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Research Paper

Heat transfer enhancement of Al_2O_3-EG nanofluid in a car radiator with wire coil inserts

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HIGHLIGHTS

- The purpose of this paper is heat transfer enhancement in a car radiator.
- The simultaneous impacts of nanofluid EG/Al_2O_3 with wire coil inserts are studied.
- Results show that the thermal performance enhancement up to 14%.
- With increasing speed of cooling fan, Nusselt number at Reynolds numbers increased.

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ABSTRACT

In this experimental study, Aluminums Oxide (Al_2O_3) in Ethylene Glycol (EG) as nanofluid was used for heat transfer enhancement in car radiator together with wire coil inserts. Two wire coils inserts with different geometry and nanofluids with volume concentrations of 0.08%, 0.5% and 1% were investigated. The results indicated that the use of coils inserts enhanced heat transfer rates up to 9%. In addition, the simultaneous use of the coils inserts with the nanofluid with concentration of 0.08%, 0.5% and 1% resulted the thermal performance enhancement up to 5% as compared to the use of coils inserts alone.

1. Introduction

Cooling system in engines is very important part because a lot of energy (about one third) is wasted by this system. Therefore, if even for a short time the cooling system cause the problem or it unable to perform his work well, it can lead to increase fuel consumption, evaporation of fuel, increase pollution and this could cause irreparable damages to the vehicle engine components. Due to the reduction of fuel consumption and power consumption in cooling system, performance improvements and optimization of the cooling system is necessary. Therefore, researchers have forced to think about the different ways to enhance heat transfer and cooling performance in the engine. There are several methods to improve the performance of the cooling system. These methods can be divided into active and passive methods. The active techniques require additional external power such as surface vibration and fluid injection. The passive techniques do not require direct input of external power [1].

Taymaz et al. [2] conducted an experimental study of heat loss in a diesel engine with ceramic coating. They attempted to increase the efficiency of the internal combustion engine in recent years by reducing energy loss in the engine coolant during the cycle. The main purpose of their study was to determine heat losses in many different engine speeds, with or without ceramic

coating. The results showed that using the 0.5 mm thickness of the insulating coating on the piston crown and cylinder head, 5–25 percent reduction in heat loss occurs. David Huang et al. [3] experimentally investigated the effects of anti-freeze concentration in the engine coolant on the cavitation temperature of a water pump. They examined the cavitation temperature of the water pump in an engine-cooling system using three different coolants contains 100% pure water, 50% EG/ 50% pure water and 100% EG at various rotational speeds. Three major factors such as the quality of the coolant, the inlet temperature and the inlet pressure of the water pump controlled the cavitation of the water pump. The results showed that engines have a higher tolerance to air bubbles at lower rates of rotation. At a given fixed rotational speed, the tolerable cavitation temperature of an engine's water pump will fall slowly as the amount of air bubbles increases. Ganga Charyulu

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Nomenclature

A_s	surface area of the radiator (m^2)
W	length of the radiator (m)
L	height of the radiator (m)
D	inner diameter of the pipe (m)
V	volume (m^3)
C_p	heat capacity (j/kg K)
g	gravitational acceleration (m/s^2)
h	heat transfer coefficient (w/m^2)
k	thermal conductivity (W/m K)
$\dot{m}$	mass flow rate of fluid (kg/s)
$\dot{Q}$	volumetric flow rate (m^3/s)
Nu	Nusselt number
Re	Reynolds number
$\mathscr{F}$	friction factor
U	velocity (m/s)
T	temperature (°C)
T_∞	ambient temperature (°C)
T_b	the average temperature inlet and outlet (°C)
T_w	wall temperature of the radiator (°C)

Greek symbols

μ	dynamic viscosity (kg/m^2s)
φ	volume concentration of nanoparticles (%)
ρ	density (kg/m^3)
ΔP	pressure drop across the radiator (pa)

Subscripts

EG	ethylene glycol
H	hydraulic diameter
I	inlet
O	outlet
bf	base fluid
nf	nano fluid
np	nano particle

et al. [4] presented an experimental study of performance evaluation of a radiator mounted on a turbo-charged diesel engine with and without fouling factor. The characteristics of the radiator analyzed for deferent tube rows with varying air mass velocities to enable the design engineer to select the size depending upon the requirement and application. They also examined the effect of deferent materials of construction of fins and tubes.

Vithayasai et al. [5] conducted an experimental research on the effects of the electric field on the car radiator heat transfer performance when the air speed of the front radiator is low. Results showed that the unit with electric field pronounced better heat transfer rate, especially at low frontal velocity of air. Peyghambarzadeh et al. [6] conducted an experimental research to improve vehicle radiator cooling performance using nanofluid, Al_2O_3/water compared to pure water. Nanofluid at different volume concentrations of 5%, 1% and 0.1% are used in conducting experiments. The results showed that nanofluids enhance heat transfer compared to their own base fluid. In the best conditions, the heat transfer enhancement of about 40% compared to the base fluids obtained. Naraki et al. [7] experimentally studied the overall heat transfer coefficient of CuO/water nanofluids under laminar flow regime ($100 < Re < 1000$) in a car radiator. The results showed that the overall heat transfer coefficient with nanofluid is more than the base fluid. The overall heat transfer coefficient increased with the enhancement in the nanofluid concentration from 0 to 0.4% concentration. They also observed that the overall heat transfer coefficient decreases with increasing the nanofluid inlet temperature from 50 to 80 °C. Peyghambarzadeh et al. [8] presented an experimental investigation of forced convective heat transfer in a water based nanofluid compared to that of pure water in an automobile radiator with 0.1–1% concentration. They showed that increasing the fluid circulating rate can improve the heat transfer performance while the fluid inlet temperature to the radiator has inconsiderable effects. Peyghambarzadeh et al. [9] experimentally studied the overall heat transfer coefficient in the application of dilute nanofluids (Copper oxide (CuO) and Iron oxide (Fe_2O_3) nanoparticles are added to the water at three concentrations 0.15, 0.4, and 0.65 vol.%) in the car radiator. They evaluated the heat transfer performance of the automobile radiator by calculating the overall heat transfer coefficient (U) according to the conventional ε-NTU technique. Results demonstrated that both nanofluids show greater overall heat transfer coefficient in comparison with water up to 9%. They also observed that increasing the nanoparticle concentration, air velocity, and nanofluid velocity enhances the overall heat transfer coefficient. Ravikant et al. [10] presented a numerical study of fluid dynamic and heat transfer performance of Al_2O_3 and CuO nanofluids in the flat tubes of a radiator. A three-dimensional laminar flow and heat transfer with two different nanofluids, Al_2O_3 and CuO, in an Ethylene Glycol and water mixture circulating through the flat tubes of an automobile radiator numerically studied to evaluate their advantage over the base fluid. Results for the local and the average friction factor and convective heat transfer coefficient showed an increase with increasing particle volumetric concentration of the nanofluids.

Most studies have been concerned with passive methods. Recent interests in the use of tube insert [11] and nanofluids [12] for possible heat transfer intensification have attracted the attention of many investigators. Also some researchers have focused on improving heat transfer by nanofluid and twisted and wire coiled inserts [13–16]. Syam Sundar et al. [17] experimentally studied Heat transfer and friction factor of multi-walled carbon nanotubes–Fe3O4 nanocomposite nanofluids flow in a tube with/without longitudinal strip inserts. They showed that the Nusselt number enhancement for 0.3% nanofluid flow in a tube without inserts is 32.72% and with inserts of aspect ratio 1 is 50.99% at a Reynolds number of 22,000. Chougule et al. [18] presented an experiment study of heat transfer enhancements of low volume concentration CNT/water nanofluid and wire coil inserts in a circular tube. They also observed that the use of nanofluids increases the heat transfer rate with negligible increase in friction factor in the plain tube and the tube fitted with wire coil inserts. Also, experimental investigation on heat transfer enhancement of a tube with coiled-wire inserts installed with a separation from the tube wall is done by Keklikcioglu and Ozceyhan [19].

From the above literature review, it can be noted that many of the investigations found in the literature described above did not focused on both passive technique of nanofluid and wire coiled inserts. Hence, the aim of the present study is to study both the heat transfer coefficient and friction factor in the turbulent flow of Al_2O_3/EG nanofluid in car radiator with and without wire coil insert, because the thermo-hydraulic behavior of wire coil inserts with and without nanofluids in car radiator has not been investigated.