NUMERICAL ANALYSIS OF PARALLEL FLOW HEAT EXCHANGER

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Abstract:-Heat transfer in parallel flow heat exchanger has been investigated. As we know that there is a limit of parallel flow heat exchanger that the temperature of cold liquid at outlet is never be equal to the temperature of hot liquid at outlet because in parallel flow heat exchanger, the heat exchange is not that good as in the counter flow heat exchanger. Our main focus is to increase the efficiency of the parallel flow heat exchanger and on the basis of this, decide the shape and size of the heat exchanger. The design of parallel flow heat exchanger is advantageous when two fluids are required to be brought to nearly the same temperature.

Keywords: Heat exchanger, parallel flow heat exchanger.

INTRODUCTION:-

Heat Exchanger is a device which provides a flow of thermal energy between two or more fluids at different temperatures. A heat exchanger is a device designed to efficiently transfer or "exchange" heat from one matter to another. When a fluid is used to transfer heat, the fluid could be a liquid, such as water or oil, or could be moving air. There are three types of heat exchanger. They are- 1) Parallel flow heat exchanger 2) Counter flow heat exchanger 3) Cross flow heat exchanger. Heat exchangers are used in a wide variety of engineering applications like power generation, waste heat recovery, manufacturing industry, air-conditioning, refrigeration, space applications, petrochemical industries etc. Heat exchanger may be classified according to the following main criteria. 1. Recuperates and Regenerators. 2. Transfer process: Direct contact and Indirect contact. 3. Geometry of construction: tubes, plates and extended surfaces. 4. Heat transfer mechanisms: single phase and two phase. 5. Flow arrangements: parallel, counter and cross flows. In a parallel flow heat exchanger, both fluids in the heat exchanger flow in the same direction. Whether parallel or counter flow, heat transfer within the heat exchanger involves both conduction and convection

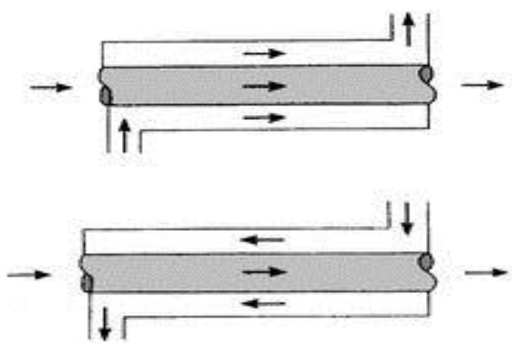


Figure : Concentric tubes heat exchangers

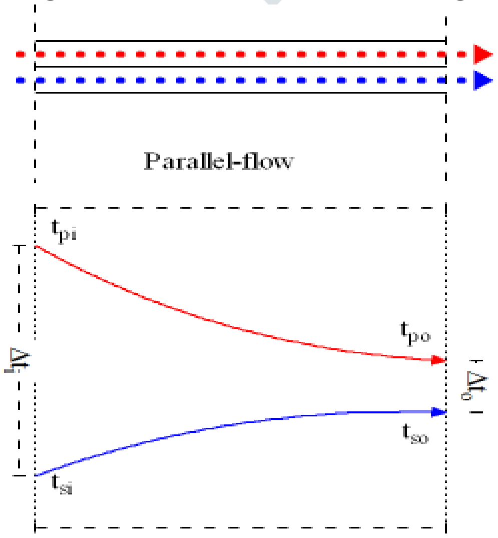


FIGURE: - Mean Temperature Difference Diagram

MATHEMATICAL FORMULATION:-

The concept of efficiency is used in many areas, particularly engineering, to assess the performance of real components and systems. Efficiency is a comparison between the actual, real, and ideal, best performances and is typically defined to be less than or at best equal to 1. The ideal behaviour is generally known from modelling, and the limitations dictated by physical laws, particularly the second law of thermodynamics. Knowing the ideal performance, the actual performance can be determined if expressions for the efficiency as a function of the system characteristics and the operating conditions are known. Efficiency provides a clear and intuitive measure of a system's performance by showing how close an actual system comes to the best that it can be and if further improvements are feasible and justified. Despite much effort, the application of the second law to heat exchangers has not yielded a consistent method for assessing the performance of heat exchangers. Two of the more widely used approaches for analysing heat exchangers are the log-mean temperature difference method, NTU method and effectiveness method.

LOGARITHMIC MEAN TEMPERATURE DIFFERENCE (LMTD) METHOD:-

Consider energy balance in a differential segment of a single-pass heat exchanger shown schematically in figure below. The rate of heat transfer in this segment is

$$dq\ (x) = U\Delta T(x)Da\ (x),$$

Where U is the overall heat transfer coefficient, ΔT is the local temperature difference between the hot and cold fluids, and dA is the contact area in the differential segment. The overall heat transfer coefficient is inversely proportional to the total resistance R_{tot} to the heat flow. The latter is the sum of (1) resistance $R_{conv,h}$ to convective heat transfer from the hot fluid to the partition between the fluids, (2) resistance R_p to thermal conduction through the partition, and (3) resistance $R_{conv,c}$ to convective heat transfer from the partition to the cold fluid. Therefore

$$U = \frac{1}{Rtot} = \frac{1}{RCONV,H+RP+RCONV,C}$$

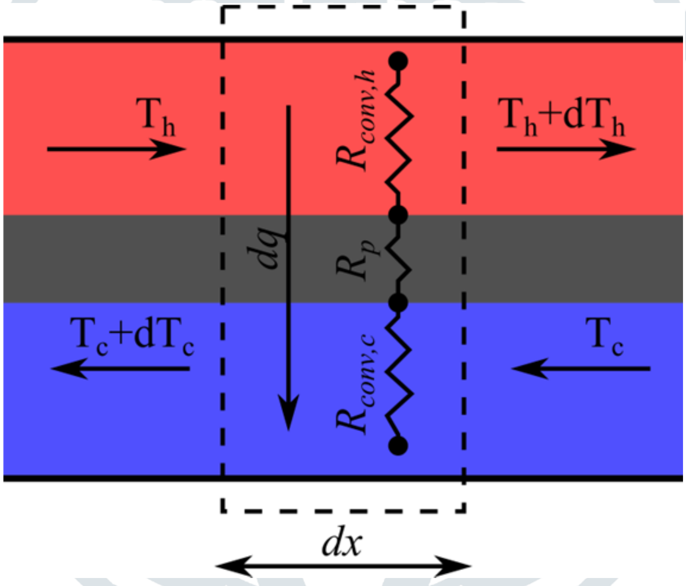


Figure 1-1. Energy balance in a differential element of a single pass heat exchanger operated in the counter-flow regime.

Red, blue, and grey colours represent the hot fluid, cold fluid, and the partition between the fluids, respectively. The dashed rectangle shows a differential segment corresponding to the energy balance Eq. (1). Three resistances ($R_{conv,\ h}$, R_p, and $R_{conv,\ c}$) contributing to the total resistance to the heat transfer are indicated schematically.

The total heat transfer rate is:

$$Q = \int_2^1 dq$$

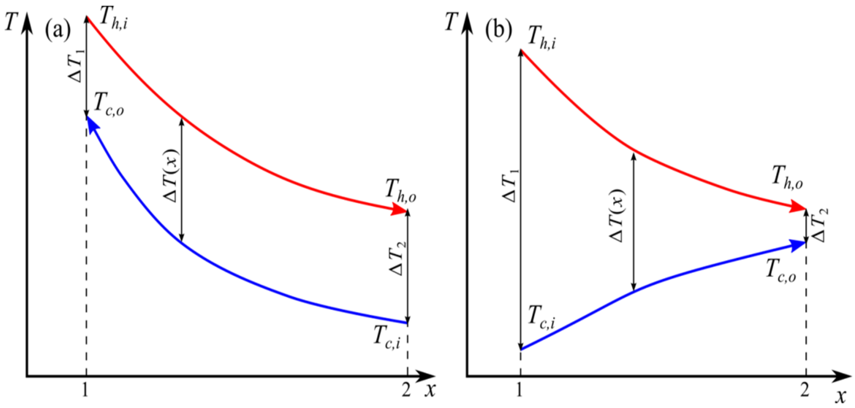


Figure 1-2. Temperature profiles in (a) counter-flow and (b) parallel flow single pass heat exchangers.

Note that in a counter-flow heat exchanger the outlet temperature of the cold fluid can exceed the outlet temperature of the hot fluid but this cannot happen in a parallel flow system. However, it is possible to obtain q by combining Eq. (1) with energy balances in differential segments of the heat exchanger

$$dq = C_h dT_h = C_C dT_c$$

Here, dTk is the temperature change of fluid k (k = c or h) in the interval under consideration, and here C_k is the heat capacity rate of fluid k,

$$C_k = m_k c_k \text{ , K = C or h}$$

Where m_k and ck are the mass flow rate and heat capacity of fluid k, respectively. This analysis yields

$$q = UA\Delta T_{lm}$$

Where A is the total contact area and ΔTlm is the logarithmic mean temperature difference (LMTD),

$$\Delta T\text{lm} = \frac{\Delta T1 - \Delta T2}{\ln(\Delta T1 - \Delta T2)}$$

Here, ΔT_K refers to temperature difference between the hot and cold fluids at point k (k = 1 or 2), i.e.
For the counter-current flow and

$$\Delta T_1 = T_{hi} - T_{co}, \quad \Delta T = T_{ho} - T_{co}$$

For the parallel flow,

$$\Delta T_1 = T_{hi} - T_{ci} \text{ , } \Delta T_2 = T_{ho} - T_{co}$$

EFFECTIVENESS-NTU METHOD:-

LMTD method is useful for determining the overall heat transfer coefficient U based on experimental values of the inlet and outlet temperatures and the fluid flow rates. However, this method is not very convenient for prediction of outlet temperatures if the inlet temperatures and U are known. In this case, one has to solve a nonlinear system of two equations and the overall energy balance) for two unknowns ($T_{h,o}$ and $T_{c,o}$). This solution requires application of an iterative approach.

A more convenient method for predicting the outlet temperatures is the effectiveness- NTU method. This method can be derived from the LMTD method without introducing any additional assumptions. Therefore, the effectiveness-NTU and LMTD methods are equivalent. An advantage of the effectiveness-NTU method is its ability to predict the outlet temperatures without resorting to a numerical iterative solution of a system of nonlinear equations. The heat-exchanger effectiveness ε is defined as

$$\varepsilon = \frac{q}{qmax}$$

Where q is the actual rate of heat transfer from the hot to cold fluid and q_{max} is the maximum possible rate of heat transfer for given inlet temperatures of the fluids?

$$q_{max} = C_{min} (T_{hi} - T_{co})$$

Here ,C_{min} is the smaller of the two heat capacity rates C_c and C_h. The efficiency ε depends on the heat exchanger geometry, flow pattern (parallel flow, counter-flow, cross-flow, etc.). And the number of transfer units.

$$NTU = \frac{UA}{Cmin}$$

Relationships between the effectiveness and NTU have been established for a large variety of heat exchanger configurations. Most of these relationships involve the ratio Cr = C_{min}/C_{max} ofthe smaller and the larger of the heat capacity rates Cc and Ch. For example, for a single pass heat exchanger in the parallel flow regime

$$\varepsilon = \frac{1 - \exp[-NTU(1+Cr)]}{1+Cr}$$

And for a single pass heat exchanger in the counter-flow regime,

$$\varepsilon = \frac{1 - \exp[-NTU[(1-Cr)]}{1 - Cr\exp[-NTU(1-Cr)]} \text{ , if } Cr \leq 1$$

$$\varepsilon = \frac{NTU}{1+NTU} \text{ , if } Cr = 1$$

RESULTS & DISCUSSION:-

When cold water constant

Thi (°c)	Tho (°c)	Tci(°c)	Tco(°c)
38.8	37.8	30.8	32.5
39	38.1	30.9	32.6
39	38.4	31	32.8
40	38.9	31.2	33.1

When hot water constant

Thi (°c)	Tho (°c)	Tci(°c)	Tco(°c)
39.5	36.7	27.7	29.2
40.7	37.8	28.8	30.4
41.7	38.1	29.8	31.4
41.9	39.4	30.4	32.9

For Hot Water

LMTD 1	9.49
LMTD 2	9.47
LMTD 3	8.77
LMTD 4	8.72

For Cold Water

LMTD 1	**6.56**
LMTD 2	**6.71**
LMTD 3	**6.74**
LMTD 4	**7.21**

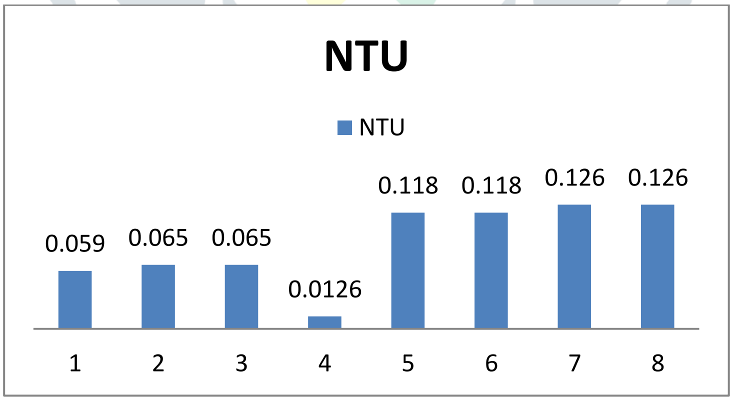
dQ1	**11.70**
dQ2	**12.12**
dQ3	**10.86**
dQ4	**10.45**
dQ5	**7.10**
dQ6	**7.1**
dQ7	**7.52**
dQ8	**7.94**

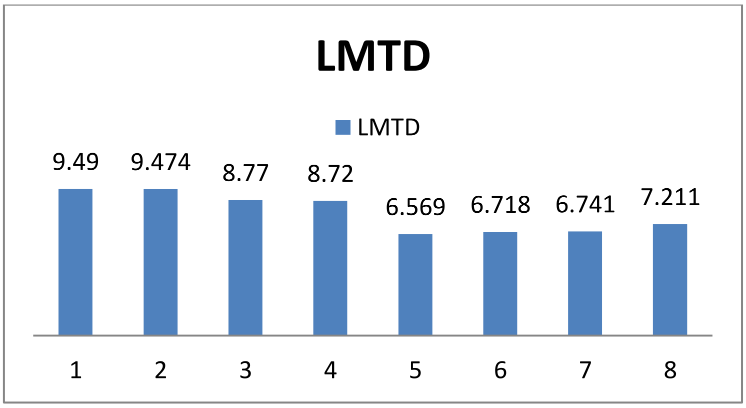
Effectiveness

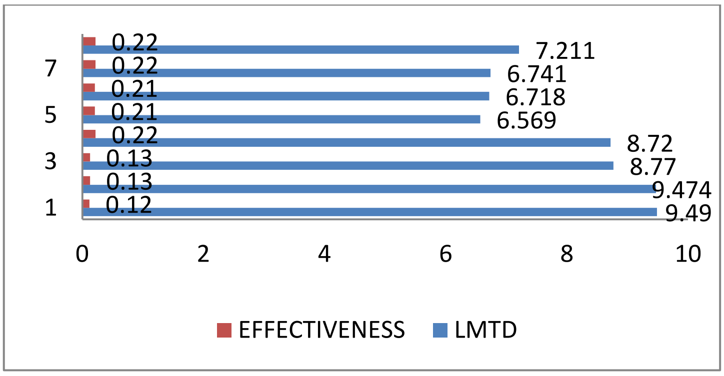
ε_1	**0.12**
ε_2	**0.13**
ε_3	**0.13**
ε_4	**0.22**
ε_5	**0.21**
ε_6	**0.21**
ε_7	**0.22**
ε_8	**0.22**

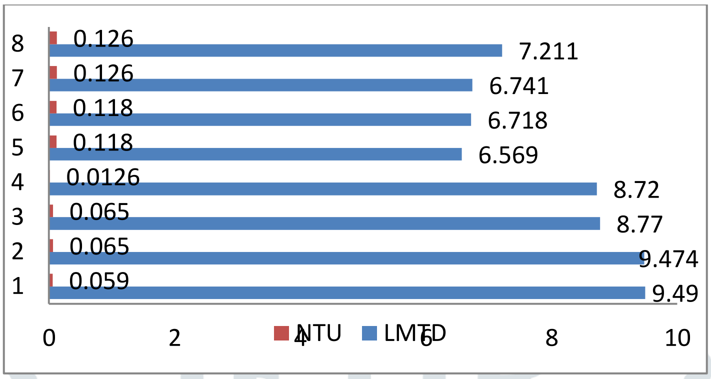
Net transfer unit

NTU_1	**0.059**
NTU_2	**0.065**
NTU_3	**0.065**
NTU_4	**0.126**
NTU_5	**0.126**
NTU_6	**0.118**
NTU_7	**0.126**
NTU_8	**0.126**









CLOSURE:-

The effect of heat transfer through a parallel flow heat has been analysing under parallel flow operation. As we know in parallel flow heat transfer, heat transfer is less than counter flow heat exchanger. Temperature difference in parallel flow heat exchanger (hot inlet is much more than the cold outlet). In our research we study the performance of parallel flow heat exchanger and its temperature behaviour which is identified by some methods like (L.M.T.D, NTU) and we created some graphs to differentiate temperature phenomenon between L.M.T.D and NTU.

NOMENCLATURE:-

A = Area
T_{hi} = Temperature of hot fluid at inlet.
T_{ho} = Temperature of hot fluid at outlet.
T_{ci}= Temperature of cold fluid at inlet.
T_{co} = Temperature of cold fluid at outlet.
dQ = Heat transfer rate
Q = Heat transfer rate per unit time
T = Absolute temperature
K = Thermal Conductivity
Q = Heat transfer per unit area per unit time
C_p = Specific heat of fluid
Δt = Temperature drop or rise of a fluid across the heat exchanger
C_h= Heat capacity or water equivalent of hot fluid
C_c = Heat capacity or water equivalent of cold fluid
Hs = Fouling factor
C_r = Ratio of minimum heat capacity to the maximum heat capacity

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