Experimental study for Heat Transfer Performance in Maruti Suzuki Alto 800 Radiator Using different coolants

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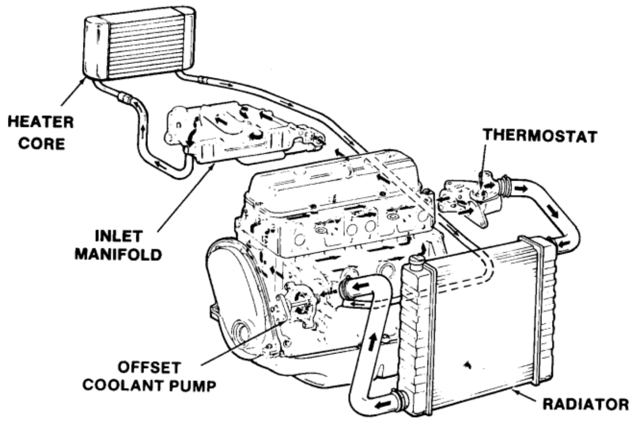
ABSTRACT

In today's world one of the most important tasks is to handle the energy available and to minimize the heat losses. Talking about the automobile sector, engine is the prime energy source. Cooling system in any automobile system is of utmost importance as it carries the heat from the engine and dispenses it to the atmosphere. It also enhances the fuel economy and heat transfer rate which in turn helps in maximizing the engine performance**.** This paper presents an experimental investigation of an automobile radiator performance by varying the coolant ratio and composition.

Keywords
Radiator, Nanofluids, Nanoparticles,Ethylene Glycol, Propylene Glycol, thermal conductivity, heat transfer coefficient, effectiveness

INTRODUCTION

Heat transfer is an important aspect in performance evaluation of any system that does work. Automobile radiator is one such system which acts as an heat exchanger where excessive heat from the engine is extracted and released into the atmosphere. The radiator is the heat exchanger where the engine heat is dissipated to the air. The metal air interface should greatly exceed that of water/metal area. When operating in a high altitude condition the loss of water through boiling and evaporation is common. It is found out that at an height of about 2000m the atmospheric pressure falls to about 80KPa and the water boiling to about 94°C, to counter this problem radiators are provided with pressure caps to maintain the desired pressure within the system. It is also found out that for every 10KPa increase in pressure, the boiling temperature of the coolant rises by 2°C.[1]



Radiator Working is quite simple to understand but cumbersome to analyse. As the engine starts to operate and reaches a high temperature towards the engine walls the cooling system stars operating. Initially only incoming air is used to cool the engine until very high temperatures are reached. At higher temperatures when sensed by thermostat valve the pump starts to circulate the coolant through the hose pipes. This coolant first flows through the whole system and enters a radiator at the last which is provided with multiple tubes of small diameter. These tubes divide the coolant flow and thus provide higher surface contact area for heat transfer to take place. The radiator tubes are provided with fins which are connected to these tubes at the base. These fins often called extended surface again increase the effective heat transfer area. The radiator fan which is running at the speed of engine by virtue of a belt drive sucks in air. This cools the coolant and it is ready to be recirculated.

Literature Review

Coolants are very important part of the liquid cooling system as by varying the coolant the amount of heat transferred, effectiveness, total pumping power required can be varied which could lead us towards smaller cooling system and eventually low cost and weight which is very desirable and is needed.

Water alone as stated earlier have excellent cooling properties but even at higher pressure its freezing and boiling points do not change drastically which is needed specially while operating in colder regions and hence antifreeze are mixed to avoid freezing of coolant in northern parts. One more problem that arises with pure water us that of rust. It can cause rusting of the cooling system components and hence anti rusting agents are mixed with water.

Ethylene glycol ($C_2H_60_2$), often called antifreeze, acts as a rust inhibitor and a lubricant for the water pump, two properties not present when water is used alone. When mixed with water, it lowers the freezing temperature and raises the boiling temperature, both desirable consequences. This is true for mixtures with ethylene glycol concentrations from a very small amount up to about 70%. Ethylene glycol is water soluble and it is found that it has a boiling temperature of 197°C and a freezing temperature of -11°C in pure form at atmospheric pressure.[2]

Rahul Bhagore et.al performed and experiment on an automobile radiator with Al_2O_3 nanofluid they observed that with increase in volume concentration of nanoparticles (ranging from 0% to 1%) heat transfer rate is increased. He observed that by adding of 1% Al_2O_3 nanoparticles at constant air Reynolds number of 84391 and constant mass flow rate (0.05 Kg/s), an increase of about 40% heat transfer was achieved . Also overall heat transfer based on air side was found to be increased by about 36% with addition of 1% Al_2O_3 nanoparticles by volume fraction than the base fluid at constant air Reynolds number and constant mass flow rate. He also noted that at the same particle volume fraction, mass flow rate and air Reynolds number, effectiveness of the radiator increased up to 40%.[3]

Golakiya Satyamkumar et.al studied the heat transfer in an automobile radiator. He found out that by adding 4% volume fraction of Al2O3 in water heat transfer rate increases by 17% further, addition of 8% volume fraction of Al_2O_3 in water the effective heat transfer increase is of about 26% as compared to water.[4]

Mohammad Hemmat Esfe et.al in his experiment, studied the variations of effective thermal conductivity ofMgO/water–EG (60:40) with temperature and particle concentration and suggested new correlations by using regression at different solid volume fractions and temperatures. He concluded that the thermal conductivity of nanofluid increases with increasing temperature. However the variations of thermal conductivity with temperature were more tangible at higher concentration. On the contrary, he also said that at low solid volume fraction, the thermal conductivity is unaffected by temperature.[5]

Sai Kiran .S et.al compared the results of CFD analysis with the experimental results and found them to be in good agreement with each other.According to him,the Brownian motion of the nanoparticles plays a vital role in improvement in heat transfer rate of radiator. As the nanoparticles move randomly in the fluid it results in the decrease of the boundary layer thickness and thus enhancing the heat transfer. It is observed that nanoparticle concentration plays an important role towards heat transfer enhancement.[6]

Methodology:

It involves a series of different steps to be followed for experimentation. However there cannot be any one specific approach but more or less it is the same. We started with literature review that involved going through the historical work done in this field. Radiators are heat exchangers of cross flow type with one fluid liquid and other air. After our literature survey we arrived at a decision to control the coolant properties by keeping the air and outlet atmospheric conditions unchanged. Next we emphasised on different coolants and decided to work with Ethylene glycol and propylene glycol. After performing series of experiments and test runs we finally concluded it using empirical and experimental relations developed earlier.

Experimental Setup and working:

our experimental setup involved following components.

1. Radiator and fan assembly
2. Heating element and reservoir
3. Pump
4. Thermocouples
5. Temperature sensor and controller

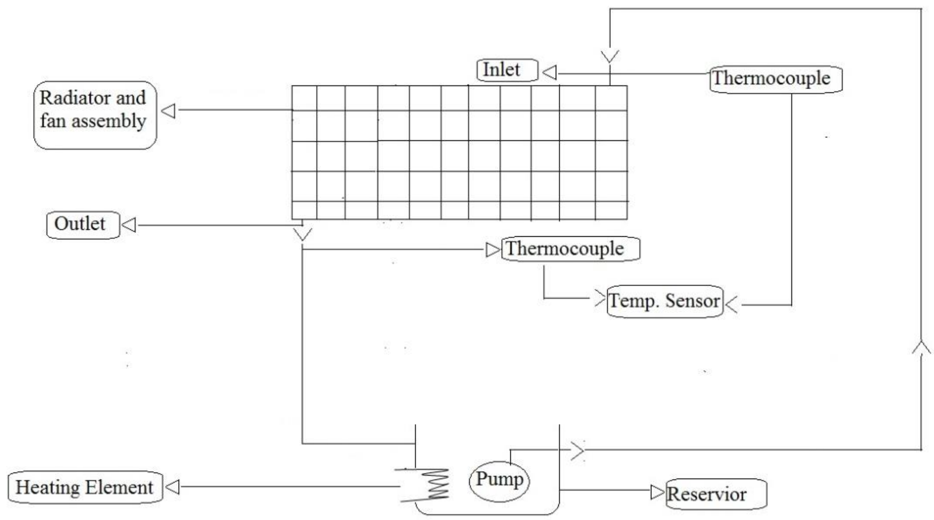


Figure 1: Schematic of Experimental setup used.

Figure 1 shows our test rig used for the experimental work . The coolant was first heated in a reservoir using a heating element upto a temperature of 85 °C which was then circulated through the radiator using a submersible pump. There were two thermocouples attached one at the entry of the radiator and another one at the exit to record the temperature which were connected to the temperature sensor and controller. The fan attached to the radiator is run using a battery attached. The fan is a pull type fan which extracts the heat from the coolant.

Mathematical Calculations and formulae:

Heat transfer modelling

Density and specific heat of the coolant is calculated using following relation eveloped by Pak [30] and Xuan [31]

$$\rho_f = (1-\phi)\, \rho_w + \phi \times \rho_{EG} \qquad (1)$$

$$C_c = \frac{(1-\phi)\rho w \times Cpw + \phi.\rho EG \times CpEG}{\rho f} \qquad (2)$$

Frontal Area of Radiator Afr= 0.35 x 0.35 = $0.123 m^2$

External diameter of tube = 9.66 mm

Internal diameter of tube = 8.73 mm

Number of tubes = 38

$Q_{max} = C_{min} \times (T_{ci} - T_{ai})$, Where (3)

$C_{min} = \min(m_a \times c_{pa},\ m_c \times c_c) = m_a \times C_{pa}$

The total heat transfer is given by,

$Q_t = m_c \times C_{pc} \times (T_{ci} - T_{co})$ (4)

Heat transfer coefficient based on coolant side is given by

$H_c = \frac{Qt \times Atubes}{Tci - Tai}$ (5)

The effectiveness is calculated as

$E = \frac{Qt}{Qmax}$ (6)

The velocity and Reynolds number of coolant are calculated using relation 7,8.

$V = \frac{Mc}{\rho c \times Atube}$ (7)

$Re_c = \frac{\rho cVcL}{\mu c}$ (8)

Pumping power calculations:

$PD = \frac{2 \times Gf \times Gf \times Ff \times H}{\rho c \times Dh} \times (\mu c/\mu w)^{0.25}$ (9)

PP = PD*V (10)

Above are the relations used to calculate the heat transfer parameters for various coolant flow characteristics. Reynolds number play a major role in deciding the heat transfer rate.

For validation of the experimental work use of dimensionless numbers are done. Nusselt number for flow were calculated.

Dittos boelter suggested empirical relation for the nusselt number which is given by $Nu_{emp} = .023 \times Re^{.8} \times Pr^{.2}$ This value was than compared with experimental nusselt number which is given by $Nu_{exp} = \frac{Hc * Dhyd}{K}$ these values were found to have variation in range of 5-12% .

Results and discussions:

Using above relation and observations made following are the results we found.

1. Variation in Re number with mass flow rates.

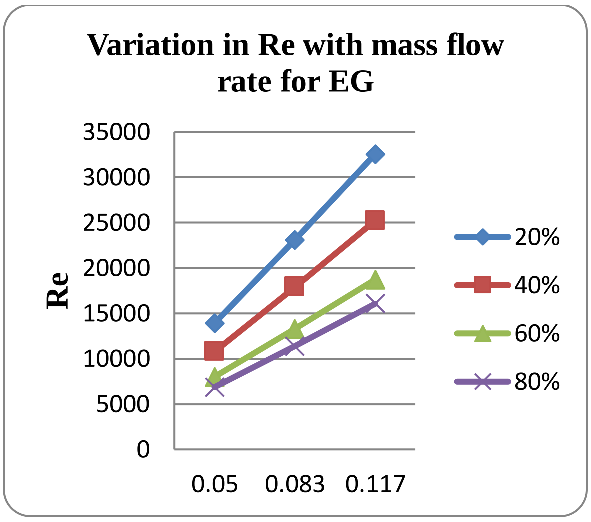


Figure: 2

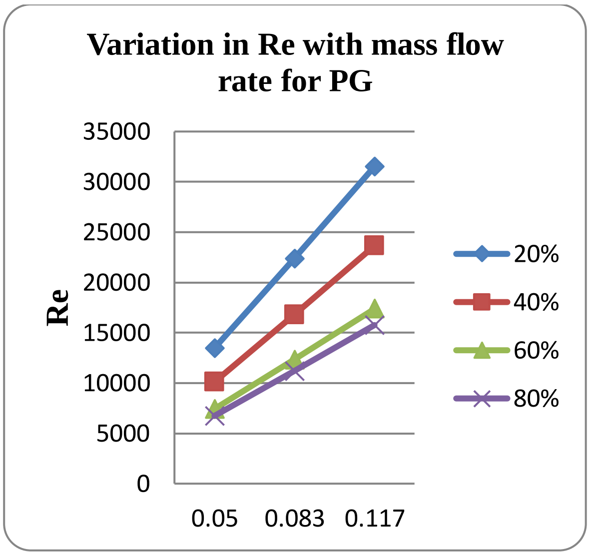


Figure: 3

The Reynolds number of coolant increases with increasing mass flow rate as seen from figure 2 and 3. This also shows that at constant mass flow rate with increasing with increasing volume concentration of glycol, the Reynolds number decreases. This may be attributed to the fact that with increasing volume concentration the density of the coolant varies which affect the Reynolds number of the coolant.

2. Comparison of nusselt number with mass flow rate:

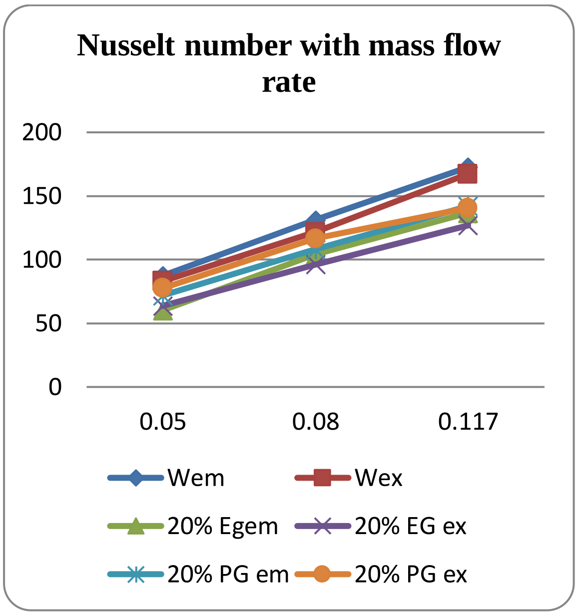


Figure 4

The figure 4 above shows the variation in nusselt number with mass flow rate for pure water, 20% EG and 20 % PG. It compares both experimental and empirical values of nusselt number which are found to be in accordance. The nusselt number was also found to increase with increasing mass flow rate.

3. Comparison of total heat transfer with varying mass flow rates:

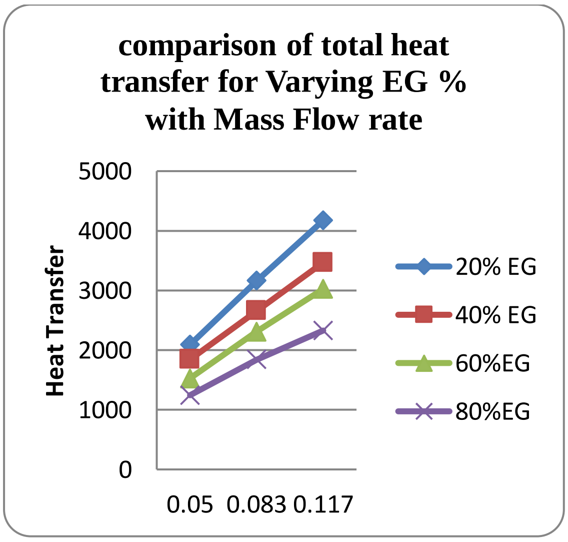


Figure 5

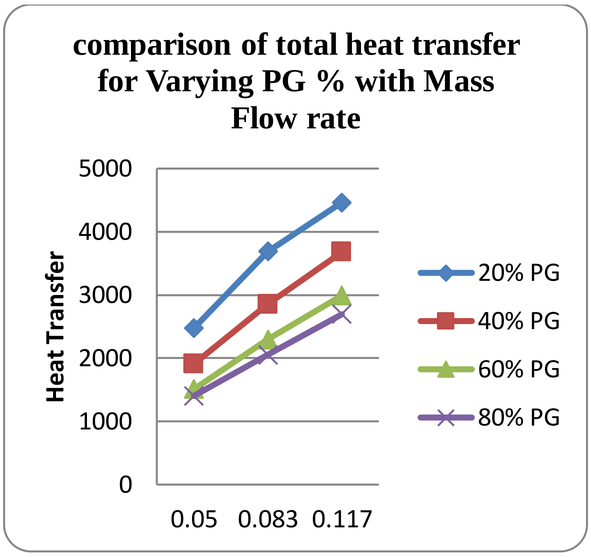


Figure 6

Experiments were performed by varying the mass flow rate of the coolant for all coolant compositions. Figures 5 and 6 above show the variation in total heat transfer with varying mass flow rates for different coolants. It was found that as the mass flow rate was increased from 0.05 to 0.117 Kg/m^3 for 20% EG solution the heat transfer increased from 2090.83J to 4173.04J. Similar relation was observed for each set of coolant.

4. Comparison of Heat transfer coefficient based on coolant side:

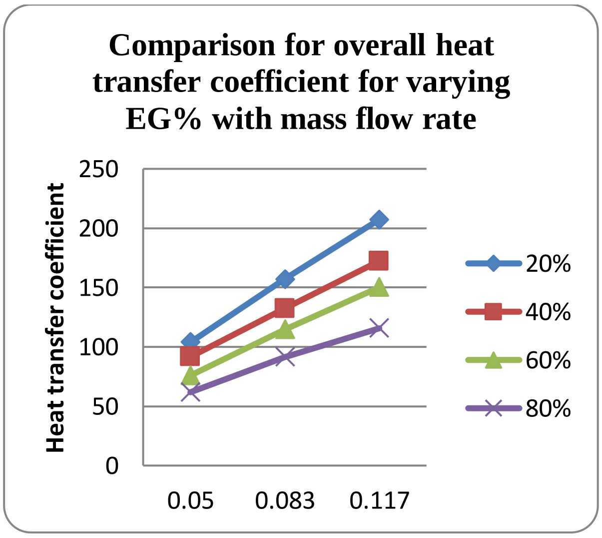


Figure 7

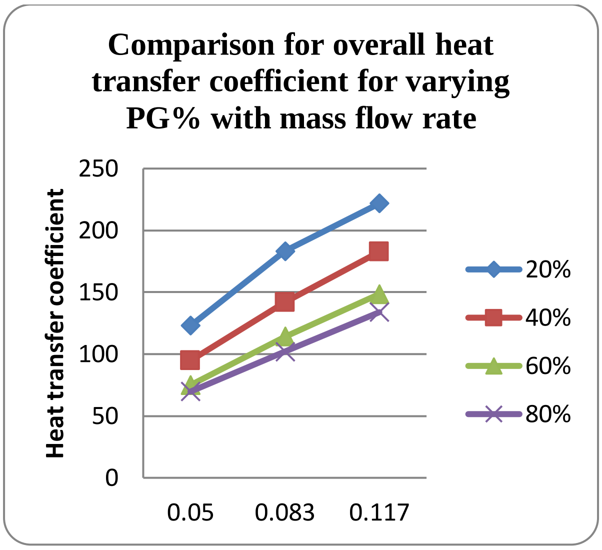


Figure 8

Figures 7 and 8 shows the variation in heat transfer coefficient based on coolant side with mass flow rates. It is observed that with increasing mass flow rate, the heat transfer coefficient tends to increase. The value of heat transfer coefficient increases from 103.86 W/m^2K to 207.3 W/m^2K for 20 % EG solution when mass flow rate is increases from 0.05 Kg/m^3 to 0.117 Kg/m^3. Similar results were observed for all coolants which are shown in above figures.

5. Variation in Effectiveness with mass flow rate:

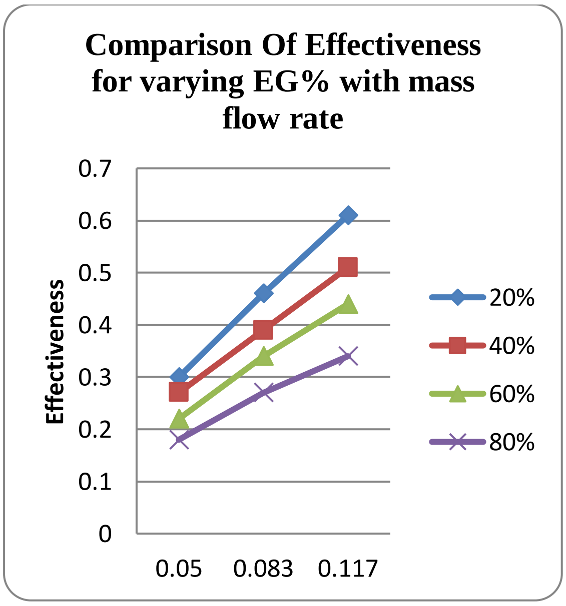


Figure 9

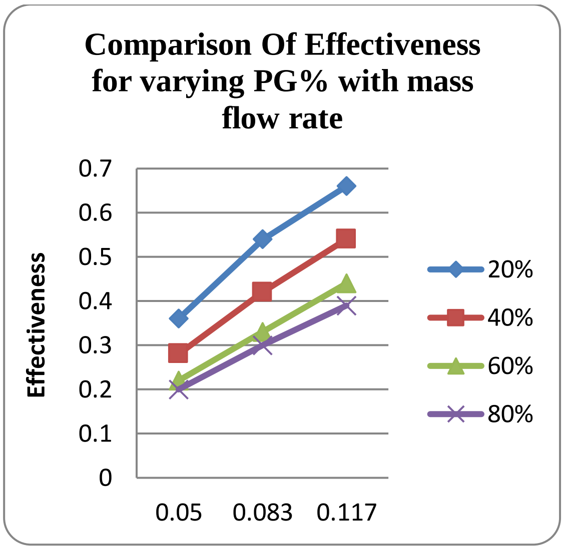


Figure 10

From the figures 9 and 10 above it is clear that with increasing mass flow rate the Effectiveness increases. For 20% EG solution the value of effectiveness increases from 0.3 to 0.61 when mass flow rate is varied from 0.05 Kg/m^3 to 0.117 Kg/m^3.

6. Variation in pumping power with mass flow rate:

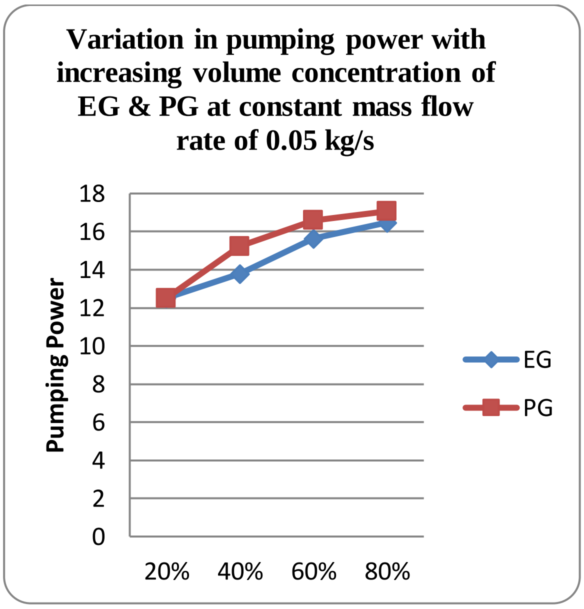


Figure 11

With variation in concentration of glycol in coolant the pumping power was found to increase. The study was done by keeping the mass flow rate of the coolants fixed at 0.05 Kg/s for both EG and PG.

It was that at 20% EG the pumping power was 12.518 W which increased to 16.478 W for 80% EG similarly for PG the trend was found to be similar which is shown in figure 10 above.

Conclusion:

From our study we can conclude that:-

1. The Reynolds number of the coolant increase with increasing mass flow rate for a particular coolant.

2. At a constant mass flow rate with increasing volume percentage of glycol the total heat transfer, heat transfer coefficient based on coolant side and effectiveness decreases.

2. With increasing mass flow rate the total heat transfer, heat transfer coefficient on coolant side and effectiveness increases.

4. By keeping the coolant mass flow rate constant comparison was made for the pumping power required which was found to increase for increasing glycol volume concentration.

Future Scope:

In this experimental study we focused on studying the variation of different flow characteristics and controlling parameters and their effects on the heat transfer performance. However this field is ever changing and scope of research is too high. We restrained the air flow conditions and varied inlet conditions only on the coolant side. It is also possible to study effects by varying air inlet conditions s well. Further a new class of coolants called nano fluids are found nowadays which are said to posses high heat transfer capacity as compared to pure water. The main issue with them is about the stability of the particles in the coolant fluid.

References:

1. A textbook on "Internal combustion engine fundamentals " J.B Heywood pg no. : 668-671.

2. A textbook on "Engineering fundamentals on internal combustion engines" Willard W. pulkrabek.

3. Rahul A. Bhogare, B. S. Kothawale “Performance investigation of automobile radiator operated with Al2O3 operated nanofluid”, May-Jun. 2014, IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE), Volume 11, Issue 3 pp:23-30.

4. Golakiya Satyamkumar, Sarvaiya Brijrajsinh, Makwana Sulay,Thumar Ankur, Rathwa Manoj “Analysis of radiator with different types of nanofluids”, Jan.-March, 2015, Journal of Engineering Research and Studies, Vol. VI Issue I pp:1-2

5. Mohammad Hemmat Esfe , Masoud Afrand , Arash Karimipour , Wei-Mon Yan, Nima Sina, ” An experimental study on thermal conductivity of MgO nanoparticles suspended in a binary mixture of water and ethylene glycol”, 2015, International Communications in Heat and Mass Transfer, pp:173-175.

6. Modeling & Analysis Of Louvered Fin Radiator With Nanofluids Using Cfd September - 2017 International Journal Of Advance Engineering And Research Development Volume 4, Issue 9, pg:26-33