Journal of New Materials for Electrochemical Systems
Vol.23, No.4, October, 2020, pp. 235-243
http://new-mat.org
http://iieta.org/journals/jnmes

Performance Improvement of Base Fluid Heat Transfer Medium Using Nano Fluid Particles

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ABSTRACT

Base fluids like water, ethylene glycolandengineoilare conventionally used as a heat transfer medium. The performance of heat transferred is improved in the conventional fluids with the addition of Nano particles. Hence, this paper considers the forced conventional flow problem over the base fluid within a uniform heated tube placed on a wall. The analysis of heattransferco-efficientis done through a constant Reynoldsnumberfor both Nano and base fluid with a simulation tool. Further, a comparative analysis is carried out with heat transfer coefficient over the base and various Nano fluids. It is seen that the Nano fluids has a better performance due to its better thermal characteristics under standard conditions.

Keywords: *heat transfer coefficient, CFX simulation, ansys simulation, nano fluid and base fluid*

Received: July-20-2020, Accepted: October-26-2020, https://doi.org/10.14447/jnmes.v23i4.a03

1. INTRODUCTION

The Nano fluids contains fluid with Nanometer-sized particles [1], which has good stability, increased thermal conductivity even with small suspended Nanoparticles and heat transferring performance. The Nano fluidmaterials vary based on metal oxides, chemically stable metals, metal carbides, oxide ceramics etc. However, most literatures focus on single-particle based Nano fluids to test the thermal characteristics [2]. The thermal fluids like oil, water and ethylene glycol plays a major role in cooling process in many power applications. However, these fluid contains poor thermal properties and the properties of heat transfer rate is affected. Hence, to heat transfer coefficient is improved with the help of extended surface channels, surface vibration and fluid injection. The use of new technology is being an enhancing factor to improve the thermal properties of such substance [3].

The main advantage of Nano fluids include ling term stability, superior thermal conductivity and reduced drop in pressure, when compared with mm and µm sized particle. The materials like metal carbides, oxide ceramics, metals, nitrides, nonmetals, carbon Nanotubes and Nanoparticles is used to form the Nano fluid. A synthesis optimization is used to make the suspensions of Nanoparticle to be stable inside the base fluid.

In order to improve the thermal properties, several combinations of base fluid with Nano particle is possible. Also, the Nano fluids are produced using a single step or two step method, where the former one uses formation and dispersion of Nanoparticles within the base fluid, using several experimental procedures [4]. Hence, the use of storage, drying, transportation and dispersion is avoided with such method.

The solid substance possesses better thermal conductivities than other substances. Most researches concentrated on the thermal properties associated with the suspension of solid particles in conventional fluids. Such dispersed particles vary from mm to µm size over the base fluid and this leads to change in thermo-physical properties of such fluid and that results in enhancing the heat transfer ratio. The main disadvantage of such mm to µm sized particle leads to poor stability and suspension and this results in channel clogging. However, recent advances with the help of new materials improves the thermal properties of the fluid than the conventional fluids [5]. From conventional studies, it is seen than the thermal conductivity of the Nano fluids is found higher than base fluid [6-8].

Out of which, water is used as a base fluid, where a rod and spherical shaped TiO_2 [9] Nanoparticles are dispersed in water. The use of aqueous/non-aqueous solution as base fluid is used with metal oxide particles of varying shapes and concentration [10]. The water is further used with Al_2O_3 [11, 12], Fe_3O_4 [13], NH_3 [14], $Al_2O_3$and TiO_2 [15], MgO [16], COOH [17], to measure the pH effect with varying thermal conductivity. With different fractional weights, the copper based water base fluid is used to measure the pH rate with sodium dodecyl benzene sulfonate surfactant [18]. Also, water is used with carbon Nano tubes and TiO_2 [19] with carbon Nano tubes measures the time and temperature [20] variations and Nanodiamond particle with deionized fluid measures varying loads [21]. Nanoparticlesgraphene [22], Nanoshell [23], graphene oxide Nanosheets [24] and Nano diamond [25] with water as base fluids.

The use of Ethylene Glycol as base fluid is experimented in several researches, which includes: synthetic EG multiwalled carbon Nanotubes [26], ZnO-EG Nano fluids [27, 28], Al-Zn with EG Nanoparticles [29], graphene Nanosheets with EG [30], Aluminum nitride with EG Nanoparticle [31], Al_2Cu and Ag_2Al with EG Nanoparticles [32], Al_2O_3, CuO, ZnO with EG [33], TiO_2Nanoparticles with EG [34], CuO Nanoparticles [35], Cu Nanoparticles [36], α-SiC Nano fluids [37], spherical ZnO Nanoparticles [38], Al_2O_3 with EG and water [39, 40].

The increased techniques to improve the heat transfer coefficients suffer majorly the important strategy required to achieve effective heat transfer over conventional base fluid. Hence, the heat transfer is intensified with the suspension of Nanoparticles with the use of base fluid. In the proposed work, we considered the problem of improving the heat transfer coefficient by the use of Nano fluids. Here, base fluids like engine oil, ethylene glycol and water and the Nanoparticles of gold, copper, aluminum and silver is used. Empirical relations are used to calculate the properties of the Nano fluids. Further, the thermo-physical properties of ethylene glycol, water, copper, engine oil, gold, aluminum and silver is calculated to find the Nano fluid properties. The heat transfer rate of the Nano and base fluid is analysed with the use of CFX simulation tool under a constant Reynolds number. Finally, comparative analysis is carried between the thermal conductivity models namely, Maxwell, Hamilton and Crosser, and Davis models [41, 42].

The outline of the paper is mentioned as follows: Section 2 provides the proposed model to analyse the flow rate in base and Nano fluid analysis. Section 3 provides the experimental method for finding the thermo-physical properties. Section 4 provides the evaluation on different combinations of Nano fluids with base fluid. Section 5 concludes the paper.

2. METHODS

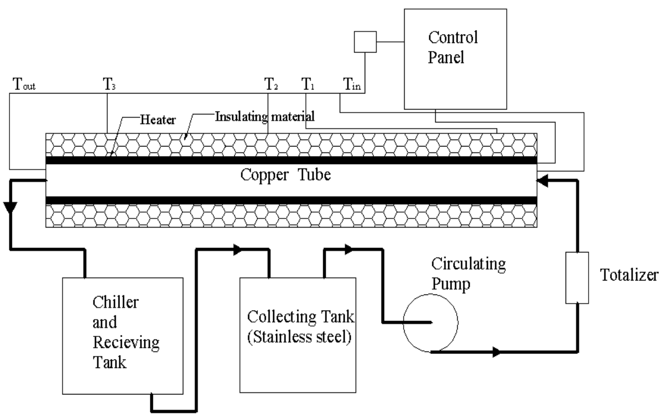


Figure 1. Experimental Setup

Figure 2. Geometry of Tube

The experimental setup of the proposed method is shown in Figure 1. The system has alooping pipeline flow structure, pumping and copper tube of length1mand diameter 60mm and are servoir tank. Further, the tube is insulated with 25mm glass made of fiber and heat electrically at 5000 W/m^2. The tube is coated with nickel chrome wire, which is connected with a 300W DC supply. The tube is installed with four k type tube, where two of which is placed at two end. This is used to measure the temperature of the Nano fluid.

The numerical simulation uses single phase method to find the values of convective heat transfer. Here, the geometry of the tube is shown in Figure 2. The tube allows the Nano fluidto enter at a uniform velocity rate (U_1)and the rate of temperature(T_1).The condition of full development is assumed at the tube end. Based on the tube's centerline, the assumptions are made symmetrically on thermal and velocity fields. The local heat transfer coefficient rate is h_{local}:

$$h_{local} = \frac{\left(T_{local} - T_{input}\right)\rho CpuD}{4\pi\left(T_w - T_{input}\right)} \tag{1}$$

The averagerate of heattransferco-efficient is given as h_{ave}:

$$h_{ave} = \frac{1}{L\int_0^L h(z)\,dz} \tag{2}$$

The Average Nusselt number is then given by:

$$Nu_{ave} = \frac{h_{ave}D}{K_{af}} \tag{3}$$

Heat transfer(Q)

$$Q = \sqrt{\frac{C_d a_1 a_2 \left(2gh_a\right)}{\left(a_1^2 - a_2^2\right)}} \tag{4}$$

3. ESTIMATION THERMO-PHYSICAL PROPERTIES

The measuring the thermal conductivity of the Nano fluid use heat transfer coefficient, both in forced and natural fluid flow. The main limitation involves thermal characteristics of the Nanoparticles without changing the phase. The proposed model uses two phase systems for finding the heat transfer ratio of particles in the Nano fluid. Here, the coefficient of heat transfer rate depends on thermal conductivity, density, specific heat ratio and dynamic viscosity of particles in the Nano fluid. The properties of particles in the Nano fluid at normal temperature is shown in Table 1 and the properties of base fluid at normal temperature is shown in Table 2.

3.1. Density Estimation

The Nanofluiddensity is calculatedwith massbalance, which is given as:

$$\rho_{nf}=(1-\varphi_S)\rho_{f}+\varphi_S\rho_p \tag{5}$$

The particles present in the Nano fluid has a volume fraction < 1% and the changeof <5%fluiddensityis thus expected. Further, the density for 1% particles with copper mix and water as base fluid, the Nano fluid density is found to be 1075.865Kg/m^3. From Eq. (5), the Nano fluid density for different % mixes i.e. 1,3,5,...,25, various combinations are calculated, which is shown in Table.3. The different mixture of Nano fluids include: copper as base fluid with water as Nano fluid, gold as base fluid with water as Nano fluid, silver as base fluid with water as Nano fluid, aluminum as base fluid with water as Nano fluid, copper as base fluid with ethyleneglycol as Nano fluid, gold as base fluid and ethyleneglycol as Nano fluid, silver as base fluid with ethyleneglycol as Nano fluid, aluminum as base fluid with ethyleneglycol as Nano fluid, copper as base fluid with engine oil as Nano fluid, gold as base fluid with engine oil as Nano fluid, silver as base fluid with engine oil as Nano fluid and finally aluminum as base fluid with engine oil as Nano fluid. The density of these base fluid and Nano fluid mixtures are shown in Table 3.

3.2. Specific heat estimation

The estimation of specific heat of Nano fluids with mass balance is calculated as:

$$(1-\varphi_S)\rho_f C_f+\varphi_S\rho_p C_P \quad (6)$$

where, $C_{nf}=\rho_{nf}$, a small reduction over the Nano particle's specific heat while the dispersion of solid particle in liquid is estimated using following calculations. Further, the specific heat for 1% particles with aluminum oxide mix and water as base fluid, the Nano fluid density is found to be 3863.981J/KgK. The specific heat for other Nano-fluid mixes for different percentage is shown in Table 4.

3.3. Velocity of Nano Fluid

The input parameter for the simulation model is the velocity of Nano fluid possessing its own materialistic properties. Initially, the co-efficient for heat transfer rate is estimated for base and Nano fluid using constant Reynold number, where $Re = ud\rho/\mu = 2000$.The velocity of the water is found as 0.29m/s, and for ethylene glycol =4.7m/s and engine oil is 183m/s. Further, the velocity of different Nano-fluid mixes for different percentage is shown in Table 5.

Table 1. Nano particles Properties

Property	Copper	Gold	Silver	Aluminum
Thermal conductivity (K_S)W/mK	401	317	429	237
Density (ρ_p)kg/m^3	8933	19300	10500	2702
Specific heat (C_P) J/kg K	385	129	235	903

Table 2. Base Fluid Properties

Property	Water	E. glycol	Engine Oil
Thermal conductivity (K_f)W/mK	0.613	0.252	0.145
Density (ρ_f)kg/m^3	996.5	1114.4	884.1
Specific heat (C_f)J/kgK	4179	2415	1909
Dynamic viscosity (μ_f) Kg/ms	0.000855	0.0157	0.486

Table 3. Various Nano fluid Density (in Kg/m^3)with different base fluid combinations

Volume fraction (%)	copper-water	gold-water	silver-water	aluminum-water	copper-Ethylene glycol	gold-Ethylene glycol	silver-Ethylene glycol	aluminum-Ethylene glycol	copper-Engine Oil	gold-Engine Oil	silver-Engine Oil	aluminum-Engine Oil
1	1075.865	1179.535	1091.535	1013.555	1192.586	1296.256	1208.256	1130.276	964.589	1068.259	980.259	902.279
3	1234.595	1545.605	1281.605	1047.665	1348.958	1659.968	1395.968	1162.028	1125.567	1436.577	1172.577	938.637
5	1393.325	1911.675	1471.675	1081.775	1505.33	2023.68	1583.68	1193.78	1286.545	1804.895	1364.895	974.995
7	1552.055	2277.745	1661.745	1115.885	1661.702	2387.392	1771.392	1225.532	1447.523	2173.213	1557.213	1011.353
9	1710.785	2643.815	1851.815	1149.995	1818.074	2751.104	1959.104	1257.284	1608.501	2541.531	1749.531	1047.711
11	1869.515	3009.885	2041.885	1184.105	1974.446	3114.816	2146.816	1289.036	1769.479	2909.849	1941.849	1084.069
13	2028.245	3375.955	2231.955	1218.215	2130.818	3478.528	2334.528	1320.788	1930.457	3278.167	2134.167	1120.427
15	2186.975	3742.025	2422.025	1252.325	2287.19	3842.24	2522.24	1352.54	2091.435	3646.485	2326.485	1156.785
17	2345.705	4108.095	2612.095	1286.435	2443.562	4205.952	2709.952	1384.292	2252.413	4014.803	2518.803	1193.143
19	2504.435	4474.165	2802.165	1320.545	2599.934	4569.664	2897.664	1416.044	2413.391	4383.121	2711.121	1229.501
21	2663.165	4840.235	2992.235	1354.655	2756.306	4933.376	3085.376	1447.796	2574.369	4751.439	2903.439	1265.859
23	2821.895	5206.305	3182.305	1388.765	2912.678	5297.088	3273.088	1479.548	2735.347	5119.757	3095.757	1302.217
25	2980.625	5572.375	3372.375	1422.875	3069.05	5660.8	3460.8	1511.3	2896.325	5488.075	3288.075	1338.575

Table 4. Nano fluid Specific Heat Capacity (inJ/KgK) with different base fluid combinations

Nano particle %	copper-Water	gold-Water	silver-Water	Aluminum-Water	copper-Ethylene glycol	gold-Ethylene glycol	silver-Ethylene glycol	aluminum-Ethylene glycol	copper-Engine Oil	gold-Engine Oil	silver-Engine Oil	aluminum-Engine Oil
1	3863.981	3516.324	3799.608	4091.666	2262.944	2074.637	2225.553	2378.855	1767.863	1587.411	1729.69	1878.874
3	3355.447	2661.827	3209.622	3925.529	2011.711	1617.639	1923.083	2309.527	1546.146	1191.586	1459.298	1822.123
5	2962.78	2134.589	2772.032	3769.869	1812.674	1324.912	1692.316	2243.887	1379.913	957.3103	1265.104	1769.604
7	2650.429	1776.822	2434.545	3623.725	1651.097	1121.377	1510.457	2181.649	1250.653	802.4449	1118.877	1720.861
9	2396.039	1518.129	2166.337	3486.251	1517.314	971.6587	1363.448	2122.554	1147.266	692.4656	1004.798	1675.501
11	2184.847	1322.363	1948.061	3356.697	1404.722	856.9054	1242.147	2066.37	1062.69	610.3278	913.315	1633.184
13	2006.711	1169.052	1766.962	3234.398	1308.656	766.1491	1140.353	2012.888	992.2192	546.6472	838.32	1593.613
15	1854.433	1045.737	1614.287	3118.762	1225.725	692.5751	1053.71	1961.916	932.5968	495.8309	775.7238	1556.53
17	1722.763	944.3986	1483.83	3009.257	1153.408	631.7257	979.0705	1913.284	881.4968	454.3383	722.6865	1521.707
19	1607.784	859.6432	1371.071	2905.41	1089.79	580.5627	914.1013	1866.832	837.2137	419.8191	677.1738	1488.943
21	1506.511	787.708	1272.637	2806.792	1033.391	536.9437	857.0375	1822.417	798.4687	390.6516	637.6904	1458.062
23	1416.631	725.8888	1185.962	2713.019	983.0471	499.3146	806.519	1779.909	764.2841	365.6807	603.1126	1428.904
25	1336.324	672.1919	1109.057	2623.742	937.8336	466.521	761.4806	1739.187	733.8995	344.0615	572.5798	1401.331

Table 5. Velocity (in m/s) of Different Nano fluid mixtures

Nano particle %	copper-Water	gold-Water	silver-Water	aluminum-Water	copper-Ethylene glycol	gold-Ethylene glycol	silver-Ethylene glycol	aluminum-Ethylene glycol	copper-Engine Oil	gold-Engine Oil	silver-Engine Oil	aluminum-Engine Oil
1	0.264903	0.241621	0.2611	0.281188	4.388223	4.037268	4.331312	4.630138	167.9472	151.6486	165.2624	179.5454
3	0.230845	0.184394	0.222377	0.272034	3.879538	3.152671	3.748892	4.503621	143.9275	112.7681	138.1572	172.5907
5	0.204547	0.149084	0.193657	0.263456	3.476536	2.586048	3.30454	4.383834	125.9186	89.75591	118.6904	166.1547
7	0.183628	0.125124	0.171506	0.255403	3.149381	2.192071	2.954362	4.270254	111.9153	74.544	104.032	160.1815
9	0.16659	0.107799	0.153903	0.247827	2.878504	1.902267	2.671289	4.162411	100.7149	63.74111	92.59624	154.6228
11	0.152446	0.094688	0.139577	0.240688	2.650533	1.680142	2.437719	4.059881	91.55237	55.67299	83.42564	149.437
13	0.140516	0.084421	0.127691	0.233949	2.456021	1.504468	2.241709	3.962281	83.91795	49.41786	75.90784	144.5877
15	0.130317	0.076162	0.11767	0.227577	2.288106	1.362053	2.074875	3.869263	77.45878	44.42634	69.63294	140.0433
17	0.121499	0.069375	0.109108	0.221542	2.141682	1.244268	1.931154	3.780513	71.92287	40.35067	64.31626	135.7758
19	0.113798	0.063699	0.101707	0.21582	2.012872	1.145234	1.806053	3.695742	67.12547	36.95997	59.75388	131.7608
21	0.107016	0.058881	0.095247	0.210386	1.898676	1.060802	1.696174	3.61469	62.92804	34.09493	55.7959	127.9763
23	0.100996	0.054741	0.089558	0.205218	1.796743	0.987964	1.598898	3.537116	59.22466	31.64213	52.32969	124.4032
25	0.095618	0.051145	0.08451	0.200299	1.705197	0.924487	1.512174	3.462802	55.93295	29.51855	49.26895	121.0242

3.4. Viscosity of Nano fluids

The Nano fluid viscosity is estimated using 2 phase mixtures,

$$\mu=\mu_0(123\varphi_S^2+7.3\varphi_S+1) \tag{7}$$

Further, the viscosity of 1% particles with copper mix and water as base fluid, the Nano fluid density is 0.000928kg/ms. The combination of Nano fluid with water, ethylene glycol and engine oil is estimated and shown in Table 6.

3.5. Nano fluid Thermal Conductivity

TheNano fluid contains smaller particles with high thermal conductivity than the base fluid. The thermal conductivity depends entirely on particle volume fraction for its better enhancement. The thermal conductivity of the Nano fluids are estimated using three models, which depends entirely on the particle shape:

3.5.1. Maxwell Model

This model considers the spherical Nano particle and the relation is given by,

$$K = K_L \frac{K_S + 2K_L + 2(K_S - K_L)\phi_S}{K_S + 2K_L - (K_S - K_L)\phi_S} \tag{8}$$

3.5.2. Hamilton and Crosser Model

This model considers the non-spherical Nanoparticle and the relation is given by,

$$K = K_L \frac{K_S + (n-1)K_L - (n-1)(K_L - K_S)\phi_S}{K_S + (n-1)K_f - (K_L - K_S)\phi_S} \tag{9}$$

where n totally depends on the shape of particleand K_S/K_L,Also,$n$is $3/\psi\forall K_S/K_L>100$ and the value of n is 3forothercases

3.5.3. Davis Model

This model considers the tubularNanoparticle and the relation is given by,

$$K = K_L \times 1 + \frac{3\left(\frac{K_S}{K_L-1}\right)\left[\phi_S + f.\phi_S^2 + O\left(\phi_S^3\right)\right]}{\left(\frac{K_S}{K_L+2}\right) - \left(\frac{K_S}{K_L-1}\right)\phi_S} \times K_L \tag{10}$$

Table 6. Nano fluid Viscosity (in kg/ms) with water, ethylene glycol and engine oil

Nanoparticle %	Nanoparticle-Water	Nanoparticle-Ethyleneglycol	Nanoparticle-Engineoil
1	0.000928	0.017039	0.527456
3	0.001137	0.020876	0.646234
5	0.00143	0.026258	0.812835
7	0.001807	0.033185	1.027258
9	0.002269	0.041657	1.289504
11	0.002814	0.051673	1.599572
13	0.003444	0.063235	1.957462
15	0.004157	0.076341	2.363175
17	0.004955	0.090992	2.81671
19	0.005837	0.107189	3.318068
21	0.006803	0.12493	3.867248
23	0.007854	0.144215	4.46425
25	0.008988	0.165046	5.109075

Table 7(a). Nano fluid thermal conductivity

Nano particle %	Water & Copper			Ethylene glycol & Copper			Engine oil & Copper		
	Maxwell	Hamilton and crosser	Davis	Maxwell	Hamilton and crosser	Davis	Maxwell	Hamilton and crosser	Davis
1	0.63149	0.619042	0.631677	0.259622	0.25449	0.259699	0.149389	0.146434	0.149433
3	0.669608	0.630775	0.671357	0.275336	0.259326	0.276057	0.158439	0.149219	0.158854
5	0.709324	0.642063	0.714381	0.291711	0.263978	0.293795	0.167869	0.151898	0.169069
7	0.750739	0.652931	0.761056	0.308788	0.268457	0.313041	0.177704	0.154476	0.180153
9	0.793966	0.663402	0.811718	0.326615	0.272771	0.333934	0.187971	0.156961	0.192186
11	0.839125	0.673497	0.866735	0.345241	0.276931	0.356625	0.198699	0.159355	0.205255
13	0.88635	0.683237	0.926505	0.364721	0.280943	0.38128	0.209919	0.161665	0.219456
15	0.935785	0.692638	0.991466	0.385116	0.284816	0.408079	0.221667	0.163895	0.234892
17	0.98759	0.70172	1.062096	0.406492	0.288556	0.437221	0.23398	0.166049	0.251678
19	1.041938	0.710498	1.138921	0.428921	0.292172	0.468923	0.246901	0.16813	0.26994
21	1.099022	0.718986	1.222521	0.452483	0.295667	0.503426	0.260474	0.170143	0.289816
23	1.159054	0.7272	1.313533	0.477266	0.29905	0.540994	0.274752	0.17209	0.311459
25	1.222269	0.735151	1.412665	0.503368	0.302324	0.58192	0.289791	0.173975	0.335038

Table 7(a). Nano fluid thermal conductivity (continued)

Nano particle %	Water & Gold			Engine oil & Gold			Ethylene glycol & Gold		
	Maxwell	**Hamilton and crosser**	**Davis**	**Maxwell**	**Hamilton and crosser**	**Davis**	**Maxwell**	**Hamilton and crosser**	**Davis**
1	0.631467	0.619035	0.631654	0.188879	0.146434	0.149432	0.259618	0.254489	0.259695
3	0.669538	0.630754	0.671285	0.192767	0.149218	0.15885	0.275324	0.259323	0.276045
5	0.709201	0.64203	0.714251	0.19682	0.151896	0.169062	0.29169	0.263973	0.293773
7	0.75056	0.652886	0.760863	0.201046	0.154474	0.180142	0.308758	0.268449	0.313009
9	0.793725	0.663346	0.811454	0.205458	0.156957	0.192171	0.326574	0.272762	0.333889
11	0.838817	0.673431	0.86639	0.210068	0.159352	0.205236	0.345188	0.276919	0.356567
13	0.885969	0.683161	0.926069	0.21489	0.161661	0.219431	0.364656	0.28093	0.381206
15	0.935325	0.692554	0.990926	0.219938	0.16389	0.234861	0.385038	0.284801	0.407987
17	0.987043	0.701628	1.06144	0.225229	0.166044	0.251641	0.406399	0.288541	0.437109
19	1.041297	0.710398	1.138135	0.230781	0.168125	0.269896	0.428812	0.292155	0.46879
21	1.098278	0.71888	1.221587	0.236613	0.170137	0.289764	0.452357	0.295649	0.503267
23	1.158196	0.727087	1.312432	0.242748	0.172084	0.311397	0.47712	0.299031	0.540807
25	1.221286	0.735033	1.411375	0.249209	0.173968	0.334965	0.503201	0.302304	0.581701

Table 7(b). Nano fluid thermal conductivity

Nano particle %	Water & Silver			Ethylene glycol & Silver			Engine oil & Silver		
	Maxwell	**Hamilton and crosser**	**Davis**	**Maxwell**	**Hamilton and crosser**	**Davis**	**Maxwell**	**Hamilton and crosser**	**Davis**
1	0.631496	0.619044	0.631682	0.259623	0.254491	0.2597	0.149389	0.146434	0.149434
3	0.669626	0.63078	0.671375	0.275339	0.259327	0.27606	0.15844	0.149219	0.158855
5	0.709354	0.642072	0.714413	0.291716	0.26398	0.293801	0.16787	0.151898	0.169071
7	0.750783	0.652943	0.761103	0.308796	0.268459	0.31305	0.177706	0.154477	0.180156
9	0.794025	0.663416	0.811784	0.326625	0.272774	0.333945	0.187974	0.156961	0.19219
11	0.839201	0.673514	0.86682	0.345253	0.276933	0.35664	0.198703	0.159356	0.20526
13	0.886444	0.683255	0.926613	0.364737	0.280946	0.381298	0.209924	0.161666	0.219462
15	0.935899	0.692659	0.991599	0.385136	0.284819	0.408101	0.221673	0.163896	0.234899
17	0.987725	0.701743	1.062257	0.406515	0.28856	0.437248	0.233988	0.16605	0.251687
19	1.042096	0.710522	1.139115	0.428948	0.292176	0.468956	0.246909	0.168132	0.269951
21	1.099206	0.719012	1.222751	0.452514	0.295672	0.503465	0.260485	0.170144	0.289829
23	1.159266	0.727227	1.313805	0.477302	0.299054	0.54104	0.274764	0.172091	0.311474
25	1.222511	0.73518	1.412984	0.503409	0.302329	0.581974	0.289804	0.173976	0.335055

Table 7(b). Nano fluid thermal conductivity (continued)

Nano particle %	Water & Aluminum			Ethylene glycol & Aluminum			Engine oil & Aluminum		
	Maxwell	**Hamilton and crosser**	**Davis**	**Maxwell**	**Hamilton and crosser**	**Davis**	**Maxwell**	**Hamilton and crosser**	**Davis**
1	0.631431	0.619023	0.631617	0.259612	0.254487	0.259689	0.149386	0.146433	0.14943
3	0.669424	0.630721	0.671167	0.275305	0.259317	0.276025	0.158428	0.149216	0.158843
5	0.709003	0.641976	0.714043	0.291656	0.263964	0.293738	0.167851	0.151893	0.16905
7	0.750271	0.652813	0.760553	0.308709	0.268437	0.312956	0.177677	0.15447	0.180125
9	0.793337	0.663256	0.811029	0.326508	0.272747	0.333817	0.187935	0.156952	0.192147
11	0.838323	0.673325	0.865834	0.345104	0.276901	0.356472	0.198653	0.159346	0.205204
13	0.885358	0.68304	0.925367	0.364552	0.280909	0.381086	0.209863	0.161654	0.219391
15	0.934586	0.692419	0.99006	0.384912	0.284779	0.40784	0.221599	0.163883	0.234813
17	0.986165	0.70148	1.060387	0.40625	0.288516	0.43693	0.2339	0.166035	0.251582
19	1.040267	0.710238	1.136872	0.428637	0.292128	0.468575	0.246806	0.168116	0.269825
21	1.097081	0.718709	1.220086	0.452153	0.29562	0.503012	0.260365	0.170127	0.289679
23	1.156817	0.726906	1.310663	0.476886	0.299	0.540506	0.274626	0.172073	0.311297
25	1.219707	0.734842	1.409303	0.502932	0.302272	0.581348	0.289646	0.173957	0.334848

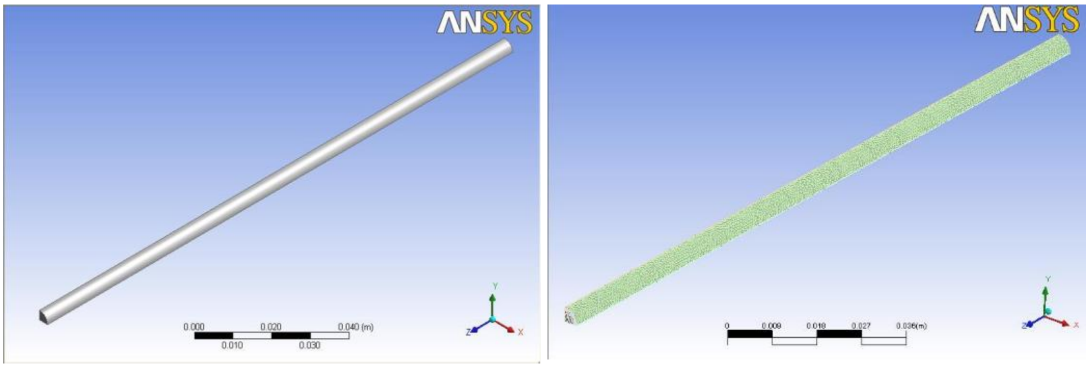
Further, the thermal conductivity of 1% particles with copper mix and water as base fluid is 0.63149 using Maxwell model, 0.619042 suing Hamilton and crosser model, and 0.631677 using Davis model. The thermal conductivity of different Nano particle mixtures for all the three models is given in Table 7(a) and Table 7(b).

From the results, it is found that the Maxwell model provides a better results with regular variation and the mean values has better values than the other two models. Since, most of the particles in the Nano fluid possess spherical in shape.

4. RESULTS AND DISCUSSION

This research considers the problem related to convection flow of Nano particles in a tube, which is heated uniformly. The chosen measurements for the study includes 6mm diameter and length of 170mm and the simulation analysis is carried out in Ansys Workbench tool.

The proposed tubular module is connected to a constant and uniform heat flux at the wall of the chamber. The analysis to find the heat transfer rate is analysed on base and Nano fluid with constant Reynolds number.



(a) Modeling after symmetry; (b) Modeling after meshing

Figure 3. 3D modelling of uniform heated tube

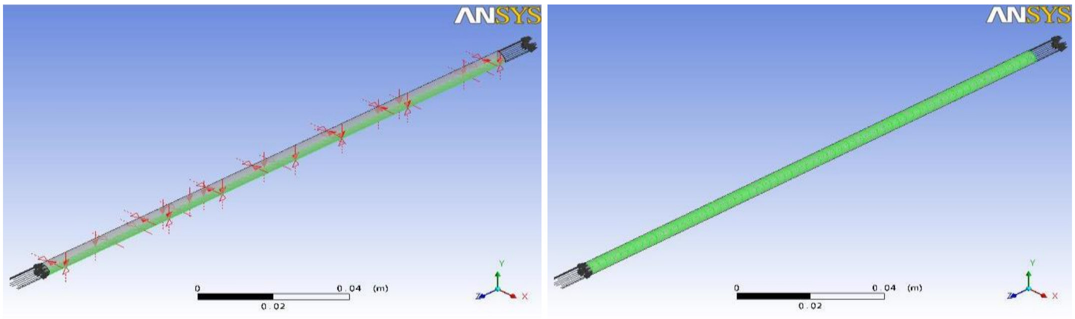


Figure 4. CFX Modelling

Table 8. Heat transfer co-efficientof Water, Ethylene glycol (E.GL) and Engine oil (E.Oil) with Nanoparticles at 333K

Nano particle %	H_2O + Cu CFX	H_2O + Cu Experimental	H_2O +Au	H_2O + Ag	H_2O + Al CFX	H_2O + Al Experimental	E.Gl + Cu CFX	E.Gl + Cu Experimental	E.Gl + Au	E.Gl + Ag
1	13540	13689.4	13610.8	13553.1	13493.3	13520.36	3935.24	4018.2	3963.36	3940.53
3	14533.5	14628.3	14681.2	14564.6	14412.6	14530.42	4262.92	4325.8	4351.45	4280.27
5	15542.4		15722.6	15584.3	15367.1		4613.62		4766.56	4644.98
7	16572.7		16762.8	16621	16357.2		4985.12		5204.62	5032.2
9	17629.6		17816.8	17681.4	17384.1		5376.37		5662.75	5440.7
11	18719		18894	18772	18451.3		5788.12		6140.56	5870.95
13	19846.1		20003.9	19898.5	19562.8		6222.22		6638.89	6324.61
15	21014.9		21159.9	21065.5	20722.4		6680.16		7158.86	6802.98
17	22230.6		22366.3	22278	21933.7		7163.46		7701.48	7307.41
19	23497.6		23629.5	23543.2	23200.6		7673.6		8267.87	7839.16
21	24821.8		24951.6	24869.8	24527		8212.31		8859.32	8399.79
23	26213.4		26335.6	26261.3	25918.9		8782.36		9478.35	8991.85
25	27675.5		27784.7	27725.1	27381.1		9385.15		10126.3	9616.54

Table 8. Heat transfer co-efficientof Water, Ethylene glycol (E.GL) and Engine oil (E.Oil) with Nanoparticles at 333K (continued)

Nano particle %	E.Gl + Al CFX	E.Gl + Al Experimental	E.Oil+Cu CFX	E.Oil+Cu Experimental	E.Oil +Au	E.Oil +Ag	E.Oil +Al CFX	E.Oil +Al Experimental
1	3919.66	4022.3	2063.1	2098.13	2611.27	2063.21	2062.78	2125.35
3	4212.63	4275.7	2203.46	2258.93	2685.83	2203.89	2202.32	2428.8
5	4523.97		2351.2		2763.99	2352.03	2349.1	
7	4851.74		2505.11		2843.93	2506.48	2493.56	
9	5195.2		2664.68		2924.94	2666.71	2659.89	
11	5555.59		2830.4		3007.39	2833.25	2823.93	
13	5934.99		3003.09		3092.09	3006.93	2994.63	
15	6335.11		3183.36		3179.35	3188.41	3172.65	
17	6757.88		3372.03		3269.79	3378.49	3358.75	
19	7205.07		3569.77		3363.77	3577.91	3553.57	
21	7678.88		3777.6		3461.99	3787.74	3758.06	
23	8182.34		3996.7		3565.12	4009.16	3973.32	
25	8717.26		4229.73		3673.56	4243.13	4200.22	

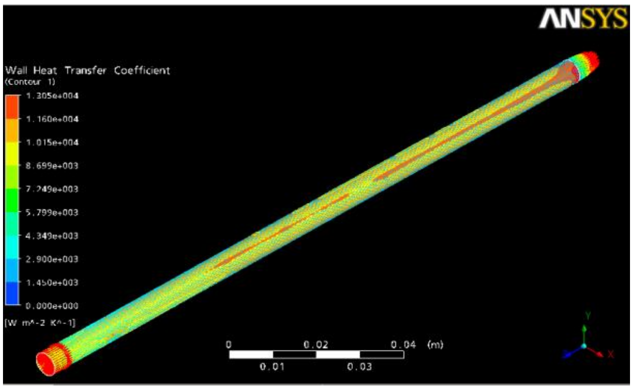


Figure 5. Heat transfer co-efficient of water at 333K

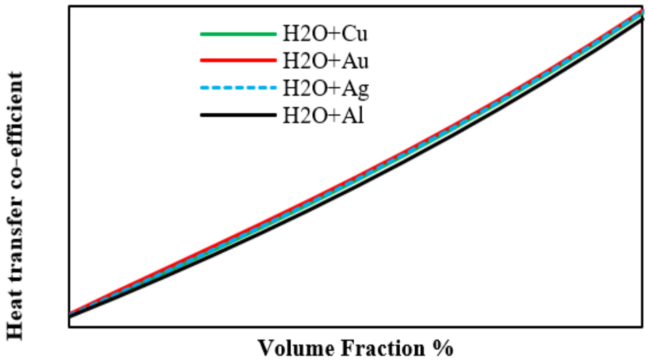


Figure 6. Heat transfer co-efficient of Water with Nano particles at 333K

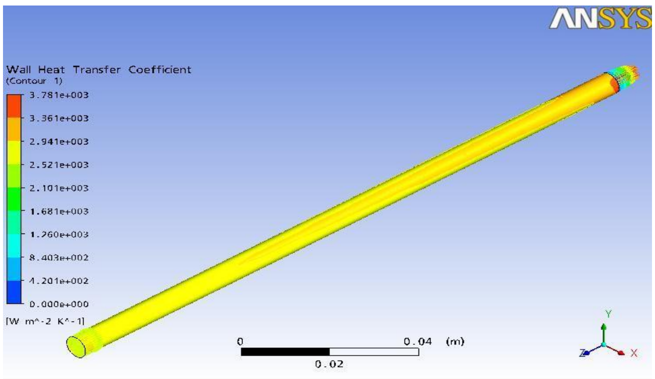


Figure 7. Heat transfer co-efficient of ethyleneglycolat333K

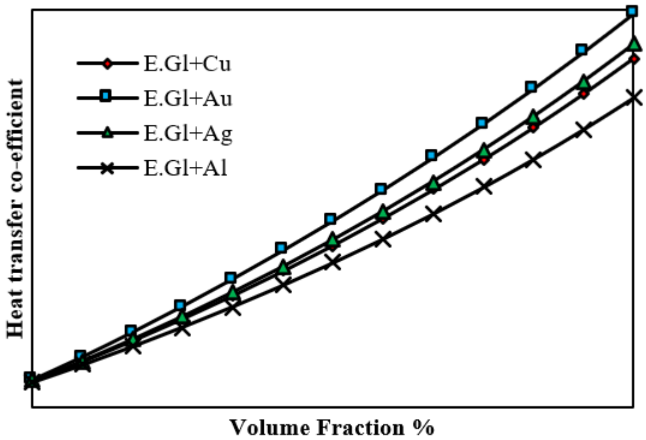


Figure 8. Heat transfer co-efficient of Ethylene glycol with Nano particles at 333K

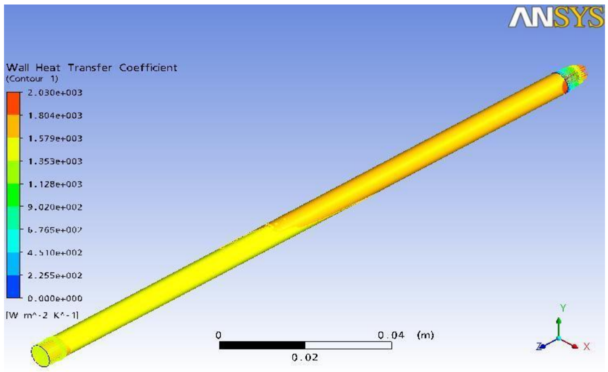


Figure 9. Heat transfer co-efficient of engineoil at 333K

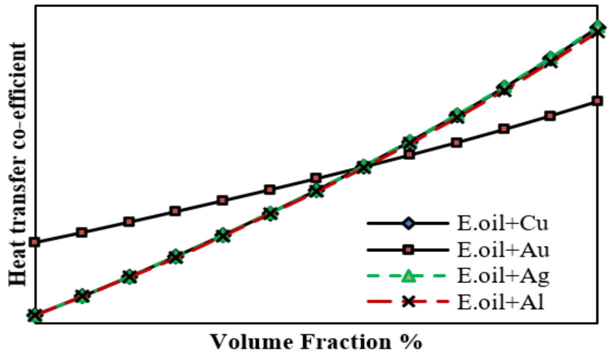


Figure 10. Heat transfer co-efficient of Engineoil with Nanoparticles at 333K

The analytical work is carried out with a CFX11.0 module inside the tubular structure, as shown in Figure 4. The modeling is done in Ansys Workbench 11.0 and imported into CFX11.0 software to analyse the flow and finding the heat transfer co-efficient of water.

From the analysis, it is found that the heat transfer coefficient (Figure 5) for water is 13048.1 W/ m^2K at 333K. From Table 7 or Figure 6, it is seen that the Nano fluids other than copper, gold, silver and aluminum Nanoparticles mixture with water proves a higher heat transfer rate than water in both experimental and simulation method. Likewise, it is found that the heat transfer coefficient (Figure 7) for ethylene glycol is 3781.16 W/ m^2K at 333K.

From Table 8 or Figure 8, it is seen that the Nano fluids other than copper, gold, silver and aluminum Nanoparticles mixture with ethylene glycol proves a higher heat transfer rate than ethylene glycol in both experimental and simulation method. Also, it is found that the heat transfer coefficient (Figure 9) for engine oil is 1996.36 W/ m^2K at 333K. From Table 7 or Figure 10, it is seen that the Nano fluids other than copper, gold, silver and aluminum Nanoparticles mixture with ethylene glycol proves a higher heat transfer rate than engine oil in both experimental and simulation method.

5. CONCLUSIONS

This paper solves the convective heat transfer problem using a heated tube at 333K over base and Nano fluids and that includes: water, ethylene glycol and engine oilas base fluids and Water/ Nano particles of Copper, Gold, Silver and Aluminum, Ethyleneglycol/ Nanoparticles of Copper, Gold, Silver and Aluminum, Engineoil/ Nanoparticles of Copper, Gold, Silver and Aluminum as Nano fluid combination. The performance results prove that the Nano fluids possess higher heat transfer coefficient than the base fluid under constant Reynolds number. The Nanoparticles suspended in the base fluid increases constantly the performance of convective heat transfer rate and it could further be concluded that with constant Reynolds number, the heat transfer coefficient has increased with its associated particle volume fraction.

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NOMENCLATURES

v_i	[ms^{-1}]	velocity in i^{th} position
t_{max}	[min]	maximal time limit
T_0	[K]	initial temperature