International Journal of Emerging Technologies in Engineering Research (IJETER)
Volume 5, Issue 10, October (2017) www.ijeter.everscience.org

# Use of Nanofluids as Radiator Coolant: A review

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**Abstract – Nanotechnology deals with the new fluids called as nanofluids. With this technology development of fluid with enhanced heat transfer capability is developed by mixing nanoparticles with the base fluids, hence there is scope of making compact, lighter and more efficient thermal system. This paper gives the clear-cut summary of the recent research on the use of nanofluids as coolant in a radiator. The review mainly focused on the experimental study of various key researches on the performance of radiator with the use of nanofluids, effect of concentration of nanoparticles, effect of inlet temperatures of nanoparticles and property variation with the variation of particle size, shape and concentration. The potential application of nanofluids in a radiator is analyzed and it is observed that there is enhancement of heat transfer with the use of nanofluids. Further this effect intensified at higher concentration of nano particles. Challenges to use nanofluids are also discussed. It was seen that constant pumping criterion in a radiator to judge the performance of radiator with the use of nanofluid is found to be suitable.**

**Index Terms – Nano fluids, Nanoparticles, Nanotechnology, Enhanced heat transfer, Thermal system.**

| **Nomenclature** | |
|---|---|
| **Pr** | **Prandtl number** |
| **Re** | **Reynolds numbers** |
| **CNT** | **Carbon Nanotube** |
| **W** | **Water** |
| **EG** | **Ethylene Glycol** |
| **W** | **Water** |
| **NC** | **Nano Coolant** |
| **U** | **Overall heat transfer coefficient** |
| **k** | **Thermal conductivity** |

## 1. INTRODUCTION

Radiator is a device used to cool the coolant of an engine; a typical conventional radiation is shown in figure 1. In conventional radiator cold water absorb heat from the hot engine in a water jacket, the heated water from the water jacket then passes into the radiator where it cools by the flow of air and again reaches to the water jacket. Earlier researches have improved the designed by providing fins. The present researchers are trying to develop further optimized radiator in the present era of energy crisis. The performance of radiator strongly depends upon fluid properties like Pr, Re thermal conductivity as well as inside and outside heat transfer coefficients. The radiator should be compact, lighter with enhanced performance. If the coolant has more heat exchanging capacity then task is performed by circulating lesser amount of coolant and pumping power can be saved. Further there will be more uniform cooling of engine, engine works smoothly and problem due to thermal expansion will be avoided. These all factors can be managed by using superior radiator coolants like nanofluids.

Use of nanofluids is one of the effective techniques found without disturbing the design of the engine much and it has became active field of many researches in the last decades because of its performance of enhancing heat transfer. With the use of efficient coolant the size of the engine, specific fuel consummation and drag on engine will reduces. Nanofluid is a fluid containing nanometer sized solid particle of various shapes suspended in the base fluids. It has efficient heat transfer capability compared to conventional fluids, this is due to fact that it has higher thermal conductivity and it intensifies mixing in the fluid compared to the base fluids.

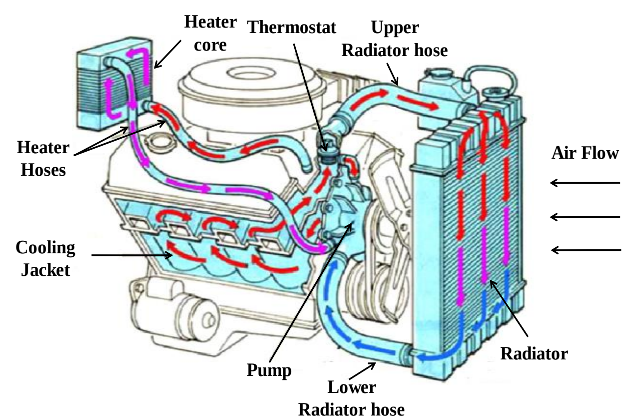


Figure 1. Conventional radiator of a vehicle showing circulation of coolant

Some typical common nanoparticles made up of pure metals are iron (Fe), Copper (Cu), Gold (Au), silver (Ag). Nanoparticles of metal oxides likes copper oxide(CuO), Ferro ferric oxide($Fe_3O_4$),silicon dioxide ($SiO_2$), Zinc oxide(ZnO), Titanium dioxide ( $TiO_2$), aluminum oxide ($Al_2O_3$) are also used. Silicon carbides, titanium carbides, silicon nitrides and aluminum nitrides are the common carbides and nitrides used as nanoparticles. Different types of carbons are also used as efficient nano particles. These nanoparicles combines with base fluids like water ethylene glycol and form nanofluids. The characteristics of nanofluid is given by its various properties like purity of nanoparticles, average particle size, specific surface area, bulk density, true density, morphology spherical, thermal conductivity and thermal expansion coefficient.

## 2. A TYPICAL EXPERIMENTAL SETUP

A typical experimental system used for the research analysis of the heat transfer enchantment in radiator with the use of nanofluids is shown in the figure 2. It consists of a reservoir tank, heater, coolant circulating pump, forced draft fan, fluid flow meter, fluid controller, temperature sensors and radiator. The system of nanofluid flowing into the radiator works on closed cycle. Nanofluids from the storage tank flow through the flow controller by a pump to the heater. Heater heats the nanofluis to the required temperature, heated nanofluid then flow through the radiator where it cools by the air of forced draft fan. Cold nanofluids from the radiatior enter into the storage tank and cycle is repeated. The flow of nanofluid is kept constant. The observed readings are temperatures of nanofluids at inlet and outlet of the radiators, mass flow rate of nanofluids through the radiator etc.

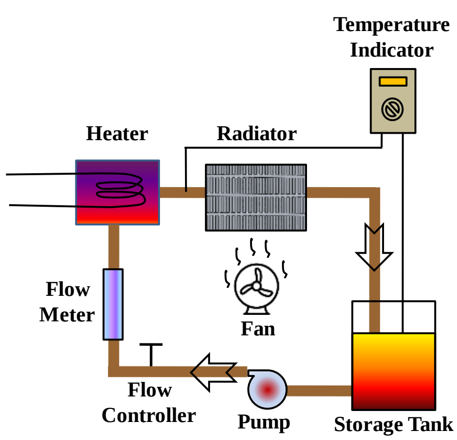


Figure. 2 Schematic of a typical experimental set up used for the investigation of heat transfer in a radiator using nanofluids as coolant

## 3. REVIEW ON THE USE OF NANOFLUIDS AS COOLANT IN A RADIATOR

In the present situation to utilize the energy wisely, most of the researchers have concentrated their focus on the use of nanofluids in radiations. Reviews of key researches on the performance of radiators using nanofluids as a coolant, research on effect of properties of nanfluids and criterion to judge the performance by use of nanofluids are discussed bellows.

C Kannan *et al.* [6] has found out effect of nanofluid concentration on heat transfer enhancement in a radiator. They have worked with water as base fluid with 0.25% and 0.5% of Al2O3 by volume as nanoparticles concentration to form nanofluids. They found significant augmentation of heat transfer with rise in the concentration of nanoparticles as compared to pure water as coolant. The rise in heat transfer with the rise in nanofluid flow is also observed, further they have concluded that the heat transfer coefficient increases with increase in inlet temperature of nanofluids.

Chougule and Sahu [1] worked with Al2O3-water and CNT-water as nanofluids for four different concentrations of nanoparticles. The experimental results shows that the performance of CNT-water nanofluid was better as compare to Al2O3 based nonofluids, heat transfer coefficient increases with concentration and velocity of nanoparticles for both the case and it is more than pure water coolant.

Ray and Das [4] worked numerically for a radiator with Al2O3, SiO2 and CuO nanoparticles mixed in 60:40 mixtures of ethylene glycol and water by mass as base fluid. It was found that 1% concentration is better than higher concentration. They also observed that there is requirement of less pumping power with the use of nanofluid for same heat transfer. The order of performance of nanoparticles found in the study is Al2O3, CuO and SiO2.

H.M. Nieh *et al.* [7] experimentally estimated viscosity, thermal conductivity and specific heat of NC with Al2O3 and TiO2 as nanoparticles with six different proportions. It was found that TiO2 gives better performance in terms of heat dissipation capacity as compared to Al2O3. The overall performance increases with increase in concentration and flow velocity of nanoparticles in NC.

Mehtre *et al.* [2] performed experimental study for the performance of car radiator with Al2O3 blended in water in three different concentrations. They have found 19 to 42% rise in heat transfer coefficient as compare to pure water as coolant. It was observed that rise in heat transfer coefficient with air flow for the same mass flow rate of NC and with rise in NC for the same air flow rate.

Hussein *et al.* [3] studied experimentally and numerically the performance of a car radiator with SiO2 nanoparticles blended with water in laminar flow regime. The presented result shows that there is decrease in friction factor with mass flow rate and it increases with nanoparticle concentration. Further it was seen that there is augmentation of heat transfer rate with increase in flow rate, nano particle concentration and inlet temperature.

Naraki *et al.* [5] have used CuO-water blending as nanofuid to study the effect of different volumetric flow of air and nanofluids on the overall heat transfer coefficient of a car radiator in a laminar flow region. Their main findings are as follows

- As inlet temperature rises U will decrease.
- U will increases with increase in volumetric flow of air and nanofluids.
- They also used Taguchi method and predict that best favorable conditions are minimum temperature of nanofuids, maximum flow rates of both fluids and higher concentration of nanoparticles.
- The challenges of stability of nanoparticles and sedimentation are needed to resolve.

Hussein *et al.* [8] has summarized challenges to be cope up for the use of nanofluids and those are

- The recommended nanoparticles size should be below 100 nm.
- Higher size of nanoparticles produces fouling and provides additional resistance to the heat transfer surfaces.
- Large size of nanoparticles demands more pumping power.
- Larger sizes of particles may also clog some micro channel.

Hatami *et al.* [10] have investigated numerically the effect of nanoparticles shapes on the performance of NC of a radiator. Water and EG are blended with copper oxides, $TiO_2$, $Al_2O_3$ and $Fe_3O_4$ nanoparticles of various shapes like spherical, brick shape, platelet and cylindrical shapes. It was observed from their numerical study that the order of performance of heat transfer from higher heat transfer coefficient to lower heat transfer coefficients is "platelet, cylindrical, brick and spherical shapes"

Devireddy *et al.* [11] have experimentally investigated on cooling performance of radiator with EG and water based $TiO_2$ nanofluids in the Re range of 4000 to 15000. The blending of nanofluids were 40:60% EG/W with three different concentration of $TiO_2$. It was observed that heat transfer coefficient increases with rise in the flow rate of nanofluids and there is little effect of variation of inlet temperature of working substance on heat transfer coefficient.

Elias *et al.* [18] worked on thermo physical properties of $Al_2O_3$ blended with car radiator coolant. It was found that in the range of 10 °C to 50 °C thermal conductivity (k) increases with temperature, further it was seen that k increases with increase in the concentration of nanoparticles. Viscosities of nanofluids were found to be higher than base fluids and it increases with concentration of nanoparticles. Density of nanofluids increases with increase in the concentration of nanoparticles where as specific heat decreases with increase in nanoparticles. Specific heat is higher at higher temperature. It is seen that at higher temperature the performance of nanofluid is better this is due to fact that at higher temperature, k increases while density and viscosity decreases.

Ali *et al.* [19] used ZnO-water nanofluids with 0.01%, 0.08%, 0.2% and 0.3% three different volumetric concentrations to investigate heat transfer in a car radiator for a Re in between 7,500- 27,600. The experimental result shows the significant enhancement of heat transfer up to 46% in their study at a volumetric concentration of 0.2%. It was seen that heat transfer enhancement increase with concentration, reaches maximum at certain concentration and then start decreasing. It was also concluded that heat transfer coefficient is weekly depend upon inlet temperature and there is little rise in heat transfer coefficient with rise in temperature.

Sajedi *et al.* [20] have performed experimental study to choose the criterion to judge performance of nanofluids as radiator coolant. Two criterions were chosen; the first one is constant Re and second is constant pumping power. Using $SiO_2$-water and $Al_2O_3$-water as nonofluid, it was experimental seen that there is difference between these two criterions further at higher temperatures the difference between the two become significant. Based on the experimental results it was concluded that use of constant Re criterion is misleading concept.

## 4. CONCLUSION

The present paper gives an inclusive review on the use of nanofluids in a radiator of a vehicle. The review has covered wide range of topics like thermal performance, nanofluids properties, nanoparticles sizes, particle concentration and criterion to evaluate thermal performance of radiator with the use of nanocoolant. It was found that heat transfer enhancement increases with increase in concentration of the nanoparticles. Most of researchers agree that the optimum performance of radiator can be achieved at lower concentration of nanoparticles (1%). A large number of available references showed that the higher performance of a radiator with the use of nanofluids as compared to base fluids. This may lead to the compact, lighter radiator, which may further reduces capital and running cost of a radiator. The best criterion to measure the performance of a radiator using nanofluids is constant pumping power. Although use of nanofluids enhances thermal performance of the radiator as compare to base fluids, some problems are also associated like stability, sedimentation which needs further research to cope up these challenges.

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