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Parametric Analysis of Automotive Radiator Using Silicon Oxide Nanofluid as Coolant

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ABSTRACT:

Tremendous increase in demand for high-capacity propulsion systems being reported with the advancement in technology. One such propulsion system usually found in transportation sector is an internal combustion engine. The engine performance depends on many factors among which best cooling system is one. Radiators play a key role in dissipating the waste heat to atmosphere quickly and effectively so that working life of the engine can be extended. Hence, radiator is one focusing zone where in the best efforts can be directly seen reflecting on performance of I.C. engine. Present work aims to study the performance of a car radiator with silicon oxide nano fluid as cooling media instead of water. This work focuses on the comparison of heat transfer coefficient and effectiveness of the radiator by using nano fluid as coolant with that of conventional coolant.

Key words: Automotive radiator, Nanofluid, Performance Parameters

Introduction:

In an internal combustion engine air-fuel mixture undergoes combustion in combustion chamber by either external excitation or due to self-ignition conditions. This combustion phenomenon releases huge amount of thermal energy which will be attempted to transform into mechanical energy of the crank. But due to unavoidable reasons whole heat energy could not be seen as work. The unavailable energy which is present with the combustion gases leads to overheating of the engine cylinder and associated parts which ultimately leads to mechanical failure of the entire system. Hence in order to dissipate the waste heat immediately and continuously from the internal combustion engine system it is very important to provide best cooling arrangement. Almost all heavy-duty engines provided with radiator setup to fulfill the purpose. Usually either water or water-ethylene glycol solution found as cooling agent in radiators.

Figure1: schematic of automobile radiator

With the conventional coolants the major drawback observed by the research community is their thermophysical properties. In the present analysis efforts are put to understand the trend of performance parameters of the radiator with a novel cooling media that is silicon oxide based nanofluid.

Hardik Kumar B Patel et al reviewed the effect of various operational parameter on heat transfer rate and pressure drop of radiator with computational fluid dynamics analysis. Their review reported that CFD analysis results find good agreement with experimental outcome. Vijay Sagar et al conducted computer simulations to understand the influence of mass flow rate of coolant on heat transfer rate and compared the performance for the cases of with and without louvered fins. Their analysis reported that the provision of louvered fins with higher pitch contributes for decreasing the pumping power requirement of the system while enhancing heat transfer rate.With modified louvered fin arrangement air velocity increased by 29.16% and the heat transfer rate improved by 53.88% as compared to conventional fin arrangement.

Present analysis focuses on the study of effectiveness of radiator by utilizing nano fluid-based coolant and compare with that of conventional coolant. Analytical approach adopted to perform the investigate the parametric variations. The major concerning parameters are heat transfer rate and convective heat transfer coefficientof the chosen radiator. Specifications of the car radiator are given below.

Table 1: Specifications of radiator:

Sl.No	Parameter	Dimension
1	Radiator core width	0.323m
2	Radiator core height	0.422m
3	Core depth	30mm
4	No of flow tubes	37
5	Fin width	8mm
6	Fin thickness	0.5mm
7	No of fin layers	37
8	Fin pitch	3mm
9	Tube thickness	0.4mm

In this study water and ethylene glyol blend was considered as base fluid. Thermophysical properties of the base fluid constituents are as follows.

Table 2: Thermophysical properties of base fluid:

Base fluid	Density (kg/m3)	Specific heat (J/kg K)	Thermal conductivity (W/m K)	Viscosity (Pa s)
Pure Water	973.7	4184	0.668	0.000365
EG	1101–1114	2382–2415	0.252–0.267	$(9.5–15.7)10^{-3}$

Various kinds of nano particles were dispersed into base fluid in order to improve the heat transfer capacity such as metal powders, metal oxides, carbides, and nitrides. In the present study silicon oxide particles was chosen because of their unique properties of bio compatibility and nontoxic nature.Thermophysical properties of the nano particles are presented below.

Table 3:Detailed description SiO2 nanoparticles

Purity (%)	99+
Approximate size (nm)	20
Morphology	Spherical
Color	White
Thermal conductivity (W/m-K)	1.4
Specific heat (j/Kg-K)	745
True density (g/cm3)	2.22

Empirical analysis:

Wavy fin type aluminum radiator with flat flow tube arrangement is considered in the present investigation. In this heat exchanger the coolant fluid and the rushing air stream flows perpendicular to one another. Air velocity taken within the range of 2.5 to 7.5m/sec while taking the coolant volume flow rate between 5 to 10 LPM. Inlet temperature of air considered to be same as atmospheric temperature of 32°C. In order to mimic the engine waste heat,the inlet temperature coolant fluid flowing through the flow tube is considered as variable which is ranging between 30°C to 80°C.

Rate of heat gain by the air is expressed as

$Q_a=\rho_a\times H_{core}\times W_{core}\times C_{p,a}$

Air heat transfer coefficient may be expressed as

$ha= Nu_{,a}\times K_a\div D_{h,a}$

Where the Nusselt number value of air for laminar flow zone is expressed by

$Nu=0.664\times Re^{0.5}\times Pr^{0.333}$

The heat rejectionrate of tube sidefluid is given by,

$Q_c=\rho_c\times V_c\times C_{p,c}$

Tube side heat transfer coefficient could be given by,

$h_c= \frac{Nu_{,c}\times K_c}{D_{h,c}}$

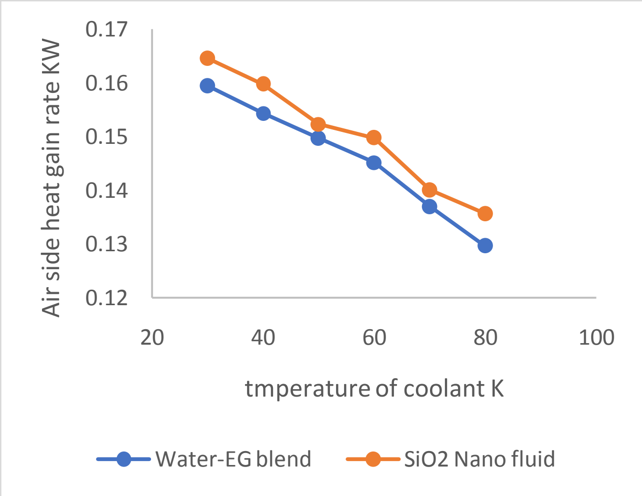

Fig1: variation of heat transfer rate of air with temperature

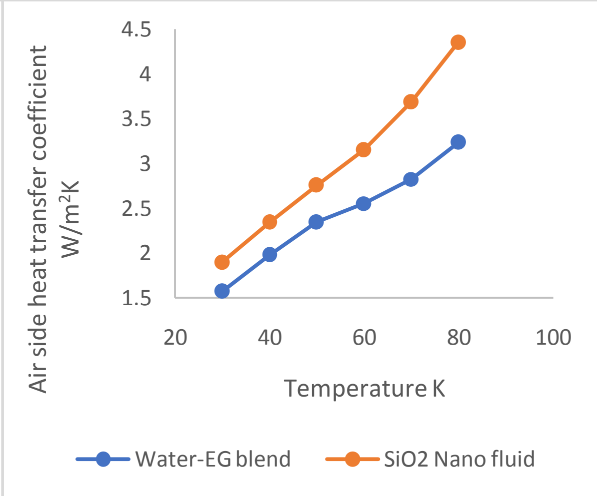

Fig2: variation of heat transfer coefficient with temperature

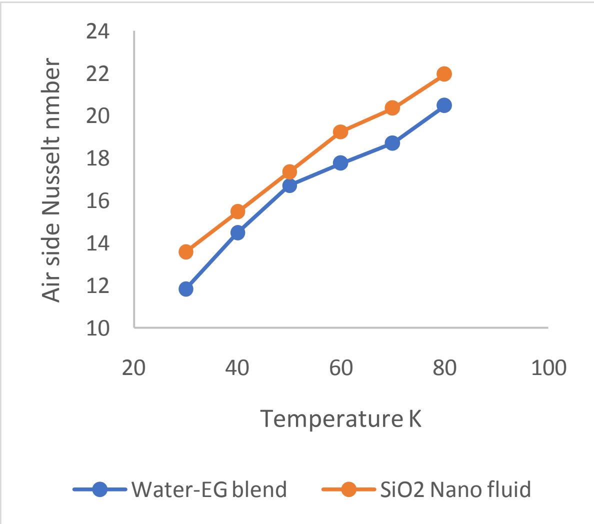

Fig3: variation of Nusselt no of air with temperature

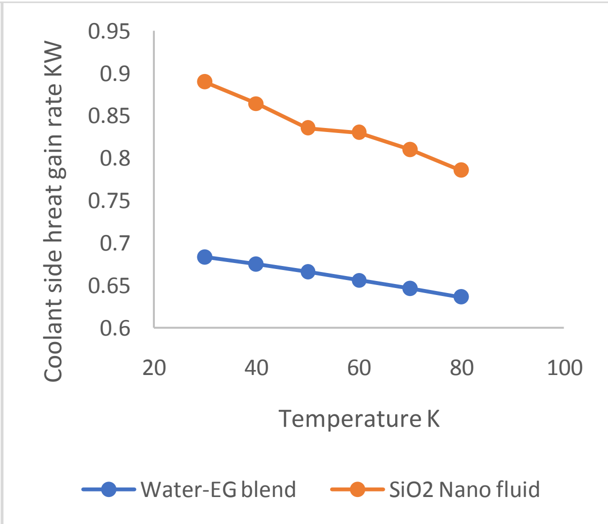

Fig4: variation of heat transfer rate of coolant with temperature

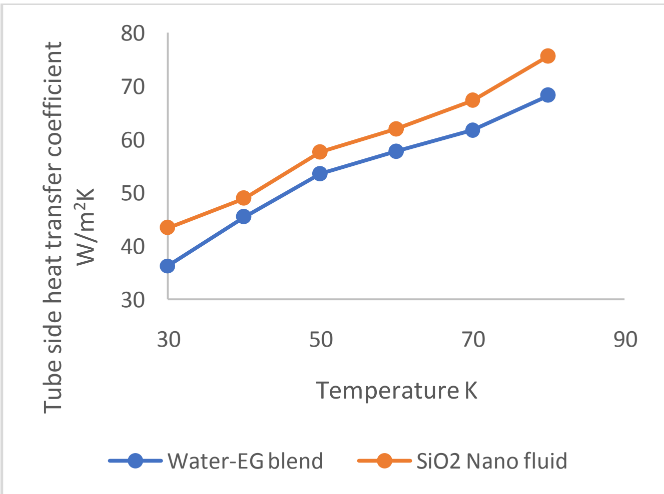

Fig5: variation of heat transfer coefficient of coolant with temperature

In the present study performance analysis of wavy fin type radiator with flat tube arrangement is performed. Major concern of this study is to compare the performance of radiator with silicon oxide based nano fluid as coolant. Byobserving the analysis results, the heat transfer rate at walls is increased by 33.88% for the nanofluid coolant than the conventional coolantthat is water-Ethylene Glycol blend. Heat transfer analysis is performed to analyze the heat transfer rate to determine the thermal flux. Thematerial taken is Aluminum alloy 6061 for thermal analysis.

So, it can be concluded that using nanofluid based coolant yields better results. Analysis reports that the heat transfer coefficient enhanced by around 17.5% by utilizing nano coolant. Nusselt number value increased by an average value of 7.6%.

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