Experimental Study of Convective Heat Transfer Augmentation of a Radiator using ZnO-Water Nanofluids a Review

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ABSTRACT

It is found that the heat transfer performance of car radiator is enhanced by using nanofluids. ZnO nanoparticles are added to base fluid water to obtain nanofluids in different volumetric concentration. An effect of different volumetric concentration on the heat transfer rate of the radiator is checked experimentally. In this experimentally process fluid flow rate is also varied in the range. Heat transfer rate differs with difference in volumetric concentration. Heat transfer rate increases with increase in volumetric concentration and attains the maximum value then decrease. Decrease in heat transfer rate is because of the increase in viscosity of the nanofluids and this increase results in increase in thermal boundary layer which reduces the heat transfer rate. Fluid inlet temperature is kept between the range of 45°-55° which results increase in heat transfer rate.

Keywords:*Nanofluids, Nanoparticles, Zn-water, Heat transfer enhancement, Heat exchanger*

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1. INTRODUCTION

Today improving the thermal efficiency in heat transfer is a great challenge for thermal engineers. Many techniques[9] are used to increase the thermal efficiency but these techniques have their limitations so new techniques are developed. Therefore, Nano fluids were developed to increase the efficiency. Convective heat transfer referred as convection. Heat transfer through movement of fluid/particles from one part to the another part is called as convective heat transfer. In gas and liquids convection is dominant form where in solids conduction is the dominant form. Advection and conduction are the combined process which is involved in heat transfer to the convection mode of heat transfer.

Radiators are the heat exchangers which are used the exchange the heat or energy from one medium to other medium and these are called radiators. Buildings, automobiles and electronics are where radiator plays an important function. A radiator acts as source of heat to the surrounding and for the cooling medium because radiators get the heat from the environment. The bulk of heat[10] is transferred through convection mode of heat transfer instead of thermal radiation. Nanofluid is developed to increase convective heat transfer, nanoparticles are nanometer-sized particles which constitutes in the fluid and it is known as nanofluids[11]. Nanofluids are the engineered colloidal suspension of nanoparticles in base fluids[12]. Metals, Oxides, carbides, or carbon nanotubesare major constitutes of nanofluids[13]. Base fluids which are commonly used include water, ethylene glycol and oil.

Hybrid powered engines fuel cells, microelectronics, pharmaceutical processes engine and cooling/vehicle[14] thermal management, heat exchanger, in machining, in boiler flue gas temperature reduction, chiller domestic refrigerator, grinding are applications of the heat transfer where nanofluids are used because of their novel properties of the nanofluids. They display increased thermal conductivity[15] and the convective heat transfer coefficient compared to the base fluid. The propriety for convective heat transfer applications [16] depends critically on the knowledge of the rheological behavior of nanofluids. Extra shear-wave reconversion of an incident compressional wave in ultrasonic display is the special acoustical property of nanofluid in which the effect becomes more definite as concentration increases[17].Large no. of experimental investigations are being performed on nanofluids which lead to conclusion that thermal properties of nanofluids have resulted in enhanchment in heat transfer with relation to conventional methods .Transient hot wire method is used to determine the thermal conductivity of different nanofluids like Al_2O_3-water, Al_2O_3-EGR, CuO-water and this was done Lee et al[18]. This shows thermal conductivity depends on shape and size of particles. Increase in thermal conductivity means increase in concentration that implies increase in the viscosity this was determined by Chandrasekhar et al[19]. Nanofluids have great thermal properties than water was founded by Xuan and Li[20] and investigated it experimentally using Cu-water Nano fluids. Heat exchanger like shell and tube[21], double tube heat exchangers[22], plate heat exchangers[23] is used in radiator to exchange the heat more efficiently.

2. LITERATURE REVIEW

1.]CHOI[4] :Choi study regarding use of nanofluids in automobiles to save fuel. He found 10% enhancement in heat transfer at 0.5% of gold nano particles.

2.]ESFE et Al[5] : He investigated the heat transfer rate is enhanced by using less than 1% vol. of MgO nanoparticles in the base fluid. As compared to base fluid pressure drop was more in nanoparticles with the base fluid, but without consuming much power nanoparticles in base fluids i.e., nanofluids increased the heat transfer. Thermal conductivity increases because of increase in the volumetric concentration of nanofluids was reported by him, because of this viscosity increases which leads to increase in boundary layer and finally however this lead to increase in boundary layer because of increase in viscosity which leads to decrease in heat transfer rate.

3.]Xie et Al[6]: He experimented with nanofluids like Al_2O_3,ZnO,TiO_2 and MgO regarding the enhancement of heat transfer. Following nanoparticles with mixture of water and ethylene glycol at 55% and 45% respectively. Heat transfer enhancement in TiO_2 is lower than that of Al_2O_3,ZnO and MgO.252% enhancement was reported using MgOnanofluids at 1000 Reynolds number.

4.]Fotukian and Esfahany[7] : convective heat transfer enhancement using CuO-water nanofluids in circular fin and it was reported to be increase in 25% of heat transfer rate.

5.]Peyghambarzadeh et Al[8]: He used Al_2O/water nanofluids to test radiator of car. Range of 0.1-1% is varied in volumetric concentration of nanoparticles. It is reported that maximum enhancement of 45% is at 1% of volumetric concentration. He also varied the flow rate of coolant in range of 2-6LPM. Inlet temperature is varied in range of 35-50 C and 45-60 C for water based and ethylene glycol based nanofluids. Reynolds no. was in range of 1200-2500 and 9000-23000 for ethylene glycol and water respectively 40% increase in Nusselt no. compared to base fluids by addition of 1% of vol. of nanoparticles.

3. EXPERIMENTAL SETUP AND METHODOLOGY

Nanofluids used in car radiator should be homogenous and stable in nature to hold the good heat transfer characteristics. Agglomeration of particles and suspension of particles in base fluid are factors which play the important role in stability of nanofluids. Particle should not settle down during the experiment so particle suspension is also an important aspects. Experiments are done using the nanofluidsof Zinc oxide(ZnO). Zinc oxide doesn't get dissolve in water at normal pH . So the suspension solution of ZnO is repared by lowering the pH in distilled water as particles are homogenous to acidic solution. This is tested at different pH and after 72hrs most stable solution was obtained with pH around 2.2 .

Following are the two step preparation method.

I) particles are dissolved into distilled water by maintaining pH at 2.2 and constant stirring for 2h.2h sonication is carried out to keep the particle away from each other with proper suspension in fluid to avoid agglomeration. Sodium Hexa Meta Phosphate is added to attain the stability of nanofluid[24].

This is schematic diagram of the experimental setup. Setup consists of reservoir, heater, pump, gate valve, flow meter, data acquisition system, thermocouples, heat exchanger and tube. Here heat exchanger refers to car radiator.

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371 – 376

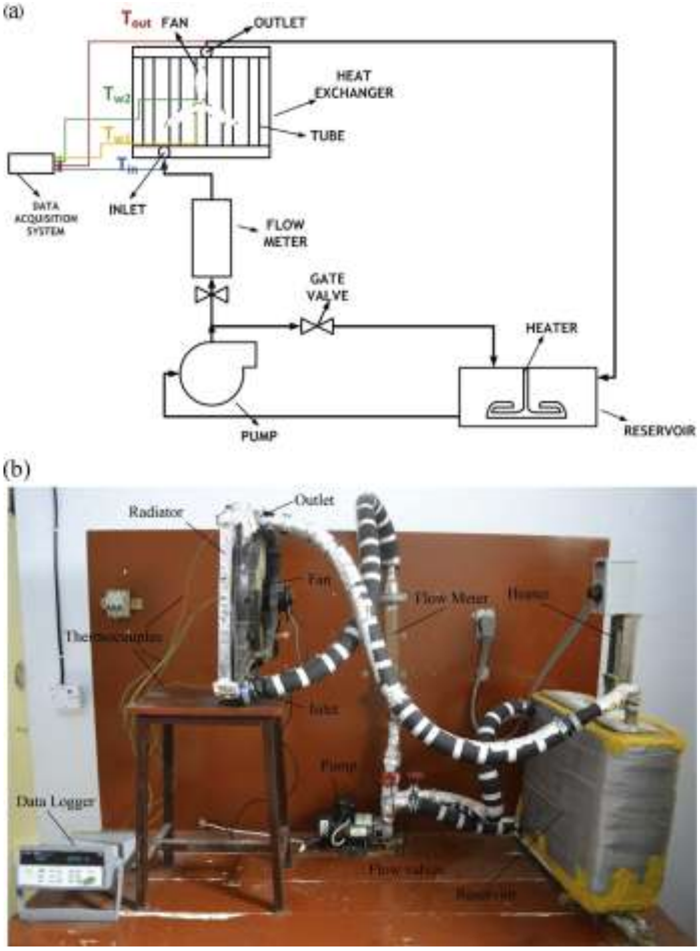

Fig.1 EXPERIMENTAL SETUP

Constant flow rate is provided using pump which takes the fluid from the storage. Fluid is passed to flow meter via gate valve. An extra line is provided to with the pump using gate valve to pass the extra fluid back to tank to get the desired flow rate. Heater temperature controller is used to set the inlet temperature of radiator[25]. Thermocouples are installed on the both walls of inlet and outlet line and the temperature is measured through data acquisition system which displays temperature up to 6 decimal places[26]. Equipment's used in setup is calibrated with certifications. Mainly the radiator is made up of aluminum with 32 tube of aluminum in vertical direction and distance between the tubes in filled with the fins. Forced draft fan is used in radiator cooling. This experiment is carried out a constant flow rates for specific interval of time.

4. DATA REDUCTION

Nanofluids should be characterizing fully to analysis the heat transfer. It means to determine the thermal properties of nanofluids mainly over the temperature range.

Following are the relations used for calculation of density of specific heat of nanofluids.[27],[28]

$$\rho_{nf} = \psi\rho_p + (1-\psi)\rho_{bf}$$
$$(\rho Cp)_{nf} = \psi(\rho Cp)_p + (1-\psi)(\rho Cp)_{bf}$$

Where 'ρ' is density Cp is specific heat, ψ is nanoparticle volume fraction

And subscript 'nf','p', and 'bf' stand for nanofluid, nanoparticles and base fluid respectively.

$$Q=(m^{\circ}Cp)(T_{in}-T_{out})$$

Q is heat transfer rate, 'm' is mass flow rate, Cp is specific heat and Tin and Tout are inlet and outlet temperature respectively.

Re=(ρvd)/μ 'Re' Reynolds no., 'v' is velocity of the flow, 'd' is diameter of tubes and μ is dynamic viscosity of fluid. Wang et al.[29] calculated viscosity of nanofluids using following models . $\mu_{nf}=\mu_{bf}(1+7.3\psi+123\psi^2)$ 'μ_{nf}' and 'μ_{bf}' are basefluid and nanofluid respectively Hamilton and Crosser calculated thermal conductivity of nanofluids using following equation $K_{nf}=[k_p+(z-1)k_{bf}-\psi(z-1)(k_{bf}-k_p)]*k_{bf}/[k_p+(z-1)k_{bf}-\psi(k_{bf}-k_p)]$ 'k' is thermal conductivity and 'z' is empirical shape factor which is taken 3 because of spherical shape of nanoparticles.

Below given equation gives the heat transferrate $h=[mCp(T_{in}-T_{out})]/[A(T-T_w)]$ 'h' is heat transfer coefficient, 'Cp' is specific heat, 'A' is total area for convection, 'T' is average temperature. T_{in} and T_{out} are the inlet and outlet temperature T_w is wall temperature. Nu=(hd)/k 'h' is convective heat transfer coefficient, 'd' is diameter of tubes and 'k' is thermal conductivity of fluid.Diameter of tubes is calculated by formula. D=4A`/P A` is tube surface area and 'P' is perimeter of tubes.

5. RESULTS

-EXPERIMENTAL RESULTS VALIDATION

To validate the results we have to get the get results thought the theoretical and experimental method So we have to compare both the results of nusset no. over the range of Reynolds no. for distilled water.Empirical relation for nusslet no. for turbulent flow is given by Dittus-Boelter[30] $Nu=0.0236Re^{0.8}Pr^{0.3}$ -nusselt number, Re-reynolds number and Pr-prandtl number, where prandtl no. is given by the relation $Pr=(\mu C_p/k)$ μ is dynamic viscosity Cp is specific heat and k is thermal conductivity of the fluid. Below given figure shows the comparison between the experimental data and empirical correlation of the base fluid.Empirical relation of Dittus-Boelter gives good experimental results that for distilled water at low Reynolds number. While going from lower flow rate to higher flow rate the experimental values are same, and this process is carried out three times and values found out to be approximately same repeatability. Nanofluids repeatability is also checked and data obtained after 3 days was within small deviations from 0.2% ZnO[31]. Values of heat transfer rate are taken at different flow rates at different volumetric concentration[32]. Change of heat transfer rate is calculated by taking the heat transfer rate of water as a reference to that of nanofluid[33]. It is observed the increasing the flow rate increases the heat transfer rate that indicates the direct relationship between both factors. Use of ZnOnanofluids instead of water increase the rate of cooling in the car radiator. But different concentrations show the different rate of cooling and heat transfer. At 0.2% the heat transfer rate and cooling is observed to be maximum. Lesser the volumetric concentration of ZnOnanofluid lesser would be the heat transfer rate. This is because of less quantity of nanoparticles in the fluid so the moving particles in the fluid are less and finally the motion of the particles increase the heat transfer rate therefore with less concentration of nanoparticles heat transfer is less. The enhancement in heat transfer reaches its maximum limit at 0.2% of volumetric concentration of the nanoparticles. When we increase the volumetric concentration there is decrease in heat transfer rate as compared to heat transfer rate at 0.2%.

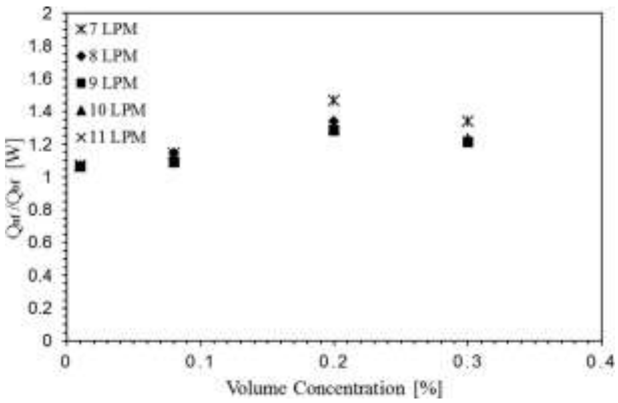

Fig.2. Heat transfer enhancement of nanofluids as a function of volumetric concentration.

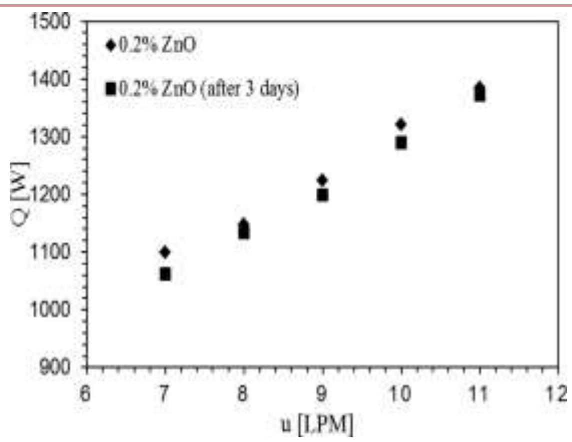

Fig 3.Repeatability of experimental data for nanofluid

This decrease in heat transfer rate is because of the increase in viscosity of the fluid which lead to thicker boundary layer and thus its affects in decrease of heat transfer rate. From experiments it is observed that the maximum at 0.2%ofZno which results in increase in 46% heat transfer.

6. CONCLUSIONS

Above paper is reviewed and it gives the heat transfer rate of a radiator, which investigated using ZnOnanofluids. Following are the results obtained through study of this paper

- Increase in heat transfer using ZnOnanofluids compared to the base fluid.
- There is less heat transfer rate at low volumetric concentration of nanoparticles and it increases to maximum and then again decreases.
- 0.2% concentration of ZnO results in maximum heat transfer rate which increase efficiency to 46% as compared to base fluid.
- Nanofluid added to base fluid increase the heat transfer rate and finally there is increase in efficiency of the radiator.

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