Experimental Investigation into Coefficient of Heat Transfer of Al2O3 based Engine Coolant

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Abstract— A mixture of nano-sized particles in a base liquid called nanofluid, which is the new generation of heat transfer fluid for various heat transfer applications where transport characteristics are substantially higher than the base liquid. In the present study, the effects due to temperature and concentration on thermo physical properties (thermal conductivity, viscosity, density) for Al2O3/water/ethylene glycol based nanofluids are experimentally investigated. The volume fractions of nanoparticles used were 0.005%. The present work focuses on Heat Transfer Coefficient of Nanofluid. This however, has not been addressed properly so far. Results show that coefficient of heat transfer increases with increase in Flow rate as well as Heat Transfer (Q).

Key words: Heat Transfer, Al2O3, Engine Coolant

I. Introduction

Radiator is a key component of engine cooling system. Coolant surrounding engine passes through radiator. In radiator coolant gets cooled down and re-circulated into the system. Normally, it is used as a cooling system of the engine and generally water is the heat transfer medium .For this liquid-cooled system, the waste heat is removed via the circulating coolant surrounding the devices or entering the cooling channels in devices. The coolant is propelled by pumps and the heat is carried away mainly by radiator.

Nowadays, alumina is one of the most used oxides due to its use in many areas such as thin film coatings, heat-resistant materials, and advanced ceramic abrasive grains. Improved devices using nanoscale structures requires the understanding of thermal, mechanical electrical and optical properties of nanostructures involved and also their manufacturing process. Nano-particles, generally a metal or metal oxide, increase conduction and convection coefficients, allowing for more heat transfer out of the coolant. There have been several advancements recently which have made the nanofluids more stable and ready for use in real world applications.

These properties would be very beneficial to allow for an increased amount of heat to be removed from the engine. This is important because it will allow for a greater load to be placed on the fluid for cooling. Conventional fluids, such as refrigerants, water, engine oil, ethylene glycol, etc. have poor heat transfer performance and therefore high compactness and effectiveness of heat transfer systems are necessary to achieve the required heat transfer. Among the efforts for enhancement of heat transfer the application of additives to liquids is more noticeable. Recent advances in nanotechnology have allowed development of a new category of fluids termed nanofluids.

Nanofluids are formed by suspending metallic or non-metallic oxide nanoparticles in traditional heat transfer fluids. These so called nanofluids display good thermal properties compared with fluids conventionally used for heat transfer and fluids containing particles on the micrometer scale. 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

In this report data is presented on an experimental investigation of the convective turbulent heat transfer characteristics of nanofluids (Al2O3 ethylene glycol) with 0.005 vol. %. Heat transfer In this paper, forced convection coefficients are reported Ethylene Glycol/alumina Nano powder mixtures under fully turbulent conditions. The test section is made up with a typical automobile radiator, and the effects of the operating conditions on its heat transfer performance are analysed.

II. Important Formulas

Heat Transfer Coefficient $(Q) = hA\Delta$ ….(2.1)

Heat Transfer rate $(Q) = \dot{m}C\Delta T$. …..(2.2)

Mass Flow Rate $(\dot{m}) = \varrho . V$ …. (2.3)

Heat Transfer Coefficient –

$$h_{exp} = \frac{Q}{37 \times A_c \times (T_{cem} - T_{cim})} \quad ....(2.4)$$

Hydraulic Diameter –

$$D_h = \frac{4(\pi/4 \times d^2 + (D-d) \times d)}{\pi \times d + 2 \times (D-d)} \quad ....(2.5)$$

Reynolds number –

$$Re = \frac{\varrho \times D_h \times u}{\mu} \quad ....(2.6)$$

Nusselt Number-

$$Nu = \frac{h_{exp} \times D_h}{k} \quad ....(2.7)$$

A. Nomenclature

EG -Ethylene Glycol
NF- Nanofluid
FAST-Function Analysis System Technique
CFD-Computational Fluid Dynamics
TEM-Transmission Electron Microscopy
UV-Ultra Violet
C- specific Heat
D- diameter of tube
k- Thermal Conductivity
Nu- Nusselt Number
Pr- Prandtle Number
Re- Reynolds Number
u- Velocity
µ-Viscoty

ϱ- density
Φ- Volume Concentration
– Subscripts
i-inlet
e-outlet
m-mean

III. METHODOLOGY

1) Literature study.
2) Project identification.
3) Design.
4) System drawing.
5) Material Procurement
6) Manufacturing.
7) Fabrication of Assembly.
8) Trails and troubleshooting.
9) Testing
10) Conclusion

IV. DISCUSSION ON LITERATURE STUDY

1) Two step Method is economical than single step method.
2) Thermal conductivity and viscosity increases with the increase of the volume concentration (%).
3) Mechanical stirring is an important step in achieving nanofluids by dispersing nanoparticles in a base fluid.
4) Nusselt number behaviour of the nanofluids highly depended on the volume flow rate, inlet temperature and nanofluid volume concentration.
5) Thermal conductivity increase with Temperature and viscosity decreases Temperature.

V. RADIATOR

A radiator is a type of heat exchanger. It is designed to transfer heat from the hot coolant that flows through it to the air blown through it by the fan. Most modern cars use aluminium radiators. These radiators are made by brazing thin aluminium fins to flattened aluminium tubes. The coolant flows from the inlet to the outlet through many tubes mounted in a parallel arrangement. Radiator is a key component of engine cooling system. Coolant surrounding engine passes through radiator.

In radiator coolant gets cooled down and re-circulated into the system. Radiator size is controlled by heat load and packaging space availability. In this paper NTU method is described to do heat transfer calculations and to decide radiator size. Size is verified through 1-D simulation.

Air flow(m/s)	Coolant flow (lpm)	Heat Rejection
2	4	9.2
4	8	16.5
6	12	22.8

Table 1: Heat Rejection Requirement [4]

Fig. 1: Radiator

VI. EXPERIMENTAL SETUP

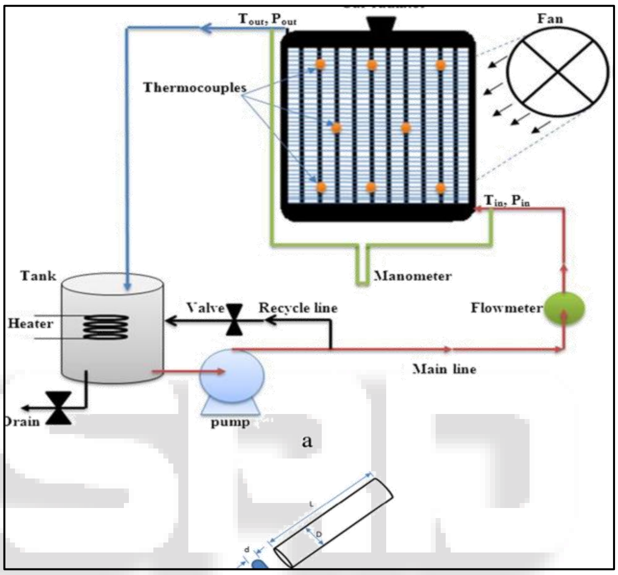

Fig. 2: Experimental Setup [7]

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. Due to very small thickness and very large thermal conductivity of the tubes, it is reasonable to equate the inside temperature of the tube with the outside one. The temperature was noted through the temperature indicator. Error details were measured from calibration of each thermo couples by comparing the temperature which was measured by thermo meter.

For heating the working fluid an electric heater of capacity 2000 watt and controller were used to maintain the temperature. Two thermocouples were implemented on the flow line to record the radiator inlet and outlet temperature. Four thermocouples is installed on the radiator to measure the wall temperature of the radiator. Battery is used to run the Motor of radiator Fan.

Fig. 3: Temperature Sensor

VII. PROPERTIES OF FLUID

Srno	Properties	Water	Ethylene glycol	Nanofluid
1	Density(Kg/m3)	1000	1110	1239.5
2	Specific Heat (J/kg K)	4183	3140	2802.68
3	Thermal Conductivity (W/mK)	0.599	0.253	0.26467
4	Kinematic Viscosity (m2/s)	1.006×10-6	0.000013	1.27x10-6

Table 2.Thermo Physical Properties of Fluids

VIII. RESULTS

Q	h_{exp}	h_{th}
2333.32	1588.93	1504.72
2153.866	1457.97	1415.373
1840.25	1355.98	1303.631

Table 3 .Variation of Coefficient of Heat Transfer with Heat Transfer rate (Q) of Nanofluide

Flow rate (LPM)	hexp	h_{th}
9	1588.93	1504.72
8	1457.97	1415.373
7	1355.98	1303.631

Table 4 .Variation of Coefficient of Heat Transfer with Flow rate (Q) of Nanofluide

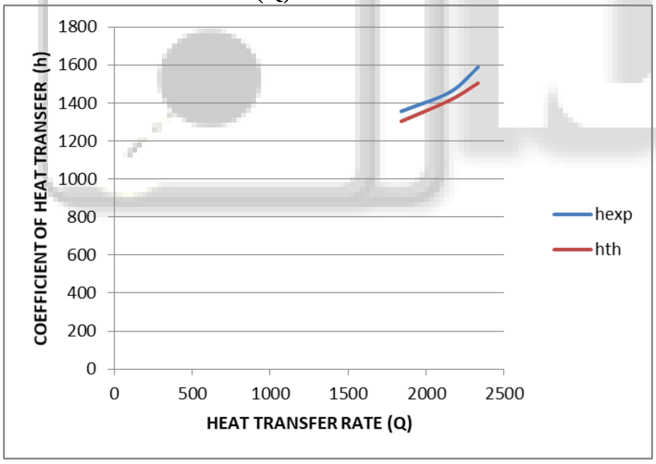

Fig. 4: Variation of Coefficient of Heat Transfer with Heat Transfer rate (Q) of Nanofluide

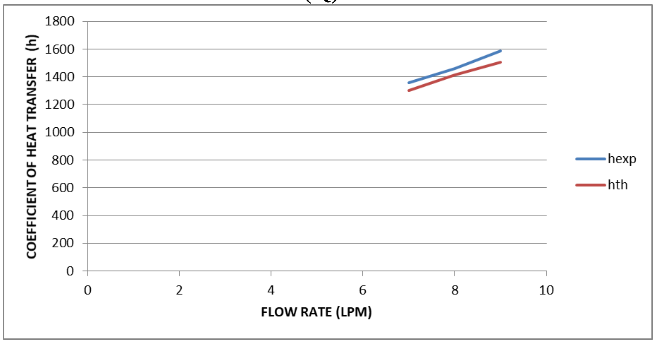

Fig. 5: Variation of Coefficient of Heat Transfer with Flow rate (Q) of Nanofluide

IX. CONCLUSION

The experiment conducted on the Maruti Suzuki 800 radiator by replacing the conventional coolant by the modern nanocoolant proved comparatively effective. The results obtained so far is the evidence of increase in the efficiency of the radiator. The following inferences can be drawn by demonstrating the experiment successfully:

1) The heat transfer rate of nanofluid is greater than that of conventional coolant as the conductivity of the Alumina is higher than the simple coolant.
2) The size of the radiator is reduced in the case if we want same heat transfer rate as that of the conventional coolant.
3) Hence it becomes possible to improve the aerodynamic shape of the car which would reduce the air drag.
4) The reduced air drag, improved heat transfer rate, better engine cooling reducing the average fuel consumption.
5) The volumetric efficiency of the engine cylinder is also improved due to better and faster cooling.
6) The most important the Nox emission is also considerably reduced as the engine temperature is reduced below 11000C.
7) Results show that coefficient of heat transfer increases with increase in Flow rate as well as Heat Tranfer(Q) .

Thus we finally conclude that this experiment proved to be very beneficial in all-round aspects improving the overall vehicle performance covering all important aspects.

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