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ENHANCEMENT OF HEAT TRANSFER USING NANOADDITIVES IN AUTOMOBILE RADIATOR

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ABSTRACT: Nanofluids are the potential heat transfer fluids with enhanced thermo physical properties. Thermal conductivity is considered as an important factor for rapid heating and cooling application. Base heat transfer fluid normally has low thermal conductivity; addition of nanoparticles to the base fluid can increase the thermal conductivity of the base heat transfer fluid. The nanofluids have the ability to increase the cooling rates of the engine cooling system and also leads to design the more compact cooling parts especially radiator.In this project we carried out the experimental investigation and comparison on the performance of the radiator with three different coolants; conventional coolant, CuOnanofluid coolant, TiO_2 nanofluidcoolant.Nanofluid coolant has been tested as potential substitute for the conventional coolant. The nanofluid coolant shows the better and higher heat transfer rate and overall heat transfer coefficient compared to the conventional coolant. In the comparative study of CuO and TiO_2nanofluid coolant CuO has the better heat transfer rate than TiO_2. The overall heat transfer rate of CuOnanofluid coolant is higher than that of conventional coolant by 16.4% while TiO_2nanofluid coolant shows increase of 13.7%.

Key words: Nano fluid, radiator, coolant, heattransfer, automobile.

1. Introduction

Internal combustion(IC) engines are heat engines where the combustion of the fuel occurs usually with an oxidizer (usually air) in the combustion chamber. In an internal combustion engine the expansion of the high-temperature and high-pressure gases produced by the combustion of fuel will apply direct pressure on some mechanical components commonly a piston inside the cylinder and displacing the piston to certain extent, thus the chemical energy of the fuel is converted into mechanical energy. The first commercially successful internal combustion engine was developed by Étienne Lenoir around 1859 and the first modern internal combustion engine was created in 1864 by Siegfried Marcus.

Internal combustion engines are quite different from external combustion engines, such as steam or Stirling engines, in which the energy is delivered to a working fluid not consisting of, mixed with, or contaminated by combustion products. Working fluids can be air, hot water, pressurized water or even liquid sodium, heated in a boiler. IC Engines are usually powered by energy-dense fuels such as gasoline or diesel, liquids derived from fossil fuels. While there are many stationary applications, most IC Engines are used in mobile applications and are the dominant power supply for vehicles such as cars, aircraft, and boats.

2. Cooling System Of Ci Engine

Some environments such as those found in northern latitudes may expose an engine to periods of extreme cold, requiring the fluid remain liquid in order to function properly. In effect, the heat transfer fluid must be impervious to freezing or expressed in other terms, it must possess "anti-freezing" characteristics. It is for this reason that engine coolant is sometimes referred to as antifreeze. Antifreeze is a more specific term used to describe products that provide protection against freezing. Many people use the terms coolant and antifreeze interchangeably. However not all engine coolants need to provide freeze protection. This is especially true when equipment is used in tropical climates. In this type of climate you will always need an engine coolant but you may not need the coolant to have freeze protection.

Conversely, during engine operation the fluid must possess the ability to remain a fluid as it is heated during operation. It must resist the tendency to boil and form vapors as this reduces its ability to transfer heat. An efficient heat transfer fluid for use in combustion engines may require a low freeze point as well as an elevated boil point ensuring its capacity to perform in all situations encountered in the environment. Such characteristics are exhibited when glycols are combined with water. These two reasons form the basis for the composition of the conventional engine coolant used at present.

3. Anti-Freeze Solutions

In order to prevent the water in the cooling system from freezing, some chemical solutions which are known as anti-freeze solutions are mixed with water. In cold areas, if the engine is kept without this solution for some time, the water may freeze and expand leading to fractures in the cylinder block, cylinder head, pipes and/or radiators. The boiling point of the anti-freeze solution should be as high as that of water. An ideal mixture should easily dissolve in water, be reasonably cheap and should not deposit any foreign matter in the jacket pipes and radiator. No single anti-freeze solution satisfies all these requirements. The materials commonly used are wood alcohol, denatured alcohol, glycerin**,** ethylene glycol, propylene glycol, mixtures of alcohol and glycerin and various mixtures of other chemicals.

Water is a much better heat transfer fluid than ethylene glycol or propylene glycol. The engine cooling system is engineered to take advantage of water as the primary heat transfer fluid. Water is assigned a heat transfer value, specific heat, of 1.0. Other fluids, compared to water having higher values transfer heat more poorly. While values of less than 1.0 would transfer heat more efficiently. Ethylene glycol has a specific heat of 2.78, and propylene glycol has a specific heat of 2.73. At 50% water and 50% antifreeze, the specific heat of engine coolant is much closer to that of water.This illustrates the necessity of mixing water and antifreeze to make engine coolant.

4. Recent Trends In Coolants-Nanofluids

Now a day the automobile designers are trying to reduce the fuel consumption of the vehicle by reducing the front area of the automobile. The front area of the car mainly depends upon the size of the radiator. The radiator size can be reduced by using the high thermal conductive coolant. The thermal conductivity of the coolant can be increased by adding nanoparticles of high thermal conductivity in the conventional base coolant.

5. Literature Survey

"Enhancing thermal conductivity of fluids with nanoparticles", S.U.S Choi.(1995)Initially the concept of nanofluid is introduced by Choi and they have been proven to provide efficient heat transfer compared to conventional fluids in this paper."Enhanced thermal conductivity through the development of nanofluids", J.A.Eastman.(1997)

In this paper, the author experimentally proved that 5 vol% of nano-crystalline copper oxide particles suspended in water resulted in an improvement of thermal conductivity for almost 60% compared to pure water."Nanofluids for vehicle thermal management", S.U.S Choi et al.(2001).In this paper, Choi and his co-workers have experimentally measured the thermal conductivity of metallic and oxide, Ethylene glycol based nanofluids using a transient hot wire method. They claimed that the thermal conductivity was much higher than the predicated conventional one."The effect of nanoparticle additions on the heat capacity of common coolants", L.K Goldstein et al.(2002)

In this paper, L.K. Goldstein et al. proved the addition of nanoparticles to water leads to high thermal diffusivity of nanofluids. This excellent characteristic as a coolant can be applied to any system that needs a quick response to thermal changes such as vehicle radiator. "Improving the cooling performance of automobile radiator with Al_2O_3-Water nanofluid", Peyghambarzedh et al.(2011). In this paper, the author conducted experimental investigation on the performance of automobile radiator with Al_2O_3-Water nanofluid. He found that maximum enhancement of thermal conductivity of nanofluids was 3.0% with 1.0 vol% of Al_2O_3 nanoparticles."Effect of heat transfer enhancement and NO_x emission using Al_2O_3 / water nanofluid as coolant in CI engine", Raja et al.(2013). In this paper, the author found that maximum overall enhancement of heat transfer coefficient of the nanofluids was 25% with 2.0 vol% of nanoparticles."Performance investigation of an automotive car radiator operated with nanofluid based coolants", K.Y.Leong et al.(2010). In this paper, the author studied the performance of CuO nanoparticle based coolant in automobile radiator. He found that the maximum heat transfer rate of nanofluids was enhanced about 3.8% compared to pure EG.

"Enhanced heat dissipation of a radiator using oxide nano-coolant", H.M.Nieh et al.(2014). In this paper, the author conducted the experimental investigation of radiator cooling system with 2 nanofluid based coolants, Al_2O_3-EG/Water and TiO_2-EG/Water. He and his co-worker found that thermal conductivity of Al_2O_3nano-coolant and TiO_2 nano coolant was similar and about 24-39% higher than EG/water at all nano particle concentrations. Maximum efficiency factor was 27.2% using TiO_2 –EG/water with 2 Vol% nanoparticle concentration whereas it is 14.4% using Al_2O_3-EG/water with 2 Vol% nanoparticle concentration compared to conventional pure EG/water coolant."The effect of nanofluid concentration on the cooling system of vehicles radiator", M.Ali et al.(2014)

Most recent experimental investigation on an actual vehicle cooling system was conducted by Ali and his co-workers. They attempted to investigate the characteristics of forced convection heat transfer in Toyota Yaris radiator filled with Al_2O_3-Water nanofluid. They concluded that the heat transfer coefficient reached its optimum only when the volume fraction was 1%. Increasing the volume fraction would detoriate the performance of the cooling system.

6. Nano Coolants

The nano coolants are made by suspending the nanoparticles of materials such as Cu, CuO, Al_2O_3in the conventional coolant or water/ethylene glycol mixture. They are heat transfer fluids prepared to meet the challenges in cooling rate. In simple terms the nano-coolant consists of nanoparticles which have high thermal conductivity. The size of nanoparticles in the nano-coolant is not more than 100 nm. They exhibit enhanced thermal conductivity and the convective heat transfer coefficient compared to the base fluid. Knowledge of the rheological behavior of nano-fluids is found to be very critical in deciding their suitability for convective heat transfer applications.

In looking for ways to improve the aerodynamic designs of vehicles, and subsequently the fuel economy, manufacturers must reduce the amount of energy needed to overcome wind resistance on the road. At high speeds, approximately 65% of the total energy output from a truck is expended in overcoming the aerodynamic drag. This fact is partly due to the large radiator in front of the engine positioned to maximize the cooling effect of oncoming air. The use of nano-fluids as coolants would allow for smaller size and better positioning of the radiators.

In analysis such as computational fluid dynamics (CFD), nano fluids can be assumed to be single phase fluids. However, almost all of new academic paper uses two-phase assumption. Classical theory of single phase fluids can be applied, where physical properties of nano fluid are taken as a function of properties of both constituents and their concentrations.

7. How Nano Fluid Can Be Potential Heat Transfer Fluids

If you study the properties of a coolant in any text books you can find the line that the good coolant should have higher specific heat capacity, so that they can absorb maximum heat. But in the case of radiator there is the heat transfer between the radiator tubes and the air i.e. the mode of heat transfer is convection. The convection heat transfer depends upon the following factors which is listed below

- The area of radiator which is exposed to the air(A)
- The temperature difference between the tubes and the air(ΔT)
- The convective heat transfer coefficient(h)

The formula for convective process is

$$Q = hA\Delta T$$

If the heat to be transferred Q is constant and A is also constant we can increase the heat transfer coefficient h by increasing ΔT.This is what happens when the nanoparticles of high thermal conductivity is added to the ordinary coolant. The temperature difference between the air and the radiator increases and the convective heat transfer coefficient is also increases.

Specific heat capacity at constant pressure of the fluid is defined as the amount of heat required to raise the temperature of 1Kg of fuel by 1˚C at constant pressure. The cooling system of the engine is designed in such a way that it should remove only 30% of the heat produced in the engine block. The ordinary coolant having high specific heat capacity absorbs the 30% of heat which it has to absorb and there will be the temperature raise in the coolant. If the nanoparticles having high thermal conductivity are added to the coolant its specific heat is decreased and the thermal conductivity is increased. It means that the coolant absorbs the same 30% of heat which is exposed to and now it will show temperature higher than the conventional coolant. Therefore the coolant with nanoparticles available at the radiator inlet will be under higher temperature compared to the coolant without nano particles. Due to higher temperature at the inlet the temperature difference between the radiator tubes and the air is increased and the convective heat transfer coefficient is increased.

8. Despersion Of Nanoparticle In Basefluid

Figure 1.1 Ultrasonicator

The nanosized powder will be dispersed into a fluid in the second processing step with the help of intensive magnetic force agitation, ultrasonic agitation, high-shear mixing, homogenizing, and ball milling. The method adopted for this project investigation is ultrasonic agitation as the equipment and technical assistance is readily available in nearby University, named Sathyabama University.

In this method a small amount of suitable surfactant, generally one tenth of mass of 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 dispersion in the host liquid. The nanoparticles remain in suspension state for a long time without settling down at the bottom of the container.

After adding the surfactants to the base fluid(water-EG;70:30), the nanoparticle of predetermined weight is added to the basefluid. All the test samples of CuO and TiO_2nanofluids were subjected to ultrasonic vibration for about 2 hours for each sample. The photographic view

9. Experimental Arrangement

For this project investigation actual Engine-Radiator system of Mahindra company with technical specification as 4 stroke diesel engine.The experimental measuring instruments are installed in the appropriate position in the Engine system to make down readings required for the project investigation. Two thermocouples of immersion type is installed, one at the inlet of radiator and another one at the outlet of radiator. These two thermocouples are used to note down Coolant Inlet temperature (T_1) and Coolant Outlet temperature (T_2) with respect to the radiator.

To measure the mass flow rate of the coolant flowing inside, a domestic flow-meter is installed between the Engine outlet and Radiator inlet piping.

Table.1. RESULT COMPARISON

Types of coolant	Heat Transfer Rate, Q KW	Overall Heat Transfer Coefficient, U W/m^2K
Conventional coolant	2.30	126.90
TiO_2nanofluid coolant	2.50	147.05
CuOnanofluid coolant	2.64	151.80

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From the above table, it is clearly visualized that the CuOnanofluid coolant seems to be most efficient and economical alternative coolant to be introduced in the automobile radiator system.

GRAPHICAL REPRESENTATION

Table. 2. Comparison of Heat Transfer Rate

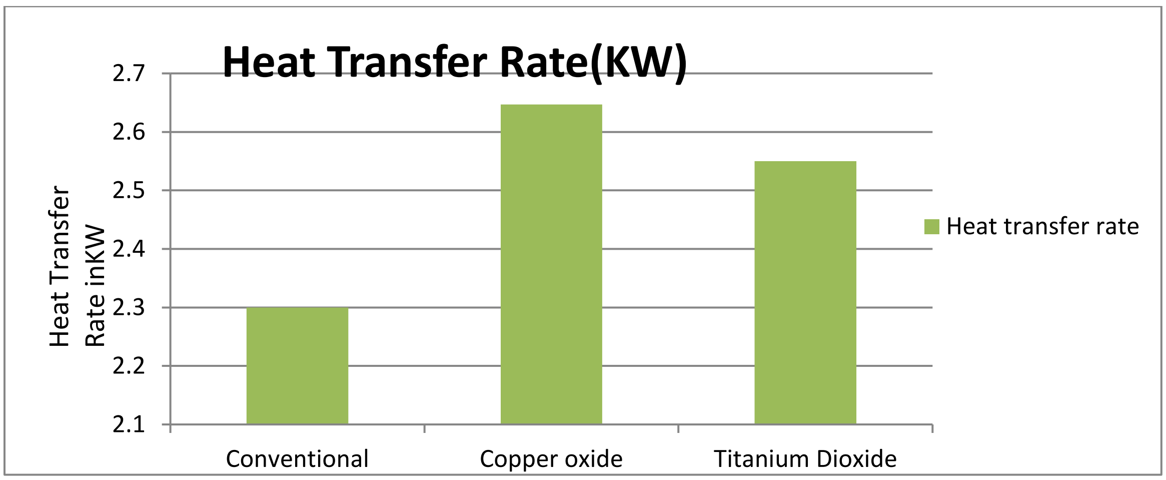

Figure 10.1 Comparison of Heat Transfer Rate

Table. 3.Comparison of Overall Heat transfer coefficient

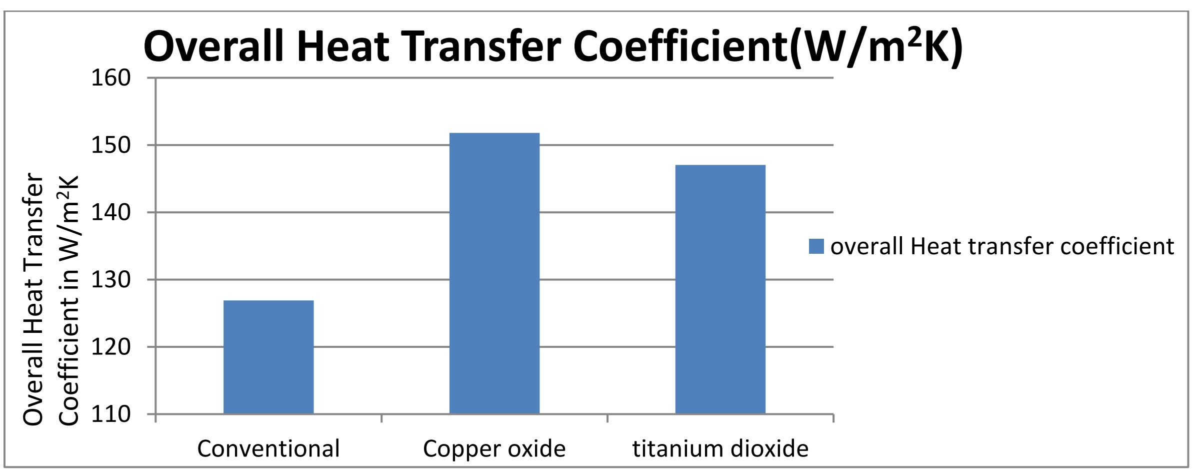

Figure 10.2 Comparison of overall heat transfer coefficient

10. Conclusion

Theoretically and practically that the nanofluid coolant gives better Heat Transfer Rate and Overall Heat Transfer Coefficient compared to the conventional Water-EG coolant. Among the two nanofluids taken into study in this project work, CuOnanofluid shows the better performance in terms of Heat Transfer Rate and Overall Heat Transfer Coefficient when compared to its family mate TiO_2nanocoolant. The percentage of increase in the Overall heat transfer coefficient of TiO_2nanofluid in the automobile radiator system is 13.7%The percentage of increase in the Overall heat transfer coefficient of CuOnanofluid in the automobile radiator system is 16.4%. It is clearly proved that the CuOnanocoolant is most efficient and economical alternative that would be used in the radiator system for enhanced heat transfer.

Figure 2.Experimental setup

Figgure 3.Thermocouples

Figure 3.ULTRASONICATOR

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