International Journal of Current Engineering and Technology
E-ISSN 2277 – 4106, P-ISSN 2347 – 5161

Available at http://inpressco.com/category/ijcet

Research Article

Experimental Determination and Comparison of Heat Transfer Coefficient and Pressure Drop for Water and Copper Oxide Nano Fluid in Shell and Tube Heat Exchangers using Helical Baffles

Kallalu Harika[†*], Tummala.Likhitha[†], Pulla Varsha Rani[†] and R.Ramakanth[†]

[†]Department of Mechanical Engineering, VidyaJyothi Institute of Technology, Hyderabad, T.S., India

Accepted 01 May 2017, Available online 02 May 2017, **Vol.7, No.3 (June 2017)**

Abstract

In this paper, the heat transfer coefficient and pressure drop on the shell side of a shell and tube heat exchanger have been experimentally obtained for two different fluids that is for water and copper oxide nano fluid. Also experimental data has been compared with theoretical data available. Water is our hot fluid, copper oxide mixed with water – which is our nano fluid is treated as cold water .Flow rate of hot water is maintained between 15-18 lpm. The volume fraction of copper oxide nano fluid is varied from 10-30%.Experimenatal results such as shell and tube heat exchanger effectiveness, overall heat transfer coefficients are calculated.

Keywords: *Shell and tube heat exchanger, heat exchanger design, sedimentation process, nano fluids, overall heat transfer coefficient, effectiveness, pressure drop.*

1. Introduction

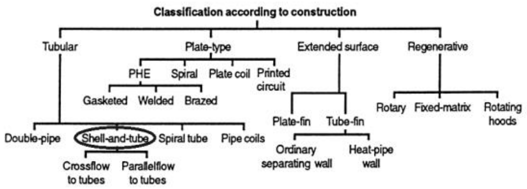
Heat exchangers are always been important part to the lifecycle and operations of many systems. Over the past quarter century, the importance of heat exchangers has increased from the viewpoint of energy conversion and performance recovery. Much more attention is paid to heat exchangers because of environmental concerns such as thermal, air and water pollution, as well as waste heat recoveries. It can be considered as key equipment in the chemical process industry. Heat exchanger is a device of finite volume used to transfer heat between a solid and a fluid or between two or more fluids. These two fluids are separated by solid wall to prevent mixing and also to prevent direct contact between them. Typically one system is been cooled while the other is heated. More than 30-40% of heat exchangers used in various industries are of this type due to their robust geometry construction, (Chunangad, K. S., *et al*,2003) easy maintenance and possible upgrades. One common example of heat exchanger is the radiation in the car, in which it transfers heat from the water (hot engine-cooling fluid) in the radiator to the air passing through the radiator. There are two main types of heat exchangers.

- Direct contact heat exchanger, where both media between which heat is exchanged are in direct contact with each other(Gaddis, E. S., *et al*,1997)
- Indirect contact heat exchanger, where both the media are separated by a wall through which heat is transferred so that they never mix.
- Heat exchangers are also classified based on different parameters like flow direction, compactness of the body, transfer type and construction. (Bell, K. J.,*et al*,1981)
- Parallel flow heat exchangers: Parallel flow heat exchangers are the one in which two fluids flow in parallel to each other.
- Counter flow heat exchangers: In counter flow heat exchangers the fluid flows in opposite direction.
- Cross flow heat exchangers: It is a combination of both parallel and counter flow.

Heat exchangers are globally assumed to be operating under adiabatic conditions. It therefore means that heat losses or gains between the heat exchangers and the environment can be assumed. The thermal inertia for heat exchangers is negligible and therefore mostly assumed therefore the general balance equation of energy is reduced to where the total energy ht is a value that can be approximated by enthalpy and stands for the difference between the output and the input. A primary objective in the heat exchanger Design (Schlünder, E. U.,*et al*,1983), is the estimation of the minimum heat transfer area required for a given heavy duty.

*Corresponding author: **Kallalu Harika**

2. Classification of heat exchangers



3. Why to use nano particles

- A remarkable characteristic of nano particles is that addition of small amount of nano particles, they show anamolous enhancement in thermal conductivity over 10 times more than the theoretically predicted values. (Stehlik, P.*et al*,,1994)
- Conventional fluids such as water,ethyl glycol and oil have low evaporation temperatures as water has low thermal conductivity in case of oils and ethylene glycol.
- The addition of nano particles in the fluid changes the flow structure, so that besides increasing the thermal conductivity, dispersion and fluctuation of the nano particles especially near the tube wall of heat exchanger leads to increase in rate of energy exchange, heat transfer between fluid and tube wall.

3.1 Working mechanism of nano particles

In general, there are three mechanisms to improve heat transfer by introducing nano particles by introducing nano particles into the base fluid.

- Nano particles benefit higher heat transfer rate; therefore as nano particle concentration in the base fluid increases the heat transfer rate accordingly.(Bell, K. J., *et al*,1998)
- The collisions occur between nano particles and the base fluid molecules on the one hand and impacts of the particles to the heat exchanger wall on the other hand result in an increase energy.
- The friction between the wall and fluid increases if nano fluids are dealt with and, therefore, heat transfer improves.

4. Sedimentation Test

The preparation of nano fluid is carried out through sedimentation test. It includes weighing of nano particle weighing pan. Then it is mixed with known concentration i.e. 1000ml of water. This mixture is mixed thoroughly with a magnetic stirrer whose setup is as shown below. Once the mixing process is completed (it is carried out for about 10 minutes) then that mixture is kept aside and stop watch is started to know the complete settling time. The above procedure is repeated for different proportions of copper oxide (CuO) water and the corresponding settling times are noted down these readings are then compared with each other. The reading of nano particle with greater settling time is found and this reading is taken as optimal condition for the preparation of nano fluid and thus the nano fluid is prepared.

4.1 Sedimentation Process

- Nano particles to nano fluids
- Mixed with 1000ml of water
- Magnetic stirrer
- Settling time
- Greater settling time is considered

Figure 1 Nano Fluid

4.2 Nano Fluids

- Nano fluids are obtained by the process of sedimentation.
- Here the base fluid is water .This base fluid is mixed with cpper oxide nano particle and acts as nano particle which serves as shell side fluid.(Bell, K. J.,*et al* ,1986)
- Hot water is obtained from the geyser and acts as tube side fluid.(Bell, K. J., *et al*.1988)
- The reaction between base fluid and hot water helped us in increasing thermal effectiveness, overall heat transfer rate, pressure drop, thermal conductivity and efficiency (Schlünder, E. U.,*et al*,1983)

4.3 Properties of copper oxide

Table 1 Properties of copper Oxide

Appearance	Blackcolour
Molecular Formula	Cuo
Molecular Mass	79.55gm/mole
Odour	Odourless
Density	6.31gm/cm^3
Melting point	1201^{0}c
Solubility in water	Soluble
Thermal conductivity	76W/mk

5. Experimental Progress

Heating and heated fluid volume flow rate measurements were done with standard measuring orifices, as well as on the basis of pressure drop. 3.5bar. Pressure drops in the Shell and tube heat exchanger tube bundle and on orifices were measured by the hydrostatic manometer .In the performed measurements the average tube bundle pressure drop was 3710Pa.

5.1 Equipment details

Figure 2 Experimental Set up

Majorly in shell and tube heat exchanger tubes are made up of copper and the material used for shell is mild steel. In general hot fluid flows in copper tubes and the cold water in shell. Four baffles are added in this experimental setup which acts as obstacles for cold water, which allows better heat transfer between hot and cold fluids. Base fluid used is water mixed with copper oxide nano particle with a volumetric concentration of 0.023% and hot fluid is water from geyser. Flow rate of cold water varies between 8-15lpm and for hot water it is between 10-30lpm.

5.2 Experimental Overview

- To increase thermal efficiency.
- To increase pressure drop
- To obtain maximum heat transfer rate
- To increase thermal conductivity
- To decrease the flow rate with better heat efficiency
- To increase velocity
- To dissipate heat
- For rapid cooling

5.3.1 Values for water

Table 2 Values for Water

Mass flow rate of cold water M_{fc}	Mass flow rate of hot water M_{fh}	Cold water inlet temperature T_{ci}	Cold water outlet temperature T_{co}	Hot water inlet temperature T_{hi}	Hot water outlet temperature T_{h0}
0.02	0.04	35	40	60	50
0.02	0.04	35	41	60	49
0.02	0.04	35	42	60	48
0.02	0.04	35	43	60	47
0.02	0.04	35	44	60	46

5.3.2 Values for copper oxide Nano fluid

Table 3 Values for Copper Oxide Nano Fluid

Mass flow rate of cold water M_{fc}	Mass flow rate of hot water M_{fh}	Cold water inlet temperature T_{ci}	Cold water outlet temperature T_{co}	Hot water inlet temperature T_{hi}	Hot water outlet temperature T_{h0}
0.03	0.06	38	48	85	79
0.03	0.06	38	45	83	74
0.03	0.06	38	44	82	60
0.03	0.06	38	42	81	57
0.03	0.06	38	40	80	55

5.4. Calculations

5.4.1 Calculations for water

- Tube mean temperature:

$$T_m = \frac{60 + 50}{2} = 55°C$$

- Thermal properties of water at 55°C
  i. P = 985.615kg = 985.6kg/m^3
  ii. c_p= 4.18245 = 0.48J/kg-k
  iii. K = 648.9 = 0.648w/m-k
  iv. μ = 506.5 = 0.546x10^{-3}

- Reynolds number :

$$R_e = \frac{\rho v d}{\mu i}$$

$$= \frac{985.6*0.032*0.010}{0.546*10^3}$$

= 577

- Nusselt number :
  $0.023*R_e*pr^{0.4}$
  = 7.18

- Heat transfer coefficient:

$$hi = \frac{Nuk_i}{d_i}$$

$$= \frac{7.18*0.648}{0.01}$$

$$462.5\ {}^{w}/_{m^2}$$

- Shell side mean temperature:

$$T_m = \frac{35+41}{2} = 37.5^{\circ}c$$

- Thermal properties of water at 37.5◦c
  i. P = 0.9939 = 993.0kg\m^3
  ii. $c_{p= 4.179}$ =4170 $kg\backslash m^3$
  iii. $k = 622.95 = 0.67w\backslash m^2k$
  iv. μ = 725.45 = 0.719*10^{-3}
  v. pr = 5.18

- Equivalent diameter

$$D_E = 4[\frac{p_{t^2} - \frac{\pi d_{o^2}}{4}}{\pi d_o}]$$

$$= 0.01$$

- Cross flow area

$$A_{s=} \frac{D_{is} * c * L_b}{p_t}$$

$$= \frac{0.107*2.5*10^{-3}*0.033}{0.0125}$$

$$= 7.062*10^{-3}$$

- Maximum velocity

$$\frac{Q_s}{A_s} = 0.354 = 0.0932$$

- *Reynolds number*

$$\frac{\rho v_{max} D_t}{\mu_s}$$

$$= \frac{997.2*0.354*0.01}{0.72*10^{-3}} = 4917.7$$

- Heat transfer coefficient

$$h_o = \frac{0.36 * k_s * R_e * pr^{0.33}}{0.0122} = 3693.79\ w\backslash m^2k$$

- Overall heat transfer coefficient:

$$U_{o=} \frac{1}{\left(\frac{1}{h_o+\frac{r_o}{k}}\right)\ln\left(\frac{r_o}{r_i}\right)+\left(\frac{r_o}{r_i}\right)*\frac{1}{h_i}}$$

$$= \frac{1}{\frac{1}{3693.25}+\frac{6.25*10^{-3}}{0.63})*\ln\left(\frac{6.25*10^{-3}}{5*10^{-3}}\right)+(\frac{6.25*10^{-3}}{5*10^{-3}})}$$

$$= 201.86\text{w}/m^2\text{k}$$

- Heat transfer rate:

$$Q_c = m_c * c_c(T_{co} - Tc_i)$$

$$= 501.48\text{w}$$

$$Q_h = m_p * c_p(Th_i - Tc_o)$$

$$=1671.6\text{w}$$

- Heat transfer coefficient:

$$Q = \frac{Q_c+Q_h}{2}$$

$$= \frac{501.48+1671.6}{2}$$

$$= 1086.54\text{w}$$

- LMTD:

$$\frac{(Thi - Tc_o) - (Th0 - Tc_i)}{\ln(\frac{Thi-Tc_o}{Th0-Tc_i})}$$

5.5 Comparison of heat transfer coefficients for water and copper oxide

Table 4 Comparison of Heat Transfer Coefficients for Water and Copper Oxide

S.No	Heat transfer coefficient for cold water H_c w/m^{2}K	Heat transfer coefficient for H	coefficient for copper oxide cold water H_c w/m^{2}K	coefficient for copper oxide hot water H_h w/m^{2}K
1	465.2	3541.2	7425.13	6272
2	456.3	3425.79	7268.41	6018.1
3	450.46	3551.2	7132.16	5988.6
4	443.64	3294.6	7086.96	5791.91
5	436.9	3162.12	7000.2	5432.8

5.6 Comparison of effectiveness of water and copper oxide

Table 1 Comparison of Effectiveness of Water and Copper Oxide

S.No	Effectiveness of water	Effectiveness of copper oxide
1	0.25	0.61
2	0.27	0.65
3	0.29	0.69
4	0.31	0.74
5	0.33	0.77

5.7 Comparison of Pressure Drop between Water and Copper Oxide

Table 6 Comparison of pressure drop between water and copper oxide

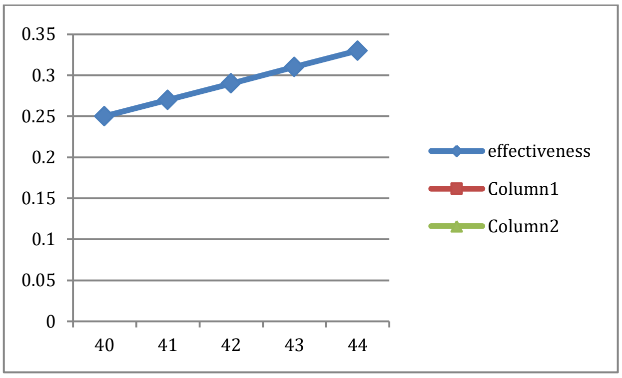
S.No	Pressure drop for water	Pressure drop for copper oxide
1	2.6	4.8
2	2.43	3.12
3	2.18	2.93
4	1.97	1.56
5	1.65	0.89

5.8 Comparison of overall heat transfer coefficient (u_0) for water rand copper oxide

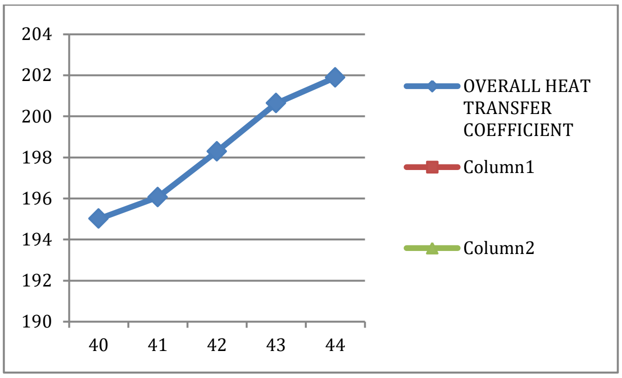
Table 7 Comparison of pressure drop between water and copper oxide

S.No	u_0 (w/m²k) for copper oxide	u_0 (w/m²k) for water
1	614.6	201.86
2	602.13	200.63
3	596.36	198.29
4	590.98	196.06
5	586.14	195.01

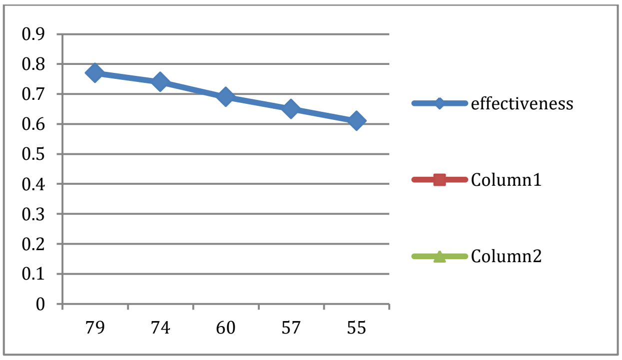
5.9 Graphs



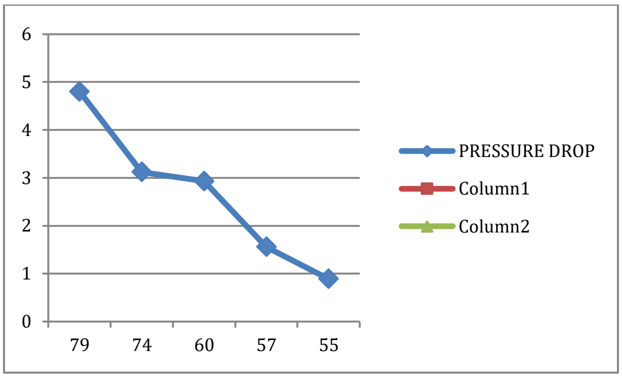
Temperature v/s effectiveness for water



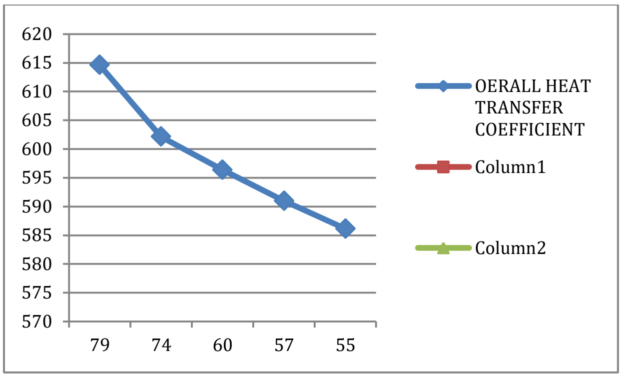
Temperature v/s overall heat transfer coefficient for water



Temperature v/s effectiveness for copper oxide



Temperature v/s pressure drop for copper oxide



Temperature v/s overall heat transfer coefficient

Conclusions

- After this study it is said that the shell and tube heat exchanger has given the respect among all the classes f heat exchanger due to their virtues like comparatively large ratios of heat transfer area to volume and weight and many more.
- By using copper oxide nano fluids in shell and tube heat exchanger we have achieved increase in overall heat transfer coefficient, pressure drop, effectiveness, heat transfer coefficients with the volumetric concentration of 0.023%

Acknowledgement

The authors express their thanks to Head of the Mechanical Engineering Department, Principal, Director and Correspondent of Vidya Jyothi Institute of Technology, Aziz Nagar, Hyderabad for the help and support extended towards this work

References

Master, B. I., Chunangad, K. S.,and Pushpanathan, V., 2003, Fouling Mitigation Using Helixchanger Heat Exchangers, Proceedings of the ECI Conference on Heat Exchanger Fouling and Cleaning: Fundamentals and Applications, Santa Fe, NM, May 18–22, pp. 317–322

Bell, K. J., 1981, Delaware Method for Shell Side Design,Heat Exchangers Thermal Hydraulic Fundamentals and Design,

S. Kakac, A. E. Bergles, and F.Mayinger, eds., Taylor & Francis, Washington, DC.

Bell, K. J., 1986, Delaware Method of Shell Side Design,Heat ExchangerSourcebook, J. W. Pallen, ed., Hemisphere, Washington, DC.

Bell, K. J., 1988, Delaware Method of Shell-Side Design,Heat TransferEquipment Design, R. K. Shah, E. C. Sunnarao, and R. A. Mashelkar, eds.,Taylor & Francis, New York.

Schlünder, E. U., ed., 1983,Heat Exchanger Design Handbook, Vol. 3, Hemi-sphere, Washington, DC

Stehlik, P., Nemcansky, J., and Kral, D., 1994, Comparison of CorrectionFactors for Shell-and-Tube Heat Exchangers With Segmental or HelicalBaffles, Heat Transfer Eng.,151, pp. 55–65.

Schlünder, E. U., ed., 1983Heat Exchanger Design Handbook, Vol. 2, Hemisphere, Washington, DC.

Gaddis, E. S., and Gnielinski, V., 1997, Pressure Drop on the Shell Side ofShell-and-Tube Heat Exchangers With Segmental Baffles, Chem. Eng. Pro-cess.,362, pp. 149–159.