A CRITICAL REVIEW ON HEAT TRANSFER ENHANCEMENT IN A CAR RADIATOR BY USE OF NANO FLUID

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Abstract— *Radiator plays vital role in engine cooling. It is used to cool the engine. Conventionally, Water and ethylene glycol are used as a coolant, water and ethylene have low thermal conductivity. Heat transfer in car radiator can be improved by either increasing heat transfer area or by increasing temperature difference which can be achieved by decreasing temperature of fluid or by improving heat transfer coefficient of fluid which can be improved by two methods active and passive. Nanoparticles are generally metal, metal oxide or non-metallic particles. The present paper summarizes the current research in Nano fluid studies on convective heat transfer performance, effect of fluid temperature, mass flow rate of fluid, volume concentration of nanoparticles, particle size, air velocity etc., In this paper, a comprehensive literature on the thermal behaviour of nano fluids have been compiled and reviewed. Latest up to date literatures in terms of PhD and master thesis, Journal articles, conference proceedings have been reviewed. This paper aims to review some of these researches and compare the results obtained in previous studies.*

Keywords— ***Nano fluids; Car Radiator; Heat Transfer Enhancement***

1. INTRODUCTION

Nomenclature
H Heat transfer coefficient
K Thermal conductivity
Nu Nusselt number
Re Reynolds number

Radiator is an important equipment of vehicle engine. Radiators are one type of heat exchangers used to cool the engine. Cooling system is one of the most important factors in engine as it is responsible to take large amount of waste heat yo surrounding for best working of an engine. Conventionally, water and ethylene glycol are used for cooling the engine as a coolant. Water and ethylene glycol have low thermal conductivity. The technology of automobile industry has been increasing continuously and it requires a high efficiency engines which can be obtained by better heat transfer in radiator. Need of high heat flow processes has created significant demand of new technologies to enhance heat transfer. The heat flow of process Q is directly proportional to h, A and T, where Q is the heat flow, h is the heat transfer coefficient, A is the heat transfer area and ΔT is the temperature difference that results in a heat flow. Increased heat transfer can be achieved by increasing ΔT, increasing A, increasing h.

A greater temperature difference ΔT can lead to increase the heat flow which can be achieved by decreasing the temperature of the coolant which has no means. (Saidur, 2011) Maximizing the heat transfer area A is a common strategy to improve heat transfer , increasing the heat transfer area can only be achieved by increasing the size of the heat exchangers which can lead to unwanted increase in weight. Heat transfer enhancement can also be achieved by increasing the heat transfer coefficient h of fluid which can be improved by two methods active and passive methods. In active method of improving heat transfer coefficient some external power input are involved while in passive method it does not require any external power input. Addition of Nanoparticles to the base fluid is one type of technique to enhance heat transfer. Nano fluids are engineered by suspending and well dispersing nanoparticles with average size of particles below 100nm in heat transfer fluids (base fluid) such as water, ethylene glycol, oil. Nanoparticles are generally metal or metal oxide or non-metallic particles such as ZnO, CuO, Al_2O_3, TiO_2, SiO_2.

2. REVIEW OF WORK CARRIED OUT

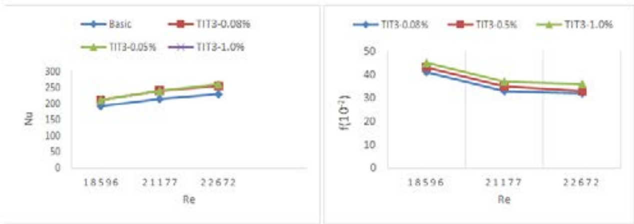
TABLE 1 SUMMARY OF THE HEAT TRANSFER ENHANCEMENT USING NANO FLUIDS

Researcher	Base fluid Nanoparticles Volume concentration Inlet temperature range	Title	Observation
K. Goudarzi et al. (Goudarzi, 2017)	Ethylene glycol Al_2O_3 0.08%, 0.5%, 1% 80%	Heat transfer enhancement of Al_2O_3-EG nano fluid in a car radiator with wire coil inserts.	Nusselt no. at Reynolds no. in the range of 18500<Re<22700 with tube inserts and nano fluid with different concentrations is higher when compared to EG as base fluid.

Hafiz et al. (Ali, 2015)	Water ZnO 0.01%, 0.08%, 0.2%, 0.3% 45-55°C	Experimental investigation of convective heat transfer augmentation for car radiator using ZnO-water nano fluids.	Increase in heat transfer rates have been observed using ZnO- water nano fluids compared to base fluid. Heat transfer enhancement up to 46% is achieved using 0.2% vol. Nano fluid.
Guilherme	Water MWCNT 0.05-0.16% 50, 60, 70, 80°C	Experimental study on the heat transfer of MWCNT/water nano fluid flowing in a car radiator.	Results show a maximum enhancement of 54% for concentration of 0.16% wt at 30°C.
Devireddy sandhya et al. (sandhya, 2016)	EG water TiO2 0.1, 0.3, 0.5% Around 60°C	Improving the cooling performance of automobile radiator with ethylene glycol water based TiO2 nano fluids	At the concentration of 0.5% the heat transfer enhancement of 35% compared to base fluid was observed. the degree of heat transfer enhancement depends on the quantity of vol. Concentration of nanoparticles.
M..Naraki	Water CuO 0-0.4% 50-80°C	Parametric study of overall heat transfer coefficient of CuO/water nano fluids in a car radiator	At the concentrations of 0.15 and 0.4 vol.% of CuO nanoparticles the overall heat transfer coefficient
Adnan et al. (Adnan, 2016)	Water TiO2 1, 2, 3 ,4% 60-90°C	Numerical study on turbulent forced convective heat transfer using nano fluids TiO2 in an automotive cooling system	The highest Nusselt number obtained for TiO2 nanoparticles in water was 18% better than that of pure water.
Vahid delavari et al.(Delavari , 2014)	Water EG Al2O3 0.1, 0.3, 0.5, 0.7, 1% 35, 40, 45, 50, and 60°C	CFD simulation of heat transfer enhancement of Al2O3/water and Al2O3/Ethylene Glycol nano fluids in a car radiator.	The Nusselt number increased uniformly as the Reynolds number and concentration of nanoparticles increased.

3. ANALYSIS OF NANO FLUIDS IN CAR RADIATOR

K.G oudarzi et al. Investigated Experimentally the heat transfer performance of the automobile radiator using nano fluid of Al2O3/Ethylene glycol along with wire coil inserts of different geometry. The results demonstrated that Nusselt no. in the defined range of Reynolds no. is higher with wire coil inserts compared to EG without coil inserts. Nusselt number with tube inserts and nano fluids with the volume concentrations of 0.08%, 0.5%, and 1% is higher when compared to ethylene glycol as a base fluid. For the same above condition Nusselt no. increased with increasing speed of cooling fan in the range of 750<N<1220. Friction factor at Reynolds no. in the range of 18500<Re<22700 with the coil inserts and with different volume concentrations is higher compared to EG as base fluid. (Goudarzi, 2017) Graphs obtained by Goudarzi et al. shown below.



(a) (b)

Figure (a) Effect of Al2O3/EG nano fluid volume concentration on Nusselt no. of nano fluid with tube insert (b) experimental friction factor of EG and different volume concentrations of Al2O3 nano fluid with tube inserts.

Hafiz Muhammad Ali et al. experimentally observed that using ZnO/water nano fluid there is significant increase in heat transfer rates compared to base fluid. They observed that heat transfer enhancement of nano fluids are highly dependent on the volumetric concentration of nanoparticles in base fluid. The best heat transfer enhancement up to 46% is achieved using 0.2% volumetric concentration of nano fluid. They observed that inlet temperature are weakly dependent on heat transfer rates only 4% increase in heat transfer rate was observed when fluid inlet temperature was increased from 45 to 55°C. This heat transfer enhancement may lead to smaller and lighter car radiators. (Ali, 2015)

Guilherme azevedo et al. performed experimental study on the heat transfer of MWCNT/water nano fluid flowing in a car radiator. They varied concentrations between 0.05 and 0.16% and varied mass flow rate from 30 to 70g/s and the inlet temperature was maintained constant at 50. 60, 70, and 80°C. They observed that thermal conductivity of nano fluids resulted slightly higher than pure water. The experimental results demonstrated that the heat transfer enhancement of nano fluids are strongly dependent on the concentration. The greater heat transfer rates were obtained with distilled water instead of nano fluid, so they concluded that this nano fluid is not ideal to replace coolant. Heat transfer rates were found dependent of the temperature, increase in the temperature from 50 to 80°C increment in heat transfer rate was observed. (Guilherme, 2016)

Devireddy et al. estimated experimentally cooling performance of automobile radiator with ethylene glycol water based TiO2 nano fluids. Nano fluids were prepared taking 40% ethylene glycol and 60% water with volume concentrations of 0.1%, 0.3% and 0.5% of TiO2 nanoparticles. They found that the presence of TiO2 can enhance the heat transfer rate in

the automobile radiator. The degree of heat transfer enhancement depends on the quantity of nanoparticles added to the base fluid. At the concentration of 0.5% the heat transfer enhancement of 35% compare to base fluid was observed. They observed that fluid inlet temperature have slightly dependence on heat transfer rate. They also observed that increasing fluid flow rate increases heat transfer rate. (sandhya, 2016)

M. Naraki et al. did parametric study on overall heat transfer coefficient of CuO/water nano fluid in a car radiator. The nano fluid has been stabilized with variation of pH and use of suitable surfactant. They observed tat the overall heat transfer coefficient decreases with increasing inlet temperature. Enhancement of heat transfer rate was observed when nano fluids with concentration of 0.15 and 0.45 was used and increment in heat transfer rate was observed were 6 and 8%. Increase in air flow rate can enhance the heat transfer rate. They used taguchi method for analysis and observed that the best operating condition includes minimum inlet temperature, maximum concentration of nano fluid, maximum flow rate of nano fluid and maximum flow rate of air. The air volumetric flow rate has 42% contribution in the overall heat transfer coefficient. Nano fluid volumetric flow rate, inlet temperature and concentration of nano fluid have 23%, 22%, and 13% contribution in the overall heat transfer coefficient. (Naraki, 2013)

Adnan M. Hussein et al. performed an experimental and computational study of the heat transfer performances of a car radiator running with TiO2/water nano fluid under turbulent forced convective heat transfer. They used four different nano fluid volume concentrations 1, 2, 3, and 4%. The Reynolds number and inlet temperature ranged from 10000 to 100000 and from 60 to 90℃, respectively. Adnan and colleagues observed that the maximum values of friction factor increased by 12% for TiO2 nanoparticles dispersed in water at a 4% volume concentration. The highest Nusselt number obtained was 18% better than that of pure water. Nusselt number behaviour of the nano fluids were highly dependent on the volume concentration, inlet temperature and Reynolds number. The potential enhancement of car engine cooling rates could entail more engine heat being removed and hence reduction in cooling system leads to smaller and lighter car radiator. (Adnan, 2016)

Vahid delavari et al. used CFD for simulating heat transfer enhancement of Al2O3/water and Al2O3/ethylene glycol nano fluids in a car radiator. They studied behaviour of nano fluids numerically in turbulent and laminar flow regimes in a flat tube. The numerical results were the same as for the experimental data, indicating that increasing the concentration of nanoparticles in the base fluid increased the heat transfer coefficient and the Nusselt number. Friction factor results showed that the tube friction coefficient increased as the concentration of nanoparticles in the nano fluid increased. (Delavari, 2014)

4. CONCLUSION

From the above review we can concluded that as we are increasing volume concentration of nanoparticles in a base fluid it enhances the heat transfer coefficient also increasing fluid flow rate also enhance heat transfer rate. With increase in air flow rate or air velocity increment in heat transfer rate observed. There is insignificant effect of inlet temperature on heat transfer rate as in such cases increase in inlet temperature can slightly enhance heat transfer rate, in some cases increase in inlet temperature do not affect heat transfer rate, and in some cases there is decrement in heat transfer rate observed when there was increase in fluid inlet temperature. Use of nano fluid in car radiator enhance heat transfer rate which leads to compact and lighter radiator which also enhance engine fuel efficiency.

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