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Experimental evaluation of tube and tube heat exchanger for water-water and water-salt solution combination

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Abstract

Tube and Tube heat exchanger (TTHE) is designed with help of solidworks and simulation done with Ansys software. The TTHE is fabricated with stainless steel metal and it is prepared to compare the heat exchange between water-water and water-salt solution. Experimental results show that the heat exchange rate in water-water combination (256.7) is comparatively higher than water – salt solution combination (91.78). Thermal conductivity, density and specific heat of solutions are considered in experimentation. It is observed that variation in flow rates are directly proportional to the inlet and outlet temperature of TTHE. It seems that turbulence allowance may affect flow rate of the solutions and it might have impact on heat exchange rate.

Keywords: *Tube and Tube heat exchanger, Flow rate,Water-water combination, water-salt solution combination*

1. Introduction

Heat exchanger is one of the important devices in heat transfer process in various fields like industries, construction sites, transports and others. The heat exchanger is found in large constructions to support cooling process such as fossil fuel power plant. The heat exchanger is a device which transfers the heat from hot medium to cold medium without mixing both the mediums since both mediums are generally separated with the solid wall. There are different types of heat exchanger that are used based on the application, e.g. Tube and Tube heat exchanger is used in chemical process like condensing the vapor to the liquid. To construct this type of heat exchanger, type of material should be selected wisely since it affects the overall heat transfer coefficient.

There are many studies and experimentation has been performed on the topic of Heat Exchanger which has been reviewed in research. Apu Roy, D.H.Das has conducted study on analysis of a shell and finned tube heat exchanger using CFD for waste heat Recovery applications in 2011. They found, the increasing of velocity the Heat transfer also increased. Also, Temperature increases along the fins tube and in case of shell the temperature is decreasing.
K.Sivakumar, K.Rajandid analysis of Heat Transfer and Effectiveness on Laminar Flow with Effect of different Flow Rates in 2014-15. They did experimental investigation of heat transfer and friction factor characteristics with different flow rates by means of CFD simulation. This work is conducted by the double pipe heat exchanger with opposite flow direction.
K. Sivakumar, Dr. K. Rajan, S. Murali, S. Prakash, V. Thanigaivel,T. Suryakumar conducted a Experimental Analysis Of Heat Transfer And Friction Factor For Counter Flow Heat Exchanger in 2015. They studied heat transfer and effectiveness of the double pipe heat exchanger with two flow directions. One is parallel flow and counter flow direction. A commercial CFD package, Ansys fluent version are used for this study.

For this research, the small heat exchanger is constructed which I want to make practical in daily life such as for oil refineries and their chemical processes. Good design for the small Tube and Tube heat exchanger is selected. Good design referred to heat exchanger with least possible area & pressure drop to fulfill heat transfer requirement.
In this experimentation, Inner tube side hot water rejects heat to the outer shell side cold water. The properties of materials and its size are considered in design process. Heat exchanger is fabricated by using cutting, TIG welding and drilling. The experiment is performed for two combinations water-water and water-salt solution. Hot water is inside the tube and shell side fluid is normal water for first combination and salt solution for second combination. The experiment is performed under three different conditions where, i) Hot and cold water flow rate is manipulated for 7:1 concentration for salt water-water combination.
ii)By keeping tube side and shell side fluid flow rate constant.
iii)By varying salt water concentration.

2. Experimental analysis of heat exchanger

2.1Solidworks Model

Solid works is used for designed the TTHE. Below are some key figures of design.

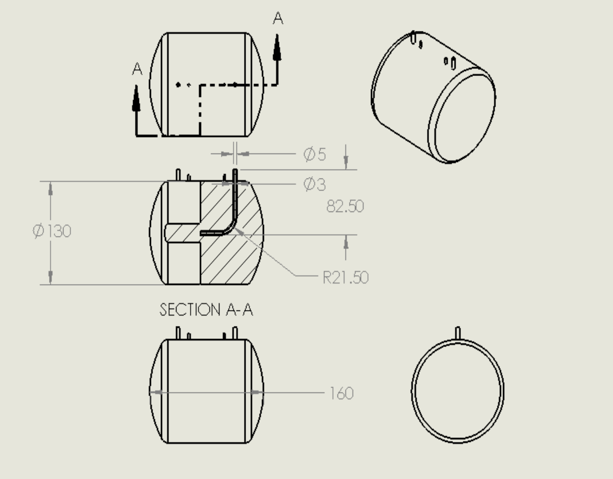

Fig.1 Solidworks 2D model

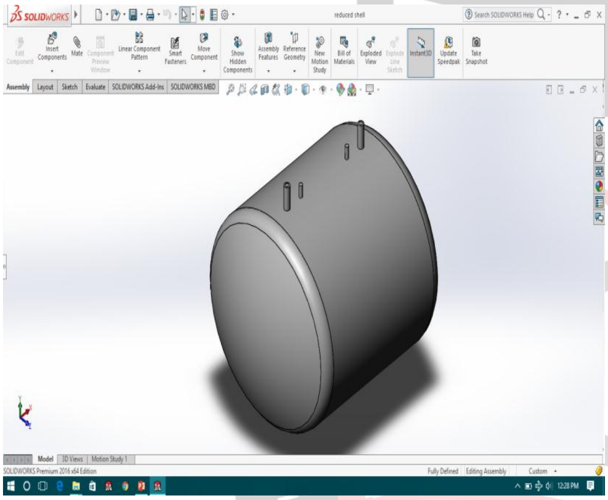

Fig.2 Solidworks 3 D model

Fig.1 and fig.2 shows the heat exchanger 2-D and 3-D model as per specification .

2.2 Mathematical Formulation:

$$Q = A \times V \qquad (1)$$

Q= discharge (m^3/s)
A= area (m^2)
V = velocity (m/s)

$$Q_{Rejected} = m \times C_p \times \Delta T \qquad (2)$$

"$Q_{Rejected}$" = Heat Transfer
m = mass flow rate
C_p= specific heat at constant volume
ΔT = change in temperature

2.3 Project Layout

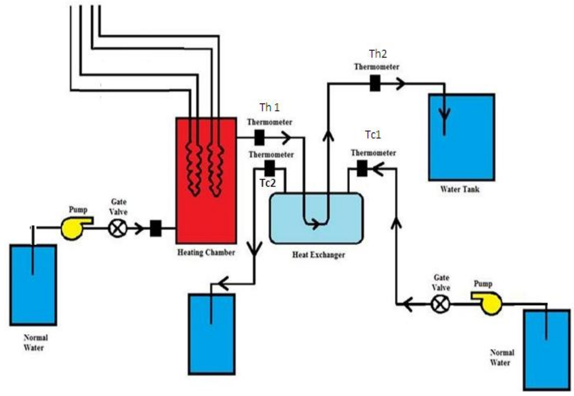

Fig.3 Project layout

Fig. shows project layout contains two pumps, two flow control valves, heating chamber, heat exchanger, water tanks. Water is taken from water tank by first pump. Flow control valve mounted next to the pump to manipulate flow of fluid. Water is then pass through heating chamber by pneumatic pipes. This heated water is used as shell side fluid.

Similarly, room temperature water is taken from second water tank through second pump and this flow is controlled by second flow control valve. This water is used as shell side fluid for water-water combination. For water-salt solution combination shell side fluid is salt solution. Inlet and outlet temperatures of outer shell side and inner tube side fluid are measured and used for calculation purpose.

2.4Fabrication

The basic components of an Tube& Tube Heat Exchanger are:

- Heat Exchanger
- Two 2kw Heating Coils
- Heating Chamber
- 4 Digital Thermometers
- 2 Pumps
- 2 Gate valves
- pneumatic pipe

heat exchanger is fabricated by using cutting, bending, TIG welding and drilling.

Fig.4 Fabrication work

Fig.5 Experimental Setup

2.5 Calibration

For calibration of temperature measuring devices the laser thermometer was compared with thermocouple and the following readings were obtained-

- - for hot water : leaser thermometer reading is 68.8 degree and thermocouple reading is 69.1 degree.
- - for cold water + ice : leaser thermometer reading is 4.3 degree and thermocouple reading is 4.0 degree.
- - for room temperature water : leaser thermometer reading is 4.3 degree and thermocouple reading is 4.0 degree.
- - for room temperature: leaser thermometer reading is 37.2 degree and thermocouple reading is 37.0 degree.

Fig.6 Comparing laser thermometer with thermocouple

2.6 Observation Table

The observations obtained are as follows:

2.6.1 Observation for 7:1 concentration for salt water-water combination:

Table 2.6.1 Observation table for 7:1 concentration for salt water-water combination

combination	Shell side			Tube side		
	Flow rate (lps)	Inlet water temperature(°C)	Outlet water temperature(°C)	Flow rate (lps)	Inlet water temperature (°C)	Outlet water temperature (°C)
Water - water	1/107	27	30	171	86.8	76
Water -salt solution	1/202	29	31.5	148	82.5	78.7
Water - water	1/110	28	31.2	175	88.9	79
Water -salt solution	1/205	30	32.8	151	85.5	81.2
Water - water	1/106	29	32.1	168	85.6	74.1
Water -salt solution	1/198	30	33	145	81.2	76.6

2.6.2 By keeping tube side and shell side fluid flow rate constant:

Table 2.6.2 Observation table for By keeping tube side and shell side fluid flow rate constant

combination	Shell side			Tube side		
	Flow rate (lps)	Inlet water temperature(°C)	Outlet water temperature(°C)	Flow rate (lps)	Inlet water temperature (°C)	Outlet water temperature (°C)
Water - water	1/180	28	31.6	1/190	83.4	70
Water -salt solution	1/296	27	29.8	1/188	85.5	79.2
Water - water	1/250	29	32.3	1/256	85.6	71.2
Water -salt solution	1/262	28	30.3	1/253	88.1	81.3
Water - water	1/170	28	31	1/175	82.7	68.8
Water -salt solution	1/180	29	31.6	1/188	86.2	80.1

2.6.3 By varying salt water concentration:

Table 2.6.3 Observation table for By varying salt water concentration

combination	Shell side			Tube side		
	Flow rate (lps)	Inlet water temperature(°C)	Outlet water temperature(°C)	Flow rate (lps)	Inlet water temperature (°C)	Outlet water temperature (°C)
Water -salt solution 5:1	1/200	28	30.2	1/178	81.6	78.2
Water -salt solution 5:1	1/256	28	30.4	1/303	86.3	83.3
Water -salt solution 5:1	1/193	29	31.1	1/203	84.6	81.4
Water -salt solution 20:1	1/193	28	29.8	1/187	87.7	80.2
Water -salt solution 20:1	1/160	27	28.8	1/226	82.1	75.8
Water -salt solution 20:1	1/146	29	30.3	1/217	83.7	77.1

3.Results and Discussion

WATER-WATER combination:

Initial water temperature = *31° C*

For tube water, time required to fill 1 liter bottle

$t_{tube} = 171\ sec$

For shell water, time required to fill 1 liter bottle

$t_{shell} = 107\ sec$

$Q = A \times V$

For tube water,

$$(1 \times 10^{-3})/171 = \pi/4 \times (5.5/1000)^2 \times V\_tube$$

$V_{tube} = 0.246\ m/s$

For shell water,

$$(1 \times 10^{-3})/107 = \pi/4 \times (5.5/1000)^2 \times V\_shell$$

$V_{shell} = 0.393\ m/s$

Water temperatures $t_{inlet} = 86.8°C$ & $t_{outlet} = 76°C$

WATER-SALT SOLUTION combination:

Initial water temperature = *29° C*

For tube water, time required to fill 1.2 liter bottle

$t_{tube} = 148\ sec$

For shell water, time required to fill 1.2 liter bottle

$t_{shell} = 202\ sec$

$Q = A \times V$

For tube water,

$$(1.2 \times 10^{-3})/148 = \pi/4 \times (5.5/1000)^2 \times V\_tube$$

$V_{tube} = 0.3412\ m/s$

For shell water,

$$(1.2 \times 10^{-3})/202 = \pi/4 \times (5.5/1000)^2 \times V\_shell$$

$V_{shell} = 0.250\ m/s$

Water temperatures $t_{inlet} = 82.5°C$ & $t_{outlet} = 78.7°C$

Result :

Water – water combination

$$Q_{Rejected} = m \times C_p \times \Delta T$$
$$= \rho \times Q \times C_p \times (\Delta T)$$

Taking ρ at 81ºC = 970.97 kg/m^3

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$$= 370.97 \times \frac{1\times10^{-3}}{171} \times 4.187 \times (86.8 - 76)$$

$$= 256.7 \text{ Watt}$$

Salt water – water combination

$$Q_{Rejected} = m \times C_p \times \Delta T$$

$$= \rho \times Q \times C_p \times (\Delta T)$$

Taking ρ at 80ºC = 971.7 kg/m^3

$$= 971.1 \times \frac{1.2\times10^{-3}}{202} \times 4.187 \times (82.5 - 78.7)$$

$$= 91.786 \text{ Watt}$$

The results obtained from the above observations are as follows:

5.3.1 Observation for 7:1 concentration for salt water-water combination

Table 5.3.1 Result table for 7:1 concentration for salt water-water combination

combination	Shell side				Tube side				H rat flow (wat)
	Flow rate (lps)	inlet water temperature(°C)	Outlet water temperature(°C)	velocity(m/s)	Flow rate (lps)	Inlet water temperature (°C)	Outlet water temperature (°C)	Velocity(m/s)	
Water-water	1/107	27	30	0.393	1/171	86.8	76	0.246	256.7
Water-salt solution	1/202	29	31.5	0.25	1/148	82.5	78.7	0.341	91.78
Water-water	1/110	28	31.2	0.383	1/175	88.9	79	0.241	250.3
Water-salt solution	1/205	30	32.8	0.205	1/151	85.5	81.2	0.279	89.4
Water-water	1/106	29	32.1	0.398	1/168	85.6	74.1	0.251	261.7
Water-salt solution	1/198	30	33	0.213	1/145	81.2	76.6	0.290	84.2

5.3.2 By keeping tube side and shell side fluid flow rate constant:

Table 5.3.2 Result table for By keeping tube side and shell side fluid flow rate constant

combination	Shell side				Tube side				H rat flow (wat)
	Flow rate (lps)	inlet water temperature(°C)	Outlet water temperature(°C)	velocity(m/s)	Flow rate (lps)	Inlet water temperature (°C)	Outlet water temperature (°C)	Velocity(m/s)	
Water-water	1/180	28	31.6	0.234	1/190	83.4	70	0.222	300.8
Water-salt solution	1/296	27	29.8	0.215	1/188	85.5	79.2	0.224	96.2
Water-water	1/250	29	32.3	0.168	1/256	85.6	71.2	0.164	350.3
Water-salt solution	1/262	28	30.3	0.161	1/253	88.1	81.3	0.168	95.3
Water-water	1/170	28	31	0.248	1/175	82.7	68.8	0.241	360.8
Water-salt solution	1/180	29	31.6	0.234	1/188	86.2	80.1	0.224	98.3

5.3.3 By varying salt water concentration:

Table 5.3.3 Result table for By varying salt water concentration

combination	Shell side				Tube side				H rat flow (wat)
	Flow rate (lps)	inlet water temperature(°C)	Outlet water temperature(°C)	velocity(m/s)	Flow rate (lps)	Inlet water temperature (°C)	Outlet water temperature (°C)	Velocity(m/s)	
Water-salt solu	1/20	28	30.2	0.210	1/17	81.6	78.2	0.237	60.2

tion 5:1	0				8				
Water-salt solution 5:1	1/256	28	30.4	0.168	1/303	86.3	83.3	0.139	49.1
Water-salt solution 5:1	1/193	29	31.1	0.218	1/203	84.6	81.4	0.207	68.9
Water-salt solution 20:1	1/193	28	29.8	0.218	1/187	87.7	80.2	0.225	95.7
Water-salt solution 20:1	1/160	27	28.8	0.263	1/226	82.1	75.8	0.186	100.2
Water-salt solution 20:1	1/146	29	30.3	0.289	1/217	83.7	77.1	0.194	150.6

The observations are the result of simplification of model and uncertainties of numerical calculation. Also, inability of getting constant flow rate in both solutions might have impacted the results since flow rate of water-water combination is greater than flow rate of water-salt solution combination in observation. Also, Specific heat of salt solution varies according to solution concentration. Density of salt solution is less than water. Difference in turbulence of water and salt solution also has impact on results.

The results for heat flow rate of water-water solution and water-salt solution are 256.7and 91.78 watt respectively. Heat flow rate for water-salt solution is less than the water-water combination.

4.Conclusions

1.As seen in the calculations we can conclude that when we change the shell side fluid from water to salt water heat rejection rate decreases.

2.Thermal conductivity, density, specific heat etc. of salt solution is less than the properties of water. So, the heat transfer rate in case of salt solution in shell is less as compared to that of water in shell.

3. Turbulence in water is higher than salt solution. This has an impact on heat flow rate difference between water-water and water - salt solution combination.

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References

Apu Roy, D.H.Das(2011) “CFD analysis of a shell and finned tube heat exchanger for waste heat Recovery applications” International Journal of Mechanical & Industrial Engineering, Volume-1 Issue-1.

K.Sivakumar, K.Rajan (2014-2015)“Performance Analysis of Heat Transfer and Effectiveness on Laminar Flow with Effect of Various Flow Rates”

K. Sivakumar, Dr. K. Rajan, S. Murali, S. Prakash, V. Thanigaivel,T.Suryakumar (2015)“Experimental Analysis Of Heat Transfer And Friction Factor For Counter Flow Heat Exchanger”

Kern,(1950),Process Heat Transfer, McGraw-Hill, New York,D.Q,620-625.

Taborek, J.,(1979), Evolution of heat exchanger design techniques, *Heat Transfer Eng*. 1, No. 1, 15-29 .

Perry, R.H., Green,(1997) D.W., Eds. Perry’s Chemical Engineers’ *Handbook*, McGraw-Hill, New York, 7th Edition.

Phadke,(September 3, 1984), P.S., Determining tube counts for shell-and-tube exchangers, Chemical Engineering, pp. 65-68.

TEMA, Tubular Exchanger Manufacturers Association,(1988). “Standards of the Tubular Exchanger Manufacturers Association,” 7th ed., New York.

MD, Heat Transfer, Thermodynamics and Fluid Flow Fundamentals, Columbia, General Physics Corporation, Library of Congress Card #A 326517.

Tinaut F. V., Melgar A. and Rehman Ali A. A. (1992)Correlations for Heat Transfer and Flow Friction Characteristics of Compact Plate Type Heat Exchangers. International Journal of Heat and Mass Transfer. 35(7): 1659:1665

Swapnil Ahire,PurushottamShelke, Bhalchandrashinde, Nilesh Totala,(5- September 2014)"Fabrication and Analysis of Tube and Tube heat exchanger” – International Journal of Engineering Trends and Technology (IJETT)-Volume 15 Number.

Jensen, M.K. and Bergles, A.E., (1981), Trans ASME, 103: 660–666.

J. P. Holman – Heat Transfer McGraw Hill Publication, 9th Ed, Pg. no. 11, 12, 511 – 527.

Warren M. Rohsenow-HANDBOOK OF HEAT TRANSFER MCGRAW-HILL Publication, 3rd Edition, Page No. 2.26

Nasser Ghorbani , HessamTaherian , MofidGorji , HessamMirgolbabaei ,(2010) "An experimental study of thermal performance of shell-and-coil heat exchangers.

Ramesh K. Shah and Dušan P. Sekulic, John Wiley & Sons, Inc. S. L. Phillips, A.Igbene, J. A. Fair, H. Ozbek and M.Tavana"Fundamentals of Heat Exchanger Design”,

(June 1981) – Technical Data Book for Thermal Energy Utilization, L. B. Laboratory, University of California, June 1981 Page no. 28-63.