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Research Paper

PERFORMANCE ANALYSIS OF OVERALL HEAT TRANSFER COEFFICIENT USING NANO FLUIDS ON AN AUTOMOBILE ENGINE TEST RIG

B Vishnuprasad[1]*, B Jaya Prakash[1] and V Venkata Ramana[1]

*Corresponding Author: B Vishnuprasad, ✉ bvishnuprasad@rediffmail.com

Looking into the present day need of automobile heat disposal methods, many researchers are exploring the best means to absorb and dissipate the heat from an engine in an efficient manner. Many automobile giants have invested enormous time and money in this field to analyze overall heat transfer coefficient with variety of fluids. The recent developments were use of nano particles in the base fluids as heat transfer medium. This paper focuses on analysis of overall heat transfer coefficient in an automobile engine radiator with nano fluids (TiO_2) a research proposal to investigate how best these nano fluids are beneficial to the automobiles with certain objectives and the expected out comes were discussed.

Keywords: Nano fluids, Volume flow, Turbulent flow, Nusselt number, Reynolds number, Heat transfer co-efficient

INTRODUCTION

The present crisis in energy saving along with hike in prices, motivate industries to apply energy saving methods to the greater extent in all their possible facilities. One among these important tools to save energy is heat transfer enhancement technique in different processes. Use of solid particles in conventional fluids, because of their higher thermal conductivity, has been considered for decades to enhance heat transfer. But in practice, problems like fouling, sedimentation and increased pressure drop reduce the interest of industries to this heat transfer technique.

In recent years, significant advances in nano-materials technology has made it possible to overcome these problems by producing desirable particles in nanometer size ranges. Nano-particle suspensions in fluids make a new innovative category of fluids, called nanofluids. This kind of fluids are now of great interest not only for modifying heat transfer performance of fluids, but also for improving other different characteristics such

[1] Department of Mechanical Engineering, Ballari Institute of Technology and Management, Bellary 583104, Karnataka, India.

as mass transfer and rheological properties of fluids (Syam *et al.*, 2012).

Replacement of nano-fluids as a heat transfer medium and its relevant advantages over the conventional heat transfer fluids were over emphasized in the recent investigations. Different experimental studies were performed to analyze and verify their advantages in various heat exchange systems like shell and tube heat exchangers (Leong *et al.*, 2012), double tube heat exchangers, plate heat exchangers (Amirhossein *et al.*, 2011), shell and tube heat exchanger (Ulzie *et al.*, 2009; and Farajollahi *et al.*, 2010), circular tube (Fotukian and Nasr, 2010), electronic cooling (Huaqing *et al.*, 2010), automobile radiator (Leong *et al.*, 2010; and Peyghambarzadeh *et al.*, 2011), Heavy Vehicle Systems (Choi, 2006), etc.

Another major application in the field of heat transfer in automobiles is implementation of nano-fluids instead of the conventional heat transfer fluids in automotive radiators in specific which is recently under focus. The radiator is an important accessory of vehicle engine, basically, it is used as a cooling system of the engine and generally water is heat transfer medium. This air cooler configuration is louvered fin and flat tube and due to its complicated geometry less experimental studies can be found in the open literature. This has given us to take up a research work in the said area so as to bridge the gap.

LITERATURE REVIEW

Devdatta *et al.* (2008) in their paper, application of aluminum oxide nanofluids in diesel electric generator as jacket water coolant, in a Diesel Electric Generator (DEG) experimented on specific heat measurements of aluminum oxide nanofluid with various particle concentrations. The results showed reduction in their values with an increase in the particle concentration and temperature, along with reduction of cogeneration efficiency due to decrease in specific heat, which influences the waste heat recovery from the engine. However, they concluded that efficiency of waste heat recovery heat exchanger was increased for nanofluid, due to its superior convective heat transfer coefficient.

David *et al.* (2012) in their study, “Heat transfer to a silicon carbide/water nano fluid”, stated that water-based nano fluid containing 170-nm silicon carbide particles at a 3.7% volume concentration are having potential commercial viability. Heat transfer coefficients for different Reynolds numbers (3300 to 13,000) are compared to the base fluid water. Further the slip mechanisms of Brownian diffusion and thermophoresis were investigated.

Abbasian and Amani (2009) in their research paper titled, “Experimental study on the effect of TiO_2-water nano fluid on heat transfer and pressure drop”, investigated the effect of nano particle volume fraction (0.002 and 0.02) on the convection heat transfer characteristics and pressure drop of TiO_2 (30 nm)-water nano fluids, for Reynolds number (8000 and 51,000) on a horizontal double tube counter-flow heat exchanger. The outcome is Nusselt number increases with increase in Reynolds number or nano particle volume fraction, also concluded that using nano fluids at high Reynolds numbers compared with low Reynolds numbers, have lower benefits.

Most of researches with nano fluids are related to thermal conductivity and heat transfer properties of nanofluids based on water or ethylene glycol. Mahbubula *et al.* (2013) in their research “Heat transfer and pressure drop characteristics of Al_2O_3-R141b nano refrigerant in horizontal smooth circular tube”, stated nano refrigerants are promising nanofluids used for refrigerants. Their study focused to determine the heat transfer and pressure drop characteristics of Al_2O_3-R141b nano refrigerants for different volume concentrations. Their observations were heat transfer and pressure drop characteristics increased with the increased volume concentrations and concluded that an optimum concentration of nano particles with refrigerants (compromising the heat transfer performance and pressure drop characteristics) can improve the performance of a refrigeration system so as to increase the energy efficiency and cooling capacity.

OBJECTIVE

The main objective of this investigation is to target fuel savings for the automotive industries through the development of energy efficient nanofluids for compact and lighter radiators. Further it is important to reduce the size and weight of the vehicle cooling systems by greater than 10% despite the cooling demands of higher power engines. Nanofluids enable the potential to allow higher temperature coolants and higher heat rejection in the auto engines. It is estimated that a higher temperature radiator could reduce the radiator size approximately 30%. This translates into reduced aerodynamic drag and fluid pumping and fan requirements, leading to conceivably a 10% savings in fuel.

THE PROBLEM

It is clearly evident from the research studies and survey that very small amount of work is carried out on the performance of overall heat transfer coefficient using nano fluids in the field of automobiles especially pertaining to nano fluids of different concentrations in the radiators. Based on the above facts a research proposal to evaluate the Overall Heat Transfer Coefficient of Nano Fluids in a Radiator experimentally and theoretically is established in order to explore the possible outcomes.

The experimental investigation can be carried out in different stages, they are

Stage 1: Identify the best suitable nano fluid that can be used.

Stage 2: Select the suitable radiator.

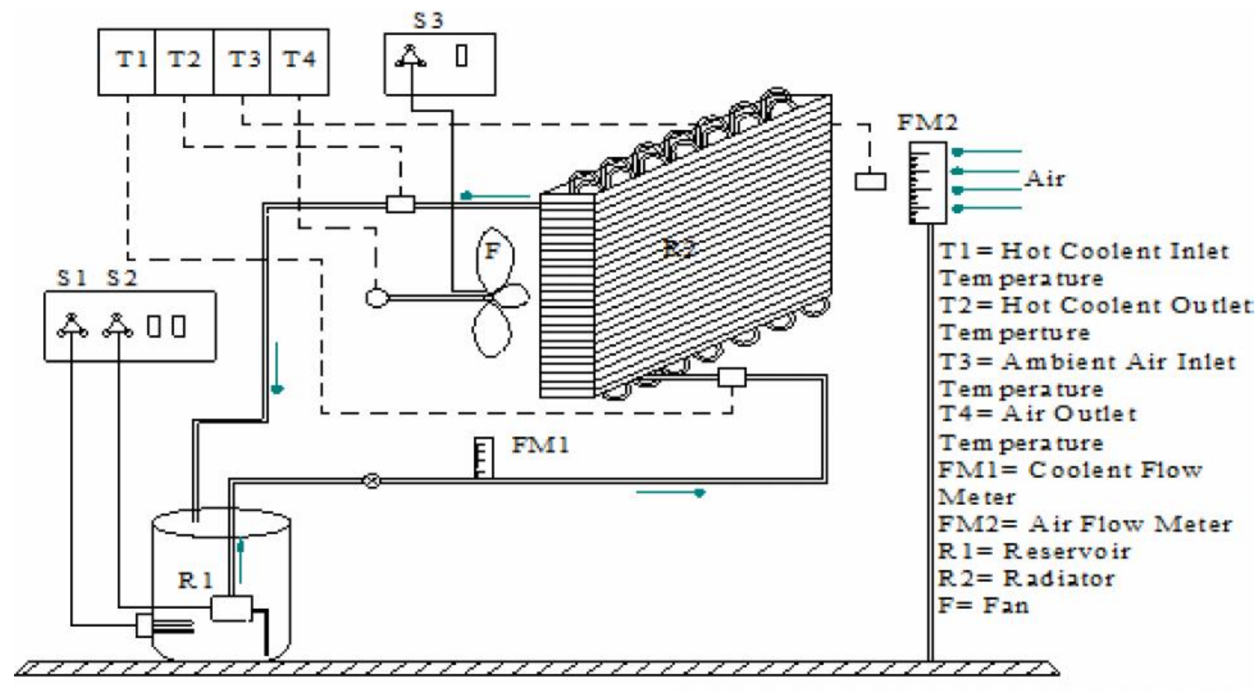
Stage 3: Compare the overall heat transfer co-efficient for different nano fluids.

Stage 4: Study the flow rate of the selected nano fluid.

PROPOSED EXPERIMENTAL SETUP

The experimental system recommended for the research comprises of flow lines, a reservoir tank (R1), a heater, a centrifugal pump, flow meters (FM), induced draft fan (F) and a cross flow heat exchanger (an automobile radiator – R2). The pump gives a constant flow rate to the test section by regulating a globe valve on the recycle line (Figure 1). The working fluid will be stored in a reservoir. The total volume of the circulating liquid is kept constant for all the experiments. A precision flow meter will be used to control and manipulate the flow rate. For heating the working fluid, an electrical heater and a controller will be used to maintain

Figure 1: Experimental Setup



the temperature between 40 °C to 80 °C. Two temperature detectors are implemented on the flow line to record radiator fluid inlet and outlet temperatures. Two appropriate thermocouples will be used for radiator wall temperature measurement. The locations of the surface thermocouples are chosen in such a way that they give the average wall temperature. The thermocouples are attached by silicon paste at various positions of the external walls on either sides of the radiator.

EXPECTED OUTCOMES

The temperatures will be measured at two locations so as to get the average wall temperature, this will give interesting results as the thickness is very small and thermal conductivity of the tubes is very large. The temperatures from the thermocouples and detectors were measured by two digital multimeters, which are calibrated by using a constant temperature water bath. Error calculations can be carried out from the above comparison. The uncertainty range of Re comes from the errors in the measurement of volume flow rate and hydraulic diameter of the tubes and the uncertainty of Nu refers to the errors in the measurements of volume flow rate, hydraulic diameter, and all the temperatures. The errors may be 5-6% for Re, 16-20% for Nu is expected.

The automobile radiator configuration used is of fin and tube type, with vertical tubes oval shaped cross section. The fins and the tubes are made with aluminum.

For cooling the liquid, an induced fan (approximately 1200 rpm) is installed closely, face to face to the radiator, 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. Constant velocity and temperature of the air are assumed throughout the experiments in order to clearly investigate the internal heat transfer. The test liquids are water based nano fluids which consist of water and small amount TiO_2 nano particle. The mean grain size of this is 20 nm and is a white noncombustible and odorless particle with a molecular weight of 79.9 g/mol, boiling point of 2972 °C, melting point of 1843 °C, and relative density of 4.26 g/cm^3 at 25 °C. No dispersant or stabilizers are to be added to nano fluid as the addition of these may change the fluid properties (Syam *et al.*, 2012) and the authors are interested to simulate the easiest actual condition encountered in the automobile radiator. In addition, to stabilize the nano particle in water, creation of highly turbulent flow condition in the radiator tubes and connecting pipes is necessary.

CONCLUSION

The intended research work is to investigate the behavior of the nano fluids with variable concentrations for the overall heat transfer coefficient in an automobile radiator. The requirements of experimental setup, properties of nano particle, temperatures, variable flow rates along with the base fluid (ethylene glycol) selection, and certain assumptions in order to carry out the experimentation were precisely discussed in this proposed work, further experiments have to be carried out and the results should be compared.

REFERENCES

1. Abbasian Arani A A and Amani J (2009), "Experimental Study on the Effect of TiO_2–Water Nanofluid on Heat Transfer and Pressure Drop", *Experimental Thermal and Fluid Science*, Vol. 42, pp. 107-115.
2. Amirhossein Zamzamian, Shahin Nasseri Oskouie, Ahmad Doosthoseini, Aliakbar Joneidi and Mohammad Pazouki (2011), "Experimental Investigation of Forced Convective Heat Transfer Coefficient in Nanofluids of Al_2O_3/EG and CuO/EG in a Double Pipe and Plate Heat Exchangers Under Turbulent Flow", *Experimental Thermal and Fluid Science*, Vol. 35, pp. 495-502.
3. Choi S (2006), "Nanofluids for Improved Efficiency in Cooling Systems", in *Heavy Vehicle Systems Review*, April 18-20, Argonne National Laboratory.
4. David M France, David S Smith, Dileep Singh, Elena V Timofeeva, Jules L Routbort and Wenhua Yu (2012), "Heat Transfer to a Silicon Carbide/Water Nanofluid a Energy Systems", *International Journal of Heat and Mass Transfer*, Vol. 52, pp. 3606-3612.
5. Devdatta P Kulkarni, Ravikanth S Vajjha and Debendra K Das (2008), "Daniel Oliva Application of Aluminum Oxide Nanofluids in Diesel Electric Generator as Jacket Water Coolant", science direct.com, June.
6. Farajollahi B, Gh. Etemad S and Hojjat M (2010), "Heat Transfer of Nanofluids in a Shell and Tube Heat Exchanger", *Int. J. Heat Mass Transfer*, pp. 12-17.
7. Fotukian S M and Nasr Esfahany M (2010), "Experimental Study of Turbulent Convective Heat Transfer and Pressure Drop of Dilute CuO/Water Nanofluid Inside a Circular Tube", *International*

Communications in Heat and Mass Transfer, pp. 214-219.

8. Huaqing Xie, Yang Li and Wei Yu (2010), "Intriguingly High Convective Heat Transfer Enhancement of Nanofluid Coolants in Laminar Flows", *Physics Letters A*, pp. 2566-2568.

9. Kim D, Kwon Y, Cho Y, Li C, Cheong S and Hwang Y (2009), "Convective Heat Transfer Characteristics of Nanofluids Under Laminar and Turbulent Flow Conditions", *Current Applied Physics*, pp. 119-123.

10. Leong K Y, Saidur R, Kazi S N and Mamun A H (2010), "Performance Investigation of an Automotive Car Radiator Operated with Nanofluid-Based Coolants (Nanofluid as a Coolant in a Radiator)", *Applied Thermal Engineering*, pp. 2685-2692.

11. Leong K Y, Saidur R, Mahlia T M I and Yau Y H (2012), "Modeling of Shell and Tube Heat Recovery Exchanger Operated with Nanofluid Based Coolants", *International Journal of Heat and Mass Transfer*, Vol. 55, pp. 808-816.

12. Mahbubula I M, Saidura R and Amalinaa M A (2013), "Heat Transfer and Pressure Drop Characteristics of Al_2O_3-R141b Nanorefrigerant in Horizontal Smooth Circular Tube", *Procedia Engineering*, Vol. 56, pp. 323-329.

13. Peyghambarzadeh S M, Hashemabadi S H, Hoseini S M and Seifi Jamnani M (2011), "Experimental Study of Heat Transfer Enhancement Using Water/Ethylene Glycol Based Nanofluids as a New Coolant for Car Radiators", *International Communications in Heat and Mass Transfer*, Vol. 38, pp. 1283-1290.

14. Peyghambarzadeh S M, Hashemabadi S H, Seifi Jamnani M and Hoseini S M (2011), "Improving the Cooling Performance of Automobile Radiator with Al_2O_3/Water Nanofluid", *Applied Thermal Engineering*, pp. 1833-1838.

15. Saeedinia M, Akhavan-Behabadi M A and Razi P (2012), "Thermal and Rheological Characteristics of CuO-Base Oil Nanofluid Flow Inside a Circular Tube", *International Communications in Heat and Mass Transfer*, Vol. 39, pp. 152-159.

16. Syam Sundar L, Naik M T, Sharma K V, Singh M K and Ch. Siva Reddy T (2012), "Experimental Investigation of Forced Convection Heat Transfer and Friction Factor in a Tube with Fe_3O_4 Magnetic Nanofluid", *Experimental Thermal and Fluid Science*, Vol. 37, pp. 65-71.

17. Ulzie Rea, Tom McKrell, Lin-wen Hu and Jacopo Buongiorno (2009), "Laminar Convective Heat Transfer and Viscous Pressure Loss of Alumina-Water and Zirconia-Water Nanofluids", *International Journal of Heat and Mass Transfer*, pp. 2042-2048.

18. Weerapun Duangthongsuk and Somchai Wongwises (2009), "Heat Transfer Enhancement and Pressure Drop Characteristics of TiO_2-Water Nanofluid in a Double-Tube Counter Flow Heat Exchanger", *International Journal of Heat and Mass Transfer*, pp. 2059-2067.

19. Zeinali Heris S, Nasr Esfahany M and Gh. Etemad S (2007), "Experimental Investigation of Convective Heat Transfer of Al_2O_3/Water Nanofluid in Circular Tube", *International Journal of Heat and Fluid Flow*, pp. 203-210.