Analysis of Heat Exchanger through Different Materials Tubes

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Abstract— Double pipe heat exchanger is simplest type's concentric pipes of different diameter. In this paper parallel and counter both flow arrangements will do. Selecting different materials copper, aluminum and steel for heat exchangers and producing tubes of heat exchangers have been studied and the discus effects of thermal conductivity on them. Operations on the different tubes with different materials are having the same dimensions (diameter and length) and the factors affecting heat exchangers. Further, selection of the most appropriate tube material and obtained with regard results to these factors. By analysis and experimentation of systematic data degradation leads to the conclusion that the maximum heat transfer rates is obtained in case of the inward counter flow configuration compared to all other factors, except these we observe to vary with small difference in each section. Comparing of these three tube heat exchangers, effectiveness is more for copper tube heat exchanger ie., it can carry out more heat from inner hot fluid to outer cold fluid. The correlations of Nusselt number, Reynolds number and Prandtl number will be determined through multivariate linear normal regression.

Key words: Heat Transfer Coefficient, Heat Transfer Rate, Reynolds Number, Nusselt Number, Effectiveness, NTU

I. INTRODUCTION

Heat exchanger is the one of the most important processes in engineering which transfers the heat between flowing fluids means is the process of transfer of heat from one fluid to another fluid. To transfer internal thermal energy between two or more fluids at different temperatures heat exchanger is used. In usually fluids are not mix most of the heat exchanger. Mostly heat exchangers are using petroleum power refrigeration and air conditioning, alternate fuels and automobiles field day to day its uses increases. In a transient manner, heat transfer between fluids takes place through a separating wall or into and out of a wall in a heat exchanger. Fluids are separated by a heat transfer surface in many heat exchangers, and ideally they do not mix or leak is direct transfer type, or simply recuperators heat exchangers are referred to as. In an indirect type of heat exchanger simply regenerator's thermal energy storage and release through the exchanger surface or matrix there is intermittent between the hot and cold fluids. Shell-and tube exchangers like automobile radiators, condensers, evaporators, air preheaters, and cooling towers due to pressure difference and matrix or valve switching usually having fluid leakage from one fluid stream to the other. Sometimes it referred to as a sensible heat exchanger if there is no phase change occurs in any of the fluids in the exchanger.

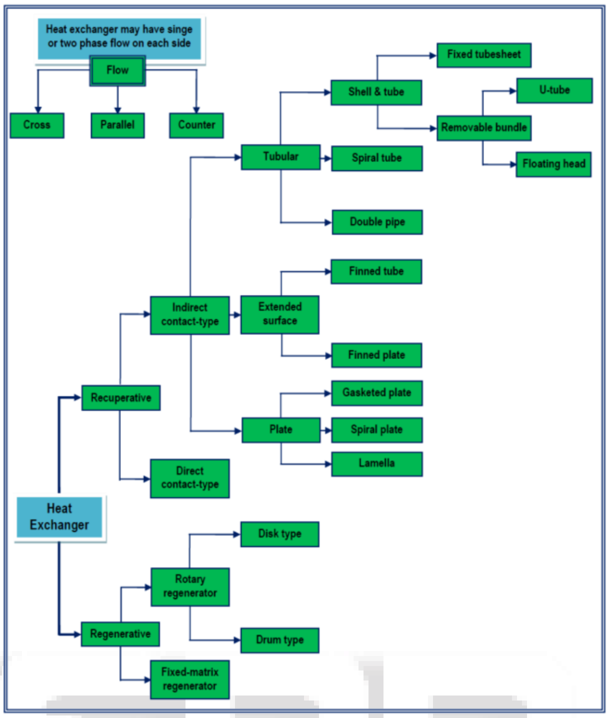

Fig. 1: Classification of heat exchanger

A. *General criteria for materials selection*

A general procedure that could be used for identifying the most appropriate material for a specific heat exchanger application would consist of the following steps.

- Define the heat exchanger requirements
- Establish a strategy for evaluating candidate materials
- Identify candidate materials
- Evaluate materials in depth

Special considerations which affect materials selection include:

B. *Physical Properties*

- High heat transfer coefficient (requiring high thermal conductivity for tube material)
- Thermal expansion coefficient to be low and as compatible as possible with those of the materials used for tube sheet, tube support and shell to provide resistance to thermal cycling.

C. *Mechanical Properties*

- Good tensile and creep properties (High creep rupture strength at the highest temperature of operation and adequate creep ductility to accommodate localised strain at notches are important).
- Good fatigue, corrosion fatigue and creep-fatigue behaviour.
- High fracture toughness and impact strength to avoid fast fracture.

D. *Corrosion Resistance*

- Low corrosion rate to minimise the corrosion allowance (and also radioactivity control in heat exchangers for nuclear industry)
- Resistance to corrosion from off normal chemistry resulting from leak in upstream heat exchanger or failure in the chemistry control
- Tolerance to chemistry resulting from mix up of shell and tube fluids.

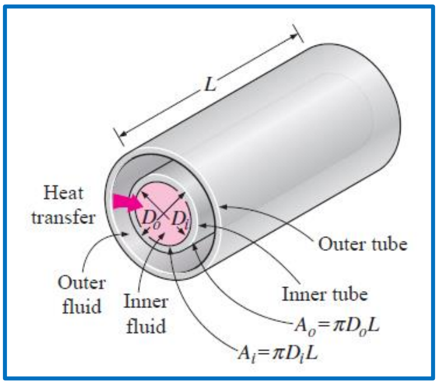

Fig. 2: Double pipe heat exchanger

II. LITERATURE SURVEY

Shah and London, 1978 -to study heat exchangers there are several different approaches have been devised. Early attempts include analytical solutions of the Nusselt number for a large collection of duct shapes under laminar flow with either constant wall temperature or constant wall heat flux boundary conditions, using different techniques such as conformal mapping

Sastry 1964, 1965 or Galerkin integral methods (Haji-heikh et al 1983) are given many simplified models for heat exchangers have also been proposed. Single-phase heat exchanger with louvered fins was developed an analytical approach for predicting the air-side performance of a heat exchanger.

Sahnoun and Webb 1992 - Their predicted model of heat transfer coefficients with errors of as much as 25%. For calculating the air-side heat transfer in heat exchangers under condensing conditions an analytical method has been described (Ramadhyani 1998). Srinivasan and Shah (1997) recently examined in condensation phenomena occurring in compact heat exchangers. To analyze transport phenomena in the air-side, within the fin-tube passages that was other attempts.

(Kushida et al 1986; Bastani et al 1992; Torikoshi et al 1994), have been carried out with CFD techniques assuming isothermal fins and in the water-side, inside the tube bends (Goering et al 1997), Ranganayakulu and Seetharamu (1999) a single-phase heat exchanger using finite elements had been performed in a steady state simulation. Their analysis included the effect of one-dimensional heat conduction at the wall, no uniformity in the inlet fluid flow, and a few different models of temperature distributions Due to the fact that no analytical or accurate numerical solutions are available; the information has been usually derived experimentally. A large amount of experimental information about transport phenomena in and evaporator heat exchangers are reported in the open literature.

(Webb 1980; Kakac et al 1981; Kays and London 1984; Shah et al 1990). For instance, Beecher and Fagan (1987) determined performance data for single-phase finned-tube heat exchangers; Jacobi and Goldschmidt (1990) characterized, experimentally, heat and mass transfer performance of a Condensing heat exchanger. Similar studies were also examined by McQuiston (1976 and 1978), Mirth and Ramadhyani (1995), and Yan and Sheen (2000). Thermal performance data for evaporators have been developed by Panchal and Rabas (1993). These findings are all based on the experimentally determined overall, air-side and water-side heat transfer coefficients.

A few studies have been carried out to find correlations for the performance of compact heat exchangers. The most representative examples are those for single phase operating conditions (Gray and Webb 1986), for heat exchangers operating under wet conditions (McQuiston 1978), and for evaporators (Kandlikar 1991).

Shell and Tube heat exchangers by changing different parameters to meet the industry requirements an extensive research work has been done till date. Lunsford (1998) provided some methods for increasing shell and-tube exchanger performance. The methods considered whether the exchanger is performing correctly to begin with, excess pressure drop capacity in existing exchangers, the re-evaluation of fouling factors and their effect on exchanger calculations, and the use of augmented surfaces and enhanced heat transfer. Sparrow and Reifschneider (1986) conducted experiments on the effect of inter baffle spacing on heat transfer.

Huadong Li and Volker Kott Ke (1998) on experiments getting the effect of leakage on pressure drop and local heat transfer in shell and tube heat exchangers for staggered has slight contribution to the local heat transfer at the surfaces of the external tubes of the tube bundle, but reduces greatly the per-compartment average heat transfer.

III. METHODOLOGY

A. *Tube Types Heat Exchanger*

It’s like a pipe heat exchanger generally known as double pipe heat transfer which is named by its construction because two pipes are fitted in such way that one pipe is fitted into other inside space. By cross section they look concentric by coaxial view. It can be extend as requires length and bend like hair pin shape at the edges to make it fit in particular area. Hot fluid is flow into the inner tube and cold fluid is flow into the space between inner and outer pipes.

1) Applications:

1) Refrigerators,
2) Domestic heating systems and
3) Car radiators etc.

General equation of heat transfer rate across a heat exchanger is usually expressed in the form

$$Q = UA\,\Delta T_m \qquad \ldots\ldots\ldots\ldots.. (1)$$

The following assumptions are applicable using this equation:

1) Overall heat coefficient U is constant,
2) Specific heats of the hot and cold fluids are constant,

3) Heat exchange with the ambient is negligible, and 4. The flow is steady and either parallel or counter flow.

Where:

Q = heat transfer rate, Watts

U = overall heat transfer coefficient, W/m^2 K

A = heat exchanger area, m^2

ΔT_m = average temperature difference between the fluids, K

S.No	Types of Heat Exchanger	U, W/m^2 ^{o}C
1	Water to Water	850-1700
2	Water to Oil	100-350
3	Water to Gasoline	300-1000
4	Feedwater heaters	1000-8500
5	Steam to light fuel oil	200-400
6	Steam to heavy fuel oil	50-200
7	Steam Condenser	1000-6000
8.	Ammonia condenser (Water Cooled)	800-1400
9	Gas to Gas	10-40
10	Water to Air in Finned tube (Water in tubes)	30-60 400-850

Table 1: Values of heat transfer coefficient

$$Q = -(mC_p)_h (T_{h1} - T_{h2}) = (mC_p)_c (T_{c2} - T_{c1}) \quad \ldots. \quad (2)$$

$$Re = (\rho V d)/\mu \quad \ldots. \quad (3)$$

$$\text{Effectiveness } (\epsilon) = \frac{\text{Actual heat transfer}}{\text{Maximum possible heat transfer}} \quad \ldots. \quad (4)$$

Materials	Thermal Conductivity W/m^{0}C
Aluminum	200-250
Aluminum brass (76 Cu-22Zn-2Al)	100-110
Brass (70 Cu-30Zn)	98
Carbon Steel	45
Copper	386
Cupro-nickel (90 Cu - 10 Ni)	70
Nickel	62
Stainless Steel, type 316 (17 Cr-12 Ni-2 Mo)	16
Stainless Steel, type 304 (18 Cr-8 Ni)	16

Table 2: Thermal conductivity of some materials

IV. Result and Analysis

Fig. 3: Experimental Setup

Particulars	Inner diameter (mm)	Outer diameter (mm)	Length (mm)
Cu pipe	25	28	250
Al pipe	25	28	250
Steel pipe	25	28	250

Table 3: Specifications of heat exchanger pipes

S.No	Hot Water Parallel flow			Hot Water Counter flow		
	Mass Flow rate (kg/s)	T_{ci} (^{o}C)	T_{co} (^{o}C)	Mass Flow rate (kg/s)	T_{ci} (^{o}C)	T_{co} (^{o}C)
1	0.02	38	49	0.02	37	46
2	0.02	37	45	0.02	36	44
3	0.02	38	46	0.02	36	45
4	0.02	38	45	0.02	37	46
Avg	0.02	37.75	45.5	0.02	36.5	45.25

Table 4: Observation of Parallel and Counter flow hot water

S.No	Cold Water Parallel flow			Cold Water Counter flow		
	Mass Flow rate (kg/s)	T_{hi} (^{o}C)	T_{ho} (^{o}C)	Mass Flow rate (kg/s)	T_{hi} (^{o}C)	T_{ho} (^{o}C)
1	0.03	59	49	0.03	65	51
2	0.03	58	48	0.03	63	49
3	0.03	59	49	0.03	64	50
4	0.03	57	48	0.03	65	50
Avg	0.03	58.25	48.5	0.03	64.3	50

Table 5: Observation of Parallel and Counter flow Cold water

Materials	ε	'Q' (W)	'U' (w/ m^2 K)	Re	Nu	LMTD
Copper	0.713	265.46	1326	28830	137	9.10
Aluminium	0.713	264.53	1321.33	28830	137	9.10
Steel	0.713	256.05	1279	28830	137	9.10

Table 6: Parallel Flow Observation

Similarly we calculate all the parameter for counter low heat exchanger.

Materials	ε	'Q' (W)	'U' (w/ m^2 K)	Re	Nu	LMTD
Copper	0.75	345.39	1346	31306	142	11.84
Aluminium	0.75	344.18	1338	31306	142	11.84
Steel	0.75	333.15	1286	31306	142	11.84

Table 7: Counter Flow Observation

Tube Material	NTU		U	
	Parallel Flow	Counter Flow	Parallel Flow	Counter Flow
Copper	0.1980	0.1996	1346	1326
Aluminium	0.1959	0.1984	1338	1321.33
Steel	0.1897	0.1907	1286	1279

Table 8: NTU for Parallel and Counter flow

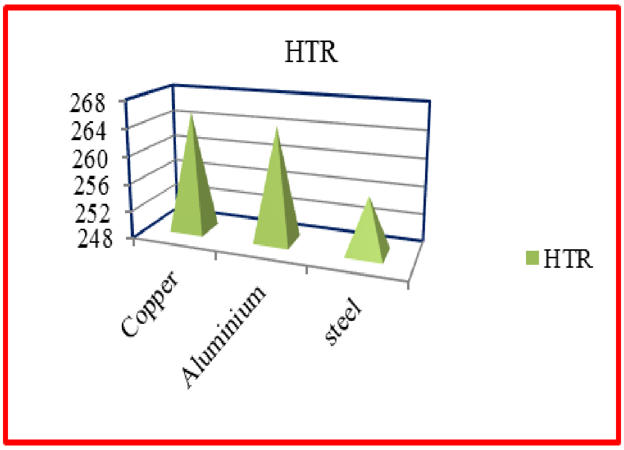

Fig. 4: heat transfer rate (HTR) for Parallel Flow

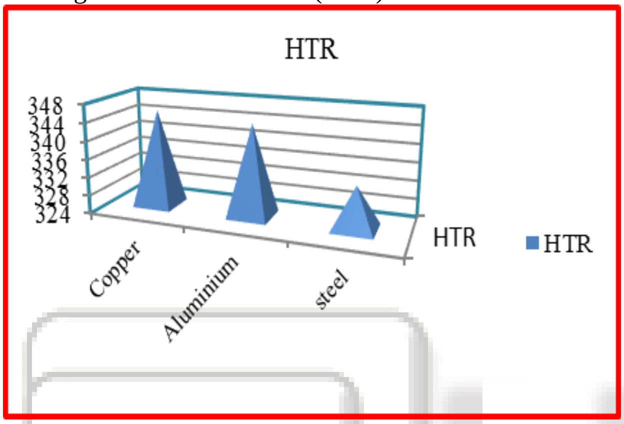

Fig. 5: heat transfer rate (HTR) for Counter Flow

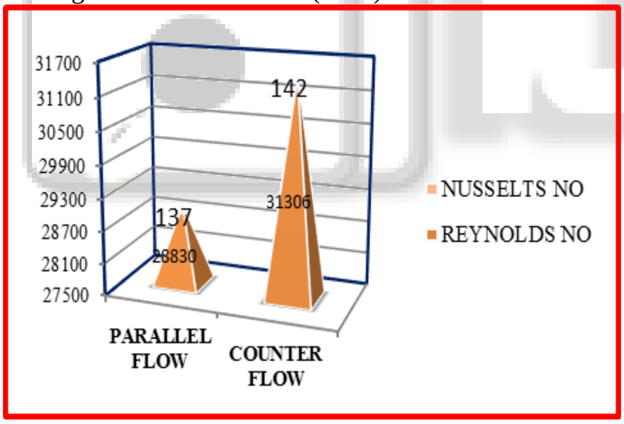

Fig. 6: Reynolds & Nusselts no for Parallel and Counter flow

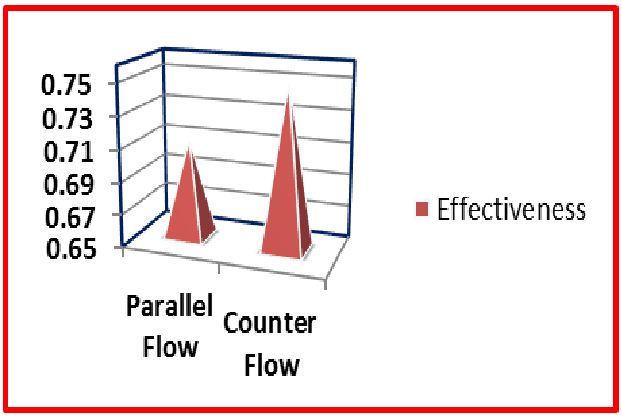

Fig. 7: Comparisons of Effectiveness

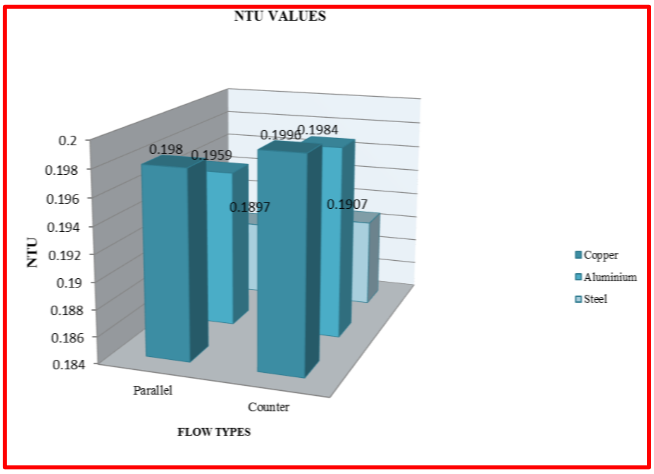

Fig. 8: NTU for different materials

V. Conclusion

An Experiment shows that effectiveness of counter flow heat exchanger is maximum compare to parallel flow. In a setup we used three different types of materials copper, aluminium and steel. Analyses of setup we find that copper have higher thermal conductivity then aluminium after steel. Variation of thermal conductivity depends on temperature as the increases of temperature thermal conductivity increases but I analyses at constant temperature 42°C for all three material. As same temperature and same length and diameter of circular tube heat transfer rate and overall heat transfer rate is maximum for copper tube in both the cases either parallel flow or counter flow. Calculation of Number of transfer unit shows for different materials as the same length and diameter we find that copper tube have maximum value of NTU as compare to Aluminium and steel respectively. Once again it also shows that counter flow heat exchanger have slightly more number of transfer units compare to parallel flow tube heat exchanger. I also observe at time of experiments that get high temperature profile at outlet in case of Aluminium and copper compared to steel material.

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