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DESIGN AND ANALYSIS OF HEAT EXCHANGERS WITH ENHANCEMENT OF INSERTS

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ABSTRACT

This paper presents performance analyses of shell and circular double tube heat exchangers with enhancement of insert. In this study, heat transfer in a horizontal circular double tube heat exchanger, with water as the working fluid has been increased by means of inserts. In the experimental set up, cold water in ambient condition was passed through the inner tube while hot water was flowing through outer tube. The Reynolds number of water varied from 15000 to 110000. Modeling work of the heat exchanger with and without inserts are done by PRO-E 5.0. The results were compared with the plain tube with no inserts by using ANSYS 11.0. The work included the determination of friction factor and heat transfer coefficient for helical tape insert in both counter and parallel flow. In rectangular insert, it was observed that the heat transfer coefficient varied from 0.9 to 1.9 times that of the smooth tube value but the corresponding friction factor increased by 1 to 1.7 times that of the smooth tube value. It was also observed that with an increase in Reynolds number (Re), the heat transfer coefficient increased, where as the friction factor decreased.

I. INTRODUCTION

Heat exchangers are one of the most important devices of mechanical systems in modern society. Most industrial processes involve the transfer of heat and more often, it is required that the heat transfer process be controlled. a heat exchanger is a device of finite volume in which heat is exchanged between two media, one being cold and the other being hot.

There are different types of heat exchangers; but the type widely used in industrial application is the shell and tube. As its name implies, this type of heat exchanger consists of a shell with a bundle of tubes inside it. One fluid runs through the tubes, and another flows over the tubes to transfer heat between the two fluids. The tube bundle may consist of several types of tubes: plain, longitudinally finned, etc. To ensure that the shell side fluid will flow across the tubes and thus induce higher heat transfer, baffles are installed in the shell to force the shell-side fluid to flow across the tube to enhance heat transfer and to maintain uniform spacing between the tubes.

As the two fluids in the heat exchanger that are at different temperatures, heat exchanger analysis and design therefore involve both convection and conduction. Two important problems in heat exchanger analysis are (1) rating existing heat exchangers and (2) sizing heat exchangers for a particular application. Rating involves the determination of the rate of heat transfer, the change in temperature of the two fluids and the pressure drop across the heat exchanger. Sizing involves selection of a specific heat exchanger from those currently available or determining the dimensions for the design of a new heat exchanger, given the required rate of heat transfer and allowable pressure drops.

1.1 PROBLEM DEFINITION:

The tube side design of a shell-and-double tube heat exchanger; in particular the baffle spacing, baffle cut and shell diameter dependencies of the heat transfer coefficient and the pressure drop are investigated by numerically modeling a small heat exchanger.

We are taking the inlet and outlet conditions as velocity inlet and pressure outlet. As this is counter flow of inner hot fluid flow and outer cold fluid flow so there will be two inlet and outlet respectively. There is a pipe which separates the two flows which is made by copper. The detail about all boundary conditions

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is as follows. Inner fluid is taken as hot water and outer fluid is taken as cold water.

ROOT CAUSES:

The scope of this project is to improving cooling efficiency of the heat exchanger by remodeling the tube and also installs the helical tape insert to overlap the tube. The flow and temperature fields inside the shell and tube are resolved using an Ansys v12 package. Our heat exchanger consists of two fluids of different starting temperatures flow through the heat exchanger. One flows through the tubes (the tube side) and the other flows outside the tubes but inside the shell (the shell side). And the heat exchanger designed by pro-e wildfire 5.0.

KEY WORDS:

Heat exchanger, Double tube, Helical tape insert, Performance of heat coefficient, Thermal conductivity, Turbulence modeling, Friction factor, Nusselt number, Friction factor ratio, Nusselt number ratio.

II. DESIGN OF HEAT EXCHANGER

HEAT EXCHANGER DESIGN METHODS

The goal of heat exchanger design is to relate the inlet and outlet temperatures, the overall heat transfer coefficient, and the geometry of the heat exchanger, to the rate of heat transfer between the two fluids. The two most common heat exchanger design problems are those of rating and sizing. We will limit ourselves to the design of recuperators only. That is, the design of a two fluid heat exchanger used for the purposes of recovering waste heat.

We will begin first, by discussing the basic principles of heat transfer for a heat exchanger. We may write the enthalpy balance on either fluid stream to give:

$$Qc = \dot{m}\ c\ (hc2 - hc1)$$

And

$$Qh = \dot{m}\ h\ (hh1 - hh2)$$

For constant specific heats with no change of phase, we may also write

$$Qc = (\dot{m}\ cp)\ c\ (Tc2 - Tc1)$$

And

$$Qh = (\dot{m}\ cp)\ h\ (Th1 - Th2)$$

Now from energy conservation we know that Qc = Qh = Q, and that we may relate the heat transfer rate Q and the overall heat transfer coefficient U, to the some mean temperature difference ¢Tm by means of

$$Q=UA\Delta T_m$$

Where A is the total surface area for heat exchange that U is based upon. Later we shall show that

$$\Delta T_m=f(T_{h1},T_{h2},T_{c1},T_{c2})$$

It is now clear that the problem of heat exchanger design comes down to obtaining an expression for the mean temperature difference. Expressions for many flow con- figurations, i.e. parallel flow, counter flow, and cross flow, have been obtained in the heat transfer field. We will examine these basic expressions later. Two approaches to heat exchanger design that will be discussed are the LMTD method and the effec- tiveness - NTU method. Each of these methods has particular advantages depending upon the nature of the problem specification.

III. DESIGN PARAMETERS

Specify that all purchase-fabrication welding be done by certified ASME welders in accordance with the approved ASME Boiler and Pressure Vessel Code.1

Avoid longitudinal welds in vessels less than 6 in. (0.15 m) in diameter. Seamless tubing or pipe, or bar stock is usually available in these smaller diameters.

Avoid stress concentrations. This is most critical when vessel material elongation or fracture toughness is relatively low.

Adjust the design and the allowable stresses to compensate for environmental conditions such as vibration, cycling, temperature fluctuation, shock, corrosion, and extreme thermal operating conditions.

Specify inspection by appropriate nondestructive detection methods, such as

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radiographic, ultrasonic, dye penetrate, and magnetic particle inspection, when designing a high-strength, high-pressure vessel. Specify appropriate ultrasonic inspection of all manned-area pressure vessels with wall thickness over 2 in. (50 mm). Maximum permissible defects should be based on the capability of the vessel material to resist crack growth under the specified operating conditions. Contact the subject-matter expert for assistance with properly specifying ultrasonic inspection.

Prepare a Fracture Control Plan for all gas-pressure vessels with wall thickness over 2 in. (50 mm) that are to be operated in a manned area. These vessels should be periodically monitored using appropriate nondestructive inspection techniques to assure that previously undetectable, undetected, and detected cracks are not approaching critical size. Contact the subject-matter expert for assistance. A plan should be prepared for vessels with thinner wall thick nesses wherever radioactive, toxic, explosive, or flammable materials are involved.

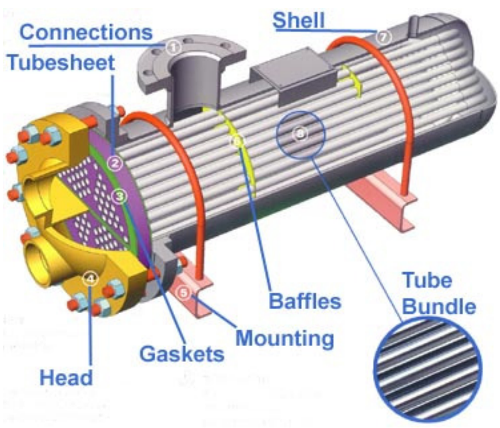

fig 3.1 cross section of heat exchanger

Checking a weld cross-section for toughness, because a weld might be brittle and welding might embitter the material in the heat-affected zone.

Including realistic joint efficiencies in calculations (see Ref. 1, Table UW-12), because a weld might not penetrate to the full thickness of the parent material.

Including the reduced properties of the heat-affected zone when calculating the overall strength of the vessel, because welding normally anneals the material in this zone.

Consulting with a welding or materials expert when planning to weld a vessel that will contain a high-pressure hydrogen gas, because welding reduces resistance of some materials to hydrogen embrittlement.

Design all barricades for remote-operation pressure systems in accordance with the requirements in TEMA Code.

TYPES OF HEAT EXCHANGER COLUMMS:-

From the above introduction, it is becomes transparent that Reactors are required for refineries & processindustries. There are various types of pressure vessel defined based on type of construction & manufacturing methods.

SINGLE WALL VESSEL

These are the vessel made of carbon-manganese steel or alloy steels having single wall. These vessels generally work as lower pressure & temperatures. As they at lower pressures, the thickness required to withstand the pressure is less & can be achieved with normal plate rolling mills. This type of vessel is preferred in industries as it is easier to manufacture & cheaper in cost.

MULTIWALL VESSEL

Fertilizer plants use the vessels like Ammonia converter Baskets. These vessels are working at very high pressure and temperature, which in turn raises the requirement of very high thickness. It is difficult to roll such a high thickness & weld as pressure joint. In such cases, the technology used for manufacturing is opting for Multiwall vessel.

These vessels are manufactured based on simple principle of shrinkage with of help of temperature variation. In this method, the shell are made with small thickness in form of rings in such a way that these rings can fit within another with close tolerances. The outer ring is heated which allows expansion of that ring to higher diameter.

The lower diameter ring is inserted within red hot

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outer ring & allowed to cool to normal temperature. As the temperature goes down, the outer ring shrinks & fits with inner rings. Generally there are more than 3 to 4 Vessel wall i.e. rings. Finally the higher thickness is achieved with multiwall, & therefore these vessels are called as Multiwall vessel.

It should be noted that now-a-days, such vessel are obsolete due to difficult manufacturing & lot of heat treatment involved with very high accuracy. These multiwall vessels are now replaced by use of special alloy steel having chromium & Vanadium.

CLAD VESSELS & OVERLAYED VESSELS

These vessels are specially designed for corrosive services. The reactors which process corrosive fluids are handled in Stainless steel environment. Clad vessels are manufactured out of clad plates. Elaborating little more, clad plates are the plate having Alloy steel plate & Stainless plate rolled together at higher temperature which allows bonding.

The thickness of alloy steel plate is much higher than SS plate because of the strength is given by outer Alloy steel & corrosion resistance is provided by SS inner layer.

The manufacturing sequences are similar like single wall vessel with a difference of extra care during rolling of clad plate having SS buffed surface inside.

Another option for such corrosive services is carrying out Stainless Steel overlay inside the Alloy steel shell after rolling to required diameter.

This is more time consuming method as it requires generation of a complete layer of SS inside shell. On the other hand, this much cheaper than Clad Vessels.Overlayed vessels are now-a-days preferred much over clad vessel by Modern Process Licensors like IFP.

HIGH THICK HEAT EXCHANGER

As the chemical technology advances with fast pace, the refineries have now started using high production rate with smaller sizes of plants. In turns, the refineries requires high thickness Heat exchanger made of costly alloy steel contain Chromium Vanadium.

These reactors work are very high pressures & temperatures with lot of automation inside. Hence, these high thick vessel (approx. 200mm & above) with special manufacturing technology & special skills.

MATERIAL SELECTION HEAT EXCHANGER

Select materials that remain ductile throughout the working temperature range of the heat exchanger. If you cannot avoid using a brittle material for the body of a manned-area pressure vessel, your Department Head must sign the ESN.

Select materials that are compatible with the liquid or gas to be contained in the vessel.

Use lower-strength vessel materials such as type 304, 316, 321, 347, stainless steel; 2024 or 6061 aluminum alloy; oxygen-free copper; phosphor bronze; beryllium copper; or other materials recommended by a recognized expert in the field or through a peer review.

Include an inner liner (or bladder vessel) made of one of these hydrogen-resistant materials. When designing such a liner, be sure that it will withstand working and testing stresses. Consider positively venting the liner/body interspaced so that any hydrogen that penetrates the liner cannot subject the high-strength vessel body to high-pressure hydrogen. Provide means for periodic verification that the vent path is open to the atmosphere.

To be able to transfer heat well, the tube material should have good thermal conductivity. Because heat is transferred from a hot to a cold side through the tubes, there is a temperature differences through the width of the tubes. Because of the tendency of the tube material to thermally expand differently at various temperatures, thermal stresses occur during operation. This is in addition to any stress from high pressures from the fluids themselves. The tube material also should be compatible with both the shell and tube side fluids for long periods under the operating conditions (temperatures, pressures, PH etc.,) to minimize deterioration such as corrosion. All of these requirements call for careful selection of strong, thermally-conductive, corrosion-resistant, high quality tube materials, typically metals. Poor choice of tube material could result in a leak through

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a tube between the shell and tube sides causing fluid cross-contamination and possibly loss of pressure. A device used to transfer heat from a fluid flowing on one side of a barrier to another fluid (or fluids) flowing on the other side of the barrier.

When used to accomplish simultaneous heat transfer and mass transfer, heat exchangers become special equipment types, often known by other names. When fired directly by a combustion process, they become furnaces, boilers, heaters, tube-still heaters, and engines. If there is a change in phase in one of the flowing fluids – condensation of steam to water, for example – the equipment may be called a chiller, evaporator, sublimator,distillation-column reboiler, still,condenser,or cooler-condenser.

The heat exchanger was constructed from copper tubing and standard copper connections. The outer tube of the heat exchanger had an outer diameter of 1.26 m and a wall thickness of 0.05 m. The inner tube had an outer diameter of either 0.1m, both with wall thickness of 0.05 m. The end connections are shown in Figure 5.1, which were constructed from standard copper tees and reducers. Each coil had a radius of curvature (measured from the center of the inner tube) of 0.25m. Small holes were drilled in the outer tube and tapped so that set screws could be used to ensure that the inner tube was centered prior to the final soldering of the end connections, which then held the inner tube in place. After soldering the set screws were removed and the holes covered so that the fluid flow in the annulus would not be disturbed. The heat exchanger consisted of one loop.

PROPOSED MATERIAL AND ITS PROPERTIES:

The proposed material of heat exchanger is stainless steel, copper, iron (existing material), Silicon Carbide and Cupro Brass. The copper is the common material for all heat exchangers. It is brittle and strong in compression and good heat disicipation capacity and good thermal conductivity.

MATERIAL PROPERTIES OF COPPER

Table 3.1 material properties of copper

Property	Unit	Cu
Density	g/cm3	8.95
Thermal conductivity	W/m °C	377
Tensile strength, room Temp	MPa	330
Tensile strength, 260 °C	MPa	270
Thermal expansion	µm/m °C	16.5
Specific heat	J/kg °K	377
Melting temperature	°C	1083
Safety margin in brazing (against core melting)	°C	300

IV MODELING OF HEAT EXCHANGER

Heat exchanger consist of various elements like Cylindrical Shell, Closing Head, circular double tube with helical tape insert, various instrument & process nozzles, tube Maintenance openings, fasteners, supporting structure & connecting Piping.

INTRODUCTION ABOUT PRO-ENGINEER:

Pro-Engineer is a powerful application. It is ideal for capturing the design intent of your models because at its foundation is a practical philosophy. Founder of this Pro-Engineer is Parametric Technology Corporation. After this version they are released Pro-E 2000i^2, Pro-E 2001, Pro-e Wildfire, Pro-e Wildfire2.0… pro-e 5.0.,In 2011, PTC rebranded Pro/Engineer as Creo Parametric. The current version of the software is 1.0. Pro/ENGINEER (Pro/E for short) is a commercial CAD/CAM package that is widely used in industry for CAD/CAM applications. It is one of the new generation of systems that not only over a full 3-D solid modeler, in contrast to purely 2-D and surface modelers, but also parametric functionality and full

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associatively. This means that explicit relationships can be established between design variables and changes can be Pro/ENGINEER is a feature based, parametric solid modeling program. As such, it's use is significantly different from conventional drafting programs. In conventional drafting (either manual or computer assisted), various views of a part are created in an attempt to describe the geometry.

MODELLING IN EXISTING HEAT EXCHANGER SPECIFICATIONS BY USING PRO-E:

Table 4.1 heat exchanger specification

PARTS NAME	DESCRIPTION	DIMENSIONS (m)
Shell	Outer diameter	1.26
	Inner diameter	1.21
	Thickness	0.05
	Length	6.00
U tube	Outer diameter	0.1
	Inner diameter	0.05
	Thickness	0.05
	Length	6.00
Helical tape insert	Pitch	0.3
	Thickness	0.02
	Length	4.2

MODELING IMAGES

SHELL ARRANGEMENT

Thickness of cylindrical shell in terms of inside dimensions or (longitudinal joints)

$$t = \frac{PR}{SE - 0.6P} + C.A. \quad OR \quad P = \frac{SEt}{R + 0.6t}$$

When thickness does not exceed one half of the inside radius, or p does not exceed 0.385 se the following formula shall apply.

The cylindrical enclosure resisting pressure which called as Shell.This geometrically a cylinder undergoing circumferential stress.

The function of the steam generator is to transfer the heat from the reactor cooling system to the secondary side of the tubes, which contain feed water. As the feed water passes the tube, it picks up heat and eventually gets converted to steam.

The Shell and Tube is the most common type of heat exchanger used in the process, petroleum, chemical industries, it contains a number of parallel u tubes inside a shell. Shell Tube heat exchangers are used when a process requires large amounts of fluid to be heated or cooled. Due to their design, shell tube heat exchangers offer a large heat transfer area and provide high heat transfer efficiency.

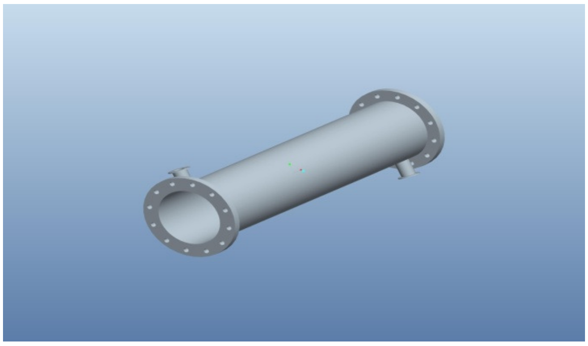

Fig 4.1 shell

Our heat exchanger consists of flange and a head and it's made up of cast iron. It is then bolted to the heat exchanger with the gaskets. The gaskets are made of rubber material such that it arrests the water leakage. The connection from the boiler enters the hot water inlet tube of the exchanger. The same time the cold water flushes over the copper tubes.

U - TUBE ARRANGEMENT

As the name implies, the tubes of a U-tube heat exchanger (Figure 2.6) are bent in the shape of a U. There is only one tube sheet in a U tube heat exchanger. However, the lower cost for the single tube sheet is offset by the additional costs incurred for the bending of the tubes and the somewhat larger

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shell diameter (due to the minimum U-bend radius), making the cost of a U-tube heat exchanger comparable to that of a fixed tube sheet exchanger.

The advantage of a U-tube heat exchanger is that because one end is free, the bundle can expand or contract in response to stress differentials. In addition, the outsides of the tubes can be cleaned, as the tube bundle can be removed.

The disadvantage of the U-tube construction is that the insides of the tubes cannot be cleaned effectively, since the U-bends would require flexible-end drill shafts for cleaning. Thus, U-tube heat exchangers should not be used for services with a dirty fluid inside tubes.

ENHANCED OF THIS TUBE

Enhanced tubes are used extensively in the refrigeration, air-conditioning and commercial heat pump industries while, in contrast, their consideration for use in the chemical, petroleum and numerous other industries is still not standard practice, although increasing. Designing *enhanced* tubular heat exchangers results in a much more compact design than conventional *plain* tube units, obtaining not only thermal, mechanical and economical advantages for the heat exchanger, but also for the associated support structure, piping and/or skid package unit, and also notably reduced cost for shipping and installation of all these components (which often bring the installed cost to a factor of 2 to 3 times that of the exchanger itself in petrochemical applications). The compact enhanced designs also greatly reduce the quantities of the two fluids resident within the exchanger, sometimes an important safety consideration. This chapter describes some of the practical considerations and advantages regarding the use of enhanced tubes and tube inserts in tubular heat exchangers and provides some guidelines for identifying their applications.

In this tube consist of helical tape insert. This is placed to overlap the U tube to increase the friction factor of the heat exchanger. Helical tape insert made up of same material of tube (i.e.) copper.

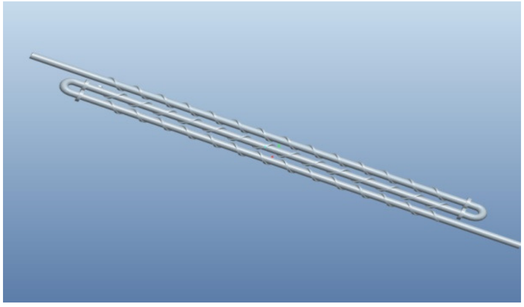

Fig 4.2 Double tube with helical tape insert

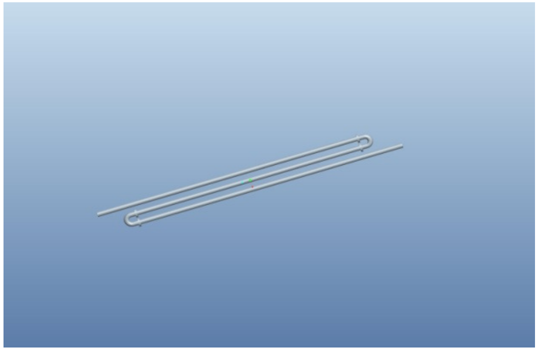

Fig 4.3double tube without helical tape inserts

FLOATING HEAD

The floating-head heat exchanger is the most versatile type of STHE, and also the costliest. In this design, one tube sheet is fixed relative to the shell, and the other is free to"float" within the shell. This permits free expansion of the tube bundle, as well as cleaning of both the insides and outsides of the tubes. Thus, floating-head SHTEs can be used for services where both the shell side and the tube side fluids are dirty-making this standard construction type used in dirty services, such as in petroleum refineries.

There are various types of floating- head construction. The two most common are the pull-through with backing device and pull through without backing service designs. The design (Figure 2.7) with backing service is the most common configuration in the chemical process industries (CPI). The floating-head cover is secured against the floating tube sheet by bolting it to an ingenious split backing ring. This floating-head closure is located beyond the end of the shell and contained by a shell cover of a larger

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diameter. To dismantle the heat exchanger, the shell cover is removed first, then the split backing ring, and then the floating-head cover, after which the tube bundle can be removed from the stationary end.

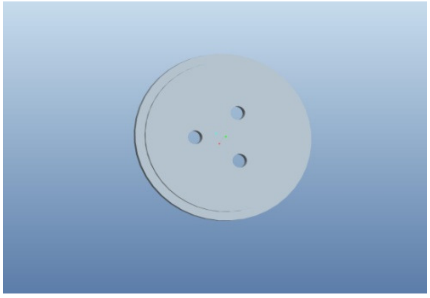

Fig 4.4 floating plate

FLANGE

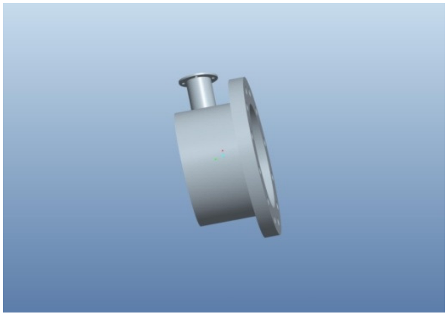

Fig 4.5 flange

EXPLODED VIEW FOR HEAT EXCHANGER

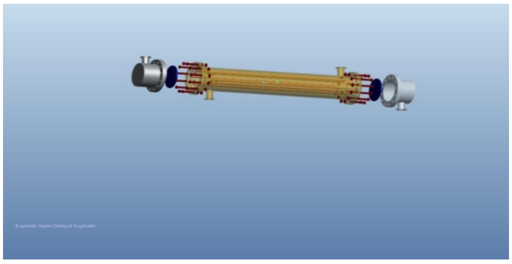

Fig 4..6 Exploded view for heat exchanger

V CONCLUSION

The design of heat exchanger with helical shape inserts and without insert is done by pro - E software in this phase of the project. The main aim is to improve thermal efficiency of the exchanger tube. So we have chosen two types of design, with inserts and the other one is a conventional type. Till now the modeling of two types are included, for the future work the comparison result of both the design is to be done using FEM (ANSYS).

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