Evaluation of Nano Particle Effect on Engine Cooling System Performance over Conventional Base Fluid

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Abstract: Experimental study of effective thermal conductivity of ZnO based Nano fluid is presented in thisresearch. The Nano fluid was prepared by dispersing ZnO nanoparticles in ethylene glycol using asonicator and adding surfactant. Ethylene glycol based Nano fluid containing ZnO nano particles at different solid volume fractions (very low to high) was examined for the investigation. The thermal conductivity of Nano fluidsis experimentally measured, and it is found that the thermal conductivity ofNano fluids increase with the nanoparticles volume concentration improvement. This work is carried out for Engine cooling system application where as we can apply these effects on to nearly all heat transfer applications. The concentration added is in of total volume fraction as 0.5, 1.0, 1.5, 2.0, and 2.5 % for total volume fraction, and the results are plotted. There is observation of significant changes in thermal properties.

Keywords: - Nano fluid, Concentration, Conductivity, Engine Cooling, Thermal Properties

I. INTRODUCTION

The performance of the conventional engine-cooling system has always been constrained by the passive nature of the system and the need to provide the required heat-rejection capability at high-power conditions. This leads to considerable losses in the cooling system at part-load conditions where vehicles operate most of the time. A set of design and operating features from advanced engine-cooling systems is reviewed and evaluated for their potential to provide improved engine protection while improving fuel efficiency and emissions output. Although these features demonstrate significant potential to improve engine performance, their full potential is limited by the need to balance between satisfying the engine-cooling requirement under all operating ambient conditions and the system effectiveness, as with any conventional engine-cooling system. The introduction of controllable elements allows limits to be placed on the operating envelop of the cooling system without restricting the benefits offered by adopting these features. The integration of split cooling and precision cooling with controllable elements has been identified as the most promising set of concepts to be adopted in a modern engine cooling system.

We know that in case of Internal Combustion engines, combustion of air and fuel takes place inside the engine cylinder and hot gases are generated. The temperature of gases will be around 2300-2500°C. This is a very high temperature and may result into burning of oil film between the moving parts and may result into seizing or welding of the same. So, this temperature must be reduced to about 150-200°C at which the engine will work most efficiently. Too much cooling is also not desirable since it reduces the thermal efficiency. So, the object of cooling system is to keep the engine running at its most efficient operating temperature. It is to be noted that the engine is quite inefficient when it is cold and hence the cooling system is designed in such a way that it prevents cooling when the engine is warming up and till it attains to maximum efficient operating temperature, then it starts cooling.

There are mainly two types of cooling systems:

(a) Air cooled system, and

(b) Water cooled system.

II. NANO FLUIDS

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 hybridpowered 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 their suitability for convective heat transfer applications

Nano fluids are fluids containing nanoparticles (nanometre-sized particles of metals, oxides, carbides, nitrides, or nanotubes). Nano fluids exhibit enhanced thermal properties, amongst them; higher thermal conductivity and heat transfer coefficients compared to the base fluid. Simulations of the cooling system of a large truck engine indicate that replacement of the conventional engine coolant (ethylene glycol-water mixture) by a Nano fluid would provide considerable benefits by removing more heat from the engine.

The benefits for transportation would be:
Radiator size reduction
Pump size
Possible of elimination of one heat exchanger for hybrid-electric vehicles
Increased fuel efficiency

Using silicon carbide nanoparticles from partner Saint Goblin, the team has created an ethylene glycol/water fluid with silicon carbide nanoparticles that carries heat away 15 percent more effectively than conventional fluids. And working with industrial partner Valvoline, they've developed a graphite-based Nano fluid that has an enhanced thermal conductivity of 50 percent greater than the base fluid, which would, under specific conditions, eliminate the need for a second heat exchanger for cooling power electronics. To develop Nano fluids for heat transfer (i.e., cooling), the team used a systems engineering approach. This method enables scientists to look at how Nano fluid systems work by analysing the behaviour of the whole system, which is different than looking at each individual property of the system, such as nanoparticles material, concentration, shape, size and more. Using this scheme, the team discovered that particle size and concentration are important factors in designing Nano fluid systems.

III. EXPERIMENTAL SETUP

3.0 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.

3.1 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.

IV. 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.

5Hybrid 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 (Al2O3) is a ceramic material that exhibit several excellent properties such as very good stability and chemical inertness. But Al2O3 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.

Table 1: List of various types of nanoparticles and the corresponding base fluids

Nano particle materials include	*Base fluids include*
Oxide ceramics – Al_2O_3, CuO, ZnO	Water
Metal carbides – SiC	Ethylene/tri-ethylene-glycols and other coolants
Nitrides – AlN, SiN	Oil and other lubricants
Metals – Al, Cu	Bio-fluids
Non-metals – Graphite, carbon nanotubes	Polymer solutions
Layered – Al + Al_2O_3, Cu + C	Other common fluid
PCM – S/S	
Functionalized nanoparticles	

Advantages of Nano fluids

Nano fluids offers following advantages than other methods to improve heat transfer in conventional fluids.

1. Simple manufacturing methods. The availability of simple manufacturing methods enables to produce Nano fluids that meet the needs of a wide variety of current and future applications. Researchers can choose the most appropriate material to be added to a fluid currently in use. (For example, the two-step method works best with fluids that have high vapor pressure, like water.) The two-step method first produces nanoparticles and then disperses them in a base fluid. It is simple, and it is less costly and works with more fluids than the one-step method. But the one-step method, employs a direct evaporation condensation method that results in very small, essentially no agglomerating nanoparticles that disperse well.

2. **Can use many particle materials.** One can choose from a variety of nanoparticle materials, which is most compatible with an already existing base fluid. One can use non-metals when the use of metals would not be appropriate (for example, because they oxidize), and can exploit the enhanced heat transfer capabilities and stability of metal nanoparticles.

3. **Works with a variety of base fluids.** Nano fluids work with a variety of base fluids. This feature enables them to be used in many current applications. Existing fluids can be easily improved instead of being replaced. Examples include radiators that use an ethylene glycol/water mixture and thermal systems that use synthetic fluids.

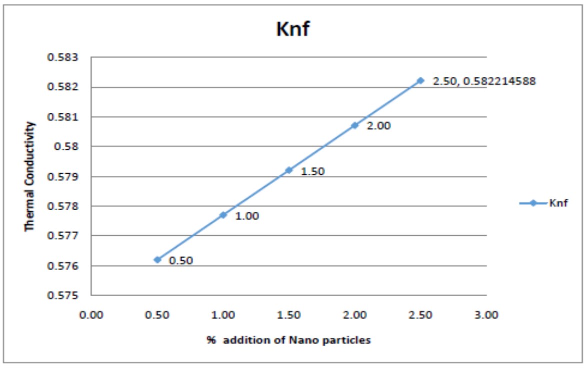
4. **Does not settle rapidly.**Nano fluids outperform existing heat transfer fluids containing solid particles in terms of long-term stability. Such stability is a requirement for enhancing heat transfer, since heat transfer occurs at the surface. Particles also need to stay suspended to ensure that the properties of the fluid do not change. Moreover, if particles settle, more particles need to be added to replace them, which represent extra time, expense, and effort.

V. RESULT AND DISCUSSION

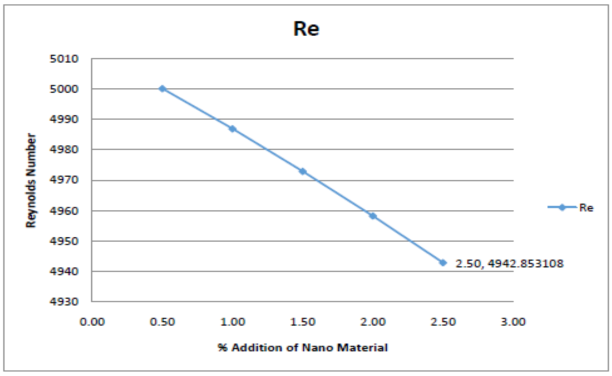
Table No 2: Similarly Calculations for different % of volume fraction of Nano Particles:

Sr no	% Nano Particles	Mass Fraction	Ø	μ_{nf}	ρ_{nf}	C_{p-nf}
1	0.5	0.004975	0.000891107	0.000803269	1004.104438	4.162587065
2	1.0	0.009901	0.001780627	0.000808684	1008.201567	4.146336634
3	1.5	0.014778	0.002668564	0.000814244	1012.291407	4.130246305
4	2.0	0.019608	0.003554924	0.000819949	1016.373978	4.114313725
5	2.5	0.02439	0.004439709	0.000825798	1020.449299	4.098536585

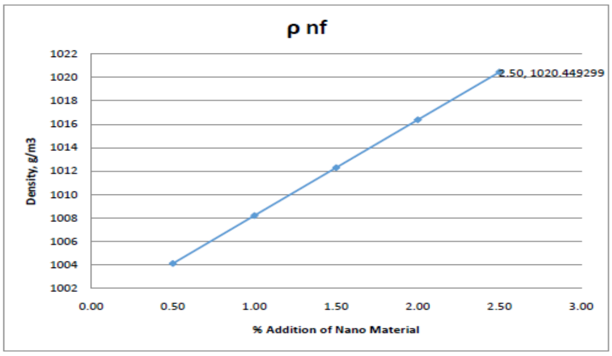
Sr no	% Nano Particles	K_{nf}	Re	h	Q
1	0.5	0.576196633	5000.091	639.2657	7059.002
2	1.0	0.577701208	4986.8749	1083.561	8546.479
3	1.5	0.579205726	4972.9117	1963.287	9291.14
4	2.0	0.580710186	4958.2286	2544.827	10036.04
5	2.5	0.582214588	4942.8531	3905.385	10781.17



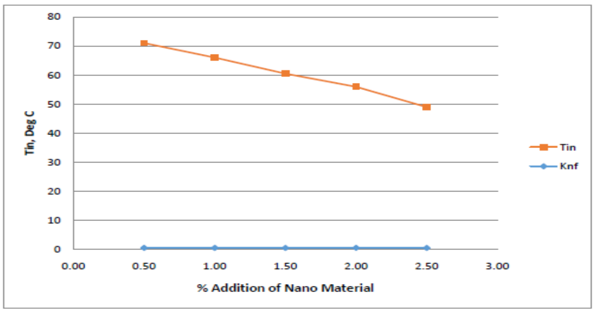
Graph 1: % Addition of Nano particles Vs Thermal Conductivity



Graph 2: % Addition of Nano particles Vs Reynolds Number



Graph 3: % Addition of Nano particles Vs Density of Fluid



Graph 4: % Addition of Nano particles Vs Tin to Radiator

VI. 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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