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Experimental Investigation of Pumping Power and Effectiveness of Car Radiator Using Al_2o_3 Nanofluid

P.A. Ingole[1], S.M. Shinde[2], Dr. P.A. Patil[3]
PG Student[1],Mechanical Engineering Department, Jayawantrao Sawant College of Engineering, Savitribai Phule Pune University, Pune, Maharashtra, India.
Research Scholar[2], Mechanical Engineering Department, Jayawantrao Sawant College of Engineering, Savitribai Phule Pune University, Pune, Maharashtra, India.
Research Guide[3], Mechanical Engineering Department, Jayawantrao Sawant College of Engineering, Savitribai Phule Pune University, Pune, Maharashtra, India.

Abstract: This experimental investigation shows the effect of Aluminium oxide (Al_2O_3) nanoparticles addition on temperature and time required for cooling in car radiator. The case considered involves initially heating the coolant and once the temperature near the heater reaches to 80^0C, pump is started and pump will continue to circulate the fluid till the temperature reaches to 50^0C. Time required for cooling from 80^0c to 50^0c for 0%, 2%, 2.5%, 3% and 3.5% volume concentration of Al_2O_3 nanoparticles in base fluid - water and ethylene glycol (W+EG) have been presented. The result shows that there is significant time difference between base fluid cooling and nano cooling system. In best possible conditions 31.29% time reduction was achieved by 3.5% Al_2O_3 nano fluid compared to base fluid. Pumping power for 2% Al_2O_3 vol. concentration is less by 23.81% than base fluid. This experiment also presents the effect of nanoparticles on effectiveness of radiator and nano fluids shows as high as 34.01% effectiveness than base fluid.

Keywords: *Al_2O_3 nano-particles; Car radiator; Rate of cooling; Effectiveness of radiator; Experimental study.*

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1. INTRODUCTION

Due to the globalization and industrialization there is a need for advance cooling system. During past years, lots of efforts have been put to improve the performance of heat exchanger. Some of them include changing the geometry of heat transfer devices, increasing the surface areas, changing material composition of heat exchanger devices, increasing flow rate, etc. Though these traditional methods improve the thermal performance of heat exchanger, but it unnecessarily increases the size, weight and cost of the equipment. However looking towards the development of automotive sector, reducing the vehicle weight and size is of the important factor. Moreover with the advancement in technology with the rising thermal load there is necessity of faster cooling. As discussed above the conventional methods are already reached to its limit [1]. Nanofluids have the potential to be the next generation of coolants for vehicle thermal management due to their significantly higher thermal conductivities. Nanofluid is a suspension of nanosized particles in the conventional fluid. This nanoparticle is having higher thermal conductivity than that of base fluid [2]. Therefore we can conclude that by suspending nanoparticles into the conventional fluid, the thermal performance of heat exchanger can be improved.

Mixture of ethylene glycol and water along with additives are traditionally used coolant in engine cooling system. The heat transfer coefficient of this kind of engine coolant is very limited. It has been well validated that nanofluids could be potential replacement of conventional car engine coolants [2]. In the engineering field, nanofluids have been mainly indicated as novel coolants for both electronic and automotive components, with the potential to reduce the dimensions of traditional heat exchangers [3]. In current era, time required for meeting the desired output with minimum space and cost is of utmost importance. Hence there is a need to study the time basis relationship of nanofluid effect on cooling time required.

Some of the results discussed are extracted from the literature are presented as follows;

Devdatta P. Kulkarni et al, (2008), presented his work on the different concentration of aluminium oxide nanofluid and time verses temperature data and it was found that as the concentration of nanoparticles increases the specific heat decreases also as the temperature of nanofluid increases specific heat increases [1]. Xiaoke Li et. al. (2016) experimentally studied the thermo-physical properties of car engine coolant containing water and ethylene glycol based SiC nanofluids. It was found that the highest thermal conductivity enhancement of 53.81% was achieved for 0.5 vol. % nanofluids at 50°C. In addition, the overall effectiveness of the SiC nanofluids (0.2 vol.%) was found to be ~1.6, which proved that coolant containing SiC nanoparticles was better than coolant without SiC nanoparticles [2]. K. Y. Leong et. al. (2010), showed that with addition of 2% copper particles in a base fluid of engine coolant, upto 3.8% of heat transfer enhancement can be achieved at a Reynold's number of 6000 and 5000 for air and coolant respectively [4]. S. M. Payghambarzadeh et. al. (2011), experimentally determined the effect of different amount of nanoparticles added into the base fluid on heat transfer performance of the car radiator. It was reported that application of nanofluid in engine cooling system with low concentration can enhance heat transfer efficiency up to 45% in comparison with pure water [5]. L. Syam Sundar et. al. (2013) developed the new correlations for estimating the thermal conductivity of Al_2O_3 and CuO nanofluids by considering the volume concentrations and temperatures. Through his study it was found that application of nanofluid in higher temperature region rather than lower temperature region will be more beneficial. [6]. M. Ali et. al. (2014), experimentally studied the heat transfer enhancement by coolant containing varying concentration of aluminium oxide nanoparticles ranging from 0.1 to 2% volume. He concluded that there was a gradual heat transfer enhancement for 0.1%, 0.5% and 1% volume concentration of nanoparticles but beyond 1% volume concentration heat transfer enhancement reduces with increasing concentration [7]. Hwa-Ming Nieh et. al. (2014), experimentally measured the effect of different concentration of nanoparticles on the thermal conductivity, viscosity, specific heat, with sample temperature. It was observed that as the concentration of nanoparticles increases specific heat of nanofluid decreases while the thermal conductivity and viscosity of nanofluid increases. Also as the temperature of nanofluid increases specific heat increases and viscosity decreases [8]. D. Madhesh et. al. (2014), performed the experimentation on different concentration of nanoparticles in base fluid ranging for 0.1% to 1%. It was found that as the concentration and temperature of nanofluid increases the thermal conductivity of nanofluid increases [9].

2. EXPERIMENTAL SET-UP

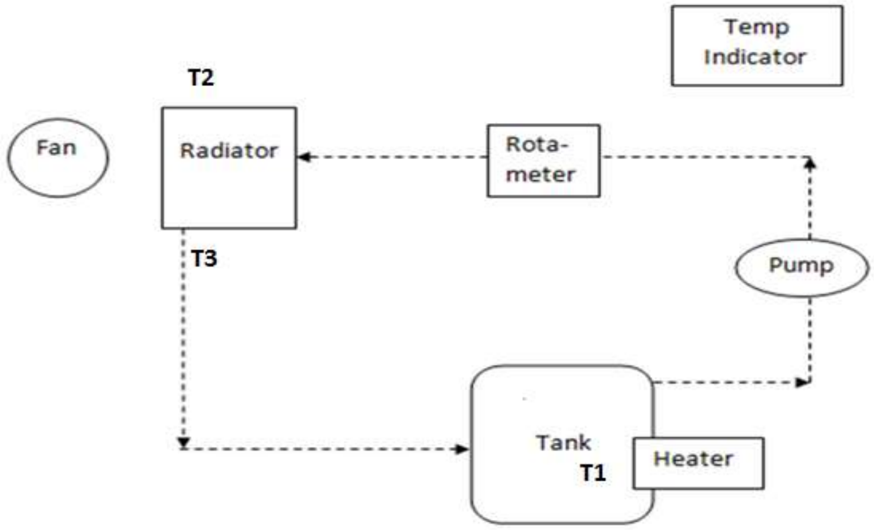

Figure 1: Set up Layout

The experimental set-up shown in **figure 1** includes a steel reservoir, electrical heater, pump, rotameter, hose pipes, flow control valves, fan, K type thermocouples for temperature measurement and automobile radiator (heat exchanger). An electrical heater (1 kW) is used to generate temperature of 80^0C is placed inside a steel reservoir of 12 ltr capacity (45 cm height and 30 cm diameter). A rotameter (2000 lph) and two flow control valves are used to measure and control the flow rate respectively. The fluid circulates through hose pipes (0.5 in) by a pump (0.5 hp and 30-40 m head) from tank through the radiator. AC mains power supply provides the power to keep the inlet flow to the radiator as 500 lph. The total volume of the circulating fluid is 3 ltr and is kept constant for all the working fluids. One thermocouple is placed around the heater region (T_1). Other two thermocouples are kept in the radiator inlet and outlet for recording the inlet (T_2) and outlet (T_3) fluid temperatures. For radiator cooling, a fan (1500 rpm) is installed centrally to the radiator. Time for cooling is measured using stop watch. Testing is done at constant conditions, as when temperature of heater region reaches 80^oC then pump gets started and fluid will remain in circulation till T_1 reaches 50^0C, and time is noted for this cycle. Time and Temperatures are taken for each interval of 5^0C in total 30^oC temperature reduction. Radiator used is of Maruti 800, having 37 tubes, each of diameter 10 mm.

3. WORKING FLUID SELECTION

Five different working fluids are selected as a coolant. First working fluid is conventional radiator fluid i.e. water + ethylene glycol mixture in 50/50 proportion, which is most commonly used in almost every automotive cooling system. Remaining four working fluids are nanocoolants which are Al_2O_3 nanoparticles suspension in conventional radiator fluid. Four different nanocoolants are prepared by using 2%, 2.5%, 3% and 3.5% concentration of Al_2O_3 nanoparticles. Experimental process is mapped in layout as shown below.

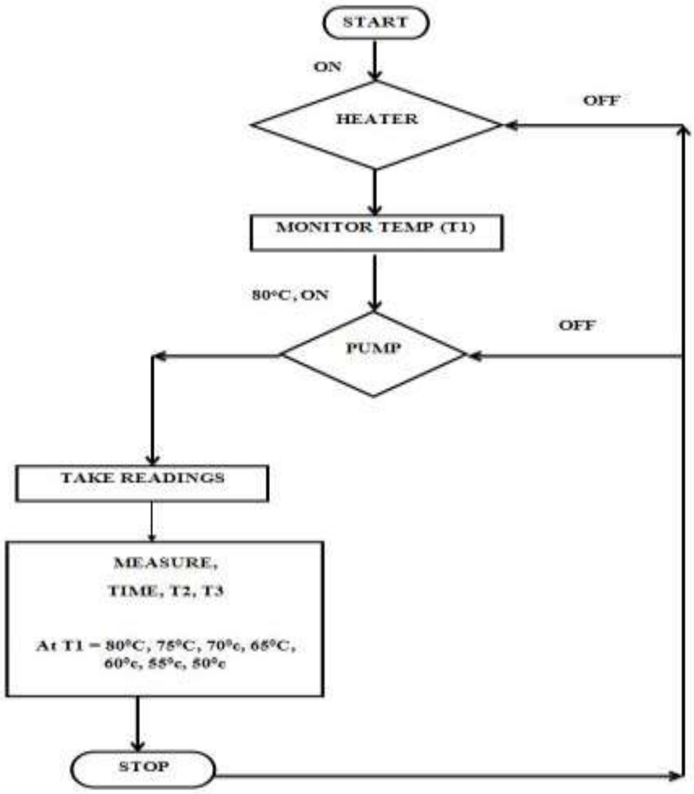

Figure 2: Flow chart of experimental procedure

Table 1: Range of experimental operating conditions

Parameters	Contents
Coolant fluid	W+EG, Al_2O_3
Nano particle concentration	0 to 3.5 %
Flow Rate	500 lph
Coolant quantity	3 Litre
Flow type	Turbulent
Radiator inlet temperature	50 to 80 ^OC

4. EXPERIMENTAL TESTING

To investigate the effect of nanoparticles addition on rate of cooling, time required for achieving temperature of 80°C to 50°C with 5°C temperature decrement is measured for all working fluids.

Also readings of Radiator in and out temperature along with fluid tank are monitored for all intervals. For pumping power reading, electricity meter reading is taken at start of each working fluid experiment and at the end of respective experiment.

Here,

T_1 = Tank fluid Temperature (around heater region), °C

T_2 = Radiator in Temperature, °C

T_3 = Radiator out Temperature, °C

T_4 = Room Temperature = 32 $\pm$1°C

ΔT = Temperature difference along Radiator, °C

P_1= Electricity meter reading at start of experiment, kW

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P_2= Electricity meter reading at end of experiment, kW

Pumping power required = (P_2-P_1), kW

Effectiveness of radiator is calculated as,

$$\varepsilon = \frac{(T2-T3)}{(T2-T4)}$$

5. TEST RESULTS

Figure 3 below shows the trend of temperature difference along radiator for all working fluids for 80 °C to 50 °C temperature cycle. The temperature difference trend along radiator is nearly similar for all working fluids.

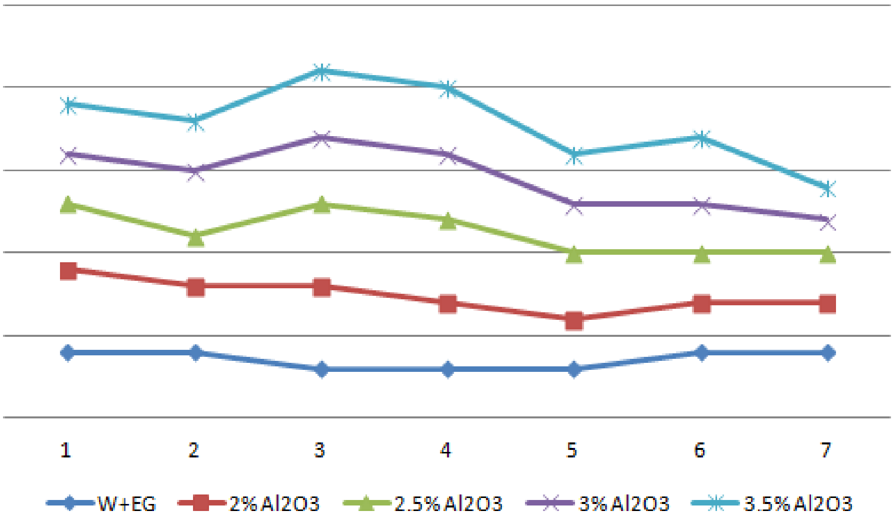

Figure 3: Temperature difference trend through Radiator for 30°C cycle

Time required for cooling from 80°C to 50°C temperature is shown in **figure 4** and **figure 5**. From the results we can see that the difference of cooling time required is 21.90%, 25.63%, 28.56% and 31.69% for 2%, 2.5%, 3.0%, and 3.5% vol concentration of Al_2O_3 nano fluid respectively as compared to base fluid i.e. there is significant cooling time reduction using nano fluid compared to base fluid. Also as % concentration of nano increases the time required is reduces. Pumping power is directly proportional to % vol. concentration, but it's not applicable while considering time required for cooling of same interval, like our case of 30°C. Pumping power requirement is high for base fluid and it's significantly low for nano fluid. Pumping power required for 2% Al_2O_3 nano fluid is 23.81 % less than base fluid. The pumping power is not having significant difference after 2.5% vol. concentration, as shown in **figure 6**. Relation between time required for cooling and pumping power is shown in **figure 7**. Time required for cooling is directly proportional to nano % vol. concentration. Pumping power is not having certain relation for same operating cycle, as we found that after 2.5% vol. concentration it's not having significant difference. The pumping power consumption is less for nano fluid as there is reduction in time of cooling.

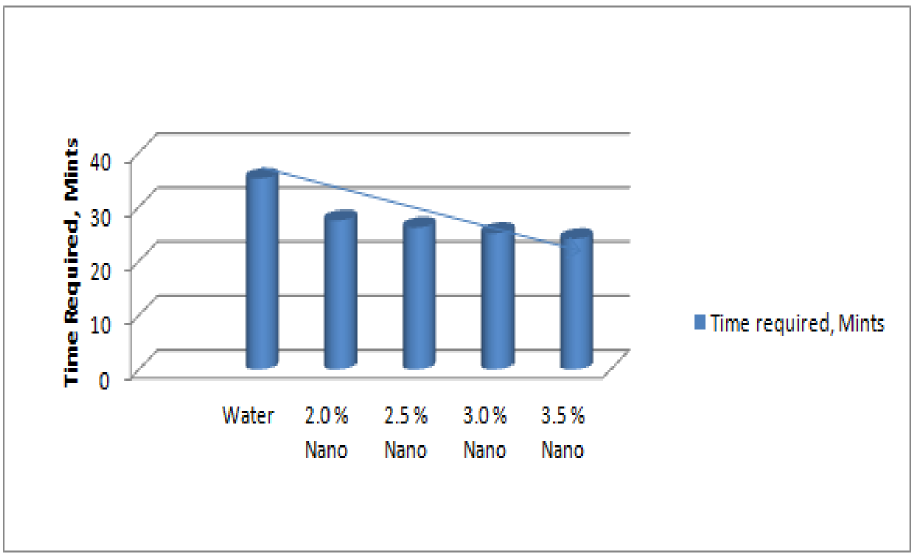

Figure 4: Time required to each working fluid for cooling from 80°C to 50°C

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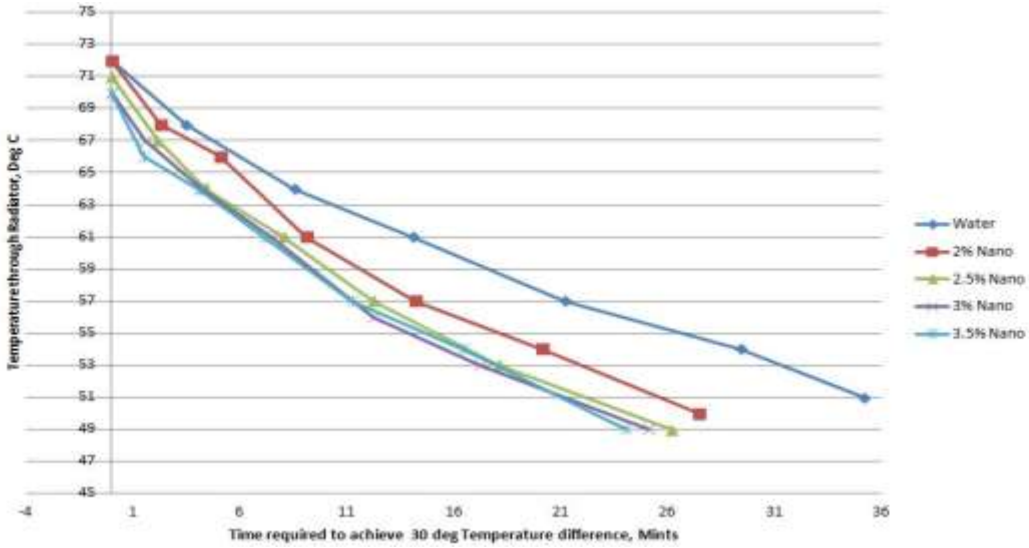

Figure 5: Temperature Vs Time plot for working fluids

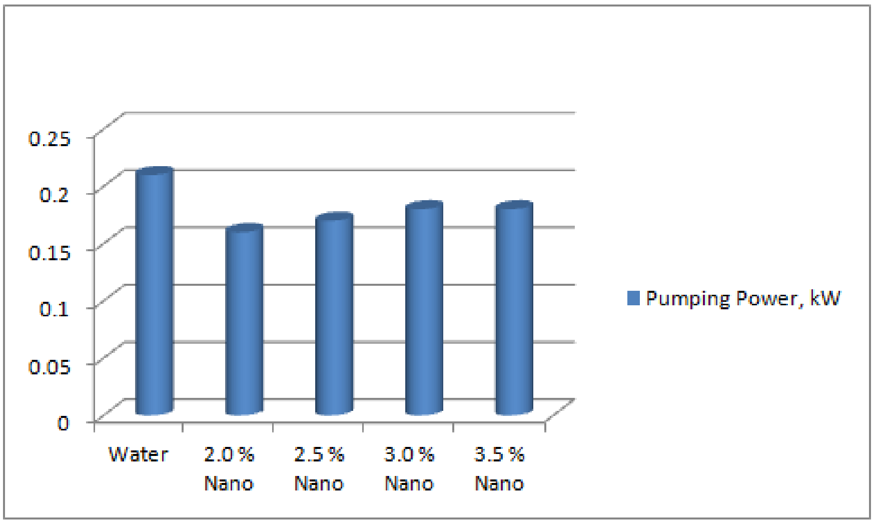

Figure 6: Pumping power required by each working fluid for achieving cooling from 80°C to 50°C

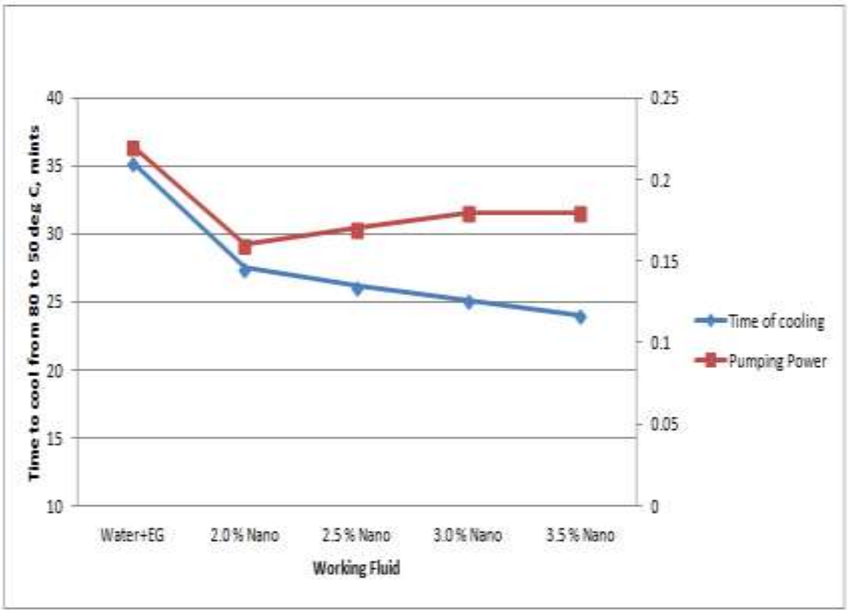

Figure 7: Time and pumping power requirement of base fluid

Further, Radiator effectiveness is calculated at time interval of 5, 12 and 20 minutes of cooling. The readings are interpolated for these time intervals and the effectiveness is calculated at respective time. From results it's observed that the radiator is having highest effectiveness at 2.5 % vol. concentrations for all time intervals. Compared to base fluid, 2.5% Al_2O_3 has highest effectiveness as 34.01 % at 12 minutes interval; 27.51% and 27.95% at 5 and 20 minutes respectively. The results are shown in **figure 8** and **figure 9** below.

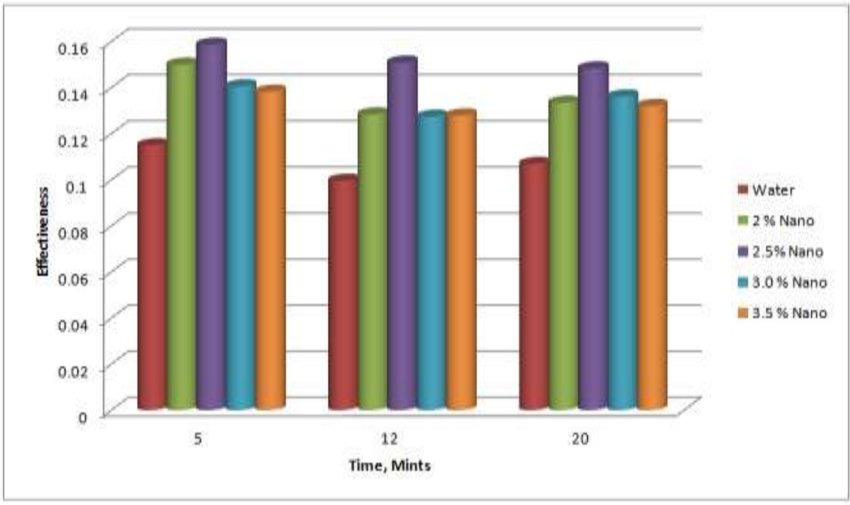

Figure 8: Radiator effectiveness chart for working fluids at 5, 12 and 20 minutes

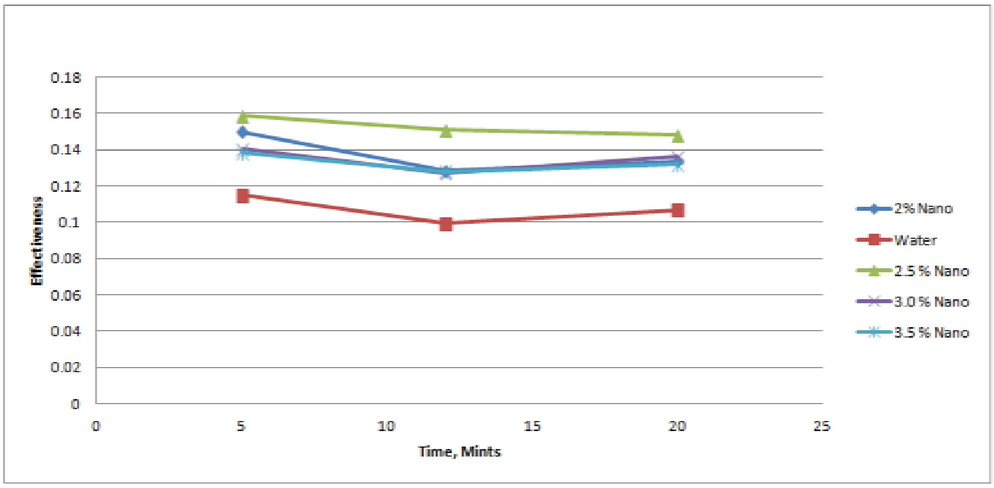

Figure 9: Radiator effectiveness graph for working fluids at 5, 12 and 20 minutes

6. CONCLUSION

From the study of base fluid and 2-3.5% vol. concentration of Al_2O_3 nano fluid, following are the observed points:

- Time required for cooling is directly proportional to nano vol. concentration. In best possible conditions nano fluid requires 31.29% less time to cool than base fluid.
- Pumping power is not having uniform relation with vol. % concentration for same temperature interval. Pumping power for 2% Al_2O_3 vol. concentration is less by 23.81 % than base fluid. It increases for 2.5% and it remains same after 2.5% vol. concentration. But for all nano fluids it remains less than base fluid.
- Radiator effectiveness is good for nano fluids compared to base fluid and in best possible condition it's as high as 34.01 %. The highest effectiveness is found at 2.5% concentration.

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