ENHANCEMENT IN HEAT TRANSFER RATE OF DIESEL ENGINE RADIATOR USING NANO FLUID

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ABSTRACT

A High efficiency engine is based on its performance and also based on better fuel economy and less emission. Cooling system is also one of the important elements to control the engine temperature. An efficient cooling system using proper cooling fluid can prevent engine from overheating. Radiator plays an important role in cooling system. In radiators different conventional fluids are used such as water, ethylene or ethylene glycol. These fluids have low thermal conductivity that greatly limits the heat exchange efficiency. This project focuses on enhancement of heat transfer in diesel engine radiator using Nano fluid instead of conventional fluid. The effect of varying Nano fluid particle concentration in water was experimented. It was observed that this enhancement in heat transfer rate has been increased by 20%. (A Heat transfer textbook by John H. Lienhard [14])

Keyword: - *Nano fluid, Radiator, Al2O3, Thermal Conductivity, Heat Transfer Rate.*

NOMENCLATURE

T_1 to T_8- Temperature on surface of radiator (^{0}C)
T_9- Inlet temperature of fluid in radiator (^{0}C)
T_{10}- Outlet temperature of fluid out radiator (^{0}C)
T_b- Bulk temperature (^{0}C)
T_s- Surface temperature (^{0}C)
P- Density of water (kg/m^3)
P_{bf}- Density of base fluid (kg/m^3)
P_{nf}- Density of Nano fluid (kg/m^3)
P_p- Density of Nano particle (kg/m^3)
ϕ- Volume concentration or weight concentration of nano particle
W_p- Weight of Nano particle
W_{nf}- Weight of Nano fluid
Cp_{bf}- specific heat of base fluid (J/kgk)
Cp_p- Specific heat of Nano particle (J/kgk)
Cp_{nf}- Specific heat of Nano fliud(J/kgk)
μ_{nf}- Viscosity of Nano fliud (Pa-s)
μ_{bf}- Viscosity of base fluid (Pa-s)
K_{nf}- Thermal conductivity of Nano fluid (W/mk)
K_{bf}- Thermal conductivity of base fluid (W/mk)
Q- Heat Transfer (W)
m^*- Mass flow rate (Kg/s)

C_{pw}- Specific heat of water (J/Kgk)
h_{exp}- Heat Transfer coefficient (W/m^2k)
k- Thermal conductivity (W/mk)

1. INTRODUCTION

High performance cooling is one of the important needs of many industries. Heat transfer flow fluid such as water, engine oil, ethylene glycol though they play important role in thermal management in industries they have poor heat transfer properties compared with those of most solid .

Nanofluids is a fluid having non sized solid particles, normally particle size less than 100 nm, disperse in the convectional based fluid water, mineral oil, ethylene glycol. This tremendously enhance the heat transfer characteristics (and little penalty in pressure drop) of original fluid. This is because of solid non particles these fluids have thermal conductivities several times higher than that of convectional fluid, several types of Nano particles can be employed for Nano fluid preparation, including metals such as gold, copper and silver. And also metal oxides such as Al2O3, CuO, TiO2, Fe2O4 metals oxide are many more.

For this particular topic related to enhancing heat transfer using Nano fluid lots of work has been done previously. Though this concept is not new but the work done on this subject is related with considering the factors which affects Heat transfer rate, like by changing volume concentration or by changing flow rate, at varied load condition on engine, change in inlet temperature of radiator, and comparing heat transfer rate enhancement by using different Nano fluids.

Peyghambarzadeh et al. [6] have recently investigated the application of Al2O3/water Nanofluids in the car radiator by calculating the tube side heat transfer coefficient. They have recorded the interesting enhancement of 45% comparing with the pure water application under highly turbulent flow condition.

In the other study, Peyghambarzadeh et al. [7] have used different base fluids including pure water, pure ethylene glycol, and their binary mixtures with Al2O3 nanoparticles and once again it was proved that Nanofluids improves the cooling performance of the car radiator extensively.

Yu, W., France, D.M., Choi, S.U.S. et al, [8] reported that about 15-40% of heat transfer enhancement can be achieved by using various types of Nanofluids. This translates into a better aerodynamic feature for design of an automotive car frontal area. Coefficient of drag can be minimized and fuel efficiency can be savings for the automotive industries through the development of energy efficient Nanofluid and smaller and lighter radiators.

D. Wen, Y. Ding et al. [9] investigated the effect of temperature, particle size and volume fraction on thermal conductivity of water based Nano fluids of copper oxide and alumina. Authors suggested that thermal characteristics can be enhanced with increase of particles volume fraction, temperature and particle size. Authors found that the smaller the particle size, the greater the effective thermal conductivity of the Nano fluids at the same volume fraction.

HuaqingXie et al. [10] performed their experiments in the radiator type heat exchanger and at 6.8 vol. % Al2O3 in water obtained 40% increase in heat transfer coefficient.

Eastman, J. A., Choi, S. U. S., Li, S., Yu, W et al. [11] measured thermal conductivity of Nano fluids containing Al2O3, nanoparticles with two different base fluids: ethylene glycol and pump oil. Results showed a 30 % & 40 % improvement in the thermal conductivity as compared to the corresponding base fluids for 5 vol. % of nanoparticles and the size of the nanoparticles used with both the fluids is 60 nm.

While studying different research paper it has been observed that clogging of nanoparticles occur when volume concentration of nanoparticles increases in base fluid beyond certain limit. Also nanoparticles show tendency of settling down after some period.

Objective of our work is not only to enhance heat transfer rate of radiator by using Al_2O_3, as Nano fluid but also try to avoid settling and clogging problem of nanoparticles when concentration of nanoparticles increased in base fluid. The use of a stirrer is done so as to avoid settling and clogging of nanoparticles.

2. METHODOLOGY

2.1 Experimental Test Rig

The test rig in Fig. 1 has been used to measure heat transfer coefficient in diesel engine radiator with and without. This experimental setup includes a steel tank as reservoir, electrical heater, a centrifugal pump, a flow meter, tubes, valves, a fan, dimmer (8Amp), a DC power supply & Digital thermocouples (type K) for temperature measurement& heat exchanger (Car radiator).

An electrical heater (2000W) inside a steel storage tank (40cm height and 30 cm diameter) represents the engine and to heat the fluid.A voltage regulator (dimmer of 8Amp) provides the power to keep the inlet temperature to the radiator from 60^{o}C to 80^{o}C. A flow meter (0–100 LPH) and valve is used to measure and control the flowrate.The fluid flows through GI pipes (12.7mm) by a centrifugal pump (0.5Hp and 3m head) from the tank to the radiator at the flow rate ranging from40-70 LPH.

Two thermocouples (copper–constantan; types K) have been fixed on the flow line for recording the inlet and outlet fluid temperatures. 8 thermocouples (type K) have been fixed to the radiator surface to ensure more of surface area measurement. To read all the temperatures of thermocouples a DTI is provided. Two small plastic tubes with 0.25inch diameter is connected to inlet and outlet pipe of radiator and further joined with U-tube manometer to measure pressure drop on inlet and outlet of the pipe.

The car radiator has 195 louvered fins and 18 vertical tubes. For an airside, an axial fan (2800rpm) installed close on axis line of radiator. A small motor of 20v capacity is provided to drive the fan. In addition to this a stirring mechanism is provided to avoid clogging and settling of Nano particles. A stirring mechanism consists of a shaft on which steel plates are brazed to form a stirrer. This stirrer is driven by 20v motor.

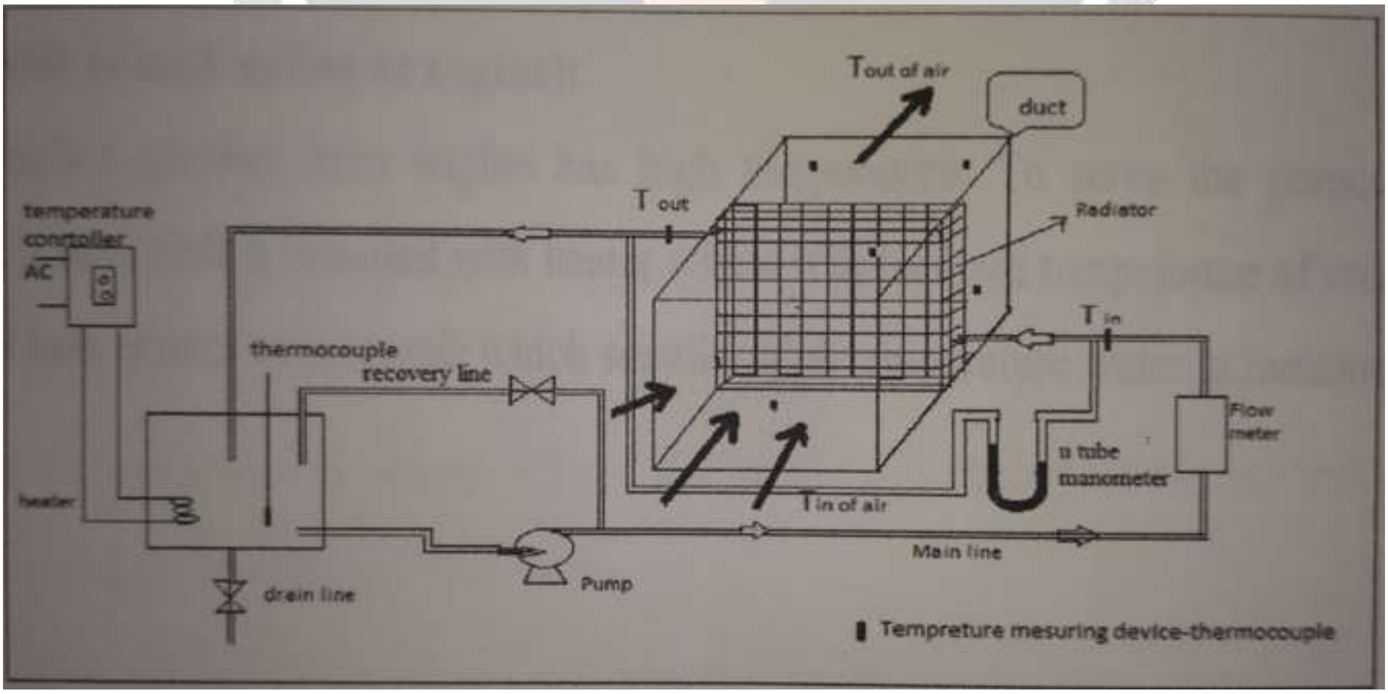

Fig -1: Schematic diagram of Experimental setup

Fig -2: Actual picture of Experimental Setup

Mean Diameter	Density	Specific Heat	Thermal Conductivity	Particle Shape
<50nm	3.98 Mg/m3	955 J/kg.K	38.5 W/m.K	Spherical, Elongated

Table -1: Physical Properties of Al_2O_3 Nano Particle

3. RESULTS AND DISCUSSIONS

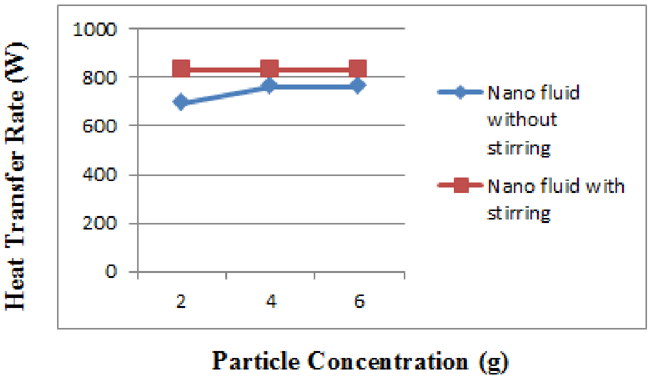

Chart -1: Temperature on Heat Transfer Rate under varying Particle Concentration

By increasing concentration of Nano powder in base fluid, results obtained are

1. Increasing volume concentration from 2 to 4g increases the heat transfer rate by 9.88% but friction factor also increases resulting in pressure drop across radiator.
2. Further increasing concentration of Nano fluid beyond certain limits results in increasing problem of clogging and particle settlement.
3. With the use of stirring mechanism clogging and particle settlement get reduces; resulting in increased in heat transfer by 9.09% for 4g concentration.
4. Further due to stirring mechanism at low concentration of Nano fluid heat transfer rate increases which can be effectively used to reduce friction resistance and pressure drop.

Hence the heat transfer rate is attributed to the fact that with addition of Nano particles the conductivity of the fluid increase thereby increasing the heat gain capacity.

In accordance with A Heat transfer textbook by John H. Lienhard [14].

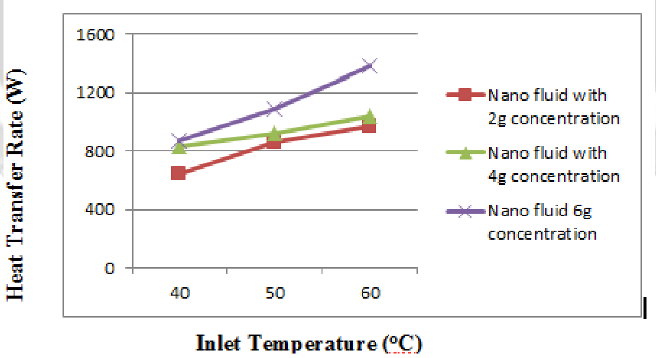

Chart -2: Temperature on Heat Transfer Rate under varying Flow Rate

By increasing flow rate of Nano powder in base fluid, results obtained are

1. With the increase in flow rate from 40 to 50 LPH the heat transfer rate for 2g concentration of Nano fluid increases by 33.68%.
2. Further if the flow rate is increased from 50 to 60 LPH then the heat transfer rate for 2g concentration of Nano fluid increases by 12.13%.
3. Now for 4g concentration of Nano fluid the increase in heat transfer rate for increase in flow rate from 40 to 50LPH is 11.11% and for 50 to 60 LPH is 12.49%.
4. Now for 6g concentration of Nano fluid the increase in heat transfer rate for increase in flow rate from 40 to 50LPH is 25.00% and for 50 to 60 LPH is 27.06%.

Thus with increase in flow rate the turbulence level increases, thus fluid particle comes in contact with larger surface area thereby absorbing more heat hence for a given concentration of Nano fluid the heat transfer rate increases.

Based on the experimental results, introducing nanoparticles to the fluid will increase heat transfer rate of the system. Surface properties, particle shape, and concentration of nanoparticles play important role to improve Nano fluid heat transfer properties.
The increase in heat transfer rate while using Nano fluid as compared to that of the base fluid i.e. water is obtained because of higher value of Thermal Conductivity of Al2O3 Nano powder (40 W/m K) and further it has been proved that abulk material has constant physical properties regardless of its size, but at the Nano scale, size-dependent properties are often observed. Thus, the properties of materials change as their size approaches the Nano scale and as the percentage of the surface in relation to the percentage of the volume of a material becomes significant.

4. RESULTS AND DISCUSSIONS

The convective heat transfer performance of Al_2O_3 Nano fluid flowing on diesel engine radiator has been experimentally investigated. Experiments have been carried out under turbulent conditions. The effect of particle concentration and inlet temperature has been determined. Comparison of heat transfer in water and in Nano fluid without stirring action and with stirring action is done from readings by plotting graph.

Important conclusions are:

1. Dispersion of nanoparticles into distilled water increases the thermal conductivity and viscosity of Nano Fluid.
2. This augmentation increases with increase in particle concentration.
3. Though increase in particle concentration increase friction factor. This problem can be overcome by using stirring mechanism which enhances heat transfer rate at low concentrations also.
4. It has been observed that using stirring mechanism clogging and settlement of particles problems can be effectively overcome.
5. Stirring mechanism improves heat transfer rate by 10-15% than without stirring.

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