Published by :
http://www.ijert.org
International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 8 Issue 08, August-2019

Comparison of Al203 and Tio2 Nano-Fluids for Enhancing the Cooling Performance of an Automobile Radiator

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***Abstract*:- This paper aims to compare the efficiency of cooling rate of the coolants of an automobile radiator. The Nano-coolant 1 is made by using Nano-particles Al203 and Ti02 in distilled water and the 2 is made by using $Ti0_2$ Nano-particles in distilled water. These Nano-coolants increase the heat transfer coefficient and Nusselt number and thus helps in increasing the heat transfer rate at a particular flow rate and at a specific concentration. Increasing these parameters increases the efficiency of the radiator and prevents engine from unwanted processes like knocking, engine overhauling and pre-ignition of fuel etc.**

1. INTRODUCTION

Nowadays the problems related to overheating of the engine increases which reduces the performance and hence life of an engine due to the processes like knocking, pre-ignition of fuel, overhauling of engine etc [1]. To solve this problem, an effective cooling of the engine is necessary which is not possible with the traditional coolant which is water. An experiment has been performed to find the optimum flow rate and concentration of Nano-coolant in water at which most heat will be absorbed by the coolant via convection and conduction [2] phenomenon.

2. SOLUTION PROPOSED

The proposed solution discloses an improved results in heat transfer coefficient, Nusselt number and also the Reynolds number. To increase these parameters, two things need to be found. One is the optimum flow rate of the Nano-coolant [3] and another one is the best concentration of Nano-particles in distilled water. This is found by performing an experiment in which rig is made by using an automobile radiator 1200cc enclosed in GI sheet duct of 18 gauge [4]. To flow the coolant in the duct of radiator, a centrifugal pump is installed. A thermometer is used to check the temperature of the coolant. An agitator has been employed to make homogeneous solution [5] of Nano- particles in water. PT-100 [6] sensors has been used to check the temperatures at different places of the radiator in order to have accurate data of temperature drop at different places of the radiator.

In the first experiment, Nano-coolant is prepared by using Al203 [6] particles in different concentrations (0.10%, 0.15% and 0.2%) with the distilled water. The flow rates have been changed from 2-5 l/min. of the coolant in the radiator and concentrations have been varied from 0.10% to 0.20% by volume. The inlet temperature of the coolant has been increased to 50^0c and the time taken by it cool from 50 to 30 c is noted and graphs have been plotted. On the basis of the data, Reynolds number, Nusselt number and heat transfer coefficient has been found at all concentrations and flow rates. The most efficient concentration and flow rate have been recorded.

In the 2^{nd} experiment, rig set up is same as discussed above. Nano-coolant is changed by adding Ti02 [7] in distilled water at three different concentrations [8] (0.10%, 0.15%, and 0.2%). Flow rate [9] have been also varied from 2-5 L/min. The various parameters have been recorded and most efficient flow rate [10] and concentration have been found and graph is plotted.

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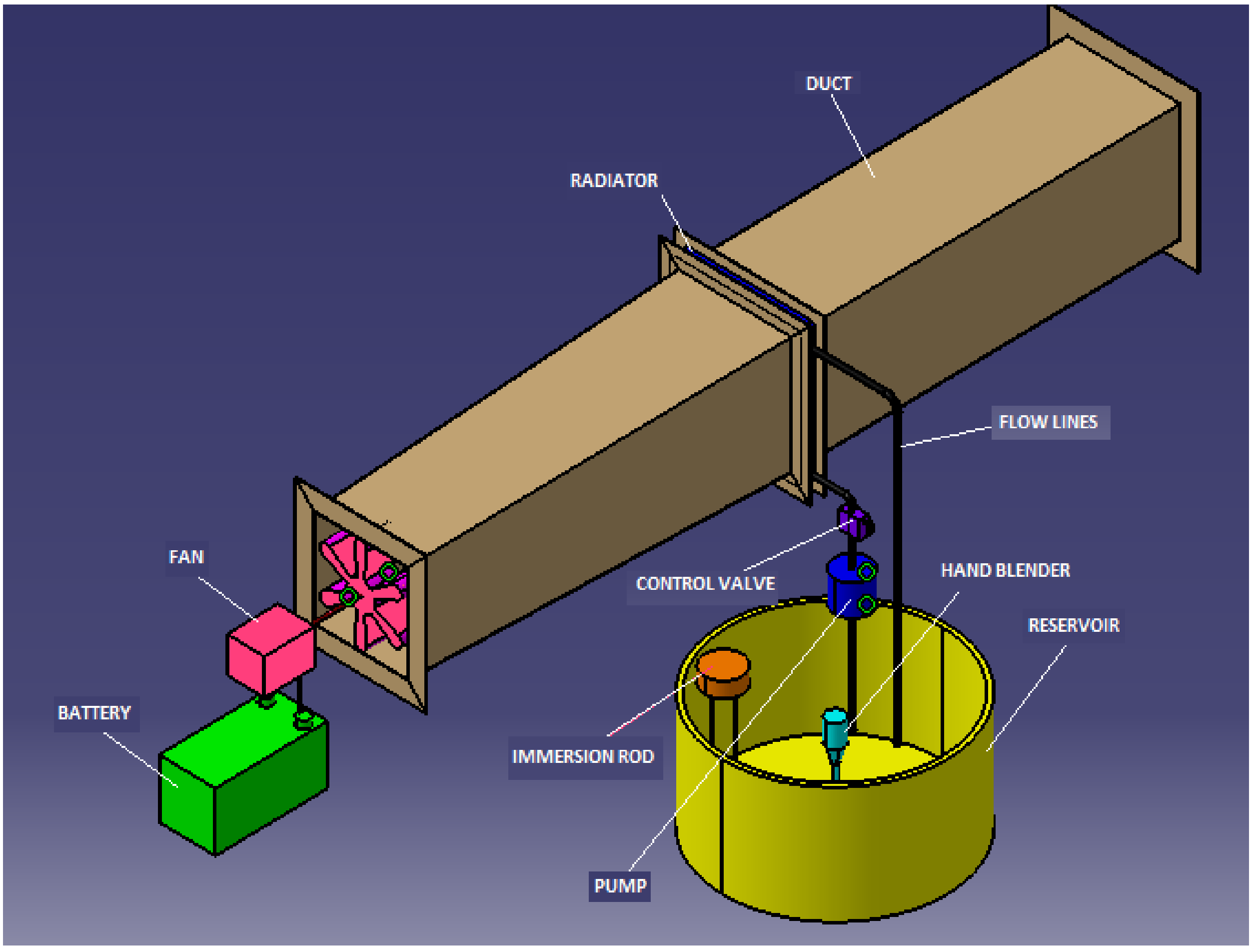
3. EXPERIMENTAL SETUP



The test rig contains a battery,an automobile radiator, a duct of GI sheet of gayge 18mm, a radiator of 1000cc, a reservoir, ana immerion rod [11], flow lines,control valves, PT-100 sensors and a pump[12].

4. EXPERIMENTAL PROCEDURE:

1. Firstly, the Nano-coolant is made by mixing the Nano-particles (Al203 and Ti02) in three different volume concentrations (0.1%, 0.15%, and 0.2%) in distilled water.
2. The prepared Nano-coolants are then stirred with an agitator to form homogeneous mixture and then it is stored in reservoir (bucket).
3. The immersion rod is used to increase the temperature of the coolants initially to 50^0c.
4. The flow rate of the Nano- coolants have been controlled and varied by using a control valve from 2 l/min to 5 l/min.
5. The Nano-fluids (coolant) is then allowed to flow into the radiator which is enclosed in duct of G.I sheet of 20 gauge via flow lines.
6. The coolants when flows through the tubes of the radiator, cools down (temperature drop) due to forced convection and conduction processes.
7. The temperature drop is then recorded and the graphs have been plotted to analyze the heat transfer rate of the coolant 1 and coolant 2.
8. The time taken by coolant 1 i.e. (AL203+water) to cool from 50^0c to 30^0c is analyzed and the most efficient flow rate and concentration of Nano-fluid is noted.
9. Similarly, the time taken by 2^{nd} Nano-coolant (Tio2 +water) is recorded and its concentration and flow rate at which maximum heat is dissipated is noted.
10. The heat dissipation time of both the coolants is noted at different concentrations and flow rates and thus compared to achieve most efficient results.

5. EXPERIMENTAL CALCULATIONS:

The various parameters required to perform an experiment such as Reynolds number, heat transfer coefficient and Nusselt number are calculated by using the formulas discussed below-

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1. **Density of the Nano-fluid (ρ_{nf}) is calculated by using the given formula**:-

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

Where

ρ_w = density of water (1000kg/m^3)

ρ_p = density of Al_2O_3 (3900 kg/m^3) f

φ= Nano Fluid volume concentration % (at three different values i.e. 0.1%, 0.15% and 0.2%)

ρ_{nf} = density of Nano fluid (kg/m^3)

2. Now, the specific heat capacity of the Nano- coolant is calculated as:

$$C_{nf} = \frac{(1-\varphi)(\rho C)_w + \varphi(\rho C)p}{(1-\varphi)(\rho C)_w + \varphi\rho_p} \quad (2)$$

Where

C_{nf} = specific heat capacity of the Nano coolant (J/Kgk)

C_w = Specific heat capacity of water (4180 J/kgk)

C_p = Specific heat capacity of Al_2O_3 (880 J/kgk)

3. The heat transfer rate is calculated as by given equation:

$$Q = mC_{nf}\,(T_{in} - T_{out}) \quad (3)$$

Where, m = mass flow rate [13] of the Nano-coolant (Kg/min)

T_{in}= Inlet temperature (°c)

T_{out}= outlet temperature (°c)

Now the heat transfer coefficient is calculated by using the given equation:

From Newton's law of cooling:

$$Q = hA\,(T_b - T_s) \quad (4)$$

Where

Q is the heat transfer rate (watt)

h = heat transfer coefficient (w/m^2k)

A is the surface area of the tube of radiator (217cm^2)

T_b is the bulk temperature (°c) which is calculated by taking the average of T_{in} and T_{out}

$$T_b = \frac{T_{in} + T_{out}}{2} \quad (5)$$

T_s is the average wall temperature of the radiator measured from various transverse and longitudinal locations of radiator (°c)

$$h_{exp} = \frac{mC_{nf}(T_{in} - T_{out})}{nA(T_b - T_s)} \quad (6)$$

Where n = number of tubes (50)

4. Now the average Nusselt number can be calculated as:

$$N_u = \frac{hD_h}{k} \quad (7)$$

Where D_h = hydraulic diameter of the tube and is calculated as

$$D_h = \frac{4\left[\frac{\pi d^2}{4} + (D-d)d\right]}{\pi d + 2(D-d)} \quad (8)$$

D and d are the width and height of radiator tube.
Here d=1.8 mm; D=15.5mm.

5. Finally the Reynolds number can be calculated as:

$$Re = \rho_{nf} v D_h / \mu \quad (9)$$

Where
ρ_{nf} =density of Nano-fluid (kg/m^3)
μ = dynamic viscosity of the Nano coolant (Ns/m^2)
v= Fluid velocity (m/s)
D_h = hydraulic diameter of the tube

6. OBSERVATIONS :

The analysis of the Nusselt number, Reynolds number and the heat transfer coefficient for the two Nano-coolants Al203 and Tio2 at different flow rates and different volume concentrations is shown in the tables and graphs below.

Table 1: The table for the calculated values of Reynolds number and Nusselt number at different flow and concentrations for Al_2O_3.

m=2.27l/m			m=3.4l/m			m=4l/m		
Re	**Nu**	**φ (%)**	**Re**	**Nu**	**φ (%)**	**Re**	**Nu**	**φ (%)**
2804	1.91	0.2	2804	2.97	0.2	2804	3.06	0.2
3249	2.46	0.15	3249	3.822	0.15	3249	4.66	0.15
4807	1.61	0.1	4807	3.177	0.1	4807	3.5	0.10

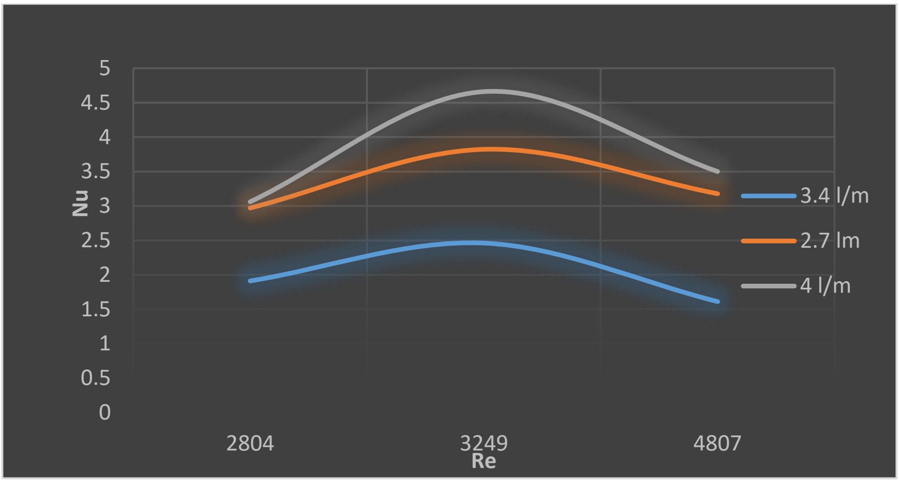

Figure 1: Graph representing the variation in Reynolds number vs. Nusselt number at different flow and concentrations for Al_2O_3.

The graph shows the analysis of Nusselt number and Reynolds number for Al_2O_3 at different flow. Nusselt number increases with Reynolds number with increasing flow. Blue line shows the lesser flow of 2.27 l/m, red shows the 3.4 l/m and green likewise shows the 4 l/m. Three points in a single curve line represents the three volume concentrations. Maximum value of Nusselt number is obtained at 0.15 %. At 0.20 % the friction factor is maximum and it decreases the Reynolds number. The friction factor at 0.15 % lesser than other concentrations. The Nusselt number at 0.10 % is lesser than 0.15 % but greater than 0.20 %.

Table 2: Comparative table for the calculated values of Reynolds number and Nusselt number at different flow and concentrations for TiO_2

m=2.27 l/m			m=3.4 l/m			m=4 l/m		
Re	**Nu**	**φ (%)**	**Re**	**Nu**	**φ (%)**	**Re**	**Nu**	**φ (%)**
2373	1.8	0.2	2373	2.3	0.2	2373	2.02	**0.2**
3272	2.23	0.15	3272	2.8	0.15	3272	3.36	0.15
5316	1.3	0.1	5316	3.11	0.1	5316	2.76	0.10

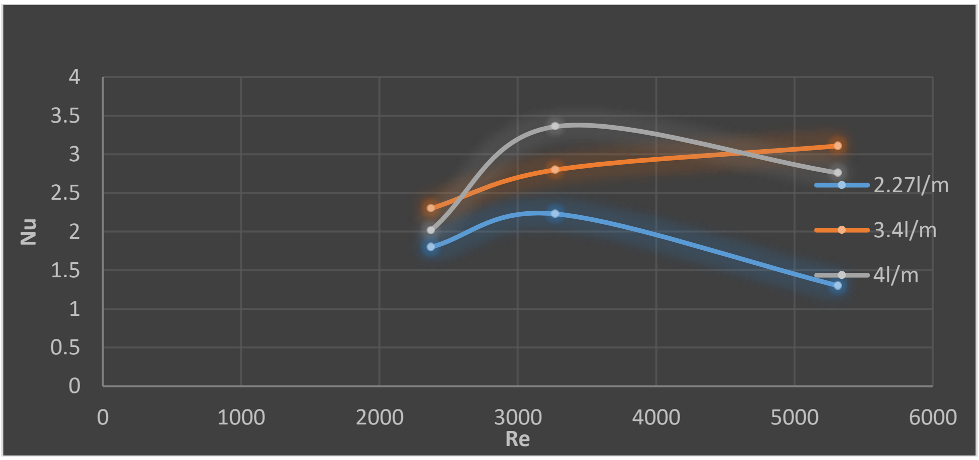

Figure 2: Graph representing variations in Reynolds number vs. Nusselt number at different flow and concentrations for TiO_2

The graph shows the experimental results in case of TiO_2 at three different flow rates and at three different volume concentrations. The values of Nusselt number for TiO_2 are smaller than the Al_2O_3 because the viscosity of TiO_2 is sharply decreases with increasing inlet temperature as compared to Al_2O_3 so its Reynolds number increases more than Al_2O_3. At 4 l/m the value of Nusselt number got decreased than 0.15 % because of increasing friction factor.

Table 3: A comparative table between Al_2O_3 and TiO_2 for their respective flow characteristics at fixed mass flow rate of 2.27 l/m

TiO_2			**Al_2O_3**		
Re	**Nu**	**φ (%)**	**Re**	**Nu**	**φ (%)**
2373	1.8	0.2	2804	1.9	0.2
3272	2.23	0.15	3249	2.46	0.15
5316	1.3	0.1	4807	1.61	0.1

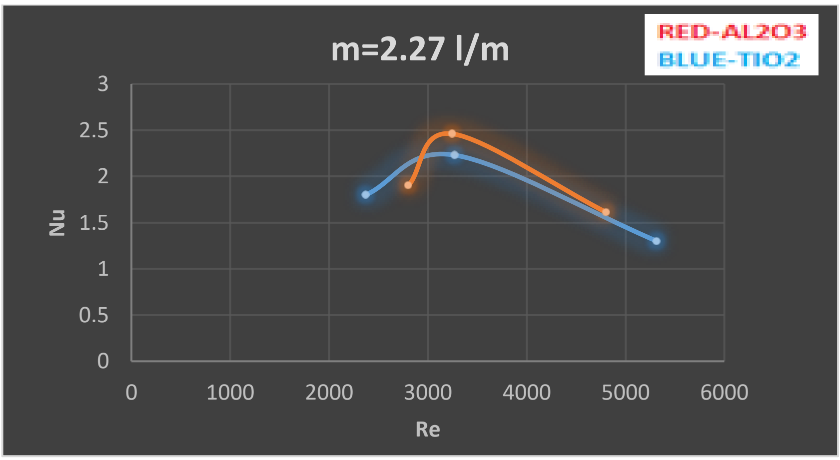

Figure 3: Graph between Reynolds vs. Nusselt number for Al_2O_3 and TiO_2 at m=2.27 l/m

International Journal of Engineering Research & Technology (IJERT)
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This graph shows the analysis of Nusselt number and Reynolds number for both Al_2O_3 and TiO2 at 2.27 l/m flow. This is the lesser flow in the experiments. The blue line shows the TiO_2 and red line indicates the Al_2O_3. At starting the viscosity of the Nano-particle is higher and Reynolds number is less hence the low value of the Nusselt number. The thermo-physical properties of the both the Nano-fluids are such that the Al_2O_3 shows the better results as compared to TiO_2 at a particular flow of 2.27l/m.

Table 4: A comparative table between Al_2O_3 and TiO_2 for their respective flow characteristics at fixed mass flow rate of 3.4 l/m

TiO_2			**Al_2O_3**		
Re	**Nu**	**φ (%)**	**Re**	**Nu**	**φ (%)**
2373	2.3	0.2	2804	2.97	0.2
3272	2.8	0.15	3249	3.822	0.15
5316	3.11	0.1	4807	3.177	0.1

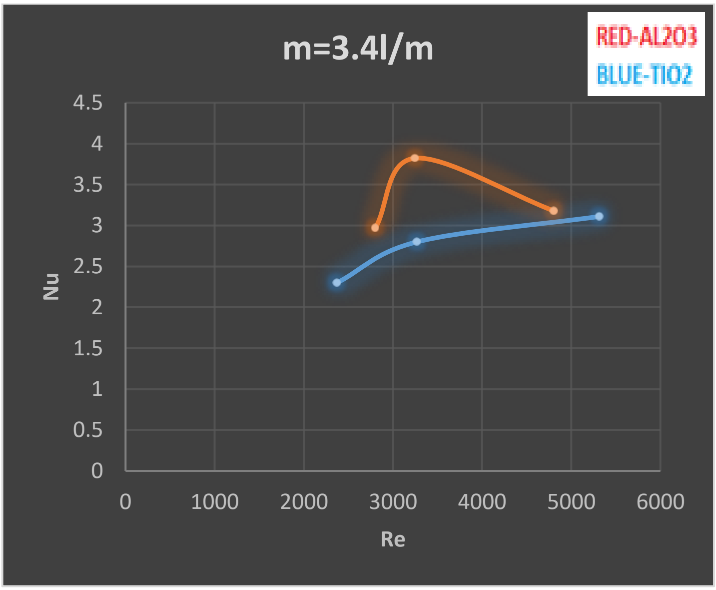

Figure 4: Graph between Reynolds vs. Nusselt number for Al_2O_3 and TiO_2 at m=3.4l/m

Fig. 4 shows the graphical representation of both Nano-fluids at 3.4l/m. There are three different values at particular value of flow. At this flow the TiO_2 goes linear as compared to the Al_2O_3. Sliding velocity of Al_2O_3 is more than the TiO_2 but this factor plays less role in this flow. At this flow the agitator mixed the TiO_2 as compared to the Al_2O_3 because of its shape and composition.

Table 5: A comparative table between Al_2O_3 and TiO_2 for their respective flow characteristics at fixed mass flow rate of 4 l/m

TiO_2			**Al_2O_3**		
Re	**Nu**	**φ (%)**	**Re**	**Nu**	**φ (%)**
2373	2.02	0.2	2804	3.06	0.2
3272	3.36	0.15	3249	4.66	0.15
5316	2.76	0.1	4807	3.5	0.1

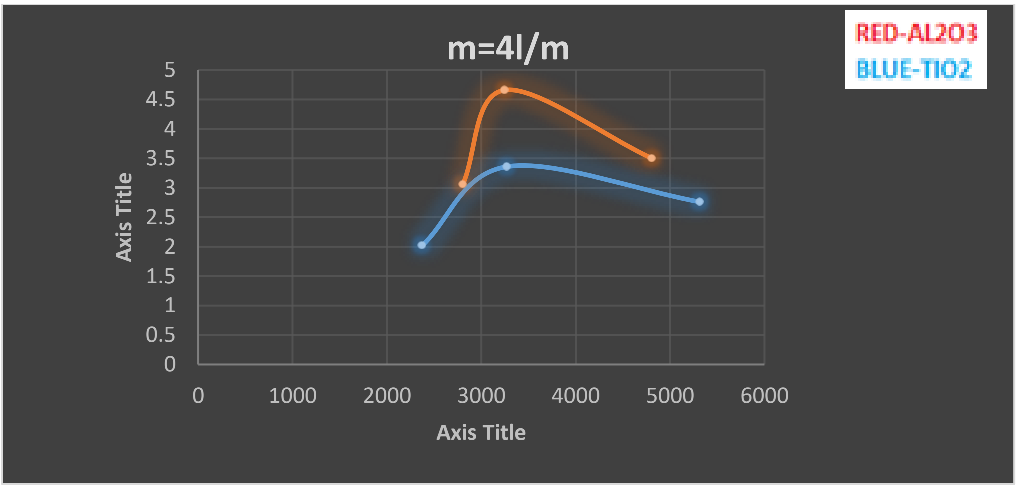

Figure 5: Graph between Reynolds vs. Nusselt number for Al_2O_3 and TiO_2 at m=4l/m

This graph shows the best results and we can find it easy for comparison. For both Nano-fluids the Al_2O_3 shows the best results at flow 4 l/m and the volume concentration of 0.15 %. At maximum concentration the slip velocity causes the increase in friction causes decrease the Reynolds number hence lesser value of the Nusselt number as compare to other concentrations. Agitator work well at 0.15% concentrations for both Nano-fluids.

So the graphs and calculations shows that the corresponding parameters are giving better results for Al_2O_3 as compared to the TiO_2 proving Al_2O_3 is better Nano coolant.

7. CONCLUSION:

- From the table and graph of aluminum as a Nano-Particle shown above, it is clear that the Nano-particle Al203 shows better results at a flow rate of 4l/min. and 0.15% concentration by volume. The Nusselt number is greater at this particular concentration and flow rate which means its convective heat transfer rate is maximum.
- The table and graph of Tio_2 as a Nano-particle shows that the heat transfer rate is maximum which is determined by nusselt number at a flow rate of 4l/min and at a concentration of 0.15% by volume.
- From the tables and graphs of comparison between the Nano-fluids, it is deduced that the Al203 shows better results than the Tio2 as a Nano-fluid at all concentrations and flow rates.
- The Nusselt number increases with the concentration and flow rate but decreases at the maximum concentration (0.2%) because the slip velocity causes increase in friction which causes the decrease in Reynolds number and the Nusselt number and thus decreases the heat transfer capacity of the Nano-fluid.
- By comparing the two Nano-fluids it has been concluded that the Al_20_3 dissipates heat by convection medium at a faster rate than the Tio2. Thus Al_20_3 is better Nano-fluid than the Tio2 at a flow rate of 4l/min. and at a concentration of 0.15% by volume in distilled water.

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