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Computational Analysis of CuO Nano Coolant in a Car Radiator

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Abstract: *Nanofluids are basically nanoparticles in base fluids. Nanofluids have unique features different from conventional solid-liquid mixtures in which nano sized particles of metals and nonmetals are dispersed. Due to improvement of mechanical properties, nanofluids are widely used in heat transfer industries. The coolant is used water-based, with the addition of glycols to prevent freezing and other additives to limit corrosion, erosion and cavitations. In this study 50-50 mixture of Ethylene Glycol with water (EGW) is tested and compared with another mixture by adding 2 percent Copper oxide (CuO). The geometric model of radiator is uploaded in Autodesk CFD software for its computational analysis. It is analyzed up to 100 iterations. Both the results are compared to find the improved heat transfer rate due to the addition of 2% CuO with Ethylene Glycol and water.*

Keywords: *Nanofluids, nanoparticles, car radiator, thermal conductivity, Copper oxide*

I. Introduction

Vehicle thermal management is a crosscutting technology because it directly or indirectly affects engine performance, fuel economy, safety, reliability, aerodynamics, driver and passenger comfort, material selection, emissions, maintenance and component life of a vehicle **[13].** Nanofluids are defined as suspensions of nanoparticles in a base fluid. The size of nanoparticles are varied from 1 to 100 nm, with the commonly use base fluid of water, ethylene glycol or mixture of both. Most of the research have been done on nanofluids are supporting the fact and theory of nanofluids enhance the heat transfer of the system. **Xiang-Qi Wang**, **Arun S. Mujumdar [14]** has studied heat transfer characteristics of nanofluids. The use of nanofluids in a wide range of applications appears promising, but the development of the field faces several challenges: (i) the lack of agreement between experimental results from different groups; (ii) the often poor performance of suspensions; and lack of theoretical understanding of the mechanisms. In another research **Mostafa Mahmoodi** et al**.[15]** has studied free convection of a nanofluid in a square cavity with a heat source on the bottom wall and partially cooled from sides that the problem of free convection of Cu-water nanofluid inside a square cavity with a heat source on its bottom wall and two heat sinks with six different location on its side walls has been investigated numerically using the finite volume method and Simpler algorithm. The obtained results show that the average Nusselt number of the heat source increases with increase in the Rayleigh number and the volume fraction of the nanoparticles. Results of different nanofluid for the middle middle case show that at low Rayleigh number, maximum and minimum rate of heat transfer are obtained by Ag-water and TiO2-water nanofluids, while; at high Rayleigh numbers its maximum and minimum are obtained by Cu-water and TiO2-water nanofluids. **Sadik Kakaç and Anchasa Pramuanjaroenkij [18]** has investigated the convective heat transfer enhancement and concluded that nanofluids significantly improve the heat transfer capability of conventional heat transfer fluids such as oil or water by suspending nanoparticles in these base liquids. Later similar study was conducted by **Nor Azwadi Che Sidik et. al. [17]** on computational analysis of Nanofluids in vehicle radiator with concluding remarks that vehicle thermal management is a crosscutting technology because it directly or indirectly affects engine performance, fuel economy, safety, reliability, aerodynamics, passenger comfort, material selection, emissions, maintenance and component life of a vehicle. **R. Saidura et al. [2011] [16]** has presented a review on applications and challenges of nanofluids. They concluded that nanofluids are potential heat transfer fluids with enhanced thermo physical properties and heat transfer performance can be applied in many devices for better performances.

II. Cfd Analysis And Procedure

2.1 Properties of Nano Fluids

The particle size is an important physical parameter in nanofluids because it can be used to tailor the nanofluid thermal properties as well as the suspension stability of nanoparticles. The key building blocks of nanofluids are nanoparticles. The research on nanofluids got accelerated because of the development of nanotechnology in general and availability of nanoparticles in particular. Thermal conductivity of nanofluids is found to be an attracting characteristic for many applications. It represents the ability of material to conduct or transmit heat. Considerable researches have been carried out on this topic. **Eastman et al. [19]**, found that thermal conductivity of 0.3% copper nanoparticles of ethylene glycol nanofluids is increased up to 40% compared to basefluid. Researchers working on nanofluids have been trying to exploit the unique properties of nano particles to develop stable as well as highly conducting heat transfer fluids. Compared to micrometer sized particles, nanoparticles possess high surface area to volume ratio due to the occupancy of large number of atoms on the boundaries, which make them highly stable in suspensions. Thus the nano suspensions show high thermal conductivity possibly due to enhanced convection between the solid particle and liquid surfaces. Since the properties like the thermal conductivity of the nano sized materials are typically an order of magnitude higher than those of the base fluids, nanofluids show enhancement in their effective thermal properties. Due to the lower dimensions, the dispersed nano -particles can behave like a base fluid molecule in a suspension, which helps us to reduce problems like particle clogging, sedimentation etc. found with micro particle suspensions. The combination of these two features; extra high stability and high conductivity of the dispersed nanospecies make them highly preferable for designing heat transfer fluids.

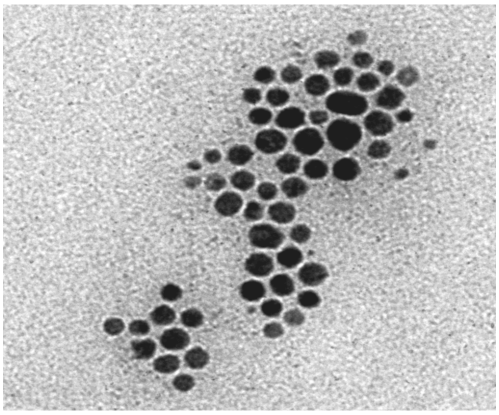


Fig. 1 Microscopic view of nanoparticle **[12]**

Table 1 Thermo physical properties

Thermo physical Properties	**EG**	**Water**	**CuO (2%)**
Density	6315	100	2.526
Viscosity	0.0214	0.0005015	0.0118
Conductivity	0.249	0.6	0.01672
Bulk modulus	3.2	4182	123×10^6
Specific Heat	2382	2.18×10^9	0.000846
Emissivity	1	1	0.0156

2.2 Experimental Setup for Geometric Modeling

The experimental setup of a radiator is shown in fig.2 It contains upper hose, lower hose and a tank. The dimensions and specifications of its parts are mentioned in the table2.

Fig. 2 Experimental Setup **[5]**

2.3 Boundary Conditions

Boundary conditions are obtained from experimental setup under analysis. The experimental test was conducted by **Bhanu et.al [5]** ,the measured value as mentioned in the table-1 provides inlet temperature of air 40°C and inlet temperature of fluid 107°C . Air inlet velocity is taken as 22m/s and mass flow rate of air and coolant are taken as 0.09kg/s and 0.049kg/s respectively.Fig.3 shows the geometric modeling of car radiator designed on Autodesk.

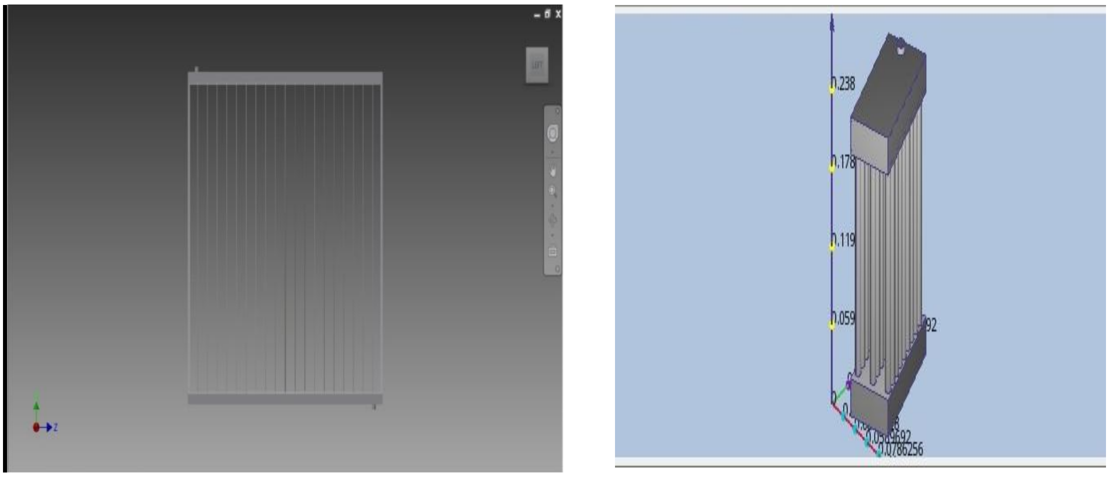


Fig. 3 Geometric model of Car radiator

2.4 Geometric modeling and CFD

In this research firstly a radiator is designed on Autodesk Inventor software using dimensions of experimental setup listed in table2 given below:

Table 2 Geometric Dimensions of Radiator

SERIAL NO.	PART	DIMENSIONS/ SPECIFICATIONS
1	Core Height	350mm
2	Core Width	350mm
3	Core Depth	16mm
4	Tubes Arrangement and Material	Staggered, Aluminum
5	No. of Tubes	30
6	Tubes	7mm x 300mm

After designing the radiator it is uploaded in the Autodesk CFD software for its computational analysis. It is analyzed up to 100 iterations. First it is analyzed with 50:50 mixture of Ethylene Glycol with water (EGW) and compared with another mixture analyzed by adding 2 percent Copper oxide (CuO). Both the results are compared to find the improved heat transfer rate due to the addition of 2% CuO.

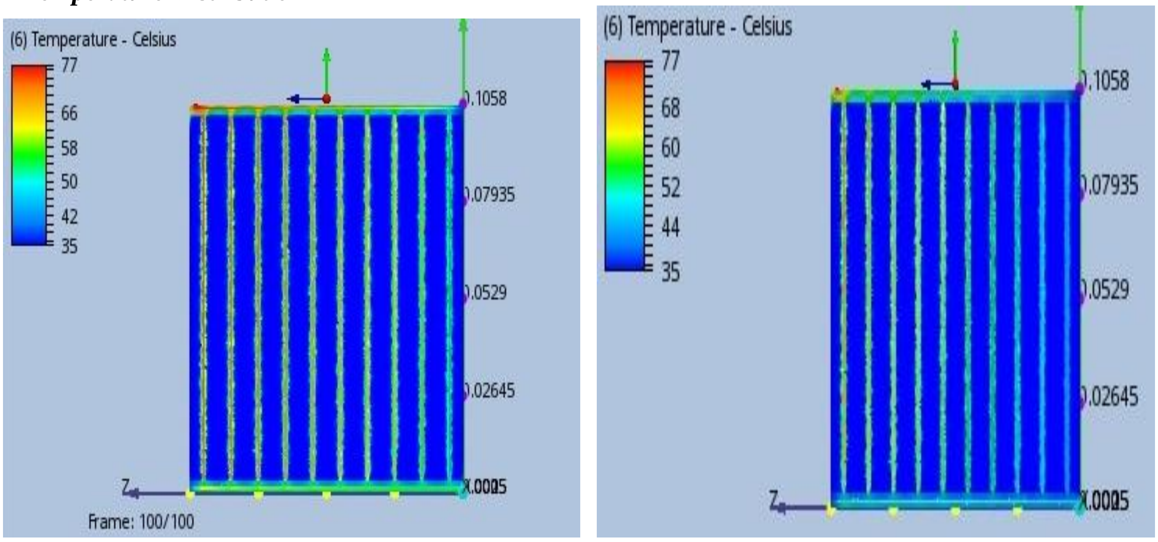
2.5 Steps used in CFD Analysis

1. Problem Identification and Pre-Processing
   a. Design is uploaded.
   b. Domain model is selected.
   c. Model is designed and grid is created.
2. Solver Execution
   d. The temperature distribution at various node of mesh are obtained as shown in fig.-4
3. Post-Processing
   e. Static pressure and velocity magnitude of fluid are obtained,as shown in fig.- 5 & 6 respectively.

III. Results

The results of temperature distribution, static pressure and velocity magnitude obtained through computational analysis for both the fluids are as follows:-

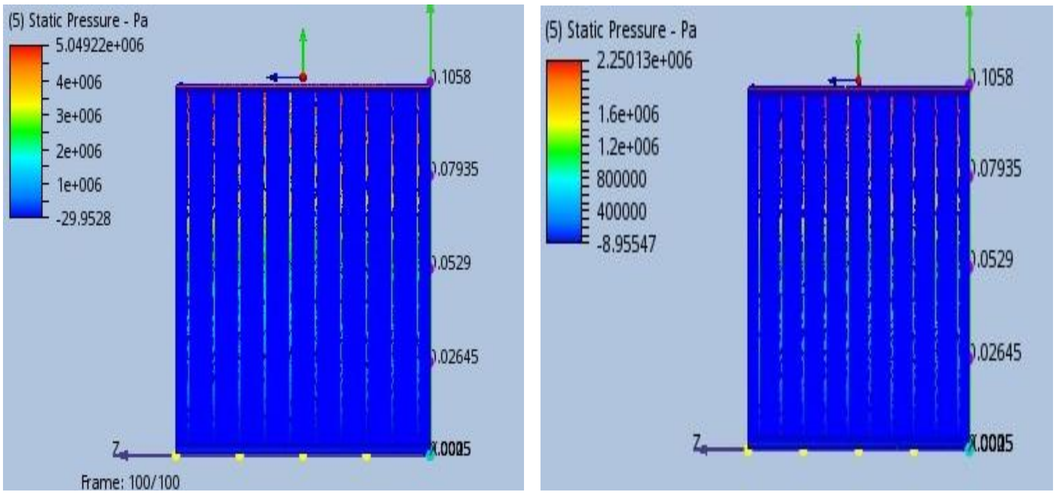
3.1 Temperature Distribution



(a) Temp.with EG + WATER **(b)** Temp.with EG + WATER + CuO

Fig. 4 Temperature Distribution

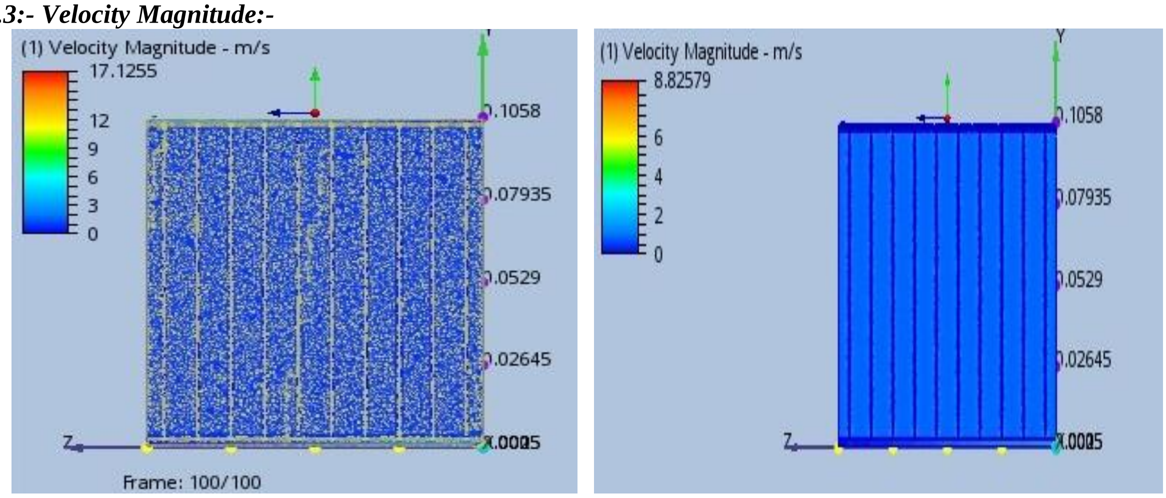
3.2 Static Pressure Distribution



(a) Static pressure with EGW **(b)** Static pressure with EGW + CuO

Fig. 5 Static Pressure

3.3:- Velocity Magnitude:-



(a) Velocity magnitude with EGW **(b)** Velocity magnitude with EGW + CuO

Fig. 6 Velocity Magnitude

3.4 Comparative analysis of results:-

S.No.	Coolant	Initial Temperature	Final Temperature	Temperature Reduction
1	EGW	176°F	171.5	4.5
2	EGW + CuO	176°F	165.2	10.8

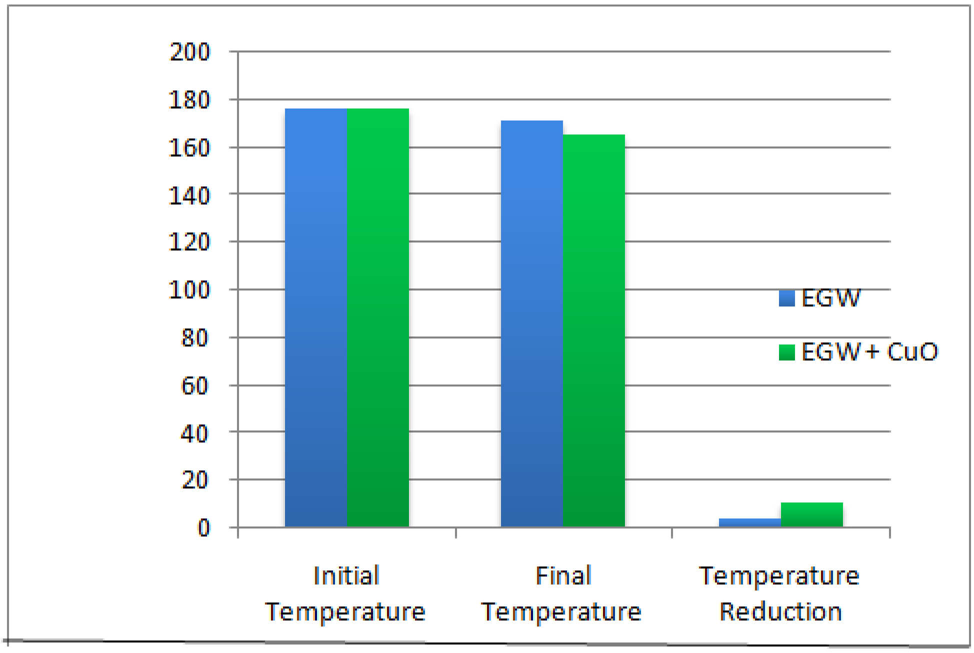


Fig. 7 Comparative analysis of Temperature Variation

IV. Conclusion

From this computational analysis on the radiator, it may be concluded that efficiency of radiator and thermal conductivity of the system increases with usage of nanoadditives. The temperature reduction due to addition of CuO is 42.8°F, the initial temperature was 176°F and with the mixture of CuO it gets reduced to 165.2°F. The addition of CuO to the coolant has the potential to improve automotive and heavy-duty engine cooling rates. The research will ultimately help in reducing the size of cooling system required for removing heat from engine, which in turn benefit almost every aspect of vehicle performance and lead to increased fuel economy.

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