EXPERIMENTAL INVESTIGATION OF HEAT TRANSFER RATE ON CONCENTRIC TUBE HEAT EXCHANGER USING Al_2O_3 AND CuO TRANSFORMER OIL BASED NANO FLUIDS

[1]Kishore,[2]Dr.H N Vidyasagar,[3]Dr.D K Ramesha

[1]Research Scholar,[2]Professor, [3]Professor
[1] Department of Mechanical Engineering,
[1]UVCE, Bangalore, India.

Abstract: Heat exchangers are the equipments used for transferring the heat from one fluid to another which are at different temperatures. Heat exchangers are playing a integral role in many engineering applications like petrochemical plants, power cycles, automobile, building and electronic sectors. For transferring the heat between cold and hot fluids different types of heat exchangers are extensively used in various industries. The key role of the heat exchanger is to transfer heat at maximum rate. In this paper concentric tube heat exchanger is fabricated with inner pipe made of copper and outer pipe made of galvanized iron. The Al_2O_3 and CuO nano particles of about 25 nm diameter are used in the present study .To enhance the rate of heat transfer and overall heat transfer coefficient nano particles were dispersed in the base fluid. The results shows that heat transfer rate and overall heat transfer co-efficient of nano fluid is slightly higher than that of the base liquid for same mass flow rate .The heat transfer rate and overall heat transfer co-efficient of nano fluid increases with the increase of the volume concentration of the Al_2O_3 nano fluid and CuO nano fluid and the results of Al_2O_3 nano fluid and CuO nano fluid were compared. There is a lot of scope on performance of heat exchanger and applications of nano fluid in the coming years.

***Index Terms*:** *Concentric tube heat exchanger, Nano fluids, Heat Transfer, Overall heat transfer coefficient*

I.INTRODUCTION

Heat exchangers are the equipments used for transferring thermal energy from a fluid at high- temperature to a fluid at low-temperature with both fluids moving through the device. It facilitates the exchange of heat between the fluids that are at different temperature while keeping them from mixing with each other. Heat exchangers are widely used in power generation, chemical processing, electronic cooling, air-conditioning, refrigeration, and automotive applications. Nano fluid is a fluid containing nanometer size metal particle, called nano particles. These fluids are engineering colloidal suspension of nano particle in base fluid. Nano particle are typically made of metals, oxides, carbides or carbon nano tube that are dispersed in base fluids to form nano fluids. Commonly used to base fluids include water, ethylene glycol and oil. High thermal conductivity and convective heat transfer coefficient exhibits compared to the base fluid. Nano fluid is used as a cold fluid in heat exchanger which is considered as a three phase fluid i.e. solid phase (nano particles), liquid phase (base fluid), and interfacial phase therefore it increases the rate of heat transfer and efficiency of heat exchanger as well. One step or two step technique is used in preparation of nano fluids. One-step method involves synthesis of nanoparticles in base fluid by using chemical methods. In case of two step technique nanoparticles are firstly prepared in powder form by physical or chemical methods like laser ablation and sol- gel processing. Nano fluid stability and concentrations are characterized for best results. Argonne National Laboratory of USA by Choi in 1995 [1] which showed that thermal performance of conventional liquid could be remarkably improved using nano particles. Albadr et al. [2] experimentally examined horizontal shell and tube heat exchanger for forced convective heat transfer and flow characteristics of a counter flow under turbulent flow conditions for water as base fluid and different volume concentrations of Al_2O_3 nano fluid. Farajollahi et al. [3] used shell and tube heat exchanger for comparative analysis of Al_2O_3 and TiO_2 water nano fluid. They deliberated that at different nano particle concentrations the heat transfer enhancements of both nanofluids are different. At higher volume concentrations TiO_2/water nanofluids has better heat transfer than Al_2O_3/water nano fluids.V.SanthoshCibi, et al., [4] examined convective heat transfer increment with graphite nano fluids by the use of shell and tube heat exchanger. Graphite nano fluids performed better in shell and tube heat exchanger for laminar. They used Graphite nano powders for the experimentation and stirrer with the base water by varying its concentration in the range of 0.025, 0.05, and 0.075 (in percent) by volume. During the experimentation they observed that when the concentration of the graphite rises with different concentrations, the heat-transfer-co-efficient rises gradually with the concentrations. They also concluded that the performance of graphite on thermal conductivity value of nanofluids was much better and also heat transfer-coefficient of nanofluids increases with graphite rise concentration and flow performance of the coldest fluid. Murali Krishna et.al. [5] conducted experimentation to study the effect of heat transfer rates of Al_2O_3–water nanofluids for different flow rates and volume concentrations in a concentric tube heat exchanger. Dharmalingam et.al.[6] carried out experimental study on heat transfer characteristics of water based Aluminum oxide nano fluid in a counter, parallel flow direction in a shell and tube heat exchanger in this the overall heat transfer coefficient increases with increase in mass flow rate of the nano fluid. Leong et al. [7] examined the application of nanofluids as working fluids for a biomass heating plant with shell and tube heat recovery exchangers. The results showed that with the application of nano fluids the overall and convective heat transfer coefficient increased compared to ethylene glycol or water base fluids. P.V.Durga Prasad et.al. [8] carried out experimental investigation to enhance the heat transfer by using Aluminum oxide nanofluids at low volume concentrations and trapezoidal cut twisted tapes. The results indicated the enhancement of parameters like heat transfer co-efficient with increase in volume concentration.Vajjha R et al. [9] researched experimentally convective heat transfer and pressure drop characteristics of turbulent flow of three nano fluid (CuO SiO_2 and Al_2O_3) flowing through circular pipe. The result revealed that the heat transfer increased with the increase of volume concentration. Raei et.al.[10]conducted experiments in a double pipe heat exchanger and determined overall heat transfer coefficient and friction factors of water based γ-Al_2O_3 nano fluid and results revealed that increasing the concentration of nano fluid, flow rate increase the overall heat transfer coefficient and heat transfer rate.

In this present paper Al_2O_3 and CuO nano particle are selected with transformer oil as base fluid. The experimentation is conducted to study the effect of heat transfer rate and overall heat transfer coefficient by the use of transformer oil based nano fluids of different volume concentrations.

II.PREPARATION OF NANO-FLUIDS

In this work, nano fluids were prepared using two step technique for different volume concentrations. The commercially available Nano powders obtained from different mechanical, physical and chemical routes such as milling, grinding, and sol-gel and vapor phase methods were used. $Al_2O_3$and CuO nano particles of average size 20-50 nm are uniformly distributed into the base fluid Transformer oil for making stable nano-fluids of different volume concentration of 0.05 %, 0.1%, 0.5%, 1.0% and 1.5%

Table 1: Specifications of Base fluid (Transformer oil)

Sl. No.	Properties	Base fluid (Transformer Oil)
1	Density	900 kg/m^3
2	Thermal conductivity	0.157 W/mK
3	Specific heat	1860 J/kg K
4	Viscosity	0.013350 Pa-s

2.1Characterization of Nanofluids

Thermo physical properties of Nanofluid

1. The effective properties of nano fluids like specific heat, density, viscosity and thermal conductivity are calculated according to the mixing theory.

2. The density of Nanofluid is determined using Pak and Cho correlations

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

where, ρ_{nf} is the density of nanofluids, ρ_{bf} is the density of base fluid (Transformer oil),ρ_p is the density nanoparticles (Al_2O_3 and CuO),φ is the volume concentration.

3. The specific heat of Nanofluid is determined from Xuan and Roetzel correlation .

$$\rho_{nf}Cp_{nf} = (1-\varphi)\, \rho_{bf}Cp_{bf} + \varphi\, (Cp)p\, \rho_p$$

where, Cp_{nf} is the specific heat of Nanofluid, Cp_{bf} is the specific heat of base fluid (transformer oil),Cp_p is the specific heat of nanoparticles (Al_2O_3 and CuO).

4. The thermal conductivity of Nanofluid is determined from Maxwell formula

$$k_{nf} = \frac{k_p + 2k_{bf} + 2\varphi(k_p - k_{bf})}{k_p + 2k_{bf} - \varphi(k_p - k_{bf})} k_{bf}$$

where, K_{nf} is the thermal conductivity of Nanofluid, K_{bf} is the thermal conductivity of base fluid (transformer oil), Kp is the thermal conductivity of nanoparticles (Al_2O_3 and CuO).

5. The viscosity of nanofluids is determined using Drew and Pass man correlation.

$$\mu_{nf} = (1 + 2.5\,\varphi + 6.2\varphi^2)\mu_{bf}$$

Where, μ_{nf} is the viscosity of Nanofluid, μ_{bf} is the viscosity of transformer oil.

III. EXPERIMENTAL SET UP

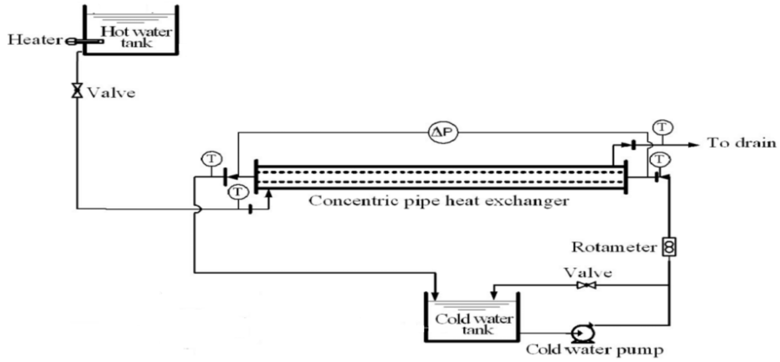

Fig. 1: Line diagram of Experimental Setup

The Fig:1 shows the line diagram of concentric tube heat exchanger. The setup mainly consists of the following components namely heating element, heat exchanger, reservoir and pump. Concentric tube is considered in the heat exchanger. The outer tube is made up of a galvanized iron (GI) with outer diameter 42mm, inner diameter40mm. The inner pipe is made up of copper with outer diameter 13mm and inner diameter 12mm.The length of the pipe is 1000mm. The reservoir is made up of mild steel, which is coated to avoid corrosion. Here in reservoir nanofluids is stored which is supplied to the test section. The pump with (voltage 160-230V, maximum head 1524mm, discharge 800litres/hr) is used to supply working fluid or nano fluids from reservoir to test section .A heater of capacity 0-10 litres is used.

The experimental setup with the above principle components also consist of measuring components such as flow meter having a maximum capacity 350 cc/sec to measure flow rate of working fluid which is pumped to the test rig using the pump. It is fixed in between the reservoir output and entry section of the heating element. Thermocouples are fixed at the different points along the flow of working fluid in order to measure the working fluid temperature at different states of system.

3.1 Analysis of heat Exchanger

The experiment is performed by using concentric tube heat exchanger under constant rate of mass flow and the flow is parallel. Hot and cold fluid temperatures were recorded for different volume concentration 0.05, 0.1, 0.5, 1.0, 1.5% under three different temperatures 60^0,70^0,80^0C. From the obtained value heat transfer and overall heat transfer co-efficient are estimated using empirical equations.
From the observation made from experimentation suggests that, the temperature values were recorded for hot and cold fluid at inlet and outlet for nano fluids of various volume concentrations under constant mass flow rates.

Heat transfer rate for hot fluid

$$Q_h = m_h * C_{ph} * (T_{hi} - T_{ho})$$

Heat transfer rate for cold fluid

$$Q_c = m_c * C_{pc} * (T_{co} - T_{ci})$$

where, m_h and m_c are the mass flow rate of hot and cold fluid respectively.
C_{ph} and C_{pc} are the specific heat of hot and cold fluid respectively. T_{hi} and T_{ci} are the temperatures of hot and cold fluid at inlet and T_{ho} and T_{co} are the temperatures of the hot and cold fluid at outlet respectively.

Logarithmic mean temperature difference is

LMTD

$$\Delta T_{lm} = \frac{(T_{hi} - T_{co}) - (T_{ho} - T_{ci})}{\ln\left(\frac{T_{hi} - T_{co}}{T_{ho} - T_{ci}}\right)}$$

The overall heat transfer coefficient is

$$Q = UA_s \Delta T_{lm}$$

IV.RESULTS AND DISCUSSION

In this paper a concentric tube heat exchanger was fabricated and the standard experimental procedure was followed and results were obtained by using certain equations and are graphically represented.

Overall heat transfer coefficient

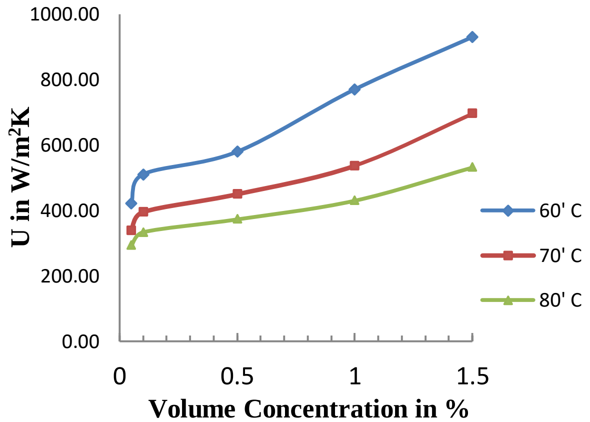

Fig.2: Variation of overall heat transfer co-efficient for different volume concentration of Al_2O_3 Transformer oil nano-fluids for different temperature

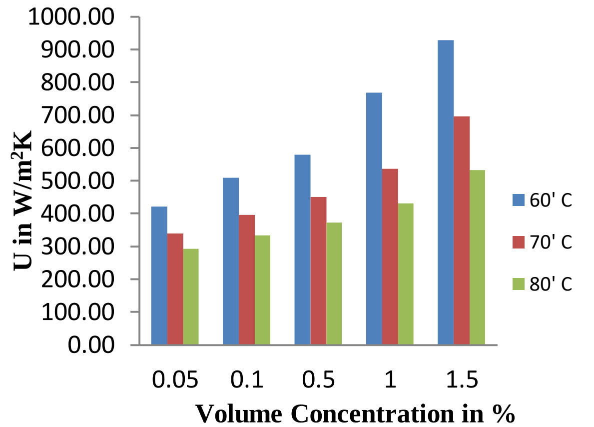

Fig.3: Variation of overall heat transfer co-efficient for different volume concentration of Al_2O_3 Transformer oil nano-fluids at different temperature (Bar chart)

From the results it is observed that overall heat transfer coefficient increases with increase in volume concentration compared to base fluids. The maximum enhancement of overall heat transfer co-efficient exists at 1.5% volume concentration for Al_2O_3 transformer oil nano-fluids.

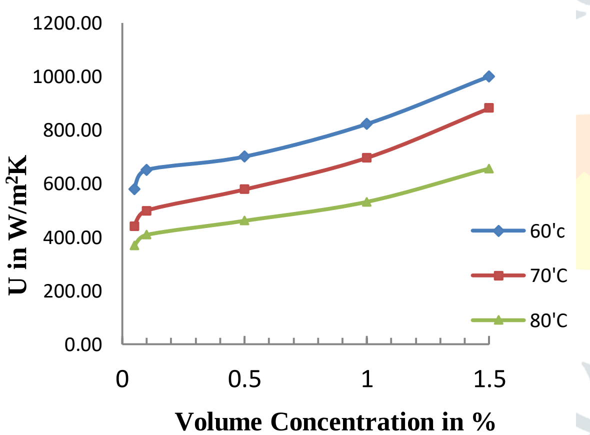

Fig. 4: Variation of overall heat transfer co-efficient for different volume concentration of CuO Transformer oil nano fluids at different temperature

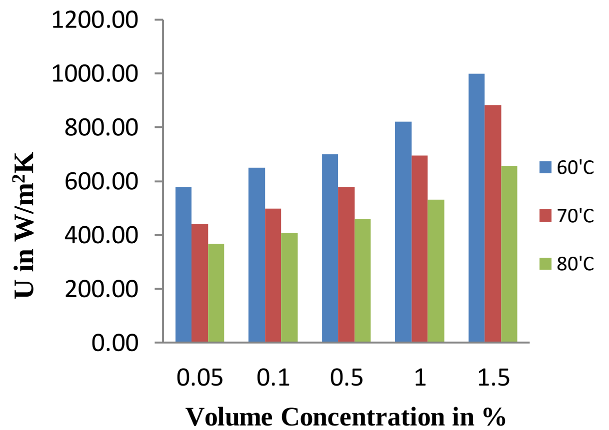

Fig. 5: Variation of overall heat transfer co-efficient for different volume concentration of CuO Transformer oil nano fluids(Bar chart)

From the results it is revealed that maximum enhancement of overall heat transfer co-efficient occurs at 1.5% volume concentration for CuO transformer oil nano-fluids.Also the overall heat transfer co-efficient of CuO transformer oil nano-fluids is higher in comparison with Al_2O_3 transformer oil nano-fluids. Due to high concentration of nano particles towards the wall side by particle migration and force of attraction has led to increase of heat transfer co-efficient. The overall heat transfer coefficient of nano fluids decreases with the increase of temperature since it depends on logarithmic mean temperature difference.

Heat Transfer Rate

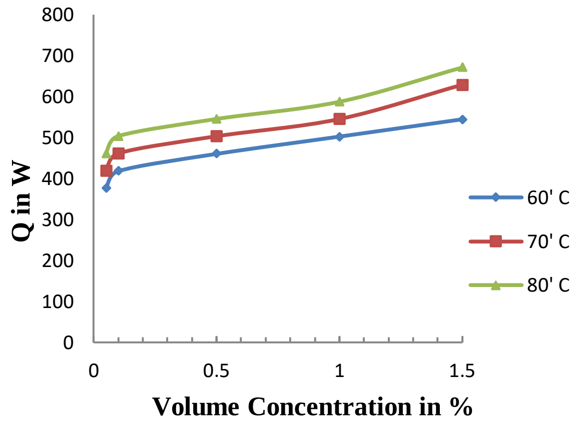

Fig 6: Variation of heat transfer for different volume concentration of Al_2O_3 Transformer oil nano-fluids for different temperature

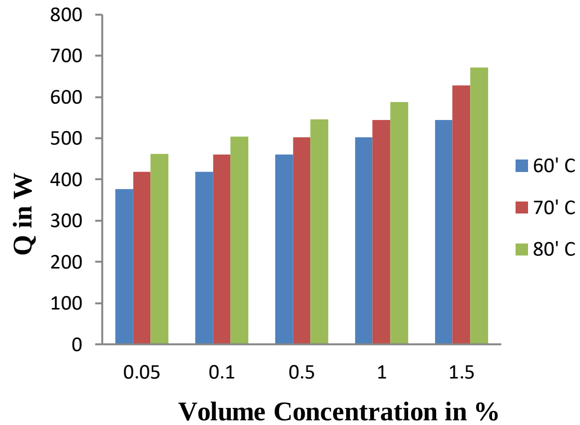

Fig 7 : Variation of heat transfer for different volume concentration of Al_2O_3 Transformer oil nano fluids for different temperature (Bar chart)

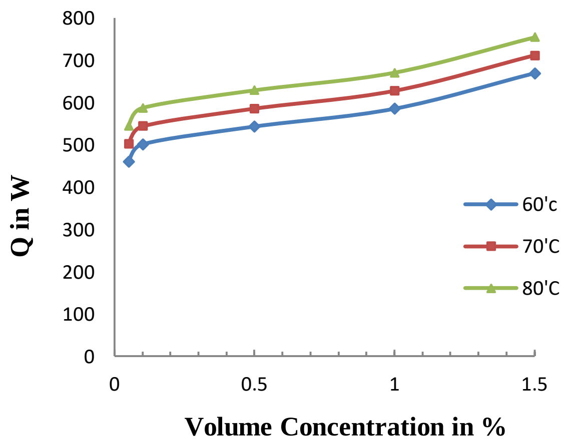

Fig. 8: Variation of heat transfer for different volume concentration of CuO Transformer oil nano-fluids for different temperatures.

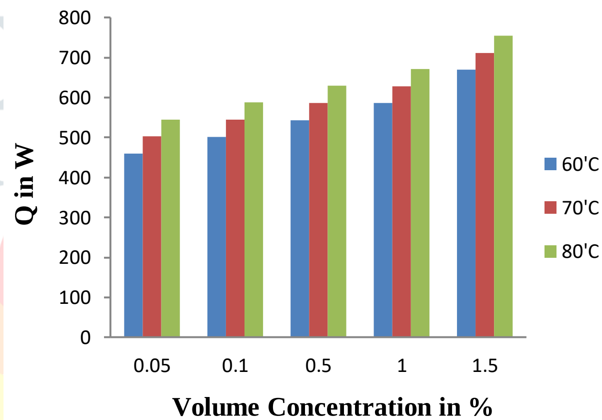

Fig. 9: Variation of heat transfer for different volume concentration of CuO Transformer oil nano fluids for different temperature(Bar chart)

Fig: 6&8 shows the deviation of heat transfer for different volume concentration of Al_2O_3 transformer oil and CuO transformer oil based nano fluids. The trends shown by the nano fluid is due to the fact that the nano particles presented in the base fluid increase the thermal conductivity and the viscosity of the base liquid at same time. The enhancement of thermal conductivity leads to increase the heat transfer rate. The thermal conductivity of CuO nano particle is higher than Al_2O_3 nano particle leads to high heat transfer rate of CuO transformer oil based nano fluids. Since the heat capacity of nano particles decreases as the concentration of nanoparticles into the base fluid increases it leads to nano-fluids enhanced heat transfer than conventional fluids.

V.CONCLUSION

In this work concentric tube heat exchanger is fabricated and experimental analysis is carried. Nano particles used were Al_2O_3 and CuO. Nano-fluids with different concentration (0.05, 0.1, 0.5, 1.0, and 1.5%) were used for experimental analysis.

The following conclusions are drawn

- Heat transfer rate and overall heat transfer coefficient were determined for Al_2O_3 transformer oil based nano fluids, CuO nano fluids of different volume concentrations.
- Heat transfer rate increases with increasing volume concentration for both Al_2O_3 transformer oil nano fluids and CuO transformer oil nano fluids. CuO transformer oil based nano fluids has shown higher heat transfer rate in comparison with Al_2O_3 transformer oil based nano fluids.
- Overall heat transfer co-efficient increases with increase in volume concentration for particular temperature. CuO-Transformer oil nano-fluids has showed increase in heat transfer rate with increase in volume concentration as compared with Al_2O_3 transformer oil nano-fluids.

Thus Nano fluids are found to be more decisive as compared to other base fluids.

REFERENCES

[1]. Choi SUS 1995 Enhancing thermal conductivity of fluids with nano particle. ASME FED **231** 99.

[2] J. Albadr , S. Tayal , M. Alasadi, Heat transfer through heat exchanger using Al_2O_3 nano fluid at different concentrations, Case Studies in Thermal Engineering, 1(1), 2013, 38–44

[3] B. Farajollahi, S.Gh. Etemad , M. Hojjat , Heat transfer of nanofluids in a shell and tube heat exchanger, International Journal of Heat and Mass Transfer, 53(1-3),2010, 12–17

[4] V.SanthoshCibi, K.Gokul raj, P.Kathiravan, R.RajeshKanna, B.Ganesh, Dr.S.Sivasankaran, V.Vedhagiri Eswaran, 'Convective heat transfer enhancement of graphite nano fluids in shell and tube heat exchanger'. IJIRSET An ISO 3297: 2007 Certified Organization, Volume 3, Special Issue 2, April2014 ISSN (Online): 2319-8753 ISSN(Print): 2347 – 6710

[5] V. Murali Krishna,2016, Experimental investigation of heat transfer enhancement by using Al_2O_3 water nano fluid in a concentric tube heat exchanger , International Journal of Mechanical Engineering and Technology (IJMET) Volume 7, Issue 6, November–December 2016, Pp.449–458.

[6] R.Dharmalingam, K.K.Sivagnanaprabhu, J. Yogaraja, S. Gunasekaran, R. Mohan Experimental investigation of heat transfer characteristics of nanofluid using parallel flow, counter flow and shell and tube heat exchanger, Archive of mechanical engineering , VOL. LXII 2015. Pp: 509-522.

[7] Leong KY, Saidur R, Mahlia TMI, Yau YH. Modeling of shell and tube heat recovery exchanger operated with nano fluid based coolants. International Journal of Heat and Mass Transfer2012;55(4):808–16.

[8] P.V. Durga Prasad, A.V.S.S.K.S. Gupta and K. Deepak, 2014, Investigation of Trapezoidal-Cut Twisted Tape Insert in a Double Pipe U-Tube Heat Exchanger using Al2O3/Water based Nanofluid, 2nd International Conference on Nano materials and Technologies (CNT 2014), Procedia Materials Science10(2015) 50 – 63,Pp: 50-63

[9]. Ravikanth S. Vajjha et al, Development of new correlations for convective heat transfer and friction factor in turbulent regime for nanofluids International Journal of Heat and Mass Transfer 53 (2010) 4607–4618.

[10] B. Raei1, F. Shahraki1, M. Jamialahmadi, S.M. Peyghambarzadeh, 2017, Experimental investigation on the heat transfer performance and pressure drop characteristics of γ-Al2O3/water nano fluid in a double tube counter flow heat exchanger , Trans. Phenom. Nano Micro Scales, 4(1), Pp: 64-77