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Nanofluid Based Radiator for Efficient and Compact Design

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Abstract:- As part of an effort to evaluate water-based nanofluids for radiator heat transfer applications, creation, modification and characterization has been performed for nanofluids being considered for radiator as a coolant for nanofluid heat transfer experiments. Three methods of generating these nanofluids are available: creating them from chemical precipitation, purchasing the nanoparticles in powder form and mixing them with the base fluid, and direct purchase of prepared nanofluids. Characterization of nanofluids includes colloidal stability, size distribution, concentration, and elemental composition. Mixer of nanoparticles, glycol and water is use as a coolant in radiator which gives the maximum heats extraction from engine.

Keywords:- *Nanofluids, Glycol, Radiator, Pump, Temperature sensor.*

I. INTRODUCTION

In case of Internal Combustion engines, combustion of air and fuel takes place inside the engine cylinder and hot gases are generated. The temperature of gases is around 2300-2500°C. This is a very high temperature and may result into burning of oil film between the moving parts and may result into seizing or welding of the same. So, this temperature must be reduced to about 150-200°C at which the engine works most efficiently. Too much cooling is also not desirable since it results in overcooling and hence reduces the thermal efficiency. The objective of cooling system is to keep the engine running at its most efficient operating temperature. From total heat generated in the engine:

- About 20-25% of total heat generated is used for producing brake power (useful work).
- Cooling system is designed to remove 25-30% of total heat.
- Remaining heat is lost in friction and carried away by exhaust gases.

Most automotive cooling systems consist of the following components: radiator, pump, cooling fan, radiator pressure cap, and thermostat.

Radiators are used for cooling internal combustion engines, mainly in automobiles but also in piston-engine aircraft, railway locomotives, motorcycles, stationary generating plants and other places where such engines are used.

To cool down the engine, a coolant is passed through the engine block, where it absorbs heat from the engine. The hot coolant is then fed into the inlet tank of the radiator and distributed across the radiator core. As the coolant circulates through the radiator tubes on its way to the opposite tank, it cools again. The cold coolant is fed back to the engine, and the cycle repeats.

As it circulates through the tubes, the coolant transfers its heat to the tubes which, in turn, transfer the heat to the fins that are provided between each row of tubes. The fins then release the heat to the ambient air. Fins are used to greatly increase the contact surface of the tubes to the air, thus increasing the exchange efficiency. Coolant is must for every radiator to work efficiently. But, a good coolant must have high heat transfer coefficient for effective heat transfer. There are many commercially available coolants which claim high heat transfer. Once these coolants are tested, the most effective of them can be found out. If further research is carried out such as adding additives to coolants, their performance can be improved. Thus, the size of the radiator will decrease thus reducing the weight of the vehicle which will further increase its efficiency.

II. PROBLEM STATEMENT

The bottle neck in the vehicle performance is the low radiator efficiency. Thus improvement in the radiator performance will be very beneficial. Conventional radiator is large in size due to lack of thermos physical properties of the conventional coolant. There are some disadvantages like more No_X emission, low radiator efficiency, more fuel consumption, etc. which can be overcome by replacing the coolant. There is a need for the experimental demonstration to show the effectiveness of the Nanofluids.

III. LITERATURE REVIEW

The technical newsletter bulletin 'issue 43' of Wear check Africa has published the temperature at which a standard water cooled engine should operate. They have also mentioned the working temperature of the lubricating oil and the temperature of the coolant in the water jacket of the engine. A standard water cooled engine should operate with a cooling system temperature between 80°C and 90°C. Considering that the oil operating temperature should be 10°C to 15°C above the coolant temperature, and then the oil operating temperature should be within 90°C to 105°C but should not exceed 105°C. [1]

Efeovbokhan, Vincent Enontiemonria, Ohiozua, Ohireme Nathaniel, from the Department of Chemical Engineering, Covenant University, Canaan Land,Ota, Nigeria have published a paper related to the performance of coolants. They made 3 samples for testing. Three different coolants were water, a coolant purchased from auto car care products, and the formulated coolant, were considered. The formulated coolant consisted of a 50/50 blend of ethylene glycol and water, 1% corrosion inhibitor and a Dye (green) were all mixed in their correct proportions. Paper concludes that formulated coolant is good for cooling system than water and coolant alone. Though water has high specific heat but it results in corrosion of the system and has low boiling point and higher freezing point and hence formulated coolant is effective in terms of heat transfer as well as corrosion resistance. The paper also gives a good method of calculating specific heat of the coolants using Joule's calorimeter [2].

Prof. A. R. Khot, Prof. D.G. Thombare, Prof. S. P. Gaikwad and Prof. A. S. Adadande Mechanical Dept., JJMCOE JSP, India and Automobile Dept, RIT Sakhrale, India have given two methods of evaluation of performance of radiator, first is analytical and second is experimental. The experimental method can be used in laboratory for evaluating performance of radiator. The same setup can be used to evaluate the performance of the coolants used in the cooling system of the automobile. It concludes that pressure drop as well as heat dissipation increases with increase in mass flow rate of coolant [3].

Prof. Chavan D.K. and Prof. Tasgaonkar G.S. have studied that the heat exchanger, used in refrigeration unit, air conditioning unit, radiator used with IC engine automobiles is either rectangular or square in shape. But the air blown/sucked by the fan is in circular area developing low velocity zones or high temperature regions are created in the corners. They studied different heat exchangers/radiators, did calculations and developed a geometrical model. They also calculated power consumed by fan. They found that the power consumed by fan is 2 to 5% of power produced by engine. They have proposed to have circular heat exchanger for refrigeration, air conditioning unit and for car radiators for maximum efficiency [4].

Paresh Machhar, Mechanical Engineering Department, RK University, Rajkot, Gujarat, India and Falgun Adroja, Mechanical Engineering Department, RK University, Rajkot, Gujarat, India have published their paper on nanofluids used in radiators. In their paper, they experimentally compared forced convective heat transfer in a water based nanofluids to that of pure water in an automobile radiator. They prepared five different concentrations of nanofluids in the range of 0.1 - 1 vol. % by the addition of TiO_2 nanoparticles into the water. They observed that use of nanofluids with low concentrations enhanced heat transfer efficiency up to 45% in comparison with pure water. They also analyzed the effect of fluid inlet temperature to the radiator on heat transfer coefficient by varying the temperature. They found that heat transfer performance can be improved by increasing the flow rate of the coolant [5].

IV. EXPERIMENTAL SETUP

The experimental setup of the project is as shown in figure 1. below:

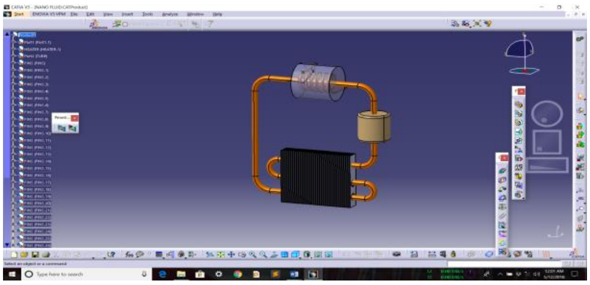

Fig 1:- Experimental Setup

- *Construction*

The experimental setup consists of the following components.

- *Radiator*

It is the most important component of the experimental setup. The radiator selected was that of Maruti 800 car. It was selected as it is the smallest available radiator of a four wheel automobile in the market. It has least volume of about 1200 ml and thus helps to make the setup compact.

- *Cylinder Block*

The cylinder block selected resembles the water jacket of an actual Maruti 800 car. Water coming out of the radiator is sucked into the jacket by means of pump in built in the cylinder block. The jacket is selected to make setup similar to the actual cooling system of Maruti 800.

- *Pump*

The pump is inside the water jacket and is run using an AC motor. The power from AC motor is used to drive the cooling fan as well as the pump. It is a suction type of pump with negligible head. It sucks the water from the radiator outlet and gives it to the tank.

- *Tank*

The tank is used for storing coolant and then circulating it to the radiator. It is made of aluminium. It is double layered and contains glass wool between two aluminium sheets providing insulation to the coolant inside the tank. Thus, the heat loss from the tank is made minimum.

- *Cooling Fan*

The coolant flowing from the radiator has to be cooled before introducing it to the hot engine cylinder surface. For this an axial flow type fan is used behind the radiator. The fan sucks air which flows over the heated fins thus cooling those using phenomena of convection. The fan is driven by a pulley which is run by an AC motor.

- *Connections*

The various components in the setup mentioned above are connected using rubber hoses to avoid heat loss. Some parts of the connections are made of steel to mount manometer connections and thermocouples.

- *Temperature Sensors*

There are two types of sensors used in the setup: -thermocouples and RTD. Thermocouples used are K type having good accuracy. One thermocouple is mounted at the inlet to radiator and one at the outlet. Two more are attached at two points on the aluminium tube of the radiator. An RTD of type PT-100 is immersed into the tank. It is used for sensing and controlling the temperature of the coolant in the tank at desired temperature of 90°C.

➢ *Law of Intermediate Metals*

Insertion of an intermediate metal into a thermocouple circuit will not affect the EMF voltage output as long as the two junctions are at the same temperature.

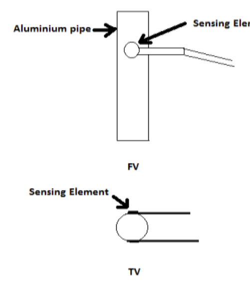

Fig 2:- Mounting of Thermocouple

Simulations used are follows:

Where,

Simulation No.1 = Water + Ethylene Glycol.

Simulation No.2 = 0.001% Al_2O_3 + Water + Ethylene Glycol.

Simulation No.3 = 0.002% Al_2O_3 + Water + Ethylene Glycol.

Simulation No.4 = 0.003% Al_2O_3 + Water + Ethylene Glycol.

A. Simulation Obsevation

Simulation No.	Inlet Temp.(^{0}C)	Outlet Temp.(^{0}C)
1	51.1	41.8
2	57	46.1
3	58.8	46.2
4	57.7	44.6

Table 1. Simulation Observations

B. Equations

$$VIt = (McCc+MwCw)\,[(T2+p)-T1] \quad (1)$$

$$p = (A1/A2)*2^0C$$

C. Calculations

Theoretical Calculations:
Air Properties,
ρ=1.125 kg/m^3
μ = 1.895 x 10^{-5} N-s/m^2
Cp=1005 J/kg k
K=0.02625
Velocity=5 m/s

1) $R_e = \frac{\rho v D}{\mu}$

$= \frac{1.25 \times 5 \times 6.82 \times 10^{-3}}{1.895 \times 10^{-5}}$

= 2249.34

2) $P_r = (\mu Cp) / k$

$= \frac{1.85 \times 10^{-5} \times 1005}{0.02625}$

= 0.7255

3) N_u = relation used

$N_u = 0.242 \times (Re)^{0.688} \times (s/h)^{0.297} \times (P1/P2)^{-0.91} \times (Pr)^{1/3}$

$= 0.242 \times (2249.34)^{0.688} \times (1.4/3.75)^{0.297} \times (14/12.82)^{-0.91} \times (0.7255)^{1/3}$

= 30.252434

S = distance between adjacent fin
h = height of off set strip fin

Air Side H.T coefficient

$h_0 = \frac{k \times Nu}{Dr}$

$= \frac{0.02625 * 30.252434}{6.82 \times 10^{-3}}$

h_0= 116.44 w/m^{2}k

Effective air side H.T coefficient referred to e surface
$h_0' = h_0 \times A/AT$
= (116.44 x 4443066.60) /314957.229
= 1642.60 w/m^{2}k

V. TESTING OF COOLANTS

The testing of available coolants is done using the setup explained in above fig 1. The coolants are evaluated for calculating heat transfer coefficient ‘h’. The coolant having highest ‘h’ is the best for the radiator.

Procedure:

The following is the procedure for testing of coolants as shown in above fig 1.

- Fill the whole setup including tank, water jacket model and radiator with coolant. Switch ON the controller circuit and motor which drives the pump.
- The microcontroller automatically controls the heating coil and maintains the temperature of 90°C in the tank.
- Let the setup run for some time till the desired temperature is obtained in the tank.
- Note down the inlet and outlet temperatures of the radiator and the 2 surface temperatures of the aluminum pipe of the radiator.
- Measure the mass flow rate of the coolant before it enters the radiator.

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VI. CONCLUSION

A new manufacturing method would also be needed for mass production due to large time requirements of current methods Instead of using parallel setup a single tube with multiple passes could be beneficial this should increase the time that the fluid is exposed to the flowing air which would allow for more heat transfer. As mentioned before, the tube thickness could also be reduced which would allow for less time for the heat to conduct through the tube, and thus increase heat removal. Determining the key energy transport mechanism in Nanofluids. Future research should be focused on finding out The main parameters affecting the thermal conductivity of Nanofluids. The challenging point is to obtain the desirable nanoparticle product. The development of the nanoparticle production technique will be very helpful for the Nanofluid research. Nanofluids engineers would be prudent to pursue green designs by choosing nontoxic co biodegradable nanoparticles. So in last we can say that low cost, high volume production of stable green Nanofluids is one of the most challenging directions for future applied research.

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