Prototype of Heat Exchanger U-Tube Model Shell and Tube Counter Flow

(Second Project)

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Abstract— The objective of this research is to be discussed about the results of the study of the manufacture of the Heat Exchanger Cooler type U-Tube with 2 types of fluid namely: Water as cold fluid and Oil as a hot fluid where the flow direction of each fluid is counter flow. In this research also uses 2 kind of method, first method is empirical method which is using some formula to identification the impact of using U-Tube as a heat exchanger and second method is practial/experimental method which take datum in real time. This heat exchanger using diffrent pump there are water pump and oil pump with adding the same static variable in the form of oil pump avarage flowrate and Temprature is about 9.64 L/min and 95,17oC, water pump average flowrateand temprature is about 30,42 L/min and 30,50 oC. The material of tubes was made from cooper tube with diameter 4mm for inner inlet and 6mm for outer inlet, total 31 tube cooper shaped U with 1000mm length. From the experimental method proves that 58.83% temprature drop was occured in this type of heat exchanger.

Keywords— *Heat Exchanger, Counter Flow , U- Tube, Fluids, Cooler, Flowrate*

I. INTRODUCTION

Heat exchangers are off-the-shelf equipment targeted to the efficient transfer of heat from a hot fluid flow to a cold fluid flow, in most cases through an intermediate metallic wall and without moving parts. There many different types of heat exchangers; some more appropriate for certain environments than others. Some have built-in dividers to separate the heat storage, while others allow the mixing of heat. Counter-flow Exchangers push the cold fluid from one direction of the exchanger while the hot will enter from the other direction and they will flow past each other. Counter-flow exchangers are often considered the most efficient at transferring heat.

II. LITERATURE REVIEW

A. *Shell and Tube Heat Exchanger*

The shell-and-tube heat exchanger (STHE) is the most common type of heat exchanger. It originated from the jacketed-coil distiller, and is used in heavy industries (steam condensers, boilers), and residential hotwater and heating systems (fire-tube water heaters). Several details of STHEs are presented in Fig.1
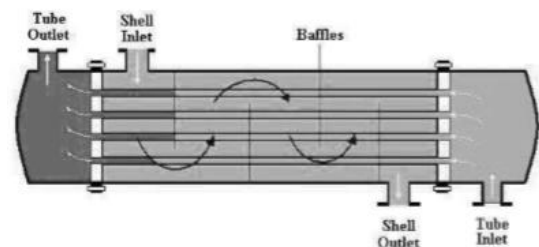

Fig. 1. Schematic diagram of a STHX with one shell pass and one tube passMaintaining the Integrity of the Specifications

B. *Heat Exchanger Analysis*

The thermal analysis of a heat exchanger is based on the simple coaxial configuration (Fig. 2), where one fluid goes along a pipe, and the other fluid goes along the annular section within a larger cylindrical sheath with openings at the ends, and in particular, to the counter-current configuration shown in Fig. 2a, more thermally-efficient than the co-flow set-up of Fig. 2b. The coaxial cross-section is sketched in Fig. 2c. Longitudinal temperature-profiles for the counter-flow and the co-flow configurations are also shown, and a detail of the transversal temperature profile across the wall separating the two fluids (Fig. 2d). The minimum temperature jump from one fluid to the other is called the (temperature) 'approach' of the heat exchanger.
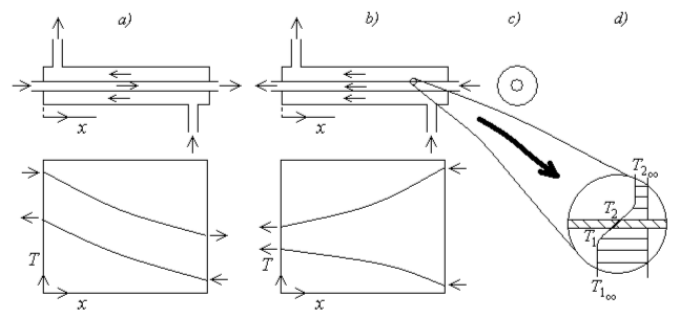

Fig. 2. Simple annular heat exchanger : a) sketch and temprature profile in a counter flow configuration, b) sketc and temprature profile in co-flow, c) cross-section sketch, d) detail accros the separating surface

III. RESEARCH APPROACH

This research used 2 methods of analysis, there are : experimental methods that have been made in the previous journal and the theoretical methods that will be discussed in this journal. In the theoretical method will analyze the heat exchanger using several formulas

A. Teoritical/Emprical Method

This method uses the formula to do a quantity of heat transfer that occurs in the tube, the calculation of the heat exchanger prototype analysis, determined by a default setting as follows :

- Discharge on water pump spcified by 10 liters/min
- Flowrate at the oil pump specified by 5 litres/minute
- T_{cold}, in (water-in temperature) = 25°C.
- T_{hot}, in (oil-in temperature) = 60°C.

B. Practical/Actual Method

Practical/actual method is retrieving data from a device that is read by sensors installed around the tube, the data that will be taken is the data from the the temprature sensor and flowrate sensor.

IV. RESULT

Calculation of the heat exchanger analysis is determined by default setting :
Properties on Heat Exchanger

- Q (debit) $_{air}$ = 30 liter/menit
- Q (debit) $_{oli}$ = 9 liter/menit
- $T_{cold,in}$ (temperature water in) = 30° C
- $T_{hot,in}$ (temperature oil in) = 100° C

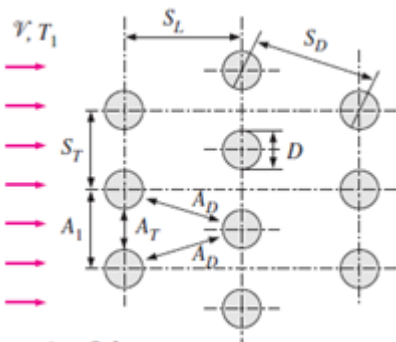The prototype heat exchanger model follows the bank's staggered tube model, as shown in Fig 2

Fig. 3. Staggered tube bank

With default setting as follows :

- S_L = 0,02 m
- D = 0,004 m
- S_T = 0,02 m
- $T_{cold,in}$ = 25°C
- $T_{hot,in}$ = 60°C
- $Q_{pump\ water}$ = 10 l/min

The first step in the ε NTU method is determine the heat capacity rates of the hot and cold fluids and identity the smaller one. Based on thermal table we can conclude that :

ρ_{water} (30°C) = 996 kg/m³.

ρ_{oil} (100°C) = 840 kg/m³

$C_{p.hot}$ (oil), T_{oil}= 100°C = $2220 \frac{J}{kg}.K$

$C_{p.cold}$ (water) , Twater =30°C = $4178\frac{J}{kg}.K$

Calculation of m° $_{water}$ using formula[1] as follows :

$$\dot{m}(water) = \rho_{water}.Q_{water}$$

$$\dot{m}(water) = \frac{996kg}{m^3}.30\frac{l}{min}$$

$$\dot{m}(water) = 996\frac{kg}{m^3}.\left(30x10^{-3}.\frac{m^3}{min}\right).\frac{1min}{60s}$$

$$\dot{m}(water) \doteq 0,498 kg/s$$

Calculation of m° $_{oil}$ using formula[1] as follows :

$$\dot{m}(oli) = \rho_{oli}.Q_{oli}$$

$$\dot{m}_{oli} = 840\frac{kg}{m^3}.9\frac{l}{min}$$

$$\dot{m}(oli) = 840\frac{kg}{m^3}.\left(9x10^{-3}\frac{m^3}{min}\right).\frac{1min}{60s}$$

$$\dot{m}(oli) = 0,126\frac{kg}{s}$$

Calculate heat capacity rate using formula as follows :

$$C_h = \dot{m}_{oli} \times C_{p.oli}$$
$$C_h = 0,126\frac{kg}{s} \times 2220\frac{J}{kg}.K$$
$$C_h = 0,28 \frac{K.W}{^oC}$$

Calculate heat capacity rate-cool (water) using formula as follows :

$$C_c = \dot{m}_{water} \times C_{p.c}(water)$$
$$C_c = 0,498\frac{kg}{s} \times \frac{4178 J}{kg}K$$
$$C_c = 2,09 K.\frac{W}{C^o}$$

Calculate Cmin = Ch (oil) = 0,28 K.W/°C

$$C = \frac{C_{min}}{C_{max}} = \frac{0,28}{2,09} = 0,134$$

Calculate heat transfer-rate maximum

$$\dot{Q}_{max} = C_{min}\left(T_{hot(oli)} - T_{cold(air)}\right)$$

$$\dot{Q}_{max} = 19,6\ KW.$$

To calculate heat transfer on surface area using formula as follows :

$$A_s = n(\pi.D.L)$$

$$A_s = 31(3{,}14 \times 0{,}004 \times 30)$$

$$A_s = 11{,}68 m^2$$

To find the value from NTU on the heat exchanger, it must first find the U value, using the equation:

$$U = \frac{\dot{Q}_{max}}{A_s \times \Delta T_{lmtd}}$$

$$U = \frac{19{,}6 \ kw}{11{,}68.m^2 (100-30)C^o}$$

$$U = \frac{19{,}6.KW}{817{,}6 \ m^2 C^o}$$

$$U = 0{,}024 \frac{KW}{m^2 C^o}$$

The next step is to find the value from NTU using the equation:

$$NTU = \frac{U.A_s}{C_{min}}$$

$$NTU = \frac{0{,}24 \frac{KW}{m^2 C^o} \times 11{,}68 m^2}{0{,}28 \frac{KW}{C^o}}$$

$$NTU = 1{,}00$$

To find the value of the effectiveness of the heat exchanger, with the value of C = 0.134 and the value of NTU = 1.00, then by looking at figure 13-26, in Yunus.A Cangel's book, page 695, in table C, so the value of effectiveness can be define as follows :

$$\in = 0{,}63$$

So to find the actual rate value of the heat exchanger, follow the equation:

$$\dot{Q} = \in . \dot{Q}_{max}$$

$$\dot{Q} = (0{,}63) \times 19{,}6 \ KW$$

$$\dot{Q} = 12.34 \ KW$$

To determine the outlet temperature of the cold and the hot fluid stream, it is determined by the equation:

$$\dot{Q} = C_c (T_{c,out} - T_{c,in})$$

To find the value of $T\_ (c, out)$, in water (the temperature of the water out) using the equation :

$$T_{C,oout} = T_{c,in} + \frac{\dot{Q}}{C_c}$$

$$T_{c,out} = 30C^o + \frac{12{,}34 \ KW}{2{,}09 \ KW/C^o}$$

$$T_{c,out(water\ out)} = 35{,}9 \equiv 35C^o$$

So we can define the value of T oil out using equation :

$$T_{c,out}(oil\ out) = T_{c,in} - \frac{\dot{Q}}{C_h}$$

$$T_{c,out} = 100C^o - \frac{12{,}4 \ KW}{0{,}28 \ KW/C^o}$$

$$T_{c,out\ (oil\ out)} = 100C^o - 61C^o$$

$$T_{c,out(oil\ out)} = 39C^o$$

Based on the actual data from the prototype heat exchanger that already presented in the previous journal, the average temperature data was obtained:

- Water-In = 30°C
- Temprature Water-Out = 33°C
- Temprature Oil-In = 100°C
- Temprature Oil-Out = 45.06°C

As for the results of calculations using a mathematical model, the results of the temperature of the water coming out and the temperature of the oil out are:

- Temprature Water-Out = 35°C
- Temprature Oil-Out = 39°C

By comparing the results of actual data and empirical data, for the prototype of the U tube heat exchanger model the effectiveness of the heat exchanger will be calculated by equation as follows :

$$Effectiveness\ H.E(model\ U\ tube) = 100\% - \frac{45C^o - 39C^o}{45C^o} x100\%$$

$$Effectiveness\ H.E(model\ U\ tube) = 86{,}67\%$$

V. CONLUSION

From the research that has been done and the data that has been obtained, that the calculation data shows that there is a decrease in oil temperature at 45°C and according to the actual data there is a decrease in temperature at 39 °C. By comparing the results of actual data and empirical data, for the prototype of the U tube heat exchanger model the effectiveness of the heat exchanger about 86%, it proves that heat exchanger type U-Tube with Counter Flow has the best design for Dropping the Temprature

VI. REFRENCES

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