Global Journal of Advanced Engineering Technologies Volume 7, Issue1- 2018
ISSN (Online): 2277-6370 & ISSN (Print):2394-0921

CHARACTERISTICS OF WATER BASED NANO FLUID & HEAT DISSIPATION BY ANALYTICAL & EXPERIMENTAL APPROACH

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Abstract: *Most IC engines are liquid cooled utilizing a fluid coolant passing through a heat exchanger cooled via air. It is noticed that conventional coolants have a lesser heat transfer rate when compared to nanofluids. Water as we all know is the most used coolant in automobile industry. It is used for cooling of the engine due to excess heat produced inside the engine which are caused due to reasons such as low coolant level , low supply of air from radiator fan or the radiator damage. In this setup a mixture of water based nanofluid with multi walled carbon nano tube particle between the range 0.1 to 0.8 volume percentageis used as the base fluid and various fluid &thermal properties were determined. The above setup which is constructed adopts gravity method for circulating nanoparticle mixed in water. This paper concludes that by mixing Nanoparticles with water the overall heat dissipation is improved.*

Keywords: *Heat transfer rate, Multi walled carbon nanotubes, Nanofluid, Magnetic stirrer, Thermal conductivity.*

I. INTRODUCTION

Most IC engines are liquid cooled utilizing a fluid coolant passing through a heat exchanger cooled via air. It is noticed that conventional coolants have a lesser heat transfer rate when compared to nanofluids. Water as we all know is the most used coolant in automobile industry. It is used for cooling of the engine due to excess heat produced inside the engine which are caused due to reasons such as low coolant level, low supply of air from radiator fan or the radiator damage. In this setup a mixture of water based nanofluid with multi walled carbon nano tube particle between the range 0.1 to 0.8 volume percentageis used as the base fluid and various fluid &thermal properties were determined. The above setup which is constructed adopts gravity method for circulating nanoparticle mixed in water. This paper concludes that by mixing Nanoparticles with water the overall heat dissipation is improved.

Keywords: Heat transfer rate, Multi walled carbon nanotubes, Nanofluid, Magnetic stirrer, Thermal conductivity.

II. RELATED STUDY

Weerapun Duangthongsuk et al. [1] they used water based nanofluid with TiO_2 nanoparticles dispersed in it with volume concentration 0.2-2vol% .The temperature was varied from 15°C-35°C. They found out that the thermal conductivity increases from the range 3-7% when compared to base fluid.

Wei Yu et al. [2] prepared a ethylene glycol based nanofluid using ZnO nanoparticle of size 10-20nm in volume concentrations ranging from 0.002–0.05.They found that the absolute thermal conductivity increases with temperature for ranges of 10-60°C.

S.M.Peyghambarzadeh et al. [3] prepared a water based nano fluid of Al_2O_3 nano particle of size 20nm with different concentrations from 0.1 to 1vol%.They found that the increase in flow rate effectively increases the heat transfer rate. They also estimated low concentrations increases the heat capacity by 45% as compared to pure water.

S.M.Peyghambarzadeh et al. [4] they used water and ethylene glycol based nanofluids containing different volume percentage concentrations of Al_2O_3 ranging from 0.1-1 volume percentage with different flow rates in the range 2-6 l/min and fluid inlet temperature ranging from 35-50°degree.. for water based nanofluids and 45-60 for EG based nanofluid . They found that there is a heat enhancement of 40% compared to base fluid.

S.M. Peyghambarzadeh et al. [5] prepared a water based nanofluid of CuO and Fe_2O_3 of size 60 nm and 40nm respectively with 3 different concentrations 0.15, 0.4 and 0.65 vol%. The inlet liquid temperature were changed to 50, 65 and 80°C. They found that the overall heat transfer coefficient increases with increase in liquid flow rate, increase in air flow rate and decrease in inlet temperature.

Hwa-Ming Nieh et al. [6] used TiO_2 and Al_2O_3 nano particles of size 10-20nm and 20-30nm respectively in water and ethylene glycol to form nanofluids in three weight fractions 0.5wt%,1.0wt% and 2.0wt% which were used in the radiator. These nano particles were dispersed in water using 0.2wt% of chitosan and then mixed with ethylene glycol. They found that the thermal conductivity increased from 26.6% to 39.&% when compared to the EG/W, viscosity was higher for TiO_2 than Al_2O_3 having ratios from 16.8%-30.4% when compared to EG/W, specific heat of the nano coolant decreased as the concentration of the nanoparticle increased. Overall the nano coolant has higher heat dissipation capacity than EG/W and TiO_2 NC has higher heat dissipation capacity than Al_2O_3 NC .

Adnan M. Hussein et al. [7] prepared a water based nanofluid of TiO_2 and SiO_2 Nanoparticles of size 50nm and 22nm respectively. They found that as the volume concentration increases the heat transfer rate also increases .The highest Nusselt's number recorded was 16,4 for TiO_2 and 17.85 for SiO_2.It was further noticed that there was a 20% increases in the energy rate for TiO_2 and 32% increases for SiO_2.They concluded that SiO_2 with water has higher Nusselt's number due to larger number of low density of particles interacting with the fluid.

Devireddy Sandhya et al. [8] prepared a 60% water and 40% EG based nanofluid of TiO_2 nanoparticle of size 21nm with different concentrations ranging from 0.1-0.5 vol%.In addition 0.5ml of oleic acid surfactant was used for every 100ml of nanofluid. They found that the heat transfer rate increased by 37% when compared to the base fluid that is EG/W.

M.M. Elias et al. [9] found out that the thermal conductivity increases with increase in temperature in the temperature range from 10-50°C. The highest thermal conductivity was 8.30% for 1 vol%. Nanofluids viscosities were higher than the base fluids. The highest viscosity was 150% for 1 vol% for Al_2O_3 at 10°C. Density increases with increase in volume concentration. Highest density was 2.99% for 1 vol% of Al_2O_3 at 15°c.

Guilherme Azevedo Oliveira et al. [10] used a solution of 3wt% of MWCNT in water which was prepared using two step method preparation in varying concentrations between 0.05 and 0.16wt%.The air flow rate was maintained constant at 0.175kg/s, the mass flow rate was varied from 30-70g/s and inlet temperatures were maintained constant from 50-80°C.They found that the viscosity of the nanofluid was higher than base fluid and decreased when temperatures increased also the heat transfer rate of the nano fluid had a 5% decrease for all test conditions when compared to water .

III. METHODOLOGY

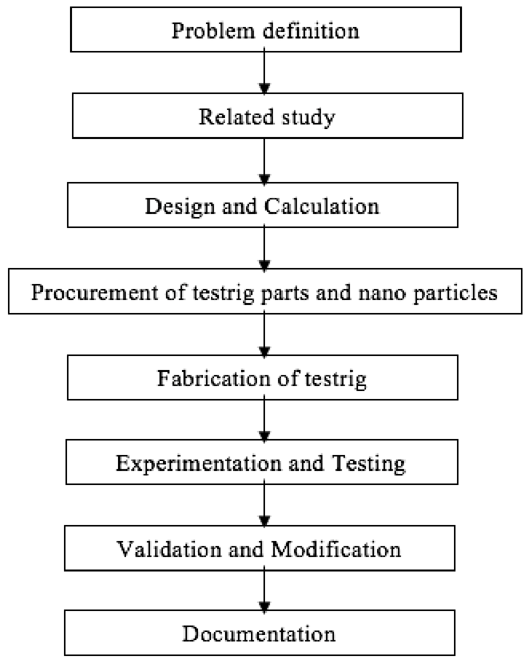

Figure 1: Methodology involved in design and fabrication of nanofluid test rig

The above figure represents the entire process involved in design, construction and testing of the entire set up. It begins with the setting of the objectives , then the characterization of the nano particles is carried out using analytical approach. The test rig is fabricated and the testing is carried out using water as working substance and with mixing water with nano particles. Overall heat dissipation from the system is determined experimentally. The results which are obtained are validated with the output of similar systems.

$$Volume\ Concentraton, \varphi = \left[\frac{\frac{w_{particle}}{\rho_{particle}}}{\frac{w_{particle}}{\rho_{particle}}+\frac{w_{base\ fluid}}{\rho_{basefluid}}}\right] \ldots\ldots\ldots \quad (1)$$

$$\rho_{eff} = (1-\emptyset)\rho_f + \emptyset\rho_{np} \ldots\ldots\ldots \quad (2)$$

$$K_{eff} = K_f \left[\frac{(K_p + 2K_f - 2\emptyset(K_f - K_p))}{(K_p + 2K_f - \emptyset(K_f - K_p))} \right] + 5 \times 10^{-4} \beta \emptyset \rho_f C_p \sqrt{\frac{K_\beta T}{d_p \rho_p} f(T\emptyset)} \ldots\ldots \quad (3)$$

$$f(T,\emptyset) = (-6.04\emptyset + 0.4705)T + (1722.3\emptyset - 134063) \ldots\ldots \quad (4)$$

$$\frac{\mu_{eff}}{\mu_f} = \frac{1}{1 - 34.87\left(\frac{d_p}{d_f}\right)^{-0.3} \emptyset^{1.03}} \ldots\ldots \quad (5)$$

$$(\rho C_p)_{eff} = (1-\emptyset)(\rho C_p)_f + \emptyset(\rho C_p)_{np} \ldots\ldots (6)$$

$$Q = m\, C_p\, \Delta T \ldots\ldots \quad (7)$$

The above equations (1) (2) (3) (4)(5) (6) & (7) are used to obtain the fluid and thermal properties of the nano particles used. Volume concentration, density, thermal conductivity, viscosity, specific heat and heat transfer rate is determined by the same.

IV. DESIGN & MATERIAL PROCUREMENT

The schematic diagram was made of the whole test rig [8]. Detailed models of the tank were made with the help of Creo for fabrication purpose and the best size was chosen.

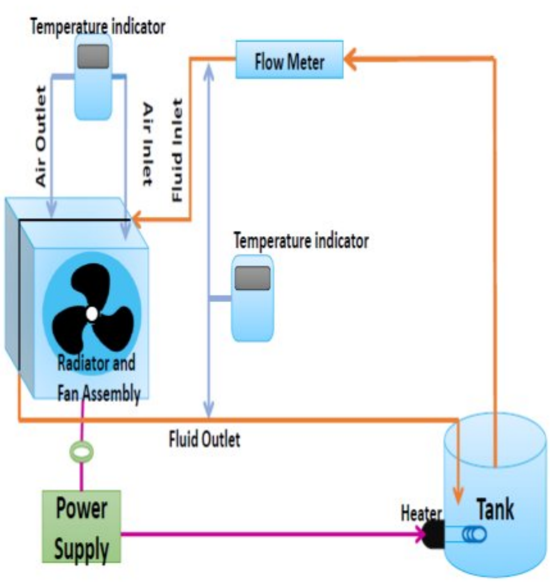

Figure 2: Schematic diagram of the test rig

The aspects on which the tank design was chosen was the capacity of the tank, thermal conductivity of the tank, material of the tank, cost of material, etc. A duct was designed around the radiator and fan assembly for capturing the temperature difference with the help of the thermocouple.

The duct was insulated using PU foam to prevent the inlet air from mixing with the outlet air. Brass components like reducers of 3/4th, T Joint of 3/4th and steel component's like clamps of 3/4th size were used for the fixing of the pipes , stainless steel sheets, hose pipes, radiator, radiator fan, rotor meter, control valve, pump, pressure regulator. These were the components chosen for the setup by keeping in mind the pressure bearing capacity of the components as well as the materials of the component's used as the whole setup was to come in contact with the water, high temperature and pressure.

Construction & Working:

Figure 3 shows the *stainless steel tank* which was built. It consisted of three layers, first layer being of stainless steel in the shape of a cylinder, then a layer of PU foam for insulation purpose followed by the third layer which was of stainless steel. The tank has a slot on the left side for the coiled heater to be fitted in the tank [8] that was used for heating of the water and the nano fluids. The right side of the tank has a slot for the waste water to come out of the tank. For the continuous mixing of the nano particles with the water a stirrer was fabricated out of stainless steel which consisted of three blades and was attached to the top of the tank. The fabrication of the duct was done in three steps, first the steel frame was built, after which the ply wood was fixed around the frame and the radiator and fan assembly was fitted in between, once these steps were done the whole duct was insulated with the help of thermocol and silicon so that the inlet and outlet don't mix with each other. Material used for the fabrication of the tank was stainless steel. The height of the tank constructed is 35cm, its diameter is 30cm and the thickness of the stainless steels used was 0.5mm. A sheet of PU foam was used between two layers of the stainless steel for insulation purpose that could take up to 80°C. The flow tank is used as a source for the flow of water/nanofluid into the entire setup. It has 1 inlet port and 1 outlet. The inlet port brings water back from the radiator outlet and the outlet port sends the water into the circuit.It has a heater inserted into the tank which heats the water to the desired temperature. The heating can be controlled from outside. It has a stirrer which provides continuous movement of the particles mixed with the water to prevent agglomeration of the nanoparticles. The stirrer rotates with the help of the motor attached on its head.

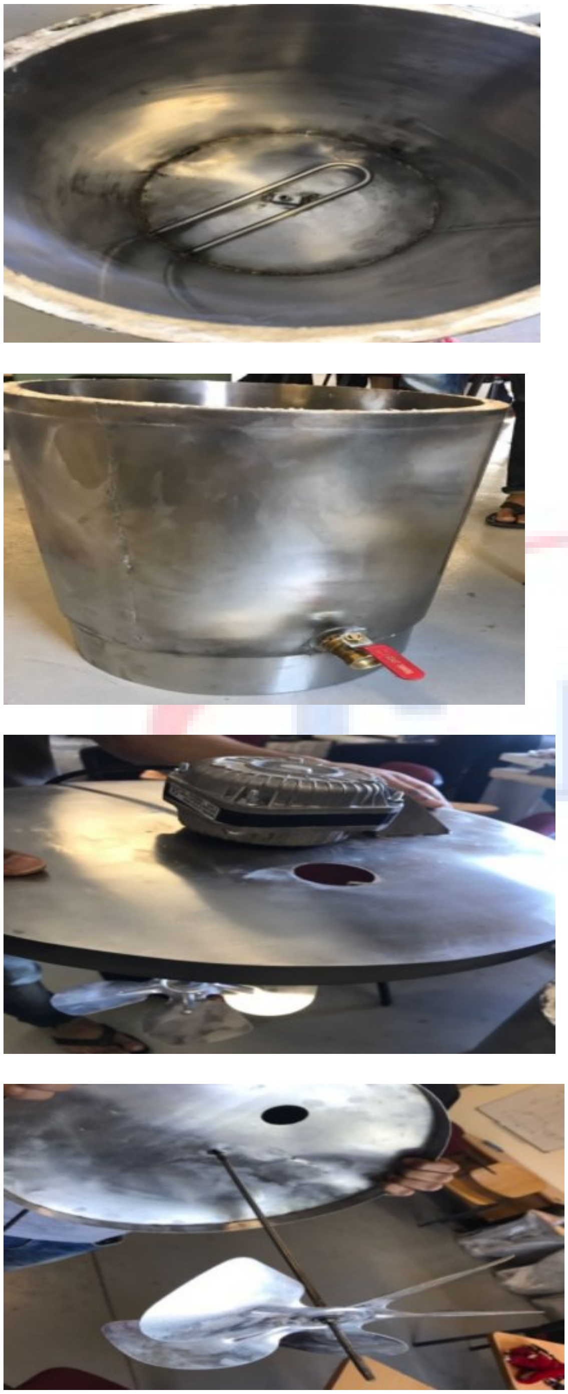

Figure 3: Steel tank with heater, stirrer and motor

Figure 4: 4-Channel K-Type Digital indicator and thermocouple

Figure 4 shows a device was used to measure the inlet and outlet *temperatures* of air and fluid. The temperature was measured using 4 probe sensors each of length 95cm and having a range of -30°C to 300°C.It was operated using a battery of 9V.A 3/4th *flow controller* shown in figure 5 made of brass was used to permit or prevent the flow of the fluid into the rotor meter which is obtained by opening and closing the knob on top. A *flow meter* shown in figure 6 made of glass with a range of 8-80 l/min was used to measure the flow rate of the fluid which was controlled by the flow controller. The rota meter consisted of a tube and float. As the flow rate increased or decreased the float inside moved up and down respectively. A *Radiator* shown in figure 7 is a heat exchanger that transfers the heat from hot engine coolant to the air. A 2007 Toyota corolla radiator made of aluminum and 1.6l capacity was used.

Figure 5: Flow controller

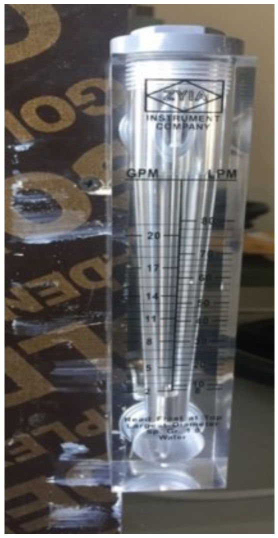

Figure 6: Flow meter

Figure 7: Radiator

Figure 8: Radiator fan

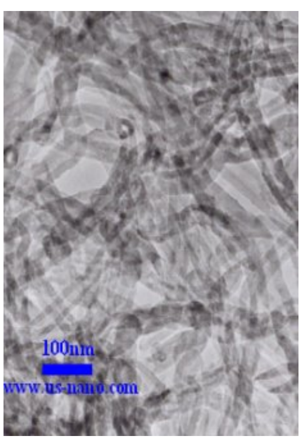

Figure 9: Nano Particles

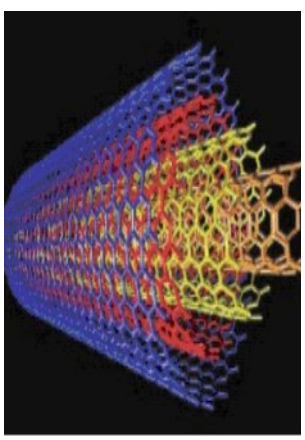

Figure 10: MWCNT Structure

A *Radiator Fan*shown in figure 8 increases air flow around the radiator so that the coolant is properly cooled which is located in front of the radiator and forces cooler outside air around the radiator fins. The figure 9 shows the *Nano particle* which is Multiwall Carbon Nano tubes (MWCNT's). They are highly conductive in nature and have several tubes in concentric cylinders. The Purity of the nanotube which is shown in figure 10 is more than 95 wt% (carbon nanotubes) (from TGA & TEM) and more than 97 wt% (carbon content). It's outside diameter range from 50-80 nm (from HRTEM, Raman) and its inside diameter ranges from 5-15 nm. The length of the nanotube is 10-20 um (TEM) and is black in color. *Multi walled carbon nanotubes* can conduct electricity more than 100 s/cm and its true density is 2.1 g/cm^3.

Final Assembly of test rig and Working

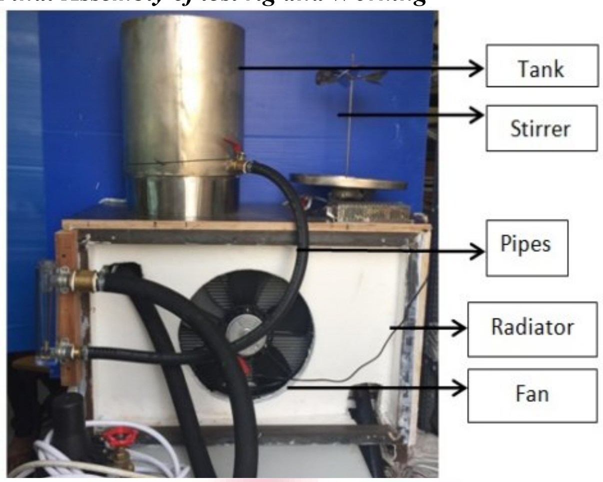

Figure 11: Assembled Test Rig setup (using Gravity Method)

Working: In this method, the water bath was placed at a level higher than that of the entire setup to achieve flow by gravity. The fluid flowing into the radiator was cooled via air blown by the fan. Distilled water in the tank was heated up to 90°C after which the inlet and outlet temperature for air and water was constantly noted. The flow rate is varied and the time taken to empty the entire tank for different flow rates was noted. Maximum temperature change was noticed at the lowest flow rate; therefore, this flow rate was used for nanofluid testing as well. Further testing was performed using MWCNT. Initially MWCNT was first measured as seen in figure 12 for different batches and then mixed in water using magnetic stirrer method as seen in figure 13 which was a two step method [10].Further on this mixture was put into the tank for testing at flow rate$_1$ with continues stirring. A temperature drop was noticed when compared to water.

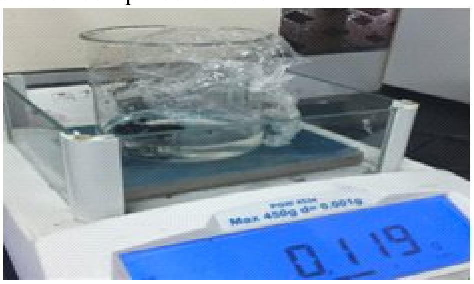

Figure 12: MWCNT being weighed

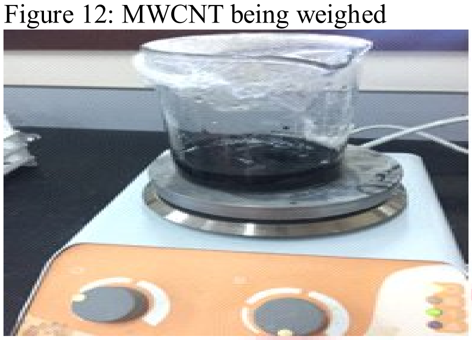

Figure 13: MWCNT being mixed in water using magnetic stirrer method.

V. RESULTS AND DISCUSSION

Using the equation 1 the *weight of the nano particle* was found in table 1 .It is noticed that weight of the nanoparticle increases with increase in volume concentration.

Table 1: Volume Concentration and weight of nanoparticle

Sl. No.	Volume Concentration %	Weight of Nano Particle (g/cm3)
1	0.1	0.21021
2	0.2	0.42084
3	0.3	0.63189
4	0.4	0.84337
5	0.5	1.05527
6	0.6	1.26760
7	0.7	1.48036
8	0.8	1.69354

Using equation 2 from the literature [10] ***Effective density*** of the nanofluid was found for volume concentrations varying from 0.1%-0.8% shown in table 2.It is noticed by theoretical calculations effective density has a very small increse with increase in volume concentration.

Table 2 : Volume Concentration and effective density of nanofluid

Volume Concentration,φ (%)	$\rho_{eff}\left({}^{g}/{}_{cm^3}\right)$
0.1	1.001
0.2	1.0022
0.3	1.0033
0.4	1.0044
0.5	1.0055
0.6	1.0066
0.7	1.0077
0.8	1.0088

Using equation 3 and 4*thermal conductivity* with volume concentrations ranging from 0.1%-0.8% at room temperature of 299K is found as shown in table 3.It is noticed by theoretical calculations effective thermal conductivity increases proportionally with increase in volume concentration.

Table 3: Effective thermal conductivity for different volume concentration

Volume Concentration, φ (%)	K_{eff} (W/mK)
0.1	336.98
0.2	668.96
0.3	995.26
0.4	1317.62
0.5	1635.31
0.6	1946.51
0.7	2254.38
0.8	2557.41

Diameter of the nanoparticle being used is 50-80nm ,Using equation 5 for particle concentration varying from 0.1%-0.8% *viscosity* for each was found respectively as shown in table 4.It is noticed viscosity changes only in the third and fourth decimal place. Hence there will be no effect on the flow due to addition of MWCNT.

Table 4: Effective viscosity

Volume Concentration, φ (%)	$\frac{\mu_{eff}}{\mu_f}$	$\mu_{eff}\left(\frac{Ns}{m^2}\right)$
0.1	1.0030	0.0912
0.2	1.0062	0.0917
0.3	1.0095	0.09207
0.4	1.0128	0.0923

0.5	1.0162	0.0926
0.6	1.0196	0.0929
0.7	1.0231	0.0933
0.8	1.0266	0.0936

Heat capacity for volume concentrations varying from 0.1%-0.8%was founds using equation 6 from literature [10] and the results are shown in table 5. It is noticed heat capacity decreases with increase in volume concentration.

Table 5: Heat capacity with respect to various volume concentrations

Volume Concentrations ,φ (%)	Heat Capacity (J/cm^3 K)
0.1	4.177
0.2	4.174
0.3	4.171
0.4	4.169
0.5	4.166
0.6	4.163
0.7	4.131
0.8	4.158

Heat transfer rate for volume concentrations varying from 0.1%-0.8% was found using equation 7 from literature [10] and the results are shown in table 6. It is noticed heat transfer rate increases proportionally with increase in volume concentration.

Table 6: Heat Transfer with respect to weight of nano particle

Weight of Nano Particle (g/cm^3)	Heat Transfer (J/cm^3)
0.21021	5.95
0.42084	11.92
0.63189	17.90
0.84337	23.89
1.05527	29.89
1.26760	35.90
1.48036	41.93
1.69354	47.97

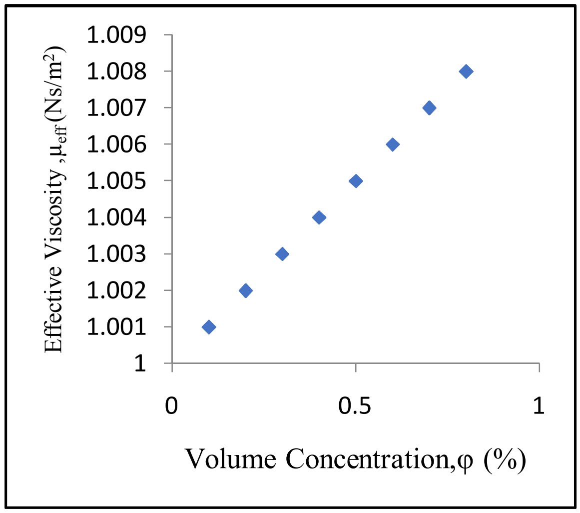

Figure 14: Results of viscosity change with respect to volume concentration of nanoparticle

A figure infers that as volume concentration increases the effective viscosity also increases [3,10].

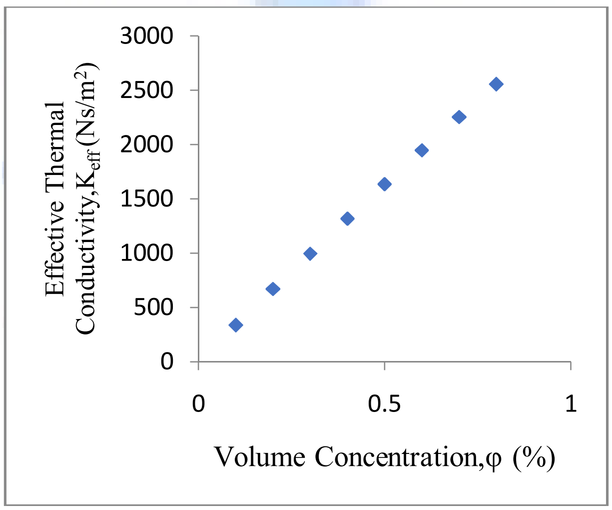

Figure 15: Results of thermal conductivity with respect to volume concentrations

Similarly, a figure 15 was plotted for effective thermal conductivity vs volume concentration [1,10], it was noticed that effective thermal conductivity increases with increase in volume concentration.

Global Journal of Advanced Engineering Technologies *Volume 7, Issue1- 2018*
ISSN (Online): 2277-6370 & ISSN (Print):2394-0921

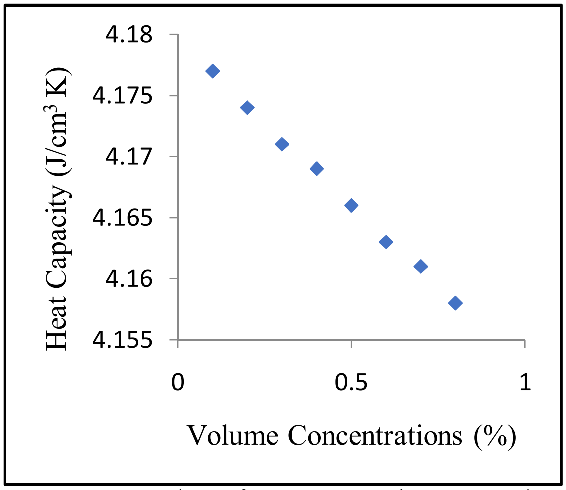

Figure 16: Results of Heat capacity vs. volume concentrations

Figure 16 signifies that heat capacity decreases with increase in volume concentration [9].

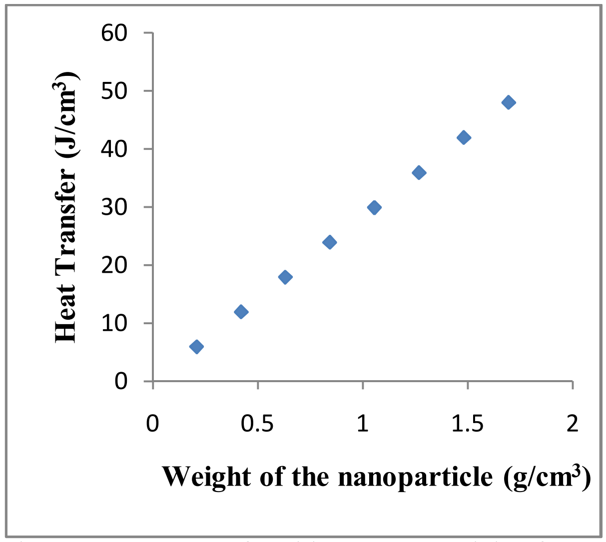

Figure 17: Heat Transfer with respect to weight of nano particle

Figure 17 signifies heat transfer rate increases with increase in weight of the nano particle [7].

Experimental results:

Table 7: Air and water temperatures with respect to flow rate$_1$ for Flow Rate$_1$=0.167l/min

Air Inlet Temp T_1 (°C)	Air Outlet Temp T_2 (°C)	Water Inlet Temp T_3 (°C)	Water Outlet Temp T_4 (°C)
25.8	27.9	88.4	23.7
25.2	28.2	86.9	23.6
25.9	29.5	84.9	23.5
25.8	29.5	84.9	23.4
25.2	29.4	82.4	24.6
25.1	28.9	81.7	25.3
26.1	28.8	80.1	26.4
25.3	28	79.3	26.3
25.7	28.2	77.8	26.4
25.7	27.9	76.5	26.6
25.6	25.3	75	26.9
25.6	27.1	73.7	26.8
26	25.8	71.9	26.7
26.2	27.2	71.2	26.8
25.6	25.5	69.6	27
25.5	25.3	68.7	27
25.3	25.2	67.4	27.2
27	26.7	66.3	27.5

26.6	26.5	64.5	27.3
25.7	26.1	63.7	27.2
25.5	27.5	60.2	27.5
25	27	61.5	27.7
25.6	27.3	60.2	28
25.4	27	59.3	28.1
25.7	26.4	57.9	27.2
26.8	27	56.4	28.4
26	27.3	54.7	27.9
24.9	25.8	53.6	27.9
25.4	26.7	51.7	28.1
25	26.4	50.2	27.3
25.1	26.6	48	27.9
24.5	26.3	45.8	28
24.4	25.6	43.4	27.9
Average reduction in temperature of water		**67.20**	**26.73**

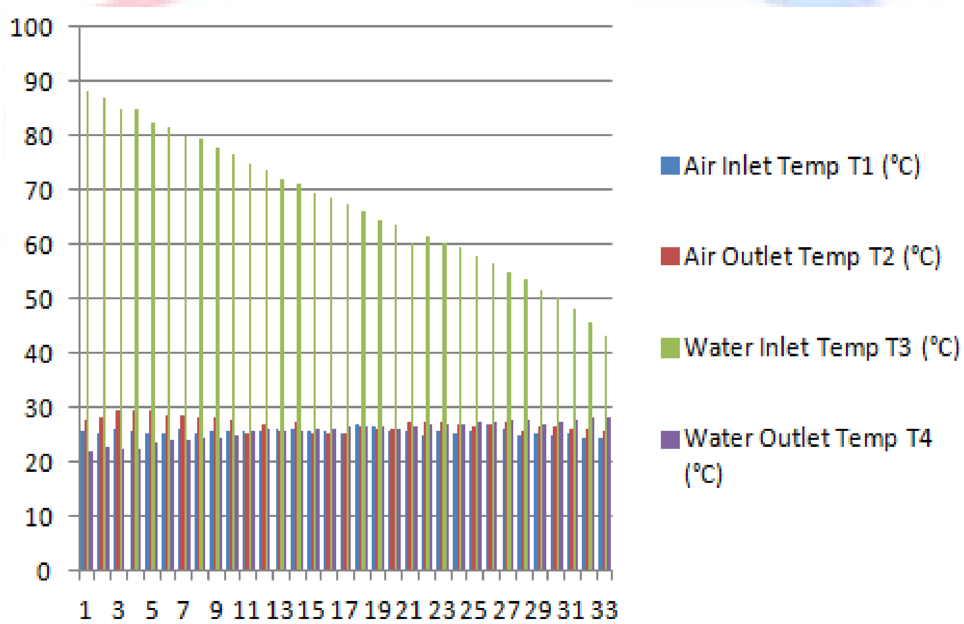

Figure 18: Temperatures at different points when the working substance is water

Table 8: Air and water temperature with respect to flow rate$_1$ using nanoparticles

Air Inlet Temp T_1 (°C)	Air Outlet Temp T_2 (°C)	Water Inlet Temp T_3 (°C)	Water Outlet Temp T_4 (°C)
25.8	27.8	88.4	17
25.2	28.2	86.9	17.6
25.9	29.5	84.9	17.4
25.8	29.5	84.9	18.3
25.2	29.4	82.4	18.6
25.1	28.8	81.7	18.9
26.1	28.8	80.1	19
25.3	28	79.3	19.3
25.7	28.2	77.8	19.5
25.7	27.8	76.5	20
25.6	25.2	75	20.6
25.6	27.1	73.7	20.9
26	25.7	71.9	20.7
26.2	27.2	71.2	21.8
25.6	25.4	69.6	21
25.5	25.3	68.7	21.2
25.3	25.2	67.4	21.4
27	26.5	66.3	21.5
26.6	263	64.5	21.5
25.7	26.1	63.7	21.2
25.5	27.5	60.2	21.5
25	27.4	61.5	22
25.6	27.3	60.2	22
25.4	27	59.3	22.1
25.7	26.4	57.9	22.4
26.8	27	56.4	22.4
26	27.3	54.7	22.6
24.9	25.8	53.6	22.8
25.4	26.5	51.7	27.1
25	26.4	50.2	22.3
25.1	26.3	48	22.9
24.5	26	45.8	23
24.4	25.6	43.4	23.1
Average reduction in temperature of water		**67.20**	**21.70**

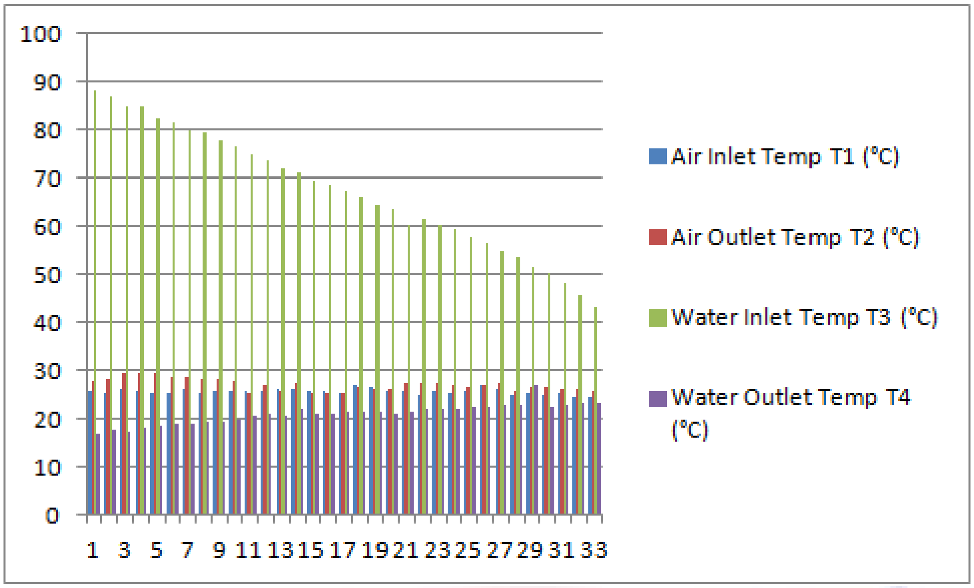

Figure 19: Temperatures at different points when the working substance is water mixed with nano particles

Table 7 shows the various temperature values noted by the experimental test rig using water . T_1 and T_2 are the inlet and outlet temperature of air which plays a role in heat dissipation. T_3 and T_4 are the temperature of the water at inlet and outlet points. The same experiment is repeated and carried out with the mixing of nano particles in water. The results which are obtained are shown in table 8. By comparing the results from both table 7 and 8 it is very clear that the average temperature of the water outlet is less in the case where nano particles are mixed with water. Figure 18 and 19 shows the inlet and outlet temperatures of air and water, with or without mixing the nano particles.

According to the related study it is noticed thegraph from source [1,10]plotted for thermal conductivity vs volume fraction matches with the results of the current work. Similarly graph plotted in the literature [3,10] for viscosity vs. volume concentration is closer with the result of the current study, graph from source [7] plotted for heat transfer rate vs volume concentration matches with the result of the current paperand according to graph [9] plotted for heat capacity vs volume concentration matches with the result of the above study hence the results are validated.

VI. CONCLUSION

Initially, the setup consisted of a 0.5HP pump, pressure regulator and a flow meter connected in between the radiator and the tank. When tested with water first difficulty noticed was water flow through the pump which was not constant due to the air gap being produced. Secondly, the pump pulling capacity did not match the reading on the flow meter when measured. Modifications were made which are mentioned below to overcome the above problems. During the test using nanoparticle, the main problem was the settlement of nanoparticles due to lack of the required surfactant. We planned on using Sodium Dodecyl Benzene Sulphonate which was not available in the country and the ones available did not match the required characteristics.To overcome the above mentioned problem gravity method was chosen to obtain constant flow.It consisted of the radiator and fan assembly and the tank which was placed at a level higher than the radiator and fan.The theoretical calculation signifies that there is a rise in viscosity and thermal conductivity with the volume concentration. Also there is a drop in heat capacity with the volume concentration. Future scope includes a smaller capacity pump can be used to match the flow meter reading. And by using an alternative surfactant which is available and matches the required characteristics. By mixing the nano particles to the water which is an working substance in the initial case, increases the heat transfer rate by cooling the system more effectively. Also the results obtained on theroretical and experimental work in this paper is validated with the standard literatures which show that the results are very much close and the nature of the graph is same.

- *Nomenclature*
- *ρ = Density*
- *eff = Nanofluid*
- *f = Base fluid*
- *p = Nano particle*
- *$\rho_{particle}$ = Density of nanoparticle, 2.1g-cm^{-3}*
- *ρ_{fluid} = Density of base fluid water,1g-cm^{-3}*
- *K_{eff} = Thermal Conductivity of Nanofluid*
- *K_f = Thermal Conductivity of base fluid (W-m^{-1}K^{-1})*
- *K_p =Thermal Conductivity of nanoparticle (W-m^{-1}K^{-1})*
- *K_β = Thermal Conductivity of particle*
- *Cp = Specific heat of the particle (J-Kg^{-1}K^{-1})*
- *d_f, = equivalent diameter of base fluid molecule*
- *M = Molecular weight of the base fluid, g-mol*
- *N = Avogadro Number = 6.022×10^{23}mol^{-1}*
- *ρ_{bf} = Mass density of base fluid, g-cm^{-3}*
- *μ_f = Viscosity of base fluid = 0.091 Ns-m^{-2}*
- *d_p =Diameter of nanoparticle , nm*
- *$(C_p)_f$ = Specific heat of water, J-g K*
- *$(C_p)_{np}$ = Specific heat of nanoparticle, J-g K*

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