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NANOFLUIDS: A NEW ADVENT IN COOLING SYSTEM OF INTERNAL COMBUSTION ENGINE

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Abstract— Inclination of vehicle designer is to increase the power . Also his focus will be to get power-weight ratio as high as possible. For this purpose his interest lies in making the component parts as small as possible. Smaller component parts will help to keep the size, volume, weight less which thereby help to increase the engine efficiency. About 1/3 rd heat generated in the engine is rejected through engine cooling system. The heat load to the cooling system will increase by about the same percentage as the increase in engine horsepower. The cooling system occupies considerable space and adds weight on the vehicular structure. Above all the radiator also increase the drag force. Placing the component parts of the cooling system at the most feasible place it the major concern from the designer point of view. Conventional approaches and designs have reached the limits and only the cooling problem threatens to be the limiting factor, to both further increase in speeds and power as well as miniaturization of system to reduce the weight, volume etc. The main focus of this project is the physical testing and analysis of the data collected during experimentation. The engine cooling system design has been refined as a result of the testing undertaken during the project. The test data has been analyzed to identify the heat rejection requirement, analysis of heat transfer area available in radiator, heat carrying capacity of coolant, pumping power and other important design parameters. During experimentation it is seen that the heat carrying capacity of Nanofluid is relatively more than that of 50/50 water ethylene glycol. This not only reduces the surface area of radiator but also gives benefits associated thereby. The use of Nanofluids present various advantages such asReduced size in cooling system Reduced weight of cooling system Reduced pumping power All these lead to cost saving in manufacturing of operating (running cost).So it is worthwhile to explore further the viability of use of Nanofluids in various applications.
Keywords— ethylene glycol, Nanofluid, Radiator, Aluminium oxide.

1. INTRODUCTION

Considering the customer requirements for an increased engine power and performance has necessitated to improve the heat management system of the vehicle. There is a substantial increase of the heat release into the engine cooling system. The main source for this increase heat is the need for increased power and more stringent emission norms leading to new combustion technologies. Simultaneously efforts are to reduce the noise levels and increase the fuel economy.

This has led to rethink new concepts regarding the bulk cooling system and the coolants. The heat transfer properties of thermo fluid plays an important role in the development of energy efficient heat transfer equipment. So whenever any liquid is used to cool the engine. It has to have a very low freezing point, a high boiling point and it has to have the capacity to hold a lot of heat.

One of the salient features to be considered while using the traditional heat transfer liquids is their low thermal conductivities. Thermal conductivity reflects the ability of a medium to conduct heat. It is seen that water, engine oil and ethylene glycol are inherently poor heat transfer fluids with low thermal conductivities of 0.613 w/mk, 0.145 w/mk and 0.253 w/mk respectively and thus major improvement in cooling capabilities have been constrained.

The passive means to enhance the heat transfer rates have reached their limits and seems to have exhausted. Development of advanced heat transfer fluids with higher heat transfer properties is in strong demand.Thermal conductivity of metals can be hundreds or even thousands times greater than the conventional heat transfer fluids such as water or ethylene glycol. So one obvious solution is to boost up the thermal conductivity of a fluid by using a suspension of particles of a highly conducting solid in it. These types of liquids are called Nanofluids.Nanofluids having suspended Nanoparticles in liquids results in increased thermal conductivity and convective heat transfer performance of the base liquids.The potential impact of Nanofluids on general heat transfer applications is quite large and this includes ethylene glycol and water mixtures for engine cooling. If Nanofluids can improve the heat transfer co-efficient of vehicle radiator they can facilitate the reduction in its size and lead to increased fuel and energy efficiency, lower pollution and improved reliability.

There is a scope for using Nanofluids containing aluminium oxide, copper, carbon Nanotubes, etc. in the engine cooling system as a coolant so as to get a reduced size of cooling system for the same rate of heat transfer. The reduced size of engine cooling system will decrease the weight of cooling system, reduce the pumping power needed to circulate the coolant which will in turn lead to increasing the efficiency and economy of the engine.

Another added advantage of the reduced size of cooling system is that there will be material saving for manufacturing and maintenance.

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2. OBJECTIVES AND SCOPE OF WORK

The use of Nanofluids has the potential to improve the engine cooling rates.These improvements can be used to remove engine heat with a reduced size cooling system. Smaller cooling system lead to use of smaller and lighter radiators which in turn will lead to better performance and increased efficiency. Alternatively , improved cooling rates can be used to remove more heat from higher horsepower engines with same size of cooling system. The IC engine temperature in an automobile is maintained by circulating a cooling fluid through the cooling circuit.Ethylene glycol and water mixture, the nearly universally used automotive coolant, is a relatively poor heat transfer fluid compared to water alone. Aim is mainly to maintain the coolant in single-phase throughout the cooling system. So engines with higher horsepower will lead to heavier and bigger cooling systems which may hamper the overall efficiency.

3. EXPERIMENTAL SETUP AND PROCEDURE

3.1 NanoFluid Preparation ;

Nanofluid is a fluid in which Nano-meter sized particles are suspended.

3.2 Argonne National Laboratory.

Nanoparticles are a class of materials that exhibit unique physical and chemical properties compared to those of larger physical and chemical properties compared to those of larger particles of same material.Experiments remain the primary source of information when complex flow situations such as multiphase flows, boiling or condensation are involved.

The two-step method employs a two-step process to make Nanofluids in which Nanoparticles are first produced as a dry powder and the as-prepared Nanoparticles are then dispersed into a base fluid in a second processing step.A certain degree of agglomeration may occur in the Nanoparticle preparation, storage and dispersion processes, it is well known that these agglomerates require very little energy to break up into smaller constituents. And thus it is possible that even agglomerated Nanocrystalline powders can be successfully dispersed into fluids and result in good properties. This two-step process works well in many cases, especially for oxide and nonmetallic Nanoparticles.

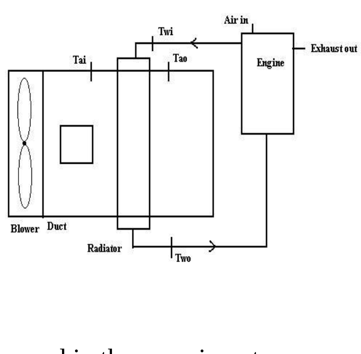
The second processing approach, referred to as the single-step method, has been used with success to produce Nanofluids containing dispersed high thermal conductivity metal Nanoparticles. During this process, Nanoparticles were synthesized and dispersed into a fluid within a single step. As with the inert gas–condensation technique, the technique involves vaporization of a source material under vacuum conditions.

In this case, however, condensation of the vapor to form Nanoparticles occurs via contact between the vapor and a liquid. Nanoparticle agglomeration is minimized by flowing the liquid continuously.

In this experimentation a two step procedure was used for preparing the Nanofluid.A measured quantity of nanoparticle was taken. It was mixed thoroughly in the 50/50 water-ethylene glycol. Mechanical stirrer was used to mix it uniformly. It was kept in the sonicator and subjected to vibrations so as to reduce to problem of agglomeration.

It Nanofluid was kept still for two days to check for sedimentation. Even after two days there was no appreciable sedimentation and the important fact is that the moment it was stirred again it turned into a uniform fluid with evenly suspended nanoparticles in it.

3.3 Block Diagram of Experimental Setup :



Specifications

The specification of the equipments used in the experiment are :

1) Engine 4 stroke, 4 cylinder petrol engine
2) Make Fiat, Premier Padmini
3) Radiator size 335 mm × 300 mm × 17mm
4) Tube side area 330905.3 mm2
5) Fin side area 2310000 mm2
6) Blower Axial fan with 3 speeds
7) Duct 335 mm × 300 mm × 1500 mm
8) Thermocouple 4 in number of range 0-200 oC
9) Volume of coolant 3.5 litre

10) Dynamometer Eddy current
11) Dynamometer constant 2000
12) Nanoparticles Al2O3 nano powder dispersible in water
13) Purity 80 %
14) APS 30 nm
15) Water dispersibility more than 95 %
16) SSA 100 m2/g

3.4 System Assembly

The apparatus is assembled following the schematic of the apparatus setup. The open circuit of the engine cooling system is converted to closed circuit by first disconnecting the calorimeter. The outlet those of the engine is connected to the inlet of the radiator and the outlet pipe of the radiator is connected to inlet of the coolant circulating pump of the engine. All the thermocouples are properly installed according to the apparatus set up and tested to be in good condition. One thermocouple gives the air temperature before the radiator and another gives the air temperature after the radiator. Similarly one thermocouple gives the water temperature entering the radiator and another gives the water temperature leaving the radiator.
The blower is mounted on the duet and fixed properly. Electrical connections to the blowers are given. The radiator is mounted on the duct as per the schematic of experimental set up.

3.5 Sample Filling

In all three coolants, viz water, 50/50, water-ethylene glycol mixture and Nanofluid are used. The required quantity of coolant is filled in the radiator. Precaution is taken to avoid any air pocket in the cooling system. After loading the coolant the radiator cap is to be closed tightly. Thereon , all the pipes, hoses etc are checked for leakages and problems, if any are resolved before proceeding with the experimentation.

1) Thermal Testing
2) Turn on the engine
3) Adjust the engine speed.
4) Adjust the load on the dynamometer. Start the blower.
5) Each experimental run is long enough to reach a steady state.
6) Temperature at all locations are to be noted at steady state.
7) Change the blower speed to get two more sets of readings for same load and speed.
8) Then change the speed and repeat the procedure.
9) Similar readings are taken by changing the loads.
10) After taking the readings, the engine is turned off.
11) Take out the sample and clean the system.
12) Load the next sample coolant and repeat the procedure.
13) There is little alteration in radiator and pump even though different engine speeds, engine loads and different blower speeds are experimented upon for the different coolants.

4. RESULTS AND DISCUSSIONS

At 20% load :

N	u m/s	Re	Nu	h	Area	Savings in area	% savings
900 rpm	2.4	441.18	9.16	83.266	2.284	0.356	13.48
	3.2	590	10.94	99.65	2.221	0.419	15.87
	3.8	700.62	12.157	110.7	2.19	0.45	17.04
1200 rpm	2.4	439.9	9.14	83	2.25	0.39	14.77
	3.2	588.24	10.92	99.29	2.21	0.43	16.3
	3.8	700.62	12.15	110.7	2.18	0.46	17.42
1500 rpm	2.4	438.6	9.12	82.73	2.23	0.41	17.04
	3.2	586.25	10.9	98.99	2.19	0.45	17.04
	3.8	698.54	12.13	110.31	2.16	0.48	18.18

2000 rpm	2.4	437.34	9.11	82.44	2.21	0.43	16.3
	3.2	584.8	10.88	98.65	2.17	0.47	17.8
	3.8	696.5	12.11	109.97	2.15	0.49	18.56

There is an appreciable savings in surface area when Nanofluid is used instead of 50/50 water ethylene glycol mixture. When compared to 50/50 water ethylene glycol mixture, the % saving in area at higher speeds of the Nanofluid is considerably more.

5. CONCLUSIONS

A savings of 12-18 % of surface area can be seen by use of Nanofluids. As the load on the engine and the speed of the engine increases the percentage savings of surface area also increases. The thermal conductivity of Nanofluid is temperature dependent. As the temperature increases at higher load and speeds the heat carrying capacity of Nanofluids increases. This is advantageous when engine is running at high speed and load. At higher air velocity the % savings in surface area is more.It means that at higher vehicle speed the use of Nanofluid has a lot of advantage. The use of Nanofluid makes it possible to design the system with higher power- size ratio. With increase in air velocity the dimensionless numbers and heat transfer coefficient increases. For the same air velocity, the dimensionless numbers and the heat transfer coefficient go on decreasing with increase in load and speed of engine. The heat carrying capacity of Nanofluids as compared to 50/50 water-ethylene mixture is more but relatively less compared to water alone. The surface area required for the given amount of heat to be transferred is less when Nanofluid is used as a coolant in comparison to the 50/50 water-ethylene glycol mixture but when compared to water the surface area required is more.As the surface area required in case of Nanofluid is less, the volume occupied by the cooling system also reduces.

It is seen that the heat carrying capacity of the Nanofluid increases with increase in engine speed. This is advantageous particularly when the engine is running at high speed and more heat is to be rejected out. The use of Nanofluid helps to use a smaller cooling system. To increase the boiling point, normally the entire cooling system is maintained at positive pressure. Use of Nanofluids allows the cooling system to be operated at atmospheric pressures and the advantages associated with it.

The weight of the heat transfer equipment and the entire cooling system as such will be reduced when Nanofluid is used as coolant. As less coolant is needed to be circulated, due to the enhanced heat carrying capacity of the Nanofluid, the pumping power required will also be reduced. In case of vehicles, the reduced weight, reduced volume, reduced pumping power, will eventually increase the engine efficiency. When the radiator size, volume and weight is reduced, it will reduce the drag force experienced by the frontal area of the vehicle. All these factors give the designers additional versatility from the ergonomic and aesthetic point of views when designing the vehicle. Reduction in size or the simplification in designing the cooling system decreases the manufacturing and also the maintenance cost of the cooling system equipments. It was also seen that the metallic Nanoparticles in the coolant helped to warm-up the engine quickly when started from cold condition.

6. FUTURE SCOPE

Studying the Nanofluids to validate their properties from theoretical point of view is fine but the focus should be to try to extract whatever advantage can be had by their use. It will be worthwhile to workout with various permutations and combinations of the Nanoparticles and base fluids which might help to develop the science related to Nanofluid. Many glycol based coolant base have merits but there are a few out there in the market that are more about marketing than science. New fanciful coolants such as 50/50 mixture of water ethylene glycol are good regions here temperature below 0oC. But as we can understand, other than a few northern states, in most part of India atmospheric temperature rarely goes below 0oC. So with addition of corrosion inhibitors it will be quite beneficial to go for water to be used in the cooling system. So it becomes important to study the behavioral characteristics of the water based Nanofluids more extensively.

Furthermore, suspensions of metal Nanoparticles are also being developed for other purpose, such as medical applications including cancer therapy. The interdisciplinary nature of Nanofluid research presents a great opportunity for exploration and discovery at the frontiers of Nanotechnology. By using the Nanofluids the general trends for an enhanced heat transfer were observed but also areas of discrepancies do exist. The inaccuracies encountered are mainly due to poor characterization of Nanofluids which are experimented upon. It is difficult to measure and quantify the size, shape and distribution of Nanoparticles in fluids. Viscosity measurement of Nanofluids could be a important parameter which will be helpful when comparing Nanofluid results. A major apprehension while using any particle laden flow due to the fluid motion. is the effect of erosion of the material surfaces. The Nanoscale of the particles involved in Nanofluids tend to mitigate the particle erosion problems. Also Nanoparticles tend tofollow the fluid streamlines better than larger particles in flows. The use of Nanofluids with carbon Nanotubes was unacceptable for radiator use because of the severe coating of all the surfaces.

The transitions for the use of Nanofluids from research to industrial practice requires that the Nanofluid technology becomes further developed and some key barriers be overcome. Nanofluids have been mainly produced in small quantities.This is adequate for research work, but large scale production of well dispersed Nanofluids at low cost is required for commercial applications.

7. CHALLENGES AND BARRIERS

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Nanofluids have been mainly produced in small quantities. This is adequate for research work, but large scale production of well dispersed Nanofluids at low cost is required for commercial applications. This is a serious barrier for use of Nanofluids in cooling system of vehicles.

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