Heat Transfer Enhancement in Double Pipe Heat Exchanger by Alumina – Water Nanofluid

Mr. B. Parameswara Rao[1], Mr.V. Nageswara Rao[2], Dr.S.C.V. Ramana Murthy Naidu[3] Mr.T.Veeraiah[4]

[1]M.Tech Scholar, Department of Mechanical Engineering, KHIT, Guntur, Andhra Pradesh, India
[2]Associate Professor, Department of Mechanical Engineering, KHIT, Guntur, Andhra Pradesh, India
[3]Professor, Department of Mechanical Engineering, KHIT, Guntur, Andhra Pradesh, India
[4]Assistant Professor, Department of Mechanical Engineering, KHIT, Guntur, Andhra Pradesh, India

---***---

Abstract - *Fluid heating and cooling plays an important role in many industries includes thermal power stations, production processes, petrochemical and electronic components. The heat transfer enhancement methods in different processes are abundant. Most of these methods are based on structure variation, extended surfaces fins. These enhancing techniques hardly meet the ever increasing requirement for heat transfer and the compactness of the devices in processes involving electronic chips, laser applications or high-energy devices. In this regard improvement of the thermal properties of energy transmission fluids has become one of the methods of augmenting heat transfer. Therefore, fluids with suspended solid particles are expected to have better heat transfer properties compared to conventional fluids. So far due to associated technological problems, the majority of studies on heat transfer have been with suspensions of millimeter or micron-sized particles. Such large particles cause problems such as settlement, abrasion of surfaces due to flow, clogging in flow channels in heat transfer equipments.*

The present work is directed towards estimation of heat transfer coefficient and Nusselt number for Al_2O_3 of diameter 47 nm with water nanofluid in a Plain concentric double pipe counter flow heat exchanger at different volume concentrations from 0.01%, 0.02% and 0.03% are measure experimentally. The experimental results of nano fluids under different volume concentrations are compared with base fluid Water. The use of Al_2O_3 nanoparticles as the dispersed phase in water can significantly enhance the convective heat transfer in the transition flow, and the enhancement increases with increase in Reynolds number, as well as particle concentration.

Key Words: **Nusselt Number, heat transfer coefficient, Reynolds Number, Al_2O_3 Nanofluid, LMTD, Thermal conductivity.**

1. INTRODUCTION

Less weight fractions of nanoparticles, when dispersed and suspended stably in base fluid medium, provide drastic enhancements in the thermal properties of base fluids. This nanofluid technology is given primary importance where thermal engineering and nanotechnology meet together, has developed largely over the past decade. The vital role of nanofluids is to attain the highest possible thermal properties with low particle weight fractions by uniform dispersion and stable suspension of nanoparticles in base fluid medium. In order to achieve this goal, it is crucial to determine the enhancement of thermal energy transport in liquids. Several engineers and scientists, in the growing nano-fluid era, have performed research breakthrough by investigating unexpected thermal properties of nanofluids and also nanofluid technology even offers a vital part for the development of compact and cost effective cooling systems. Within the realm of thermal science, nanofluids are developed for their inexplicably enhanced thermal conductivities, which provide the concept of utilizing nanofluids as heat transfer fluids. The improved thermal properties of nanofluids provide a better insight into an enormous innovation for heat transfer intensification, which is of major importance to industrial sectors including power generation, transportation, and thermal therapy for cancer treatment, micro manufacturing, metallurgical and chemical sectors, as well as cooling, heating and air conditioning

1.1 Materials Used

Nanofluids are two phase mixtures engineered by dispersing nanometer sized particles with sizes ranging below 100 nm in base fluids. The nanometer sized particles which are used for the dispersion in base fluids are nanoparticles, nanofibers, nanotubes, nanowires and nanorods. Materials generally used as nanoparticles include metal oxides (e.g., alumina, silica, zirconia, titania), oxide ceramics (e.g. Al2O3, CuO), chemically stable metals (e.g. gold, copper), carbon in various forms (e.g., diamond, graphite, carbon nanotubes, fullerene) metal carbides (e.g. SiC) and functionalized nanoparticles. The base fluid types include oils, water, organic liquids such as glycols, refrigerants, polymeric solutions, bio fluids, lubricants and other common liquids. From the available nano materials we have taken the Aluminium oxide (Al_2O_3) because of availability and cost.

Table 1: Properties of water and Aluminum oxide [10]

S.No	Property	Units	Water	Aluminium Oxide(Al_2O_3)
1	Specific heat(C)	J/Kg K	4179	765
2	Density (ρ)	Kg/m³	997.1	3970
3	Thermal conductivity (K)	W/m K	0.65	40

2. EXPERIMENTAL SETUP

2.1 Fabrication

The experimental set up fabricated as per design of heat exchanger. Four temperature indicators are used to measure inlet and outlet temperatures. The pipe connections are made to connect pump with Heat exchanger for recirculating the nanofluid (cold fluid) which is receiving heat from hot fluid. The Nano fluid at outlet of Heat exchanger is discharged into collecting tank from which the pump sucks the nanofluid. The collecting tank is provided with Evaporative cooling system to maintain the constant temperature of nanofluid

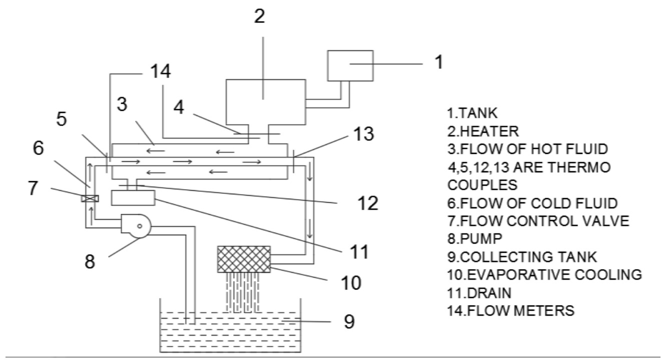

Fig-1: Line diagram of double pipe counter flow heat exchanger

2.2 Preparation of Nanofluid

Preparation of nanofluid is the most important step. Nanoparticles Al2O3 of particles diameter size 47 nm were purchased from Aarshdhattu Green nano Technologies India private limited Company. To the base fluid (water) 1/10th of the Nano particles, surfactant Nonident NP40 is added with nano particles of concentrations, at 0.01%, 0.02%, 0.03%. nanofluid is prepared with the help of mechanical stirrer with electrical motor of 200 rpm. It was found that the nanofluid prepared with this method can be stable for four hours.

Fig-2:Al_2O_3Nanoparticles **Fig-3:** Preparation of nanofluid

Fig-4: Experimental setup

3. Experimentation Procedure

3.1 Formulae to calculate properties of nanofluid

The effective properties of nanofluids like density, specific heat, thermal conductivity, and viscosity are to be calculated according to the mixing theory

1. The density of the nanofluid is calculated by using Pak and Cho correlation [1]

$$\rho_{nf} = \varphi\rho_p + (1-\varphi)\rho_w$$

Where ρ_{nf} is the density of nanofluid, ρ_p is the density of nano particle, ρ_w is the density of water and φ is the volume concentration

2. The viscosity of nanofluids less than 5% is calculated by using the Drew and Passman formula [1]

$$\mu_{nf} = \mu_w(1+2.5\varphi)$$

Where μ_{nf} is the viscosity of nanofluid, μ_w is the viscosity of water

3. Specific heat of nanofluid is calculated by using the Xuan and Roetzel correlation [1]

$$C_{pnf} = \emptyset C_p + (1-\emptyset) C_w$$

Where C_{pnf} is the heat capacity of nanofluid, C_p is the heat capacity of nano particle, C_w is the heat capacity of water

4. Thermal conductivity of nanofluid is calculated by using the Hamilton Crosser correlation [2]

$$K_{nf} = \left[\frac{K_p + 2K_f + 2\varphi(K_f - K_p)}{K_p + 2K_f - \varphi(K_f - K_p)}\right] \times K_f$$

Where k_{nf} is the thermal conductivity of nanofluid, K_p is the thermal conductivity of nano particle, k_f is the thermal conductivity of water

3.2 Experimental Formulae

1. Heat energy (hot fluid)(Q_h)= $m_h c_h(T_{hi}-T_{ho})$
   Where m_h= mass of hot fluid (kg)
   C_h= specific heat of hot fluid (J/Kg.k)
   T_{hi}= inlet temperature of hot fluid (k)
   T_{h0}= outer temperature of hot fluid (k)

2. Heat energy (cold fluid) (Q_c) =$m_c\, c_c(T_{c0}-T_{ci})$
   Where m_c= mass of cold fluid (kg)
   C_c=specific heat of cold fluid (J/Kg.K)
   T_{c0}= outlet temperature of cold fluid (k)
   T_{ci} = inlet temperature of cold fluid (k)

3. Average Heat transfer Q_{avg}= Q_h+Q_c/2

4. Convective heat transfer coefficient (h_{exp})
   h_{exp}= $U/A_0(\Delta T)_{LMTD}$
   $(\Delta T)_{LMTD} = (T_{hi} - T_{c0}) - (T_{h0} - T_{ci})]/ \ln[(T_{hi} - T_{c0})/(T_{h0} - T_{ci})]$
   $A_0 = \pi D_0 L$
   D_0 = outer diameter of heat exchanger tube
   L = length of heat exchanger tube

5. Nusselt Number (Nu):
   $Nu = h_{exp} * D_0/ k$
   Where K = Thermal conductivity of fluid

6. Reynolds number (Re):
   $R_e = \rho V D_h/ \mu$
   Where ρ = density of fluid (Kg/m^3)
   $D_h = D_2 - D_1$
   D_2 ,D_1 are outer and inner diameter of Heat exchanger
   μ =dynamic viscosity ($N.s/m^2$)

7. Volume concentration of nanofluid :
   = volume of Aluminium/ (volume of Aluminium + volume of water)
   $= (w/\rho)_{Al2O3}/ [(w/\rho)_{Al2O3} + (w/\rho)_{H2O}]$

- for 0.01% volume concentration we mix 7grams of Aluminium oxide Nanoparticles in 25litres of water(base fluid)
- for 0.02% > 14 grams of Al_2O_3
- for 0.03% > 21 grams of Al_2O_3

4. Results and Discussions

The experimentation is initially done with water as the working fluid and the experimental convective heat transfer coefficient at the entire region of the tube was estimated. The test section is well designed to maintain counter flow direction between hot and Nano fluids either in the tubes of heat exchanger. Overall heat transfer coefficients in the outer region are estimated based on the logarithmic mean temperature distribution. The Convective heat transfer coefficient enhancement for 0.03% nanofluid with the base fluid is 47.53%

Nanofluids of different concentrations were introduced into the heat exchangers and the experimental overall heat transfer coefficient is estimated. A maximum of 73.94 enhancement was observed for 0.03% nanofluid by comparing with the base fluid in between 1 LPM and 4 LPM respectively between inner and outer regions.

Fig 5: It is observed that the thermal conductivity and Reynolds number are increasing with the increase of volume concentration of nanofluid and also Effectiveness increases.

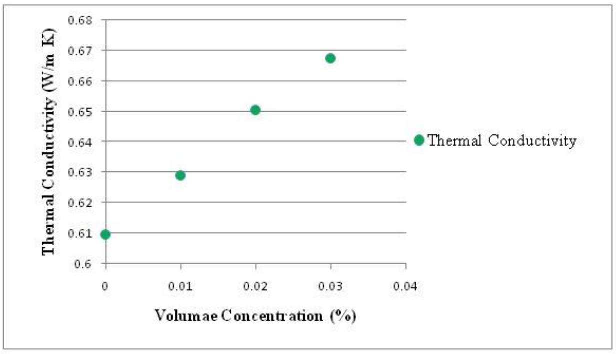

Fig-5: Thermal conductivity vs Volume concentration

Fig 6: shows the experimental results of water and different concentrations of nanofluid. It is observed that heat transfer coefficient increases with the increase in concentration of nanofluid compared to the base fluid

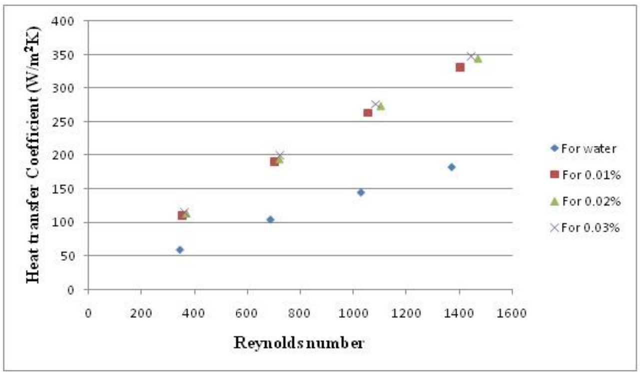

Fig-6: heat transfer coefficient vs Reynolds number

Fig 7: shows the experimental results of water and different concentrations of nanofluid. It is observed that overall heat transfer coefficient increases with the increase in concentration of nanofluid compared to the base fluid

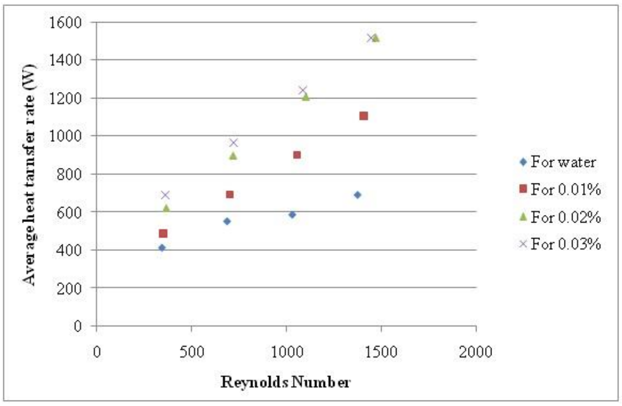

Fig-7: Average heat transfer vs Reynolds number

Fig 8: shows the experimental results of water and different concentrations of nanofluid. It is observed that average heat transfer increases with the increase in concentration of nanofluid compared to the base fluid

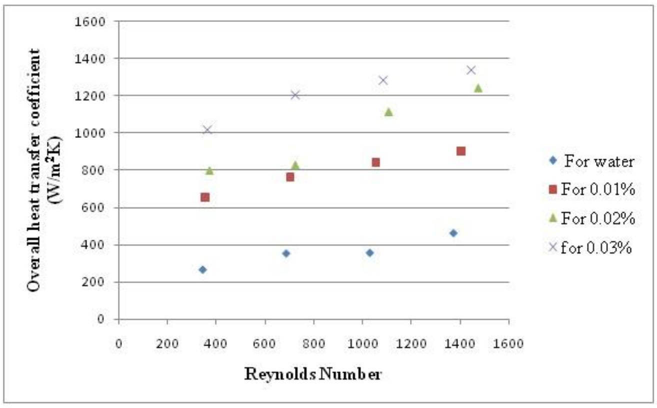

Fig 8: Reynolds number vs Overall heat transfer coefficent

Fig 9: shows the experimental results of water and different concentrations of nanofluid. It is observed that Effectiveness increases with the increase in concentration of nanofluid compared to the base fluid

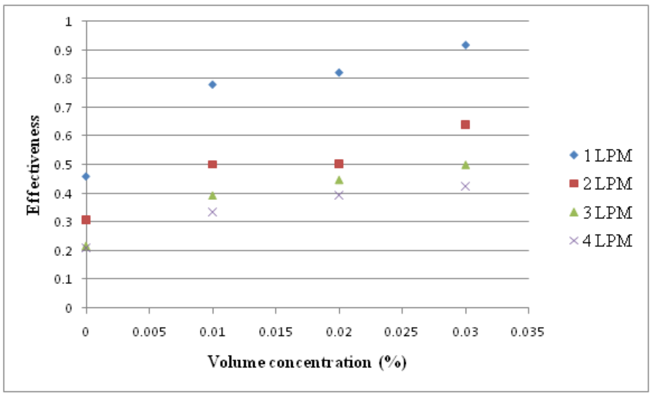

Fig 9: Volume concentration vs Effectiveness

5. Conclusion

The heat transfer coefficient and Effectiveness for water based Al_2O_3 Nanofluid at different volume concentrations were measured experimentally. It is observed that the dispersion of nanoparticles in all the base fluids, increases heat transfer coefficient and Effectiveness and it further increases with increase of particle volume concentration.

The heat transfer coefficient enhancement for Al_2O_3– water nanofluid is 73.94 % for 1 LPM and 65.25 % for 4 LPM by comparing the 0.03% with water. It indicates that heat transfer coefficient of nanofluids increases with increase of Reynolds number compared to single phase fluid. Heat transfer coefficient increases with increase of volume concentration of nanoparticles in water as base fluid.

REFERENCES

[1] Bharat B. Bhosle and Prof.D.N.Hatkar , "Analysis of Heat Transfer Enhancement of Heat Exchanger using Nanofluid," IRJET, Volume: 04 Issue: 04 | Apr -2017.

[2] S. Eiamsa-ard et.al. "Heat transfer enhancement of TiO2/water nanofluid in a heat exchanger tube equipped with overlapped dual twisted-tapes", Engineering science and Technology, an International Journal 18 (2015) 336e350.

[3] Masoud Haghshenas Fard et.al. "Numerical and experimental investigation of heat transfer of ZnO/water nanofluid in the concentric tube and plate heat exchangers", Thermal Science (2011) vol.15, Pp. 183-194.

[4] Ali Najah Al Shamani et.al. "Enhancement heat transfer characteristics in the channel with trapezoidal rib groove using nanofluids", Elsevier journal case studies in Thermal Engineering 5 (2015) 48–58.

[5] R. Dharmalingam et.al. "Experimental investigation of heat transfer characteristics of nanofluid using parallel flow, counter flow and shell and tube heat exchanger", archive of mechanical engineering (2015) vol. LXII.

[6] Lazarus Godson Asirvatham, Nandigana Vishal, Senthil Kumar Gangatharan and Dhasan Mohan Lal. "Experimental study on forced convective heat transfer with low volume fraction of CuO/water nanofluid", Energies (2009) 2, 97-119.

[7] Rohit S. Khedkar, Shriram S. Sonawane, Kailas L Wasewar. "Water to nanofluids heat transfer in concentric tube heat exchanger experimental study", Procedia Engineering 51 (2013) 318 – 323.

[8] Jaafar Albadr, Satinder Tayal, Mushtaq Alasadi. "Heat transfer through heat exchanger using Al2O3 nanofluid at different concentrations", Elsevier journal case studies in Thermal Engineering 1 (2013) 38–44.

[9] T Aseer Brabin, S Ananth. "Analysis of overall heat transfer coefficient and effectiveness in split flow heat exchanger using nano fluids", Journal of advances in mechanical engineering and science, (2015) vol. 1(3).

[10] Prof. Alpesh Mehta, Dinesh k Tantia, Nilesh M Jha, Nimit M Patel. "Heat exchanger using nano fluid", International journal of advanced engineering technology, (2012) Vol.III/ Issue IV 49-54.

[11] Mr. Vatsal. S. Patel, Dr. Ragesh. G. Kapadia, Dr. Dipak A. Deore. "An experimental study of counter flow concentric tube heat exchanger using CuO / water nanofluid", International journal of engineering research & technology (2013) vol. 2 Issue 6.

[12] Tiago A. Moreira et.al. "Flow boiling heat transfer coefficient of water/SiO2 nanofluid inside a 1.1 mm round microchannel", The 13th International conference on nanochannels, microchannels, and minichannels (2015) 48317.

[13] L. W. Hu et.al. "Preparation and characterization of various nanofluids", Cleantech (2007) ISBN 1-4200-6382-0.

[14] Adnan M. Hussein et.al. "Experimental measurement of nanofluids thermal properties", International Journal of Automotive and Mechanical Engineering, (2013) volume 7.

BIOGRAPHIES

Mr.B.Parameswara Rao, Research Scholar pursuing M.Tech in Kallam Haranadhareddy Institute of Technology, Guntur, Andhra Pradesh, India.

Mr.V.Nageswara Rao, Associate Professor in Mechanical Engineering Department of Kallam Haranadhareddy Institute of Technology, Guntur, Andhra Pradesh, India. Research areas include nanofluids in heat exchangers, Combined cycle power plants, Bio-diesels

Dr.S.C.V.Ramana Murthy Naidu,Professor and Head of the Department of Mechanical Engineering Department of Kallam Haranadhareddy Institute of Technology, Guntur, Andhra Pradesh, India. Reseach areas includes Alternate fuels, Finite Element Modeling and vibrations

Mr.T.Veeraiah, Assistant Professor in Mechanical Engineering Department of Kallam Haranadhareddy Institute of Technology, Guntur, Andhra Pradesh, India