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Design And Manufacturing of Double Pipe Heat Exchanger

[1]Archit Patel, [2]Vinit Patel, [3]Chintan Bhatt, [4]Chirag Singapuri, [5]Urvin Patel

[1,2,3,4] U.G. Student, [5]Assistant Professor
[1,2,3,4,5]Mechanical Engineering Department,
[1,2,3,4,5]Chhotubhai Gopalbhai Patel Institute of Technology, Bardoli, Surat, India

Abstract - *The design of double pipe heat exchanger for the laboratory used is aim to carry out the design of heat exchanger using data available from experiment and literature. The heat exchanger is aimed to manufacture and to prepare a experimental setup by means of this setup one can perform a practical work to understand concept of heat exchanger. Mild steel pipes are used for preparation of setup in both pipes. The effectiveness of this setup would be targeted between 10 to 20 as the losses and human errors are concerned.*

IndexTerms **-** heat exchanger, LMTD, NTU, nusselt number, prandlt number, water(H_2O), mild steel.

I. INTRODUCTION

Now a days, Heat exchangers are very prominent in the industries. In each and every way it is useful to the costumers. Any industry has some amount of heat generation. So, for the dissipation of heat generated different equipments are there for it. From that equipments double pipe heat exchanger is one of that which is prominently used in the food process industries and many more industries like chemical industries, pharmaceutical industries, power plants, etc. In heat exchanger, there are usually no external heat and work interactions. Typical applications involve heating or cooling of a fluid stream of concern and evaporation or condensation of single- or multicomponent fluid streams. In other applications, the objective may be to recover or reject heat, or sterilize, pasteurize, fractionate, distil, concentrate, crystallize, or control a process fluid.

II. LITERATURE REVIEW

C. K.Pardhi, Dr.PrasantBaredar[2] The various techniques for achieving improved heat transfer are usually referred to as “heat transfer augmentation” or “heat transfer enhancement” and the heat exchanger provided with heat transfer enhancement techniques as “Augmented Heat Exchanger”. The objective is to reduce as many of the factors as possible: Capital Cost, Power Cost, Maintenance Cost, Space and Weight, Consistent with safety and reliability. Present work describes the principal techniques of industrial importance for the augmentation of single phase heat transfer on the inside of tubes namely twisted tapes. So twisted tape should be used in heat exchanger when high heat transfer rate is required and pressure drop is of no significance.

Prof.Alpesh Mehta, Dinesh k Tantia,Nilesh M Jha,Nimit M Patel [3] This paper shows the research work on heat exchanger using Nano fluid. In this paper we are using compact heat exchanger as heat transferring device while Al_2O_3 as a Nanofluid. The effect of the Nano fluids on compact heat exchanger is analysed by using ε –NTU rating numerical method on turbo-charged diesel engine of type TBD 232V-12 cross flow compact heat exchanger radiator with unmixed fluids consisting of 644 tubes made of brass and 346 continuous fins made of copper. Comparative study of Al_2O_3+ water Nano fluids as coolant is carried out.

III. DESIGN AND EXPERIMENTAL SETUP

DESIGN

T_{h1}=50°CT_{c1}=33.2°C	Time taken for hot water =21 sec	M_h=0.047Kg/sec
T_{h2}= 44.6°CT_{c2}=35.1°C	Time taken for cold water =6sec	M_c=0.166Kg/sec

Inner tube side heat Transfer Co-efficient – first calculate the Reynolds number to determine if the flow is laminar or turbulent.

From properties of water tube, at $T_{bh}=\frac{T_{hi}+T_{ho}}{T_{h1}}$

We get,

T_{bh} =47.3°C

So properties at this temperature are,

ϱ=9.89Kg/m^3 C_p=4.174Kj/kg*k μ=0.5773N*S/m^2 K=0.644W/M*k P_r=3.748

The Velocity & Reynolds number are calculated as follow:

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$= \mu_m \frac{M_h}{\varrho_l * A_c} = \frac{0.0476}{(989.2)*\frac{\pi}{4}(0.0254)^2} = 0.09496$ m/s

$\therefore R_e = \frac{\varrho * di * \mu_m}{\pi} = \frac{4\, m_h}{\pi\, \mu\, d_i} = \frac{4*0.0476}{\pi*0.5773*10^{-3}*0.0254} = 4133.156$

Hence, the flow is turbulent.

∴Nussult Number is as follow:

$$N_{ub} = \frac{\frac{f}{2}(R_{eb})(P_{rb})}{1+8.7\left(\frac{\pi}{4}\right)^{\frac{1}{2}}(P_{rb}-1)}$$

Where,

F= $(1.58 * l_n R_e - 3.28)^{-2} = (1.58 * l_n(4133.156) - 3.28)^{-2} = 0.01025$

$$N_{ub} = \frac{\frac{0.01025}{2}(4133.156)(3.748)}{1+8.7\left(\frac{\pi}{4}\right)^{\frac{1}{2}}(3.748-1)} = 29.2789$$

$$h_i = \frac{N_{ub}*k}{d_i} = \frac{375.3*0.687}{0.0525} = 4911\ \text{W}/m^2 * k$$

Now,

The heat Transfer Co-efficient of cold water,

From properties of water tube, $T_b = \frac{T_{c1}-T_{c2}}{2}$

We get, T_{bh} =34.15°C

So properties of water at this temperature will be,

ϱ=994.2 Kg/m^3 C_p=4.174 Kj/kg*k μ=0.7397 N*S/m^2 K=0.625 W/M*k P_r=4.959

The velocity, hydraulic diameter & Reynolds number

$$U_m = m_c \frac{m_c}{A_c * \varrho} = \frac{0.166}{\left(\frac{\pi}{4}\right)(0.0635^2 - 0.034\text{^}2)\,(994.2)} = 0.07289 \text{ m/s}$$

$D_h = D_i - D_o$ = 0.0635 – 0.0334 = 0.0301 m

$$R_e = \frac{\varrho * d_i * U_m}{\mu} = \frac{994.2*0.0729*0.0301}{0.07397*10\text{^}{-3}} = 2948.85$$

Therefore, the flow is turbulent

Nussle number is as follows:

F = $(3.64 * log_{10} R_{eb} - 3.28)^{-2} = (3.64 * log_{10}(2948.85) - 3.28)^{-2} = 0.01144$

$$\therefore N_{ub} = \frac{f/2(R_{eb})P_{rb}}{1+8.7({}^{f}/_{2})^{1/2}(P_{rb}-1)} = \frac{\frac{0.01144}{2}(2948.85)(4.959)}{1+8.7({}^{0.01144}/_{2})^{1/2}(4.959-1)} = 23.20$$

Now,

The equivalent diameter for heat transfer,

$$D_e = \frac{D_i^2 - d_o^2}{d_o} = \frac{(0.0635)^2 - (0.0334)^2}{0.0334} = 0.0873 \text{ m}$$

And,

$$h_o = \frac{N_{ub}}{D_e} K = \frac{89 \times 0.609}{0.0403} = 166.094$$

Now,

The overall heat transfer coefficient based on outside area of inner tube

$$\frac{1}{u_f} = \frac{d_o}{d_i h_i} + \frac{d_o\, Rf_i}{d_i} + \frac{d_o\, l_n\,(d_o/d_i)}{2k} + R_{fo} + \frac{1}{h_o}$$

$$= \frac{0.0334}{0.0254 \times 742.35} + \frac{0.0334 \times 0.0004}{0.0254} + \frac{1}{166.094} + 0.0004 + \frac{0.0334\, l_n\left(\frac{0.0331}{0.0234}\right)}{2 \times 54.5}$$

$$\therefore \frac{1}{u_f} = 8.803x10^{-3}$$

$\therefore u_f = 113.602\ w/m^2 k$

Now,

The heat transfer surface area:

$$A_o = \frac{Q}{u_f \Delta T_m}$$

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Where,

∴LMTD $\Delta T_m = \frac{\theta_1-\theta_2}{l_n(\theta_1|\theta_2)} = \frac{(T_{hi}-T_{co})-(T_{ho}-T_{ci})}{l_n((T_{hi}-T_{co})/(T_{ho}-T_{ci})} = \frac{(50-35.1)-(44.6-33.2)}{l_n((50-35.1)/(44.6-33.2))} = 13.072$°C

$Q = m_c\, C_{pc}\, \Delta T_c$ = 0.116 x 4.174 x (35.1 - 33.2) = 1.3165kw $\therefore A_o = \frac{1.3165 x 1000}{113.602 x 13.072} = 0.8865 m^2$

The heat transfer area of hairpin

$\therefore A_{hp} = 2\pi d_o L = 2\pi \times 0.0334 \times 3 = 0.6296\, m^2$

Now,

$$\frac{A_o}{A_{hp}} = \frac{0.8855}{0.6296} = 1.3900 \approx 1.0$$

Therefore, The number of hairpin $N_{hp} = 1$

The clean heat transfer coefficient based on the outside heat transfer,

$$\frac{1}{U_c} = \frac{d_o}{d_i h_i} + \frac{d_o\, Rf_i}{d_i} + \frac{d_o\, l_n\,(d_o/d_i)}{2k} + \frac{1}{h_o} = \frac{0.0334}{0.0254 \times 742.35} + \frac{0.0334 l_n\ (0.0334/0.0254)}{2 \times 54.2} + \frac{1}{166.094} = 126.96$$

Cleanliness Factor CF = $\frac{U_f}{U_c} = \frac{113.602}{126.96} = 0.8948$

The percentage over surface:

OS = 100 $U_c R_{ft}$

$\therefore R_{ft} = \frac{1-CF}{U_c CF} = \frac{1-0.8948}{126.96 \times 0.8948}$ $\therefore R_{ft} = 0.9260 \times 10^{-3}\, m^2 K/w$

OS = 100× $126.96 \times 0.926 \times 10^{-3}$ = 11.7565%

Now,

To determine the pressure drop in the tube side, the frictional pressure drop is co related,

$\therefore\ \Delta P_i = 4f\, \frac{2L}{d_i} N_{hp} \frac{\delta u^2 m}{2}$ = 4× $0.01025 \times \frac{2\times3}{0.0254} \times 1 \times 994.2 \times \frac{(0.07289)^2}{2}$ = 25.579 P_a $\therefore\ \Delta P_i = 2.56 \times 10^{-4}$bar

Pumping power:

$P_i = \frac{\Delta P_i\, m_h}{n_p \delta_h} = \frac{25.579\times0.0476}{0.9\times989.2}$ $P_i = 0.001368\, W$

ΔP_a = 4f * $\frac{2L}{D_h}$ * ϱ * $\frac{U_m^2}{2}$ * N_{hp} = 4 * 0.01144 * $\frac{2*3}{0.0301}$ * 994.2 * $\frac{(0.07289)^2}{2}$ * 1

= 24.0907 P_a ΔP_a = 2.41 * $(10)^{-4}$ bar

EXPERIMENTAL SETUP

First of all, a design was derived of double pipe heat exchanger on Autodesk Inventor. A mild steel pipe of diameter 1 inch & 2.5 inch Then fabricated them on the basis of our design Then welded the structure. Then painted the structure and the wooden ply and assemble them. Then water heater and temperature indicator are attaching to the structure. Thermocouples are inserting in pipe. Then thermocouples wire is attaching into temperature indicator. The main wires of Water heater and Temperature Indicator are attached to main phase switch. The flexible pipes are attached to the opening of double pipe heat exchanger and two end to the water supply. The Design of Double Pipe heat exchanger is as under:

Fig. 1.1 Working Setup of Double pipe heat exchanger

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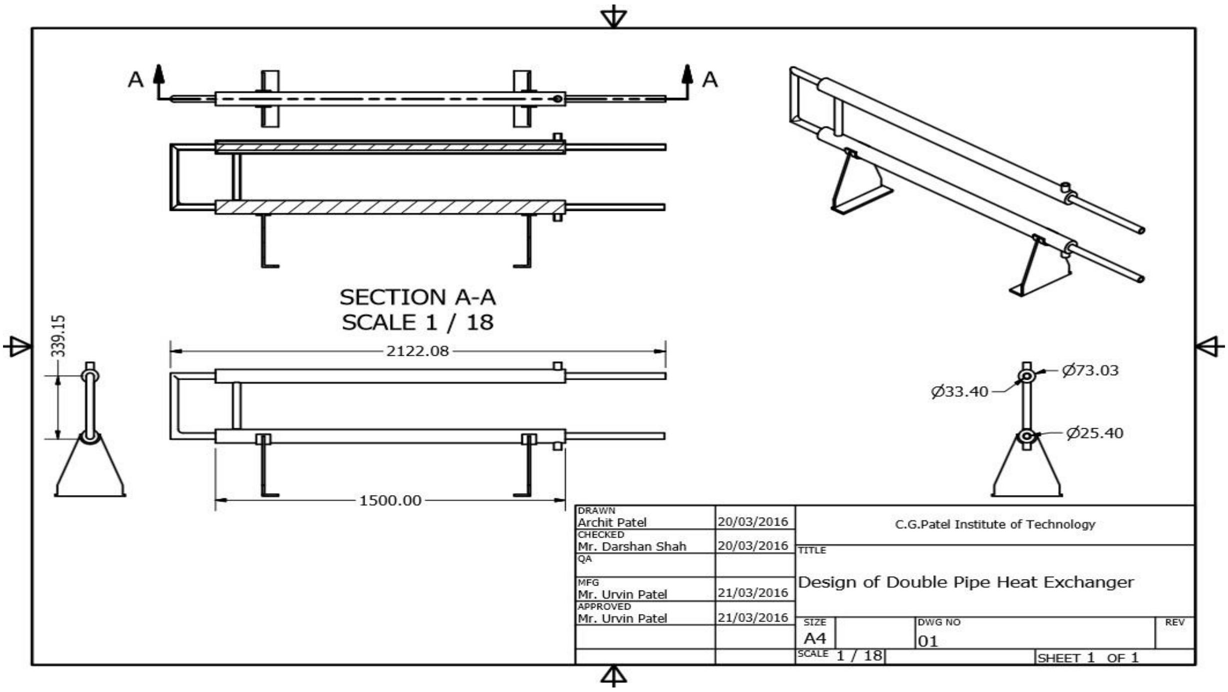

Fig. 1.2 Design and Dimensional specification of Heat exchanger

IV. Experimental Errors

The accuracy for measured heat transfer coefficients is affected by the effectiveness of thermal insulation, the amount of heat lost to the ambient, the accuracy of the thermocouple system, and the accuracy of rotameters. Simple one dimensional calculations clearly indicate that 99% of the heat transferred from the inner tube flow goes to the outer tube flow and only 1% is lost into the insulation material. It is estimated that the thermocouple system including the thermocouple wire variations and all associated measurements of •± 0.1% about the true temperature. The error can be generated due to the human mistakes in noting the mass flow rate of hot and cold water. The improper fitting of insulation on the pipe of double pipe heat exchanger. The corrosion of the MS pipe due to water also plays an important role in the exchange of heat in it. There may be the possibility of leakage in the exchanger due to which heat loss is possible. This are the different criteria of the errors in the experimental setup.

V. Result

From the setup, following results are achieved. Around 12.6% effectiveness form Number of Transfer Unit (NTU) method using the Mild Steel as the base material and have achieved Ideal effectiveness 32.143%. the result of different readings noted down is as below:

	Temperature				Time		Mass Flow Rate							
Sr. no.	T_{h1}	T_{h2}	T_{c1}	T_{c2}	t_h	t_c	m_h	m_c	NTU	% ε	h_i	h_o	U_f	ΔT_m
	°C	°C	°C	°C	sec	sec	Kg/Sec	Kg/Sec			W/m^2*K	W/m^2*K	W/m^2*K	°C
1	50	44.6	33.2	35.1	21	6	0.05	0.17	0.14	12.60	746.44	166.57	113.96	13.07
2	59.8	50.8	35.5	46.2	29.89	33.73	0.03	0.03	0.08	7.83	593.29	50.87	43.70	14.43
3	60.5	50.8	36.4	44.3	41.05	29.72	0.02	0.03	0.11	9.89	490.16	55.35	45.95	15.28
4	53.9	48.7	35.5	40.5	16.33	22.33	0.06	0.04	0.07	6.72	950.72	64.23	55.67	13.30
5	54.7	49.1	35.5	41.4	16.33	22.33	0.06	0.04	0.07	6.86	957.30	65.91	56.96	13.45
6	64.6	52.4	35.7	44.3	33.57	26.15	0.03	0.04	0.10	8.94	589.42	60.38	50.50	18.44
7	59.8	48.2	33.5	39.4	38	20	0.03	0.05	0.12	11.03	509.67	69.01	55.31	17.39
8	61.1	50.9	33.5	40.3	38	20	0.03	0.05	0.12	11.13	521.94	69.57	55.86	19.05
9	60.8	52.6	37.4	48	26.72	40.66	0.04	0.02	0.09	8.73	688.05	45.73	40.34	13.97
10	61.6	49.3	33.7	37.1	35.83	20.94	0.03	0.05	0.11	10.11	542.01	65.62	53.54	19.72
11	48.8	44.6	33.8	37.8	18.87	13.45	0.05	0.07	0.08	7.48	801.46	91.85	73.86	10.90
12	54.6	48.4	34.2	39.6	27.11	16.99	0.04	0.06	0.10	9.11	642.38	78.52	63.32	14.60
13	46.4	44.9	36.4	41.5	12.6	46.18	0.08	0.02	0.10	9.08	1087.81	39.62	36.41	6.54
14	66.5	50.1	36.5	42.4	18.33	40.09	0.05	0.02	0.09	8.59	937.64	44.09	39.85	18.35
15	60.1	50.4	36.7	43.3	34.29	31.93	0.03	0.03	0.09	8.06	559.41	52.31	44.49	15.20

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VI. Conclusion

It is concluded that the more heat transfer surface is kept in the heat exchanger the more effectiveness is achieved. Optimization of heat loss can be done by applying more thick and effective for reducing the heat loss to the atmosphere. The effectiveness of 12.6% is achieved in the experimental setup. If the losses are taken in a serious concerned then the effectiveness can be increased optimistically.

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[2] C. K. Pardhi 1, Dr.Prasant Baredar2 1 Assistant Professor Department of Mechanical Engineering, SISTec-R Bhopal, M.P., India, cpardhi@gmail.com 2 Associate Professor Department of Energy, MANIT Bhopal, M.P., India, *pbaredar@rediffmail.com*

[3] Prof.Alpesh Mehta1*, 2Dinesh k Tantia , 3Nilesh M Jha , 4Nimit M Patel *1Assistant Professor, Government Engineering College, Godhra 2,3,4 Students of 7th Semester Mechanical Government Engineering College, Godhra.

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