Heat Transfer Enhancement in Double Pipe Heat Exchanger by Using Nanofluid (Al_2O_3)

Pratik K. Chauhan[1] Prof. R. K. Waghchore[2] Pravin Kaikade[3] Mohd. Zahed Shadab[4]
[1,3,4]Student [2]Assistant Professor
[1,2,3,4]Department of Mechanical Engineering
[1,2,3,4]Jawaharlal Darda Institute of Engineering and Technology, Yavatmal, Maharashtra, India

Abstract— The Nano fluids are a new and innovative type of heat transfer fluids which are capable of holding higher thermo physical properties compared to the conventional fluids such as water, ethylene glycol and oil etc. In this paper Al_2O_3Nanofluid is used in comparison with Distilled Water in double pipe heat exchanger in parallel flow and counter flow on different flow rates for a certain interval of time. Distilled Water is non-Ionic form in nature, so, results using Nanofluid Al_2O_3 were obtained with experimental work results on thermal conductivity and heat transfer rate. The thermal conductivity of the conventional fluids such as water and ethylene glycol so the Nanofluid can be used as a coolant in heat exchanger and also the thermal conductivity of aluminium is higher than that of the other metals so the Al_2O_3 Nanofluid is more efficient as a coolant as compared to other Nano fluids.

Key words: Al_2O_3 Nano fluids, LMTD

I. INTRODUCTION

Thermal properties of liquids play a decisive role in heating as well as cooling applications in industrial processes. Thermal conductivity of a liquid is an important physical property that decides its heat transfer performance. Conventional heat transfer fluids have inherently poor thermal conductivity which makes them inadequate for ultra-high cooling applications. Scientists have tried to enhance the inherently poor thermal conductivity of these conventional heat transfer fluids using solid additives following the classical effective medium theory (Maxwell, 1873) for effective properties of mixtures. Fine tuning of the dimensions of these solid suspensions to millimetre and micrometre ranges for getting better heat transfer performance have failed because of the drawbacks such as still low thermal conductivity, particle sedimentation, corrosion of components of machines, particle clogging, excessive pressure drop etc. Downscaling of particle sizes continued in the search for new types of fluid suspensions having enhanced thermal properties as well as heat transfer performance.

A. *Al_2O_3 Nanofluidand Theirproperties:*

Characteristic	Range
Molar Mass	101.00 kg/k mole
Labelling Toxicity	Less toxic
Concentration	99.09% pure
Density	3880kg/m^3
Thermal conductivity	40 W/m K

Table 1: Properties of Nano fluid

To design or predict the performance of a heat exchanger, it is essential to determine the heat lost to the surrounding for the analysed configuration.

II. EXPERIMENTAL SETUP

DOUBLE PIPE HEATEXCHANGER	
Manufacturing Details	Technical Teaching (D) Equipment ,Bangalore
Inner Diameter of the pipe	9.5 mm
Outer Diameter of the pipe	17mm
Length of heat exchanger	1500mm
thermometers	0-100^0 C
geyser	Single phase 3kw
Material used	Copper
Rotameter	45cc/sec(maximum limit)

Table 2: Specification of Test Rig Double Pipe Heat Exchanger.

III. AN EXPERIMENTAL APPARATUS AND METHOD

A. *Experimental Apparatus:*

The most often found in industrial applications: (Double pipe heat exchangers) and to understand the factors and parameters affecting the heat transfer rates. The goal of this experiment for counter flow,

1) The heat lost to the surroundings.
2) The temperature efficiency for the hot and cold fluids.
3) As the heat transfer rate is directly proportional to the logarithmic mean temperature difference (LMTD). Then we are comparing the heat transfer rate with the distilled water. As the LMTD increases the heat transfer rate also increases.

A schematic diagram of the experimental apparatus is shown in Figure 1 and Figure 2; it consists of a test section, And line diagram of hot water loop, and cold water loop and data acquisition system.

The test section is the double pipe heat exchanger as shown in Figure2, the test section and the connections of the piping system are designed such that parts can be changed or repaired easily.

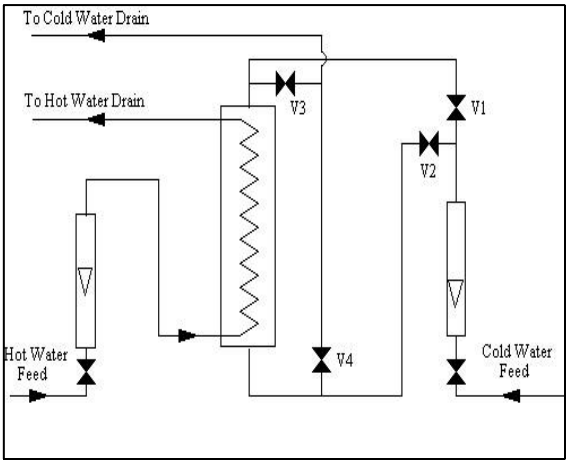

Fig. 1: Schematic Diagram of Apparatus.

Fig. 2: Cross Section of Double Pipe Heat Exchange

Sr. no.	Time (min)	Th_1	Th_2	Tc_1	Tc_2	ΔT_1	ΔT_2	LMTD
1	0	60.1	39.1	26.7	34.9	25.2	12.4	18.04
2	5	60.3	39.4	27.1	37.6	23.2	12.3	18.04
3	10	60.3	39.7	27.2	37.7	22.6	12.5	17.05
4	15	60.3	39.6	27.3	37.3	22.4	12.3	16.84

Table 3: Observation Table for Counter Flow Distilled Water (Flow Rate-25cc/Sec)

1) Calculation:

Logarithmic Mean Temperature Difference ΔT_{LMTD} in^{0}C

$$\Delta T_{LMTD} = \frac{\Delta T_1 - \Delta T_2}{\ln(\frac{\Delta T_1}{\Delta T_2})}$$

$\Delta T_1 = Th_1 - Tc_2$
$\Delta T_2 = Th_2 - Tc_1$

1) $\Delta T_1 = 60.1 - 34.9 = 25.2$
   $\Delta T_2 = 39.1 - 26.7 = 12.4$

$$\Delta T_{LMTD} = \frac{25.2 - 12.4}{\ln(\frac{25.2}{12.4})}$$

$\Delta T_{LMTD} = 18.04$

Similarly,

2) $\Delta T_{LMTD} = 18.04$
3) $\Delta T_{LMTD} = 17.05$
4) $\Delta T_{LMTD} = 16.8$

$$\text{Avg. LMTD} = \frac{18.04+18.04+17.05+16.84}{4} = 17.67$$

Sr. no	Time (min)	Th_1	Th_2	Tc_1	Tc_2	ΔT_1	ΔT_2	LMTD
1	0	61.2	38.2	25.4	33.8	27.4	12.8	19.08
2	5	61.4	38.4	25.5	32.6	28.8	12.9	19.79
3	10	61.5	38.5	25.6	31.8	29.7	12.9	20.40
4	15	61.7	38.8	25.6	31.5	30.2	13.2	20.54

Table 4: Observation Table for Counter Flow Distilled Water (Flow Rate-35cc/Sec)

2) Calculation:

Logarithmic Mean Temperature Difference ΔT_{LMTD} in^{0}C

$$\Delta T_{LMTD} = \frac{\Delta T_1 - \Delta T_2}{\ln(\frac{\Delta T_1}{\Delta T_2})}$$

$\Delta T_1 = Th_1 - Tc_2$
$\Delta T_2 = Th_2 - Tc_1$

1) $\Delta T_1 = 61.2 - 33.8 = 27.4$
   $\Delta T_2 = 38.2 - 25.4 = 12.8$

$$\Delta T_{LMTD} = \frac{27.4 - 12.8}{\ln(\frac{27.4}{12.8})}$$

$\Delta T_{LMTD} = 19.18$

Similarly,

2) $\Delta T_{LMTD} = 19.79$
3) $\Delta T_{LMTD} = 20.40$
4) $\Delta T_{LMTD} = 20.54$

$$\text{Avg. LMTD} = \frac{19.18+19.79+20.40+20.54}{4} = 19.97$$

Sr. no	Time (min)	Th_1	Th_2	Tc_1	Tc_2	ΔT_1	ΔT_2	LMTD
1	0	60.1	34.4	17.2	34.2	25.9	17.2	21.25
2	5	60.1	34.5	17.2	34.3	25.8	17.3	21.26
3	10	60.3	34.6	17.3	34.3	26	17.3	21.35
4	15	60.4	34.9	17.4	34.4	26	17.5	21.47

Table 5: Observation Table for Counter Flow Distilled Water + 5gm Al2O3 (Flow Rate- 25cc/Sec)

3) Calculation:

Logarithmic Mean Temperature Difference ΔT_{LMTD} in^{0}C

$$\Delta T_{LMTD} = \frac{\Delta T_1 - \Delta T_2}{\ln(\frac{\Delta T_1}{\Delta T_2})}$$

$\Delta T_1 = Th_1 - Tc_2$
$\Delta T_2 = Th_2 - Tc_1$

1) $\Delta T_1 = 60.1 - 34.2 = 25.9$
   $\Delta T_2 = 34.4 - 17.2 = 17.2$

$$\Delta T_{LMTD} = \frac{25.9 - 17.2}{\ln(\frac{25.9}{17.2})}$$

$\Delta T_{LMTD} = 21.25$

Similarly,

1) $\Delta T_{LMTD} = 21.26$
2) $\Delta T_{LMTD} = 21.35$
3) $\Delta T_{LMTD} = 21.47$

Avg. LMTD = (21.25+21.26+21.35+21.47)/4=21.33

Sr. no.	Time (min)	Th_1	Th_2	Tc_1	Tc_2	ΔT_1	ΔT_2	LMTD
1	0	60.2	35.2	15.8	32.4	27.8	19.4	23.34
2	5	60.3	35.4	15.8	32.5	27.8	19.6	23.46
3	10	60.4	35.5	15.9	32.5	27.9	19.6	23.50
4	15	60.5	35.5	16.1	32.6	27.9	19.4	23.39

Table 6: Observation Table for Counter Flow Distilled Water + 5gm Al2O3 (Flow Rate- 35cc/Sec)

4) *Calculation:*

Logarithmic Mean Temperature Difference ΔT_{LMTD} in ^0C

$\Delta T_1 = Th_1 - Tc_2$
$\Delta T_2 = Th_2 - Tc_1$

1) $\Delta T_1 = 60.2 - 32.4 = 27.8$
$\Delta T_2 = 35.2 - 15.8 = 19.4$

$$\Delta T_{LMTD} = \frac{27.8 - 19.4}{\ln(\frac{27.8}{19.4})}$$

$\Delta T_{LMTD} = 23.34$

Similarly,

2) $\Delta T_{LMTD} = 23.46$
3) $\Delta T_{LMTD} = 23.50$
4) $\Delta T_{LMTD} = 23.39$

$$\text{Avg. LMTD} = \frac{23.34+23.46+23.50+23.39}{4} = 23.42$$

Sr. no.	Time (min)	Th_1	Th_2	Tc_1	Tc_2	ΔT_1	ΔT_2	LMTD
1	0	62.1	35.2	15.4	30.4	31.7	19.8	25.28
2	5	62.3	35.3	15.4	30.4	31.9	19.9	25.43
3	10	62.5	35.3	15.5	30.5	32	19.8	25.41
4	15	62.6	35.4	15.6	30.6	32	19.8	25.41

Table 7: Observation Table for Counter Flow Distilled Water + 10gm Al2O3 (Flow Rate- 25cc/Sec)

5) *Calculation:*

Logarithmic Mean Temperature Difference ΔT_{LMTD} in ^0C

$\Delta T_1 = Th_1 - Tc_2$
$\Delta T_2 = Th_2 - Tc_1$

1) $\Delta T_1 = 62.1 - 30.4 = 31.7$
$\Delta T_2 = 35.2 - 15.4 = 19.8$

$$\Delta T_{LMTD} = \frac{31.7 - 19.8}{\ln(\frac{31.7}{19.8})}$$

$\Delta T_{LMTD} = 25.28$

Similarly,

1) $\Delta T_{LMTD} = 25.43$
2) $\Delta T_{LMTD} = 25.41$
3) $\Delta T_{LMTD} = 25.41$

$$\text{Avg. LMTD} = \frac{25.28+25.43+25.41+25.41}{4} = 25.38$$

Sr. no.	Time (min)	Th_1	Th_2	Tc_1	Tc_2	ΔT_1	ΔT_2	LMTD
1	0	62.2	36.4	16.4	30.2	32	20	25.53
2	5	62.4	36.6	16.5	30.2	32.2	20.1	25.67
3	10	62.4	36.7	16.5	30.3	32.1	20.2	25.69
4	15	62.5	36.8	16.6	30.4	32.1	20.2	25.69

Table 8: Observation Table for Counter Flow Distilled Water + 10gm Al2O3 (Flow Rate- 35cc/Sec)

6) *Calculation:*

Logarithmic Mean Temperature Difference ΔT_{LMTD} in ^0C

$\Delta T_1 = Th_1 - Tc_2$
$\Delta T_2 = Th_2 - Tc_1$

1) $\Delta T_1 = 62.2 - 30.2 = 32$
$\Delta T_2 = 36.4 - 16.4 = 20$

$$\Delta T_{LMTD} = \frac{32 - 20}{\ln(\frac{32}{20})}$$

$$\Delta T_{LMTD} = \frac{\Delta T_1 - \Delta T_2}{\ln(\frac{\Delta T_1}{\Delta T_2})}$$

$\Delta T_{LMTD} = 25.53$

Similarly,

1) $\Delta T_{LMTD} = 25.67$
2) $\Delta T_{LMTD} = 25.69$
3) $\Delta T_{LMTD} = 25.69$

$$\text{Avg. LMTD} = \frac{25.53+25.67+25.69+25.69}{4} = 25.64$$

IV. PERCENT RISE

We choose the maximum value of LMTD from calculated experimental data for distilled water counter flow and for 5gm nano fluid (Al2O3) counter flow so following data get observed, this data taken for flow rate 35cc/sec.

Average Maximum LMTD for distilled water counter flow =19.97 0c

Average Maximum LMTD for distilled water + 5gm Al2O3 counter flow=23.420c

So,

– % Rise in LMTD for pure water counter flow with respective nano fluid counter flow = (23.42-19.97) *100/ 19.97 = 17.28%

Now, we choose the maximum value of LMTD from calculated experimental data for distilled water counter flow and for 10gm nano fluid (Al2O3) counter flow so following data get observed this data taken for flow rate 35cc/sec.

$$\Delta T_{LMTD} = \frac{\Delta T_1 - \Delta T_2}{\ln(\frac{\Delta T_1}{\Delta T_2})}$$

Average Maximum LMTD for distilled water counter flow =19.97 0c

Average Maximum LMTD for distilled water + 10gm Al2O3 counter flow=25.640c

So,

– % Rise in LMTD for pure water counter flow with respective nano fluid counter flow = (25.64-19.97) *100/ 19.97 = 28.39%

V. RESULT AND DISCUSSION

Sr. No	Flow rate (cc/sec)	LMTD for counter Flow in ^0c		
		Distilled Water	Distilled Water + 5 gm Al_2O_3	Distilled Water + 10 gm Al_2O_3
1	25	17.67	21.33	25.38
2	35	19.97	23.42	25.64

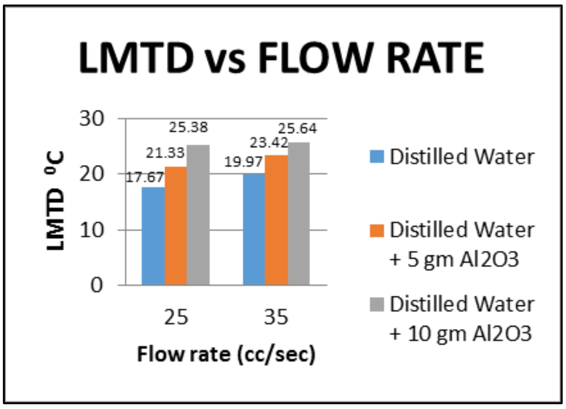

Fig. 3: LMTD Vs Flow Rate

VI. CONCLUSIONS

The counter flow shows the more efficient results as compared to parallel flow arrangement as the heat flux produced is more in counter flow. The Use of (Al_2O_3) as a blend in conventional fluids has a significant effect on the enhancement of heat transfer rate. % Rise in LMTD for distilled water + 5gm Al_2O_3counter flow with respect to distilled water counter flow 17.28%. And % Rise in LMTD for distilled water + 10gm Al_2O_3counter flow with respect to distilled water counter flow 28.39%. Thus, as the amount of nanofluid increase in conventional fluid it is more efficient in terms of heat transfer effect. Results showed that Nano fluids exhibit superior thermo physical properties compared to conventional liquids. Thus it is very promising alternative fluid to increase the heat transfer rate especially in double pipe heat exchanger.

REFERENCES

[1] Flow and convective heat transfer characteristic of spiral pipe for Nano fluid. IJRRAS 7(3).June 2011 Yanuar, N.Putra, Gunawan S.M.Bagi.
[2] Investigation of thermal performance of air toH2O heat exchanger using Nano fluid, IIUM Engineering journal special issue engineering, 2011 Nawaf H. Saeid and Tan HengChaia.
[3] Experimental investigation of silver Nano fluid On heat pipe thermal performance, Applied thermal engineering 26(2006).Shung-Wei Kang, Wei-Chiang Wei, Sheng-Hong Tsai, Shih-YANG,
[4] Experimental study on convective heat transfer of aqueous suspension of Nano sized particle, International symposium on Eco Topia science 07 (2007).Shuichi Torii,
[5] Sattar Al-Jabair "Experi mental study of thermal performance and heat transfer coefficients shell and helically coiled tube heat exchangers", HT2012-58004,
[6] Heat transfer in small heat exchanger using Nano fluids. IL/IN sectional conference. L.B.Mapa, Sana Mazhar,
[7] Nano fluid flow in very small heat sink. International journal of heat and mass transfer 48(2005). J.Koo, C.Kleinstrecer, Laminar

