimum thickness of wall of a highly conductive material. But convection is playing the major role in the performance of a heat exchanger.

Forced convection in a heat exchanger transfers the heat from one moving stream to another stream through the wall of the pipe. The cooler fluid removes heat from the hotter fluid as it flows along or across it. Different co relation are used for the calculation of Nusselt no. and heat transfer coefficient.

Heat pipes are used widespread in broad applications since their operation is generally passive in essence. High heat transfer rates are doable by heat pipes over long distances, with minimal temperature difference, exceptional flexibility, simple fabrication, and easy control, not to mention, all without any external pumping power applied. Possible applications are varied from aerospace engineering to energy conversion devices, and from electronics cooling to biomedical engineering. Heat pipe development is motivated to overcome the need to presumably manage thermal dissipation in progressively compressed and higher-density microelectronic components, while preserving the components temperatures to specification.

A heat pipe operates within a two-phase flow regime as an evaporation–condensation device for transferring heat in which the latent heat of vaporization is exploited to transport heat over long distances with a corresponding small temperature difference. Heat added to the evaporator is transferred to the working fluid by conduction and causes vaporization of the working fluid at the surface of the capillary structure. Vaporization causes the local vapor pressure in the evaporator to increase and vapor to flow toward the condenser, thereby transporting the latent heat of vaporization. Since energy is extracted at the condenser, the vapor transported through the vapor space is condensed at the surface of the capillary structure, releasing the latent heat. Closed circulation of the working fluid is maintained by capillary action and/or bulk forces. An advantage of a heat pipe over other conventional methods to transfer heat such as a finned heat sink is that a heat pipe can have an extremely high thermal conductance in steady-state operation. Hence, a heat pipe can transfer a high amount of heat over a relatively long length with a comparatively small temperature differential. Heat pipe with liquid-metal working fluids can have a thermal conductance of a thousand or even tens of thousands folds better than the best solid metallic conductors, silver or copper. In a heat

 DOI : 10.35291/2454-9150.2022.0238

pipe energy is transported by utilizing phase change of the working substance instead of a large temperature gradient and without external power. Also, the amount of energy transferred through a small cross section is much larger than that by conduction or convection. Heat pipes may be operated over a broad range of temperatures by choosing an appropriate working fluid

Heat transfer is a science that studies the energy transfer between two bodies due to temperature difference. There are three types or modes of heat transfer:

a. Conduction
b. Convection
c. Radiation

Conduction:

Conduction is a mode of heat transfer that occurs when there is a temperature gradient across a body. In this case, the energy is transferred from a high temperature region to low temperature region due to random molecular motion – diffusion. Higher temperatures are associated with higher molecular energies and when they collide with less energetic molecules the transfer of energy occurs. The simplest conduction heat transfer can be described as "one dimensional heat flow" depicted in Figure 1. In this situation, the heat flows into one face of the object and out the opposite face with no heat loss (flow) out the sides of the object. The surfaces 1 and 2 are held at constant temperature. Clearly, "in one dimensional heat flow," the temperature of an object is a function of only one variable, namely the distance from either face of the object (face 1 or 2).

Convection: The convection heat transfer mode is comprised of two mechanisms: random molecular motion (diffusion) and energy transferred by bulk or macroscopic motion of the fluid. The convection heat transfer occurs when a cool fluid flows past the warm body as depicted in Figure 2. The fluid adjacent to the body forms a thin slowed down region called the boundary layer. The velocity of the fluid at the surface of the body is reduced to zero due to the viscous action. Therefore, at this point, the heat is transferred only by conduction. The moving fluid then carries the heat away. The temperature gradient at the surface of the body depends on the rate at which the fluid carries the heat away.

Radiation: All bodies emit energy by means of electromagnetic radiation. The electromagnetic radiation propagated as a result of a temperature difference is called thermal radiation. An ideal thermal radiator or a black body will emit energy at a rate proportional to the forth power of its SS+Ticolute temperature and its surface area.

II. LITERATURE REVIEW

Heat transfer enhancement in a heat exchanger is getting industrial importance because it gives the opportunity to reduce the heat transfer area for the heat exchanger. Increase in the heat exchanger performance can help to make energy, material and cost saving related to a heat exchange process. Double pipe heat exchangers are the simplest devices in which heat is transferred from the hot fluid to the cold fluid through a separating cylindrical wall. They are primarily adapted to high temperature and high-pressure applications due to their small diameters. They are fairly cheap, but the amount of space they occupy is relatively high compared to the other types. Hence for the given design and length of the heat exchanger heat transfer enhancement in a double pipe heat exchanger is possibly achieved by several methods. Chen et al used dimples as the heat transfer modification on the inner tube. Bhuiya et al., Eiamsan et al. and Liao et al. used circular tube equipped with perforated twisted tape inserts with different configurations to enhance the heat transfer through the tube. In order to intensify the heat transfer from the heat exchanger surface to fluid, it is possible to increase convection coefficient (by growing the fluid velocity), widen temperature difference between surface and fluid or increase the surface area across which convection occurs. Extended surfaces, in the form of longitudinal or radial fins are common applications where the need to enhance the heat transfer between a surface and an adjacent fluid exists.Several researchers used extended surfaces for the enhancement in the heat transfer

Masliyah et al. studied heat transfer characteristics for a laminar forced convection fully developed flow in an internally triangular finned circular tube with axially uniform heat flux using a finite element method. For a given fin geometry, the Nusselt number based on inside tube diameter was higher than that for a smooth tube. Also, it was found that for maximum heat transfer there exists an optimum fin number for a given fin configuration. Agarwal et al. studied Laminar flow and heat transfer magnitudes in a finned tube annulus. Pressure drops and heat transfer characteristics of the fins are obtained in the periodically fully developed region by varying geometric and flow parameters. Geometric parameters are annulus radius ratio (0.3 to 0.5), fin height/annular gap (0.33 to 0.67) and fin spacing/annular gap (2 to 5). Flow parameters are Reynolds number (100 to 1000) and Prandtl number (1 to 5). Comparisons are made with a plain tube annulus having the same length, heat transfer surface area, volume flow rate, and Reynolds number. They observed that at Prandtl numbers less than 2, the use of fins may not be justified because the increase in pressure drop is more pronounced than the increase in heat transfer. At a Reynolds number of 1000 and A Prandtl number of 5, the heat transfer increases by a factor of 3.1, while the pressure drops increases by a factor of 2.3.

Soliman et al. studied steady, laminar, forced convection heat transfer in the thermal entrance region of internally finned tubes for the case of fully developed hydrodynamics. Results were presented for 16 geometries including the local Nusselt number and developing length corresponding

 DOI : 10.35291/2454-9150.2022.0238

to each boundary condition. These results indicate that internal finning influences the thermal development in a complicated way, which makes it inappropriate to extend the smooth tube results to internally finned tubes on a hydraulic diameter basis. Totala et al. conducted experiments in a double pipe heat exchanger by providing threads in the inner pipe. They observed that Nusselt number, heat transfer coefficient was increased for the threaded pipe. But the pumping power required also increased compared to the plain tube. Khannan et al. studied the heat transfer through a double pipe heat exchanger with annular fins. Three different configurations annular ring, spiral rod and rectangular projection were considered on the outside surface of the outer tube. Experiments were done with varied mass flow rates. It was observed that heat transfer rate was increased for a finned tube. Fin with annular ring showed better performance than other methods. Nagarani et al. used circular and elliptical annular fins as a heat enhancement devise in a double pipe heat exchanger. It was observed that heat transfer rate was higher in elliptical fins than circular fins. Heat transfer coefficient depends on the fin spacing, flow condition and fluid properties. Fin efficiency was higher for elliptical fins. Mir et al. studied Numerical simulation of the steady, laminar, forced convection heat transfer in the finned annulus for the case of fully developed incompressible flow corresponding to thermal boundary condition of uniform heat input per unit axial length with peripherally uniform temperature at any cross section. Various heat transfer and fluid flow characteristics were investigated for a range of values of the ratio of radii of inner and outer pipes, fin height and number of fins. The results calculated are in good comparison with the correlation results with considerable gain in the computational time. Syed et al. numerically simulated the laminar convection flow in the fully developed region of finned double pipe subjected to constant heat flux boundary conditions. They found a significant enhancement in heat transfer rate and also nusselt number. For small number of fins fin geometries like fin height, ratio of radii, and half fin angle were found to be less influential. Iqbal et al. investigated optimal configuration of finned annulus with parabolic, triangular and trapezoidal fins using finite element methods and genetic algorithms. They concluded that no single fin shape is best in all situations and for all criteria. Zhang et al. studied heat transfer enhancement for shell side of a double-pipe heat exchanger with helical fins and pin fins, the three-dimensional velocity components for the shell side with and without pin fins were measured experimentally by using laser Doppler anemometer (LDA) under cylindrical coordinate system and the fluid flow characteristics. The results showed that, for the shell side only with helical fins at large pitch, there was a pair of vortex near the upper and lower edge of the rectangular cross section the weakest secondary flow occurred at the center. By pin fins being installed, the three-dimensional velocity components in the helical channel were strongly changed. Patel et al. simulated the industrial experimental results of a double pipe heat exchanger using ANSYS14-CFX. Results indicated heat transfer, pressure drop, pumping power increased with mass flow rate whereas friction factor decreased.

For heat exchangers, built with many fins and designed for real industry, it is important to pay attention to and calculate the heat transfer considering the fluid flow and flow paths. The resistance of the body results in a pressure drops. Literature survey reveals that most of the analysis was done by considering constant heat flux or constant wall temperature boundary condition. Literature regarding the numerical study of enhancement in heat transfer characteristics using different configurations of internal longitudinal fins for a double pipe heat exchanger with conjugate heat transfer is still scare. Hence the present work aimed at comparison of heat transfer characteristics using different mass flow rate and temperature for parallel and counter flow of a double pipe heat exchanger under various operating conditions to evolve with the best possible configuration. Numerical Simulation was done using commercial CFD package. Heat transfer characteristics like temperature variation, heat transfer rate, and heat transfer coefficient for the above said models were compared and are presented.

Contours: The temperature, pressure and velocity distribution along the heat exchanger can be seen through the contours.

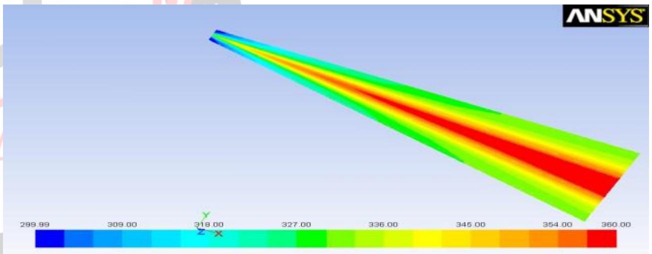

Fig1 contours of static temperature in counter flow hex in Kelvin

Table 1. Comparison of mass flow rate

Mass Flow Rate	For Parallel hex (kg/sec)	For Counter hex (Kg/sec)
Hot Inlet	0.02	0.02
Cold Inlet	0.02	0.02
Hot Outlet	-0.019999364	-0.00099999554
Cold Outlet	-0.019999927	-0.0010000009

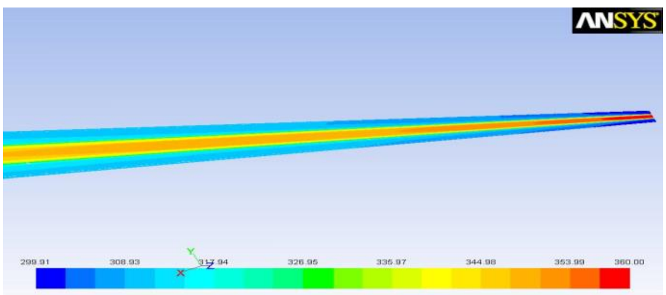

Fig 2 contours of static temperature in parallel flow hex in Kelvin

 DOI : 10.35291/2454-9150.2022.0238

ISSN : 2454-9150 Vol-08, Special Issue, MAY 2022

Table 2: Comparison of static Temperature

Temperature	For Parallel hex (K)	For Counter hex (K)
Hot inlet	360	360
Cold inlet	300	300
Hot outlet	347	321
Cold Outlet	312	336

Table 3 Comparison of Total pressure

Pressure (Pascal)	For Parallel hex (pascal)	For Counter hex (pascal)
Hot Inlet	326	7.47
Cold Inlet	10	0.3811
Hot Outlet	41	0.13
Cold Outlet	0.705	0.0021

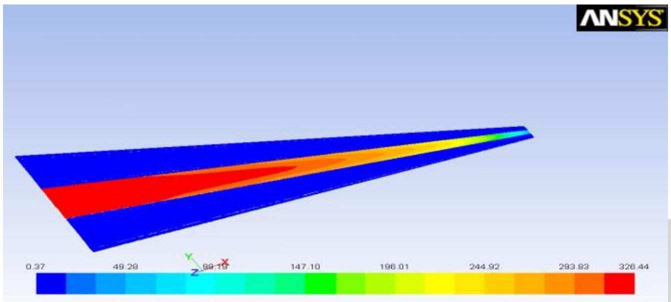

Fig 3: Contours of Total Pressure for Counter Flow hex

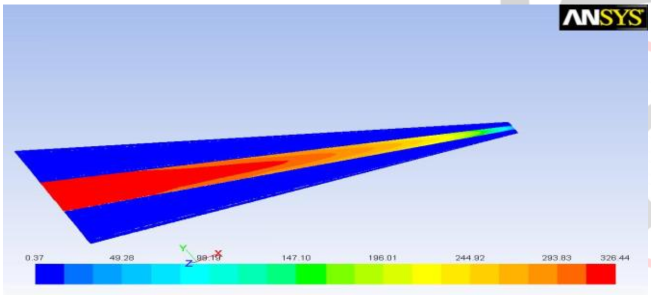

Fig 4 :Contours of Total Pressure for Parallel Flow hex

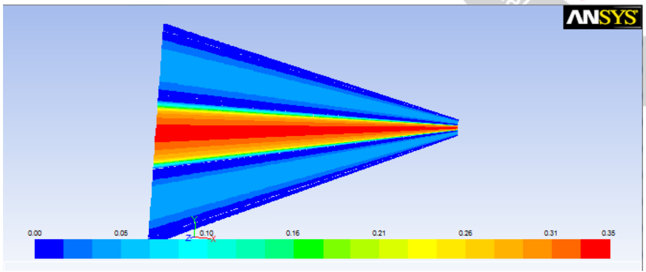

Fig 5: contours of velocity magnitude for parallel flow hex

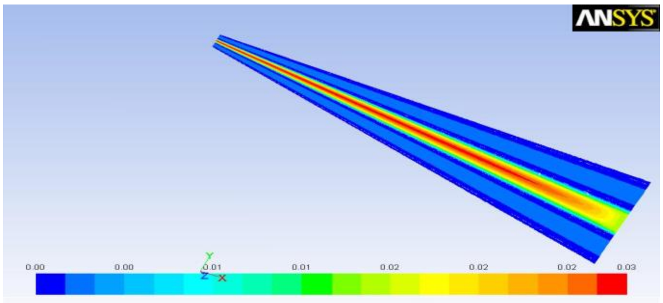

Fig 6 contours of velocity magnitude for counter flow

X-Y plots:

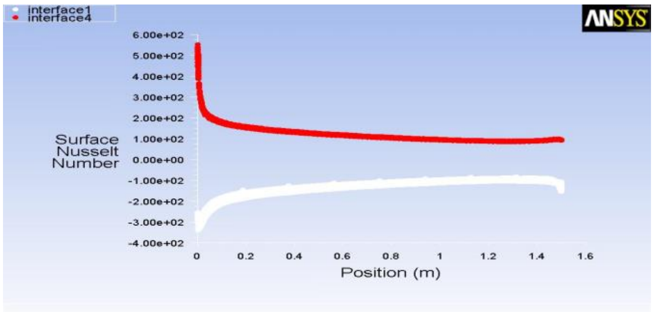

Fig 7 : Plot of surface Nusselt no. for parallel flow hex

Table 3: Comparison of Surface Nusselt No.

Surface Nusselt no.	Parallel hex	Counter hex
Interface 1 (solid inner)	144	802
Interface 4 (solid outer)	123	675

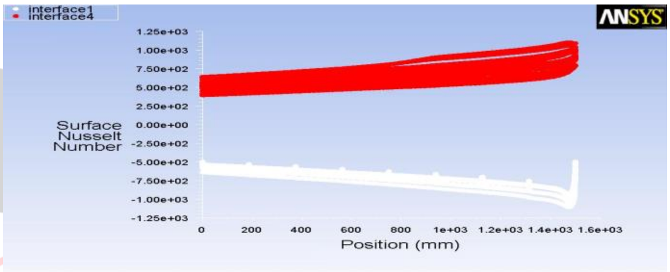

Fig 8: Plot of surface Nusselt no. for counter flow hex

XY-PLOT OF TEMPERATURE:

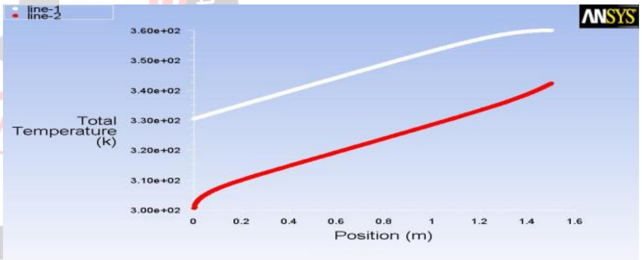

Fig 9: Plot of static temperature of counter flow

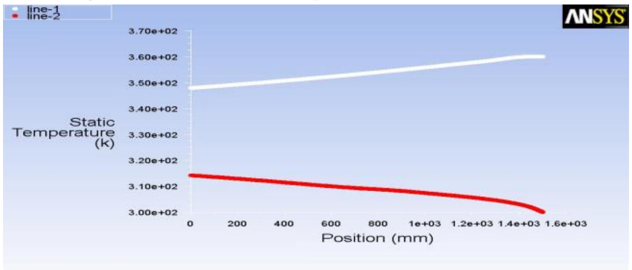

Fig 10: Plot of Static temperature of Parallel Flow

XY-PLOT OF TOTAL PRESSURE:

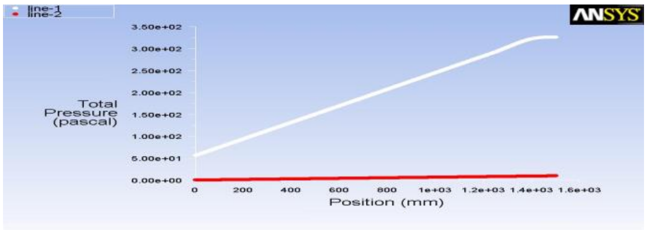

Fig 11: Plot of total Pressure of parallel flow hex

 DOI : 10.35291/2454-9150.2022.0238

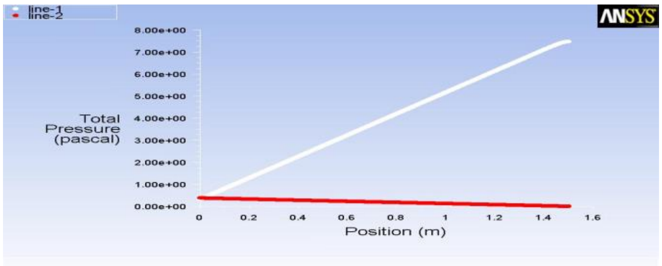

Fig 12: Plot of total pressure of counter flow hex

Table 4: Comparison of Total Heat Transfer Rate (W)

Total Heat Transfer Rate (W)	For Parallel hex	For Counter Flow hex
Hot Inlet	5173	258
Cold Inlet	154	7.694
Hot Outlet	4116	107
Cold Outlet	1210	158

XY-PLOT OF VELOCITY:

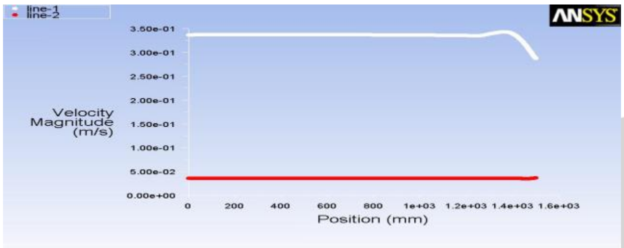

Fig 13: Plot of Velocity Magnitude for Parallel Flow

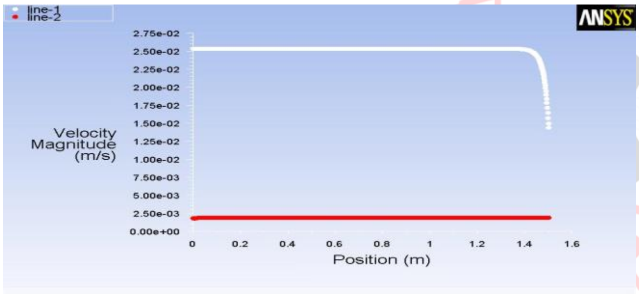

Fig 14: Plot of Velocity magnitude For Counter Flow

Table 5: Comparison of Velocity Magnitude (m/sec)

Velocity Magnitude (M/sec)	For Parallel hex (m/sec)	For Counter flow hex (m/sec)
Cold Inlet	0.037020884	0.018510441
Hot Inlet	0.28737661	0.01436883
Cold Outlet	0.037027109	0.018505444
Hot Outlet	0.28748521	0.014369163

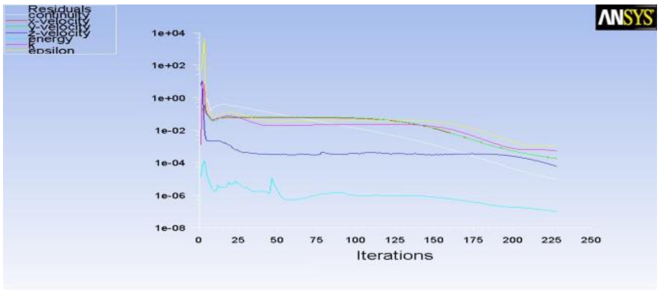

Fig 15: Scaled Residuals for Both Models

CONCLUSION

A CFD package (ANSYS FLUENT 12.1) was used for the numerical study of heat transfer characteristics of a double pipe heat exchanger for parallel flow and counter flow, and the results were then compared. The study showed that there is not much difference in the heat transfer within the error limits performances of the parallel-flow configuration and the counter-flow configuration. Nusselt number at different points along the pipe length was determined from the numerical data. The simulation was carried out for water-to-water heat transfer characteristics .and for same length and same diameter of tube and annulus and for same input temperature for cold inlet 300k, for hot inlet 360k. We analyze that in counter flow heat exchanger there is high temperature difference in output streams (hot outlet, cold outlet). Nusselt number for the counter flow heat exchanger 802 and for parallel flow is 144.

For the given design and length of the heat exchanger heat transfer enhancement in a double pipe heat exchanger is possibly achieved by several methods. These techniques are divided into active and passive techniques. Active methods involve some external input for the enhancement of heat transfer like induced vibrations, injection and suction of fluids and jet impingement etc. Another method is the passive method without the stimulation by external power such as surface coating, surface roughness and extended surfaces.

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