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Enhancing the effectiveness of the cooling system for automotive engine by employing different nanofluids: literature review

Israa Ali Abdulghafor

Middle Technical University, Institute of Technology-Baghdad, Iraq

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ABSTRACT

The cooling system of a car engine effects strongly the efficiency of the car engine so many studies were presented to enhance the cooling system of the car. The components of the cooling system are radiator, water pumps, fan, shutters, thermostats, expansion tanks/storage tanks, water pipes, water temperature gauges, etc. Among these components, the radiator considers the primary key to enhancing the efficiency of the car engine. Many studies were achieved to enhance the efficiency of car radiators by using different nanofluids as a coolant are discussed in this literature review study. These previous studies investigated various kinds of nanofluids such as Al_2O_3, CuO, TiO_2, SiO_2, and ZnO with different base fluids. Nanofluid concentrations, nanofluid temperature, and nanofluid flow rate were studied by previous studies eleven years ago.

1. Introduction

The radiator is one component of the car engine cooling system [1], that presents a very essential function in a car engine cooling system by dissipating the heat produced after combustion operation and beneficial work has been achieved [2]. The primary radiator elements are the upper reservoir, lower reservoir, and tubes. The coolant from the upper reservoir, which derives from the engine, flows down by the tubes. The heat in the coolant is conducted to the metallic fins surrounding tubes. The radiators kinds are tubular, cellular, and gilled tube radiators [3]. Many factors effect on radiators' effectiveness such as the material, fins, the flow rate of air and coolant, the temperature of the air, the type of coolant, and the inlet temperature of coolant [4]. Also, the addition of microchannel and turbulators are the traditional methods utilized to improve automotive cooling system effectiveness [5]. In the recent few decades, researchers endeavors directed to improve automotive cooling system effectiveness. The use of efficient coolants, nanofluids, is one approach to enhance the cooling rate of automotive cooling system effectiveness. Formerly, water is utilized as a classic coolant that rejects heat by absorbing heat via circulating in the water jacket of the engine. Due to the limited water working temperature domain, an appropriate coolant must be own high boiling point, high thermal conductivity, and low point of freezing. Ethylene glycol (EG) is utilized as an anti-freeze laborer and operates in a wide temperature domain. To improve the properties of water, EG is correctly mingled with it according to climate conditions [6]. Due to the low thermal conductivity of EG, the mixture of EG-water has low thermal performance in comparison

* Corresponding author: Israa Ali Abdulghafor;

with water. To beat this difficulty, some topping must be added to the coolants(water, EG, the mixture of water-EG and propylene glycol, etc.), to increase the heat transfer rate. The addition of the nanoparticles to the base fluids leads to an increase in the heat transfer rate of nanofluids so that the thermal efficiency of the system is improved[7]. Many researchers directed their efforts to the applications of nanofluids in various domains of heat transfer such as manufacturing, dairy, heat exchangers, automotive industries, solar energy, etc. [8]. Cooling of the automotive engine during various nanofluids is the present topic of discussion. This review study focuses on the studies that discuss the automotive cooling system effectiveness by using different types of nanofluids under different conditions.

2. Literature Survey

Ravikanth S et al .2010 [9] presented a numerical study, by employing Fluent, the heat transfer of a car radiator with two different Nanofluid, Al2O3 and CuO, in a mixture of water and ethylene glycol, 40% of water and 60% of ethylene glycol, circulated through the flat tube car radiator. The concentration of Al2O3 and CuO in the mixture was 0-10 and 0-6 % respectively. In the laminar regime, the calculations were achieved with Reynolds numbers changed between 100 to 2000. The viscosity and thermal conductivity of nanofluid were calculated by utilizing a new correlation that depended on volume concentrations and temperature produced from experiments that had been utilized in this study. Calculations results in the fully developed regime of Nusselt number and skin friction appeared to be a good match with available data from Shah and London(1978) [10]. The outcomes showed that the coefficient of heat transfer was affected linearly with Nanoparticles concentrations and Reynolds number. But the effect of the Reynolds number was more than the effect of nanoparticle concentrations. The heat transfer coefficient raised from 865 to 1762 at the Al2O3 concentration of 10% and the Reynolds number raised from 100 to 200. This increment was little for a lower concentration of nanoparticles. Along the pipe, the coefficient of skin friction increased as the concentration of nanoparticles increased at the fixed velocity of the inlet. For 6%CuO nanoparticles, the coefficient of skin friction was about 2.75 times relative to base fluid at the velocity of the inlet of 0.395m/s. The power of pumping was lower by 82% and 77% for 10% and 6% concentrations of Al2O3 and CuO respectively for comparing with base fluid.

Peyghambarzadeh et al.2011[11] studied experimentally the rate of heat transfer by using pure EG, pure water, and various amounts of Al2O3 nanoparticles added to these pure fluids in the car radiator. Fluid flow rate changed from 2 to 6 lpm and inlet temperature changed at all experiments. The outcome concluded that, in better conditions, the nanofluid improved the rate of heat transfer by 40% compared with pure fluids.

A numerical study of the utilize the CuO –water nanofluid, as a coolant, in the cooling system automotive of, Chevrolet Suburban, the diesel engine was studied by Bozorgan et al.2012, [12]. For turbulent flow, the overall heat transfer and local convection coefficients and pumping power by using CuO/water nanofluid at various concentrations (0.1-2)% with a diameter of CuO nanoparticles of 20 nm were investigated. The influences of Reynolds number and car speed on the automotive cooling system effectiveness were taken into count. The relations of heat transfer between the coolant, nanofluid, and airflow were get to determine the overall heat transfer and local convection coefficients, and the pumping power for nanofluid circulating in the radiator with the capacity of the heat exchanger was given. The results concluded that the radiator area of heat transfer was reduced because the nanofluid overall coefficient of heat transfer was more than that of pure water. But, the increase in pumping power might impose some restrictions on the effective utilization of this kind of nanofluid in the radiator of diesel engines. Also, the results showed that the pumping power and overall heat transfer coefficient were 23.8% and 10%greater than that of water alone at a concentration of CuO of 2% flowing in the flat tubes with Re of nanofluid of 6000 and a speed of 70km/hr.

V. L. Bhimani et al.2013, [13] studied experimentally the forced convection of heat transfer in only water and water depended on Nanofluids in a car radiator.TiO2 Nanoparticles were added to pure water at various concentrations between 0.1-1 % by vol. The elliptical cross-section with 34 vertical radiator tubes was used for the flowing of test liquid, with different flow rates changed between (90-120)l/min, in the regime of fully developed turbulent. For the internal bank tubes, the cross-flow was formed by the air. The results concluded that the rate of heat transfer of the car radiator was enhanced by adding TiO2 nanoparticles in pure water. The amount of enhancement is based on the concentration of nanoparticles in pure water. The enhancement of heat transfer rate between 40-45% at 1 % by vol concentration of nanoparticle.

While the coefficient of heat transfer, for both nanoparticles and pure water, increased with an increase in Reynolds number. The large enhancement in heat transfer did not affect by the physical properties and thermal conductivity of nanoparticles, but Brownian motion produced via nanoparticles might be one of the agents in the improvement of heat transfer rate.

M. Ebrahimi et al.2014, [14] presented an experimental study to influence SiO2 nanoparticles that add to pure water in the automotive cooling system effectiveness. The heat transfer of the automotive cooling system effectiveness was studied under different nanofluid volume fractions, inlet temperatures, and Reynolds numbers. Nanofluid volume fraction were(0.4,0.2 and 0.1)% ,inlet temperature were (43,52 and 60)°C and Reynolds number values were 12000 ,16000,20000 and 24000. The radiator dimensions of 320× 20 ×382.4 mm for width, height, and depth respectively. with the corrugated finned tube were used. Heat transfer area, side area, and volume of the fin were (1.25m2,4.7m2 and 1.14liter) respectively. Outcomes concluded that the Nusselt number increased as volume fraction, inlet temperatures and Re increased. Also utilizing nanofluid as a coolant for radiators caused increased heat transfer performance improved the automotive cooling system effectiveness and reduced consumption of fuel.

Ali et al.2015, [15] presented an experimental study of improvement of heat transfer by using ZnO nanoparticles added to water with various concentrations of 0.01%, 0.08%, 0.2%, and 0.3% in a cooling system of the car engine. Flow rates of fluid were changed from 7 to 11 lpm with Reynolds number of 17500 to 27600. The results appeared that the heat transfer improvement relative to pure fluids at all concentrations experiment. The rate of enhancement in heat transfer reaches up to 46% at a volume concentration of 0.2%. The decrease in the improvement of heat transfer was noticed at a volume concentration of 0.3 % relative to the improvement of heat transfer at a volume concentration of 0.2%. The temperature of the inlet increased from 45 to55 °C. That increase in inlet temperature appeared to enhancement in heat transfer by 4%.

Srinivasu et al.2016,[16] studied the rate of heat transfer in a cooling system of the car engine consisting of a louver fin with a mixture of base fluid, water and EG, and Al2O3. The setup of the fins radiator was accompanied with louvers via turbulence of air circulating above it and also the coolant of water-based compared with the base fluid in a car radiator. The various volume concentrations of nanoparticles of 1%, 3%, and 5% of Al2O3 nanoparticles were added into the fluid circulated during the tube of the radiator, elliptical cross-section of tubes, and a cross-flow with constant velocity and constant flow rate in the radiator was made by air. By utilizing ANSYS 14.5, analysis and the layout of the louver fin in CATIA V5R20 were achieved. The analysis of microscopic applied modeling of the detailed shape of a fin element to predict the rate of heat transfer of a louver fin element. Based on the analysis of microscopic, the numerical models of the rate of heat transfer were derived. Results proved that more air turbulence was created by the louver fins element. The heat transfer performance increased by increasing volume concentrations of nanoparticles and caused to improve the efficiency of heat transfer.

Alosious et al .2017, [17] presented an experimental and numerical study of forced convection heat transfer by utilizing CuO and Al2O3 nanoparticles circulated in a flat tube of a car radiator. The volume concentrations of Al2O3 and CuO were 0.05% with nanoparticles diameter less than 50nm. Both nanofluids passed in flat tubes car radiator by the constant inlet temperature at 90 °C. Reynolds numbers changed in experiments from 136 to 816 by using water and nanofluids. In the numerical part, modeled the flat tube of a car radiator was similar to the dimensions of that used in experiments, and heat transfer was studied. The effect of fins and thickness of the wall tube was considered in the model. Numerical investigation was achieved for both nanofluids by various volume concentrations from 0.05% to 1% with the Reynolds number changed from 136 to 816. The outcomes appeared that the improvement in coefficient of heat transfer and radiator effectiveness by increasing volume concentrations and Reynolds number. Peak improvement of heat transfer coefficient was 16.4% and 13.2% for concentrations of 1% of Al_2O_3 and CuO respectively. The pumping power increased due to increased viscosity and density due to an increase in volume concentrations. At the same water heat rejection, the radiator area decreased by 2.9 % and 2.1% by utilizing 1% volume concentrations of Al_2O_3 and CuO respectively. The ideal volume concentrations found of 0.4 to 0.8% by which the improvement of heat transfer dominated the pumping power increased. Al_2O_3 nanofluid appeared the more heat transfer improvement and stability compared with CuO.

G J. Lalpurwala et al[18] presented a global review on the thermal manner of nanofluids in a cooling system of the car. The data was made from Ph.D. and master thesis, conference proceedings, and Journal articles. The results show that the cooling system effectiveness increases as nanofluid concentration increases. Utilization of nanofluid in a cooling system of the car improves the rate of heat transfer which cause lighter and built-in which also improve the fuel efficiency of the engine.

Ahmed S et al .2018, [19] presented an experimental study for improving the cooling system of the car engine by using TiO_2-water Nanofluid, as a coolant, in a cooling system of the car engine. To calculate the influence of TiO_2-water nanofluid on the automotive cooling system effectiveness, tests were carried out by using pure water and TiO_2-water nanofluid each one alone and the results were validated via other studies focused on a cooling system of the car engine. The aspects of the TiO_2-water nanofluid heat transfer as a substitution for coolant system customary if was checked. For this aim, in the laminar flow regime, tests were achieved by utilizing TiO_2 nanofluid with volume concentrations of 0.1,0.2 and0.3 % and volume flow rates of 0.097 and 0.68m^3 /h. Reynolds number changed from 560 to 1650. The results showed that with the increase of volume concentrations and Reynolds number, the factor of friction decreased. At volume concentrations of TiO_2-water nanofluid of 0.2% improved the car radiator effectiveness by 47% when compared with volume concentrations of 0.1 and 0.3% and pure water as a coolant. The increase in nanofluid volume concentrations and Reynolds numbers effected directly on average heat transfer coefficient.

Said et al .2019, [20] investigated experimentally the effect of nanoparticles, titanium dioxide (TiO_2), and aluminum oxide (Al_2O_3), on the effectiveness of the radiator. The volume concentration of TiO_2 and Al_2O_3 dispersed in 50:50% volume ratios of distilled water and Ethylene glycol respectively. The anti-corrosive properties of TiO_2 and Al_2O_3 led to the investigation of these Nanoparticles. Also, the thermophysical properties of nanofluids were studied to calculate their effect on phenomena of heat transfer, and the stability of nanofluids was investigated by utilizing the ζ-method and analysis of particle size. The results appeared that a maximum improvement of the radiator effectiveness of 24.21% by utilizing Al_2O_3 at a volume concentration of 0.3%. The Al_2O_3 in distilled water and Ethylene glycol at a volume fraction of 0.3% with a 1:1 nanoparticle to AG surfactant ratio and TiO_2 in distilled water and Ethylene glycol at a volume fraction of 0.3%, without the addition of surfactant, was the most stable sample. The maximum Nu was obtained for both nanofluids with a volume fraction of 0.3%. The experiments on corrosion appeared that Al_2O_3 nanofluid had more corrosion rate (0.133 mmpy) than that of TiO_2 nanofluid, in an acidic electrolyte, by a rate of corrosion of (0.112 mmpy).

Kiani and Nadooshan. 2019, [21] presented an experimental study of radiator heat transfer when using water - CuO nanofluid as a coolant. Peugeot 405 XU7 car radiator was investigated. Water-ethylene glycol was used as base fluid while water-CuO was nanofluid. The volume concentration of base fluid of 80% water -20% EG and the volume concentration of nanofluid of 0.5% and 1%. The nanofluid stability was increased by using Sodium Dodecyl Sulfate (SDS). The results appeared that the heat transfer increased significantly to ambient by using CuO nanoparticles in the base fluid. The heat transfer rate increased by 3% and 6.9% with nanofluid volume concentrations of 0.5 and 1% respectively and the flow rate was 30 l/min. Increased nanofluid volume concentration and flow rate up to 20 l/min caused to increase in the convection heat transfer coefficient. The results appeared that the increase in nanofluid pressures caused an increase in the drop of the radiator pressure while the ratio of pump power and heat transfer decreased.

Rashmi Rekha. 2020, [22] investigated the rate of heat transfer and analyzed the radiator effectiveness with a novel coolant, water- base, consisting of unique form nanoparticles such as blade (Al_2O_3), cylindrical (CNT), and platelet (graphene) ternary hybrid nanofluid. Influence of non-dimensional factors, thermal performance with analysis the irreversibility, second law efficiency, and generation of entropy on the volume fraction of nanofluid and on Re number were taken into consideration. For ternary hybrid nanofluid volume fraction of 1%, the analysis of morphology was concluded. Theoretical comparative results appeared that the improvement in thermal performance was affected by the difference in concentrations of ternary hybrid and nanoparticles form. By increasing in volume fraction from 1 up to 3% for 10 lpm, the efficiency of the second law and heat transfer increase by 6.63% and 22.34% respectively. The ternary hybrid nanofluid Re number influenced the system's irreversibility. So that the entropy generation and irreversibility increased by 19.50 %and 12.24 % respectively for the concentration of ternary hybrid changed from 1 up to

3%.The change in entropy for coolants was less than that of the air.

Kumar et al.2020, [23] presented an analysis of three dimensions thermo –fluid, nano fluid-based coolants, circulated in real dimensions of car radiator that consisted of louvered fins. The base fluid was made of 40% water and 60% Ethylene glycol with various nanoparticles: Copper oxide, Aluminum oxide, and Zinc oxide. The influences of nanoparticle volume concentration and circulating velocity on the rate of heat transfer were investigated. The reliance of thermophysical characteristics on volume concentrations of nanoparticles was determined. The results showed that the coefficient of heat transfer for coolant increased by 51.1%,47.4%, and 42.5% when added 2% of Copper oxide, Zinc oxide, and Aluminum oxide respectively. For increasing Reynolds number inflow, a considerable linear increase in the coefficient of heat transfer and Nusselt number was reported. Copper oxide nanofluid was found to be greatly efficient. A group simplified of relations for Nusselt number was listed.

Hassan et al .2021, [24] presented a numerical investigation of the heat transfer in a cooling system of a car engine by using water alone and Al_2O_3 nanofluid with 20 nm in diameter added to the water with concentrations of (0.1, 0.3, 0.5, 0.7, and 1%). The numerical investigation was carried out by using ANSYS fluent with version 16.1. Tri paves and quad kinds mesh were used. The radiator, that was simulated, consisted of a rectangular tube with width, thickness, and elevation of 2, 0.3, and 31 cm respectively. In the numerical study, the fixed flow rate of 10 lpm was pumped by the centrifuge pump to circulate the test fluid to the radiator. While the air circulated with 0.1 lpm and temperatures varied from 45 to 50 ° C. This study was confirmed by experimental results with an error of 8% by using the same conditions. The confirming achieved for the Nusselt number with flow rate at a volume fraction of (0.7 and 1)%.The results showed that the Nusselt number increased by increasing the concentrations of nanofluid. That leads to the enhancement of the effectiveness of the heat exchanger. The previous experimental information showed that the heat transfer of the nanofluids depended greatly on the concentration of nanoparticles and the flux conditions.

3. Conclusion

From various previous experimental and numerical research can be concluded the results are as follows:

1- By utilizing different kinds of nanofluid as a coolant in the cooling system of a car engine with different volume concentrations, flow rates, and Reynolds numbers were effective approaches to increasing Nusselt number, heat transfer coefficient, and rate of heat transfer.

2- The coefficient of skin friction, entropy, irreversibility, and power pumping were affected by the nanofluid volume concentrations. By increasing the volume concentration of nanofluid, the coefficient of skin friction, entropy, and irreversibility increased while power pumping decreased

3- The large improvement in heat transfer did not affect by the physical properties and thermal conductivity of nanoparticles, but Brownian motion produced via nanoparticles might be one of the agents in the improvement of the heat transfer rate

4- The corrosion rate was affected by nanofluid type so that Al_2O_3 had more corrosion rate compared with TiO_2

5-The nanofluid pressure effected the drop of the radiator pressure, the ratio of pump power, and the rate of heat transfer. By increasing the nanofluid pressure, the drop of pressure radiator increased while the ratio of pump power and heat transfer decreased.

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