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Advance Cooling of Radiator by Using Nano Fluids

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Abstract – Today, the demand of automobile vehicles is on peak. So, it is a great challenge for automotive industries to provide an efficient and economical engine. The performance of an engine affects by various systems like fuel supply system, lubrication system, transmission system, cooling system etc. So, it becomes essential to account them while designing an engine for improves the engines performance. Cooling system is one of the important systems amongst all. It is responsible to carry large amount of heat waste to surroundings for efficient working of an engine. It also enhances heat transfer and fuel economy which leads to maximize the performance of an engine. Most internal combustion engines are fluid cooled using either air or a liquid coolant run through a heat exchanger (radiator) cooled by air. The heat transfer through radiator can be improved by maximizing the heat transfer area and increasing the heat transfer coefficient. The heat transfer coefficient can be increased either by using more efficient heat transfer methods or by improving the thermos-physical properties of the heat transfer material i.e. Coolant. Earlier, Water was widely used in radiator as a coolant for its good ability to holding heat, transfer heat and can be readily obtained. Also the mixture of water & ethylene glycol later introduced as a coolant. But by using a Nano-Fluid based Coolant in automobile Radiator, it increases coolant flow rate can improve the heat transfer performance.

Keywords – *Radiator, Cooling System, Engine, Nano Fluids.*

I 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 viscosity breakdown of the lubricating oil, wear of the engine parts, due to thermal stress of the engine components failure may occurs 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. The radiator considered as an important component of the cooling system of the engine. Normally, it is used as a cooling system of the engine and generally water is the heat transfer medium. For this liquid-cooled system, the waste heat is removed via the circulating coolant surrounding the devices or entering the cooling channels in devices. The coolant is propelled by pumps and the heat is carried away mainly by radiator. 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.

Nano-fluid is nothing but Nano-meter sized particles suspended in base fluid which was innovated by Choi. In this technology requirement is addressed by two means i.e. one is geometry which tells the particle size and the second one is fluid being used. Nano-fluids have unique features different from convectional solid- liquid mixtures in which mm (or) μm sized particles of metals and non-metals are dispersed. Due to their excellent characteristics, Nano-fluids find wide application in enhancing heat transfer characteristics namely extreme stability, ultra-high thermal conductivity. Heat transfer surface area increases due to Brownian motion and inter particle forces so that increased thermal conductivity, increased single-phase heat transfer, increased critical heat flux occurs. Nano particles are very small in size, usually < 100 nm. Nano-fluids used many applications like microelectronics, fuel cells, pharmaceutical process, hybrid power engines, engine cooling, vehicle, thermal management, domestic refrigerator, heat exchangers, in grinding, mashing, boiler flue gas temperature reduction, geothermal extractions of geo thermal power and other energy sources, cryopreservation.

II COOLING SYSTEM IN AUTOMOBILE

The two working fluids are generally air and coolant. As the air flows through the radiator, the heat is transferred from the coolant to the air. The purpose of the air is to remove heat from the coolant, which causes the coolant to exit the radiator at a lower temperature than it entered at. Coolant is passed through engine, where it is absorb heat. The hot coolant is then feed into tank of the radiator. From tank of radiator, it is distributed across radiator core through tubes to another tank on opposite side of the radiator. As the coolant passes through the radiator tubes on its way to the opposite, it transfers much of its heat to the tubes which, in turn, transfer the heat to the fins that are lodged between each row of tubes. The radiator acts as a heat exchanger, transferring excess heat from the engine's coolant fluid into the air. The radiator is composed of tubes that carry the coolant fluid, a protective cap that's actually a pressure valve and a tank on each side to catch the coolant fluid overflow. In addition, the tubes carrying the coolant fluid usually contain a tabulator, which agitates the fluid inside. This way, the coolant fluid is mixed together, cooling all the fluid evenly, and not just cooling the fluid that the sides of the tubes. By creating turbulence inside the tubes, the fluid can be used more effectively.

When coolant fluid overheats, it expands, causing the fluid to become highly pressurized. When it enters the radiator, the pressure increases even more because it's in an enclosed space. The radiator cap acts as a release valve set to open at the maximum pressure point. Usually this is set at a density of 15 pounds per square inch. When the fluid pressure inside the radiator exceeds 15 psi, it forces the valve open, allowing heat to escape and excess coolant fluid to overflow into the tanks on either side of the radiator. Once the radiator cools down, the coolant fluid in the overflow tanks gets sucked back into the pump, continuing its route through the cooling system. This two-step process of cooling the transmission fluid is equivalent to a radiator within a radiator. As the heated transmission fluid enters the transmission cooler, the oil's heat is exchanged with the coolant fluid in the radiator, making the transmission fluid cooler while heating the coolant fluid instead. Then the coolant fluid's heat is transferred to air in the radiator itself.

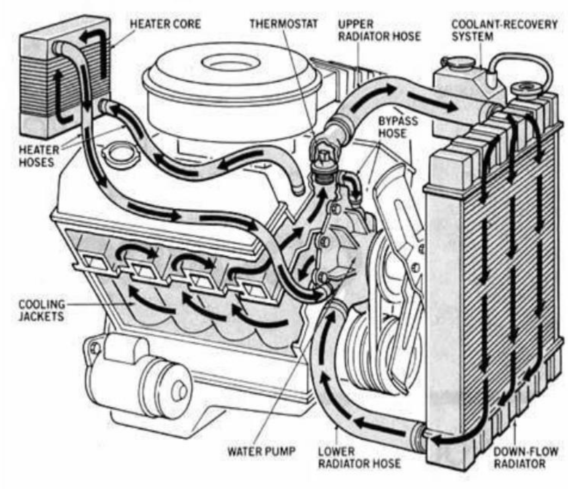

Figure 1 Cooling System in Automobile

III WHAT IS RADIATOR?

The radiator is a device designed to dissipate the heat which the coolant has absorbed from the engine. It is constructed to hold a large amount of water in tubes or passages which provide a large area in contact with the atmosphere. It usually consists of a radiator core, with its water-carrying tubes and large cooling area, which are connected to a receiving tank (end cap) at the top and to a dispensing tank at the bottom. Side flow radiators have their "endcaps" on the sides, which allows a lower hood line. In operation, water is pumped from the engine to the top (receiving) tank, where it spreads over the tops of the tubes. As the water passes down through the tubes, it loses its heat to the airstream which passes around the outside of the tubes. To help spread the heated water over the top of all the tubes, a baffle plate is often placed in the upper tank, directly under the inlet hose from the engine.

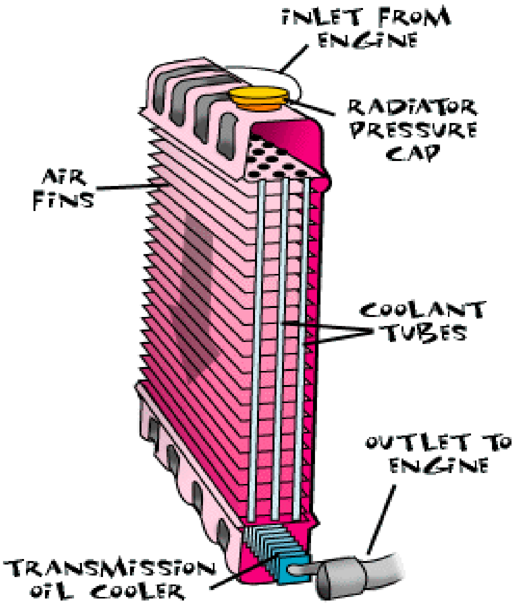

Figure 2 Schematic of Radiator

IV WHAT IS NANO-FLUID?

Nano-fluids are two phase mixtures engineered by dispersing nanometre sized particles with sizes ranging below 100 nm in base fluids. The nanometre sized particles which are used for the dispersion in base fluids are nanoparticles, nanofibers, nanotubes, nanowires and Nano-rods. Materials generally used as nanoparticles include metal oxides oxide ceramics chemically stable metals, carbon in various forms metal carbides and functionalized nanoparticles. The base fluid types include oils, water, organic liquids such as glycols, refrigerants, polymeric solutions, bio-fluids, lubricants and other common liquids.

"Nano-fluid = Base-fluid + Nanoparticle

V PROPERTIES OF NANO-FLUIDS

It may be noted that particle size is an important physical parameter in Nano-fluids because it can be used to tailor the Nano-fluid thermal properties as well as the suspension stability of nanoparticles. Researchers in Nano fluids have been trying to exploit the unique properties of Nano particles to develop stable as well as highly conducting heat transfer fluids. The key building blocks of Nano fluids are nanoparticles; so research on Nano fluids got accelerated because of the development of nanotechnology in general and availability of nanoparticles in particular. Compared to micrometre sized particles, nanoparticles possess high surface area to volume ratio due to the occupancy of large number of atoms on the boundaries, which make them highly stable in suspensions. Thus the Nano suspensions show high thermal conductivity possibly due to enhanced convection between the solid particle and liquid surfaces. Since the properties like the thermal conductivity of the Nano sized materials are typically an order of magnitude higher than those of the base fluids, Nano fluids show enhancement in their effective thermal properties. Due to the lower dimensions, the dispersed nanoparticles can behave like a base fluid molecule in a suspension, which helps us to reduce problems like particle clogging, sedimentation etc. found with micro particle suspensions. The combination of these two features; extra high stability and high conductivity of the dispersed *'Nano species'* make them highly preferable for designing heat transfer fluids. The stable suspensions of small quantities of nanoparticles will possibly help us to design lighter, high performance thermal management systems.

Cooling is indispensable for maintaining the desired performance and reliability of a wide variety of industrial products such as computers, power electronic circuits, car engines, high power lasers, X-ray generators etc. With the unprecedented increase in heat loads and heat fluxes caused by more power in miniaturized products, high tech industries such as microelectronics, transportation, manufacturing, metrology and defence face cooling as one of the top technical challenges. For example, the electronics industry has provided computers with faster speeds, smaller sizes and expanded features, leading to ever increasing heat loads, heat fluxes and localized hot spots at the chip and package levels. Such thermal problems are also found in power electronics, optoelectronic devices etc. So the enhanced heat transfer characteristics of Nano fluids may offer the development of high performance, compact, cost effective liquid cooling systems.

VI ADVANTAGES OF NANO-FLUIDS

1) The surface area and heat capacity of the fluid are increased.
2) The effective thermal conductivity of the fluid is enhanced.
3) The collision and interaction among particles, the surface of flow passage and base fluids are intensified.
4) Reduction of particle clogging rather than conventional slurries.
5) The combination of these factors makes Nano fluids highly preferable for designing heat transfer fluids.
6) These Nano fluids provide better insight into thermal management system and better lubrication.

VII PREPARATION METHODS FOR NANO-FLUIDS

The initial key step in experimental studies with Nano-fluids and the optimization of Nano-fluid thermal properties requires successful preparation methods for producing stable suspensions of nanoparticles in liquids. Some special requirements are essential i.e. negligible agglomeration of particles, uniform, durable and stable suspension and no chemical change of the fluid, etc. There are two main techniques adopted for the preparation of Nano-fluids: single-step method and two-step method.

Single step method

Single step method simultaneously produces and disperses the nanoparticles directly into the base fluid medium which is suitable for metallic Nano fluids. In this process of preparation, the condensation forms nanoparticles through direct contact between the base fluid and vapour.

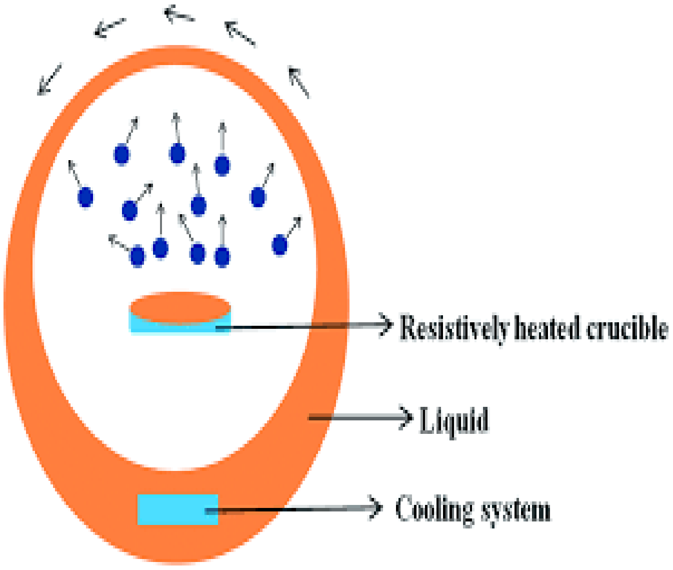

Figure 3 Single step method

The continuous circulation of base fluids minimizes the agglomeration of nanoparticles. The schematic representation of direct evaporation condensation technique is shown in figure. The researchers from Argonne National Laboratory reported yet another interesting technique is laser ablation technique, in which the metal nanoparticles in deionized water are synthesized by using multi-beam laser ablation in liquids, where the laser parameters controls the size and distribution of nanoparticles.

Two Step Method

Two-step method is the most common method for the preparation of Nano fluids and its schematic representation is shown in figure. Nano sized solid particles such as Nano rods, nanotubes, nanofibers, or other functionalized nanomaterials are used in this method. Nanoparticles are initially synthesized in powder form by physical or chemical methods. Then, the Nano sized powder particles are dispersed in base fluid in the successive processing step with the aid of intensive ultra-sonication method or by using surfactants. This method is most widely used economic method for large scale production of Nano fluids, since nanoparticle synthesis techniques were scaled up to industrial production levels.

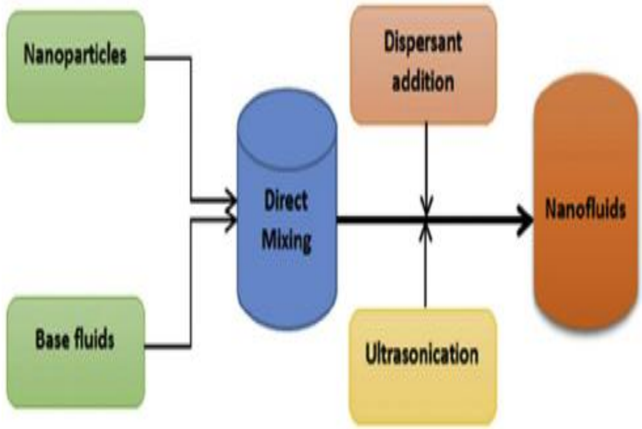

Figure 4 Two-step method

VIII TYPES OF NANO-FLUIDS

There are various metallic, non-metallic nanoparticles and multiwall carbon nanotubes (MWCNT) which are currently used with base fluids to enhance the thermal performance of the cooling systems. Common base fluids are water, ethylene glycol and oil.

The metallic nanoparticles like Cu, Fe, Au, Ag etc. and non-metallic particles or compounds like Al2O3 (Alumina), CuO, SiC, TiO2, Fe3O4 (Iron Oxide), ZrO2 (Zirconia), WO3 (Tungsten trioxide), ZnO, SiO2 etc. are generally used with base fluids.

IX EXPERIMENTAL STUDY

Why We Use Nano Fluid?

The main goal or idea of using Nano fluids is to attain highest possible thermal properties at the smallest possible concentrations (preferably<1% by volume) by uniform dispersion and stable suspension of Nano particles (preferably<10 nm) in hot fluids. A Nano fluid is a mixture of water and suspended metallic Nano particles. Since the thermal conductivity of metallic solids are typically orders of magnitude higher than that of fluids it is expected that a solid/fluid mixture will have higher effective thermal conductivity compared to the base fluid. Nano fluids are extremely stable and exhibit no significant settling under static conditions, even after weeks or months.

Experimental Test Rig and Procedure

As shown in figure, the experimental system used in this study it includes flow lines, a storage tank, a heater, a centrifugal pump, a flow meter, a forced draft fan and a cross flow heat exchanger (an automobile radiator). The pump gives a variable flow rate of 3-15 l/min. the flow rate to the test section is regulated by appropriate adjusting of a globe valve on the recycle line. The base fluid fills 30% of the storage tank whose total volume is 50 lit. The total volume of the circulating liquid is constant in all the experiments. The circuit includes insulated tubes (Isopipe0.75 inch diameter) have been used as connecting lines.

For heating the working fluid an electric heater of capacity 2000 watt and controller were used to maintain the temperature 50-80°C. Two thermocouples were implemented on the flow line to record the radiator inlet and outlet temperature. Four thermocouples is installed on the radiator to measure the wall temperature of the radiator. When the experiment started, the location of the thermocouple presented the average value of the readings was selected as a point of average wall temperature. Due to very small thickness and very large thermal conductivity of the tubes, it is reasonable to equate the inside temperature of the tube with the outside one. The temperature were noted through the temperature indicator. Error details was measured from calibration of each thermocouples by comparing the temperature which was measured by thermometer.

Assumptions for test condition A) Velocity and temperature at the entrance of the radiator core on both air and coolant sides are uniform. B) There are no phase changes (condensation or boiling) in all fluid streams. C) Fluid flow rate is uniformly distributed through the core in each pass on each fluid side. D) The flow condition is characterized by the bulk speed at any cross section. E) The temperature of each fluid is uniform over every flow cross section, so that a single bulk temperature applies to each stream at a given cross section. Heat transfer area is distributed uniformly on each side. Both the inner dimension and the outer dimension of the tube are assumed constant. F) The thermal conductivity of the tube material is constant in the axial direction. G) Room temperature is 25°C. The configuration of the automobile radiator used in this experiment is of the louvered fin-and tube type, with 34 vertical tubes with stadium-shaped cross section. The fins and the tubes are made with aluminium. For cooling the liquid, a forced fan was installed close and face to face to the radiator and consequently air and water have in direct cross flow contact and there is heat exchange between hot water flowing in the tube-side and air across the tube bundle.

Figure 5 Actual Experimental Setup

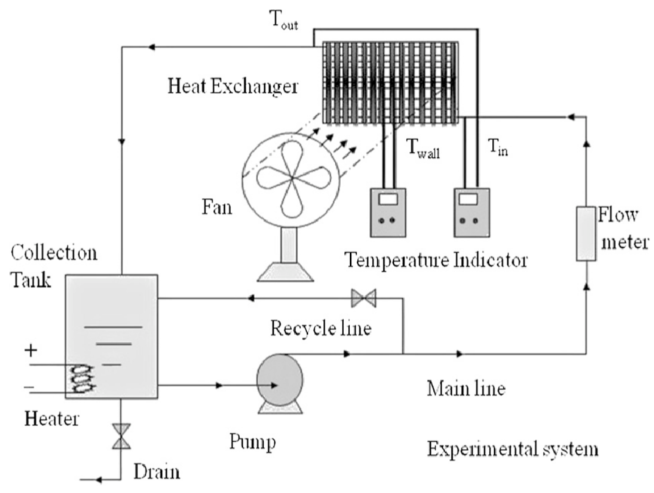

Figure 6 Schematic of Experimentation

Calculation of Heat Transfer Coefficient

To obtain heat transfer coefficient and corresponding Nusselt number, the following procedure has been performed. According to Newton's cooling law:

Q = hAΔT = hA(Tb-Tw)

Heat transfer rate can be calculated as follows

Q = mCpΔT = mCp (Tin-Tout)

Regarding the equality of Q in the above equations

$$Nu = \frac{Hexpdhy}{K} = \frac{mCp\ (Tin - Tout)}{A\ (Tb - Tw)}$$

In equation, 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, Tin 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.

X RESULT ANALYSIS

Pure water, water ethylene glycol (70:30)

Before conducting systematic experiments on the application of Nano fluids in the radiator, some experimental runs with pure water were done in order to check the reliability and accuracy of the experimental setup. Shows experimental results for constant inlet temperature of 55°c. Also done experiment with water + ethylene glycol.

Figure shows that experimental values of forced convective heat transfer coefficient at the different volume concentrations of Al2o3 Nano particles. The value is in the range between 430 W/m2K to 1360 W/m2K.the results compare with the conventional liquids enhanced up to 4% to 17%.the experiment is carried out at 3 lpm.

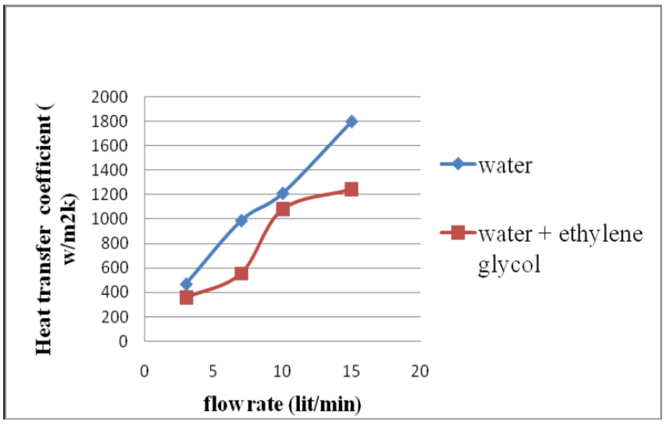

Figure 7 Experimental results for pure water in comparison with water + ethylene glycol

Figure shows experimental results for the pure water and water + ethylene glycol. Compare the results with each other then find out the fluids possess poor heat transfer performance compared to water because of lower thermal conductivity.

Nano fluid

The Nano fluid is implemented in different Al2o3concentrations, i.e. 0.01, 0.02, 0.05 and 0.08 vol. % and at different flow rates of 3,7,10 and 15 l/min were implemented as the base fluid. It is important to mention that from a practical viewpoint for every cooling system, at equal mass flow rate the more reduction in base fluid temperature indicates a better thermal performance of the cooling system. Thermal performance of the automobile radiator at constant air Reynolds number and constant flow rate have been carried out. With increase of the volume concentration of Nano particles in the base fluid viscosity of Nano fluid has been increased.

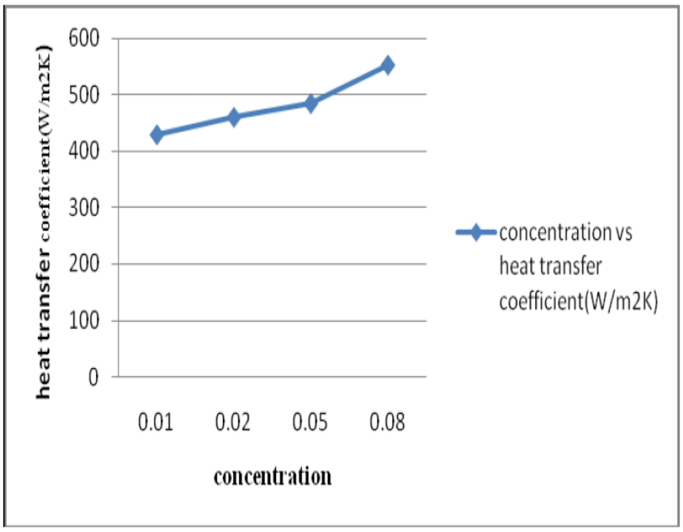

Figure 8 Effect of volume concentration of Al2o3 Nano particles on the heat transfer coefficient at 3 lpm

The concentration of nanoparticle plays an important role in the heat transfer efficiency. Figure 5 shows the heat transfer coefficient values for different volume concentrations at 7 lpm of Nano fluid passing through radiator

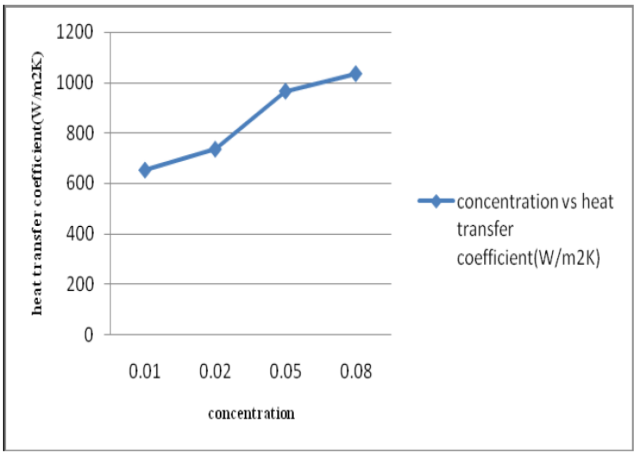

Figure 9 Effect of volume concentration of Al2o3 Nano particles on the heat transfer coefficient at 7 lpm

. The enhancement of heat transfer coefficient is in the range of 12% to 24%.

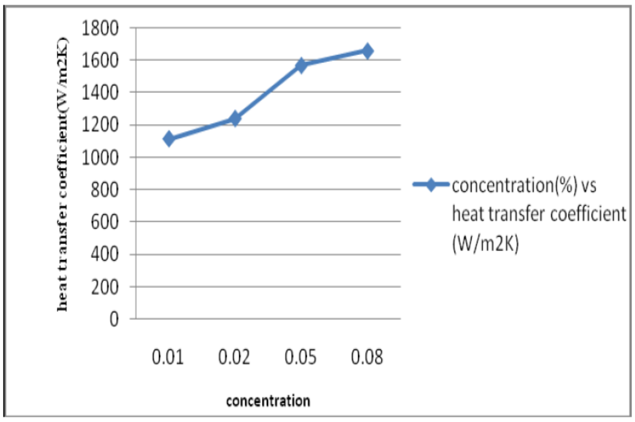

Figure 10 Effect of volume concentration of Al2o3 Nano particles on the heat transfer coefficient at 10 lpm

Figure represents the heat transfer coefficient gradually increasing for increasing the Nano particle concentration. The physical properties of Nano fluids are slightly different than the base fluid. Density and thermal conductivity increased and specific heat decreased slightly in compare to base fluid. Viscosity increases more markedly, which is unfavourable in heat transfer.

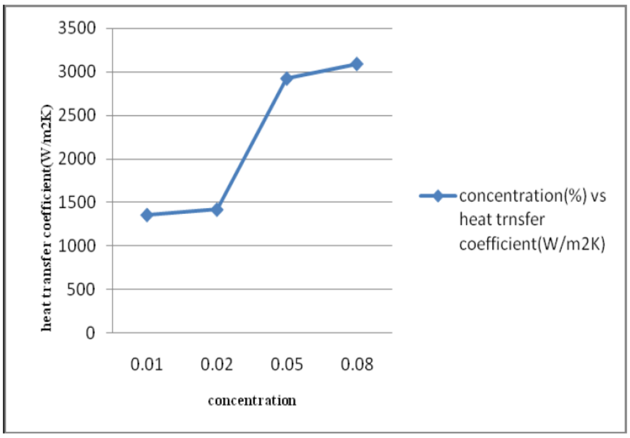

Figure 11 Effect of volume concentration of Al2o3 Nano particles on the heat transfer coefficient at 15 lpm

It can be shown that whenever the concentration becomes greater, heat transfer coefficient becomes larger. By the addition of only 0.08 vol. % of Al2o3 nanoparticle into the pure water, an increase of about 55% in comparison with the pure water + ethylene glycol heat transfer coefficient was recorded. The average heat transfer coefficient of Nano fluids as a function of volume flow rate for different nanoparticle concentrations is presented in Figure 8. It is observed that the heat transfer coefficient of all Nano fluids is significantly higher than that of the base fluid. These higher heat transfer coefficients obtained by using Nano fluid instead of water allow the working fluid in the automobile radiator to be cooler. The addition of nanoparticles to the water has the potential to improve automotive and heavy-duty engine cooling rates or equally causes to remove the engine heat with a reduced-size coolant system. Smaller coolant systems result in smaller and lighter radiators, which in turn benefit almost every aspect of car and truck performance and lead to increased fuel economy.

XI CONCL4USIONS

The presence of Al2O3 Nano particles in water + ethylene glycol can enhance the heat transfer rate of automobile radiator. The degree of heat transfer enhancement depends on the amount of the Nano particle added to water + ethylene glycol. Ultimately, at the concentration of 0.08 vol % the heat transfer enhancement around 48% compared to the pure water + ethylene glycol recorded. Increasing the flow rate (3lpm- 15lpm) of base fluid enhance the heat transfer coefficient for both water + ethylene glycol and Nano fluid considerably. It seems that the increasing in the effective thermal conductivity and the variation of the other physical properties are not responsible for the large heat transfer enhancement. Brownian motion of Nano particles may be one of the factor in the enhancement of the heat transfer.

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