

# A Review on Heat Transfer Enhancement Studies in an Automobile Radiator

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**Abstract** - Cooling is one of the most important challenges facing engines performance. Due to limited space at the front of the engine, the size of the radiator is restricted and cannot be essentially increased. Therefore, it is necessary to increase the heat transfer capabilities of working fluids. With the advancement of nanotechnology, the new generation of heat transfer fluids called, nanofluids have been developed and these fluids offer higher heat transfer properties compared to that of conventional automotive engine coolants. Nanofluids seem to be potential replacement of conventional coolants in engine cooling system. Recently there have been considerable research findings highlighting superior heat transfer performances of nanofluids about 15-40% of heat transfer enhancement can be achieved by using various types of nanofluids. With these superior characteristics, the size and weight of an automotive car radiator can be reduced without affecting its heat transfer performance.

**Keywords:** Nanofluids, Automotive radiator, Heat transfer enhancement, Heat transfer coefficient, Radiator Cooling performance.

## I. INTRODUCTION

Continuous technological development in automotive industries has increased the demand for high efficiency engines. A high efficiency engine is not only based on its performance but also for better fuel economy and less emission. Reducing a vehicle weight by optimizing design and size of a radiator is a necessity for making the world green. Addition of fins is one of the approaches to increase the cooling rate of the radiator. It provides greater heat transfer area and enhances the air convective heat transfer coefficient. However, traditional approach of increasing the cooling rate by using fins and microchannel has already reached to their limit. In addition, heat transfer fluids at air and fluid side such as water and ethylene glycol exhibit very low thermal conductivity. As a result is a need for new and innovative heat transfer fluids for improving heat transfer rate in an automotive car radiator.

New technology and advanced fluids with greater potential to improve the flow and thermal characteristics are

two options to enhance the heat transfer rate and the present article deals with the latter option. Flat tube radiators are widely used due their higher heat transfer area and lower air side pressure drop compared to round tube radiators of the same capacity. Improving the properties of heat transfer fluids can considerably enhance the heat transfer.

Development of nanofluids opens further possibilities in increasing heat transfer. Conventional heat transfer fluids such as water, engine oil, ethylene glycol, refrigerants etc. have very poor heat transfer performances. These conventional fluids can be replaced by nanofluids. Nanofluids are colloidal suspensions of nanometer sized particles called nanoparticles such as metal oxide, carbon nano-tubes or graphene. Nanofluids are the new window which was opened recently and it was confirmed by several authors that these working fluid can enhance heat transfer performance.

### 1.1 Preparation of Nanofluid

In this study two nanoparticles have been used which are  $\text{Fe}_2\text{O}_3$  and  $\text{TiO}_2$ . Distilled water has been used as base fluid in this experiment. These nanoparticles are purchased from Nano Amor (Nanostructured and Amorphous Materials). For the preparation of nanofluid two-step method has been used Fig. 1. Accurate number of nanoparticles was dispersed into the specified amount of water.

To prepare different concentration of hybrid nanofluids, the mass of the nanoparticles was first calculated and measured by a digital scale. To achieve good stability a surfactant called Sodium dodecyl Benzene Sulfonate (SDBS) of optimum amount was added into the solution. The mixtures stirred on a magnetic stirrer for 45 min at 40 °C and 1100 RPM.

Mixture was then homogenized in a homogenizer for 5 min 5000 RPM. Subsequently the mixture put in an ultrasonication bath for 9 h at 40 kHz and 150W to achieve more stable and properly dispersed hybrid nanofluid. Prepared nanofluid shows good stability and negligible sedimentation after 20 h of preparation.



Figure 1: Schematic illustration of nanofluid preparation process

## 1.2 Experimental Setup

As shown in Fig. 1, the experimental system used in this research includes flowlines, 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 constant flowrate of 10 l/min; the flow rate to the test section is regulated by appropriate adjusting of a globe valve on the recycle line shown in Fig.1. The working fluid fills 25% of the storage tank whose total volume is 30 l (height of 35 cm and diameter of 30 cm). The total volume of the circulating liquid is constant in all the experiments. Five layer insulated tubes have been used as connecting lines. A flow meter (Technical Group LZM-15Z Type) was used to control and manipulate the flow rate with the precision of 0.1 l/min.

For heating the working fluid, an electrical heater and a controller were used to maintain the temperature between 40oC and 80oC. Two RTDs (Pt-100 U) were implemented on the flow line to record radiator fluid inlet and outlet temperatures. Two thermocouples (J-type and Ktype) were used for radiator wall temperature measurement. These thermocouples were installed at the center of the radiator surfaces (both sides). The locations of the surface thermocouples have been chosen so that they give the average wall temperature. For this purpose, 10 thermocouples were attached by silicon paste to various positions of the external walls on each side 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. It would be interesting that these two locations on each side of the radiator did not exactly correspond. The test liquids are water based nanofluids which consist of water and small amount of gamma alumina nanoparticle. There was no dispersant or stabilizer added to nanofluid. These thermocouples were installed at the center of the radiator surfaces (both sides). The locations of

the surface thermocouples have been chosen so that they give the average wall temperature.

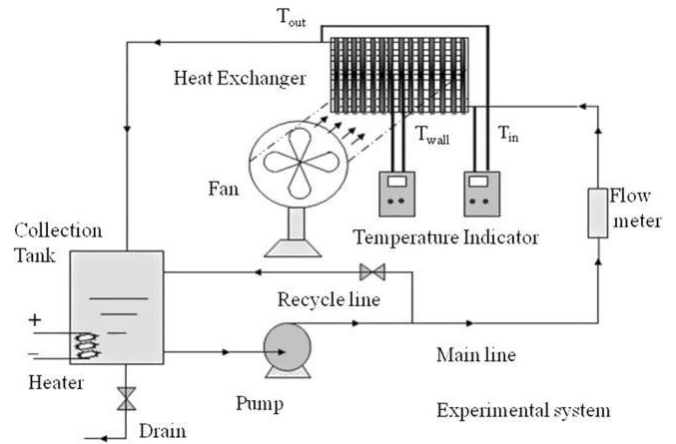


Figure 2: Experimental Setup

This is due to the fact that the addition of any agent may change the fluid properties and the authors were interested to simulate the easiest actual condition encountered in the automobile radiator. Additionally, creating highly turbulent flow condition in the radiator tubes and connecting pipes guarantees the stabilization of the nanoparticle in water.

## II. THERMAL PERFORMANCE FACTOR

The thermal performance factor (TPF) can be defined as a ratio between the enhanced heat transfers to the increased friction. Mathematically, termed as  $g$ . This factor is a measure of performance of effectiveness of the passive techniques which adapted for heat transfer enhancement. Here the notation 's' for with twisted tape insert and the notation 'p' for (Plain) without twisted tube.

The ratio of Nusselt numbers (Nu) of a case tube with twisted tape insert to plain tube case is called as enhanced heat transfer. Similarly the increase of friction is the ratio of friction in the twisted tape insert case to plain tube case.

### 2.1 Problem Statement

The use of vortex generators, particularly delta wing type generators, introduces a secondary flow consisting of two counter-rotating vortices that propagate stream wise and induce air flow between them and toward the heated surface. This is denoted as inflow in Fig. 2. The inflow increases the local heat exchange coefficient and reduces the thickness of the fluid dynamic and thermal boundary layers. In the region outside these vortices, the situation is reversed since the hot air coming from the surface toward the bulk of the flow stream, indicated as outflow in Fig. 1, reduces the local heat exchange coefficient and increases the thickness of the fluid dynamic and thermal boundary layers. Additionally, there is a strong

interaction between the vortices, which shifts both of them toward the heated surface until a stable position is reached.

### III. RESULTS AND DISCUSSIONS

Studies on hybrid nanofluids in this application is at its very initial stage and requires more experimental analysis to better understand the mechanism of their thermal properties. More correlations need to be developed and better stability enhancement techniques should be used to justify their practicality in the automobile's industry.

### IV. CONCLUSION

This study investigated the potential of hybrid nanofluid in the radiator and shows a lot of promising future in automobiles application because of their brilliant heat transfer properties. Because of their better heat transfer abilities, the size of the radiator can also be optimized with smaller radiators with lower fuel consumption.

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