Experimental Investigation of Automobile radiator using Tungsten trioxide Nano-fluid

K S Hanumanth Ramji¹, J Vinoth kumar², and A Amar Karthik³

¹,² Assistant Professor, Department of Mechanical Engineering, Bannari Amman Institute of Technology-Erode, India.
³ Professor, Department of Mechanical Engineering, Bannari Amman Institute of Technology-Erode, India.
hanumanthramjiks@bitsathy.ac.in, vinothkumar@bitsathy.ac.in, amarkarthik@bitsathy.ac.in

Abstract. Conventional fluids (ethylene glycol and H₂O) heat transfer performance results to be poor when incorporated with an automobile radiator. An experimental study was performed to explore the enactment of automobile radiator using H₂O and WO₃ nanofluid as operational fluids. Analysis and comparison were carried out for the heat transfer rate and outlet temperature of fluid for various flow rate ranging from 0.2m³/hr to 0.5 m³/hr. Preparation of nanofluid was done for water with 0.0167%, 0.034% and 0.0667% volume concentration of WO₃ nanoparticle. The inlet condition of fluid was set at 50°C as the impact for the variation of temperature conditions on system performance were minimal. On experimentation, the maximum increase in the heat transfer rate was by 4.18% on comparison with base fluid.

Keywords: Nanofluid, Radiator, Heat transfer rate, WO₃, Performance

1. Introduction

Heat dissipation using conventional coolant fluid is employed in most of the engineering systems. At present nanofluids (base fluid dispersed with nanoparticle) outperforms significantly in most of the heat transfer systems. Enough precaution need to be carried out to prevent fouling, sedimentation and increase of pressure drop. To increase the performance of the heat transfer system needs either increase in size of the system or increase in performance of cooling fluid. Due to structural constraint it’s good for increasing the performance of the coolant. Peyghambarzadeh et al. [1] investigated the radiator performance using Al₂O₃/Water nanofluid for rate of flow range 2-5 lit/min and coolant inlet temperature range 37-49°C. They concluded an increase of 45% in rate of heat transfer for 1% volume concentration nanofluid on comparison with water and minimal effect on performance for variation in inlet temperature of coolant. Sharma et al. [2] conducted experimental study on a radiator using Al/water nanofluid of 0.2% volume concentration and 0.3 volume concentration with inlet coolant fluid temperature range from 45°C-55°C. They resulted with a 23.563% increase in coefficient of heat transfer for volume concentration of 0.3%. Selvam et al.[3] summarized the enhancement of the Nusselt number for volume concentration of 0.5%. GnP/(water/EG) nanofluid by about 88% at 35°C and 90% at 40°C. Oliveira et al. [4] studied the application of MWCNT (Multi-Walled Carbon Nanotube)/water of 0.05-0.16 weight.% in an automotive radiator for coolant inlet temperature range 50°C-80°C and resulted in 17% decrement in heat transfer for 0.16 weight % nanofluid. Ali et al. [5] investigated the performance of a radiator using ZnO/Water nanofluid of 0.01%-0.3% volume concentration for inlet temperature 45°C-55°C and concluded with an enhancement of 46.5% by using 0.2% volume concentration nanofluid. Ali et al. [6] conducted experimental study on a radiator using 0.06, 0.09, &0.12 volume concentration MgO / water nanofluid and resulted with a 31% increase in the heat transfer rate for 0.12 volume concentration %. Naraki et al.
[7] studied the application of CuO/water nanofluid of 0.04-0.4 volume concentration % and resulted in 8% enhancement in overall heat transfer coefficient for using 0.4 volume concentration % nanofluid. Hussain et al.[8] investigated the performance of a radiator using SiO2/Water nanofluid of 1%-2.5% volume concentration for inlet temperature 60°C-80°C and the coolant flow rate of 2-8 lit/min. They concluded with an enhancement of 46% by using 2.5% volume concentration nanofluid. Ahmed et al.[9] conducted experimental study on a radiator using TiO2/water nanofluid of 0.1% volume concentration, 0.2% volume concentration and 0.3 volume concentration with inlet coolant fluid temperature range from 20°C-80°C and found the maximum overall heat transfer coefficient of 2050 W/m²K 23.563% for 0.3% volume concentration Palaniapan et al. [10] studied the application of Flyash nanofluid of about 2% volume concentration in a radiator for Reynold number range 4000-8000 and resulted in 43.7% increase in heat transfer at Reynold number 8000 and 2% volume concentration nanofluid. From the literature there is no study for automobile radiator using tungsten trioxide nanofluid. Tungsten Trioxide nanoparticles are a category of semiconductors that are broadly used in photo thermal systems, based on the awareness of the authors, this type of particles have not been castoff yet in automobile radiator as the additive to working fluid. Hence, the current paper targets to analyse the result of using WO3/water nanofluids at various concentrations on the performance of a radiator.

2. Heat transfer rate analysis:

Calculation of heat transfer rate in radiator is obtained by using Eq. (1) & Eq. (2)

\[ Q = m c_p (T_i - T_o) \]  
\[ Q = h A (T_b - T_w) \]  

(1)
(2)

The nanofluid’s specific heat capacity can be calculated by using Eq. (3) [11]

\[ c_{p,nf} = \frac{(1-\varphi)\rho_{bf}c_{p,bf} + \varphi \rho_{nf}c_{p,n}}{(1-\varphi)\rho_{bf} + \varphi \rho_{nf}} \]  

(3)

The nanofluid’s density is calculated from the following Eq. (4) [11]

\[ \rho_{nf} = (1 - \varphi)\rho_{bf} + \varphi \rho_{nf} \]  

(4)

The nanofluid’s Thermal conductivity is calculated from the following Eq. (5) [11]

\[ k_{nf} = \frac{k_p + (n-1)k_{bf} - \varphi(n-1)(k_{bf} - k_p)}{k_p + (n-1)k_{bf} + \varphi(n-1)(k_{bf} - k_p)} \]  

(5)

The nanofluid’s viscosity is calculated using Eq. (6) [11]

\[ \mu_{nf} = \mu_{bf}(1 + 2.5 \varphi) \]  

(6)

The Nusselt number for the entire radiator can be calculated using the Eq. (7) [11]

\[ Nu_{exp} = \frac{k_{exp} x D_h}{k} \]  

(7)

Volume fraction of the nano particle is calculated by using Eq.(8)

\[ \text{Density} = \text{mass} / \text{volume} \]  

(8)

Initially, the rate of heat transfer in the radiator setup is analysed using H2O as working fluid. As the properties of H2O are standard, the specific capacity of heat, density, thermal conductivity and viscosity
are taken from data books for corresponding working temperatures. Input parameters such as mass flow rate(m), inlet fluid temperature(Ti), outlet fluid temperature(To) and bulk mean temperature(Tb) are measured using 4 RTD Pt 100 type temperature sensors with ±0.1 °C accuracy. On substituting these parameters in Eq.(1) we obtain the rate of heat transfer. Further the calculated rate of heat transfer along with the surface area(A), bulk mean temperature(Tb) and the surrounding temperature(Tw) are substituted in Eq.(2) to obtain heat transfer coefficient(h). For nanofluid in the radiator setup, the properties-specific heat capacity, density, thermal conductivity and viscosity are found out using Eq.(3), Eq.(4), Eq.(5) and Eq.(6).

3. Preparation of nanofluid and experimentation

3.1. WO3 nanofluid synthesis

Without extra processing and of diagnostic grade, all chemicals substances were used as received. Supplier of the WO3 nanoparticle: Nano Research labs, Jharkhand, India. The size of nanoparticle is of the range of 40-50 nm and 99.9% purity. The spherical shaped nanoparticles possess a lower value of thermal conductivity than the cylindrical shaped nanoparticles same way the thermal conductivity of smaller size elements is greater than the thermal conductivity of larger size particles[14]. Nanofluids can be prepared using 1 step and 2 step method. Due to ease in preparation, nanofluid is prepared using 2-step method. Initially, grinding of WO3 nanoparticles are done by means of a mortar to prevent or minimize agglomeration. Later, the addition of WO3 nanoparticles with distilled water by an appropriate mass fraction and the mixture is manually agitated for a minimal period of 10-min. The prepared mixture is placed in the ultrasonic bath (ANALAB, India) under sonication with a frequency of 30 kHz, 1000 watts power during a period of 4 hours[12]. Three different nanofluids of 0.0166%, 0.0334% and 0.06667% volume concentration is prepared. Finally, stability testing of nanofluid is carried out using Zeta potential analyzer.

3.2. Nanofluid stability

To avoid nanofluid sedimentation during the trials, by using ultrasonication the nano-WO3 and water is mixed. Two methods have been proposed for uniformly distribute nanoparticles in nanofluids and to prevent sedimentation; using surfactants and changing nanofluids pH [15]. For all temperatures in the experimental procedure, the stability of nanofluid is found to be maintained.(Fig. 1).

Figure 1. Ultrasonicator
3.3. Experimentation

The experimental setup comprises an automobile radiator with a fan, a reservoir, connectors, rotameter, pump, thermometers, a heater, small fuses, tubes and expansion resource. 4 RTD Pt 100 type sensors(temperature) with ±0.1 °C accuracy offer tremendous exactness over an extensive range of temperature (from –200 to +850 °C) are used to quantify the inlet and outlet temperature of the fluid used as coolant and temperature of the radiator. The experiment was conducted in Government college of Engineering-Salem, India. The circulation of operational fluid into the radiator is done through pump (500W). On circulation, the working fluid enters the radiator initially and then it arrives a tank with 20 L capacity and continues the process. The constant temperature bath is utilized to cool the gain of heat obtained from the radiator. Flow rate adjustment (three way valve), a rotameter for the desired flow rate upto 4 l/min and a pressure indicator for water and nano fluid. The flow rate of the working fluid is limited to 0.5 m³/hr above which it ceases to be in laminar flow regime[9]. Radiator specification, test condition for experimentation and properties of the nano particle WO₃ is shown in Table 1. and Table 2. The Schematic layout of experiment apparatus is showed in Fig. 2.

| S.No | Parameter                        | Value (cm) |
|------|----------------------------------|------------|
| 1    | Radiator length                  | 38.4       |
| 2    | Radiator width                   | 33         |
| 3    | Radiator height                  | 2.2        |
| 4    | Width of the radiator tube       | 0.2        |
| 5    | Fin length                       | 1          |
| 6    | Distance between adjacent fins   | 0.1        |
| 7    | Fin thickness                    | 0.008      |

| Parameter                                      | Water based nanofluid               |
|------------------------------------------------|------------------------------------|
| Nanoparticle concentration (volume %)          | 0-0.0667%                          |
| Nanoparticle                                   | WO₃                                |
| Inlet temperature (K)                          | 323                                |
| Volumetric flow rate (m³/hr)                   | 0.2 to 0.5                         |
| Reynold number                                 | 200-600                            |

| S.No | Parameter                    | Value          |
|------|------------------------------|----------------|
| 1    | Density                      | 7160 kg/m³    |
| 2    | Thermal conductivity         | 1.63 W/m-K     |
4. Results and Discussion

In this study, experimentation is carried out using WO₃ nanofluid with concentrations 0.0167, 0.0334 and 0.0667 volume concentration % for various rates of flow from 0.2 to 0.5 m³/hr as working fluids. Volume concentration are limited to 0.066% since further increase in volume concentration tends to increase pumping power for nanofluid drastically. However, may professionals settle that an prime enactment can be attained at a little nanoparticle volume element of less than 1% [13].

Figure 3 it depicts an increase of the rate of heat transfer with the rise in rate of flow and nanoparticle concentrations. An increase in the coefficient of heat transfer is resulted at high flow rates due to mixing fluctuation produced by the effect of diffusion and the disordered movement of the nanoparticles. A surge in the heat transfer was found by a surge in volume concentration of nanoparticle addition with H₂O. The figure 2 shows outlet temperatures of radiator, Tₘₐₓ, as a utility of volume flow rate circulating in the radiator. It can be observed that accumulation nanoparticles to base fluid tends to reduce radiator outlet temperature. It can be concluded as for the equal mass flow rate in a heat transfer system tends to reduce fluid outlet temperature thus enabling improvement in thermal enactment of the system. Figure 2 also displays depreciation in the rate of heat transfer for rise in the volume flow rate passed through the system. The reason would be due to rise in the fluid velocity impacted by the rise in the volume flow rate. Thus, the fluid would have minimal duration for relating itself with the air circulated through fan and results in the rise of the exit temperature of coolant. It will be illustrious that all the statistics in Figure 2 were found for 54 C of radiator fluid inlet temperature.
Figure 3 illustrates the heat transfer enhancement in a radiator is obtained due to the use of nanofluids instead of base fluid. It can be perceived that the ratio of thermal energy transfer by nanofluid to base fluid increases with volume flow rate irrespective of nanofluid concentrations. In addition, the impact of volume flow rate is insignificant at higher concentration nanofluid. Also, Figure 4 displays that for an addition of 0.0667 volume concentration % WO$_3$ nanoparticle to water mixture, the heat transfer rate was found to increase by 4.18% on comparison with the heat transfer rate on using water. Moreover, suggestions by the researcher on enhancement of heat transfer due to the significant factor Brownian motion is detailed.

Finally, the replacement of conventional cooling fluid by nanofluid in car radiators, would surge the rate of heat transfer. An increased rate of heat transfer is depicted the addition of nanoparticle with the base fluid on using with the radiator. Thus results the possibility of a reduction in radiator size as well as reduced weight. So an improved fuel economy and reduced emission to an environment would be achieved.
5. Conclusion:
In this study, the impact of WO$_3$/Water nanofluids in a radiator was examined. On evaluation with water, the rates of heat transfer enhanced significantly for the usage of (WO$_3$/Water) nanofluid on evaluation to the water. In the preeminent condition, the maximum improvement in the rate of heat transfer was obtained to be 4.18% for 0.067 volume concentration % of (WO$_3$/Water) fluid. The investigational outcomes exhibited that heat transfer rate enhanced with the rise in flow rate of (WO$_3$/Water) fluid. Also, the surge in volume concentration amplified the heat transfer rate. The outcomes specifies that utilizing (WO$_3$/Water) fluid can surge the rate of heat transfer. Hence, providing hopeful means for scientists to improve extremely compact and effective automotive radiators. The weight reduction of radiator in turn reduces the consumption of fuel. Moreover, it can offer effective heat transfer and maximized the lifespan of sections of a vehicle.

Acknowledgment
This research was supported by the mechanical engineering department that was provided Government college of engineering, Salem.

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