STUDY OF ONE SHELL AND TWO TUBE PASS HEAT EXCHANGER

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Done by

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CERTIFICATE

This is to certify that the mini project titled

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of the Sixth Semester B. Tech in Mechanical Engineering in partial fulfilment of the requirement for the award of Bachelor of Technology Degree in Mechanical Engineering under the University of Calicut during the year 2015.

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ABSTRACT

As heat exchangers are prominently used in the industry , we decided to perform the mini project titled "**STUDY OF ONE SHELL AND TWO TUBE PASS HEAT EXCHANGERS".** A one shell and two tube pass heat exchanger consists of one shell enclosing three bent copper tubes passing through the length of the shell and return effectively forming a loop which increases contact surface area. The copper tubes carry hot water and the shell carries cold water which flows over the surface of the copper tubes extracting heat from the hot water. The hot and cold water flow rates are found using a measuring vessel and stopwatch and using thermometers all the input and output (both hot and cold) temperatures are determined. These values can be used to find out heat flow rate, LMTD, overall heat transfer coefficient and effectiveness of the system.

ACKNOWLEDGEMENT

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CHAPTER ONE

HEAT EXCHANGERS

A heat exchanger is a piece of equipment built for efficient heat transfer from one medium to another. The media may be separated by a solid wall to prevent mixing or they may be in direct contact. They are widely used in space heating, refrigeration, air conditioning, power plants, chemical plants, petrochemical plants, petroleum refineries, natural gas processing, and sewage treatment. The classic example of a heat exchanger is found in an internal combustion engine in which a circulating fluid known as engine coolant flows through radiator coils and air flows past the coils, which cools the coolant and heats the incoming air.

There are three primary classifications of heat exchangers according to their flow arrangement. In parallel-flow heat exchangers, the two fluids enter the exchanger at the same end, and travel in parallel to one another to the other side. In counter-flow heat exchangers the fluids enter the exchanger from opposite ends. The counter current design is the most efficient, in that it can transfer the most heat from the heat (transfer) medium per unit mass due to the fact that the average temperature difference along any unit length is higher. In a cross-flow heat exchanger, the fluids travel roughly perpendicular to one another through the exchanger.

For efficiency, heat exchangers are designed to maximize the surface area of the wall between the two fluids, while minimizing resistance to fluid flow through the exchanger. The exchanger's performance can also be affected by the addition of fins or corrugations in one or both directions, which increase surface area and may channel fluid flow or induce turbulence.

SHELL AND TUBE PASS HEAT EXCHANGER

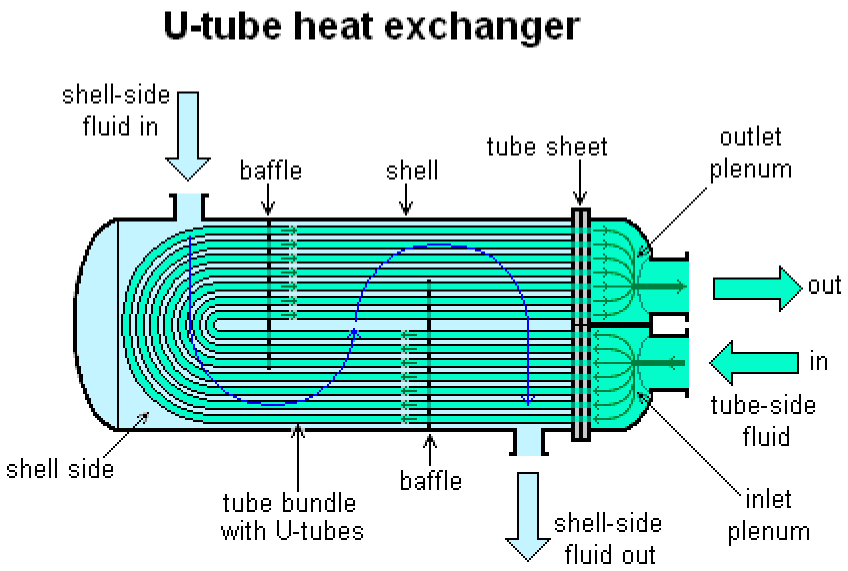
A shell and tube heat exchanger is a class of heat exchanger designs. It is the most common type of heat exchanger in oil refineries and other large chemical processes, and is suited for higher-pressure applications. As its name implies, this type of heat exchanger consists of a shell (a large pressure vessel) with a bundle of tubes inside it. One fluid runs through the tubes, and another fluid flows over the tubes (through the shell) to transfer heat between the two fluids. The set of tubes is called a tube bundle, and may be composed of several types of tubes: plain, longitudinally finned, etc.

THEORY

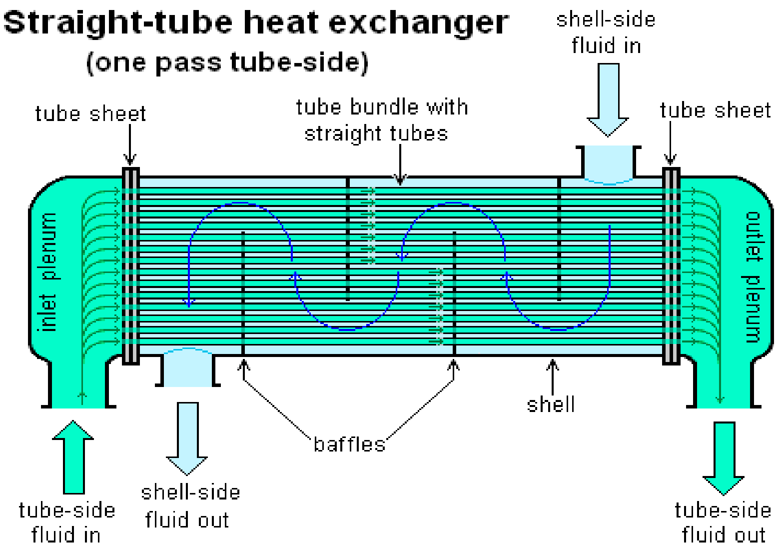
Two fluids, of different starting temperatures, flow through the heat exchanger. One flows through the tubes (the tube side) and the other flows outside the tubes but inside the shell (the shell side). Heat is transferred from one fluid to the other through the tube walls, either from tube side to shell side or vice versa. The fluids can be either liquids or gases on either the shell or the tube side. In order to transfer heat efficiently, a large heat transfer area should be used, leading to the use of many tubes. In this way, waste heat can be put to use. This is an efficient way to conserve energy.

Heat exchangers with only one phase (liquid or gas) on each side can be called one-phase or single-phase heat exchangers. Two-phase heat exchangers can be used to heat a liquid to boil it into a gas (vapour), sometimes called boilers, or cool a vapour to condense it into a liquid (called condensers), with the phase change usually occurring on the shell side. Boilers in steam engine locomotives are typically large, usually cylindrically-shaped shell-and-tube heat exchangers. In large power plants with steam-driven turbines, shell-and-tube surface condensers are used to condense the exhaust steam exiting the turbine into condensate water which is recycled back to be turned into steam in the steam generator.

There can be many variations on the shell and tube design. Typically, the ends of each tube are connected to plenums (sometimes called water boxes) through holes in tube sheets. The tubes may be straight or bent in the shape of a U, called U-tubes.



In nuclear power plants called pressurized water reactors, large heat exchangers called steam generators are two-phase, shell-and-tube heat exchangers which typically have U-tubes. They are used to boil water recycled from a surface condenser into steam to drive a turbine to produce power. Most shell-and-tube heat exchangers are either 1, 2, or 4 pass designs on the tube side. This refers to the number of times the fluid in the tubes passes through the fluid in the shell. In a single pass heat exchanger, the fluid goes in one end of each tube and out the other.



Surface condensers in power plants are often 1-pass straight-tube heat exchangers. Two and four pass designs are common because the fluid can enter and exit on the same side. This makes construction much simpler.

There are often baffles directing flow through the shell side so the fluid does not take a short cut through the shell side leaving ineffective low flow volumes. These are generally attached to the tube bundle rather than the shell in order that the bundle is still removable for maintenance.

Counter current heat exchangers are most efficient because they allow the highest log mean temperature difference between the hot and cold streams. Many companies however do not use single pass heat exchangers because they can break easily in addition to being more expensive to build. Often multiple heat exchangers can be used to simulate the counter current flow of a single large exchanger.

SELECTION OF TUBE MATERIAL

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 difference 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, including copper alloy, stainless steel, carbon steel, non-ferrous copper alloy, Inconel, nickel. Poor choice of tube material could result in a leak through a tube between the shell and tube sides causing fluid cross-contamination and possibly loss of pressure.

APPLICATION AND USES

The simple design of a shell and tube heat exchanger makes it an ideal cooling solution for a wide variety of applications. One of the most common applications is the cooling of hydraulic fluid and oil in engines, transmissions and hydraulic power packs. With the right choice of materials they can also be used to cool or heat other mediums, such as swimming pool water or charge air.

CHAPTER TWO

- **FABRICATION AND TESTING OF ONE SHELL AND TWO TUBE PASS HEAT EXCHANGER**

The critical aspect of the heat exchanger is definitely the inner tube diameter and length of the apparatus. So an analytical approach was used to determine the length and diameter using standard heat transfer formulae. The heat and mass transfer data book has been judiciously used in the below procedure.

- PROCEDURE

  First it is essential to calculate the mass flow rates so that we can calculate the required heat transfer rate. Both the inlet and outlet temperatures were found using thermometers.

  ## Input Parameters

  Cold fluid
  -->water
  -->inlet Temperature – 30 ^{0}C
  -->mass flow rate Mc=1000 L/4s =1/4 cubic m=0.25 kg/s
  Hot Fluid
  -->water
  -->inlet Temperature –50 deg C
  -->mass flow rate =Mh=1000/6.55 L/s=0.153846 kg/s
  We assume that a fall of 10 deg C takes place in hot water
  Outlet temp hot T=40 deg C
  We have Ch=Cc=4186 W/kgK(specific heat of water)
  Q=Mh Ch (50-40) =0.15384x4186x10=6439.74 W
  Qc =6439.74=McCc (Tco -Tci)
  6439.74/ (.25x4186)+30=Tco
  Tco=36.15 deg C
  LMTD*= [(Thi-Tci)-(Tho-Tho)]/ (ln((Thi-Tci)/(Tho-Thi))
  LMTD*=[(50-36.15)-(40-30)]/ln(13.5/10)
  LMTD*=11.82 deg C
  From data book we can find out the correction factor F for one shell and two tube pass heat exchanger by using P and R values
  P= (t2- t1)/ (T1-t1) = (40-50)/ (30-50) =0.5
  R= (T1-T2)/ (t2-t1) = (30-36.15)/ (40-50)=0.615
  Reading directly from data book we have
  Correction Factor =0.92=F
  LMTD=F x LMTD* =0.92x11.82=10.87440 deg C
  Q=UxAxLMTD

From data book we find Prandtl number and kinematic viscosity , using interpolation from data of property values of water.

Basically the steps are to find out both inner and outer convective heat transfer coefficients ho and hi using Nusselt number equations

Cold water: All values should be obtained at bulk mean temp

Bulk mean temp= (30+36)/2=33

Prandtl number P=7.02+ (33-20) x (4.34-7.02)/(40-20)

=5.26795

Re = 4m/3.14 D u

Density=997 kg/m^3 (from data book)

Kinematic viscosity v=1.006 + (33-20) x (0.657-1.066)/(40-20)

=$0.778x10^{-6}m^2/s$

Kinematic viscosity=absolute viscosity/density

v=u/Density

u=Density x v=$997x0.778x10^{-6}$Kg/ms

u=$7.75x10^{-4}$ kg/ms

Substituting in Reynolds number formula above, we have

Re= (4x0.25)/ ($3.14x0.5x2.5x10^{-2}$ x $0.7.757x10^{-4}$) =32828.14

Now we obtain that Reynolds number greater than 10000 and Prandtl number between 0.7 and 16700 hence from formula on internal flow from data book

Nusselt number Nu=0.027 $Re^{0.8}$ x $Pr^{0.333}$

=$0.027x32828.14^{0.8}$ x $(5.26795)^{0.333}$

=192.605

Now Nusselt number Nu=(ho x D)/k (k=thermal conductivity of water)

(ho x D) / (k) =192.605

ho=(192.605x0.6)/0.5x2.5x10-2)=9245 w/m2k

Hot water: bulk mean temp =45 deg C

Pr=4.01

Re= $\frac{4m}{3.14Dm}$ = $\frac{4x0.15}{3.14 \text{ x } 0.5 \text{ x } 2.5x\ 10\text{^-}2 \text{ x } 0.613 \text{ x } 10\text{^-}6 \text{ x}993}$

Re=25,100.45775 Again we use the same formula

Nu=0.027x25100.45775^ 0.8 x (4.01)^ 0.333

Nu=141.89

hi D/k=Nu

hi =(141.89x0.634)/ (0.5x2.5x10^-2)=7196.66 w/m2k

Now to obtain the overall heat transfer coefficient we have a formula from data book

1/U =1/hi+1/ho+fo+fi (fo and fi are fouling factors taken from data book for city or well water)

ho and hi=outer and inner heat transfer coefficients

1/U=1/9245+1/7196.66+ (0.0002) x 2

$U=1545.308 W/m^2k$

From data book for approximate overall heat transfer coefficient for water to water duty U lies between 900 and 1600.Hence a satisfactory value of U is obtained

Q=UxAxLMTD

A=Q/ (UxLMTD) = (6439.74)/ (1545.3)x(10.8744) = 0.383 sq. m

Since two tube pass, length=2L

nx3.14xDx (Lx2) =0.383

n=3 & assumed D=3/8 or 0.5 inch=0.0127 m

So we get L=1.6 m

FABRICATION:

After determining the copper tube diameter and the length we proceeded to fabricate the apparatus. We used the following parts

- PVC pipe 4" dia
- Copper tube of 3/8 inch dia(10m)
- Reducer T
- 4 ball valve (water valve)
- Pipe to connect the ball valve
- 110 mm PVC end cap
- 110 mm PVC Tee
- 50mm and 20mm PVC elbow
- 50 mm PVC pipe
- Brass baffles

After that we proceeded to assemble the entire apparatus. The copper tubes were bent to suitable curvature and then they were passed through semi-circular baffles to which they were welded to. Tube pitch is the centre to centre distance between the copper tubes which is usually greater than 1.25D=1.19 cm .In our case tube pitch=3 cm which satisfies the criteria. So the entire copper tubes and baffle system was inserted into the PVC pipe and the other fittings were placed. The hot water inlet copper tubes were connected to a single copper pipe which is then connected to half inch PVC pipe via a water valve. The cold water is also allowed to enter the shell through a valve and then exit at the other end. Thermometers are fixed at the inlet and outlet of both hot and cold fluids.

EXPERIMENT AND TESTING

To test the apparatus, we have to supply hot and cold water at the required ends. Measure all the inlet and outlet temperatures .Now adjust the valves and at different mass flow rates calculate the heat transfer using the formula

$$Q=M_h x C_h x (T_{hi}-T_{ho}) = M_c x C_c x (T_{ci}-T_{co})$$

Now calculate the overall heat transfer coefficient using $U=Q/(AxLMTD)$

$LMTD=[(T_{hi}-T_{co})-(T_{ho}-T_{ci})]/(\ln((T_{hi}-T_{co})/(T_{ho}-T_{ci}))$

$A=n x 3.14 x D x 2 x L$ $D=0.0127m$,$L=1.6m$,$n=3$

Now calculate effectiveness (e) using formula

$e=2[1+C+(1+C^2)^{0.5} X (1+\exp\{-N(1+C^2)^{0.5}\})/(1-\exp\{-N(1+C^2)^{0.5}\})]^{-1}$

$C= C_{max}/C_{min}$

$N=UA/C_{min}$

INFERENCE AND CONCLUSION

A One Shell Pass and Two Tube Pass Heat Exchanger having 7 baffles and 3 copper U tubes was designed and fabricated.

We are yet to perform the experiment on fabricated equipment

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