"Optimization of Condenser Using Nanofluid (Al2o3)"

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Abstract— according to thermodynamics, the efficiency of surface condenser is based on mass flow rate of cooling water. To reduce the mass flow rate of cooling water in surface condenser, some of the nanofluids are insert with them and measure various parameters like inlet & outlet temperature, mass flow rate water with mixed nanofluid, a particular mass flow rate will be decided and from that volume concentration. From this mass flow rate and volume concentration of nanofluid, the optimized condenser design will be start.

Keywords: Nanofluids, Condenser, rate of cooling.

I. INTRODUCTION

A. Surface Condenser

Now a day, due to the limitation of fossil fuel in the world, subject of energy consumption optimization in various industrial processes becomes very important. In chemical processes one of the most important devices related to energy and heat transfer is heat exchanger. For decades, efforts have been done to enhance heat transfer, reduce the heat transfer time, minimize size of heat exchangers, and finally increase energy and fuel efficiencies, reduction in energy consumption is possible by improving the performance of heat exchanger systems and introducing various heat transfer enhancement techniques. Further enhancement in heat transfer is always in demand.

B. NANOFLUID

Nano particles have many attractive characteristics to lend to the idea of a nanofluid. First of all, nano particles are free from the sedimentation. The particle sedimentation speed depends on particle size, base fluid viscosity, and density difference between particle and base fluid. The easiest way to be free from sedimentation is to minimize particle size and the speed goes to zero with nanometer-size particle.

C. THERMAL PROPERTIES OF VARIOUS NANOFLUIDS

Table. 1: Thermal Properties of Nanofluids

PROPERTY	WATER	ETHYLENE GLYCOL	CU	AL2O3	CUO	TIO2
C(J/kg K)	4179	2415	385	765	535.5	686.2
ρ(kg/m3)	997.1	1111	8933	3970	6500	4250
k(W/mK)	0.605	0.252	400	40	20	8.9538
α (m2/s)	1.47	93	1163	1317	57.43	30.7

So, for this project I select one power plant as a reference plant and following data of them are as below:

Mass Flow Rate = 7.083 kg/s

Cooling Water Inlet Temp = 33°C

Cooling Water Outlet Temp = 45°C

Temp. Difference, ΔT = 12°C

Steam Inlet Temp = 150°C

Steam Outlet Temp = 90°C

Temp. Difference, ΔT = 60°C

No. of Tubes: 348

Length of Tubes: 3000 mm

Outside Diameter of Tube: 60.30 mm

Inside Diameter of Tube: 54.00 mm

Wall Thickness of Tube: 06.30 mm

D. LIST OF SYMBOLS, ABBREVIATIONS AND NOMENCLATURE

Cp	Specific heat, J/kg K
D	Nano particle diameter
D_p	Tube diameter, m
U	Overall heat transfer coefficient , W/m^2 K
m	Mass flow rate, L/s
Q	Heat transfer, W
V	Mean velocity, m/s
Ø	Volume concentration, %
P	Density, kg/m^3
ΔT	°C

E. DATA PROCESSING

Heat Duty, Q = m × Cp × ΔT = 355.80 kW

Density of nanofluid (AL_2O_3)

$\rho_{nf} = [\{(1-Ø)\rho_f\} + (Ø\rho_p)]$

Table. 2: Density of Nanofluid for Different Volume Concentration

Sr. No.	Volume Concentration	Density (kg/m^3)
1	30.01	990.0397
2	0.02	980.0794
3	0.03	970.1191
4	0.04	960.1588
5	0.05	950.1985
6	0.06	940.2382
7	0.07	930.2779
8	0.08	920.3176

9	0.09	910.3573
10	0.10	900.3970
11	0.11	890.4367
12	0.12	880.4764
13	0.13	870.5161
14	0.14	860.5558
15	0.15	850.5955
16	0.16	840.6352
17	0.17	830.6749
18	0. 18	820.7146
19	0.19	810.7543
20	0.20	800.7940
21	0.21	790.8337
22	0.22	780.8734
23	0.23	770.9131
24	0.24	760.9528
25	0.25	750.9925

Specific heat of nanofluid (AL_2O_3):-

$$(\rho C_p)_{nf} = \{(1-Ø)\times(\rho C_p)_f + Ø(\rho C_p)_p\}$$

Table. 3: Specific Heat of Nanofluid for Different Volume Concentration

Sr. No.	Volume Concentration	Specific Heat (kj/kg° C)
1	0.01	4.219
2	0.02	4.257
3	0.03	4.293
4	0.04	4.330
5	0.05	4.367
6	0.06	4.407
7	0.07	4.447
8	0.08	4.488
9	0.09	4.530
10	0.10	4.572
11	0.11	4.615
12	0.12	4.660
13	0.13	4.705
14	0.14	4.751
15	0.15	4.800
16	0.16	4.847
17	0.17	4.897
18	0. 18	4.948
19	0.19	5.000
20	0.20	5.054
21	0.21	5.109
22	0.22	5.165
23	0.23	5.223
24	0.24	5.282
25	0.25	5.343

MASS FLOW RATES:-

$$Q = m \times Cp \times \Delta T, \quad m = (Q/Cp \times \Delta T)$$

Table. 4: Mass flow rates of mixing of cooling water and nanofluid for different volume concentration

Sr. No.	Volume Concentration	Mass Flow Rate (kg/s)
1	0.01	07.02
2	0.02	06.96
3	0.03	06.90
4	0.04	06.84
5	0.05	06.78
6	0.06	06.72
7	0.07	6.66
8	0.08	6.60
9	0.09	6.54
10	0.10	6.49
11	0.11	6.43
12	0.12	6.36
13	0.13	6.30
14	0.14	6.24
15	0.15	6.17
16	0.16	6.11
17	0.17	6.05

18	0. 18	5.99
19	0.19	5.93
20	0.20	5.87
21	0.21	5.80
22	0.22	5.73
23	0.23	5.68
24	0.24	5.61
25	0.25	5.55

F. COST OPTIMIZATION

1) FOR SEA WATER

a) Water Pumping Cost

$$\mathrm{Cop} = \sum_{k=1}^{ny} \frac{\mathrm{Co}}{(1+i)^k}$$

Co can be calculated by,

$$\mathrm{Co} = \mathrm{P} \times \mathrm{Kel} \times \tau$$

P can be calculated by,

$$\mathrm{P} = \frac{1}{n}\left(\frac{mt}{\rho t}\Delta pt + \frac{ms}{\rho s}\Delta ps\right)$$

Cop = 25,29,22,936.00

b) Initial cost

According to quotation, the initial cost : 02,18,05,000.00

c) Total cost using sea water

C_{TOTAL} = Operating Cost + Initial Cost
= 25,29,22,936.00 + 02,18,05,000.00
= 27,47,27,936.00

2) FOR MIXTURE OF SEA WATER AND NANOFLUID

a) Nanofluid cost

According to quotation, the nanofluid cost : 7500/kg

b) Water Pumping Cost

For Φ = 1%	25,29,22,548.50
For Φ = 2%	25,29,22,203.90
For Φ = 3%	25,29,21,859.30
For Φ = 4%	25,29,21,514.70
For Φ = 5%	25,29,21,213.20
For Φ = 6%	25,29,20,868.70
For Φ = 7%	25,29,20,524.10
For Φ = 8%	25,29,20,179.50
For Φ = 9%	25,29,19,834.10
For Φ = 10%	25,29,19,533.40
For Φ = 11%	25,29,19,143.80
For Φ = 12%	25,29,18,800.50
For Φ = 13%	25,29,18,456.64
For Φ = 14%	25,29,18,117.2
For Φ = 15%	25,29,17,725.00

c) Initial cost

Now by adding nanofluid with sea water there is a decrease in condenser area and also length of tubes. The calculation of reduction in area and length of tubes are found out through matlab programming

Table. 5: Initial Cost for Different Volume Concentration

Sr. No.	% Volume Concentration	Area (m^2)	Tube Length (mm)	Decrement in Tube Length (mm)	Initial Cost (Rs.)
1	1	562.9737	2973.3	26.7	21780500
2	2	558.1619	2947.9	52.1	21759100
3	3	553.3502	2922.5	77.5	21739200
4	4	548.5384	2897.1	102.9	21721600
5	5	543.7267	2817.7	182.3	21705800
6	6	538.9150	2846.3	153.7	21692300
7	7	534.1032	2820.8	179.2	21680100
8	8	529.2915	2795.4	204.6	21668600
9	9	524.4797	2770.0	230.0	21658900
10	10	520.4700	2748.8	251.2	21650500
11	11	515.6582	2723.4	276.6	21643200
12	12	510.0445	2693.8	306.2	21637050
13	13	505.2328	2668.4	331.6	21632000
14	14	500.4210	2642.9	357.1	21628100
15	15	494.8073	2613.3	386.7	21625350

d) TOTAL COST

Table. 6: Total Cost for Different Volume Concentration

Sr. No.	% Volume Concentration	Nanofluid Cost	Operating Cost	Initial Cost	Total Cost
1	1	25,550	25,29,22,548.50	21780500	274,728,599
2	2	47,450	25,29,22,203.90	21759100	274,728,754
3	3	73,000	25,29,21,859.30	21739200	274,734,059
4	4	94,900	25,29,21,514.70	21721600	274,738,015
5	5	01,20,450	25,29,21,213.	21705800	274,627,013

			20		
6	6	01,42,350	25,29,20,868.70	21692300	274,613,169
7	7	01,67,900	25,29,20,524.10	21680100	274,600,624
8	8	01,89,800	25,29,20,179.50	21668600	274,588,780
9	9	02,15,350	25,29,19,834.10	21658900	274,578,734
10	10	02,37,250	25,29,19,533.40	21650500	274,570,033
11	11	02,62,800	25,29,19,143.80	21643200	274,562,344
12	12	02,84,700	25,29,18,800.50	21637050	274,555,851
13	13	03,10,250	25,29,18,456.64	21632000	274,550,457
14	14	03,32,150	25,29,18,117.2	21628100	274,546,217
15	15	03,57,700	25,29,17,725.00	21625350	274,543,075

e) SAVING COST

Table. 7: Saving Cost for Different Volume Concentration

Sr. No.	% Volume Concentration	Actual Initial Cost	New Initial Cost	Saving (Rs.)
1	1	27,47,27,936.00	21780500	-663
2	2	27,47,27,936.00	21759100	-818
3	3	27,47,27,936.00	21739200	-6,123
4	4	27,47,27,936.00	21721600	-10,079
5	5	27,47,27,936.00	21705800	100,923
6	6	27,47,27,936.00	21692300	114,767
7	7	27,47,27,936.00	21680100	127,312
8	8	27,47,27,936.00	21668600	139,157
9	9	27,47,27,936.00	21658900	149,202
10	10	27,47,27,936.00	21650500	157,903
11	11	27,47,27,936.00	21643200	165,592
12	12	27,47,27,936.00	21637050	172,086
13	13	27,47,27,936.00	21632000	177,479
14	14	27,47,27,936.00	21628100	181,719
15	15	27,47,27,936.00	21625350	184,861

II. CONCLUSION

The present review is a comprehensive outlook on the research progress made in the thermal enhancement process using nanofluids. The aim of the nanofluid research is to develop new methods to augment the synthesis method, novel equipments for measuring the thermo physical properties and synthesize nanofluids with excellent transport properties. The size of the nano particles plays an important role in improving the heat transfer properties. The dispersion behavior of nano particles improves, if the nano particles can be prevented from agglomeration using appropriate surfactants. The effect of nanofluid on the reduction in area as well as tube size of the heat exchanger indicates that nanofluids will retain more heat than water. The Al_2O_3nanofluid has a significant heat gain than either water.

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