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EXPERIMENTAL AND NUMERICAL ANALYSIS ON CAR RADIATOR BY USING NANOFLUIDS

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ABSTRACT

Nanofluid is a new type of heat transfer fluid with superior thermal performance characteristics, which is very promising for thermal engineering applications.In this study,effect of adding copper nanoparticles to the base fluid(water) in radiator for the purpose of increasing the heat transfer rate.By means of this, thermal efficiency can be improved, then reduction in fuel consumption and decrease in the pollutant emission. And the thermo-physical properties of nanoparticles are thermal conductivity, specific heat, density, viscosity it can be measured at different volume concentration at various temperature ranges.

Key words: *Nano fluids, Thermal efficiency, Radiator, Heat transfer enhancement*

1.1 INTRODUCTION

The radiator is an important accessory of vehicle engine. 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. Nowadays, high prices of energy motivate industries to apply energy saving methods as much as possible in their facilities. Common heat transfer fluids such as water, ethylene glycol, and engine oil have limited heat transfer coefficient Nanofluids were developed recently by suspending solid particles (ranging from 10 nm to 100 nm) in a base fluid, these fluids have displayed better thermal characteristics and exhibited excellent heat transfer properties even at low concentration of nano particles in base fluid.In current era, a large number of experimental investigations are being performed on the properties of nano. Metallic nanofluids showed higher enhancements compared with the oxide nanofluids.

2.1 THERMO-PHYSICAL PROPERTIES OF NANOFLUIDS

2.1.1 THERMAL CONDUCTIVITY

Since then, many investigations were carried out by a number of researchers on the thermal conductivity of various nanofluids .Maxwell model was used to determine thermal conductivity of the nanofluid

$=K_L \times \frac{K_S+2K_L+2(K_S-K_L)\Phi}{K_S+2K_L-(K_S-K_L)\Phi} K_{nf}$

2.1.2 VISCOSITY

Viscosity of nanofluids is a parameter as crucial as thermal conductivity for the thermal performance investigation. Therefore, minimization of viscosity is also a critical factor in addition to the augmentation of thermal conductivity.

$\mu_{nf}=\mu_w(123\Phi^2 + 7.3\Phi + 1)$

2.1.3 DENSITY

Density of a fluid is another important thermophysical property. Like viscosity, density of any fluid has direct impact on the pressure drop and pumping power. Solids have a greater density compared to liquids; therefore, the density of nanofluids is found to be increased with the increase in concentration of nanoparticles in the fluid.

$\rho_{nf}=\Phi\rho_p+(1-\Phi)\rho_w$

2.1.4 SPECIFIC HEAT

Specific heat is also a very important characteristic of nanofluids. To study the energy performance, specific heat of nanofluid must be determined.

$(\rho c_p)_{nf}=\Phi(\rho c_p)_p+(1-\Phi)(\rho c_p)_w$

S. No	Property	Water
1	Thermal conductivity(K_L) w/mK	0.6
2	Density(ρ_f) kg/m^3	998.2
3	Specific heat(C_f) J/kgK	4182
4	Dynamic viscosity(μ_o)	0.001003

TABLE 1.1 PROPERTIES OF BASE FLUID

3.1 NUMERICAL CALCULATION

3.1.1 BASIC CALCULATION

$D_{hydralic} = \frac{4 \times A_{tube}}{P_{tube}}$

$A_{tube} = W_{tube} \times H_{tube}$

$P_{tube} = 2W_{tube} + 2H_{tube}$

$A_{radiator} = H_{radiator} \times L_{radiator}$

$$L_c = L_{fin} + \frac{H_{fin}}{2}$$

$$A_f = 2W_{fin} \times L_c$$

$$A_b = 2L_{radiator}\, W_{tube} - H_{fin}\, W_{fin}\, N_{fin}$$

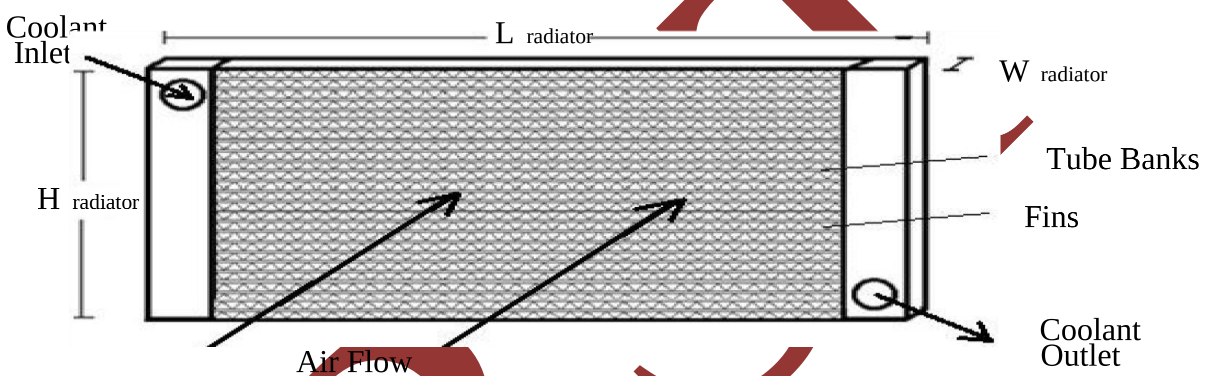
$$A_{fin,base} = N_{fin} \times A_f + A_b$$

$$A_{external} = A_{fin,base} \times N_{tube}$$

$A_{internal} = (2W_{tube} + 2H_{tube})L_{radiator} \times N_{tube}$

TABLE 1.2 RADIATOR DIMENSIONS

L(radiator)=70cm	L(fin)=0.2cm
H(radiator)=40cm	W(fin)=2.1cm
W(radiator)=2.5cm	H(fin)=0.8cm
W(tube)=2.1cm	N(tube)=38
H(tube)=0.2cm	N(fin)=220



Schematic of radiator

Radiator components

The entire theoretical process begins with equation below for the heat transfer rate of the radiator. From this equation, it is clear that the only two unknowns for the system are the outlet temperatures for air and water.

$q = m_{air}c_{p,air}(T_{air,out} - T_{air,in}) = m_{water}c_{p,water}(T_{water,in} - T_{water,out})$

4.1 INTERNAL FLOW OF NANOFLUID

4.1.1 Mean Temperature

The average temperature of nanofluid must be calculated to find the fluid's material properties. The properties will be interpolated at this temperature. The properties that are needed are density, Prandtl number, thermal conductivity, dynamic viscosity, and specific heat.

4.1.2 Velocity

$$V_{nf} = \frac{Q_{nf}}{A_{tube} \times N_{tube}}$$

4.1.3 Reynolds Number

$$Re_{nf} = \frac{\rho_{nf} \times V_{nf} \times D_{hydralic}}{\mu_{nf}}$$

Check the flow whether it is laminar or turbulent.

4.1.4 Nusselt Number

The Nusselt number was found as a constant for a rectangular cross section. The ratio of width over height of the tube is used in this table to determine the Nusselt number.

4.1.5 Convective Heat Transfer Coeffcient

$$h_{nf} = \frac{Nu_{nf} \times K_{nf}}{D_{hydralic}}$$

5.1 EXTERNAL FLOW OF AIR

5.1.1 Mean Temperature of Air

The average temperature of air must be calculated to find the correct material properties for later use. These properties are specific heat, thermal conductivity, kinematic viscosity, and Prandl number.

5.1.2 Velocity

$$V_{air} = \frac{Q_{air}}{A_{radiator} - (N_{tube} \times H_{tube} \times L_{radiator})}$$

5.1.3 Reynolds Number

$$Re_{air} = \frac{V_{air} \times W_{fin}}{\nu_{air}}$$

5.1.4 Nusselt Number

Looking at the geometry of the tubes, it can be assumed that the flow of air is similar to parallel flow over a flat plate. Since the flow never reaches the critical Reynolds number for a flat plate, Re = 5×10^5, it is said to be laminar for the entire process.

$$Nu = 0.664 Re^{\frac{1}{2}} \times Pr^{\frac{1}{3}}$$

5.1.5 Convective Heat Transfer Coefficient

$$h_{air} = \frac{Nu_{air} \times K_{air}}{W_{tube}}$$

5.1.6 Fin Dimensions and Efficiency

The geometry of the fins on the radiator is sinusoidal.

$$\eta_{fin} = \frac{\tanh(mL_c)}{mL_c}$$

$$m = \frac{(2h_{air})\hat{}0.5}{(K_{aluminum} \times H_{fin})\hat{}0.5}$$

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5.1.7 Overall Surface Efficiency

The overall surface efficiency is needed for the external flow of air because the imperfections of the flow around the fins must be considered.

$$\eta_o = 1 - \frac{N_{fin} A_f}{A_{fin,base}} (1 - \eta_{fin})$$

5.1.8 Effectiveness-NTU Method

The Effectiveness-NTU method is used to find the effectiveness of the system. The overall heat transfer coefficient is needed. The surface efficiency is needed for the external flow of air because the imperfections of the flow around the fins must be considered.

5.1.9 Overall Heat Transfer Coefficient

$$UA = \frac{1}{\frac{1}{\eta_0 h_{air} A_{external}} + \frac{1}{h_{nf} A_{internal}}}$$

5.1.10 Number of Transfer Units

$$NTU = \frac{UA}{C_{min}}$$

5.1.11 Effectiveness

The radiator utilizes a cross-flow single pass design where both fluids remain unmixed. This correlates to a specific equation to calculate effectiveness. However, this equation requires the heat capacity ratio, C_r, to be equal to 1.

$$\varepsilon = 1 - \exp^{\left[\left(\frac{1}{C_r} NTU^{0.22}\right)\left(\exp^{(-C_r NTU^{0.78})} - 1\right)\right]}$$

5.1.12 Heat transfer rate

$$q_{max} = C_{min} \left(T_{water,in} - T_{air,in}\right)$$

5.1.13 Predicated heat transfer rate

$$q_{predicated} = \varepsilon q_{max}$$

5.1.14 Temperature outlets

$$T_{water,out} = T_{water,in} - \frac{q_{predicated}}{c_{water}}$$

$$T_{air,out} = T_{air,in} + \frac{q_{predicated}}{c_{water}}$$

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TABLE 1.3 THEORETICAL RESULTS

Water	T(^{0}C) water inlet =50^{0}C	T(^{0}C) air inlet =30^{0}C	T(^{0}C) water outlet =48^{0}C	T(^{0}C) air outlet=33^{0}C
Copper/water for 5 grams of nano	T(^{0}C) nanofluid inlet =50^{0}C	T(^{0}C) air inlet =30^{0}C	T(^{0}C) water outlet =46^{0}C	T(^{0}C) air outlet=35^{0}C
Copper/water for 10 grams of nano	T(^{0}C) nanofluid inlet =50^{0}C	T(^{0}C) air inlet =30^{0}C	T(^{0}C) water outlet =44^{0}C	T(^{0}C) air outlet=37^{0}C

6.1 NANOFLUID PREPARATION AND STABILIZATION

Preparation of a stabilized nanofluid is of great importance in heat transfer applications of nanofluids. Poorly prepared nanofluids will render biphasic heat transfer (i.e. solideliquid).

7.1 EXPERIMENTAL SETUP

The schematic of experimental system used in this research includes flow lines, a reservoir tank, two heaters, a centrifugal pump,flow meter, a forced draft fan, an air flow channel, a temperature controller, four thermocouples and a cross flow heat exchanger. The test section is a cross flow heat exchanger (an automobile radiator) which was installed inside the air flow channel.Nanofluid passes through the vertical tubes with stadium-shaped cross section. The fins and the tubes are made with aluminum.For cooling the liquid, a forced draft fan which is capable of adjusting the air flow speed from low to high, was installed close and face to face to the radiator at the beginning of the air flow channel and consequently air and water have indirect cross flow contact and there is heat exchange between hot water flowing in the tube-side and air across the tube bundle.

The pump gives a constant flow rate of 0.6 m^3/h, the flow rate to the test section is regulated by appropriate adjusting of a globe valve on the recycle line. The working fluid fills 35% of the reservoir tank whose total volume is approximately 20:l (height of 30 cm and diameter of 30 cm). The total volume of the circulating liquid is constant in all the experiments. Five layer insulated tubes (Isopipe 0.75 in diameter) have been used as connecting lines and covered with glass wool to reduce heat loss to the surrounding.
A flow meter (Technical Group LZM-15Z Type) was used to control and manipulate the liquid flow rate with the precision of 0.006 m^3/h. For heating the working fluid, two electrical heaters (6000 W) and a temperature controller were used to vary the temperature between 40

and 80 C. Four RTDs (Pt-100U) were implemented on the flow line to record air flow and radiator fluid inlet and outlet temperatures. The temperatures from the thermocouples were measured by four digital multimeters, SU-105PRR, SAMWON ENG, with an accuracy of 0.1 C.

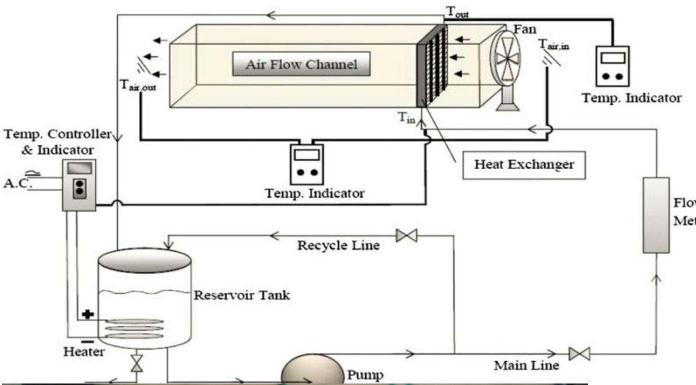

TABLE 1.4 EXPERIMENTAL RESULTS

TIME	FIRST MIN TEMP	SECOND MIN TEMP	THIRD MIN TEMP	FOURTH MIN TEMP	FIVETH MIN TEMP	TIME	FIRST MIN TEMP	SECOND MIN TEMP	THIRD MIN TEMP	FOURTH MIN TEMP	FIVETH MIN TEMP
Water inlet temp=50^0C	48^0C	47^0C	46^0C	45^0C	43^0C	Air inlet temp=32^0C	36^0C	36.3^0C	36.7^0C	37^0C	37^0C
Nanofluid inlet temp=50^0C for 5	48^0C	46^0C	45^0C	43^0C	41^0C	Air inlet temp=34^0C	38^0C	38^0C	38.5^0C	38.7^0C	39^0C

grams											
Nanofluid inlet temp=5$0^0$C for 10 grams	47^0 C	45^0C	43^0C	41^0C	39^0C	Air inlet temp=3$5^0$C	36^0 C	36.3^0C	36.8^0 C	37^0C	38^0C

CONCLUSION

This paper shows clearly about the thermo-physical properties of the nanofluids, theoretical calculation to find the heat transfer rate of the radiator,Nanofluid preparation and experimental setup of the system. Finally that the overall heat transfer coefficient of nanofluid is greater than that of conventional fluids and therefore the total heat transfer area of the radiator can be reduced.

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