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Heat Transfer and Energy Analysis of Tube in Tube Heat Exchanger and Validation Results with CFD

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Abstract - Energy is essential for the economic growth and social development of any country. The quality of life is closely related to energy consumption, which has continuously increased over the last few decades in developing countries. A solar thermal collector collects heat by absorbing sunlight. A collector is a device for capturing solar radiation. Solar radiation is energy in the form of electromagnetic radiation from the infrared (long) to the ultraviolet (short) wavelengths. A simple flat plate collector consist plate in an insulated box covered with transparent sheets. The most important part of a solar collector is the absorber, which usually consist of several narrow metal sheets aligned side-by-side. The fluid used for heat transfer generally flows through a metallic pipe, which is connected to the absorber strip. In plate-type absorber, two sheets are sandwiched together allowing the medium to flow between the two sheets. The outer casing which provides mechanical strength to the equipment is insulated to reduce the heat losses from back and side of the collector. Experimental investigation will be done on straight riser tube and zigzag riser tube on heat transfer enhancement, frictional factor.

The heat transfer in the tube with zigzag riser tube is should be more as compared to straight riser tube. The increase in relative heat transfer coefficient of water for zigzag riser tube is higher % than straight riser tube. The relative decrease in frictional factor for zigzag riser tube than straight riser tube. The relative Reynolds number for zigzag riser tube higher than straight riser tube. The relative increase in Nusselt's number for zigzag riser tubes higher than straight riser tube. If we increase the mass flow rate in the form of LPM the result for parameter temperature, pressure, and velocity will must be increase. The zigzag riser tube is better efficient than the straight riser tube.

***Key Words*:** Solar Flat Plate Collector, straight riser tube, Natural convection, relative heat transfer coefficient, zigzag riser tube, CFD etc.

1.INTRODUCTION

Engineering education is incomplete without laboratory practice. The overall goal of engineering education is to prepare students to practice engineering and to deal with the nature of problems faced by society. The laboratory practice has been an important part of professional and engineering undergraduate education; a laboratory is an ideal place for active learning. It is important for engineers to understand the principles of thermodynamics (especially the first and second laws) and heat transfer, and to be able to use the rate equations that govern the amount of energy being transferred via the three different modes of heat transfer (i.e., conduction, convection, and radiation). However, most students perceive thermodynamics and heat transfer as difficult subjects. Similarly, the integration of the present experiment into the undergraduate heat transfer laboratory would enhance and add another dimension to the teaching and learning of the subject of heat transfer. Heat exchangers are devices built for efficient heat transfer from one medium to another. They are devices that assist the exchange of heat between two fluids at different temperatures while keeping them from mixing. In contrast, exchangers in which there is intermittent heat exchange between the hot and cold fluids-via thermal energy storage and release through the exchanger surface or matrix-are 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. The design of a heat exchanger is an exercise in thermodynamics, which is the science that deals with heat energy flow, temperature, and the relationships to other forms of energy. To understand heat exchanger thermodynamics, a good starting point is to learn about the three ways in which heat can be transferred -conduction, convection, and radiation. A heat exchanger is a device, which transfers thermal energy between two fluids at different temperatures. In most of the thermal engineering applications, both fluids are in motion and the main mode of heat transfer is convection. Examples are automobile radiators, condenser coil in the refrigerator, air conditioner, solar water heater, chemical industries, domestic boilers, oil coolers in a heat engine, and milk chillers in pasteurizing plan. Heat exchanger, any of several devices that transfer heat from a hot to a cold fluid. In many engineering applications it is desirable to increase the temperature of one fluid while cooling another. This double action is economically accomplished by a heat exchanger. Heat exchangers are manufactured with various flow arrangements and in different designs. Perhaps the simplest is the concentric tube or double-pipe heat exchanger shown in Figure 1, in which one pipe is placed inside another. Inlet and exit ducts are provided for the two fluids. In the diagram the cold fluid flows through the inner tube and the warm fluid in the same direction through the annular space between the outer and the inner tube. This flow arrangement is called parallel flow. Heat is transferred from the warm fluid through the wall of the inner tube (the so-called heating surface) to the cold fluid. A heat exchanger can also be operated in counterflow, in which the two fluids flow in parallel but opposite directions. Concentric tube heat exchangers are built in several ways, such as a coil or in straight sections placed side by side and connected in series.

A double pipe heat exchanger consists of a pair of pipes (tubes) one positioned concentrically within the other. Double pipe heat exchangers are often connected in series to provide an increased heat transfer surface. They may be connected to have a parallel flow arrangement to handle large process steam flow. The inner pipe is often finned. The double pipe heat exchanger is adopted for low flow rate, high temperature and high- pressure application. These types of heat exchangers found their applications in heat recovery processes, air conditioning and refrigeration systems, chemical reactors, and food and dairy processes. The double pipe heat exchanger would normally be used for many continuous systems having small to medium head duties. The double pipe heat exchanger is used in industry such as condenser for chemical process and cooling fluid process. A lot of research has been done on the design and analysis of a double pipe heat exchanger.

In tube in tube heat exchanger there are two pipes, monopipe lower temperature fluid is passed and, in another pipe, higher temperature fluid is passed. It is done in concentric tube construction, which can have parallel or counter flow configuration. Parallel flow is when the flow of fluids is in same direction and in counter flow the flow of fluids is in opposite direction. The counter flow is more effective than parallel flow. The reason behind counter flow being most suitable in tube in tube heat exchanger is because it gives maximum rate of heat transfer for a given surface area. The design and fabrication of this tube in tube heat exchanger is done in such a way which can work in parallel as well as counter flow configuration. The heat transfer occurs from high temperature fluid to low temperature fluid and to make this happen the tube material should be thin and made of conductive material. Tube-in-tube heat exchanger (also known as double tube heat exchanger) consists of a heat exchanger with two concentric tubes. The product flows through the inner tube while the service does it through the space between the two tubes. Tube-in-tube heat exchangers, or double-tube heat exchangers, are specially designed for heating or cooling products with low-medium viscosity. The great advantage of Tube-in-tube heat exchangers is to be able to process products with fibers or particles, without the risk of clogging.

2. Literature Review

Masuda et. Al. Choi [1] Masuda et al. (1993) presented the structure of liquid suspended of nano-sized particles it was Choi (1995) who proposed the name of nanofluid for the first time. Ever since Choi published the first findings in NFs studies, there have been several other works has been done to the improvement of HT up to 20% by using densely distribution of nanoparticles in NFs. Efforts were carried out for better comprehension of changes in heat transfer coefficient in heat exchangers. Heat transfer coefficient of NFs with very low particle volume% is much higher as referred to the base fluid. On the other hand, low changes in friction coefficient and fluid viscosity in NFs have been reported.

Xuan and Roetzel et.al. [2] Xuan and Roetzel et al. has noticed an increase in energy transfer rate in their investigation on random motion of nanoparticles in NF. An experimental study on the convectional and flow characteristics of water-Cu NF through a straight pipe with constant thermal flow under laminar and turbulent regimes has been reported. Nanoparticles of Cu with less than 100 nm diameter were employed. The results show that Nano-suspended particles substantially improved the performance of conventional base fluid HT. The volume fraction of base fluid in NF fits well with that of water. Pak and Cho (1998) found in their experiment the turbulent forced convection heat transfer of Al2O3 water is higher than TiO2 /water nanofluids inside a circular tube. Li and Xuan (2002) concluded that in laminar and turbulent flow regime in forced convection, the heat transfer coefficient of Cu/water nanofluids flowing inside a uniformly heated tube remarkably increased compared to that of pure water.

.Lotti et. al. [3] Lotfi et al. Have compared the single-phase with the Mixture and Eulerian two-phase models for the forced convection flow of Al2O3/Water nanofluid with temperature independent properties. Also, they have compared the Nusselt number predictions for a 1% value concentration of nanoparticles with several correlations and one set of experimental values. They have also studied the effect of volume concentration on the wall temperature. Their results showed that the Mixture model is more precise than the other two models.

Reza Aghayari et. al.[4] Effect of Nanoparticles on Thermal Efficiency of Double Tube Heat Exchanger Reza Aghayari et al. did the experiments to find an Overall Heat Transfer Coefficient of Nano Fluids (OHTCNF)in heat exchangers and other relevant effective parameters. An improvement in Heat Transfer (HT)and OHTCNF containing Nano-aluminum oxide with ca. 20 nm particle size and particular volume fraction in the range of 0.001-0.002 was reported. The effects of temperature and concentration of nanoparticles on HT variation as well as Overall Heat Transfer Coefficient (OHTC) in a countercurrent double tube heat exchanger with turbulent flow have been studied. The experimental results fig:1 shows a remarkable 8%-10%riseinthe mean HT and the OHTC. In general, there are three mechanisms to improve heat transfer by introducing nanoparticles into the base fluid. Nano-particles benefit higher heat transfer rate; therefore, as nanoparticle concentration in the base fluid increases the heat transfer rate increases accordingly. The collisions occur between nanoparticles and the base fluid molecules on the one hand and the impacts of the particles to the heat exchanger wall on the other hand result in an energy increase. The friction between the wall and fluid increases if NFs are dealt with and, therefore, heat transfer improves.

Hassani et. al. [5] The effect of nanoparticles on the heat transfer properties of drilling fluids Hassani et al. has been found that the velocity and temperature have an important effect on the thermal property of mud. The thermal performance factor for all the cases is greater than base mud (5-22% for 0.01-2 wt.% nano-material) and convection results showed that the maximum thermal performance was found for the hybrid of CNT-silica nano-particle in higher Reynolds number. The heat transfer enhancement in 4200 Reynolds number, is 31%.

Hilde VAN DER VYVER et. al. [6] CFD accurately predicted heat transfer and Nusselt number for a three-dimensional tube in tube heat exchanger. Similarly, CFD provided good agreement with analytical and experimental results for a prototype heat exchanger. Where the experimental and CFD flows were similar, a good correlation for friction was found between the CFD and experimental results. It was concluded that CFD is valuable tool in heat exchanger design.

Wael I.A. Aly et. al. [7] The convective heat transfer and pressure drop characteristics

of Al2O3–water nanofluid flowing in helically coiled tube-in-tube heat exchangers were numerically investigated. The effects of nanoparticle volume concentrations and curvature ratio on the heat transfer and pressure drop characteristics were determined. Based onto the obtained results, the following conclusions can be stated:
(1) The 3D realizable k–e (RKE) model with enhanced wall treatment is robust and sufficient to simulate the turbulent flow and heat transfer of water and nanofluids in CTITHEs.
(2) The criteria for comparison of the heat transfer coefficient and pressure drop between base fluid and nanofluids should be carefully selected. Usually in the literature the comparisons are based on Re, this might be illusory as the higher heat transfer coefficient for the nanofluids is not because
of better nanofluids performance, but due to higher volume flow rate.
(3) When the comparison is at the same Re, the combined effects of the increased heat transfer capabilities of nanofluids and the secondary flow can be used as a compound passive approach to maximize the effectiveness of a heat exchanger and concurrently reduce the size of the heat exchanger.
(4) Also, when the comparison is at the same Re or Dn, the heat transfer coefficient increases by increasing the coil diameter and nanoparticles volume concentration. Moreover, the friction factor increases with the increase in the curvature ratio and almost there is no pressure drop penalty with increasing the nanoparticles volume concentration up to 2%.
Yunying Qi et. al. [8] Heat transfer enhancement at least 1.4 times of water in straight tubes was observed in the heat transfer tests of SPE98330 (1500 ppm) solution in the fluted tube-in-tube heat exchanger with only modest pressure drop penalties These are very encouraging results. The super-ordered micelle structure of this solution may experience a breakdown by the shear stress induced by the spirally fluted tube. This was not found in the experiments for Ethoquad T13-50/NaSal solution in the same tube and indicates that the Ethoquad T13- 50/NaSal (5 mM/8.75 mM) solution has a stronger microstructure than the SPE98330 (1500 ppm) solution, which also degraded significantly with continuous circulation.
N Sreenivasalu Reddy et. al. [9] A numerical study has been performed to investigate heat transfer and friction factor of fluid flow in the annulus region of a tube in tube helical heat exchanger for the laminar regime at different Dean Numbers. The behavior of the overall heat transfer coefficient under the influence of different cross-sections of the inner pipe of the heat exchanger revealed that effectiveness and overall heat transfer coefficient was strongly affected with Dean Number. The use of different geometry of the inner pipe of the tube in tube helical heat exchanger causes a higher friction factor at low Dean Number. The Nusselt Number for Geometry B to E is greater than that of a circular tube and was found to increase with Dean Number. The use of geometry E increases the Nusselt number and friction factor by 17.05% and 15% respectively at a Dean number of 400 as compared with a circular tube. Nusselt number of Geometry B increases by 13.73% as compared to Geometry A. It is observed that the increase in Nusselt number from Geometry B to C is 1.45% and geometry C to E is 3.24%.

3. Methodology

Its unique and compact design prevents thermal fatigue, increases efficiency, and reduces the overall size. It is ideal for high temperature, high pressure, and low flow applications. The layout of tube- in-tube heat exchangers can be customized to fit the available installation foot print or other customer requests. The use of flanged connections allows these tubular heat exchangers to be disassembled to facilitate cleaning and maintenance tasks. The design is being used by major OEMs around the world and integer- expanding wholesale replacement market. The simplicity of design and installation makes this product ideal in both markets. A Tube-in-tube heat exchanger can achieve a pure countercurrent flow, which allows a temperature crossover to be achieved, so that the cold fluid can be heated above the hot fluid outlet temperature. The use of flanged connections allows these tubular heat exchangers to be disassembled to facilitate cleaning and maintenance tasks.

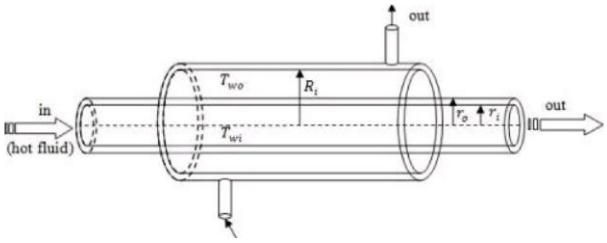

Fig. 3.1 Schematic Diagram of Tube in Tube Heat Exchanger

3.1 Working Principle

A tube-in-tube heat exchanger operates on a simple and easily understandable concept. The heat exchanger achieves a net counter current flow, allowing for temperature crossings that enable the cold fluid to be heated above the temperature of the hot fluid outlet. The key feature of this heat exchanger is that the fluid that is heating or cooling the hot or cold liquid never comes into direct contact with it. The heat exchanger consists of two concentric tubes-an inner tube and an outer tube. Both tubes can contain either hot or cold liquid, and the heat transfer occurs indirectly through the wall of the inner tube. The outer tube is usually the one that carries the fluid that needs to be heated or cooled, while the inner tube carries the fluid that transfers heat to or from the outer tube. The fluid in the outer tube enters the tube from one end and flows towards the other end, where it exits. Meanwhile, the fluid in the inner tube flows in the opposite direction, entering from the end where the outer tube exits and flowing towards the end where the outer tube enters. This flow pattern is often referred to as counterflow or counter current flow. Tube-in-tube heat exchangers are particularly useful in applications where direct steam injection heat exchangers are not appropriate. For example, they are commonly used in the preheating and cooling sections of tube systems. In these sections, the heat exchangers use the indirect heat transfer technique, but direct heat is used for the final heating step.

3.2 COMPONENTS

K TYPE THERMOCOUPLE

A K Type thermocouple isa type of temperature sensor that utilizes Chromel and Alumel conductors in its construction. This thermocouple is designed to meet the output requirements as set forth by the ANSI/ASTM E230 or IEC 60584 standards for Type K thermocouples. A K Type thermocouple can be found in various forms, such as immersion sensors, surface sensors, wires, or other styles of sensors or cables. The primary function of a K Type thermocouple is to measure temperature, and it does so by utilizing the See back effect, which generates an electromotive force (EMF) when there is a temperature difference between the two conductors. The Chromel and Alumel conductors used in a K Type thermocouple have specific characteristics that make them suitable for use in measuring temperature. Chromel is an alloy of nickel and chromium, while Alumel is an alloy of nickel, aluminum, manganese, and silicon. When these two conductors are joined, they create a thermocouple that is highly accurate and reliable in measuring temperature over a wide range of temperatures. K Type thermocouples are commonly used in various industrial and scientific applications where temperature monitoring is critical. These applications include furnaces, kilns, power plants, food processing, and many others. Additionally, the small size and flexibility of K Type thermocouples make them an ideal choice for measuring temperature in hard-to-reach or confined area.

Fig 3.2 K Type Thermocouple

MULTIPOINT TEMPERATURE INDICATOR

A multipoint temperature sensor is an instrument that is designed to measure temperature at multiple points or locations using a single access point. This type of sensor is typically used in industrial applications where it is necessary to monitor the temperature of a process at several points simultaneously. The specifications of a typical multi point temperature sensor include the following:

Input: The sensor can accept input from RTD(Pt-IO0) or thermo couple temperature sensors.

Indication: The sensor is equipped with a seven-segment LED display that shows the temperature readings in a 3.5 digit 'A' size format. The accuracy of the indication is±0.5 % of FSD (full-scale deflection) ± 1digit. Operating Temperature: The sensor is designed to operate within a temperature range of 0°C to 50°C. A multipoint temperature sensor is a highly versatile instrument that can be used to measure temperature at multiple points within a process using a single access point. It can accept input from both RTD and thermocouple sensors and has a highly accurate LED display for indicating the temperature readings. The sensor is designed to operate within a specific temperature range and is powered by a 230 VAC supply voltage.

Fig. 3.3 Multi point temperature indicator

ROTAMETER

A rotameter is a commonly used instrument for measuring the flow rate of liquids and gases in a variety of industries. It is known for its reliability, simplicity, and low cost, making it a popular choice for many applications. The design of a rotameter consists of a tapered tube through which the liquid or gas flows, and a moving internal float. As the fluid flows through the tube, the float rises or falls depending on the flow rate, indicating the rate of flow on a scale printed on the tube. Rotameters are also known by other names, such as gravity flow meters, mechanical flow meters, or variable area flow meters. The name "gravity flow meter" comes from the fact that the rotameter must be installed vertically, with the flow going from bottom to top, to function properly. This is because the float inside the tube moves due to the force of gravity acting on it. One of the advantages of a rotameter is its simplicity. It requires no external power source, as it relies solely on the flow of the fluid to operate. Additionally, it has are relatively low cost compared toother flow measuring instruments, making it a popular choice for many industries. A rotameter is a simple, reliable, and low-cost flow measuring instrument used to measure the flow rate of liquids and gases. Its design includes a tapered tube and a moving internal float, and it is also known as a gravity flow meter, mechanical flow meter, or variable area flow meter.

WATER TANK

Water tanks are containers that are used for storing water. There are different types of water tanks available, such as plastic water tanks and metal water tanks. In this case, you mentioned that there are two tanks being used for storing water -one plastic water tank for cold water with a capacity of15 liters, and one metal tank for hot water with a capacity of 15 liters. The plastic water tank is designed to hold cold water. These types of tanks are usually made of high-quality plastic material that is durable and can with stand the weight of the water. They are generally easy to install and maintain, and they come in various sizes and shapes to fit different requirements. The capacity of the plastic water tank you mentioned is 15 liters, which means that it can hold up to 15 liters of cold water. On the other hand, the metal tank is designed to hold hot water. These tanks are usually made of stainless steel or copper material, which is known for its ability to withstand high temperatures without getting damaged. They are also designed with insulation to keep the water hot for longer periods. The capacity of the metal tank you mentioned is between 10-15 liters, which means that it can hold up to 15 liters of hot water. Both the plastic and metal tanks play an important role in storing water. The plastic water tank is used for storing cold water, which can be used for drinking, cooking, cleaning, and other purposes. The metal tank, on the other hand, is used for storing hot water, which is commonly used for taking showers, washing clothes, and other activities that require warm water.

4. Experimentation

4.1 Experimental Setup

Its unique and compact design prevents thermal fatigue, increases efficiency, and reduces the overall size. It is ideal for high temperature, high pressure, and low flow applications. The layout of tube- in-tube heat exchangers can be customized to fit the available installation foot print or other customer requests. The use of flanged connections allows these tubular heat exchangers to be disassembled to facilitate cleaning and maintenance tasks. The design is being used by major OEMs around the world and integer- expanding wholesale replacement market. The simplicity of design and installation makes this product ideal in both markets.

4.2 Mean Temperature Difference

Before determining the heat transfer area required for a given duty, an estimate of the mean temperature difference *11Tlm* must be made. This is normally calculated from the difference in fluid temperatures at the inlet and outlet of the exchanger. Williams et al.(2002) states that

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Tla=[Tl,o+Tl*i*]/2

To"a=[To"o+Toj]/2

Fluid properties such as density, viscosity, heat capacity are evaluated at average temperatures, while thermal conductivity k can be evaluated at the average of the average temperatures.

4.3 Logarithmic Mean Temperature Difference

When heat capacities of both streams are constant and there is no phase change at constant pressure for streams that contain a single component: For countercurrent flow, the logarithmic mean temperature difference is given in Coulson et al. (2009) as:

Δ*Tlm*=Tl-t2-T2-tl/InTl-t2T2-tl

In heat exchanger, Δ*Tlm* is the appropriate average temperature difference to use in heat transfer calculations. Logarithmic mean temperature difference can only apply when there is no change in specific heats, the overall heat transfer coefficient is constant and there are no heat losses. In design, these conditions can be assumed to be satisfied provided the temperature change in each fluid stream is not large.

Δ*Tlm* =Tl-tl-T2-t2/*In*Tl-tlT2-t2

4.3 Overall Heat Transfer Coefficient

The overall heat transfer coefficient is necessary to determine the heat transferred from the inner pipe to the outer pipe. The coefficient considers all the conductive and convective resistances (k and h respectively) between fluids separated by the inner pipe and considers thermal resistances caused by fouling (rust, scaling, etc.) on both sides of the inner pipe.

Once all separate heat-transfer coefficients are calculated an overall heat transfer coefficient can be calculated being the sum of the inverse of the individual heat transfer coefficients.

4.4 Quantity of Heat Transferred

After determining the heat exchange duty and calculating the log mean temperature difference. An estimated value of the overall heat transfer coefficient U enables calculations for the heat transfer surface area A from the equation given in Bengtson (2010).

*Q=UA*ΔTim

4.5 Effectiveness of the Heat Exchanger

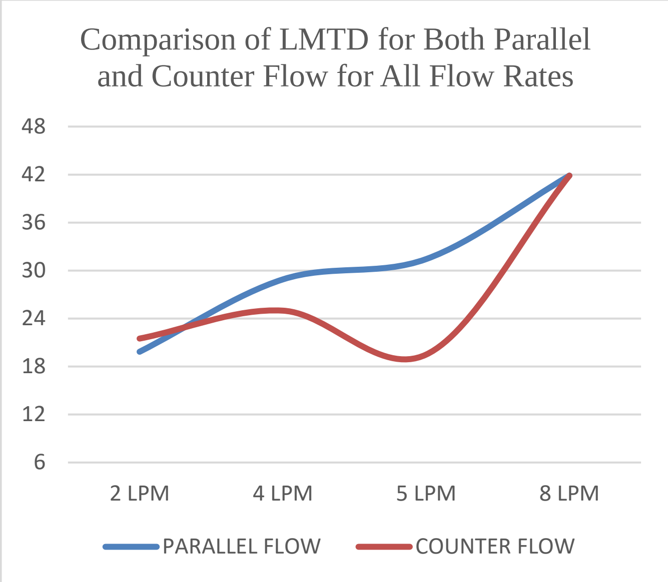
The number of transfer units (NTU) is a procedure for evaluating the performance of heat exchangers. The advantages of this procedure are that it does not require the evaluation of the mean temperature differences hence an unknown stream outlet temperature can be determined directly without any iterative calculations. The effectiveness of the heat exchanger is given by:

Qactual/Qmax

The maximum possible rate of heat transfer is that which would result if one fluid underwent a temperature change equal to the maximum temperature difference available the temperature of the entering hot fluid minus the temperature of the entering cold fluid. This method uses the effectiveness to eliminate the unknown discharge temperature and give a solution for effectiveness in terms of (mass, specific heat capacity, Area, and overall heat transfer coefficient.

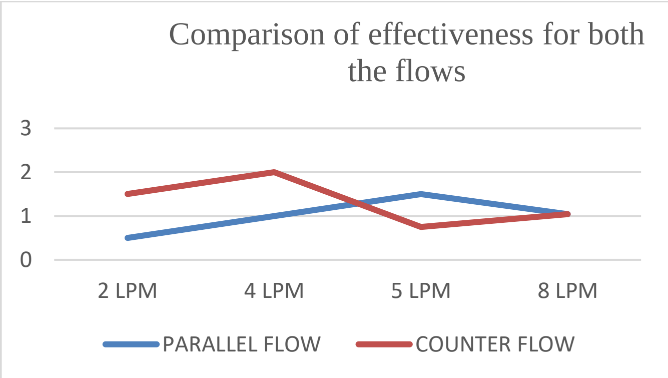
5. Results and Discussion

The comparison of LMTD for both the flow is shown in below graph. From the above we can say that at 2 LPM flow rate LMTD value for parallel flow is higher as compared to Counter flow after flow rate 4 LPM the value of LMTD for parallel flow rate decreases up to 5 LPM it increases up to 8 LPM. For counter flow LMTD value at 2 LPM is lower than Parallel flow and it is decreases up to 5 LPM then after 5 LPM it increases to 8 LPM. It is seen that counter flow continuously increases compared to parallel flow.



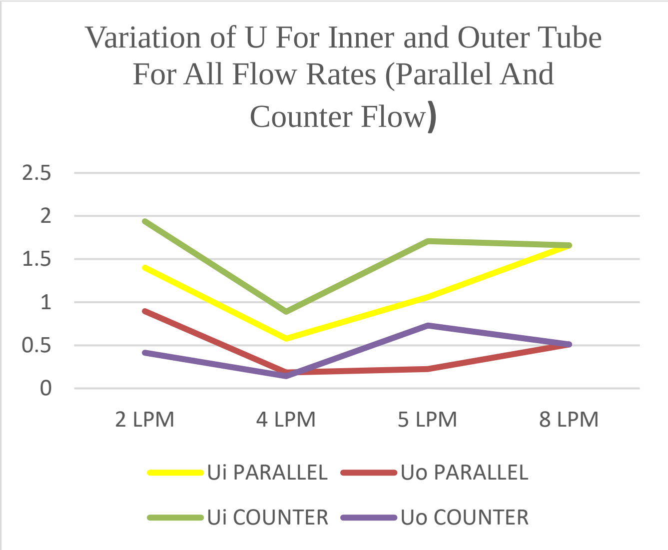
Graph. 1 Comparison of LMTD for Both Parallel and Counter Flow for All Flow Rates

The comparison of Effectiveness for both the flow is shown in below graph. From the graph we can say that at 2 LPM flow rate effectiveness value for counter flow is higher as compared to parallel flow after flow rate 4 LPM the value of effectiveness for counter flow rate decreases up to 5 LPM. And for parallel flow it increases up to 5 LPM and decrease to 8 LPM.



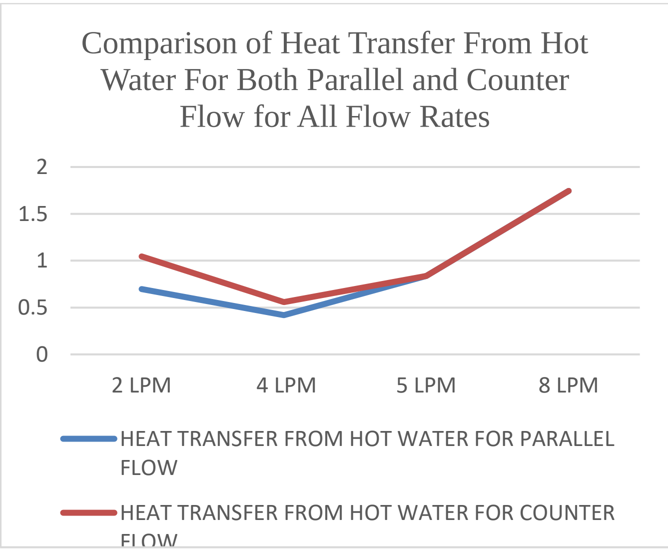
Graph 2 Comparison of Effectiveness for Both Parallel and Counter Flow for All Flow Rates

The comparison of Overall heat transfer coefficient for both the flow is shown in below graph. From the graph we can say that at 2 LPM flow rate Uo value for counter flow is lower as compared to parallel flow after flow rate 4 LPM the value of Uo for counter flow rate increases up to 5 LPM and then decrease to 8 LPM. And for Counter flow it decreases up to 5 LPM and decrease to 8 LPM. At 2 LPM Ui value of counter flow is maximum compared to Ui value of parallel flow arrangement. Then it is suddenly reducing at 4 LPM and again it is increasing from 4 LPM to 5 LPM and it is constant from 5 LPM to 8 LPM as shown in graph below. The Ui value for parallel flow arrangement from 2 LPM to 4 LPM decreases and after 4 LPM to 8 LPM it is increases. From the graph we can say that Overall heat transfer coefficient of inner tube for counter flow arrangement is higher. Initially, the overall heat transfer coefficient of outer tube for counter flow arrangement is less but as the flow rate increases from 4 LPM to 5 LPM the overall heat transfer coefficient is also increases. For parallel flow arrangement outer tube overall heat transfer coefficient decreases as the flow rate increases from 2 LPM to 4 LPM and after 4 LPM it increases to less extent and up to 8 LPM it is increases but in less amount.



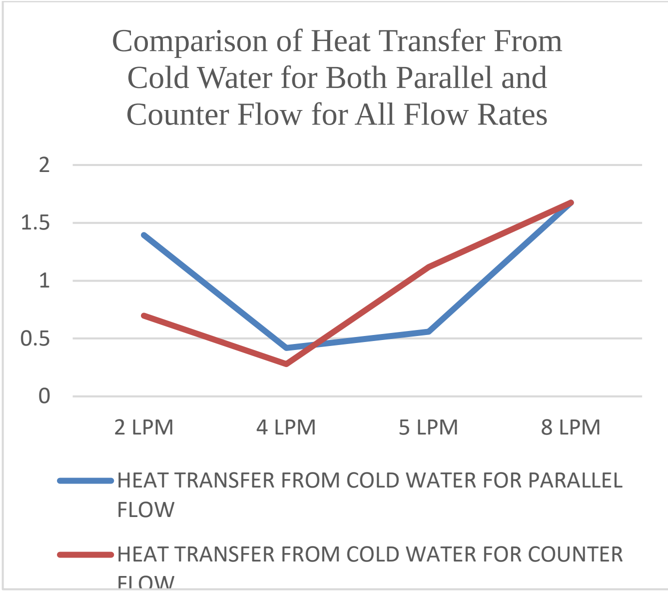
Graph 3 Variation of U For Inner and Outer Tube for All Flow Rates (Parallel and Counter Flow)

The comparison of heat transfer from hot water for both the flow is shown in below graph. From the graph we can say that at 2 LPM flow rate heat transfer from hot water value for counter flow is higher as compared to parallel flow, after flow rate 2 LPM the value of heat transfer from hot water for counter flow rate decreases up to 4 LPM and then increases to5 LPM. From 5 LPM the heat transfer from hot water is same for both the flow. From the graph we can say that after 5 LPM flow rate the heat transfer is same for both the flow but at lower flow rates the heat transfer from hot water is more in counter flow arrangement.



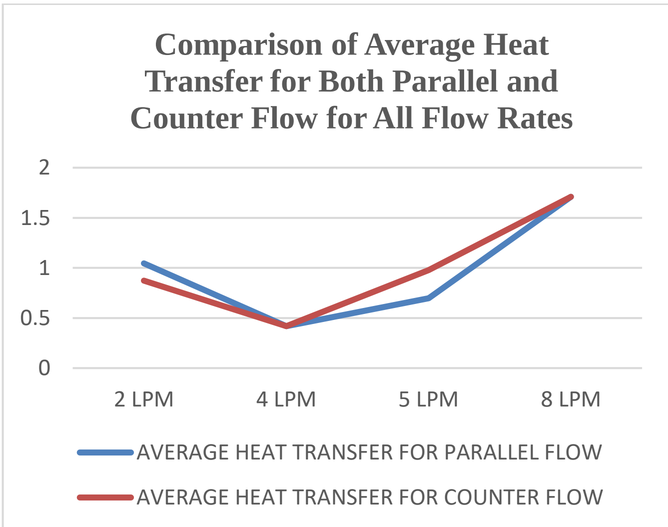
Graph 4 Comparison of Heat Transfer from Hot Water for Both Parallel and Counter Flow for All Flow Rates

The comparison of heat transfer from cold water for both the flow is shown in below graph. From the graph we can say that at 2 LPM flow rate heat transfer from cold water value for counter flow is higher as compared to parallel flow, after flow rate 2 LPM the value of heat transfer from cold water for counter flow rate decreases up to 4 LPM and then increases to5 LPM. From 5 LPM the heat transfer from cold water is increase for both the flow. From the graph we can say that at 8 LPM flow rate the heat transfer is same for both the flow but at lower flow rates the heat transfer from cold water is more in counter flow arrangement.



Graph 5 Comparison of Heat Transfer from Cold Water for Both Parallel and Counter Flow for All Flow Rates

The comparison of average heat transfer for both the flow is shown in below graph. From the graph we can say that at 2 LPM flow rate average heat transfer value for counter flow is higher as compared to parallel flow, after flow rate 2 LPM the value of average heat transfer for counter flow rate decreases up to 4 LPM and meet the parallel flow value. From 5 LPM increases to 8 LPM. At 8 LPM both the values are same for both flow arrangements. From the graph we can say that at 4 LPM flow rate the average heat transfer is same for both the flow and at 8 LPM the average heat transfer values are same for both the flow arrangements.



Graph 6 Comparison of Average Heat Transfer for Both Parallel and Counter Flow for All Flow Rates

COMPUTATIONAL FLUID DYNAMIC RESULT

SCALE RESIDUAL

The Scale Residual is shown in fig. 6.5. Different colour lines represent the different equations and parameters and on X axis it shows number of iterations to perform the calculations. White line denotes the continuity equation, purple line denotes the X velocity. Dark blue line represents the Y velocity, parrot green colour line denotes energy and yellow line represents the position.

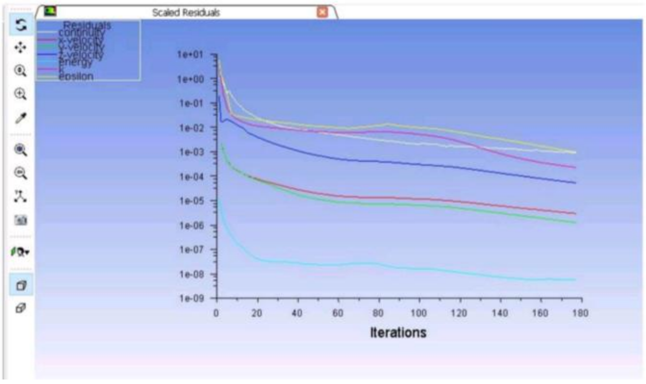


Fig.7 Scale Residual

VELOCITY OF HOT AND COLD FLUID

In this simulation we have done analysis on tube in tube heat exchanger. Hot fluid is passing through the inner tube and Cold fluid is passing through the outer tube. The heat is transferred from hot fluid to cold fluid and hot fluid get cool down from 40 °C to 35°C and Cold fluid get heated from 25°C to 30°C. It means we will get temperature difference of 5°C for counter flow. For parallel flow this difference become less i.e. 3°C. By changing the dimension and materials we can get different values of the temperature difference. The velocity of both hot and cold fluid is shown in below fig. 6.6 and 6.7.

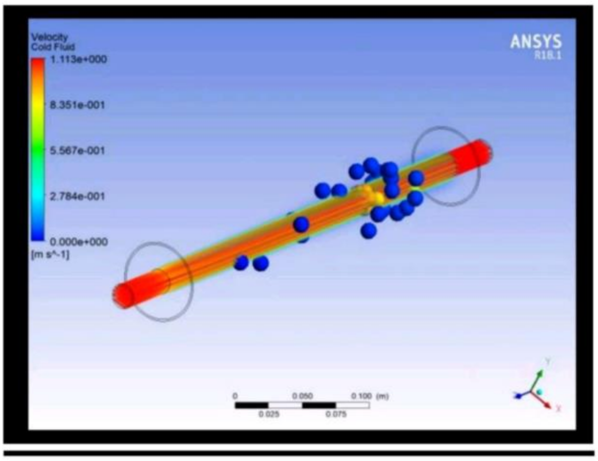


Fig. 8 Velocity of Hot and Cold Fluid

CONCLUSION

In this study, the tube in pipe heat exchanger was designed, manufactured, and integrated with the whole mechanism. The tube pipe heat exchanger is the simplest in design and very effective mode for heat transfer. The performance of the heat exchanger was measured and we found very small difference in the experiential value of heat transfer and the theoretically calculated values. For manufacturing a double pipe heat exchanger, there are many factors to be considered. The two major factors among them are selection of material of the both the inner and outer pipe and the selection of the overall dimensions of the pipes, as per the application. The selection must be done in such a way that we get optimum mechanical and economic advantages. The review indicates that Heat Exchangers are the heat transfer devices which are used in different applications. A good agreement is obtained between the experimental results of counter & parallel flow in that counter flow is more efficient for same flow rate. From the experimental results it is concluded that at higher flow rate i.e. 8 LPM all the parameters for both the flow arrangement are same. LMTD, Overall heat transfer coefficient, Average heat transfer, Heat transfer from hot and cold water all these parameters' values are same for 8 LPM flow rates for both parallel and counter flow arrangements.

In this CFD analysis of tube in tube heat exchanger we found that hot fluid gets cool down and cold fluid gets heated up to 5°C in the counter flow study and for parallel flow study the difference is 2 to 3°C. As we increase the number of iterations the solution gets converge and it will give more accurate results but if we use 500 iterations the temperature difference is less for both the flow. Also, we can conclude that if we increase the flow rate then the temperature difference and velocity counters also change. For counter flow 1000 iterations and 4 lpm flow rate it shows good results. While, in parallel flow arrangement is shows less temperature and velocity difference at 4 lpm flow. If we increase the flow of fluid in counter flow the temperature difference increases and decreases with decreasing flow rates. Also, for parallel flow the results are same but the variation in the temperature is less compared to the cross-flow arrangement. From this study finally we can conclude that if we increase the flow rate and we can use cross flow arrangement for higher length heat exchanger we will get more temperature difference compared to parallel flow arrangement.

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