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Thermal Analysis of Multi Tube Pass Shell and Tube Heat Exchanger

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ABSTRACT: This paper deals with the numerical analysis of thermal sizing of multi tube pass shell and tube heat exchanger is obtained. The thermal sizing of multi tube pass shell and tube Heat Exchanger his desired with the bell manual method and for the same the numerical Analysis have been carried out based on the prescribed pressure drop criteria. The analysis of shell and tube Heat Exchanger and performance of evaluation is presently established technique used in power plant industry. In this paper the numerical investigation on tube side water flow pressure drop variations for Multi tube pass shell and tube heat Exchanger in addition to heat transfer coefficients are to be obtained. The pressure drop values for 1,2,4,6 tube pass shell and tube heat Exchanger are obtained by using "C "PROGRAMING and compared with Bell Manual Method values.

KEYWORDS: Heat exchanger, pressure drop, Heat transfer coefficient, shell and tube

I. INTRODUCTION

Heat exchanger is a device used for affecting the process of heat exchange between two fluids that are at different temperatures. Heat exchangers are use full in many engineering processes like those in refrigerating and air conditioning systems, power plants, food processing industries, chemical reactors and space and aeronautical applications.

A Heat Exchanger in which two fluids exchange heat by coming in direct contact is called a direct heat exchanger. Examples of this type are open feed water heaters and jet condensers. Recuperators (closed type exchangers) are heat exchangers in which fluids are separated by a wall. The wall me be a simple plane wall or a tube or a complex configuration involving fins, baffles and multi-pass of tubes.

The temperature and pressure levels, as well as differences often impose several problems. The corrosiveness, toxicity and scale forming tendency in addition to thermal properties of substances must be considered. There are also economic considerations, which include factor such as initial cost of the exchanger, necessary space, and required life of the unit cases of maintenance.

Types of Heat Exchangers:

Three main types of heat exchangers are:

1. Air- Cooled Heat Exchanger

Air cooled heat exchanger is a tubular heat transfer equipment in which air passes over the tubes and thus acts as the cooling medium. Air is available in unlimited quantities compared to water. Airside fouling is negligible where as water side fouling is a frequent problem. But the heat transfer coefficient of air is less than that of water.

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2. Plate Type Heat Exchanger

The plate type heat exchanger consists of a thin, rectangular metal sheet upon which a corrugated pattern has been formed by precision pressing. One side of each plate has a full peripheral gasket. The complete unit comprises of a number of such plates mounted on a frame and clamped together. The space between adjacent plates forms a flow channel. The cold and hot fluids flow through alternate flow channels.

3. Shell and Tube Type Heat Exchanger

Shell and tube type heat exchangers are the most versatile and are suitable for almost all applications, irrespective of duty, pressure and temperature. A shell and tube type exchanger consists of a cylindrical shell containing a nest of tubes which run parallel to the longitudinal axis of the shell and are attached to perforated flat plates called tube sheets at each end. There are a number of flat perforated plates through which the tube pass. These are called baffles. The baffles serve as supports and also direct the shell side fluid across the tubes. This assembly of tube and the baffles is called a tube bundle and is held together by a system of tie-rods and spacer tubes.

NOMENCULTURE

Ht: Tube side heat transfer coefficient
Hs: Shell side heat transfer coefficient
Uf: Overall heat transfer coefficient
Dp: Pressure drop
Np: Number of passes

II. LITERATURE REVIEW

R. Hosseini , A. Hosseini-Ghaffar and M. Soltan[1], has been obtained the heat transfer coefficient and pressure drop on the shell side of a shell-and-tube heat exchanger] have been experimentallyobtained for three different types of copper tubes (smooth, corrugated and with micro-fins). Also, experimental data has been compared with theoretical data available. Correlations have been suggested for both pressure drop and Nusselt number for the three tube types. A shell-and-tube heat exchanger of an oil cooler used in a power transformer has been modeled and built for this experimental work in order to investigate the effect of surface configuration on the shell side heat transfer as well as the pressure drop of the three types of tube bundles.

Milind V. Rane, Madhukar S. Tandale [2] for superheat recovery water heating applications, condenser and evaporator in heat pumps lube oil cooler for shipboard gas turbines, milk chilling and pasteurizing application. This paper presents an experimental study on various layouts of TTHE for water-to-water heat transfer. The theoretical and experimental results on this type of heat exchanger configuration could not be located in literature. Overall heat transfer coefficient and pumping power were experimentally determined for a fixed tube length and surface area of serpentine layouts with different number of bends and results are compared with straight tube TTHE.

E. Carluccio, G. Starace, A. Ficarella and D. Laforgia [3] has done a numerical thermo-fluid–dynamic study of a compact crossed flows heat exchanger (HX), used to coolthe high-pressure oil used in hydraulic circuits of earth-movement industrial vehicles.

Yunho Hwang, Jun-Pyo Lee and Reinhard Radermacher [4] implemented properly determine the oil charge to the compressor of a closed-loop vapor compression system, it is important to be able to accurately estimate how much oil is held-up in refrigeration cycle components other than the compressor. To provide such information, this paper reports the results of an experimental investigation of the oil distribution behavior in a specific transcritical CO_2 air-conditioning system. To experimentally measure the oil retention at each individual cycle component, a novel oil injection–extraction method was applied and a new test facility was developed. Experimental results show that as the oil concentration of the working fluids discharged from the compressor increases the oil retention volume in the heat exchangers and suction line also increases.

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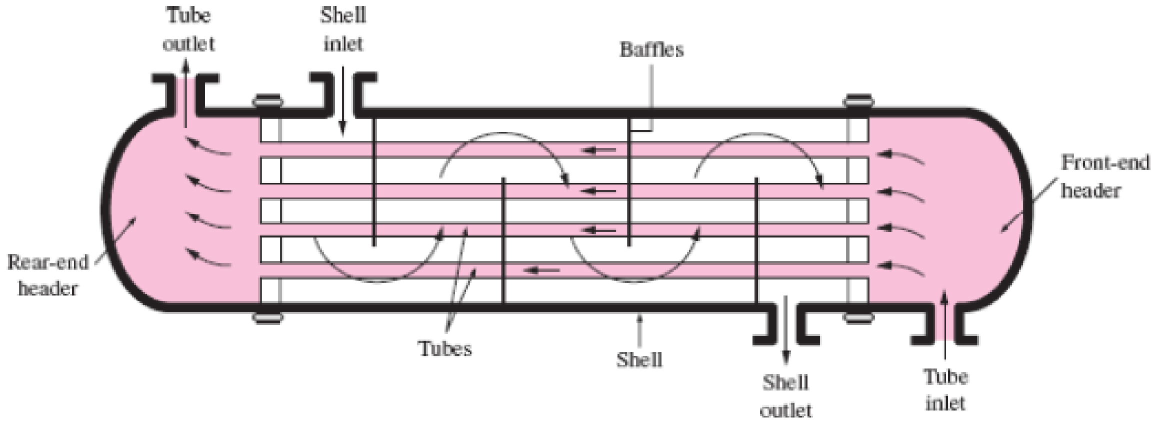
III.TEST METHOD

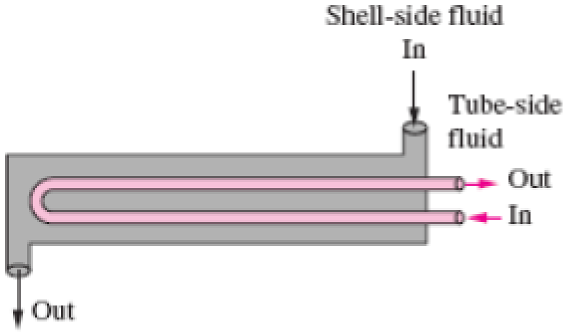
3.1 Mathematical modelling of shell and tube heat exchanger:
Figure 3.1 shows a shell and tube heat exchanger with one pass of shell and n passes of tubes. Assuming that the shell side flow is cross-mixed, all of the fluids temperatures changes are in the one direction so that this kind of heat exchangers can be modelled alone-dimensional heat exchangers and one can derive following
governing equations from energy equation :

$$N = \frac{\alpha A}{W}$$



Shell-and-tube heat exchangers contain a large number of tubes (sometimes several hundred) packed in a shell with their axes parallel to that of the shell. Baffles are commonly placed in the shell to force the shell-side fluid to flow across the shell to enhance heat transfer and to maintain uniform spacing between the tubes.

3.2 Multi passes flow arrangement in shell-and-tube heat exchangers:



(*a*) One-shell pass and two-tube passes

Fig. 3.2 (a) shows one shell pass and two –tube passes. In this hot fluid enters the shell side and the cold fluid enters the tube side. One shell and one tube pass since both the shell and tube side fluid make a single traverse through the heat exchanger. Thus, this type of shell-and-tube heat exchangers is designated as 1-1 exchanger. If we desire to pass the tube fluid twice, then it is designated as 1-2 exchangers.

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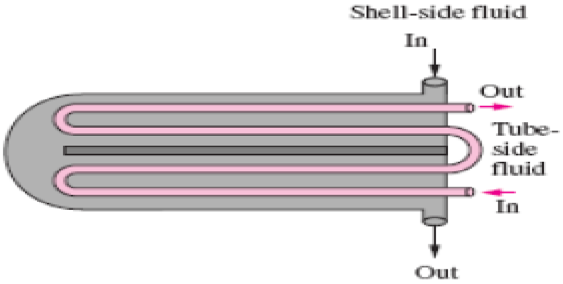

(b) Two-shell passes and four-tube passes

Fig. 3.2 (a) shows two shell pass and four –tube passes. In this hot fluid enters the shell side and the cold fluid enters the tube side. In this shell side fluid make traverses twice and tube side fluid make a four times through the heat exchanger. The designation will be 2-4 exchangers the number of pass in tube side is done by the pass partition plate

For shell side fluid:

$$Hs = 0.36 \text{ X } \frac{k}{De} \text{ X } Re^{0.55} \text{ X } Pr^{0.33} \text{ X } (\mu b/\mu w)^{0.14}$$

For tube side fluid:

$$Ht = 0.023 \text{ X } \frac{kw}{di} \text{ X } Re^{0.8} \text{ X } Pr^{0.4}$$

For tubes wall:
1/U = (1/ho+ffoil)+{(1/hi+ffwater)(Ao/Ai)}+tube wall resistance

Technical Data of Shell and tube Heat Exchanger:
Heat duty = 345000 Kcal/hr
Quantity of oil = 43.33 m^3/hr
Quantity of water = 200 m^3/hr
Cooling water inlet temperature, T_1 = 32.00ºC
Oil out let temperature, T_2 = 45ºC
Fouling factor on oil side = 0.0004 hrm^2 ºC / Kcal
Fouling factor on water side = 0.0002 hrm^2 ºC/ Kcal
Tube material =Admiralty brass
Thermal conductivity of tube material= 104.12 Kcal/hrmºC
Number of tubes = 776
Number of passes = 4
Length of the tube = 2300mm
Outside diameter of the tube do =15.875mm
Thickness of the tube =1.245mm
Inside diameter of the tube = 0.013385m
Inside surface area of the tube = $\pi \times d_i \times L = A_i$
= $\pi \times (0.013385) \times 2.3$
= $0.0967 m^2$
Outside surface area of the tube = $\pi\, d_o \times L = A_o$
= $\pi \times 0.015875 \times 2.3$
= $0.1147\ m^2$
Ratio of out side to inside surface area = A_o/A_i = 1.1862
Number of baffles = 11
Baffle cut = 28%

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Type of cooler = Shell and tube heat exchanger
Tube pitch/ type =20.64 mm/30º
Baffle thickness = 6mm
Shell inside diameter = 700mm
Number of tubes per pass =776/4=196
Baffle pitch = 141mm
OIL PROPERTIES AT AVERAGE TEMPERATURE (53 ºC): -
Density = 850 Kg/m^3
Specific heat =0.471 Kcal/Kg ºC
Thermal conductivity =0.12925 Kcal/hrmºC
Oil bulk viscosity = $(\mu_b)_{oil}$ = 73 Kg/hr m
Oil viscosity at tube wall temperature$(\mu_w)_{oil}$ =159 Kg/hr m
WATER PROPERTIES AT AVERAGE TEMPERATURE (34 ºC): -
Density = 1000 Kg/m^3
Specific heat = 1 Kcal/Kg ºC
Thermal conductivity = 0.5425 Kcal/hrmºC
Viscosity(μ_W) = 2.6 Kg/hr m

3.3 Simulation of Heat Exchanger:

In order to implement experimental data in the model, boundary conditions of each part of the system should be determined accurately.

Oil cooler heat exchanger

Oil circulates in a closed loop so the outlet and inlet oil temperatures are dependent and they can be correlated as follows:

$$Q = m_w S_w(t_2-t_1)$$

Table 3.1 Bell Manual Method

Number of passes	Ht Kcal/hrm^2 ºC	Hs Kcal/hrm^2 ºC	Uf Kcal/hrm^2 ºC	Dp Kg/m^2
1	2650	332	245	1432
2	4590	341	261	3645
4	8013.48	351.28	274.35	4178
6	11,144.68	364.45	290.14	14724

The table 3.1 represents the experimental results. in this the even number of passes increases the shell side heat transfer co efficient, tube side heat transfer and overall heat transfer co efficient increases and pressure drop also increases

Table 3.2 C Programming

Number of passes	Ht Kcal/hrm^2 ºC	Hs Kcal/hrm^2 ºC	Uf Kcal/hrm^2 ºC	Dp Kg/m^2
1-pass	2629	331.7	243.1	1143
2-pass	4578.7	340.12	259.95	2377
4-pass	7972	351	274.7	3250
6-pass	11026	364.3	285.6	11329

The table 3.2 represents the simulated results. in this the even number of passes increases the shell side heat transfer co efficient, tube side heat transfer and overall heat transfer co efficient increases and pressure drop also increases

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IV. RESULTS AND DISCUSSION

A computer code using C Programming software was developed to solve the governing equations in the number of passes, Pressure drop, Shell side, Tube side, Overall heat transfer coefficients.

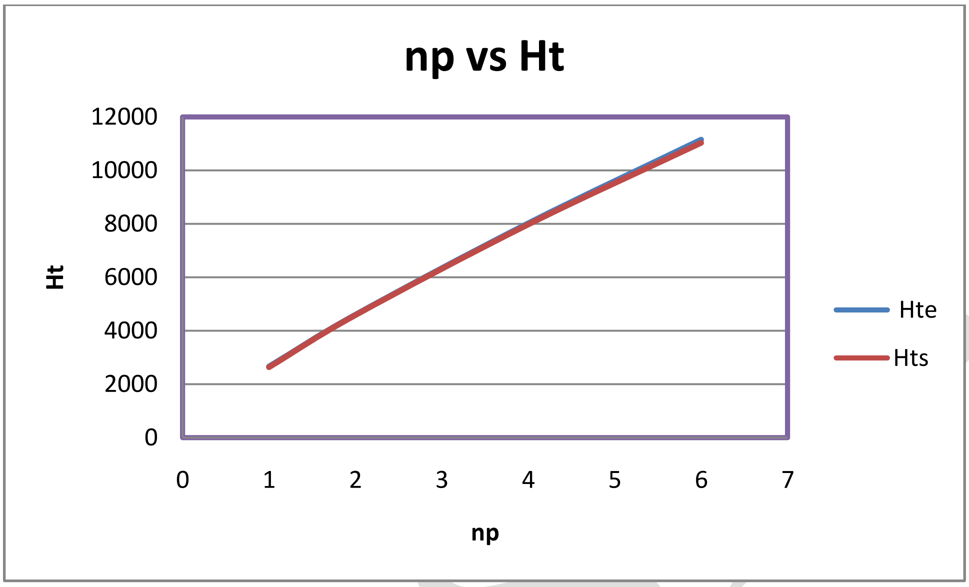

Fig 4.1 Number of passes vs Tube side Heat transfer coefficient

Fig 4.1 shows comparison of number of passes versus tube side heat transfer coefficient of experimental and simulated results is approximately same. As the even no. of passes increases, the tube side heat transfer coefficient increases.

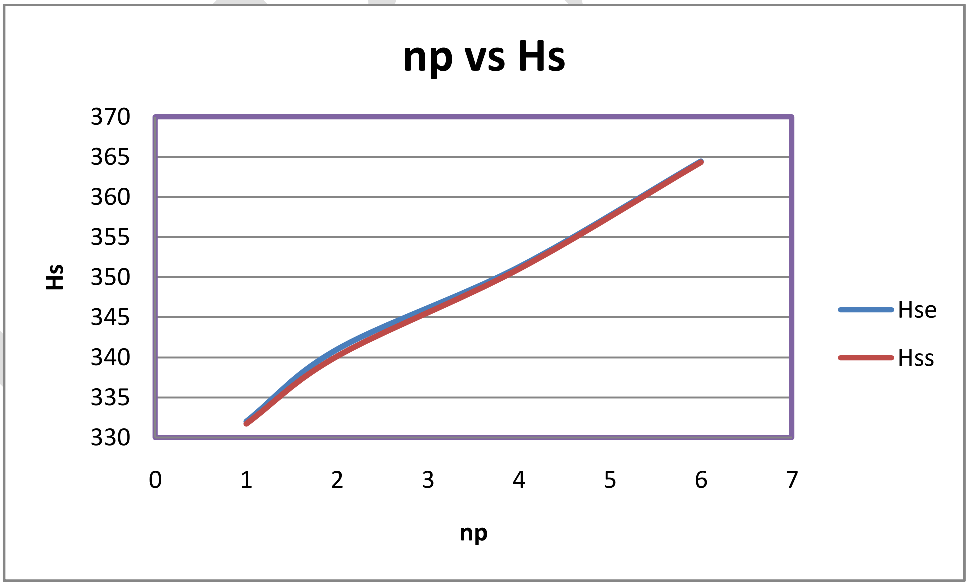

Fig 4.2 Number of passes vs Shell side Heat transfer coefficient

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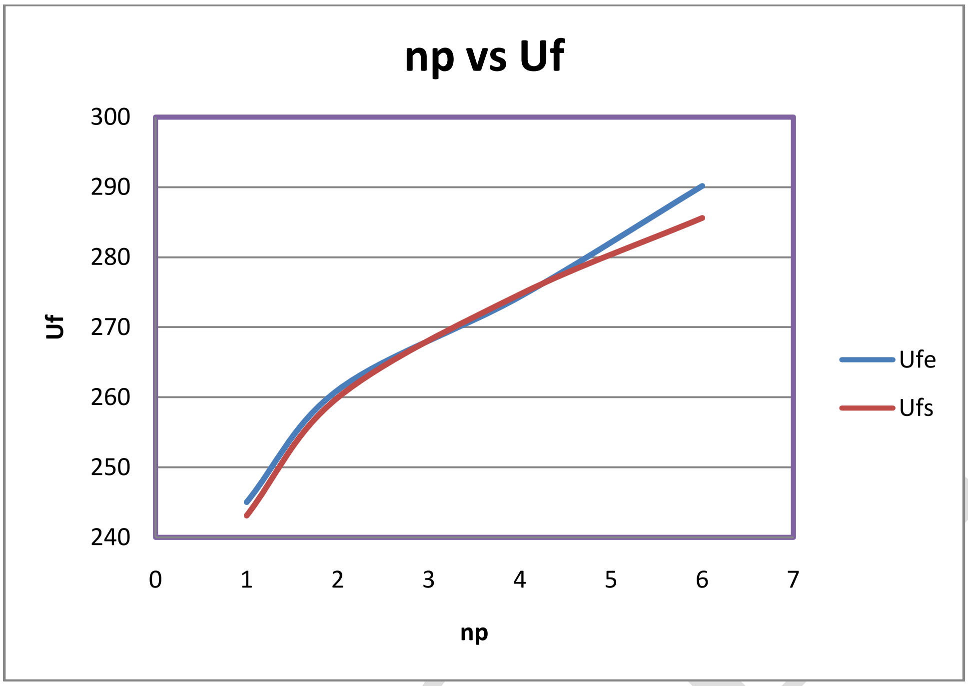

Fig 4.3 Number of passes vs Overall Heat transfer coefficient

Fig. 4.2, 4.3 shows the number of passes versus shell side and overall heat transfer coefficient. As the no. of passes increases heat transfer coefficient increases.

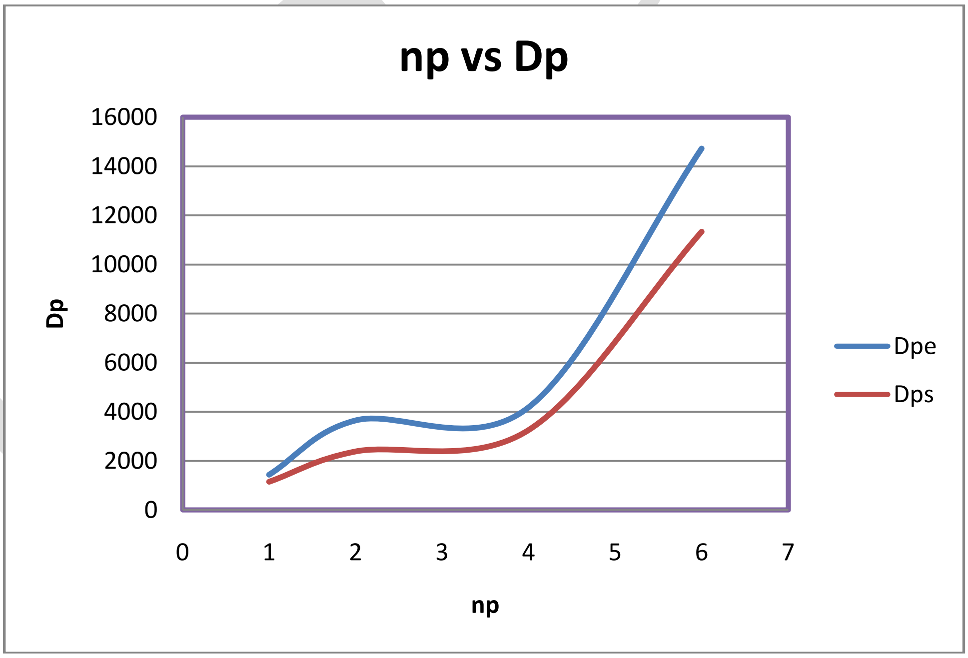

Fig 4.4 Number of passes vs Pressure drop

Fig. 4.4 shows the comparison of no. of passes versus pressure drop of experimental and Simulated values are changed. As the even number of passes increases the pressure drop increases. Due to velocity decreases the pressure drop increases.

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V. CONCLUSION

The thermal sizing of multi tube pas oil cooler is designed for various tube passes such as 1,2,4,6 tube pass with pressure drop as the main criteria. It is concluded that 4 tube pass is to be preferred than 6 tube pass since 4 tube pass calculated pressure drop is less than its allowable pressure drop. Almost similar results we observe red when we compared to simulated results with experimental results.

In the case of 6 tubes pass oil cooler the calculated pressure drop is too greater than allowable pressure drop results in the decrease of mass velocity, tube side heat transfer coefficient and overall heat transfer coefficient which inturn decreases the heat transfer rate causes heat transfer surface area is reduced. So in order to make constant heat duty load requires forced to enhance surface area.

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