Performance Analysis of Shell and Tube Heat Exchanger

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Abstract:- **The main aim of the present work is achieved by calculating heat transfer coefficient using water as a base fluid .The kern's method is simplest and easy to understand as compared to the other methods. The poor heat transfer properties of the employed fluids in the industries are obstacles for using different types of heat exchangers. Hence using Nano fluids, improves Heat Transfer and Stability, Reduced Pumping Power, Minimal Clogging, Miniaturized Systems & Cost and Energy Saving.**

Keywords — Heat exancher, heat transfer coefficient, nano fluids.

I. INTRODUCTION

Heat exchangers are devices used for effective transfer of heat energy from one or more fluids to another across a solid surface, usually for both cooling and heating large/small scale industrial processes. Globally, they are extensively used in numerous industries, namely, petrochemical, power generation and food processing. Industrial heat exchangers, in essence, are categorized in accordance to various parameters including type of transfer process, size, flow configurations and arrangements, pass arrangements and heat-transfer mechanisms. Examples of these heat exchangers include shell and tube, compact, double pipe and plate.

A heat exchanger is a piece of equipment built for efficient heat transfer from one medium to another as shown in figure 1. The media may be separated by a solid wall, so that they never mix, 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. One such type is shell & tube Heat exchanger.

L.B. Mapa, Sana Mazhar[1], analyses that the nanotechnology is concerned with the materials and systems whose structures and components exhibit novel and significantly improved physical, chemical, and biological properties, phenomena, and processes due to their nanoscale size

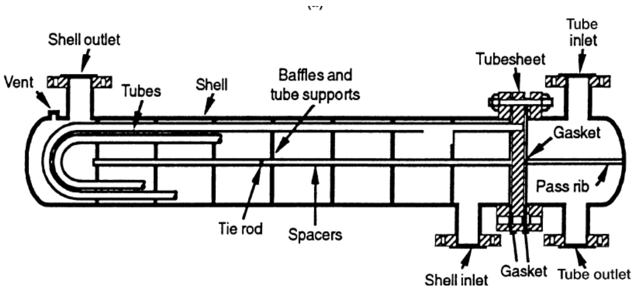

Fig. 1. Shell and tube heat exchanger

Young-Seok Son", J ee-Young Shin[2] proposes conventional shell-and-tube heat exchanger, fluid contacts with tubes flowing up and down in a shell, therefore there is a defect in the heat transfer with tubes due to the stagnation portions. Masoud haghshenas fard , Mohammad reza talaie , Somaye nasr[3] analysed with plate and concentric tube heat exchangers are tested by using the water--water and nanofluid-water streams. M. Raja, R.M. Arunachalam and S. Suresh[4] evaluated the heat transfer characteristics of Alumina/water nanofluid in a STHE with the aid of coil insert is being studied. Investigations were made on the effects of Peclet number and the effect of the Alumina/water nanofluid concentration on the heat transfer and pumping power characteristics. H. D. Li, V. Kottke[5] determined the local heat transfer coeffcients on the shell side of shell-and-tube heat exchangers for in-line tube arrangement are visualized and determined from mass transfer measurements. Navid Bozorgan, Mostafa Mafi, and Nariman Bozorgan[6] focuses on the potential mass flow rate reduction in exchanger with a given heat exchange capacity using nano fluids. A.N. Mahure and , V.M. Kriplani[7] In this paper, heat transfer augmentation techniques refer to different methods used to increase rate of heat transfer without affecting much the overall performance of the system. Ye Yao , Xingyu Zhang ,Yiying Guo [8] In this paper, a high-intensity ultrasound can induce cavitation bubbles and acoustic streaming in liquid, which makes it possible for power ultrasonic to be applied to the improvement of heat transfer process. Nenad Radojkovicl, Gradimir Ilic1, Zarko Stevanovic, Mica Vukic1, Dejan Mitrovic1, Goran Vuckovic1[9,10 and 11] has been carried out experimental investigations were done to identify influence of thermal and flow quantities and shell side geometry on STHE's heat exchange intensity.

In the present work, a stainless steel shell and tube heat exchanger is used to study the various parameters of the heat exchanger such as heat transfer coefficient, Reynolds's number, pressure drop, Overall heat transfer coefficient etc using water as a heat transfer medium

II. EXPERIMENTAL SET UP

Fig. 2. Shows the experimental setup of Shell and tube heat exchanger consisting of a calming section, test section, rotameters, overhead water tank for supplying cold water & a constant temperature bath for supplying hot water with in-built heater, pump & the control system. The test section is a smooth stainless tube with dimensions of 800mm length, Inner diameter of tube-16mm ID, and Outer diameter of tube-19mm OD. These tubes are arranged in triangular pitch in the shell. Two calibrated rotameters, with the flow ranges, are used to measure the flow of cold water. The water, at room temperature is drawn from an overhead tank using gravity flow. Similarly a rotameter is provided to control the flow rate of hot water from the inlet hot water tank. Four thermo-couples are used measure the inlet & outlet temperature of hot water & cold water (T1 –T4) through a multipoint digital temperature indicator. Sensors are inserted to measure the mass flow rate in shell and as well tubes sides.

Fig. 2. Experimental setup

III. EXPERIMENTAL PROCEDURE

1. Water is collected upto some volume in the tanks provided in the experimental set up of shell and tube heat exchanger.
2. All the rotameters & RTD are calibrated.
3. Shell and tube heat exchanger set up is made ON and heater provided is connected to the red water tank.
4. Temperature is taken into consideration as water is started to heat.
5. Pumps of shell side and tube side are started and flow takes place. Hot water at about 60°C is allowed to pass through the tube side of heat exchanger.
6. Cold water is now allowed to pass through the shell side of heat exchanger in counter current direction at a desired flow rate.
7. The water inlet and outlet temperatures for both hot water & cold water (T1-T4) are recorded only after temperature of both the fluids attains a constant value.
8. The procedure was repeated for different cold water flow rates
9. Temperatures are noted through the display. Temperatures for shell inlet and out let and tube side inlet and outlet are calibrated using thermocouples connected at every inlets and outlets.
10. Minimum five readings are taken for every flow.
11. The values are noted down through the computer connected to the experimental set up.
12. Values are logged in for every reading using the software interface.
13. Graphs are generated for every flow and temperatures in the excel sheets.
14. Properties of fluids used is to be enter if different fluid is used other than water as water's properties are already been induced in the software provided.
15. After completion of logging many readings, the log sheet of results is generated which is to be saved for calibration
16. Pressure drop is measured for each flow rate with the help log sheet.
17. Over all heat transfer rate is measured.
18. Discuss your results, by
19. Commenting on the results and possible reasons for discrepancies,
20. Reporting on the possible sources of errors in the experiment, and
21. Analyzing the assumptions made during the experiment and their effects on the results in detail.

IV. DESIGN PROCEDURE

Shell and tube heat exchanger is designed by trial and error calculations. The procedure for calculating the shell-side heat-transfer coefficient and pressure drop for a single shell pass exchanger is given below The main steps of design following the Kern method are summarized as follows:

STEP 1: Calculating the area of cross flow As, for hypothetical row of tubes at the shell Equator, given by

As = {(Pt – Do)*Ds*Lb} /Pt

STEP 2: Calculate shell side mass velocity Gs and linear velocity Us.

Gs = ms / As or Us = Gs / ρs

STEP 3: Calculate the shell side equivalent diameter De.

For square pitch:

De = [4*(Pt2 – {(π/4)* Do2}] / (π* Do)

For triangular pitch:

De = [4*{(Pt2*√3)/4} – {(π* Do2)/8}] / [(π*Do)/2]

STEP 4: Calculate shell side Reynolds number Res.

Res = (Gs* De) / µs Or Res = (Us* De* ρs) / µs

STEP 5: Calculate shell side Prandtl number Prs.

Prs = (Cps*µs) / Ks

STEP 6: Calculate the shell side heat transfer coefficient hs

hs = 0.36*(Ks / De)* (Re^0.55)*(Pr^0.33)*{(µs / µw)^0.14}

Note: The value of (µs / µw) ^0.14 = 1, for water.

CALCULATION OF SHELL SIDE PRESSURE DROP

STEP 7: Calculate the number of baffles on shell side Nb.

Nb = {Ls / (Lb + tb)} – 1

STEP 8: Calculate the friction factor f.

f = exp {0.576 – (0.19*Ln Res)}

STEP 9: Calculate the shell side pressure drop ΔPs.

ΔPs = [4* f* Gs2* Ds*(Nb+1)] / [2* ρ*De*×{(µs / µw)^0.14}]

V RESULTS AND DISCUSSIONS

The shell and tube heat exchanger is analyzed using Kern's method and heat transfer coefficient, Reynold's number, pressure drops, overall heat transfer coefficient etc are calculated for various mass flow rates and the results are shown in the graphs from figures 3 to 11. It is found that, shell side heat transfer coefficient increases with increasing mass flow rate. Also the shell side pressure increases rapidly with increasing flow rate.

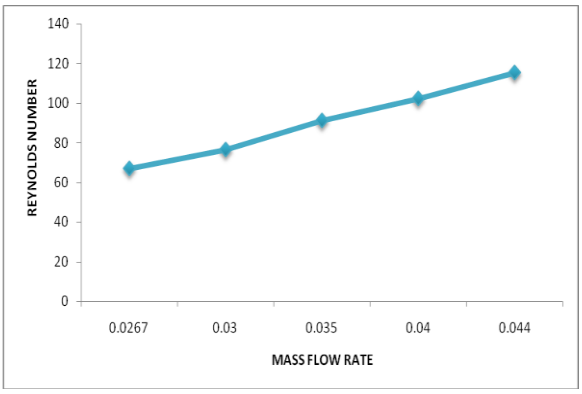

Fig. 3. Reynolds Number V/S Mass Flow Rate

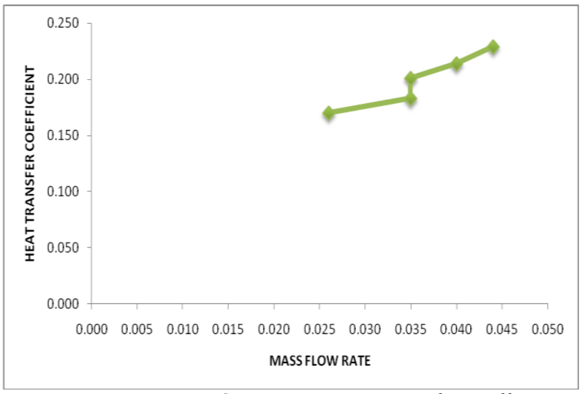

Fig. 4. Mass Flow Rate V/S Heat Transfer Coefficient

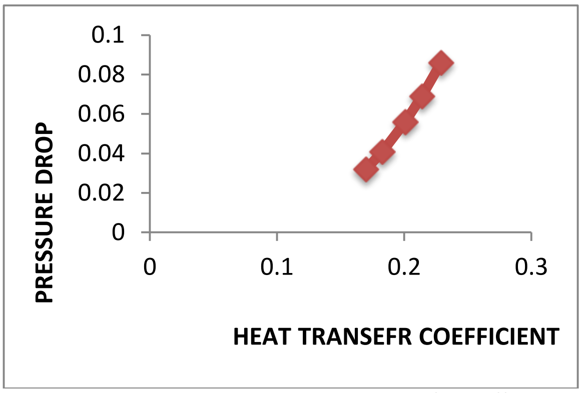

Fig. 5. Pressure Drop V/S Heat Transfer Coefficient

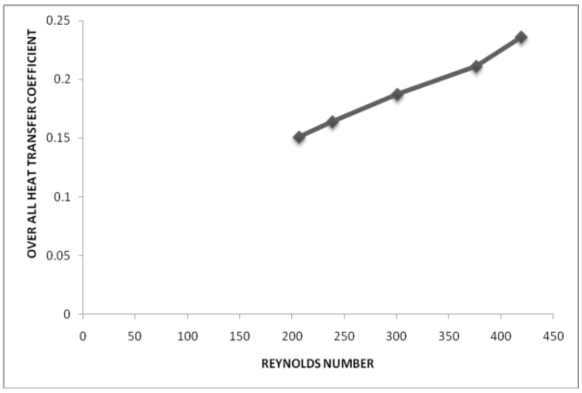

Fig. 6. Reynolds number V/s Over All Heat Transfer Coefficient on Shell and Tube Side

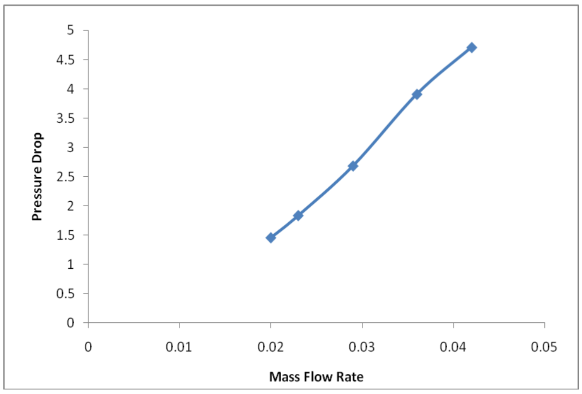

Fig. 7. Pressure Drop V/s Mass Flow Rate On Tube Side

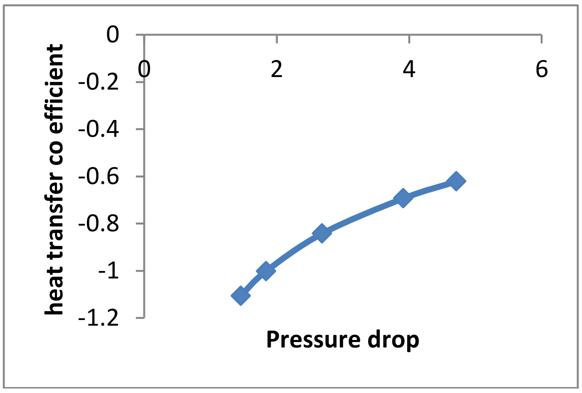

Fig. 8. Heat Transfer Co efficient V/s Pressure Drop

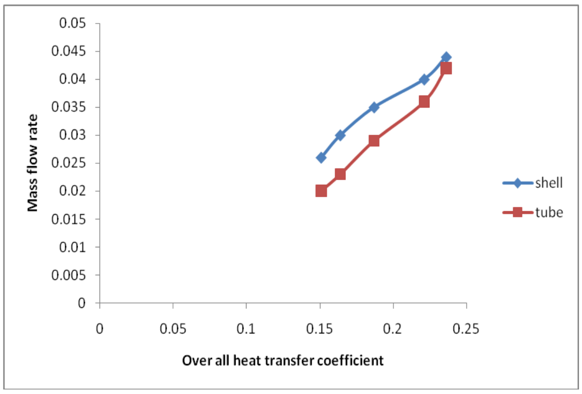

Fig. 9. Mass Flow rate V/s Overall Heat Transfer Coefficient on Shell and Tube Side

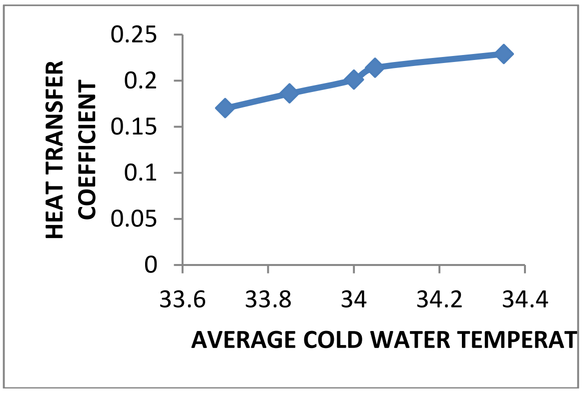

Fig. 10. Heat Transfer Coefficient V/s Average Cold Water Temperature

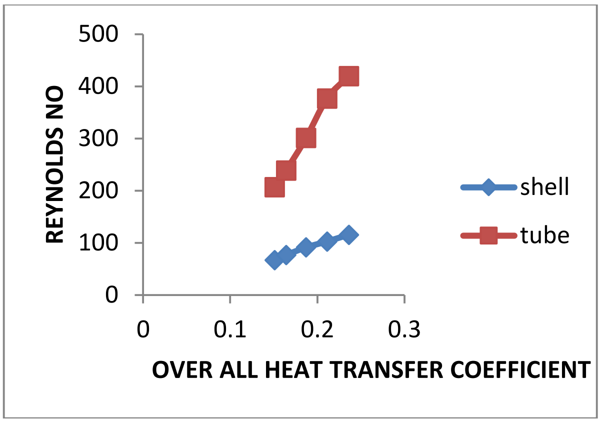

Fig. 11. Reynolds number V/s Over All Heat Transfer Coefficient on Shell and Tube Side

VI CONCLUSIONS

It is found that among the all method, the Kern method provided a simple method for calculating shell side pressure drop and heat transfer coefficient. However, this method cannot adequately account the baffle to shell and tube to baffle leakage. By this experimentation it is clear that heat transfer co-efficient and various thermal parameters can be calculated and analyzed up to higher accurate as compared to the other methods.

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