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# Effect of Using Nanofluids as Cooling Fluids on Performance of an Engine Block

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## Abstract:

Cooling system plays important roles to control the temperature of car's engine. One of the important elements in the car cooling system is cooling fluid. The usage of wrong cooling fluid can give negatives impact to the car's engine and shorten engine life. An efficient cooling system can prevent engine from overheating and assists the vehicle running at its optimal performance. This thesis was conducted to study the effectiveness of various types cooling agent in the vehicle cooling system which will influence the operation time of the engine block mainly cylinder in the light vehicle cooling systems. 3D model of the engine block is done in Pro/Engineer. Different types of fluids mixed with base fluid water considered in this thesis Aluminum Oxide, Silicon Carbide, Titanium Oxide and Copper Oxide at volume fraction of 0.4. The properties of the nanofluids are calculated theoretically.CFD analysis is done on the engine block using all nanofluids and Thermal analysis is done on the engine block by varying the materials Copper and Aluminum alloy

## I. INTRODUCTION

Although gasoline engines have improved a lot, they are still not very efficient at turning chemical energy into mechanical power. Most of the energy in the gasoline (perhaps 7¬0%) is converted into heat, and it is the job of the cooling system to take care of that heat. In fact, the cooling system on a car driving down the freeway dissipates enough heat to heat two average-sized houses. The primary job of the cooling system is to keep the engine from overheating by transferring this heat to the air, but the cooling system also has several other important jobs.

The engine in your car runs best at a fairly high temperature. When the engine is cold, components wear out faster, and the engine is less efficient and emits more pollution. So another important job of the cooling system is to allow the engine to heat up as quickly as possible, and then to keep the engine at a constant temperature.

## II. PROJECT DESIGN

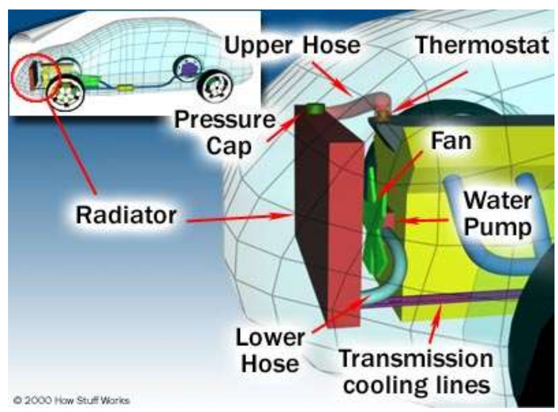


Fig1. Project Design

A nano fluid is a fluid containing nanometer-sized particles, called nano particles. These fluids are engineered colloidal suspensions of nano particles in a base fluid. The nano particles used in nanofluids are typically made of metals, oxides, carbides, or carbon nano tubes .It is a mixture of water and suspended metallic nano particles. Since the thermal conductivity of metallic solids are typically orders of magnitude higher than that of fluids it is expected that a solid/fluid mixture will have higher effective thermal conductivity compared to the base fluid.

Thus, the presence of the nano particles changes the transport properties of the base fluid thereby increasing the effective thermal conductivity and heat capacity, which ultimately enhance the heat transfer rate of nanofluids. Because of the small size of the nano particles (10-9 m), nanofluids incur little or no penalty in pressure drop and other flow characteristics when used in low concentrations. Nanofluids are extremely stable and exhibit no significant settling under static conditions, even after weeks or months. In their work (Lee & Choi) on the application of nanofluids reported significant cooling enhancement without clogging the micro-channels.

*A. Engine:*

The engine block and cylinder head have many passageways cast or machined in them to allow for fluid flow. These passageways direct the coolant to the most critical areas of the engine.

Temperatures in the combustion chamber of the engine can reach 4,500 F (2,500 C), so cooling the area around the cylinders is critical. Areas around the exhaust valves are especially crucial, and almost all of the space inside the cylinder head around the valves that is not needed for structure is filled with coolant. If the engine goes without cooling for very long, it can seize. When this happens, the metal has actually gotten hot enough for the piston to weld itself to the cylinder. This usually means the complete destruction of the engine.

Figure2. Engine

One interesting way to reduce the demands on the cooling system is to reduce the amount of heat that is transferred from the combustion chamber to the metal parts of the engine. Some engines do this by coating the inside of the top of the cylinder head with a thin layer of ceramic. Ceramic is a poor conductor of heat, so less heat is conducted through to the metal and more passes out of the exhaust.

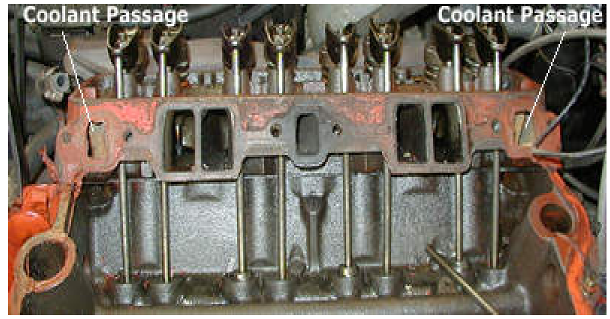


Figure2.Head of the Engine

B. *Air Cooling:*

Some older cars, and very few modern cars, are air-cooled. Instead of circulating fluid through the engine, the engine block is covered in aluminum fins that conduct the heat away from the cylinder. A powerful fan forces air over these fins, which cools the engine by transferring the heat to the air.

The cooling system on liquid-cooled cars circulates a fluid through pipes and passageways in the engine. As this liquid passes through the hot engine it absorbs heat, cooling the engine. After the fluid leaves the engine, it passes through a heat exchanger, or radiator, which transfers the heat from the fluid to the air blowing through the exchanger.

Cars operate in a wide variety of temperatures, from well below freezing to well over 100 F (38 C). So whatever fluid is used to cool the engine 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.

Water is one of the most effective fluids for holding heat, but water freezes at too high a temperature to be used in car engines. The fluid that most cars use is a mixture of water and ethylene glycol ($C_2H_6O_2$), also known as antifreeze. By adding ethylene glycol to water, the boiling and freezing points are improved significantly.

The temperature of the coolant can sometimes reach 250 to 275 F (121 to 135 C). Even with ethylene glycol added, these temperatures would boil the coolant, so something additional must be done to raise its boiling point.

The cooling system uses pressure to further raise the boiling point of the coolant. Just as the boiling temperature of water is higher in a pressure cooker, the boiling temperature of coolant is higher if you pressurize the system.

| | Pure Water | 50/50 $C_2H_6O_2$/Water | 70/30 $C_2H_6O_2$/Water |
|---|---|---|---|
| Freezing Point | 0 C / 32 F | -37 C / -35 F | -55 C / -67 F |
| Boiling Point | 100 C / 212 F | 106 C / 223 F | 113 C / 235 F |

Table 1: Different Freezing and Boiling Point

Most cars have a pressure limit of 14 to 15 pounds per square inch (psi), which raises the boiling point another 45 F (25 C) so the coolant can withstand the high tempera-tures. Antifreeze also contains additives to resist corrosion.

*C. Nano Fluids:*

Advancements in material technology have provided the opportunity to produce material particles at the nano (10-9) scale. These particles have very different prop-erties, like mechanical and electrical, than their full scale parent materials. Nano particles are particles' consisting of dimensions approximately 0.1-1000 nm in size. Some of the common oxide nano particles being used in heat trans-fer research are Zinc Oxide (ZnO), Copper Oxide (CuO), Aluminum Oxide (Al2O3), and Titanium Oxide (TiO2) while some of the metal nano particles are Gold (Au), Sil-ver (Ag), and Copper (Cu).

Nano particles of materials such as metallic oxides (Al2O3, CuO), nitride ceramics,(AlN, SiN), carbide ceramics (SiC, TiC), metals (Cu, Ag, Au), semiconductors (TiO2, SiC), single, double or multi walled carbon nano tubes (SWCNT, DWCNT, MWCNT), alloyed nano particles (Al70Cu30) etc. have been used for the preparation of nanofluids. These nanofluids have been found to possess an enhanced thermal conductivity as well as improved heat transfer performance.

The effective thermal conductivity of these nanofluids are usually expressed as a normalized thermal conductivity value obtained by dividing the overall thermal conductivity of the nano fluid by the base fluid thermal conductivity or sometimes as a percentage of the effective value with respect to the base fluid value.

Thermal properties of liquids play a decisive role in heating as well as cooling applications in industrial processes. Thermal conductivity of a liquid is an important physical property that decides its heat transfer performance. Conventional heat transfer fluids have inherently poor thermal conductivity which makes them inadequate for ultra high cooling applications

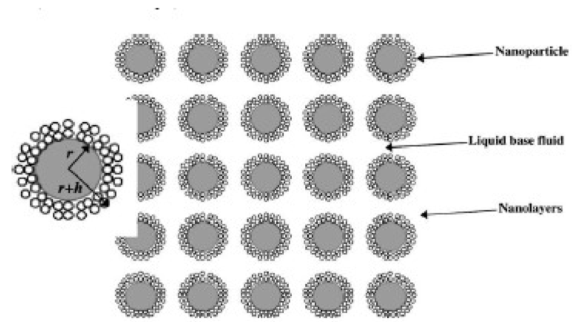


Figure4. Nano Fluids

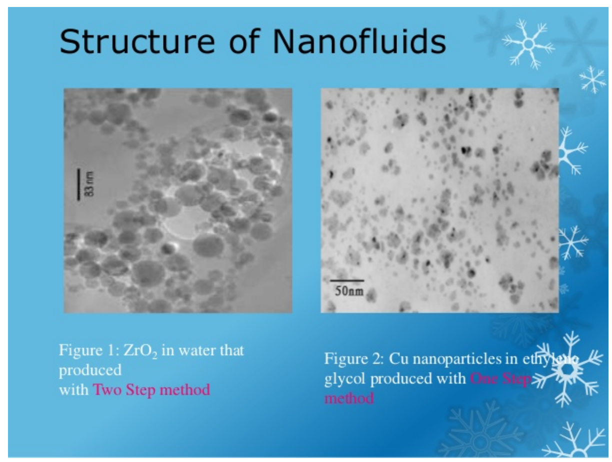


Figure5. Structure of Nano Fluids

Scientists have tried to enhance the inherently poor thermal conductivity of these conventional heat transfer fluids using solid additives following the classical effective medium theory (Maxwell, 1873) for effective properties of mixtures. Fine tuning of the dimensions of these solid suspensions to millimeter and micrometer ranges for getting better heat transfer performance have failed because of the drawbacks such as still low thermal conductivity, particle sedimentation, corrosion of components of machines.

The use of nanofluids as coolants would allow for smaller size and better positioning of the radiators. There would be less fluid due to the higher efficiency, coolant pump could be shrunk and truck engines could be operated at higher temperatures allowing for more horsepower. The use of nanofluids in radiators can lead to a reduction in the frontal area of the radiator by up to 10%. This reduction in aerodynamic drag can lead to a fuel saving of up to 5%.

*D. CAD (Computer-aided design):*

Computer-aided design (CAD), also known as computer-aided design and drafting (CADD), is the use of computer technology for the process of design and design-documentation. Computer Aided Drafting describes the process of drafting with a computer. CADD software, or environments, provide the user with input-tools for the purpose of streamlining design processes; drafting, documentation, and manufacturing processes. CADD output is often in the form of electronic files for print or machining operations. The development of CADD-based software is in direct correlation with the processes it seeks to economize; industry-based software (construction, manufacturing, etc.) typically uses vector-based (linear) environments whereas graphic-based software utilizes raster-based (pixelated) environments.

CAD environments often involve more than just shapes. As in the manual drafting of technical and engineering drawings, the output of CAD must convey information, such as materials, processes, dimensions, and tolerances, according to application-specific conventions.CAD may be used to design curves and figures in two-dimensional (2D) space; or curves, surfaces, and solids in three-dimensional (3D) objects.

CAD is an important industrial art extensively used in many applications, including automotive, shipbuilding, and aerospace industries, industrial and architectural design, prosthetics, and many more. CAD is also widely used to produce computer animation for special effects in movies, advertising and technical manuals. The modern ubiquity and power of computers means that even perfume bottles and shampoo dispensers are designed using techniques unheard of by engineers of the 1960s. Because of its enormous economic importance, CAD has been a major driving force for research in computational geometry, computer graphics (both hardware and software), and discrete differential geometry.

*E. FEA(FINITE ELEMENT ANALYSIS):*

FEA consists of a computer model of a material or design that is stressed and analyzed for specific results. It is used in new product design, and existing product refinement. A company is able to verify a proposed design will be able to perform to the client's specifications prior to manufacturing or construction. Modifying an existing product or structure is utilized to qualify the product or structure for a new service condition. In case of structural failure, FEA may be used to help determine the design modifications to meet the new condition.

FEA uses a complex system of points called nodes which make a grid called a mesh. This mesh is programmed to contain the material and structural properties which define how the structure will react to certain loading conditions. Nodes are assigned at a certain density throughout the material depending on the anticipated stress levels of a particular area. Regions which will receive large amounts of stress usually have a higher node density than those which experience little or no stress. Points of interest may consist of: fracture point of previously tested material, fillets, corners, complex detail, and high stress areas. The mesh acts like a spider web in that from each node, there extends a mesh element to each of the adjacent nodes. This web of vectors is what carries the material properties to the object, creating many elements.

*F. Computational Fluid Dynamics ANSYS (CFD Analysis):*

ANSYS is general-purpose finite element analysis (FEA) software package. Finite Element Analysis is a numerical method of deconstructing a complex system into very small pieces (of user-designated size) called elements. The software implements equations that govern the behaviour of these elements and solves them all. This type of analysis is typically used for the design and optimization of a system far too complex to analyze by hand. Systems that may fit into this category are too complex due to their geometry, scale, or governing equations. It is the standard FEA teaching tool within the Mechanical Engineering Department at many colleges. ANSYS is also used in Civil and Electrical Engineering, as well as the Physics and Chemistry departments.

ANSYS provides a cost-effective way to explore the performance of products or processes in a virtual environment. This type of product development is termed virtual prototyping. With virtual prototyping techniques, users can iterate various scenarios to optimize the product long before the manufacturing is started. This enables a reduction in the level of risk, and in the cost of ineffective designs. The multifaceted nature of ANSYS also provides a means to ensure that users are able to see the effect of a design on the whole behavior of the product, be it electromagnetic, thermal, mechanical etc.

Computational fluid dynamics, usually abbreviated as CFD, is a branch of fluid mechanics that uses numerical methods and algorithms to solve and analyze problems that involve fluid flows. Computers are used to perform the calculations required to simulate the interaction of liquids and gases with surfaces defined by boundary conditions. With high-speed supercomputers, better solutions can be achieved. Ongoing research yields software that improves the accuracy and speed of complex simulation scenarios such as transonic or turbulent flows.

*G.METHODOLOGY:*

In all of these approaches the same basic procedure is followed.

• During preprocessing

•The geometry (physical bounds) of the problem is defined.

•The volume occupied by the fluid is divided into discrete cells (the mesh). The mesh may be uniform or non-uniform.

•The physical modeling is defined – for example, the equations of motion + enthalpy + radiation + species conservation

•Boundary conditions are defined. This involves specifying the fluid behavior and properties at the boundaries of the problem. For transient problems, the initial conditions are also defined.

•The simulation is started and the equations are solved iteratively as a steady-state or transient.

•Finally a postprocessor is used for the analysis and visualization of the resulting solution.

Once the system is fully designed, the last task is to burden the system with constraints, such as physical loadings or boundary conditions. This is actually a step, because ANSYS needs to understand within what state (steady state, transient… etc.) the problem must be solved. Present the Results after the solution has been obtained

III. RESULTS

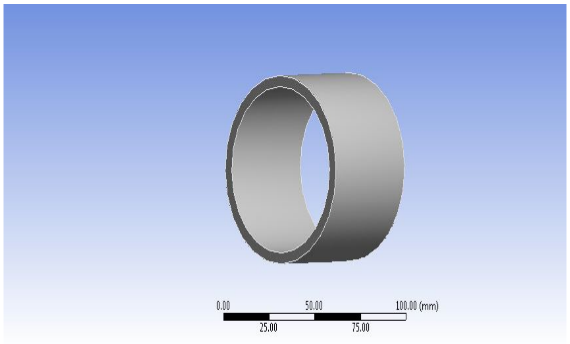


Fig6. Imported Model

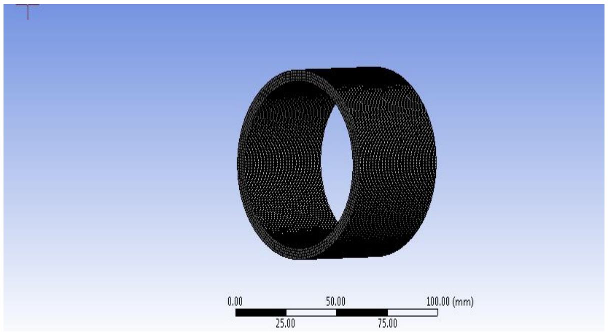


Fig7. Meshed Model

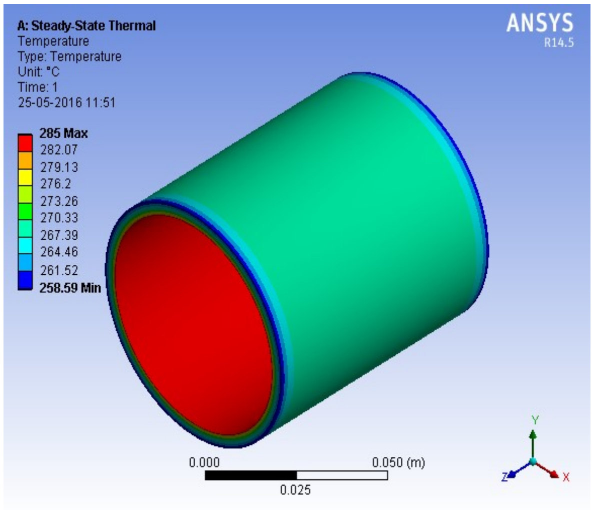


Fig8. Temperature Model

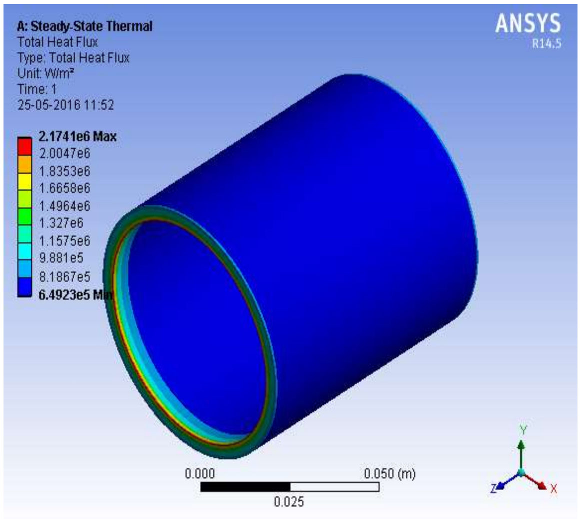


Fig9. Heat Model

| | Convection | Temp ($^0C$) | Heat flux ($W/m^2$) |
|---|---|---|---|
| Al | $Al_2O_3$ | 285 | 2.1741e6 |
| | SiC | 285 | 2.2053e6 |
| | $TiO_2$ | 285 | 1.1396e6 |
| | CuO | 285 | 8.3859e5 |
| Cu | $Al_2O_3$ | 285 | 2.2464e6 |
| | SiC | 285 | 2.2797e6 |
| | $TiO_2$ | 285 | 1.1594e6 |
| | CuO | 285 | 8.493e5 |

Table 2: Thermal Analysis

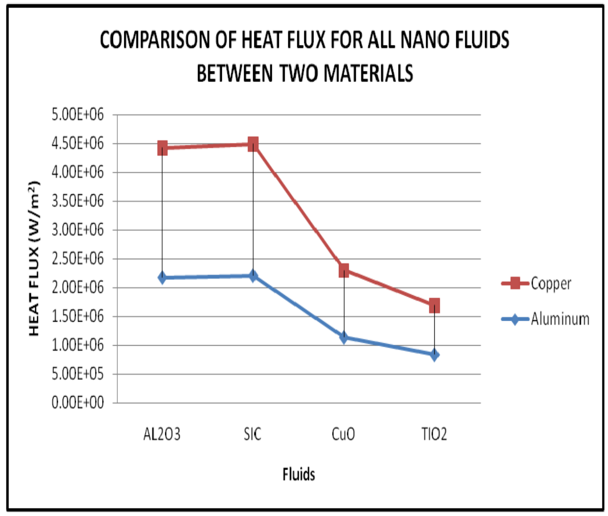


Fig10: Comparison of Heat Flux

## IV.CONCLUSION & FUTURE SCOPE

In this thesis CFD and thermal analysis is performed on the engine block of a car using nanofluids. Different types of fluids mixed with base fluid water considered in this thesis Aluminum Oxide, Silicon Carbide, Titanium Oxide and Copper Oxide at volume fraction of 0.4,the properties of the nanofluids are calculated theoretically.

By observing the CFD analysis results, the heat transfer coefficient and mass flow rate are more for silicon oxide than other nanofluids. The heat transfer rate is more for Aluminum oxide.ryi.

By observing the thermal analysis results, taking Copper as engine block material and fluid as Silicon Carbide is better since heat flux (i.e) heat transfer rate is more. But by using Copper, the weight increases than that of aluminum alloys. So when compared among aluminum alloys, using aluminum alloy with silicon oxide nano fluid is better.

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