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# A Schematic Design and Thermal Approach of Helical Tube Heat Exchanger

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## Abstract:

Heat exchangers are the important engineering equipment's used for transferring heat from one fluid to another. Heat exchangers are widely used in various kinds of application such as power plants, nuclear reactors; refrigeration and air-conditioning systems, heat recovery systems, petrochemical, mechanical, biomedical industries Helical coil heat exchangers are gaining wide importance now-a-days because it can give high heat transfer coefficient in small footprint of surface area. The performance of heat exchangers has always been an important part to the lifecycle and operation. Whether developing a new heat exchanger or optimizing the design of an existing one, understanding the coupled fluid flow and heat transfer physics, or the "conjugate heat transfer" process, associated with heat exchanger operation, is essential to provide better cooling performance. The flow pattern in the shell side of the heat exchanger with continuous helical baffles was forced to be rotational and helical due to the geometry of the continuous helical baffles, which results in a significant increase in heat transfer coefficient per unit pressure drop in the heat exchanger. Based on these results, design iterations can be easily implemented which can predict the influence of design parameters such as tube diameter, number of loops, loop distribution, etc. ultimately, an optimal fluid flow.

*Keywords* — **Heat exchangers, helical baffles, heat exchanger feasibilities.**

## 1.0 Introduction:

A Heat Exchanger may be defined as equipment which transfers energy from a hot fluid to a cold fluid, either maximum or minimum rate within minimum investment and running cost. In this process never two fluids mixed with each other. This device provides a flow of thermal energy between two or more fluids at different temperatures. Shell and tube heat exchangers are most versatile type of heat exchanger; they use in a wide variety of engineering applications like power generation, waste heat recovery, manufacturing industry, air conditioning, refrigeration, space applications, petrochemical industries. In most Industries, the designing and thermal evaluation of heat exchangers is generally carried out in order to reduce cost, material and energy and to obtain maximum heat transfer. The main challenge in heat exchanger design is to make it compact and to get maximum heat transfer in minimum space. The passive enhancement technique using coiled tube has significant ability in enhancing heat transfer by developing secondary flow in the coil. Due to enhanced heat transfer the study of flow and heat transfer in helical coil tube is of vital importance. The first attempt has been made by to describe mathematically the flow in a coiled tube. A first approximation of the steady motion of incompressible fluid flowing through a coiled pipe with a circular cross-section is considered in his analysis. The flow through a curved pipe has been attracting much attention because helical coiled pipes are widely used in practice as heat exchangers and chemical reactors. The fluid flowing through curved tubes induces secondary flow in the tubes. This secondary flow in the tube has significant ability to enhance the heat transfer due to mixing of fluid. The intensity of secondary flow developed in the tube is the function of tube diameter (d) and coil diameter (D). Due to enhanced heat transfer in helical coiled configuration the study of flow and heat transfer characteristics in the curved tube is of prime important. The several studies have indicated that helical coiled tubes are superior to straight tubes when employed in heat transfer applications. The centrifugal force due to the curvature of the tube results in the secondary flow development which enhances the heat transfer.

**BAFFLES:**

Baffle is a device used to put down the flow of a fluid, gas etc. Baffles serve two important functions. They support the tubes during assembly and operation and help prevent vibration from flow induced eddies and direct the shell side fluid back and forth across the tube bundle to provide effective velocity and Heat Transfer rates. The diameter of the baffle must be slightly less than the shell inside diameter to allow assembly, but must be close enough to avoid the significant performance penalty caused by fluid bypass around the baffles. Shell roundness is important to achieve effective sealing against excessive bypass. Baffles can be made from a variety of materials compatible with the shell side fluid. They can be punched or machined. Some baffles are made by a punch which provides a lip around the tube hole to provide more surfaces against the tube and eliminate tube wall cutting from the baffle edgeIt is apparent that higher heat transfer coefficient results when the liquid is maintained in the state of turbulence. To induce turbulence outside the tube it is customary to employ baffles, which cause the liquid to flow through the shell at right angles to the exit of the tubes. Baffles are used to support tubes, enable a desirable velocity to be maintained for the shell side fluid, and prevent failure of tubes due to flow-induced vibration.

**Helical baffle exchanger**:

The Helical Baffle Heat Exchanger is also known as a Helix changer solution that removes many of the deficiencies of Segmental Baffle Heat Exchanger. It is very effective where heat exchanger is predicted to be faced with vibration condition Quadrant shaped baffle segment are arranged right angle to the tube axis in a sequential pattern that guide the shell side flow in a helical path over the tube bundle.

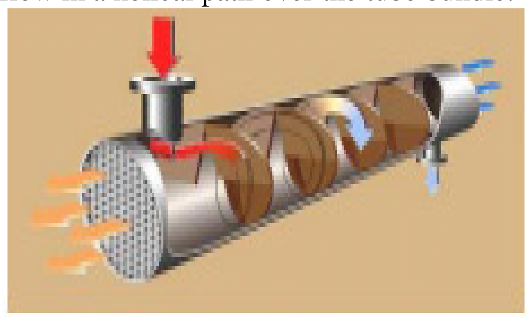

**Figure:**heat exchanger with helical baffle.

The Helical flow provides the necessary characteristics to reduce flow dispersion and generate near plug flow conditions. The shell side flow configuration offers a very high conversion of pressure drop to heat transfer. Advantages over segmental STHE are increased heat transfer rate, reduced bypass effects, reduced Shell Fouling Factor, Prevention of flow induced vibration & Reduces Pumping cost. Shell and tube type heat exchanger with helical baffle diagram is shown in Figure.

**2.0 Literature review:**

**Basawaraj S. HasuDr.G.V.SatynarayanaRao (2017)**

Heat exchangers are used extensively in engineering applications. In present day shell and tube heat exchanger are the most common type heat exchanger widely used used in cars, in planes, in boilers, in ships, in refrigeration systems, in air conditioning systems, in power stations, in oil refineries, in space applications, in renewable energy applications because it suits high pressure applications. heat transfer coefficient per unit pressure drop in the heat exchanger. Based on these results, design iterations can be easily implemented which can predict the influence of design parameters such as tube diameter, number of loops, loop distribution, etc.

**Amitkumar S. Puttewar , A.M. Andhare (2015)** The main challenge in heat exchanger design is to make it compact and to get maximum heat transfer in minimum space. The passive enhancement technique using coiled tube has significant ability in enhancing heat transfer by developing secondary flow in the coil. Due to enhanced heat transfer the study of flow and heat transfer in helical coil tube is of vital importance. The design procedure adopted gives sizing and rating analysis of helical coil heat exchanger and results are found in good agreement with the experimental results

**Pramod S. Purandarea ,Mandar M. Lele (2012)**Heat exchangers are the important engineering systems with wide variety of applications including power plants, nuclear reactors, refrigeration and air-conditioning systems, heat recovery systems, chemical processing and food industries. Helical coil configuration is very effective for heat exchangers and chemical reactors because they can accommodate a large heat transfer area in a small space, with high heat transfer coefficients with constant coil diameter (D), the curvature ratio (δ) increases, which increases the intensity of secondary's developed in fluid flow. The increase in the intensity of secondary's developed in fluid flow increases Nu. Hence, it is desirable to have small coil diameter (D) and large tube diameter (d) in helical coil heat exchange.

**DipankarDe1 ,Tarun K. Pal(2017)** they have presented a compact formulation to relate the shell-side pressure drop with the exchanger area and the film coefficient based on the full Bell–Delaware method. In addition to the derivation of the shell side compact expression, they have developed a compact pressure drop equation for the tube-side stream, which accounts for both straight pressure drops and return losses. They have shown how the compact formulations can be used within an efficient design algorithm. The pressure drop is decreases with the increases of helix angle in all the cases considered.

**3.0 Modeling:**

Modeling is a pre-processor tool; the modeling of shell and tube heat exchanger is created using the CATIA software tools which is a feature-based, parametric solid modeling system with many extended design and manufacturing applications. It is sophisticated computerized software which gives friendly experience.

**Design parameters with CATIA:**

It was later adopted in the aerospace, automotive, shipbuilding, and other industries. Computer Aided Three dimensional Interactive Application (CATIA) is well known software for 3-D designing and modeling for complex shapes. In the present context, the components of heat exchanger are modeled using part drawing features and then assembly modules used, further the assembly of the heat exchanger is model generated. The part drawing is a versatile module where in the whole heat exchanger can be modeled as a single unit as opposed to the assembly module where each part is modeled separately and finally assembled to get the required component using the various options available.

All simulations were conducted using the ANSYS software. However, checking the program library, a modification/insertion was necessary. The AISI 446 stainless steel, with its properties has been inserted into the materials database of ANSYS, and then the geometry was imported from CATIA. The next step has been the mesh generation.

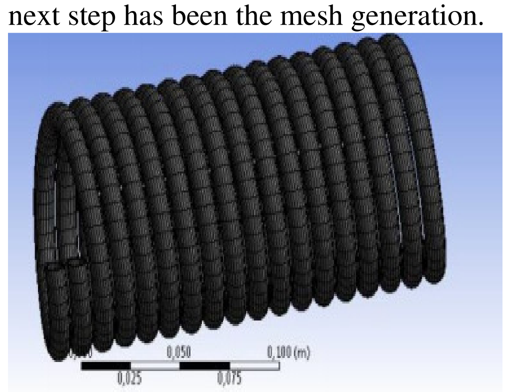


**Figure:** meshed model

Table Number of nodes and elements of the mesh for the steady-state thermal simulation

| | Nodes | Elements |
|---|---|---|
| Pre-heater | 204048 | 30544 |
| Boiler 0-0,5 | 94088 | 16204 |
| Boiler 0,5-1 | 106848 | 17224 |

**Experimental procedure:**

The schematic diagram of the experimental set up is as shown in Fig. The experimental set up consists of a shell in which the helical coil copper tube is placed through which hot water is made to flow with the help of a centrifugal pump. To ensure maximum heat transfer the copper helical coil is fully immersed in the cold water flowing through the shell, the inlet and outlet are so placed as the shell is well insulated so as to avoid the heat loss to the surrounding. The main components in the set up include centrifugal pump, heating element, cold water storage tank and hot water storage tank. The heat exchanger which includes the helical copper tube and insulated shell is perfectly sealed so as to avoid the leakage of hot water flowing through tube and cold water flowing through shell in a counter flow manner.

**Fig-2: Experimental Setup.**

The water in the storage tank is heated using a heating element, as the water reaches to a prescribed temperature. The centrifugal pump circulates the hot water through the helical coil. The ball valves are used to control the flow rate of hot and cold water. A calibrated Rota meter was used to measure the shell side cold water flow rate while for the tube side hot water flow rate a calibrated vane type flow meter is used and data was recorded using a data logger system.

**Helical tube parameters:**

The heat exchanger contains 7 tubes and 600 mm length shell and diameter of 90 mm. The helix angle of helical baffle will be varied from 0 to 200mm. In simulation will show how the pressures vary in shell due to different helix angle and flow rate. The major geometric dimensions include the diameter of the tube (d), the curvature radius of the oil (D) and the coil pitch (increase of height per rotation, b). The following four important dimensionless numbers are considered The present analysis considers the following dimensional and operating parameters.

**Results:**

The analysis is carried out for laminar and turbulent region separately for tube side heat transfer coefficient (*hi*) and *Nu*. The calculations are performed as per the data reduction procedure for helical coil configuration and the results are tabulated for heat transfer analysis. Four different correlations of *Nu* are selected from the literature for the analysis correlations fulfill the conditional requirements of the data selected for the analysis.

**The static structural simulation:**

For the structural study, the most important mechanical properties of the AISI 446 were added in the Engineering Data, as previously described. The geometry and the mash used is the same used for the thermal simulation. The following figures show the total deformation of the coiled tubes and the stress safety factor, defined as the yield stress of the material divided by the equivalent stress actually computed in the The maximum level is reached at the end of the exchanger, where the fixed supports are used. But, also in this case, the value is far from the limit value. The thermal deformations, as stress one, are low, of the order of millimeter. However, the structural simulation only covers the different.

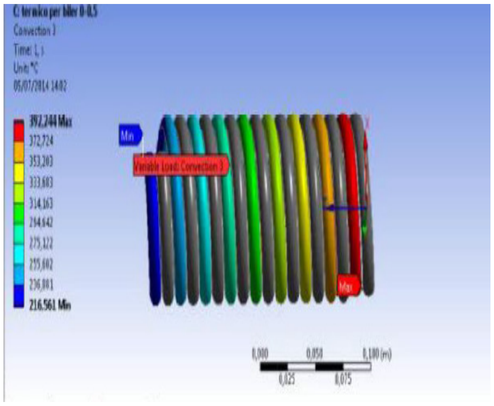

**Figure:** Thermal load applied to the geometry.

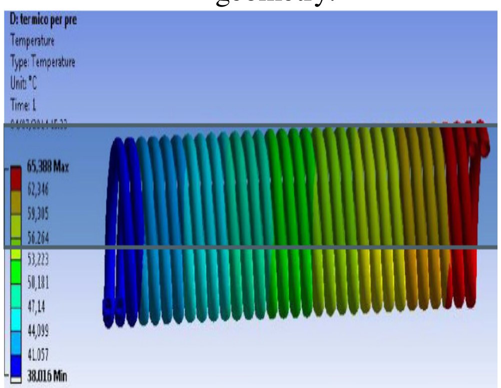

**Figure:**Temperature trend along the pre heater

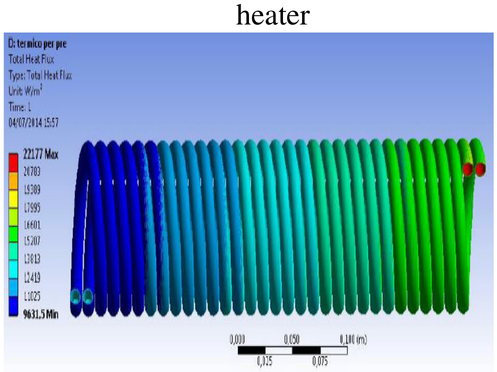

**Figure:**Heat flux trend along the pre-heater(w/m$^2$)

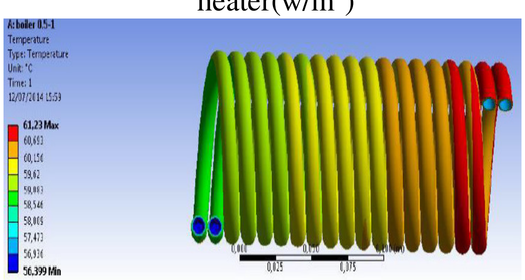

**Figure:** Temperature trend along the boiler

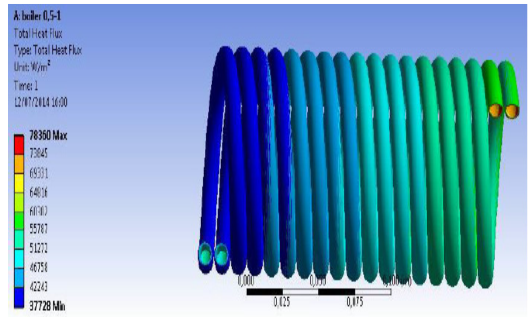

**Figure:** heat flux trend along the boiler

**Conclusions:**

The recovery of heat from the exhaust gases of an engine can lead to numerous advantages both from an economic point of view (fuel economy), once the payback time of the investment has ended, and from an environmental point of view, with consequent lower emissions of greenhouse gases and toxic atmospheric agentsit is necessary to carry out experimental tests. to be absolutely sure of the safety of the "direct" configuration (although the temperatures of self-ignition of working fluids are much higher than those reached by the inner wall of the heat exchanger). The final dimensions of the heat exchanger make it suitable for vehicular applications, primarily for large vehicles such as trucks, trains and large ships. It can also be suitable for smaller vehicles (cars), but more research has to be carried out, with the aim of decreasing the dimensions, reducing the total occupied area and then checked to eventual length reduction. However, thisapproach could lead to an increase in head losses.

**REFERENCES:**

[1] Amitkumar S. Puttewar1 , A.M. Andhare (2015) design and thermal evaluation of shell and helical coil heat exchanger" International Journal of Research in Engineering and Technology, Volume: 04 Issue: 01

[2] Pramod S. Purandarea ,Mandar M. Lele (2012) Parametric Analysis of Helical Coil

Heat Exchanger International Journal of Engineering Research & Technology (IJERT)

[3]Basawaraj S. Hasu , Dr.G.V. Satynarayana Rao (2017) "Design and Analysis of a Heat Exchanger with Helical Baffles by using CFD" International Journal of Engineering Trends and Technology (IJETT) ISSN: 2231-5381 ,volume: 40,

[4] Dipankar De1 , Tarun K. Pal(2017) Helical baffle design in shell and tube type heat exchanger with CFD analysis "international journal of heat and technology, ISSN: 0392-8764 Vol. 35, No. 2, June 2017, pp. 378-383.