Design and Fabrication of Bank of Tubes Counter Flow Heat Exchanger

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***Abstract*- Heat transfer process with conventional shell and tube heat exchangers is familiar to many engineers in many industries. Their use and performance is well-documented. Bank of tubes heat exchangers offer certain advantages. Compact size, higher film coefficients, the rate at which heat is transferred through a wall from one fluid to another and more effective use of available pressure drop result in efficient and less-expensive designs. True counter-current flow fully utilizes lavailable LMTD (logarithmic mean temperature difference). High-pressure capability and the ability to fully clean the service-fluid flow area add to the exchanger's advantages. In this project, an experimental study was performed on the Bank of tubes heat exchanger with different flow rates for the hot and cold fluid. The heat transfer rate and effectiveness were calculated for the heat exchanger.**

Keywords- Counter flow heat exchanger, bank of tubes heat exchanger, heat exchanger

INTRODUCTION

Heat exchanger is a device that facilitates the exchange of heat between two fluids that are at different temperatures. Heat Exchangers differ from mixing chambers on that they do not allow the two fluids involved to mix.

Counter flow Heat Exchangers are capable of handling high pressures and wide temperature difference. The heat exchanger comprises a hollow cylinder having a cylindrical wall to define a annular space. Within the annular space is located a neatly fitting long tubes with spaced to define a cylindrical pathway. Between the adjacent coil long tubes working fluid passes through the tubes and process fluid passes through the straight pathway to effect heat exchange between the working and process fluid.

Due to the compact structure and high heat transfer coefficient, bank of tubes heat exchangers are widely used in industrial applications, such as Power generation, Nuclear industry, Process plant, Heat recovery system,

Refrigeration, Food industry, etc…. Bank of tubes Heat Exchangers have many advantages over other type of Heat Exchangers. They are high heat transfer coefficient, Low fouling, Less maintenance, compact size reduces space requirements.

Various Type of Heat Exchangers:
The various types of heat exchangers classified on the basis of design and constructional features are ,

- Concentric Tubes
- Shell and Tube
- Plate Heat Exchanger
- Spiral type Heat Exchanger

Types of Flow in Heat Exchangers:
The various types of flow in Heat exchangers are classified as,

- Parallel Flow
- Counter Flow
- Cross flow

LITERATURE SURVEY

Experimental and CFD estimation of heat transfer in bank of tubes counter flow heat Exchangers with Fluid to Fluid Heat Transfer have been carried out. An experimental setup has been fabricated for estimation for heat transfer co-efficient. Correlations have been developed to calculate the inner heat transfer co-efficient of helical coil. It was reported by authors J.S.Jayakumar, S.M.Mahajani, J.C.Mandal, P.K.Vijayan and Rohidas Bhoi (IEEE JOURNAL) that the theoretical results based on CFD agree very well with the experimental results and that the heat transfer rates in Helical coils are higher as compared to straight tubes.

RahulKharat and NitinBhardwaj (2017) investigated on developing a Correlation for heat transfer coefficient for flow between long tubes. Existing Correlation is found to result in large discrepancies with the increase in gap between the tubes, when compared with the experimental results. In the present study experimental data and CFD simulations using Fluent 6.3.26 are used to develop improved heat transfer coefficient correlation for the flue gas side of heat exchanger. Mathematical model is developed to analyze the data obtained from CFD and experimental results to account for the effects of different functional dependent variables such as gap between thelong parallel tubs , tube diameter which affects the heat transfer. Optimization is done using Numerical Technique and it is found that the new correlation for heat transfer coefficient developed in this investigation provides an accurate fit to the experimental results within an error band of 3–4%.

R Smusz (2016) conducted an analytical and experimental analysis of heat transfer for the finned tube heat exchanger immersed in thermal storage tank. The tank is equipped with two long heating coils and cylindrical- shaped stratification device. Two coils, upper and lower, use the water as a heating medium. The third, double wall heat exchanger coil, located at the bottom head on the tank is filled by the refrigerant (freon). Calculations of thermal power of water coil were made. Correlations of heat transfer coefficients in curved tubes were applied. In order to verify the analytical calculations the experimental studies of heat transfer characteristic for coil heat exchanger were performed.

Authors, Hayder Eren, Nevin Celik, Seyba Yildiz,Aydin conducted a study on Heat Transfer and Friction Factor of Coil-Springs inserted in the Horizontal Concentric Tubes in Jan 2010(Journal of Heat Transfer-ASME). It was reported that, increasing spring number, spring diameter, and incline angle result in significant augmentation on heat transfer. Furthermore, as a design parameter, the incline angle has the dominant effect on heat transfer and friction loss while spring number has the weakest effect.

Patent (No.: 10,779,844) developed by Gerald W. E. Van Decker, Colin M. Watts in Feb – 2004 on Heat Exchanger in which a coil on - tube heat exchanger is provided that uses multiple parallel tubes to limit liquid pressure losses while providing similar performance and production times to previous coil and tube designs. Two or more coil tubes are wrapped together around a tube in a helical fashion, permitting the heat exchanger to be used in a counter-flow, or contra-flow, implementation. This helps in providing reduced pressure loss, higher performance and are generally faster to manufacture than prior heat exchangers.

Patent(No.: 4,895,203) developed by McLaren in Jan 1990 on Heat Exchanger with long parallel tubes conduct in casing was used to utilize waste heat from motor vehicle engine cooling system to heat source of water for use with shower or in the recreational environment.

Patent (No.: 4,697,636) developed by Mells Jo in Oct -1987 on Heat Exchangers with parallel Heat flow to transfer heat between gas and liquid found to be very useful in Heat pumps. One fluid media is taken through the helical tube and the other media is passed through the cylindrical space between the coil and casing. The pipe coil is tightly wounded with successive turns contacting one another and sealed by welding.

EXPERIMENTAL SETUP

The Experimental set up consists of a horizontal tube (M.S) inside which copper tube is wounded.
The working fluid used is water. The hot water is taken through horizontal tube and the cold water is passed through the copper tube which is wound inside the horizontal tube in the counter flow direction.

The reasons for choosing copper tube are being high Thermal conductivity (386 W/Mk) and ductile so that it can be easily wounded. Insulation is
provided at appropriate locations in order to reduce the heat loss. A Plastic drum is used as a Hot water tank. An Immersion water heater is used to heat the water. A tank is used as a cold water tank.

COPPER TUBE:

The cold water flows through the copper tube of inner diameter 12mm and 15000 mm length. The specification of the copper tube is listed in the table 3.1.1

SPECIFICATION OF COPPER TUBE

Material	Copper
Inner diameter	12 mm
Outer diameter	13.5 mm
Total length of the tube	15000 mm

MILD STEEL CASING:

The hot water flows through the mild steel casing of diameter 160 mm with negligible thickness in counter flow direction. The specification of the mild steel casing is listed in the table 3.1.2

SPECIFICATION OF MILD STEEL CASING

Material	Mild Steel
Diameter	180 mm
Length	750 mm

EXPERIMENTAL PROCEDURE

The water in the Hot water tank is Heated with the help of immersion water heater. The inlet temperatures of Hot water and Cold water are measured with the help of Mercury Thermometer.

Cold water from the tank will pass through the Copper tube and Hot water from the tank will pass through the M.S casing in Counter flow direction.
After the study state condition is reached, the outlet temperature of Hot water and Cold water are measured with the help of Mercury Thermometer.

The temperatures are tabulated and calculations are done to find the Heat Transfer rate and the Effectiveness of the Heat Exchanger
For counter flow,

$$\mathbf{LMTD= [(T_1-t_2)-(T_2-t_1)]/ \ln[(T_1-t_2)-(T_2-t_1)]}$$

Where,
T_1 - inlet temperature of hot water - ° C

T_2 - outlet temp. of hot water - ° C

t_1 - inlet temp. of cold water - ° C

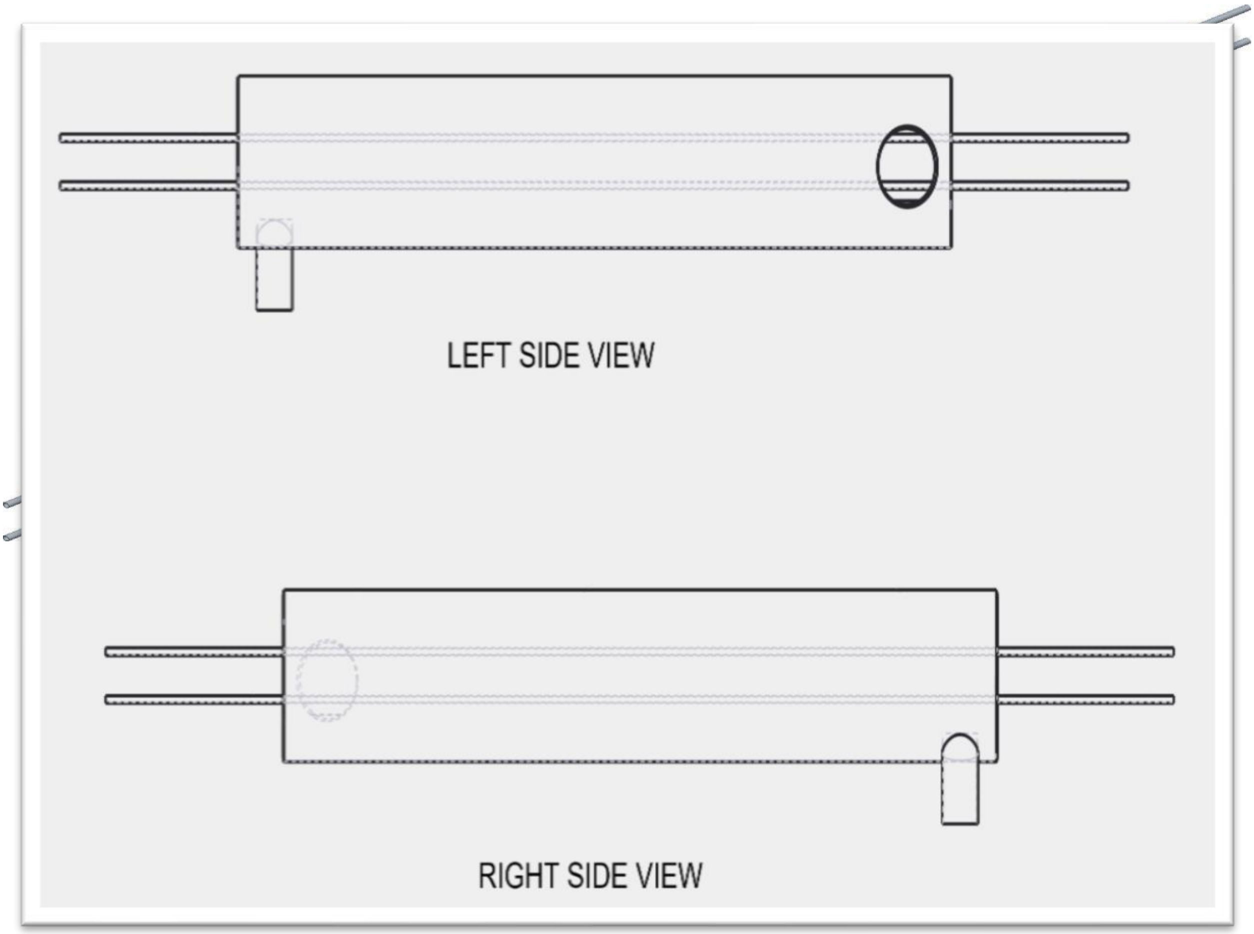
t_2 - outlet temp. of cold water -° C

Then the Effectiveness of the heat exchanger will be found using,

$$\boldsymbol{\varepsilon = Q/Q_{max}.}$$

Where,
Q – Actual transfer
Q_{max} – Maximum possible Heat transfer.

CAD MODELING



ISOMETRIC VIEW

PROPERTIES:

Property Values of Materials used:

(Page no.2 H.M.T Data Book, Eighth Edition by C.P.Kothandaraman & S.Subramanyan)

Copper:

- Thermal conductivity = 386 w/m k
- Specific heat = 383 J/kg k
- Density = 8954 kg/m^3

Mild Steel:

- Thermal conductivity = **60.5 w/m k**
- Specific heat =**434 J/kg k**
- Density = **7854 kg/m^3**

Property Values of liquids in saturated state:

(Page no.22 H.M.T Data Book, Eighth Edition by C.P.Kothandaraman & S.Subramanyan)

Cold Water Temperature = 32°C

- Density = 995 kg/m^3
- Kinematic viscosity = 0.657×10^{-6} m^2/s
- Prandtl Number = 4.34
- Thermal conductivity = 0.628 w/m k

Hot Water Temperature = 65°C

- Density = 985 kg/m^3
- Kinematic viscosity = 0.478×10^{-6}m^2/s
- Prandtl Number = 3.02
- Thermal conductivity = 0.6573 w/m k

CALCULATIONS:

Heat Transfer, **Q= UA(LMTD) Watts**.

Where,

- **U** = overall heat transfer co-efficient w/m^{2}k
- **A** = Area of heat transfer m^2
- **LMTD** = Logarithmic Mean Temperature Difference

For counter flow,

$$\mathbf{LMTD= [(T_1-t_2)-(T_2-t_1)]/ \ln[(T_1-t_2)-(T_2-t_1)]}$$

Where,

- **T_1** - inlet temp. of hot water - ° C
- **T_2** - outlet temp. of hot water - ° C
- **t_1**- inlet temp. of cold water - ° C
- **t_2** - outlet temp. of cold water -° C

Effectiveness of the Heat Exchanger,

$$\mathcal{E} = Q/Q_{max}$$

where,

- Q - Actual Heat transfer
- Q_{max} - Maximum possible Heat transfer

Heat lost by Hot fluid = Heat lost by Cold fluid

$$[\ Q_h = Q_c]$$

$$m_h * C_{ph}(T_1 - T_2) = m_c * C_{pc}(t_2 - t_1)$$

Where,

- **m_h** = Mass flow rate of Hot water
- **m_c** = Mass flow rate of Cold water
- **C_{ph}** = Specific Heat of Hot water
- **C_{pc}** = Specific Heat of Cold water

Mass flow rate for Hot water = 0.0185 kg/s
Mass flow rate for cold water = 0.095kg/s

Inlet temp. of hot water, T_1 = 65°C
Outlet temp. of hot water,T_2 = 43.2°C
Inlet temp. of cold water , t_1 = 32°C
Outlet temp. of cold water,t_2 = 36.1°C

L.M.T.D =18.6723°C

Area,

- **$A = 2*\pi*D_1*L$**
  $= 0.0816m^2$

Overall heat transfer co-efficient,

- <u>$U = 1.134kw/m^2k$</u>
- **Q = U*A*L.M.T.D**
  =653.72W
- **$\varepsilon = [\ m_c C_c\ (t_2 - t_1)\ ] / [\ C_{min}(T_1 - t_1)\ ]$**
  Effectiveness = 0.6381

RESULTS:

Mass flow rate of hot water	**Mass flow rate of cold water**	**Hot water**		**Cold water**		**Heat transfer rate (W)**	**Effectiveness**
		Inlet temp	**Outlet temp**	**Inlet temp**	**Outlet temp**		
0.0180	0.095	65	43.2	32	36.1	653.7	0.638
0.0182	0.097	65	44.1	32	36.7	649.9	0.637
0.0186	0.092	65	42.9	32	36.9	649.2	0.635
0.0184	0.095	65	44.4	32	36.1	651.9	0.639
0.0185	0.098	65	44.2	32	36.4	654.2	0.637
0.0183	0.096	65	43.7	32	36.5	653.4	0.636

ADVANTAGES:

- Compact and lightweight
- High Efficiency
- Flexible Design
- Low Maintenance
- Low Pressure Drop

DISADVANTAGES

- Flow rate is limited
- Insulation is required for better efficiency

APPLICATIONS:

- Liquid heating/cooling
- Steam heaters
- Vaporizers
- Cryogenic cooling
- Vent condensing

CONCLUSION

This experimental study carried out on bank of tubes counter flow Heat Exchanger with different flow rates of hot and cold fluid in counter flow direction. It shows that higher heat transfer rates are possible with bank of tubes counter flow heat exchangers compared to conventional heat exchangers. A further analysis can be done by varying the number of tubes for the cold fluid. It is also suggested that a theoretical analysis of the experimental model can be simulated and the experimental values can be compared with the theoretical values.

EXPERIMENTALSETUP: