Heat Transfer Enhancement in AutomobileRadiator using Nanofluids: A Review

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***Abstract* - In the development of the many modern technology the primary challenge is thermal management. If we are looking towards the automobile sector the thermal management is the most difficult challenge. Nanofluids are suspension of metallic or nonmetallic nanoparticles in the base fluid; it can be used to increase the heat transfer rate of various applications such as internal cooling system of gas turbine blades, cooling system for automobile engine. This paper contains the literature survey which gives the techniques to implementation of the nanofluids in the car radiator for the cooling of engine.**

Keywords: Heat transfer enhancement, passive method, Nanofluids, Al_2O_3, Car radiator.

INTRODUCTION:

High performance cooling is one of the important needs of many industries. Heat transfer flow fluid such as water, engine oil, ethylene glycol though they play important role in thermal management in industries they have poor heat transfer properties compared with those of most solid and are primary hindrends are of the high compactness and effectiveness of heat exchanger, extended surface, mini channel, micro channel etc. are use to enhance the cooling or heating rates but further enhancement is always in demand. Solid particles possess higher thermal conductivity.

Nanofluids is a fluid having non sized solid particles, normally particle size less than 100 nm, disperse in the convectional based fluid water, mineral oil, ethylene glycol. This tremendously enhance the heat transfer characteristics (and little penalty in pressure drop) of original fluid. This is because of solid non particles these fluids have thermal conductivities several times higher than that of convectional fluid, several types of non particles can be employed for non fluid preparation, including metals such as gold, copper and silver. And also metal oxides such as Al_2O_3, CuO, TiO_2, Fe_2O_4 metals oxide are more

attractive for heat transfer enhancement applications because of significantly lower cost compared to metals. Nanofluids are potentially applicable as alternative cooling for many areas such as electronics, air conditioning, automotives, power generation and nuclear application.

DIFFERENT METHODS OF HEAT TRANSFER ENHANCEMENT:

Active method: This method involves some external power input for the enhancement of heat transfer; some examples of active methods include induced pulsation by cams and reciprocating plungers, the use of a magnetic field to disturb the seeded light particles in a flowing stream, etc**.**

Passive method: Passive heat transfer augmentation methods as stated earlier does not need any external power input. In the convective heat transfer one of the ways to enhance heat transfer rate is to increase the effective surface area and residence time of the heat transfer fluids. The passive methods are based on the same principle. Use of this technique causes the swirl in the bulk of the fluids and disturbs the actual boundary layer so as to increase effective surface area, residence time and consequently heat transfer coefficient in existing system. Following Methods are generally used,

1. Inserts
2. Extended surface
3. Surface modifications
4. Use of additives.

ADDITIVES

The additives include liquid droplet or solid particles, soluble trace additives and gas bubbles in single phase flows and trace additives which usually depress the surface tension of the liquid boiling system. Additives refers to a substance used to improve the performance of anything, like additives in fuel for better combustion, additives in water like ethylene glycol for increasing the heat transfer coefficient.

There are different types of additives but we only discuss with nano particles. The nano particles are the particles having the diameter below the 100nm. Nanofluids are prepared by dispersing nanometer-sized particles, generally less than 100 nm, in a base fluid such as water, ethylene glycol, propylene glycol, oil and other conventional heat transfer fluids. Addition of high thermal conductivity metallic nanoparticles (e.g., copper, aluminum, silver) etc. to the base fluid increases the thermal conductivity of such mixtures, thus enhancing their overall heat transfer capability. In the past decade and half, there have been abundant experimental as well as numerical studies would be carried out for exploring the advantages of nanofluids under wide variety of conditions. According to the subject the condition may be different like the preparation of nanofluids at various volumetric concentrations. The numerous works regarding this are carried out by various researchers.

REVIEW OF WORK CARRIED OUT:

Sidi El Becaye Maiga et al., [1] thoroughly investigated laminar convective heat transfer for two nanofluids, water-Al_2O_3 and Ethylene Glycol-Al_2O_3. The presence of such particles induced drastic effect on the wall shear that increase appreciably with the particle loading. Among the two, Ethylene Glycol-Al_2O_3 has better heat transfer enhancement than that of water. They conclude that, in general the heat transfer enhancement also increases with the augmentation of the flow Reynolds number.

Weerapun Duangthongsuk et al., [2] paper reports an experimental study on the forced convective heat transfer and flow characteristics of a nano fluid consisting of water and 0.2 vol. % TiO_2 nano particles. For dispersing the nanoparticles in the base fluid water they use the ultrasonic vibrator and the additional surfactant. The operating condition were Reynolds number varies from 4000-18000, the temperature of nanofluid was 15, 20, 25^0 C., and mass flow rate varies from 3 LPM to 4.5 LPM. From investigation they conclude that heat transfer coefficient of the nanofluid increases with an increase in the mass flow rate, and increases with a decrease in the nano fluid temperature, and the temperature of the heating fluid has no significant effect on the heat transfer coefficient of the nano fluid. The use of TiO_2–water nano fluid significantly gives higher heat transfer coefficients than those of the pure base fluid. The convective heat transfer coefficient increases with increasing Reynolds number and increasing mass flow rate of the heating fluid, and increases with a decreasing nanofluid temperature. And they also said that the nanofluids incur no penalty of pump power and they may be suitable for the practical application.

M. Naraki et al., [3] they investigated the overall heat transfer coefficient of CuO/water nanofluids experimentally under laminar flow regime ($100 \leq Re \leq 1000$) in a car radiator. The concentration selected by them were 0, 0.15, 0.4 Vol. %. The experimental system was kept quite similar to cars cooling system. The nanofluids in all the experiments had stabilized with variation of pH and with the use of suitable surfactant called SDS (Sodium Dodecyl Sulfonate). They prepare the sample of nanofluids with pH=10.1 with five different concentrations of SDS surfactant were 0.04, 0.08, 0.1, 0.2, and 0.3. They concluded that the overall heat transfer coefficient decreases with increasing the nano fluid inlet temperature from 50^0 to 80^0 C. and the implementation of nano fluid increases the overall heat transfer coefficient up to 8% with nano fluid concentration of 0.4 vol. % in comparison with the base fluid.

S.M. Peyghambarzadeh et al., [4] experimentally studied the forced convective heat transfer in a water based nano fluid and compared with that of pure water in an automobile radiator. They conducted experiments with Al_2O_3/water nanofluid with volume concentration ranging from 0.1 to 1.0 %. For preparation of nanofluids they neglect the use of the dispersant and stabilizer in nanofluids. Liquid flow rate were varied in the range of 2-5 l/min to have the fully turbulent regime i.e. the Reynolds number changed from $9x10^3$ to 2.3×10^4. They concluded that increasing the fluid circulating rate can improve the heat transfer performance, but with the fluid inlet temperature to the radiator has trivial effects. Meanwhile, application of nano fluid with low concentrations can enhance heat transfer efficiency up to 45% in comparison with pure water.

S.M. Peyghambarzadeh et al., [5] they did experimental analysis of heat transfer enhancement in automobile radiator with water and ethylene glycol based Al_2O_3 nanofluids. They selected the range of Reynolds number 9000-23000 for water based nanofluids and 1200-2500 for ethylene glycol based nanofluids and ambient air for cooling. They select inlet temperature range from 35^0-50^0 for water based nanofluids and 45^0-60^0 for ethylene glycol based nanofluid, the fluid flowing range from 2-6 lit/min and the concentration range from 0-1 Vol. %. For avoiding the any changes in fluid property they neglect the addition of the dispersant and stabilizer to the nanofluids. They concluded that the heat transfer behaviors of the nanofluids are highly dependent on the particle concentration and weakly dependent upon the temperature.

K. Y. Leong et al., [6] focused on the application of copper/ ethylene glycol nanofluids in automotive cooling system. They fixed the Reynolds number for nanofluids and the air. They selected the inlet temperature range 70^0-95^0 for nanofluids and the concentration of nanoparticles in base fluid 0-2 Vol. %, and the mass flow rate of the nanofluids was 0.106-0.118 m^3/hr. From experimentation they observed about 3.8 % of heat transfer enhancement could be achieved with addition of 2% copper particles in a base fluid at the Reynolds number of 6000 and 5000 for air & coolant respectively. And they also conclude that there is need of additional 12.13% pumping power for radiator using the 2% copper particles at 0.2 m3/s coolants volumetric flow rate compared to that of the same radiator using the only pure ethylene glycol.

JP Yaday et al., [7] experimentally investigated the heat transfer characteristics of automobile radiator. They did the comparative analysis between the different coolants. One coolant as water and other mixture of water in propylene glycol in the ratio of 40:60 was used. They kept the mass flow rate 5LPM constant and inlet temperature 60-65^0 C for water as coolant and inlet temperature 80^0 C., different mass flow rate 5, 5.5, 6.0 to 8.5 LPM for mixture of water in a propylene glycol. From the experimental study they found that the water was still the best coolant but some limitations because of that the corrosive property of the water, it contain dissolved salts that degrades the coolant flow passage.

J.A. Eastmam et al., [8] studied experimentally the overall heat transfer coefficient in an automobile radiator with nanofluids. The nanofluids selected by them were ethylene glycol based Cu nanoparticles and the concentration range was 0-1 Vol. %. They prepared the nanofluids with selecting the based fluid of pure ethylene glycol. For preparation of nanofluids they use a small amount of thiogly-colic acid 1 Vol. % to the nanofluids to improve the particles dispersion behavior. The nanoparticles concentration was approximately 0.3 vol. % of diameter 10 nm. From the research they observed that there is no effect of the particle size.

Devdatta P Kulkarni et al. [9] they performed the experiment on Diesel Electrical Generator using the water based Al_2O_3 nanofluids as a coolant in jacket cooling fluid. They used the nanofluids with various particle concentrations of 2%, 4% and 6%. The Reynolds number varies from 200-1400, and the fluid inlet temperature varies from 20^0-70^0 C. The investigation carried out by them, they shown that applying nanofluids resulted in reduction in cogeneration efficiency due to decrease in specific heat, which influences the waste heat recovery from the engine. From that, they concluded that efficiency of waste heat recovery heat exchanger was increased for nanofluids, due to its large convective heat transfer coefficient.

Durgeshkumar Chavan et al. [10] performed experiment on the automobile radiator with using the Al_2O_3/ water nanofluid as a cooling fluid. For avoiding the any changes in fluid property they neglect the addition of the dispersant and stabilizer to the nanofluids. They took the five different concentrations in range of the 0-1.0 vol. %. The test fluids flow rate was changed in the range of 3 lit/min to 8 lit/min to obtain the fully turbulent regime having Reynolds number 4000-16000. From the experimental investigation they concluded that with increase in the fluid circulating rate increased the heat transfer rate, with increase in the Reynolds number enhance the heat transfer coefficient of both water and nanofluids considerably and with addition of 1.0 Vol. % of Al2O3 nanoparticles into the pure water, the heat transfer coefficient increased about 40-45% with compare to the pure water.

M. Ebrahimi et al., [11] experimentally studied the effect of the adding of SiO_2 nanoparticles to the base fluid water in the automobile car radiator. The operating condition of his experiment were, the fluid inlet temperature range 43^0 C, 52^0 C, and 60^0 C, the volume fraction of the nanoparticles as 0.1 %, 0.2 %, 0.4 %, and Reynold number from 8000-24000. They observed that there were improvement in the heat transfer when $\varphi=0.04$ and water considered as based fluid was about 3.8%, and this value is about 4% for water-propilenglycol. They concluded that with increasing the fluid inlet temperature, nanoparticles concentration, and Reynolds number the Nusselt number would be increased.

Yi-Hsuan Hung et al., [12] did the study of the evaluating the feasibility of the alumina (Al_2O_3)/water nanofluid for the cooling system use in the automobile using the air-cooled heat exchanger for heat dissipation. They prepared the Al_2O_3/water nanofluid by using the direct synthesis method and mechanical agitations with different weight fraction of nanoparticles. They took the concentration 0, 0.5, 1.0, 1.5 % of weight fraction. The fluid inlet temperature would be 30^0, 40^0, 50^0 and 60^0. They kept the air flow rate fixed and mass floe rate of liquid side was controlled by input voltage of circulating pump. The operating range would be 1.8, 2.1 and 2.4 lit/min. For decreasing the measurement errors they measured each condition five times. From the experimentation they found result for the concentration of 0.5 % by weight and a temperature range 30^0-60^0 C, the thermal conductivity increased by 3.8-17.2%, for a concentration of 1.0 % by weight the thermal conductivity increased by 4.6-19.7%, for a concentration of 1.5 % by weight the thermal conductivity increased by 8.1-20.5% with pure water. They conclude that the maximum enhancement of heat exchange occurred compared with the distilled water was of 40% at high weight fraction (1.5 % by weight) of nanoparticles and low inlet temperature (30^0 C).

S.M. Peyghambarzadeh et al., [13] experimentally investigated the effect of the dilute nanofluids on the overall heat transfer coefficient in the car radiator. For preparation of the copper oxide (CuO) and Iron oxide (Fe_2O_3) water based nanofluids they suspended the nanoparticles according to their volume was measured and gradually added to the distilled water. In the making of nanofluid they took the various concentrations of the nanoparticles like 0.15, 0.4, and 0.65% vol. with considering the best pH for higher stability. The operating condition were Reynolds number varies from 50-1000 and the inlet temperature of the fluid 50, 65, and 80^0 C. from the experimental investigation they state that increasing the nanoparticles concentration enhance the heat transfer rate. They observed that at the 0.65 vol%. the heat transfer enhancement of about 9% was obtained for Fe_2O_3/water nanofluids in comparison with pure water. From observation they conclude that the addition of low concentration of CuO and Fe_2O_3 particles into the water gives almost the same heat transfer enhancement for the application in the car radiator.

CONCLUSION:

From this review, various ways of enhancing the heat transfer rate in automobile radiator by using different types of nanofluids, Reynolds number, fluid flow rate, and the volumetric or weight concentration. Addition of various nanoparticles or additives to a liquid slightly increases the viscosity and the thermal conductivity moderately. The suspension of nanoparticles in the base liquid increases the heat transfer area and ultimately it leads to the increase in the heat transfer because the heat transfer rate depend upon the total surface area available for transferring the heat. The thermal conductivity of aluminum oxide is lower than the copper oxide, silicon oxide and titanium oxide. From the above study it is seen that with increasing the fluid flow rate, particle concentration the heat transfer rate increases with little penalty of the pressure drop.

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