Investigation On Automotive Radiator Performance Using Water, Coolant Oil And Nanofluid

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Abstract: The nanofluids have emerged as a new generation of heat transfer fluids, attracted the attention of researchers over the past few years and found its applications in heat exchangers of chemical plants, automotive cooling, building heating, etc. Nanofluid is a new class of heat transfer fluid engineered by dispersing metallic or nonmetallic nanoparticles with a typical size of less than 100 nanometers in the conventional heat transfer fluids. Nanofluids offer advantages like heat transfer enhancement, heat transfer system size reduction over other conventional heat transfer fluids. The nanoparticles like Al_2O_3, Sic, CuO and TiO_2 are the very commonly used in thermal systems heat exchangers. An experimental study on performance of automotive radiator using water and Al_2C_3 nanofluid was studied in the present work. The Al_2O_3 nanoparticles were tested in automotive radiator by varying the percentage of nanoparticles mix with water. As a reference case, Distiled water is used in an automotive radiator and its performance was studied. Al_2O_3 nanoparticles are mixed in water in 0.025%, 0.05%, 0.1% and the performance of nanofluid is tested. The performance comparison will be made between pure water and nanofluids tested in an automotive radiator. Finally the recommendations are made and conclusions are drawn based on the improved performance of nanofluids in an automotive radiator.

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I INTRODUCTION

A quick look at the history and progress of nanofluids is examined in this section. The selection of nanofluids based on properties, suitability and cost effective was emphasized! The various measuring techniques used for preparation and measurement of nanofluids were also discussed.Heat removal fluids such as water, minerals oil and ethylene glycol play an vital role in many industrial region including power generation, fabrication, transportation and microelectronics. The performance of these conventional heat transfer fluids is often limited by their low thermal conductivities. According to industrial needs of process build-up and device miniaturization, advancement of high performance heat transfer fluids has been a subject of numerous inspections in the previous few decennium. It is well familiar that at room temperature, metallic solids retain an order-of-huge thermal conductivity than fluids. Therefore, the thermal conductivities of fluids containing suspended solid metallic or nonmetallic (Metallic oxide) particles would be expected to be significantly higher than those of conventional heat transfer fluids.).

An innovative way of developing) the heat transfer exploit of common fluids is to suspend various types of small solid particles, such as metallic, nonmetallic and polymeric particles, in conventional fluids to form colloidal. However, dangling particles of the order of μm (micrometer) or even mm (millimeter) may aim some problems in the flow channels, increasing pressure drop, produce the particles to rapidly settle out of suspension. Compared with micrometer sized particle interruption, nanoflids have shown a various potential advantages such as superior long-tem strength and rheological properties, and can have somewhat higher thermal conductivities.

A number of scientist have investigated and reported the correlations for predicting the thermal conductivity, viscosity, density and specific heat of the nanofluids. Understanding the physical and thermal properties of nanofluid is important before using nanofluids in practical applicance. There are a less great correlations for predicting the thermo physical properties of nanofluids that are often cited by a number of researchers. Their works have both experimentally and theoretically investigated the heat transfer behavior of the nanofluids. The use of nanofluids is one of the most effective mechanisms of increasing the amount of heat transfer in heat exchangers. The worn of flat tubes, in that the fluid flow has a lower thermal resistance, is another way of improving the rate of heat transfer in rubes. The subject of the present paper is increase of heat transfer. The nanofluid refers to a mixture in which solid particles of (generally less than 90 nm) are added to a base fluid and cause the increase of heat transfer in that mixture nanofluids particles instead of traditional liquids which include water, ethylene glycol etc. Use of such nanoparticles in me base fluids gain their thermal conductivity and heat transfer achievement of nanofluids. Nanofluids are modern generation heat transfer fluids and can be worn for aeat transfer enrichment, Nanofluids are used in micro channel cooling without any clogging and sedimentation problems. The nanofluids can also be engaged in huge heat flux applications where single phase plain fluids are not skillful of transferring the heat at desired rate.

Nanofluids sustain energy and hence elected over conventional base fluids. Heat ster employing nanofluids is one of the develop areas of research. Broadly conventional single phase fluids have less thermal conductivities when comparision to metals and their oxides. The fluids along dangling particles of metals and metal oxides are supposed to display better heat transfer properties than the conventional fluids beyond solid particles. Particles clogging, sedimentation and erosion are some of the natural problems identify with the need of micro or millimeter sized solid particles when suspended in the host fluids. Parallel

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problems can be reduced by substitution micrometer sized particles by Nano sized particles. Crowded heat exchangers with greater exploit demand fluids acquire improved heat transfer capabilities. Parallel devices outcome in material saving, energy conservation and hence less cost of heat exchangers. Nanofluids progress thermal conductivity of host fluids and now grow into great area of research appeal to the attention of many researchers beyond the world. The nanofluids will check the thirst of examiner who are in quest to engineer superior heat transfer fluids. Usage of two phase nanofluids for heat transfer improvement has encourage the research interest among many investigation groups beyond the globe. Article proved that nanofluids give higher heat transfer coefficient correlated to the display using coolants. The analysis outcome on nanofluids marked that heat transfer boost with percentage of nanoparticle concentration in the water.

Most of the analysis works done so far on nanofluids are experimental studies and held either to laminar or turbulent flow conditions. The base fluid is water in superiority of the cases. In harsh cold climatic circumstances glycols are added to water in various apportions to lower the freezing point of heat transfer liquids. Glycol placed fluids are used in base board heaters, automobile radiators and operation plants particulary in cold contries point the ambient temperatures are below zero degree Celsius. A coolant is a fluid which flows through or around a device to prevent the device from overheating, transferring the heat produced by the device to other devices that either use or dissipate it. An ideal coolant has high thermal capacity, low viscosity, is low-cost, non-toxic, chemically inert, and neither causes nor promotes corrosion of the cooling system. Some applications also require the coolant to be an electrical insulator. While the term coolant is commonly used in automotive and HVAC applications, in industrial processing heat transfer fluid is one technical term more often used in high temperature as well as low temperature manufacturing applications. The term also covers cutting fluids. The coolant can either keep its phase and stay liquid or gaseous, or can undergo a phase transition, with the latent heat adding to the cooling efficiency. The latter, when used to achieve below-ambient temperature, is more commonly known as refrigerant. Ethylene glycol is an organic compound with the formula $(CH_2OH)_2$. It is mainly used for two purposes, as a raw material in the manufacture of polyester fibers and for antifreeze formulations. It is an odorless, colorless, sweet-tasting syrup. Ethylene glycol is moderately toxic.
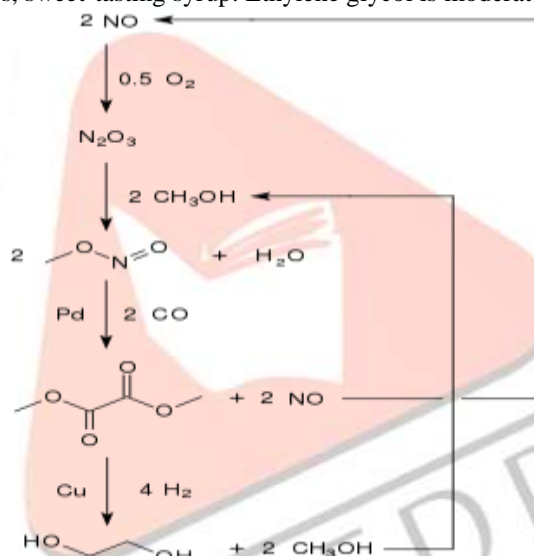

Fig 1 Methanol is recycled. Therefore only carbon monoxide, hydrogen, and oxygen are consumed

Uses of Ethylene glycol:

Ethylene glycol is primarily used in antifreeze formulations (50%) and as a raw material in the manufacture of polyesters such as polyethylene terephthalate

Coolant and heat transfer agent

The major use of ethylene glycol is as a medium for convective heat transfer in, for example, automobiles and liquid cooled computers. Ethylene glycol is also commonly used in chilled water air conditioning systems that place either the chiller or air handlers outside, or systems that must cool below the freezing temperature of water. In geothermal heating/cooling systems, ethylene glycol is the fluid that transports heat through the use of a geothermal heat pump. The ethylene glycol either gains energy from the source dissipates heat to the sink, depending if the system is being used for heating or cooling.

Pure ethylene glycol has a specific heat capacity about one half that of water. So, while providing freeze protection and an increased boiling point, ethylene glycol lowers the specific heat capacity of water mixtures relative to pure water. A 50/50 mix by mass has a specific heat capacity of about 3140 J/kg C three quarters that of pure water, thus requiring increased flow rates in same system comparisons with water. The formation of large bubbles in i.c. engines cooling passages will seriously inhibit heat-flow from that area thus allowing nucleation heat-transfer to occur is not advisable. Large bubbles in cooling passages will be self sustaining or grow larger, with virtually the complete loss of cooling in that spot. With pure MEG that hot spot has to get to 200*C.Cooling due other effects such as air draft from fan etc. will assist in preventing large bubble formation.

Antifreeze

Ethylene glycol disrupts hydrogen bonding when dissolved in water. Pure ethylene glycol freezes at about −12 °C (10.4 °F), but when mixed with water, the mixture does not readily crystallize, and therefore the freezing point of the mixture is depressed. Specifically, a mixture of 60% ethylene glycol and 40% water freezes at −45 °C Diethylene glycol behaves similarly. It is used as a de-icing fluid for windshields and aircraft. The antifreeze capabilities of ethylene glycol have made it a component of vitrification mixtures for low-temperature preservation of biological tissues and organs. Mixture of ethylene glycol and water

can also be chemically termed as Glycol Concentrate/ Compound/ Mixture/ Solution. However, the boiling point for aqueous ethylene glycol increases monotonically with increasing ethylene glycol percentage. Thus, the use of ethylene glycol not only depresses the freezing point, but also elevates the boiling point such that the operating range for the heat transfer fluid is broadened on both ends of the temperature scale. The increase in boiling temperature is due to pure ethylene glycol having a much higher boiling point and lower vapor pressure than pure water; there is no chemical stabilization against boiling of the liquid phase at intermediate compositions, as there is against freezing.

Precursor to polymers

In the plastic industry, ethylene glycol is an important precursor to polyester fibers and resins. Polyethylene terephthalate, used to make plastic bottles for soft drinks, is prepared from ethylene glycol.
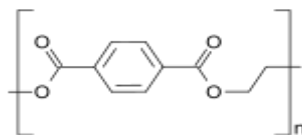

Fig 2 Ethylene glycol is one precursor to polyethyleneterephthalate, which is produced on the multimillion ton scale annually.

Other uses

Dehydrating agent

Ethylene glycol is used in the natural gas industry to remove water vapor from natural gas before further processing, in much the same manner as triethylene glycol (TEG).

Hydrate inhibition

Because of its high boiling point and affinity for water, ethylene glycol is a useful desiccant. Ethylene glycol is widely used to inhibit the formation of natural gas clathrates (hydrates) in long multiphase pipelines that convey natural gas from remote gas fields to a gas processing facility. Ethylene glycol can be recovered from the natural gas and reused as an inhibitor after purification treatment that removes water and inorganic salts.

Natural gas is dehydrated by ethylene glycol. In this application, ethylene glycol flows down from the top of a tower and meets a rising mixture of water vapor and hydrocarbon gases. Dry gas exits from the top of the tower. The glycol and water are separated, and the glycol recycled. Instead of removing water, ethylene glycol can also be used to depress the temperature at which hydrates are formed. The purity of glycol used for hydrate suppression (monoethylene glycol) is typically around 80%, whereas the purity of glycol used for dehydration (triethylene glycol) is typically 95 to more than 99%. Moreover, the injection rate for hydrate suppression is much lower than the circulation rate in a glycol dehydration tower.

Niche applications

Minor uses of ethylene glycol include the manufacture of capacitors, as a chemical intermediate in the manufacture of 1,4-dioxane, as an additive to prevent corrosion in liquid cooling systems for personal computers, and inside the lens devices of cathode-ray tube type of rear projection televisions. Ethylene glycol is also used in the manufacture of some vaccines, but it is not itself present in these injections. It is used as a minor (1–2%) ingredient in shoe polish and also in some inks and dyes. Ethylene glycol has seen some use as a rot and fungal treatment for wood, both as a preventative and a treatment after the fact. It has been used in a few cases to treat partially rotted wooden objects to be displayed in museums. It is one of only a few treatments that are successful in dealing with rot in wooden boats, and is relatively cheap. Ethylene glycol may also be one of the minor ingredients in screen cleaning solutions, along with the main ingredient isopropyl alcohol. Ethylene glycol is commonly used as a preservative for biological specimens, especially in secondary schools during dissection as a safer alternative to formaldehyde. It can also be used in killing jars.It is also used as part of the water-based hydraulic fluid used to control subsea oil and gas production equipment.Another interesting use is in the treatment of 'dry rot' or 'white rot' on timber joists, partially rotten or affected wood readily soaks it up and the fungus is subsequently killed. The main advantage of this type of treatment is that the glycol is hygroscopic and the wood being already water damaged readily absorbs a water based product. Ethylene glycol is used as a protecting group in organic synthesis to protect carbonyl compounds such as ketones and aldehydes.

II PREPARATION ALONG WITH EVALUATION OF NANOFLUID ESTIMATION OF NANOPARTICLE VOLUME CONCENTRATION:

The amount of Al_2O_3 nanoparticles required for preparation of nanofluids is find out using the law of mixture formula. A sensitive equity with a 0.1 mg resolution is help to weight the Al_2O_3 nanoparticles very accurately. The weight of the nanoparticles.

NANOFLUID PREPARATION USING Al_2O_3 NANOPARTICLES

The Al_2O_3 nanoparticles having an size of 20 nm and density of 40 kg/m^3 is procured from a USA based company (Sigma-Aldrich Chemicals Private Ltd) and is used for invenstigation in the present experimental work. Preparation of nanofluds is an important stage and nanofluds are prepared in a systematic and careful manner. A stable nanofluid with uniform particle dispersion is required and the same is used for measuring the thermo physical properties of nanofluids. The analysis of Al_2O_3 nanoparticles is given below

Table 1: Analysis of Al_2O_3 nanoparticles

Product Name	Alumina Powder Nano Grade
Color	White
Crystal Form	Alpha
PH Value	6.6
SSA, m^2/g	15
Particle Size	20nm

Al$_2$O$_3$ content	99.99%
Si	10.8 ppm
Na	9.01 ppm
K	10.6 ppm
Fe	9.75 ppm
Cu	0.12 ppm
Ti	0.86 ppm
Mn	0.72 ppm

In the present work, water is taken as the base fluid for preparation Al$_2$O$_3$ nanofluids. Basically three different methods are available for preparation of stable

nanofluids and are listed below. In this method, the nanoparticles are directly mixed in the base liquid and thoroughly stirred. Nanofluids made in this case give poor suspension stability, due to the nanoparticles settle down due to gravity, after a few minutes of nanofluid formation. The time of particle settlement lean on the type of nanoparticles used, density and viscosity properties of the anchor fluids.

In this method a small amount of suitable surfactant, generally one tenth of mass cf nanoparticles, is added to the base fluid and stirred continuously for few hours. Nanofluids prepared using surfactants will give a stable suspension with uniform particle Aspersion in the host liquid. The nanoparticles remain in suspension state for a long time without settling down at the bottom of the container. After estimating the amount of nanoparticles required for preparation of A1203 nanofluid for a given volume concentration.

In the present investigation, surfactants are added in the Al$_2$O$_3$ nanofluids. Addition of acid may damage the tube material because corrosion takes place after a few days with the prolonged usage of such nanofluids in practical applications. Sodium Dodecyl Benzene Sulfonate (SDBS), Ammonium Citrate (ACT), Cetyltrimethyl Ammonium Bromide (CTAB) are the surfactants likely to be used for Al$_2$O$_3$t nanoparticles. In the present work Sodium Dodecyl Benzene Sulfonate (SDBS) is used to Al$_2$O$_3$ nanofluid

Aluminum oxide nanofluids of three different volume concentrations in range 0.5%, 0.75% and 1% are prepared in the present work. Normally agglomeration of nanoparticles takes place when nanoparticles are suspended in the base fluid. All the test samples of Al$_2$O$_3$ nanofluids used subsequently for estimation of their properties were subjected to stirring process for about 5 hours. The Al$_2$O$_3$ nanofluids samples thus prepared are kept for observation and no particle settlement was observed at the bottom of the tank containing Al$_2$O$_3$ nanofluids even after four hours.

In the present experiments, the Al$_2$O$_3$ nanofluids prepared are assumed to be an isentropic, Newtonian in behavior and their thermo physical properties are uniform and constant with time all through the fluid sample.

III EXPERIMENTAL SETUP AND TESTING PROCEDURE

In this section the exprimental setup was fabricated and the different components of fabricated model were discussed. The testing procedure in fabricated model was also discussed.

EXPERIMENTAL SETUP OF AUTOMOTIVE RADIATOR:

In the performance calculation of radiator a test apparatus is planned which consists of aradiator, fan. flowmeter, heating element, pump, two thermocouples are used.

The various components used are described below.
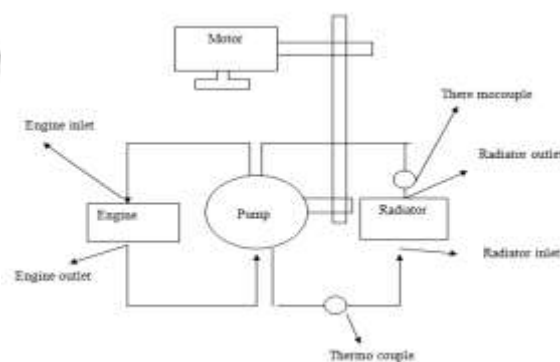
Thermocouples

The most common electrical method of temperature measurement uses the thermocouple. It is based upon see-back effect i.e. when two dissimilar metals are jointed, these forms two junctions and if these junctions are maintained at different temparatures than an emf is produced and this emf depends on the temperature difference. Therefore in thermocouple emf plays thermometric property, the property which helps in holding in finding out the temperature is named as the thermometric property.

Radiator

The radiator is a type of heat exchanger in which the coolant hoses heat by convention and conduction aspect arise in the tubes of radiator. The radiator is naturally built up of aluminum metal because of its less weight and higher thermal conductivity.

Th characteristics of automobile radiator are

Dimensions of the radiator   385x450x3mn

Fin shape   Corrugated
Volume of the fin   1.14 liters
Type of tubes and fins   Aluminum

Fan

A fan is installed just behind the radiator so as to increase the cooling capacity of re radiator. When the temperature of the coolant increases because of constant acceleration the fan starts activity, suction in the air through the fins of the radiator. This fan is controlled by placing a switch and it rotates at speed of 2300rpm. In the apparatus re ran work constantly to give an event of a moving vehicle.

Flow meter

A flow meter is used to control and manipulate the flow rate with the rigor of 0.2 liters/min. Its range is upto 70 liters/min.

Pump

The water pump help centrifugal force to deliver fluid to the out during it spins, causing fluid to be straved from the center continuously. The inlet to the pump is located near the center so that fluid returning from the radiator hits the pump vanes. The pump vanes cast the fluid to the ouside of the pump. The centrifugal pump used is 0.5 hp and 3 m head. After this the flow rate is calculated with the help of a flow meter.

(a)TESTING PROCEDURE

In the test apparatus the heating element will be acting as a source of heat which will act just like an engine in an automobile. This heating element will heat up the coolant to a temperature range above 35^0c, After heating, the hot water is pumped with the help of a pump in to the radiator. At the outlet of the pump a flow meter is installed to measure the mass flow rate of the hot coolant. The flow to flow meter is controlled by a controlling valve, which helps in obtaining different mass flow rate of the hot coolant. Then the inlet temperature to radiator is calculated by installing one thermocouple at inlet and is digitalized by one digital meter. The hot water then through the radiator core. Here with the help of a fan cold air is sucked in which helps in decreasing the temperature of the coolant flowing through the radiator. Then, the temperature at outlet is measured by a second thermocouple. After this the coolant from outlet is returned to the reservoir where it again becomes hot by the action of heating element and is re-circulated in the flow circuit to maintain the continuity of flow. During testing, at no load condition. Firstly water is taken as a coolant. It is circulate at a constant mass flow rate . The engine speed maintaned at constant speed of 980 rpm.after this the temperature of hot coolant at the engine outlet is recorded at particular radiator inlet coolant temperatures. The temperature of inet range of 35^0c-50^0c. After heating, the hot water is pumped with the help of a pump in to the radiator. At the out let of the pump a flow meter is installed to measure the mass flow rate of the hot coolant. The flow to flow meter is controlled by a controlling valve, which helps in obtaining constant mass flow rate of the hot coolant. Then the inlet temperature to radiator is calculated by installing one thermocouple at inlet and is digitalized by one digital meter. The hot water then flows through the radiatir core. Here with the help of a fan coid air is sucked in, which helps in decreasing the temperature of the water flowing through the radiator. Then, the temperature at outlet is measured by a second thermocouple. The temperature of inet range of 30^0c-40^0c After this the water from outlet is returned with the help of pump to the engine and is re-circulated in the flow circuit to maintain the constant folw

At Full load condition. firstly water is taken as a coolant. It is circulate at a constant mass flow rate . The engine speed maintaned at constant speed of 980 rpm.after this the temperature of hot coolant at the engine outlet is recorded at particular radiator inlet coolant temperatures.The temperature of inet range of 50^0c-60^0c. After heating, the hot water is pumped with the help of a pump in to the radiator. At the out let of the pump a flow meter is installed to measure the mass flow rate of the hot coolant. The flow to flow meter is controlled by a controlling valve, which helps in obtaining constant mass flow rate of the hot coolant. Then the inlet temperature to radiator is calculated by installing one thermocouple at inlet and is digitalized by one digital meter. The hot water then flows through the radiatir core. Here with the help of a fan coid air is sucked in, which helps in decreasing the temperature of the water flowing through the radiator. Then, the temperature at outlet is measured by a second thermocouple. The temperature of outlet range of 40^0c-45^0c. After this the water from outlet is returned with the help of pump to the engine and is re-circulated in the flow circuit to maintain the constant flow.

During testing, At no load condition This time water and coolant oil is taken at coolant . Here the mass flow rate is maintained at the same level as before and the engine also rotate with the constant speed 980rpm. after this the temperature of hot water and coolant oil at the engine outlet is recorded at particular radiator inlet water and coolant oil temperatures. The temperature of inet range of 35^0c-45^0c. After heating, the hot water and coolant oil is pumped with the help of a pump in to the radiator. At the out let of the pump a flow meter is installed to measure the mass flow rate of the hot water and coolant oil. The flow to flow meter is controlled by a controlling valve, which helps in obtaining constant mass flow rate of the hot water and coolant oi. Then the inlet temperature to radiator is calculated by installing one thermocouple at inlet and is digitalized by one digital meter. The hot water and coolant oil then flows through the radiatir core. Here with the help of a fan cold air is sucked in, which helps in decreasing the temperature of the water and coolant oil flowing through the radiator. Then, the temperature at outlet is measured by a second thermocouple. The temperature of outet range of 30^0c-35^0c After this the water and coolant oil from outlet is returned with the help of pump to the engine and is re-circulated in the flow circuit to maintain the constant folw.

IV RESULTS AND DISSCUSION

In this section the calculations for pure distild water (base fluid) and different percentages of nanofluids are discussed. The obtained results are tabulated and the graphs Before conducting systematic experiments on the application of nanofluids in the radiator, some experimental runs with pure distild water was carried out in order to cheek the reliability and accuracy of the experimental setup.

Heat transfer rate:

A = m cp Δ t

Sample	Water Percentage (%)	Coolant oil Percentage (%)	Nano particle Percentage (%)	Duration Time Min.	Temperature Readings		Temperature difference $T = T_1 - T_2$
					T_1	T_2	
1	100	-	-	5	57	42	15
2	66.5	33.5	-	5	56	40	16
3	50	50	-	5	51	38	13
4	75	25	0.5	5	53	38	15
5	62.5	37.5	0.75	5	68	51	17
6	50	50	1	5	65	52	13

Where

M   =   S X V   where fluid velocity is constant
    = 985 X 0.0667   for all values
    = 65.6gvg15

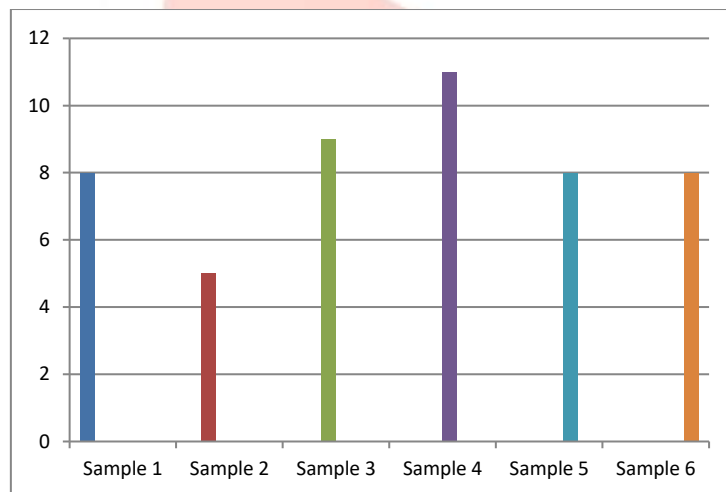Therefore m = 65.6g kg/s

Where

Cp = 4.183

Fig 3 No Load Condition Temperature bar Graphs

CALCULATION AND BAR GRAPHS FOR FULL- LOAD CONDITION TEMPERATURE AVERAGES:

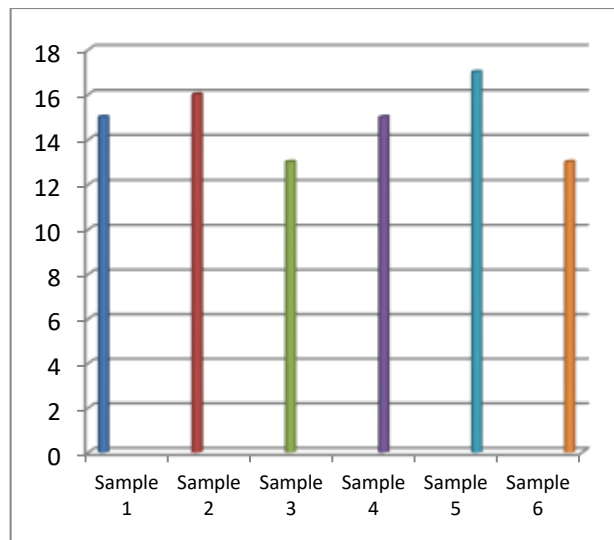**Full – load condition temperatures average:-**

Fig 4 Full Load Condition Temperature bar Graphs

CONCLUSION

The convective heat transfer performance and flow characteristics of Al_2O_3 nanofluid flowing in an automotive radiator have been experimentally inspected. Significant increase in heat transfer was observed with the used different volume concentrations of nanoparticles blended with water and coolant oil. The results showed that the variation of the nanofluids were highly lean at no load condition on the temperature decreases of volume flow rate at the 0.5% of nanofluid. The results showed that the variation of the nanofluids were highly lean at full load condition on the temperature decreases of volume flow rate at the 0.75% of nanofluid. The experimental results have shown that the heat transfer rate of the nanofluids was highly depended on the volume concentration and the volume flow rate.

SCOPE OF FUTURE WORK

Experiments can be further carried out with higher particle concentrations for measurement of heat transfer rate. Experiments can also be extended for the 0.75% of the nanofluids is used to extend and investigation of heat transfer rate is decreases with using different base fluids e.g. transformer oil, ethylene glycol etc. Carbon nanotubes (CNT) have very high thermal conductivity about 3000 w/m K. So, CNT/water nanofluid can be studied with various surfactants at different particle concentrations. Limited work has been reported on the cooling applications of nanofluid using carbon nanotubes (CNT).

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