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Experimental Investigation for Thermal Conductivity Enhancement of Ethylene Glycol Based

Nano Fluid Containing ZnO Nanoparticles

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Abstract— Experimental study of effective thermal conductivity of ZnO based Nano fluid is presented in this research. The Nano fluid was prepared by dispersing ZnO nanoparticles in ethylene glycol using a sonicator and adding surfactant. Ethylene glycol based Nano fluid containing ZnO nanoparticles at different solid volume fractions (very low to high) was examined for the investigation. The thermal conductivity of Nano fluids is experimentally measured, and it is found that the thermal conductivity of Nano fluids increase with the nanoparticles volume concentration improvement.
Keywords— Nano fluid, particle, thermal conductivity, Experimental setup.

I. INTRODUCTION

A Nano fluid is a fluid containing nanometre-sized particles, called nanoparticles. These fluids are engineered Colloidal suspensions of nanoparticles in a base fluid. The nanoparticles used in Nano fluids are typically made of Metals, oxides, carbides, or carbon nanotubes. Common base fluids include water, ethylene glycol and oil. Nano fluids have novel properties that make them potentially useful in many applications in heat transfer, including Microelectronics, fuel cells, pharmaceutical processes, and hybrid-powered engines, engine cooling/vehicle thermal Management, domestic refrigerator, chiller, heat exchanger in grinding, machining and in boiler flue gas temperature Reduction. They exhibit enhanced thermal conductivity and the convective heat transfer coefficient compared to the Base fluid. Knowledge of the rheological behaviour of Nano fluids is found to be very critical in deciding there. Suitability for convective heat transfer applications

II. LITERATURE REVIEW

Peyghambarzadeh et al. [1,2] conducted experiment on forced convective heat transfer in a water based nanofluids,has been experimentally compared to that of pure water in an automobile radiator with different concentrations of Nano fluids. Additionally, the effect of fluid inlet temperature to the radiator on heat transfer coefficient has also been analysed by varying the temperature. Results demonstrate that increasing the fluid circulating rate can improve the heat transfer performance while 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.

Chandrasekhar et al. [3] Experimental investigations on thermo physical properties and forced convective heat transfer characteristics of various Nano fluids are reviewed and the mechanisms proposed for the alteration in their values or characteristics due to the addition of nanoparticles are summarized in this review.

Pang et al. [4] studied the vehicles cooling system extensively numerically and experimentally. The research covers many individual topics which include numerical modelling of engine cooling system, under hood air flow, heat transfer at water jacket, heat transfer at radiator and coolants.

III.EXPERIMENTAL SETUP FOR TESTING AND ITS WORKING

A car engine produces a lot of heat when it is running, and must be cooled continuously to avoid engine damage.

Generally this is done by circulating coolant liquid usually water mixed with an antifreeze solution through special cooling passages. Some engines are cooled by air flowing over finned cylinder casings.

A. Water-Cooled Cooling System Working

A water-cooled engine block and cylinder head have interconnected coolant channels running through them. At the top of the cylinder head all the channels converge to a single outlet. A pump, driven by a pulley and belt from the crankshaft, drives hot coolant out of the engine to the radiator, which is a form of heat exchanger. Unwanted heat is passed from the radiator into the air stream, and the cooled liquid then returns to an inlet at the bottom of the block and flows back into the channels again.

Usually the pump sends coolant up through the engine and down through the radiator, taking advantage of the fact that hot water expands, becomes lighter and rises above cool water when heated. Its natural tendency is to flow upwards, and the pump assists circulation. The radiator is linked to the engine by rubber hoses, and has a top and bottom tank connected by a core a bank of many fine tubes. The tubes pass through holes in a stack of thin sheet-metal fins, so that the core has a very large surface area and can lose heat rapidly to the cooler air passing through it. On older cars the tubes run vertically, but modern, low-fronted cars have cross flow radiators with tubes that run from side to side. In an engine at its ordinary working temperature, the coolant is only just below normal boiling point. The risk of boiling is avoided by increasing the pressure in the system, which raises the boiling point. The extra pressure is limited by the radiator cap, which has a pressure valve in it. Excessive pressure opens the valve, and coolant flows out through an overflow pipe.

In a cooling system of this type there is a continual slight loss of coolant if the engine runs very hot. The system needs topping up from time to time. Later cars have a sealed system in which any overflow goes into an expansion tank, from which it is sucked back into the engine when the remaining liquid cools.

B.Antifreeze

The coolant that courses through the engine and associated plumbing must be able to withstand temperatures well below zero without freezing. It must also be able to handle engine temperatures in excess of 250 degrees without boiling. A tall order for any fluid, but that is not all. The fluid must also contain rust inhibiters and a lubricant.

The coolant in today's vehicles is a mixture of ethylene glycol (antifreeze) and water. The recommended ratio is fifty-fifty. In other words, one part antifreeze and one part water. This is the minimum recommended for use in automobile engines. Less antifreeze and the boiling point would be too low. In certain climates where the temperatures can go well below zero, it is permissible to have as much as 75% antifreeze and 25% water, but no more than that. Pure antifreeze will not work properly and can cause a boil over.Antifreeze is poisonous and should be kept away from people and animals, especially dogs and cats, who are attracted by the sweet taste. Ethylene Glycol, if ingested, will form calcium oxalate crystals in the kidneys which can cause acute renal failure and death.

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IV. TESTING ON ENGINE COOLING SYSTEM USING CONVENTIONAL FLUID

A. Heat Lost In Engine

$$Q_{engine} = mCp\Delta t \quad \text{-----} (1)$$

Since, there is a constant cooling air mass flow through the engine, radiator, fan and vehicle, from Energy Conservation or Continuity

$$Q_{engine} = Q_{radiator} \quad \text{-----} (2)$$

Notations:

v = Fluid velocity (m/s)

d = Diameter of Tube, m

μ_w = Viscosity of water [N s/m^2] = 0.000798

ρ_w = Density of water [Kg/m^3] = 1000

C_{pw} = Specific heat of water [W/kg^{o}C] = 4.179

K_W = Thermal conductivity of water [W/m^{o}C] = 0.574692

R_e = Reynolds Number

Q = Heat flow rate or heat lost or dissipated to cooling water, J/hr.

h = Heat transfer coefficient (W/m^{2o}C)

Reynolds Number:

$$Re = \frac{\rho_w * v * d}{\mu_w}$$

$$Re = \frac{1000 * 0.8 * 0.005}{0.000798} = 5012.53$$

Heat transfer coefficient:

$$h = \frac{m * C_{pw} * (T_{in} - T_{out})}{9 * A_s * (T_b - T_s)}$$

$$h = \frac{800 * 4.179 * (355 - 343)}{9 * 0.78874 (349 - 346)} = 1883.84 \text{ (W/m}^{2o}\text{C)}$$

$$Q = h*As*(Tb - Ts)$$

$$Q = 1883.84*0.78874*(349-346) = 4457.6 \text{ J/Hr}$$

Conventional Fluid case:

Sr no.	T_{in} (^{o}K)	T_{out} (^{o}K)	T_S (^{o}K)
1	355	343	346

Sr no	μ_w	ρ_w	C_{p-w}	K_w	Re	h	Q
1	0.000798	1000	4.179	0.574692	5012.53	1883.24	4457.6

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Table No.1:-Final Reading of Conventional Fluid case.

IV. NANO FLUIDS

A. Review On Nano Fluid

1) Back ground: Today more than ever, ultrahigh-performance cooling plays an important role in the development of energy-efficient heat transfer fluids which are required in many industries and commercial applications. Conventional fluids, such as water, engine oil and ethylene glycol are normally used as heat transfer fluids however these conventional coolants are inherently poor heat transfer fluids. Although various techniques are applied to enhance the heat transfer, the low heat transfer performance of these conventional fluids obstructs the performance enhancement and the compactness of heat exchangers.

2) Nano-Fluid: Nano-fluids are engineered by suspending ultrafine metallic or non-metallic particles of nanometre dimensions in traditional heat transfer fluids such as water, engine oil, and ethylene glycol.

B. The concept Of Nano Fluid

The concept of Nano fluids is developed at Argonne National laboratory (Choi, 1995) is directly related to trends in miniaturization and nanotechnology. Recent reviews of research programs on nanotechnology in the U. S., China, Europe, and Japan show that nanotechnology will be an emerging and exciting technology of the 21st century and that universities, national laboratories, small businesses, and large multinational companies have already established nanotechnology research groups or interdisciplinary centres that focus on nanotechnology. It is estimated that nanotechnology is at a similar level of development as computer/information technology was in the 1950s. Solids have orders-of-magnitude higher thermal conductivities than those of conventional heat transfer fluids For example, the thermal conductivity of copper at room temperature is about 3000 times greater than that of engine oil. Therefore, solid particles in fluids are expected to enhance the thermal conductivities of fluids. In fact, numerous theoretical and experimental studies of the effective thermal conductivity of dispersions that contain solid particles have been conducted since Maxwell's theoretical work was published more than 100 years ago.

However, all of the studies on thermal conductivity of suspensions have been confined to millimetre or micrometre sized particles. The major problem with these particles is their rapid settling in fluids. In recent years, nanotechnology has enabled the production of Nanoparticles with average sizes below 50 nm. Nanoparticles at this scale have unique properties. Applying this emerging nanotechnology to established thermal energy engineering, Argonne developed the concept of Nano fluids (Choi, 1995), a new and innovative class of heat transfer fluids that are engineered by suspending nanoparticles in conventional heat transfer fluids.

C. Hybrid Nano Fluid (Nano-Blends)

Nano composites, i.e., composites containing dispersed particles in the nanometre range, are significant part of nanotechnology and one of the fastest growing areas in material science and engineering.

Alumina (Al_2O_3) is a ceramic material that exhibit several excellent properties such as very good stability and chemical inertness. But Al_2O_3 has lower conductivity compared to metallic nanoparticles. Metallic nanoparticles such as copper (Cu), aluminium (Al) possess very high thermal conductivities. But stability and reactivity are two important factors that always impede the use of metallic nanoparticles in the Nano fluid applications. The incorporation of small amount of metal particles into an ammonia matrix can significantly improve the thermal properties.

D. Particle Material And Base Fluid

Many different particle materials are used for Nano fluid preparation. Al_2O_3, CuO, TiO_2, Zno, SiC, TiC, Ag, Au, Cu, and Fe nanoparticles are frequently used in Nano fluid research. Carbon nanotubes are also utilized due to their extremely high thermal conductivity in the longitudinal (axial) direction. Base fluids mostly used in the preparation of Nano fluids are the common working fluids of heat transfer applications; such as, water, ethylene, and glycol and engine oil. In order to improve the stability of nanoparticles inside the base fluid, some additives are added to the mixture in small amounts.

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V. TESTING ON ENGINE COOLING SYSTEM USING NANO PARTICLES ADDITION IN CONVENTIONAL FLUID

A. Reading from the Testing At Different % Addition Of Nano Particles

Sr no.	% Nano Particles	T_{in} (^oK)	T_{out} (^oK)	T_S (^oK)
1	0.5	344	325	320.5
2	1.0	339	316	317.5
3	1.5	333.5	308.5	315
4	2.0	329	302	310.5
5	2.5	322	293	304

Table No 2: Reading from the testing at different % addition of Nano particles

B. Nano Fluid Calculations

W_n = Mass Fraction of Nano Particles
M_n = Mass of Nano Particles [Kg]
M_w = Mass of Water [Kg]
$\varnothing$ = Volume Fraction of Nano Particles
μ_w = Viscosity of water [N s/m^2] ,μ_{nf} = Viscosity Nano particles [N s/m^2]
ρ_w = Density of water [Kg/m^3] ,ρ_p= Density of Nano particles [Kg/m^3]
ρ_{nf} = Density Nano fluid [Kg/m^3], R_e = Reynolds Number
P_r = Prandtl number, *Nu* = Nusselt Number
C_{pw} = Specific heat of water [W/kg^{o}C]
C_{pp} = Specific heat of Nano particles [W/kg^{o}C]
C_{nf} = Specific heat of Nano fluid [W/kg^{o}C]
K_W = Thermal conductivity of water [W/m^{o}C]
K_p = Thermal conductivity Nano particles [W/m^{o}C]
K_{nf} = Thermal conductivity Nano fluid [W/m^{o}C] ,Φ= Empirical shape factor
ψ = Particle sphericity ,h= Heat transfer coefficient (W/m^{2o}C)
T_{in} = Radiator Inlet temperature (^{o}C)
T_{out} = Radiator Outlet temperature (^{o}C)
T_s = Tube wall temperature (^{o}C) m= Mass flow rate (kg/s)
v = Fluid velocity (m/s) ,A_s= Total heat transfer area (m^2)
= [no. of tubes [(2*tube height*Radiator length) + (2*tube width* Radiator)]
Q = Heat flow rate or heat lost or dissipated to cooling water, J/hr

C. Sample Calculation For 0.5 % Volume Fraction Of Nano Particles

1) Mass Fraction $W_{n,}$: Where, M_n= Mass of Nano Particle (kg) = 0.0075

M_W = Mass of Water (kg) = 1.5

$$Wn = \frac{0.0075}{(0.0075+1.5)} = 0.004975$$

2) Volume Fraction (Ø) :

$$Ø = \frac{Wn * \rho_w}{(W_n * \rho_w) + (1 - W_n) * \rho_p}$$

$$Ø = \frac{1000 * 0.004975}{(1000 * 0.004975) + (1 - 0.004975) * 5606} = 0.000891107$$

3) Dynamic Viscosity (μ_{nf}): μ_{nf} = 0.00080327 N s/m^2

4) Density (ρ_{nf}):

$$\rho_{nf} = Ø * \rho_p + (1 - Ø)\, \rho_w$$

5) Reynolds Number (Re):

$$Re = \frac{\rho_{nf} * v * d}{\mu_{nf}}$$

$$Re = 5000.091$$

6) Specific Heat ($C_{p\text{-}nf}$ in kJ/kg K):

$$C_{pnf} = \frac{(1 - 0.000891107)(1000 * 4179) + 0.000891107(5606 * 880)}{(1 - 0.000891107)1000 + 0.000891107 * 880}$$

$$C_{pnf} = 4.1625870 \text{ kJ/kg K}$$

7) Thermal Conductivity K_{nf},:

$$K_{nf} = \frac{K_p + (\Phi - 1) K_w - Ø (\Phi - 1) (K_w - K_p)}{K_p + (\Phi - 1) K_w + \Phi (K_w - K_p)} * K_w$$

K_{nf} = 0.57619663 W/m^{o}C

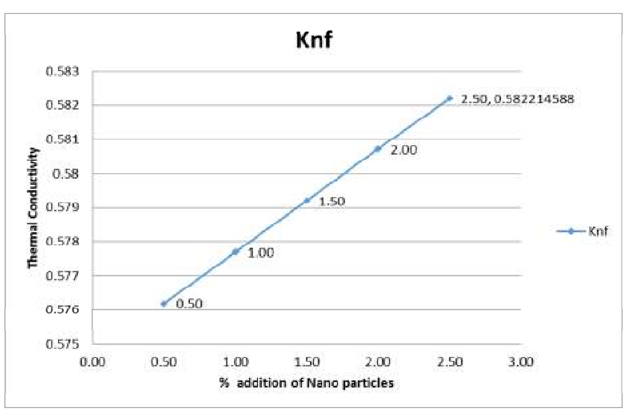
8) Heat Transfer Coefficient

$$h = \frac{m * C_{pnf} * (T_{in} - T_{out})}{9 * A_s * (T_b - T_s)}$$

$$h = \frac{803.2836 * 4.16258 * (344 - 325)}{9 * 0.78874 (334.5 - 320.5)} = 639.2657 \ (\text{W/m}^{2o}\text{C})$$

Q = h*As* (Tb - Ts)

Q = 7059.002 J/Hr



Graph: % Addition of Nano particles Vs Thermal Conductivity

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VII. CONCLUSION

The results shows that Nano fluid is giving much better results compare to conventional fluid.

Thermal Conductivity (k) is increased by _0.0076___

Heat transfer (h) is increased by _2022.14____

Density (ρ) difference is----20.445

Reynolds no.(Re) is---69.68

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