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NANOFLUIDS AS INNOVATIVE COOLANTS

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ABSTRACT

With the trend of miniaturization the size of the devices is reducing day by day which calls for the need of a new heat transfer technology as the surface area is also decreasing which results in decreasing the heat transfer. Even in big devices like heat exchangers there is the need of enhanced heat transfer rate. The nanofluids are best suited for enhancing the cooling rate when compared with the conventional coolants such as water, oil and ethylene glycol etc. This paper presents a review of the features of nanofluids as innovative coolant and the parameters affecting their cooling rate.

Keywords*: Coolant, *Conduction, Convection , Heat Transfer, Nanofluids, Thermal conductivity

I. INTRODUCTION

Use of fins to increase surface area, vibration of heated surface, injection of fluid, application of electrical or magnetic fields, adding macrosized or microsized solid particles in conventional fluids are the techniques that have been used for many years in order to enhance the cooling process. The addition of micrometre and millimetre-sized solid particles in the conventional base fluids shows the significant improvement in the heat transfer rate. But due to following limitations these mixtures have not been commercialized[1]:

1. Lack of stability of suspension due to high density large-sized particles,
2. Clogging of pipe lines
3. Erosion of pipelines due to the abrasive actions of these particles
4. Rise in pressure drop

So the need of an innovative technology for cooling was realized by researchers. In 1995 a new term "Nanofluid" was coined by Choi of the Argonne National Laboratory, U.S.A. Nanofluids are the colloidal solution of conventional base fluids with nanoparticles of average crystallite sizes below 100 nm suspended in them.[2].

These problems may be overcome up to the maximum extent by using nanofluids. Due to the small weight and size, the nanoparticles neither choke the pipelines nor settled down easily thus making more stable solutions. Small weight nano particles impart negligible momentum to the walls of pipes or other equipments. This results in reducing the chances of erosion of pipelines. While using conventional fluids more pumping power is required to get more heat transfer. But there is large saving in pumping power while using nanofluid as large heat transfer may be achieved by using small volume of nanofluid. So, Nanofluids are the new generation heat transfer fluids which are primarily used as coolants in wide areas of applications.

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II. ENHANCED HEAT TRANSFER BY NANOFLUIDS

Nanofluids are the colloidal solutions of base fluids and nanoparticles. As the heat transfer coefficient of fluid increases with the increase in temperature and the thermal conductivity of solid is higher than that of liquid, so heat transfer in nanofluids is considered to be the combined effect of conduction and convection.

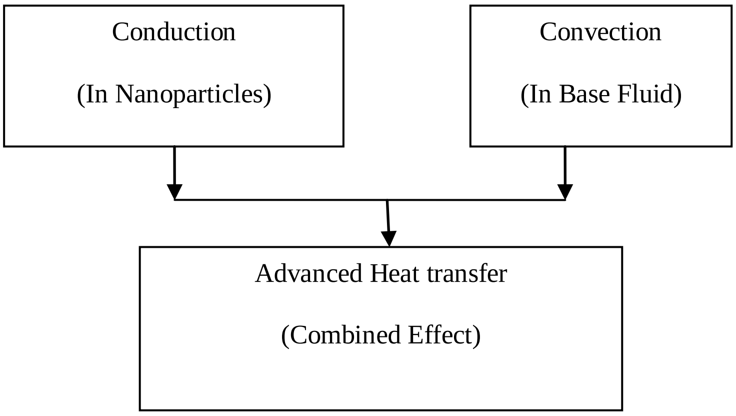

Figure:-1 Schematic view of heat transfer Process

Thermal energy (q) transferred by conduction in nanoparticles is given by Fourier's law of heat conductionas below:

$$q = kA(dt \div dx) \text{ ----------------------------(1)}$$

where $\frac{dt}{dx}$ temperature gradient in the direction of the heat flow and k is the positive constant which is the thermal conductivity of the material. The rate of heat transfer by convection is given by Newton's law of cooling.

$$Q = h\ A\ \Delta T \text{ .----------------------------(2)}$$

where the q is the rate of heat transfer, h is coefficient of convective heat transfer, A is the surface area and ΔT is the temperature difference. In order to maximize rate of heat transfer(q) for given temperature difference or surface area the coefficient of convective heat transfer or thermal conductivity may be increased. Heat transfer coefficient depends upon the fluid properties, velocity and different parameters like size, shape, concentration of nanoparticles etc. Out of different fluid properties, thermal conductivity directly influences the heat transfer coefficient at the micro-scale level [3]. Thermal conductivity is a bulk property that describes the ability of a material to transfer heat. Units of thermal conductivity are W/m K and BTU/Hr/ft.^{0}F.

The enhanced heat transfer is due to both conduction and convection, but there is major improvement in heat transfer by convection. Also there exist a absorbed interfacial layer at the interface between the nanoparticle and liquid which has different thermophysical properties and may be treated as a separate third component of nanofluid along with nanoparticles and base liquid. This layer moves with the Brownian motion of the nanoparticle and improves the heat transfer rate of nanofluid. Yu et al. [4] and Ren et al. [5] witnessed the enhancement in thermal conductivity with liquid layering.

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III. FACTORS AFFECTING COOLING

There are many factors responsible for enhancing the heat transfer rate of nanofluids. Some significant factors which affects the cooling rate are discussed below briefly;

Temperature: With the change in temperature the Brownian motion and clustering of nanoparticles get changed which further results in significant change in thermal conductivity of nanofluids. Duangthongsuk et al. [6] , Vajjha et al. [5] and Syam Sundar et al. [7]conducted experiments with different nanofluids under different conditions. They witnessed the increase in the thermal conductivity with the increase of temperature. However some nanofluids containing Al_2O_3, SiO_2, and TiO_2 in water show the decrease in thermal conductivity with increase in temperature [8].

Volume concentration: Liu et al. [9], Masuda et al. [8], Hong et al. [10], reported the improvement in thermal conductivity of nanofluid with increase of particle volume concentration and found the linear relationship of thermal conductivity with volume concentration for nanofluids. But some researchers reported a nonlinear behavior between thermal conductivity and particle volume concentration of nanoparticles [11][12].

Small size of nanoparticles- The small size of nanoparticle play a significant role in enhancing the thermal conductivity [3]. Eastman et al. [13], reported the increase in thermal conductivity of nanofluid with decrease in the size of nanoparticles. However, Karthikeyan et al. [14] reported the contradictory results in the literature. Their results revealed that the thermal conductivity increase with an increase in particle size.

Material of nanoparticle- Material of the nanoparticles is alsoa significant factor which affect the thermal conductivity of nanofluids. **The t**hermal conductivity of Alumina higher than Copper oxide . But the literature reported that the addition of CuO nanoparticle causes more enhancements than Al_2O_3 nanoparticles [15].

Shape of nanoparticles- The cylindrical nanoparticles provide higher thermal conductivity enhancement than spherical particles. Some investigations on thermal conductivity of spherical and cylindrical shaped SiC nanoparticles in water and ethylene glycol show that the spherical particles with 26 nm average diameter and cylindrical particles with 600 nm average diameter improves the thermal conductivity by 15.8% and 22.9% respectively[16].

The above brief discussion of the critical factors on the basis of the experimental data, reveals that the different parameters show different trends under different boundary conditions. The particle volume fraction dependence of thermal conductivity is much higher than the temperature dependence. The effective thermal conductivity increases with an increase in particle volume concentration and with a decrease in particle size. The viscosity increases as the particle volume fractions increase, and nanofluids behave in a Newtonian way for low particle volume concentrations.

IV. APPLICATIONS

Nanofluids are primarily used as coolants in heat transfer systems like heat exchangers, electronic systems and automobile radiators. However there is a wide range of applications which include their use as engine coolant and engine lubricant. They can be used for cooling of electronic devices, cooling of buildings, cooling of nuclear systems, solar water heating, cooling in drilling and refrigeration. They are also used in space, defence, tribiological and biomedical area for cooling of military combat vehicles, high-power laser diodes and submarines and in drug delivery.

V. CONCLUSION

Nanofluids have great potential for the cooling control involved in a variety of applications such as electronics, microelectro mechanical systems, Heat exchangers, defence and spacecraft. This may be concluded that the enhancement in thermal conductivity is a function of temperature, particle concentration, particle material type and particle shape. Most of the experimental studies reveal that nanofluids are well suited as coolants because they show an improved heat transfer coefficient as compared to its base fluid. There are some contradictory results in literature which calls for the need of further research in this new developing area of nanofluid cooling technology.

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