Enhancement of Radiator Performance by using TiO_2 Nanofluid– A Review

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ABSTRACT - *In the current age of science and technology automobile vehicles have always been one of the top priority products for the public. The demand for vehicles never depreciated since its genesis. And therefore for engineers it has been a challenge to continuously upgrade and to provide the best engines which are efficient along with being economical. When we talk about engines there are many factors which affect its efficiency like the amount and type of lubrication provided, type of fuel and supply system used and cooling method used etc. Hence by altering these parameters somehow we can control the efficiency of an engine. Therefore it is necessary to have good idea and proper calculation of them. Our main focus here is on the cooling system hence radiators which are the important part of an engine. Mostly internal combustion engines use air for the purpose of cooling which passes through the heat exchangers. Heat transfer through the Radiator can be improved by increasing the heat transfer area and it can be also improved by increasing the heat transfer coefficient. The heat transfer coefficient can be increased by using more efficient heat transfer techniques. Previously, water was widely used as a coolant in radiators because it easily obtained heat and it has better ability to hold heat transfer. Water & ethylene glycol mixture was then introduced into the coolant for improving the performance of the engine. By using a nano-fluid based coolant in an Automobile radiator, it increases the coolant flow rate and improves heat transfer performance. Nanofluids are suspension of metallic or nonmetallic nanoparticles in the base fluid. It can be used to increase the heat transfer rate of cooling. So as to decide the impact of TiO2-water nanofluid on radiator , tests were performed with water and TiO2-water nanofluid independently .For this tests were done utilizing a TiO2 nanofluid with 0.1, 0.2 and 0.3% volume focuses with stream paces of 0.097 and 0.68 m3/h in laminar flow , where Reynolds number extended from 560 to 1650. Our outcomes show that the erosion factor diminishes when Reynolds number and the volume fixation are expanded. In addition, TiO2-water nanofluid with 0.2% fixation can improve the ability of vehicle Radiator by 47% when contrasted with 0.1 and 0.3% focused water as a coolant.*

KEYWORDS- Heat transfer enhancement, Propylene Glycol, Radiator, TiO2 Nanofluid coolant. Radiator, Cooling System, Engine, Nano Fluids

1. INTRODUCTION

In an automobile lot of heat is produced due to the combustion, only a portion of heat is utilized to produce the power rest of heat is wasted in the form of exhaust heat. If this excess heat is not removed, the engine temperature becomes too high which results in overheating and due to thermal stress of the engine components failure may occur in engine. So that a cooling system is required. The automobile engine utilizes a heat exchanger device, termed as ―Radiator, in order to remove the heat from the cooling jacket of the engine. Normally, it is used as a cooling system of the engine and generally water is the heat transfer medium. For the purpose of producing high efficiency engine we need look at reducing a vehicle weight by optimizing design and size of a radiator is a necessity for making the new design model of radiator. For the need of the high performance cooling, heating efficiency, energy saving, less generation of greenhouse gases nanotechnology is applied to thermal engineering. Taking into account the rising demands of modern technology, it has been recently proposed that dispersion of small amounts of nanometer sized solids in the fluid called nanofluids can enhance the thermal conductivity of fluids.

2. WORKING OF COOLING SYSTEM

Actually, two types of cooling systems are found in motor vehicles: liquid-cooled and air-conditioned.

Air cooled engines are found in the original Volkswagen Beetle, Chevrolet Corvette and a few older cars. Many modern motorcycles still use air-conditioning, but often, Automobiles and trucks use liquid-cooled systems, which is what this article will focus on.

The cooling System is made up of:

- *passages inside the engine block and heads*
- *a water pump to circulate the coolant*
- *A thermostat to control the temp. of the coolant*
- *a radiator to cool the coolant*
- *a radiator cap to control the pressure in the system*

- *interconnecting hoses to transfer the coolant from engine to Radiator (and also to the car's heater System where hot coolant is used to warm up the vehicle's interior)*

A cooling System works by sending a liquid cooler through the passages in the engine module and heads. When the coolant flows in these passages, it takes the heat from the engine. The hot fluid then passes through a rubber tube to the Radiator in the front of the car. As it flows through the thin tubes in the radiator, the hot liquid is cooled by the air current entering the engine compartment from the grill in front of the car.

Once the liquid has cooled, it returns to the engine to absorb excess heat. The water pump has the job of moving the fluid through this System of plumbing and hidden passages.

A thermostat is placed between the engine and the Radiator to ensure that the coolant is above a certain preset temp.. If the cooling temp. Falls below this temp., the thermostat prevents the cooling flow to the radiator, directing the fluid to the engine via the bypass.

The coolant will continue to circulate until the design temp. Is reached, at which point the thermostat will open a valve and allow the coolant back through the radiator.

The cooling System is designed to be compressed to prevent overheating. Under pressure, the boiling point of the coolant is significantly raised. However, high pressure can cause holes and other areas to burst, so a System is required to reduce the pressure if it exceeds a certain point.

The job of maintaining the pressure in the cooling System belongs to the Radiator cap. It is designed to release pressure when the System reaches a certain high limit designed to handle it. Before the 70s, the cap would release this extra pressure to the sidewalk. Since then, a System has been added to capture any released liquid and temporarily store it in a reserve tank. This fluid returns to the cooling System after the engine cools.

This is called a closed cooling system.

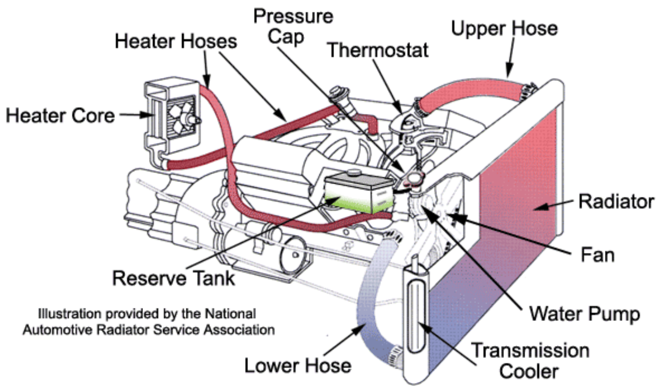

Figure 1 Cooling System in Automobile

3. RADIATOR

The Radiator is a device designed to dissipate the coolant heat from the engine. It is built to hold large amounts of water in pipes or columns that provide a large area for contact with the atmosphere. It usually consists of a Radiator core, with its water-carrying tubes and large cooling area, which are connected to the receiving tank (end cap) and a dispensing tank at the bottom. Side flow radiators have their "endcaps" on the sides, allowing for a lower hood line. In the process, water is pumped from the engine into the top (receiving) tank, where it spreads to the top of the pipes. When water goes down through the pipes, it loses its heat to the air that surrounds the outside of the pipes. To help spread hot water over all the pipes, a barrier plate is often placed in the top tank, directly underneath the entrance pipe from the machine.

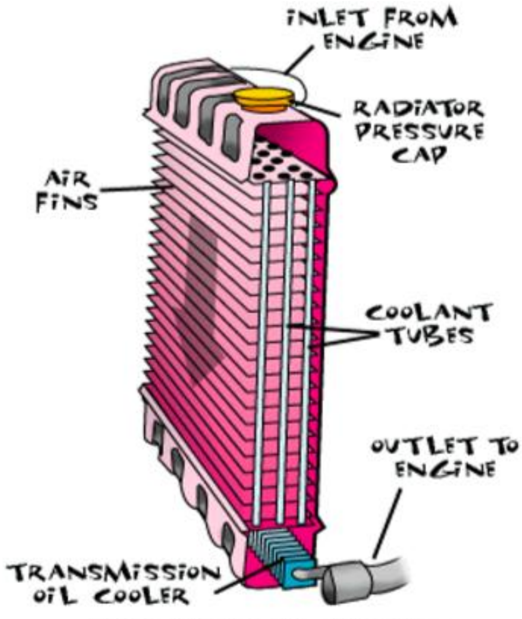

Figure 2 Schematic of Radiator

4. NANO-FLUID

Nanofluids are two-phase composites that can be applied to nanometer-sized particles at 100 nm in base fluids. Nanomaterials, nanofibers, nanotubes, nanowires and nano-rods are nanometer-sized particles used to disperse in basic fluids. Materials commonly used as nanoparticles include metal oxides, oxide ceramics, chemically stable metals, carbon metal carbides in various forms, and functional nanoparticles. Basic liquids include organic liquids such as oils, water, glycol, refrigerants, polymeric solvents, biofuels, lubricants, and other common liquids.

"Nano-fluid = Base-fluid + Nanoparticle "

5. WHY USING NANO FLUID?

The primary objective or thought of utilizing Nano liquids is to achieve most noteworthy conceivable warm properties at *the littlest potential fixations (preferably<1% by volume) by uniform scattering and stable suspension of Nanoparticles (preferably<10 nm) in hot liquids. A Nano liquid is a blend of water and suspended metallic Nano particles. Since the warm conductivity of metallic solids are normally significant degrees higher than that of liquids it is normal that a strong/liquid blend will have higher compelling warm conductivity contrasted with the base liquid. Nano liquids are incredibly steady and show no noteworthy settling under static conditions, much after weeks or months.*

6. PROPERTIES OF NANOFLUIDS

1. Compared to micrometer-sized particles, the nanoparticles have a higher surface area ratio because of the large number of atoms at the boundary and are more stable in the suspensions.

2. Nanoparticles exhibit high thermal conductivity due to enhanced convection between solid particles and liquid surfaces.

3. The thermal conductivity of nanosized materials is usually of a higher order than that of the base liquids.

4. Due to its low dimensions, dispersed nanoparticles can act as a basic liquid molecule in a suspension, which helps to minimize particulate matter and sedimentation problems with microscopic particle suspensions.

5. Nanofluids provides better lubrication.

7. EXPERIMENTAL METHODOLOGY

Experimental Setup

"The heat transfer rate of the nanofluid coolant was measured using an experimental setup as shown in Fig. 1. It consists of a car radiator, an electric heater, a reservoir tank, a centrifugal pump, an air blower, flow control valves and K-type thermocouples to measure inlet and outlet fluid temp..

An electrical heater of 2 kW was used to heat the coolant in the reservoir tank. The coolant was circulated using a 0.5 HP centrifugal pump. A globe valve was used to vary the flow rate of the coolant fluid entering the Radiator in between 3-6 lit/min. Two K-type thermocouples were placed at the inlet and the outlet of the Radiator to measure the coolant temp. Thermocouples were also fixed on both sides of the Radiator wall surface to measure air temp.

Experimental Procedure

The forced convective heat transfer experiment was conducted in the Radiator experimental setup using pure water, water/propylene glycol mixture (70:30), and water/propylene glycol/TiO2nanofluid (0.1% and 0.3% by volume). The coolant in the reservoir tank was heated up to the desired temp. And circulated through the Radiator using the pump. The inlet temp. of the coolant to the Radiator is kept constant at the nominal operating temp. Range between 50°C to 80°C. The coolant flow rate was varied between 3 to 6 l/min. The air flow rate to the Radiator was kept constant at an average of 4m/s. The outlet temp. of the coolant was recorded using a K-type thermocouple. Furthermore K-type thermocouples were fixed on the Radiator wall on both the sides to record the air temp.

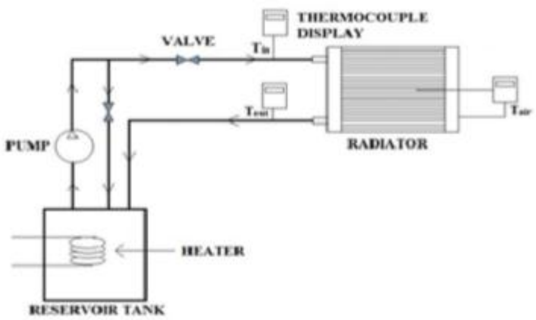

Figure 3. Schematic view of experimental setup

8. NANOFLUID PREPARATION

Titanium dioxide (TiO2) nanofluid was prepared in two different concentrations 0.1% and 0.3% by volume of the base fluid using two-step method to understand the effects of particle concentration on heat transfer rate. The base fluid was the mixture of water and propylene glycol in the ratio 70:30. The dry nanoparticles were added directly in the base fluid at required concentrations. The dispersion process was carried out using probe ultrasonicator ENUP 250.

The nanofluid was subjected to ultrasonication in the frequency of 20Hz for the duration of 6 hours.

The density, specific heat and thermal conductivity of nanofluid were calculated using two phase flow equations [1], [2].

9. HEAT TRANSFER COEFFICIENT CALCULATION

To obtain heat transfer coefficient and corresponding Nusselt number, the following procedure has been performed.

According to Newton's cooling law: $Q = hA\Delta T = hA(Tb-Tw)$

Heat transfer rate can be calculated as follows $Q = mCp\Delta T = mCp\,(Tin-Tout)$

Regarding the equality of Q in the above equations

$$Nu = h_{exp}d_{hy}/\,K = mc_p(Tin - Tout)/\,A(Tb - Tw)$$

Nu is average Nusselt number for the whole radiator, m is mass flow rate which is the product of density and volume flow rate of fluid

Cp is fluid specific heat capacity, A is peripheral area of radiator tubes, T in and Tout are inlet and outlet temperatures, Tb is bulk temperature which was assumed to be the average values of inlet and outlet temperature of the fluid moving through the radiator, and Tw is tube wall Temperature which is the mean value by two surface thermocouples. In this equation, k is fluid thermal conductivity and dhy is Hydraulic diameter of the tube. It should also be mentioned that all the Physical properties were calculated at fluid bulk temperature.

10. RESULT AND DISCUSSION

Effect of flow rate on Nusselt number

The comparison of Nusselt number among TiO2nanofluid and base fluid at different temperatures and mass flow rate was shown in Fig. 4. It was observed that the Nusselt number increases with increase in mass flow rate for both base fluid and nanofluid concentrations. Initially at 50°C of coolant inlet conditions the water/propylene glycol mixture has highest Nusselt number. The nanoparticles did not have much influence on the Nusselt number at lower inlet temperatures. The Nusslet number of nanofluids increases gradually with inlet temperature and at 80°C the nanofluid with 0.3% TiO2 has highest Nusselt number as shown in Fig. 4(d). This shows that the TiO2nanofluids have good conduction to convective ratio at higher temperature and flow rate. The particle concentration in nanofluid shows that, at 0.1% the Nusslet number does not show improvement when compared to water/propylene glycol mixture. When concentration increases to 0.3% the Nusselt number also increases above that of the base fluid.

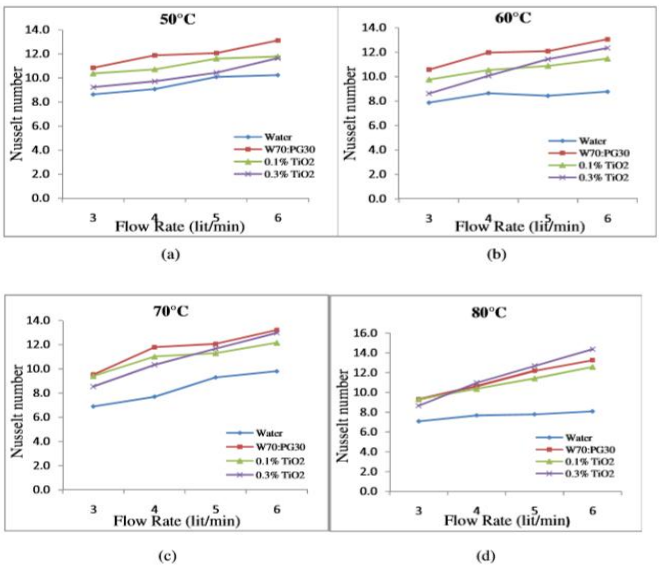

Figure 4. Effect of flow rate on Nusselt number (a) at 50)C (b) at 60)C (c) at 70)C (d) at 80)C

Effect of flow rate on Heat Transfer rate

The heat transfer rate of TiO2nanofluid coolant was compared with pure water and water/propylene glycol mixture. Fig. 5 illustrates that heat transfer rate of TiO2nanofluid increases with increase in volume flow rate. Initially at lower inlet temperature at 50°C the water and propylene glycol mixture shows higher heat transfer rate than nanofluids this was due to the high specific heat capacity and low density of water and base fluid mixture. When inlet temperature increases the heat transfer rate of nanofluid gradually increases due to the Brownian motion of nanoparticles. The density of coolant fluid decreases at higher temperature so that the random motion of nanoparticles increases and the particle comes in contact with surface of the fins which leads to increase heat transfer rate. Fig. 5 (d) shows that at 80°C of inlet conditions the nanofluid with 0.3% TiO2 has highest heat transfer rate. Therefore heat transfer enhancement in TiO2nanofluid occurs at higher temperature and flow rate[3].

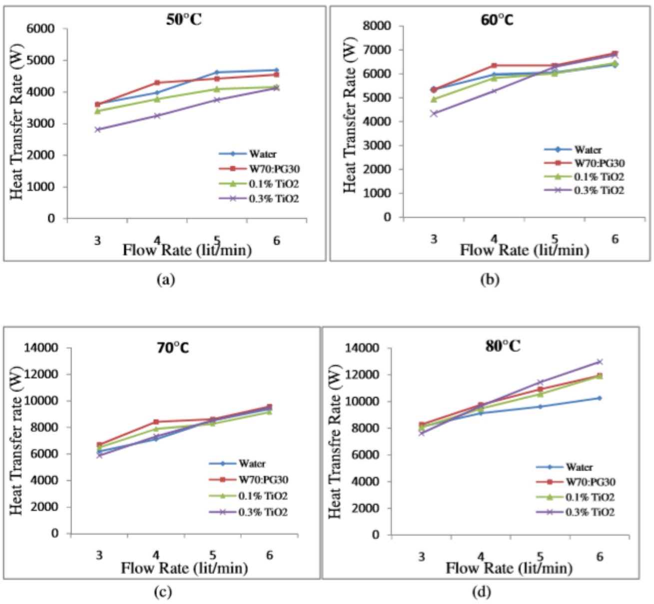

Figure 5 .Effect of flow rate on heat transfer rate (a) at 50)C (b) at 60)C (c) at 70)C (d) at 80)C.

11. CONCLUSION

It was found that nanofluids could be considered a potential candidate for Automobile use. Since Nanofluids can improve heat transfer, energy in Automobile radiators can be done efficiently and concisely. Reduced or smaller form can reduce traction, increase fuel economy, and reduce vehicle weight. The exact mechanism of enhanced heat transfer for Nanofluids has been reported by many more researchers. There are different challenges of Nanoliquids that need to be identified for the use of Automobile radiators.

Effect on flow rate

Increasing the flow rate of working fluid enhances the heat transfer coefficient for both pure water and nanofluid considerably while the variation of fluid inlet temp. to the Radiator slightly changes the heat transfer performance.

Effect on Thermal Conductivity

It seems that the increase in the effective thermal conductivity and the variations of the other Physical properties are not responsible for the large heat transfer Enhancement. Brownian motion of nanoparticles may be one of the factors in the enhancement of heat transfer. Although there are recent advances in the study of heat transfer with nanofluids, more Experimental results and theoretical understanding of the mechanisms of the particle movements are needed to explain heat transfer behavior of nanofluids.

Effect on weight and space

Lighter and compact heat exchange system can be designed due to better heat transfer obtained using nanofluid.

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