MULTI TUBE HEAT EXCHANGER IN COUNTER FLOW BY USING CFD ANALYSIS

Periyannan.L[1], Saravanan.P[2], Elayaraja.R[3], Subramaniam.D[4]

[1,3]Assistant Professor, Department of Mechanical Engineering, Mahendra Engineering College, Mallasamudram, Tamilnadu, India-637503.
[2,4]Professor, Department of Mechanical Engineering, Mahendra Engineering College, Mallasamudram, Tamilnadu, India-637503.

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Abstract - Heat exchanger is an important tool that is widely used in different industries such as operation, petroleum refining, chemical, oil, power plant and paper, etc. Energy and material savings considerations as well as environmental challenges in the sector have driven the demand for high performance heat exchangers. To order to improve the performance of the heat exchanger, attention must be given to improving the heat transfer in the heat exchanger. In addition, the increase in heat transfer allows a major reduction in the size of the heat exchanger. A high rate of heat transfer with a minimum space requirement is sufficient for a compact heat exchanger. The counter-flow heat exchanger enhances the heat transfer characteristics of the double pipe heat helical fins mounted on the outer surface of the inner tube and reduces the vibration level by rotating the inner tube. Helical fins increase the heat transfer area and the rotation of the inner tube increases the mixing of fluid particles required for the heat transfer convection mode. The heat pipe model is designed by the CREO PARAMETRIC software and analyzed by the ANSYS software.

Key Words: Counter flow, Double pipe, Cooling fins, CERO, Ansys

1. INTRODUCTION

A heat exchanger is a device that is used to transfer thermal energy between two or more fluid, between a solid surface and a fluid, or between solid particulates and a fluid, at different temperature and in thermal contact. In heat exchangers, there are usually no external heat and work interactions.

Typical application involves heating or cooling of a fluid stream and evaporation or condensation of single or multicomponent fluid streams. In other application, the objective may be to recover or reject heat, or sterilize, pasteurize, fractionate, distil, concentrate, crystallize, or control a process fluid. In a few heat exchangers, the fluids exchanging are in direct contact.

In most heat exchanger, heat transfer between fluids takes place through a separating wall or into and out of a wall in a transient manner. In many heat exchangers, the fluid is separated by a heat transfer surface, and ideally they do not mix or leak. Such exchangers are referred to as direct transfer type, or simply recuperate. In contrast, exchangers in which there is intermittent heat exchange between the hot and cold fluid-via thermal energy storage and release through the exchanger surface or matrix are refer to as indirect transfer type, or simply referred to as indirect transfer type, or simply regenerators. Such exchangers usually have fluid leakage from one fluid stream to the other due to pressure differences and matrix rotation/valve switching.

Common example of heat exchangers are shell and tube exchangers, automobile, radiators, condensers, evaporators, air pre heaters, and cooling towers. If no phase change occurs in any of the fluids in the exchanger. There could be internal thermal energy sources in the exchangers, such as in electric heaters and nuclear fuel elements. Combustion and chemical reaction may take place within the exchangers, such as in boilers, fired heaters, and fluidized-bed exchangers.

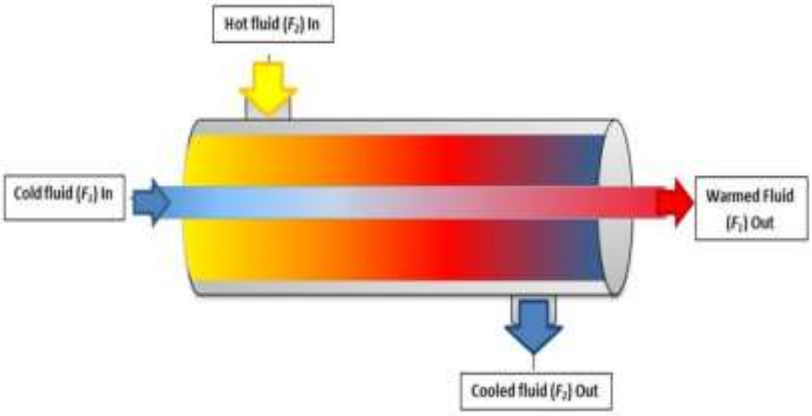

Figure 1. Double pipe heat exchanger

BASED ON FLUID ARRANGEMENT

- Counter flow
- Parallel flow
- Cross flow

Counter Flow

A counter flow heat exchanger is one in which the direction of the flow of one of the working fluids is opposite to the direction to the flow of the other fluid. In a parallel flow exchanger, both fluids in the heat exchanger flow in the same direction. The counter flow heat exchanger has three significant advantages over the parallel flow design.

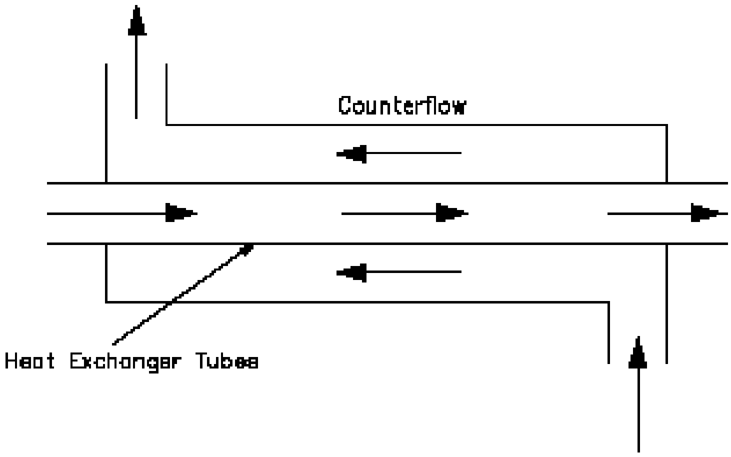

Figure 2.Counter Flow

Parallel flow

A counter flow heat exchanger is one in which the direction of the flow of one of the working fluids is opposite to the direction to the flow of the other fluid. In a parallel flow exchanger, both fluid in the heat exchanger flow in the same direction.

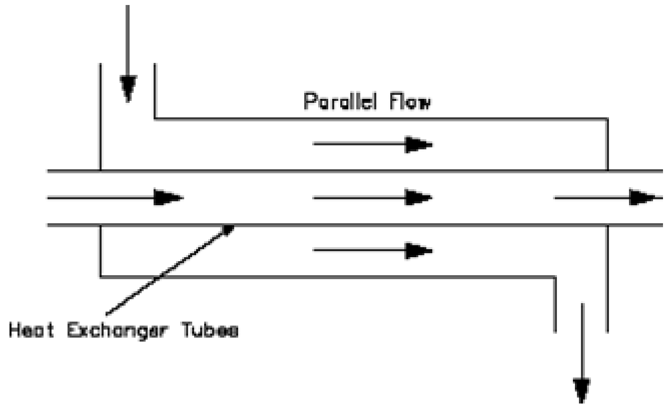

Figure 3. Parallel Flow

Cross flow

A cross flow heat exchanger exchanges thermal energy from one airstream to another in an air handling unit (AHU). A cross flow heat exchanger is used in a cooling and ventilation system that required heat to be transferred from one airstream to another.

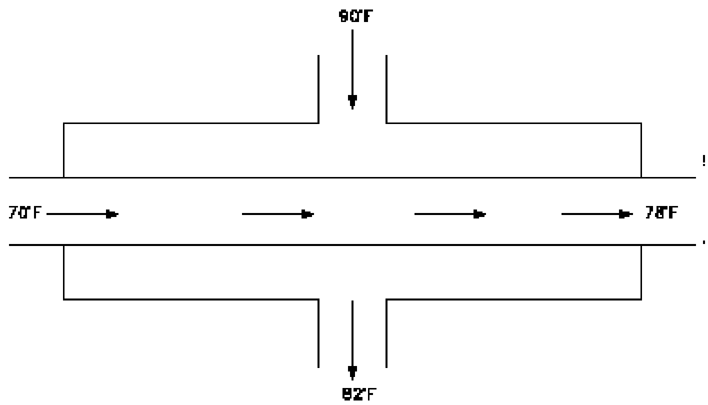

Figure 4. Cross flow

2. MATERIAL SELECTION

STEEL

Steel is an alloy of iron and carbon, and sometimes other elements. Because of its high tensile strength and low cost, it is a major component used in buildings, infrastructure, tools, ships, automobiles, machines, appliances, and weapons. Iron is the base metal of steel. Iron is able to take on two crystalline forms (allotropic forms), body cantered cubic and face centred cubic, depending on its temperature. In the body-centred cubic arrangement, there is an iron atom in the centre and eight atoms at the vertices of each cubic unit cell; in the face- centred cubic, there is one atom at the centre of each of the six faces of the cubic unit cell and eight atoms at its vertices. It is the interaction of the allotropes of iron with the alloying elements, primarily carbon that gives steel and cast iron their range of unique properties.

Figure 5. Steel

Steel property

Steel is an alloy, consisting mainly of iron, with a carbon content of 0.2% to 2.1% by weight. Though the use of carbon is most common for the production of this metal alloy, other alloying materials like tungsten, chromium and manganese are also used. The proportions and forms in which these elements are used, affect the properties of the steel that is produced - increasing the carbon content for instance, increases its strength.

Mechanical properties of steel (outer pipe)

- Density - 8030 kg/m^3
- Specific heat - 502.48 j/kg-k
- Thermal conductivity - 16.27 w/m-k
- Modulus of elasticity - 210,000 N/mm^2
- Shear modulus - 81,000 N/mm^2
- Poisson's ratio - 0.3

COPPER

Copper is a chemical element with the symbol Cu (from Latin: cuprum) and atomic number 29. It is a soft, malleable, and ductile metal with very high thermal and electrical conductivity. A freshly exposed surface of pure copper has a pinkish-orange colour. Copper is used as a conductor of heat and electricity, as a building material, and as a constituent of various metal alloys, such as sterling silver used in jewellery, cupronickel used to make marine hardware and coins, and constantan used in strain gauges and thermocouples for temperature measurement.

Figure 6. Copper

Copper property

The word copper comes from the Latin word cuprum", which means „ore of Cyprus". This is why the chemical symbol for copper is Cu. Copper has many extremely useful properties, including:

- Good electrical conductivity
- Good thermal conductivity
- Corrosion resistance

Mechanical property of copper (inner pipe)

- Density - 8978 kg/m^3
- Specific heat - 381 j/kg-k
- Thermal conductivity - 387.6w/m-k

3. DESIGN OF DOUBLE PIPE HEAT EXCHANGER

Double Pipe Design

Double Pipe Heat Exchangers. In its simplest form, the double pipe heat exchanger, (also known as a concentric pipe, hairpin, jacked pipe and jacketed U-tube heat exchangers), consists of a single tube mounted inside another. One fluid flows in the inner pipe, while a second fluid flows in the outer pipe annuals. Double pipe heat exchangers come into their own when a conventional shell and tube heat exchanger would be uneconomical. They are suited for applications where either low flow rates, large temperature cross or small duties with high flow rates are involved. Their size makes them particularly suitable for applications where space is at a premium. Multiple units can be set up in either series or parallel and mounted vertically.

Their small diameter allows high pressure units to be built with thinner walls than would be achievable with conventional shell and tube heat exchangers. A double tube heat exchanger is able to achieve pure counter current flow thus allowing for a temperature cross to be achieved whereby the cold fluid can be heated above the exit temperature of the hot fluid.

Normal Double Pipe Heat Exchanger Model:

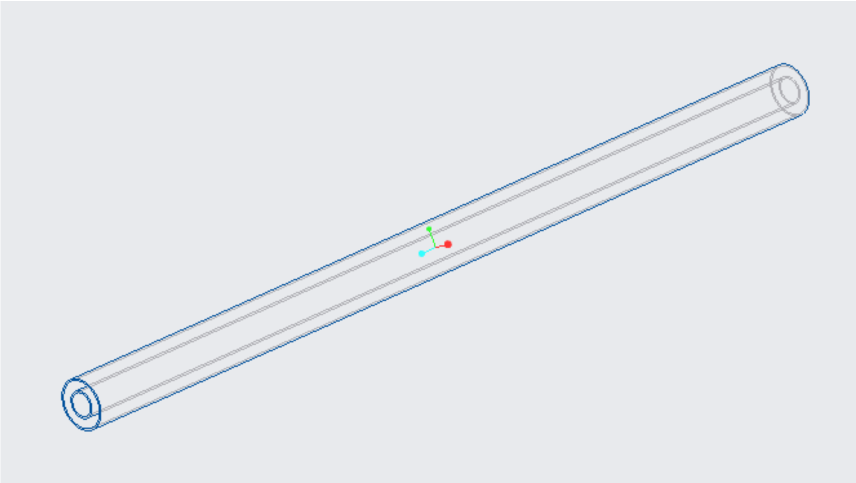

Figure 7. Normal Double Pipe Heat Exchanger Model

Double Pipe Heat Exchanger with Helical Fins:

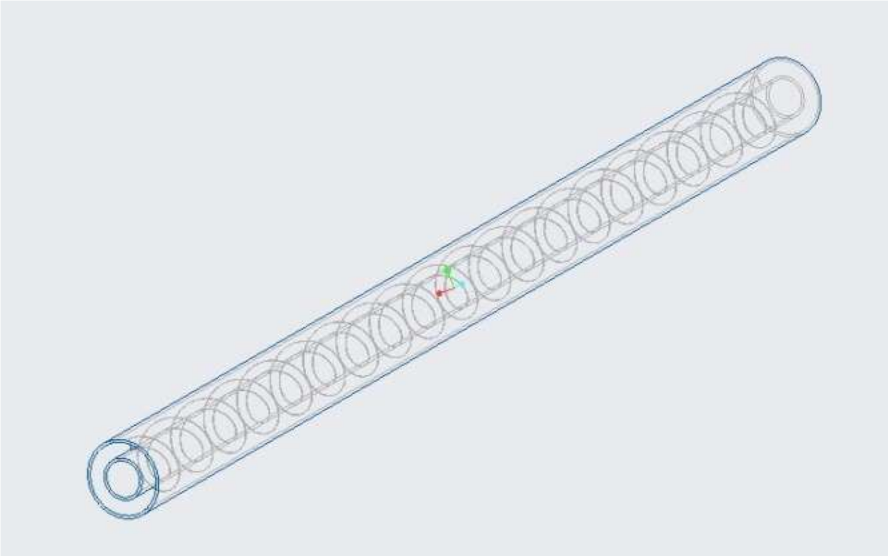

Figure 8. Double Pipe Heat Exchanger with Helical Fins

Dimension in Double Pipe Heat Exchanger

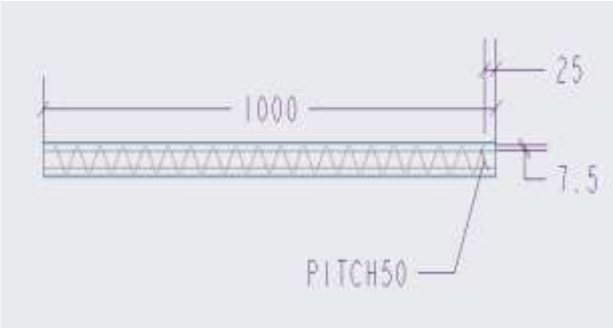

Figure 9. Dimension in Double Pipe Heat Exchanger

4. RESULT AND DISCUSSION

Purpose of CFD

- The geometry and physical bounds of the problem can be defined using computer aided design (CAD). From there, data can be suitably processed (cleaned-up) and the fluid volume (or fluid domain) is extracted.
- The volume occupied by the fluid is divided into discrete cells (the mesh). The mesh may be uniform or non-uniform, structured or unstructured, consisting of a combination of hexahedral, tetrahedral, prismatic, pyramidal or polyhedral elements.
- Boundary conditions are defined. This involves specifying the fluid behaviour and properties at all bounding surfaces of the fluid domain. For transient problems, the initial conditions are also defined.
- The simulation is started and the equations are solved iteratively as a steady-state or transient.

Mass Flow using 4 LPM in Normal

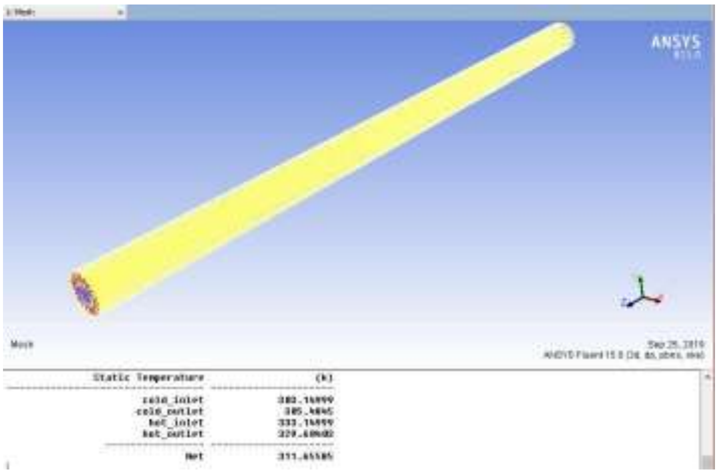

Figure 10. Temperature Difference using 4 LPM in Normal

Comparative Reading of Normal Method:

Hot water			Cold water		
Flow LPM	Inlet	Outlet	Flow LPM	Inlet	Outlet
2	50	44.56	5	30	31.78
4	50	46.45	5	30	32.33
6	50	47.33	5	30	32.63
8	50	47.85	5	30	32.82
10	50	48.19	5	30	32.95

Table 1. Comparative Reading of Normal Method

The comparative reading of normal double pipe heat exchanger used in different flow value of hot water show the reading in above table 1.The better result of 4 LPM mass flow rate graphically represented by Pressure, Velocity and Temperature.

Comparative Reading of Helical Fins Method:

Hot water			Cold water		
Flow LPM	Inlet	Outlet	Flow LPM	Inlet	Outlet
2	50	43.28	6	30	32.22
4	50	45.17	6	30	33.20
6	50	46.15	6	30	33.81
8	50	46.78	6	30	34.25
10	50	47.23	6	30	34.58

Table 2. Comparative Reading of Helical Fins Method

The comparative reading of helical fins of double pipe heat exchanger used in different flow value of hot water show the reading in above table 2 and temperature difference of different flow rate show in the figure 10. The better result of 4 LPM mass flow rate graphically represented by Pressure, Velocity and Temperature.

Comparative Reading of Normal and Helical Fins Method

Mass Flow Rate Hot Water (LPM)	Mass Flow Rate Cold Water (LPM)	Normal Method		Helical Fins Method	
		Hot Water Outlet ( )	Cold Water Outlet ( )	Hot Water Outlet ( )	Cold Water Outlet ( )
2	6	44.56	31.78	43.28	32.22
4	6	46.45	32.33	45.17	33.20
6	6	47.33	32.63	46.15	33.81
8	6	47.85	32.82	46.78	34.25
10	6	48.19	32.95	47.23	34.58

Table 3 Comparative Reading of Normal and Helical Fins Method

5. CONCLUSION

This research analyzes the heat transfer and flow properties of a tube-in-tube helical heat exchanger for counterflow using the CFD technique. The consequence of the flow rate of mass in the inner tube. When we increase the thickness of the fin, the temperature of the cold fluid at the outlet of the heat exchanger increases. The heat transfer performance of a helical tube heat exchanger is greater than that of a straight tube heat exchanger. From the velocity and temperature contours, it can be found that the velocity is higher towards the outer side of the coil, while the temperature is higher towards the inner side of the coil.

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BIOGRAPHIES

Periyannan.L
Assistant professor,
Mahendra Engineering College

Saravanan.P
Professor,
Mahendra Engineering College

Elayaraja.R
Assistant professor,
Mahendra Engineering College

Subramaniam.D
Professor,
Mahendra Engineering College