COMPUTATIONAL FLUID DYNAMICS ANALYSIS OF SHELL AND TUBE HEAT EXCHAGER WITH HAVING DIFFERENT TYPES OF FINS

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***Abstract*: A shell and tube heat exchanger is used as industrial application because of its compact structures and effective heat transfer area through inlet metal pipe and outlet metal pipe. The importance of shell and tube heat exchanger as it provides typically higher surface area density ranging in metal pipes along with the baffles are arranged in the system to support the tubes, prevent tube vibration and sagging also it guides the flow of heat transfer coefficient directionally. A CFD (computational fluid dynamics) process is studied in this study using ANSYS fluid fluent. Designing of shell and tube heat exchanger is performed using SOLIDWORKS software which is a CAD modeling software. In this study 4 different type of shell and tube heat exchanger is designed and analyzed to find out thermal behavior of shell and tube heat exchanger. 3 different type of fins are used in this study which is spiral fins, baffles and rectangular fins on inner hot fluid pipe. Results are compared in terms of hot and cold fluid throughout the heat exchanger. And the effectiveness is calculated for each case. According to the results, heat exchanger with having baffles and rectangular fins provides better effectiveness as compared to other type of fins.**

Introduction

Heat exchangers are devices used to transfer heat between two or more liquids. These usually contain a lot of active or auxiliary fluid such as water or air which removes or absorbs heat from valuable substances such as oil, petrochemical and liquids. There are many types and designs of heat exchangers. Hot and cold liquids can be separated by a highly conductive wall (usually steel or aluminium pipe) or can be connected directly. The water can have similar or different components (such as water-liquid, carbon dioxide). Changes in both fluid parameters are considered by the manufacturer during the manufacturing process. Heat exchanger are different from oil, electricity or nuclear reactors such as boilers. The source of the heat and the receiving medium must be liquid. Liquid is defined as anything that moves under the shear or external force, including liquids, air, and steam. Heat exchanges are widely used in many industries such as the food, medical, scientific and medical industries, where heating or cooling is the final or intermediate phase in the preparation of beverages for further processing. They can also be used to control germs in food and medicine. There are many cases in which the use of heat exchangers is considered to be effective.

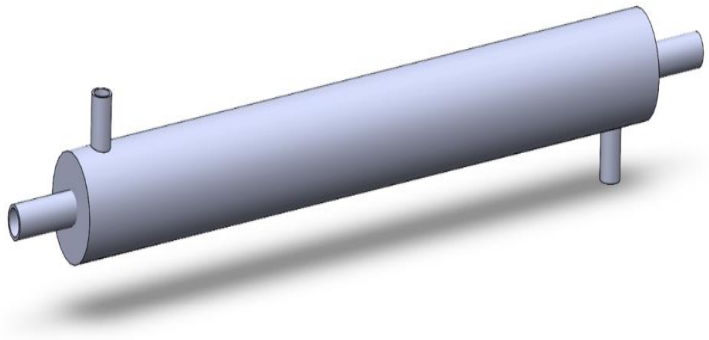
Heat exchanger is a device that converts heat between two or more liquids at different temperatures and exposure to heat. In Heat exchanger, heat dissipation occurs from very hot water to cold water. Usually, the fluid portion is not changes in temperature. Heat exchanger can be classified according to their modification methods, its operating system, fluid component, and geometric design. Several possible components are briefly described in the section. Because Heat exchanger transfers heat energy between water, it is simpler mathematics and physical bases of thermal conductivity are also provided. All types of heat exchangers work using the same thermodynamic principles as the heat transfer method. These principles describe how heat energy is transferred to a greater degree. The three bodies connect in a heat transfer system: hot water, cold water, and a wall separating the two waters. Energy flows from hot water through a wall or block and then into cold water. Below are some thermodynamic tips to help you understand how heat exchangers work: A Heat exchanger is a device designed to be able to transfer heat from one fluid medium to another fluid medium. They support the temperature between two water at different temperatures by preventing them from mixing. Various functions of the heat exchanger, evaporators, air conditioning and refrigeration boilers, etc. The heat exchanger works in car radiators. Heat exchanger is widely used in industry and engineering. The process of making heat exchangers is very complicated, since an accurate analysis of thermal conductivity, efficiency and intermediate temperature is required.

Research Methodology: Our effort to improve effectiveness of heat exchanger by inserting of various kinds of fins. The basic model of heat exchanger have been taken in first case of study. Then to improve effectiveness inserted spiral fins in the heat exchanger .in this arrangement temperature of hot fluid has been reduced to certain extent. Velocity of the fluid has also been calculated.

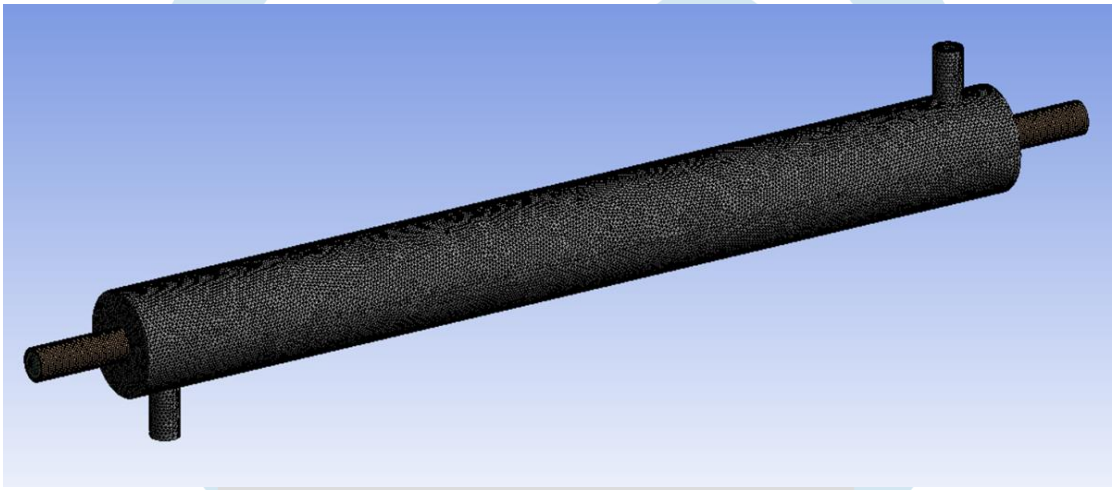
CASE-1	Without fins/ simple heat exchanger
CASE-2	Spiral fins
CASE-3	Baffle fins
CASE-4	Rectangular fins

Simple heat exchanger

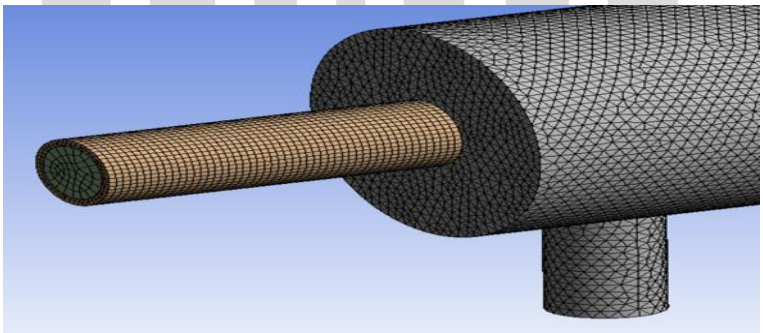
Firstly designed simple heat exchanger in solid works software which is known as CAD modelling software. Basic design of simple heat exchanger have been shown in this slide.in which inlet and outlet port also provided. Here two kind of view have shown



Here meshing of simple heat exchanger have shown in figure Here meshing of the basic heat exchanger is provided through the Ansys software And the value of nodes and elements have given this table.



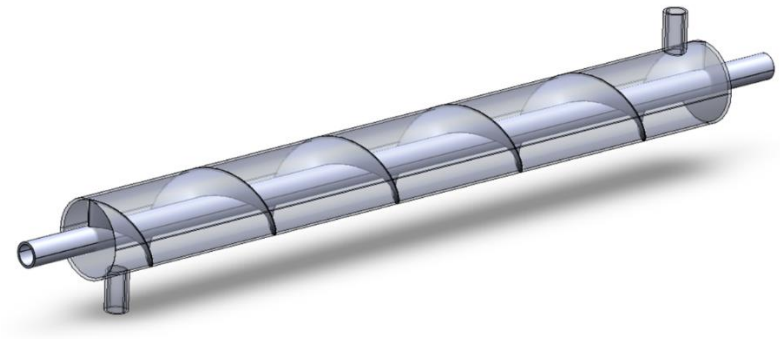
Meshing of simple heat exchanger



NODES	180736
ELEMENTS	360696

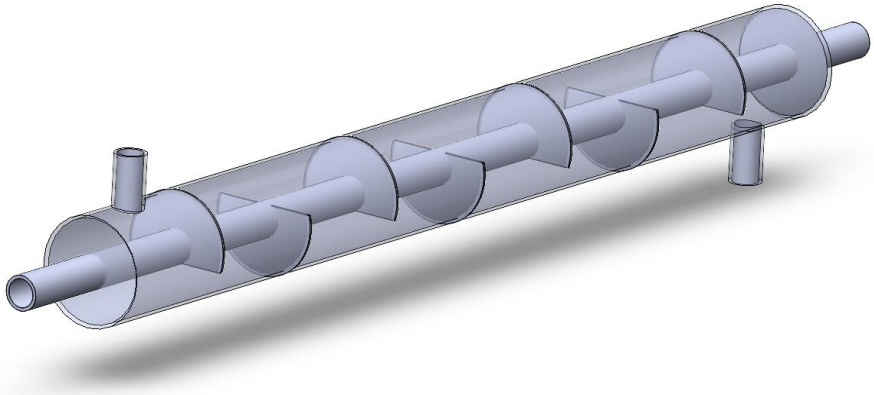
Heat exchanger with spiral fins

Heat exchanger with spiral fins have designed by solid works software and ansys software.in this type of arrangement trying to increase effectiveness of heat exchanger also in the design input and output valve have provided.



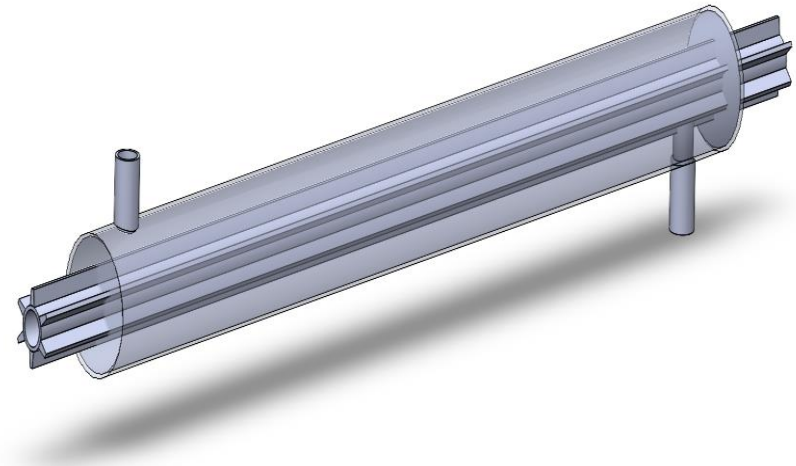
Heat exchanger with baffle fins

Heat exchanger with baffle shaped fins have been used in this type of heat exchanger. With the help of computational fluid dynamics through the Ansys software analysis has been done to improve effectiveness with the use of baffle shape fins in the heat exchanger.



Heat exchanger with rectangular fins

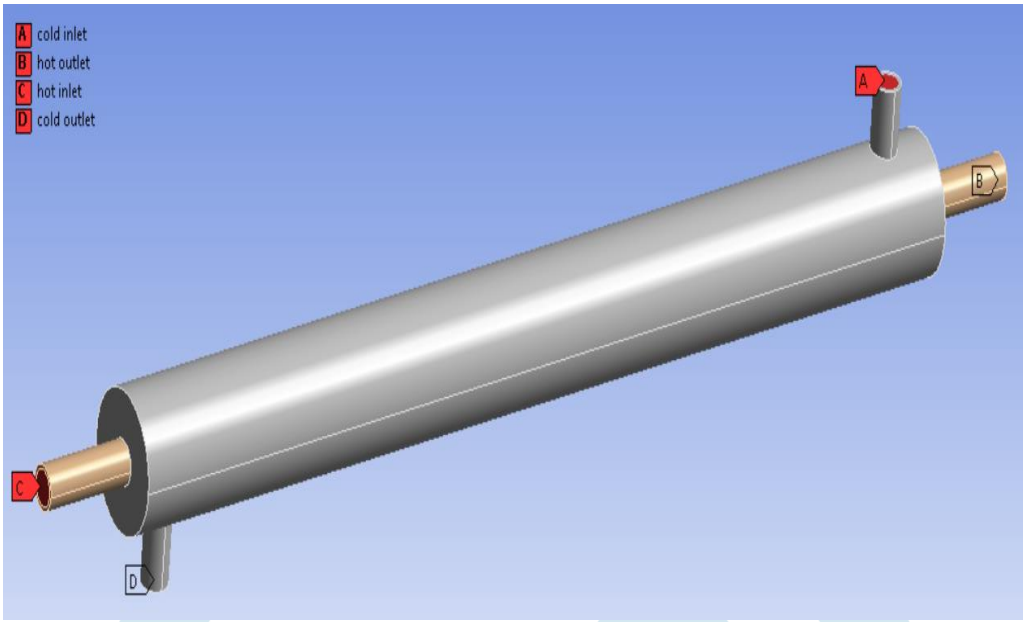
Heat exchanger with rectangular fin have designed in which rectangular fin has been inserted in the outer wall of the inner pipe also for the improvement of effectiveness of heat exchanger this type of arrangement has been done and with the help of computational fluid dynamics fluid flow ,velocity ,temperature has been calculated.



Boundary conditions

Here cold fluid enters from valve A hot fluid enters from valve C and exit of cold fluid is valve D and exit of hot fluid is from valve B.

Cold fluid inlet temperature = 298.15 K
Hot fluid inlet temperature = 373.15 K
Mass flow rate of hot fluid = 0.025 kg/s
Mass flow rate of cold fluid = 0.03 kg/s
Water is selected as fluid
Copper is selected as pipe material

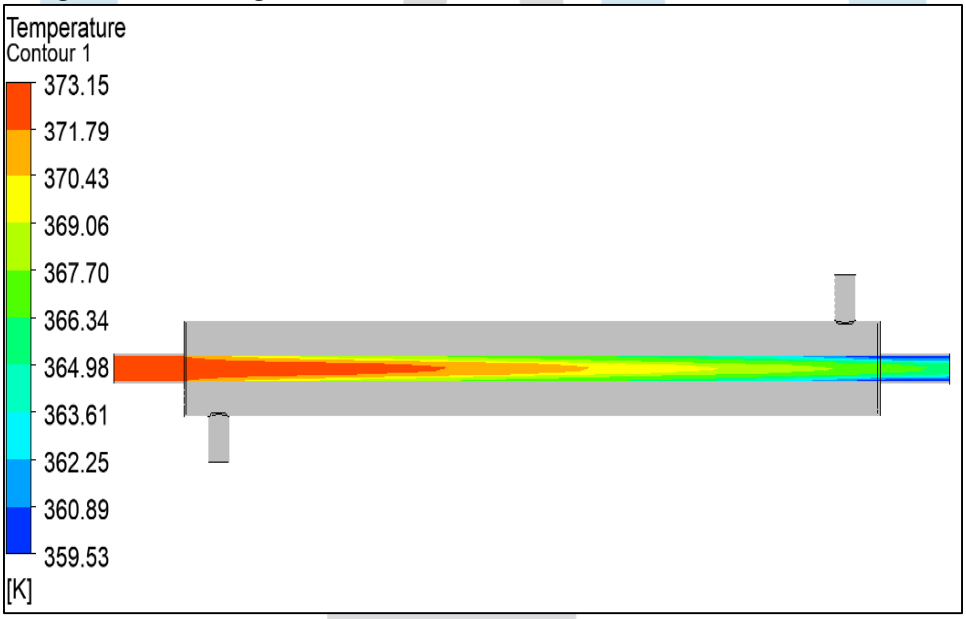


Results

Analysis of various parameter through the computational fluid dynamics in the Ansys software has been done for heat exchanger with the use of different types of fins.

Temperature variation of simple heat exchanger

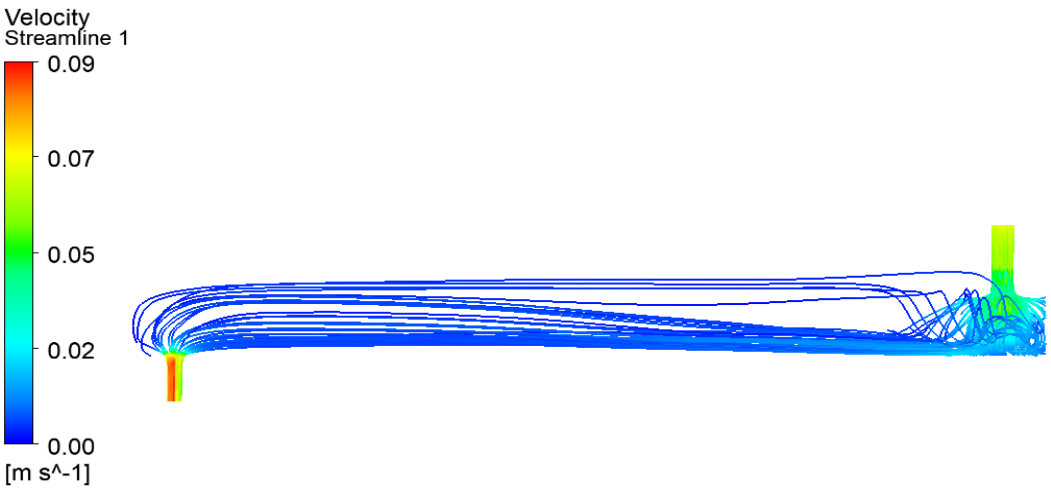
Temperature variation has been shown of simple heat exchanger. Temperature of hot fluid inside the small tube decreasing continuously with the length of heat exchanger.



Temperature variation of simple heat exchanger

Cold fluid flow in simple heat exchanger

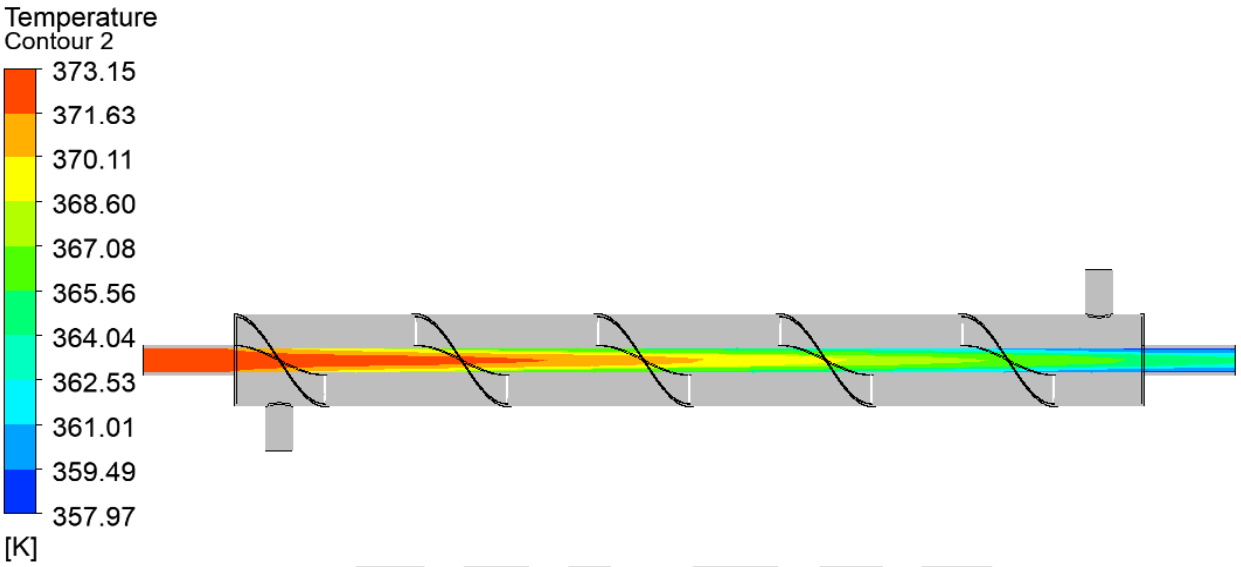
Velocity distribution shown in figure 24, in which velocity distribution of cold fluid in simple heat exchanger with inlet and outlet valve. And turbulence in minimum in simple heat exchanger.



Velocity distribution of simple heat exchange

Temperature distribution in the spiral fins heat exchanger

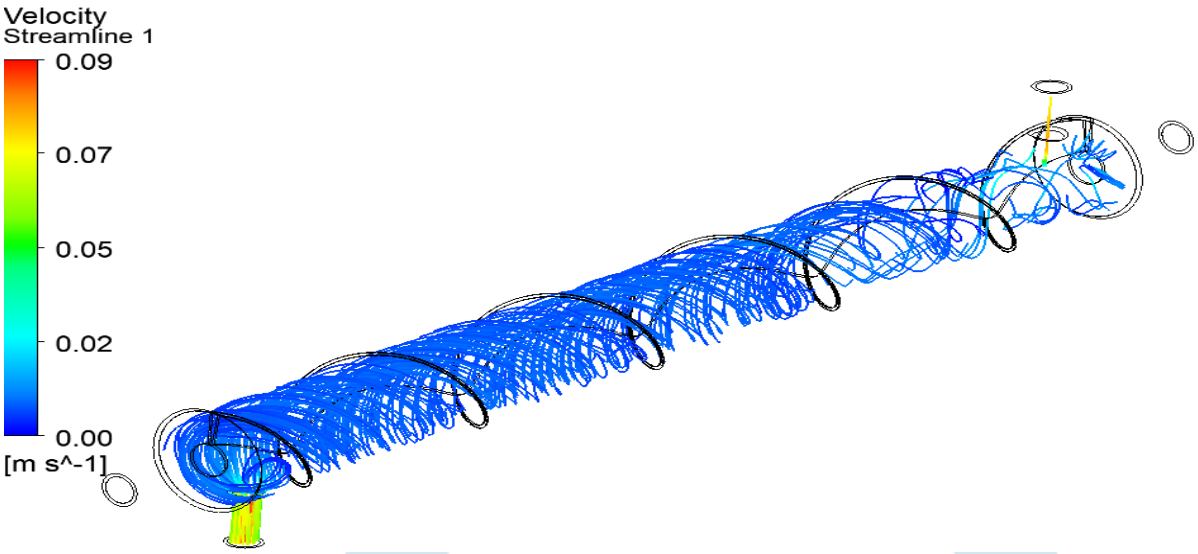
Temperature distribution in spiral fins heat exchanger has been shown in figure 25 in which temperature of hot fluid in smaller tube which is continuously decreasing with the length of pipe and larger diameter pipe cold fluid is flowing and temperature of cold is rising.



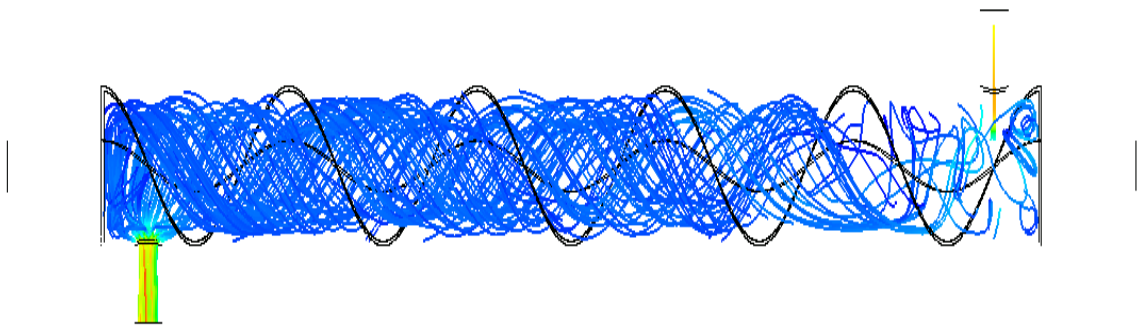
Temperature distribution of spiral fins heat exchanger in inner pipe

Cold fluid flow of spiral fins heat exchanger

Velocity of fluid inside the heat exchanger with spiral fins has shown in which turbulence has been created due to spiral fin. Due to spiral shape fins, both hot and cold fluid will be in contact for a longer time. And heavy turbulence has been created in the HE.

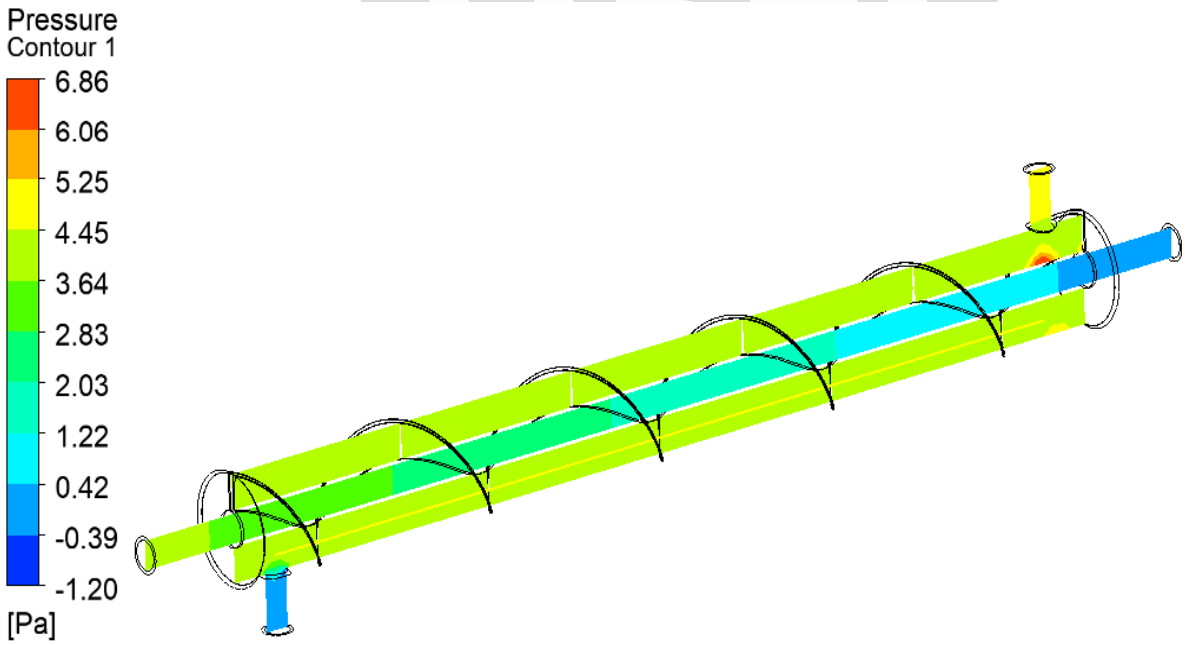


Velocity distribution of cold fluid in spiral fins heat exchanger



Velocity distribution of cold fluid in spiral fins heat exchanger side view

Cold fluid flow pressure distribution in spiral fins heat exchanger

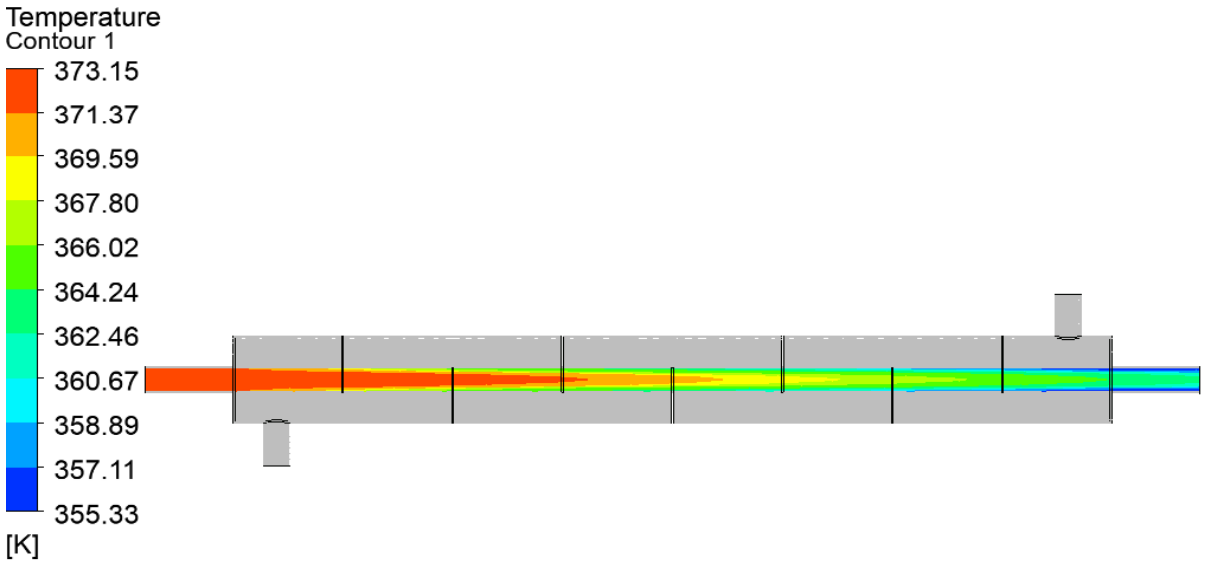


.Pressure distribution of cold fluid in spiral fins heat exchanger

In this figure pressure distribution have shown which has calculated with the help of Ansys software. Here blue colour pressure contour show lowest temperature while red colour shown highest pressure .pressure distribution in heat exchanger with spiral fins is uniform in outer pipe.

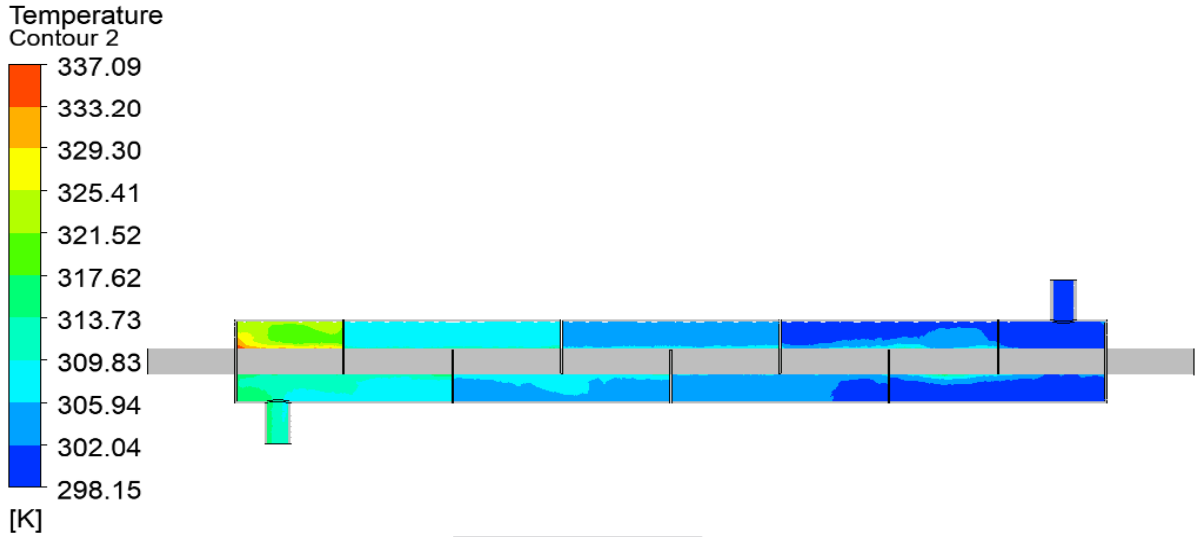
Temperature variation of baffle fins heat exchanger

Temperature variation has shown in figure which is calculated through the Ansys software with the help of solid works, red contour show maximum temp which is of hot fluid and blue contour show temperature of cold fluid also intermediate temperature also have shown. Temperature has given in kelvin.in first figure inner tube. In the figure 30 in smaller tube hot fluid is entering and temperature of which is decreasing continuously.



Temperature distribution in baffle fins heat exchanger in inner tube

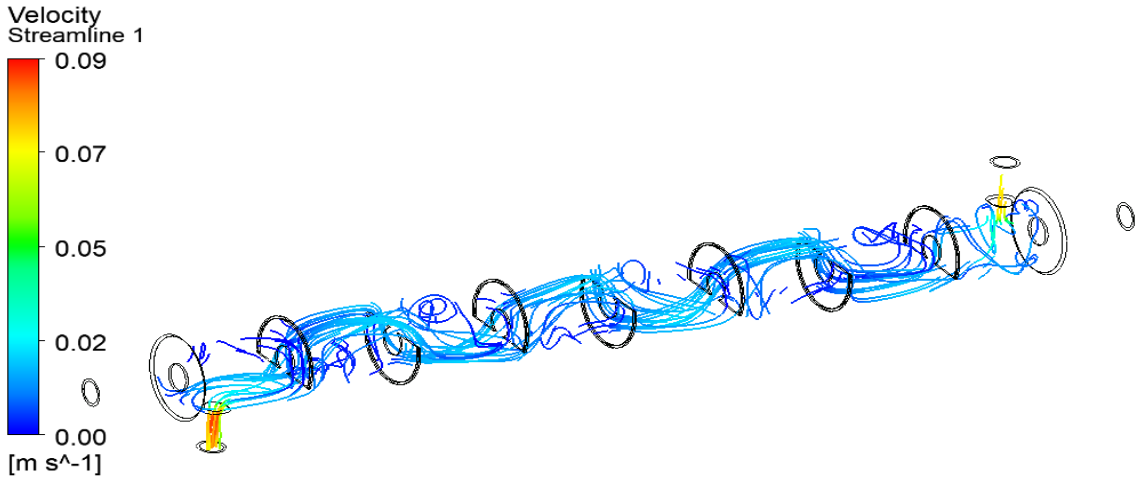
In the figure cold fluid is flowing in the larger diameter pipe.



Temperature Distribution of cold fluid in baffle fins heat exchanger side view

Cold fluid flow in heat exchanger with baffle fins

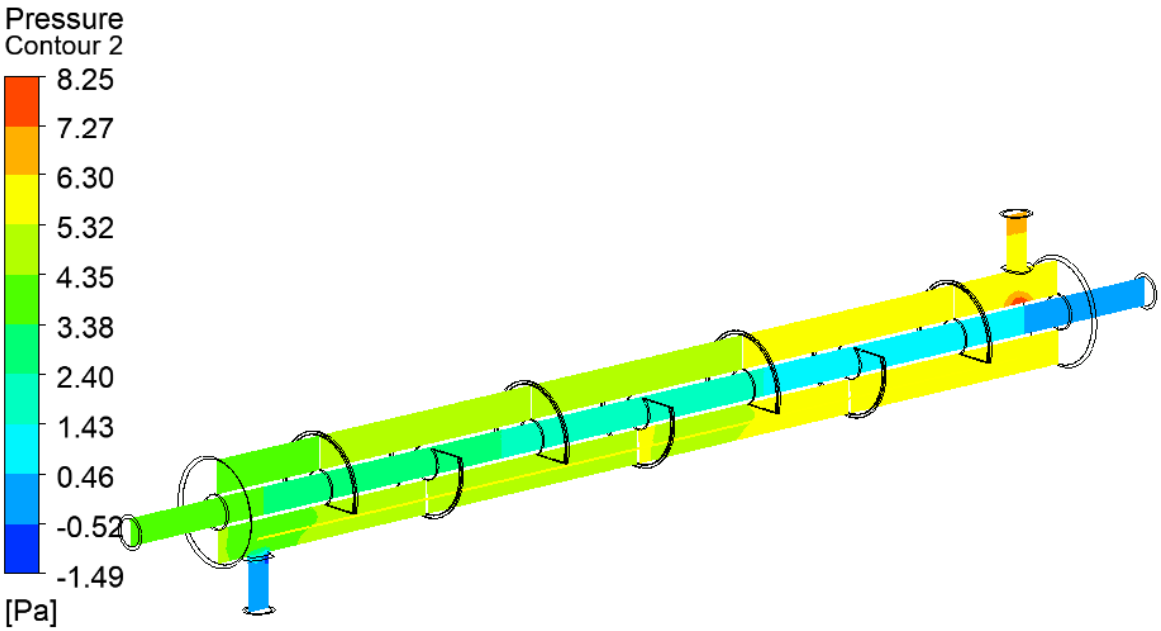
Velocity distribution of baffle fins heat exchanger has been shown in figure 32 and 33 .here turbulence is increasing continuously and water contact time of hot and cold fluid have risen.



Velocity distribution of cold fluid in baffle fins heat exchanger

Pressure throughout heat exchanger in baffle fins HE

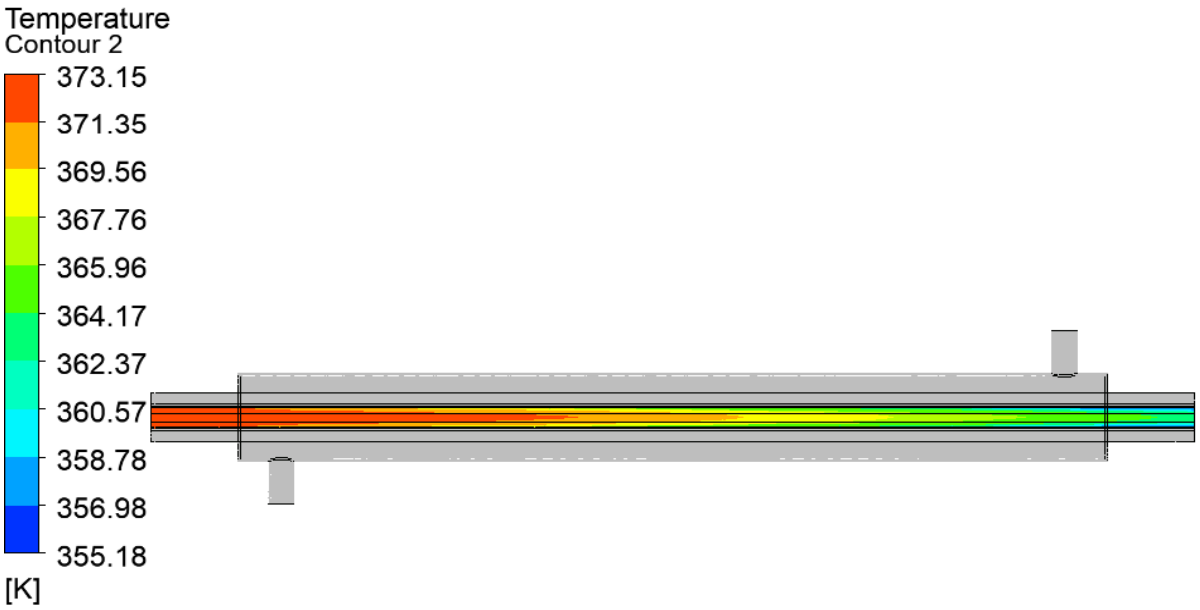
In this figure pressure in heat exchanger with baffle shape fins, gradually increases in outer pipe and in inner pipe pressure decreases continuously. Blue colour contour show minimum temperature and red colour show max pressure and pressure has been calculated in pascal.



Pressure distribution in baffle fins heat exchanger

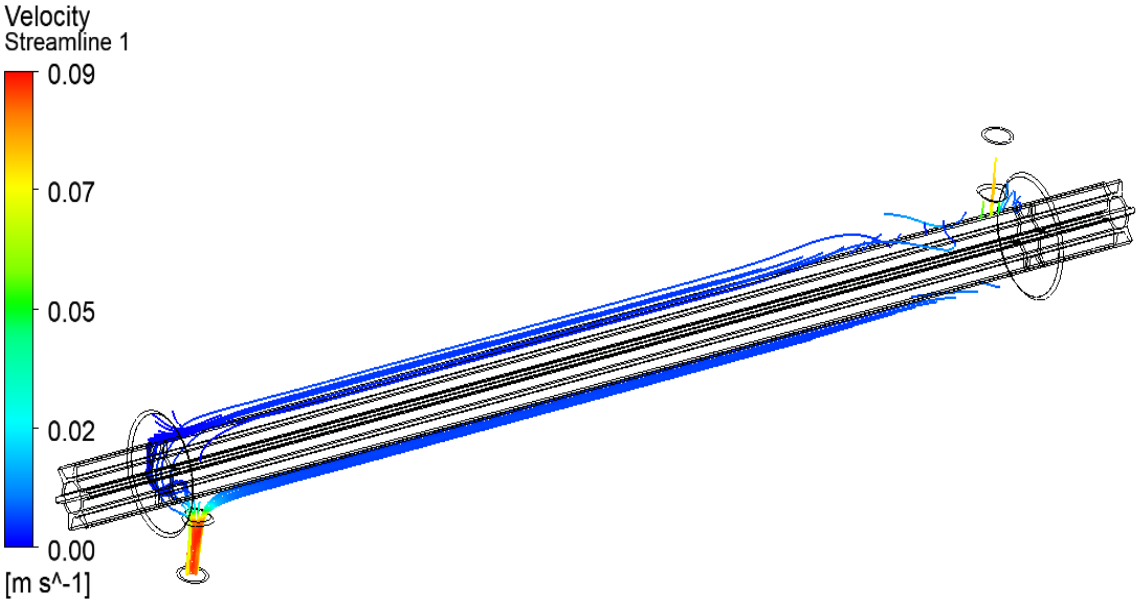
Temperature variation in rectangular fins heat exchanger

Temperature of hot fluid in smaller tube has shown in figure 35 which is decreasing continuously. Also temperature variation cold fluid in larger diameter pipe has shown in figure 36. With the help of this type fins in the HE contact time increased between hot and cold fluid.



Temperature Distribution of cold fluid in rectangular fins heat exchanger in inner tube

Cold fluid flow velocity distribution inn rectangular fins heat exchanger
In the below figure 37 and 38, velocity is increasing from inlet to outlet valve with the length of the pipe of HE and turbulence of the fluid also increasing due to rectangular fins in the HE.



Velocity distribution of cold fluid in rectangular fins heat exchanger

.Velocity distribution of cold fluid in rectangular fins heat exchanger side view

Hot and cold fluid temperature

Hot fluid lowest temperature of simple heat exchanger ,heat exchanger with spiral fin ,heat exchanger with baffle shape fins and heat exchanger with rectangular fins have shown in the below table .

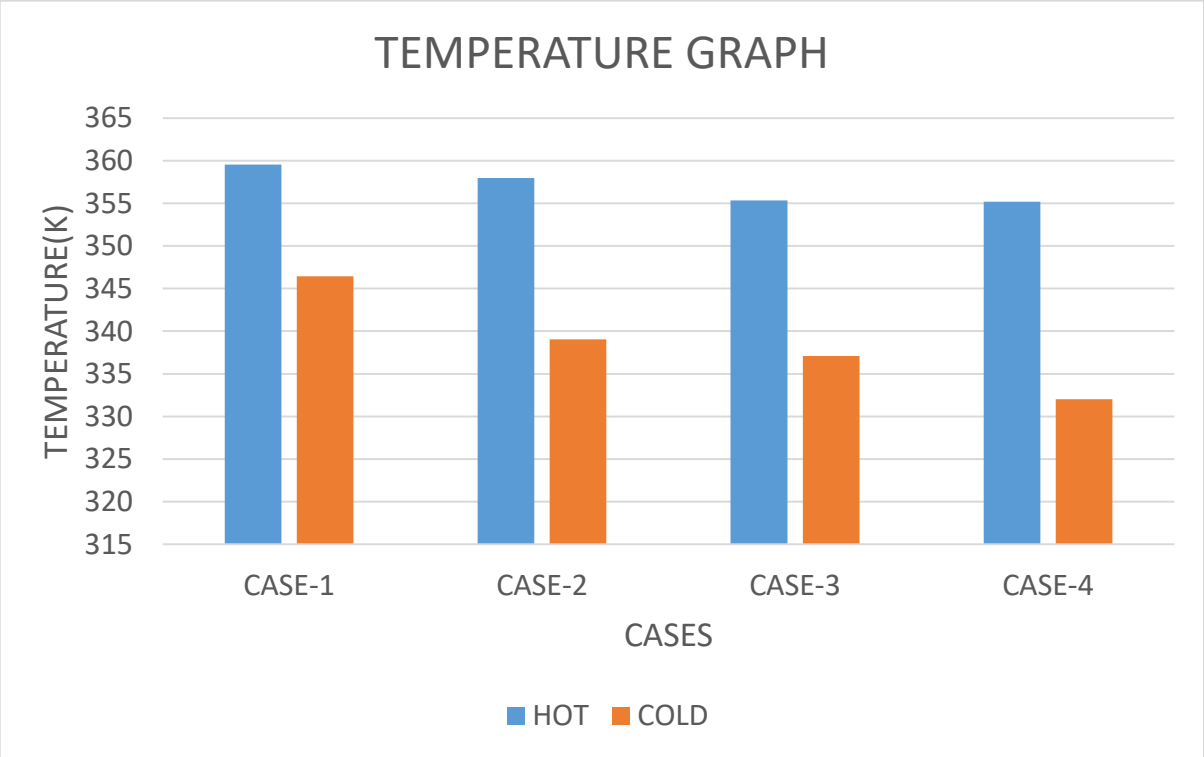
Table hot fluid lowest temperature

	Hot fluid lowest temperature
CASE-1	359.53
CASE-2	357.97
CASE-3	355.33
CASE-4	355.18

In below table, for all the four cases of our study, highest temperature of cold fluid which has been achieved by the use of different types of fins therefore our effectiveness and heat transfer also improved.

Hot and cold fluid temperature

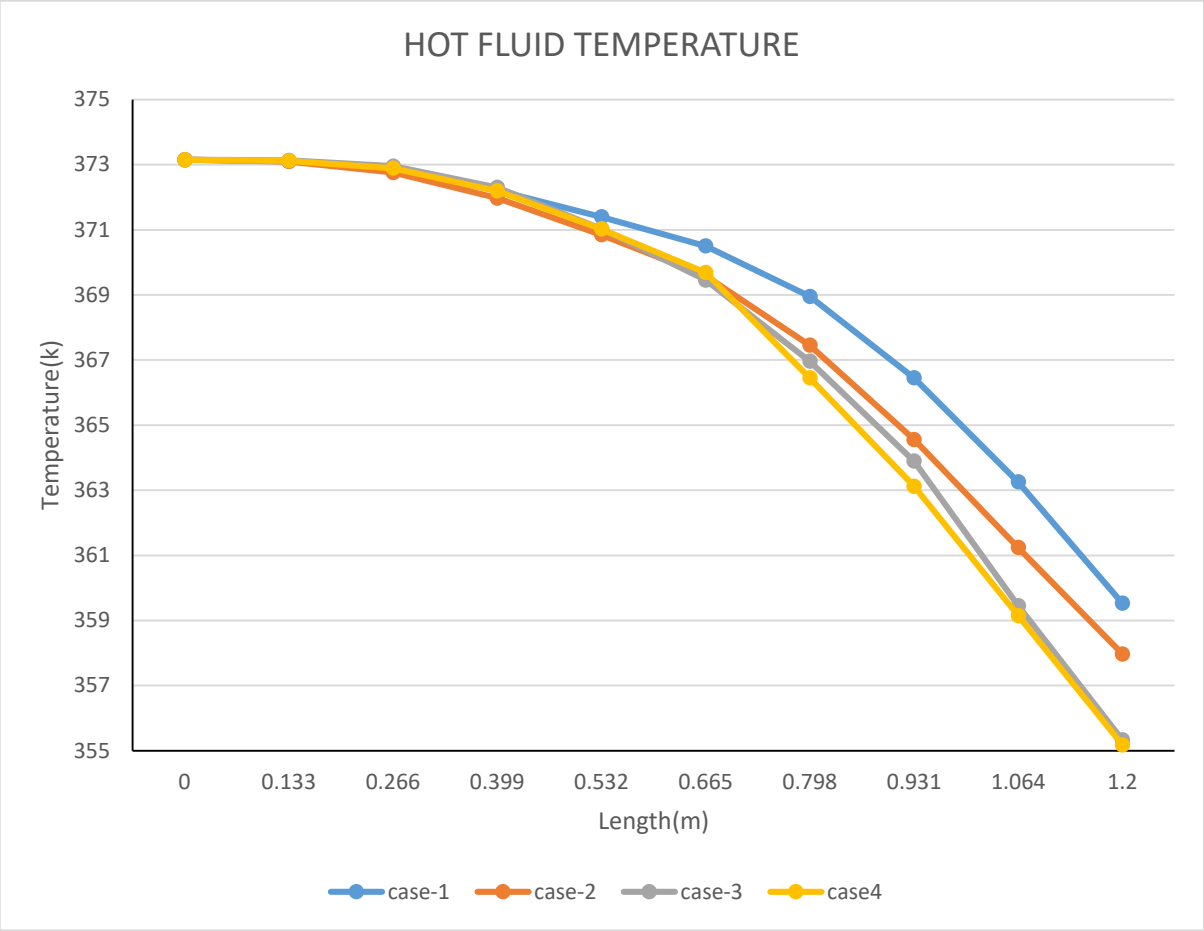
Figure show all the four cases temperature distribution of hot and cold fluid respectively .in all the four cases results are continuously showing promising result and temperature of both hot and cold fluid is minimum in shell and tube heat exchanger with rectangular fins .



Temperature graph of hot and cold fluid

Hot fluid temperature throughout the length

In the figure 40 hot fluid temperature variation with respect to length has been shown. Lowest temperature has been obtained from spiral fin heat exchanger and rectangular fins heat exchanger, which is very effective.



Temperature distribution with respect to length of heat exchanger

EFFECTIVENESS

The effectiveness (ϵ) of the heat exchanger is defined as the ratio of the actual heat transfer to the maximum possible heat transfer. Qmax is the minimum of two components. The effectiveness of a heat exchanger depends on the temperature of the heat exchanger, the temperature of the wall heater separating the two heat carriers, the type of heat exchanger, and so on

$$\epsilon = \frac{T_{hi} - T_{he}}{T_{hi} - T_{ci}}$$

T_{hi}= hot inlet temperature

T_{he}= hot outlet temperature

T_{ci}= cold inlet temperature

In this table temperature of hot and cold fluid of all the four cases of study has shown.

Hot and cold fluid temperature of all cases

	Hot Temperature	Cold Temperature
CASE-1	359.53	346.43
CASE-2	357.97	339.04
CASE-3	355.33	337.09
CASE-4	355.18	332.01

In this table, effectiveness of the heat exchanger have shown. Calculation of effectiveness has been done by the above formula for all the four cases and maximum effectiveness has been obtained from shell and tube heat exchanger with rectangular fins..

Effectiveness of all four types of heat exchanger

	Effectiveness
CASE-1	0.298339
CASE-2	0.33289
CASE-3	0.391362
CASE-4	0.394684

Conclusions

Shell and tube heat exchanger is analyzed in this study with using computational fluid dynamics by varying the design of fins inside of shell and tube heat exchanger. 3 type of fins are analysed which are spiral fins, baffle fins and rectangular fins along with inner tube. Here the fluid is selected as water and material of pipe is considered as copper. Hot fluid is flowing through inner tube which decreases its temperature by contacting with cold fluid throughout the pipe. Here the case of rectangular fins provided better results in terms of temperature decrease which is 355.18 K., and the effectiveness of heat exchanger is calculated and the highest effectiveness of 0.3946 is provided in case of having rectangular fins.

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