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Numerical Heat Transfer Analysis of Ag-Doped-CuO Nanofluids in Radiator with UDF codes in Ansys fluent

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Abstract: A nanofluid is a fluid that accommodates nanometer-sized particles (10^{-9}), called nanoparticles. These fluids implement a colloidal suspension of nanoparticles in a base fluid. The nanoparticles used in nanofluids are frequently made of metals, oxides, carbides, or carbon nanotubes. Usual base fluids include water, ethylene glycol, and engine oil. In this program, silver-doped copper oxide is used as nanoparticles. This nanoparticle has been prepared by the green synthesis method. The radiator's job is to eliminate heat from the engine. The effect of using nanofluids in a vehicle radiator was investigated. Increasing the nanoparticle volume concentration leads to improved heat transfer. The radiator size using nanofluids is revised to lose the same heat as water. The simplest option is to treat the nanofluid as a fluid with changed properties. Then, all that is needed is to recalculate the fluid properties and use any CFD software to simulate flow and heat transfer. And writing a User-Defined Function (UDF) for CFD Modeling Using a C programme or a C function that can be dynamically loaded with ANSYS Fluent to enhance its standard features.
Keywords: NanoFluids, Radiator, Governing Equation, CFD Analysis, UDF codes.

I INTRODUCTION

Nanofluid is the next exciting frontier in technology. The excitement can be attributed to the sheer brilliance of the idea and the applications of the technology. The properties of nanofluids need a lot of fine tuning, many seemingly contradicting studies need clarity and validation. Nanofluids have potential applications in microelectronics, fuel cells and pharmaceutical industry, if we mention a few of the potential applications. The applications of nanofluids are largely because of the enhanced thermal conductivity. Let us explore the history of the nanofluid technology a bit and move on to other things. The history of nanotechnology can probably be traced back to ninth century AD in Mesopotamia for its use in pottery. Various other applications can be seen in the history. The famous paper of Michael Faraday marks the beginning of nanotechnology in the modern day world. Faraday talks about the optical properties of nanometer scale metals. The conceptual birth of nanotechnology can be found in the more recent lecture of the legendary scientist Richard P Feynman. Feynman delivered his famous lecture 'There is plenty of room at the bottom' at the American physical society meeting at Caltech on December 29, 1969. Feynman made his famous waver challenging young scientists to make a working motor no more than 1/64 of an inch on all sides. Most of the work in the field of nanotechnology came about without the knowledge of this lecture, but it marked the conceptual origin of modern nanotechnology. The invention of scanning tunneling microscope triggered the growth of nanotechnology in the 1980's. The word nanotechnology was probably used for the first time by the Japanese scientist Norio Taniguchi in 1974. K. Eric. Drexler is credited with initial theoretical work in the field of nanotechnology. The term nanotechnology was used by Drexler in 1986 book “engines of creation: The coming era of nanotechnology”. Drexlers idea of nanotechnology is referred to as molecular nanotechnology. Nanofluids were a result of the experiments intended to increase the thermal conductivity of liquids. The birth of nanofluids is attributed to the revolutionary idea of adding solid particles into HTF’s to increase the thermal conductivity. This innovative idea was put forth by Maxwell in 1873. Solid particles of micrometer, millimeter magnitudes were added initially to the base fluids to achieve increase in the thermal conductivity but posed a range of serious issues like clogging, increase in the pressure drop and the erosion of pipes. These methods couldn't bring about any considerable improvement in the practical applications of heat transfer fluids.

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S. U. S. Choi and J. Eastman brought about radical changes by introducing nanoscale metallic particles and carbon nanotubes. They worked with a variety of fluids and the result was great. But uncertainty did linger on the practical utility and nature of these 'nanofluids'. The nanofluid technology is still in its early phase and various scientists are working now to help use nanofluids as a tool to solve the technological riddles of the modern society. We shall look at them later. Nanofluids are prepared by dispersing nano meter sized particles in HTF (Heat transfer fluid). They have distinctive properties like large surface area to volume ratio, roperties that depend on dimension, lower kinetic energy and greater stability. Nanofluids are more stable than micro-fluids, milli fluids. Base fluids behave more or less like pure fluids in the presence of nanoparticles thereby incurring very little pressure drop and eliminate the need for surfactants. The most curious property of nanofluid is that they show remarkable enhancement in thermal conductivity even by the addition of very small amounts of nanometer sized particles.

The Preparation Methods for Nanofluids are two types that is Two-step Method and one-step method. Two-step method is the most widely used method for preparing nanofluids. Nanoparticles, nanofibers, nanotubes, or other nanomaterial's used in this method are first produced as dry powders by chemical or physical methods. Then, the nanosized powder will be dispersed into a fluid in the second processing step with the help of intensive magnetic force agitation, ultrasonic agitation, high-shear mixing, homogenizing, and ball milling. Two-step method is the most economic method to produce nanofluids in large scale, because nanopowder synthesis techniques have already been scaled up to industrial production levels. Due to the high surface area and surface activity, nanoparticles have the tendency to aggregate. The important technique to enhance the stability of nanoparticles in fluids is the use of surfactants. However, the functionality of the surfactants under high temperature is also a big concern, especially for high-temperature applications. Due to the difficulty in preparing stable nanofluids by two-step method, several advanced techniques are developed to produce nanofluids, including one-step method. In the following part, we will introduce one-step method in detail. One-Step Method to reduce the agglomeration of nanoparticles, Eastman et al. developed a one-step physical vapor condensation method to prepare Cu/ethylene glycol nanofluids. The one-step process consists of simultaneously making and dispersing the particles in the fluid. In this method, the processes of drying, storage, transportation, and dispersion of nanoparticles are avoided, so the agglomeration of nanoparticles is minimized, and the stability of fluids is increased. The one- step processes can prepare uniformly dispersed nanoparticles, and the particles can be stably suspended in the base fluid. The vacuum-SANSS (submerged arc nanoparticle synthesis system) is another efficient method to prepare nanofluids using different dielectric liquids [8, 9]. The different morphologies are mainly influenced and determined by various thermal conductivity properties of the dielectric liquids. The nanoparticles prepared exhibit needle-like, polygonal, square, and circular morphological shapes. The method avoids the undesired particle aggregation fairly well. One-step physical method cannot synthesize nanofluids in large scale, and the cost is also high, so the one-step chemical method is developing rapidly. Zhu et al. presented a novel one- step chemical method for preparing copper nanofluids by reducing

$$CuSO4 - 5H2O \text{ with } NaH2PO2 - H2O$$

In ethylene glycol under microwave irradiation. Well-dispersed and stably suspended copper nanofluids were obtained. Mineral oil-based nanofluids containing silver nanoparticles with a narrow-size distribution were also prepared by this method. The particles could be stabilized by Korantin, which coordinated to the silver particle surfaces via two oxygen atoms forming a dense layer around the particles. The silver nanoparticle suspensions were stable for about 1 month. Stable ethanol-based nanofluids containing silver nanoparticles could be prepared by microwave-assisted one-step method. In the method, polyvinylpyrrolidone (PVP) was employed as the stabilizer of colloidal silver and reducing agent for silver in solution. The cationic surfactant octadecylamine (ODA) is also an efficient phase-transfer agent to synthesize silver colloids.

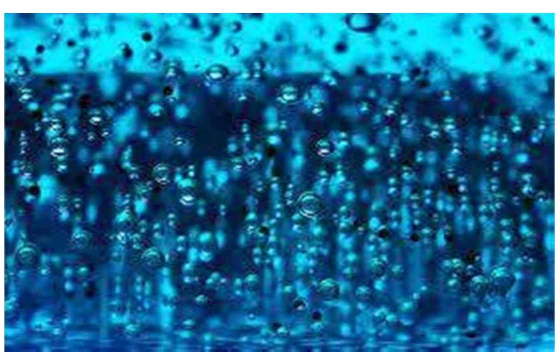

Figure 1. Nanofluids

The phase transfer of the silver nanoparticles arises due to coupling of the silver nanoparticles with the ODA molecules present in organic phase via either coordination bond formation or weak covalent interaction. Phase transfer method has been developed for preparing homogeneous and stable graphene oxide colloids. Graphene oxide nanosheets (GONs) were successfully transferred from water to n-octane after modification by oleylamine.

II NANOFLUIDS MATERIALS

Nanofluids are classified as three ways that is Base fluid, Nanoparticles and Surfactant. Base fluid like water, engine oil, acetone, decene and ethylene-glycone. Nanoparticles like metallic, oxide, carbon and Nano Droplet. The Metallic are Copper (Cu), Aluminum (Al), Iron (Fe), Silver (Ag), Gold (Au) and Silicon (Si). The Oxide are Aluminium oxide (Al_2O_3), Copper oxide (CuO), Titanium dioxide (TiO_2) and Silicon dioxide (SiO_2). Carbon like graphite, Fullerene. Now we will doped two particles as Silver and copper oxide (Ag doped copper oxide)

A. *Silver Doped Copper Oxide*

Ag-doped copper oxide nanoparticles (Ag@CuO NPs) were synthesized by using a facile co-precipitation method. Copper sulphate heptahydrate and silver nitrate were used as starting precursors. In a typical synthesis of Ag@CuO NPs, 250 mmol of copper sulfate (0.25 g) and different concentrations of $AgNO_3$ (0, 2%, 4%, 6%, 8%, 10%, and 12% (w/w) of $CuSO_4$) were dissolved in 10 mL of deionized water and stirred for 1 h. SDS (0.12 g) was added in each percentage of the above solution with constant stirring at 60 °C followed by the dropwise addition of NaOH (5 M) until the pH 14. This solution was left on constant stirring for 24 h, resulting in the formation of white precipitates of Ag@CuO NPs. The precipitates were filtered and washed several times with deionized water and ethanol (1:1) till pH becomes 7. The Ag@CuO NPs precipitates were dried at 50°C in a vacuum oven overnight. The dried Ag@CuO NPs were calcinated at 800 °C in a muffle furnace for 5 h at a heating rate of 4 °C per min. The Ag@CuO NPs were ground in piston mortar and stored. The detail composition of C1 NPs, Ag-doped CuO NPs and system codes are displayed.

Table 1. Symble codes of Silver doped copper oxide

Sr. no	System code	System	% of Ag	[Ag]: [Cu]
1	C1 NPs	CuO	0	0:100
2	C2 NPs	Ag@CuO	2	2:98
3	C3 NPs		4	4:96
4	C4 NPs		6	6:94
5	C5 NPs		8	8:92
6	C5 NPs		10	10:90
7	C6 NPs		12	12:88

B. *Charactersistics*

The surface morphology of the synthesized samples was characterized by scanning electron microscopy (TESCAN Vega 3), transmission electron microscopy (JEM-2100) and energy dispersive X-Ray spectroscopy (PANalytical X'Pert). The crystal structure characterization of the NPs was carried by X-Ray Diffraction analysis (PANalytical X'Pert). Fourier transform infrared spectroscopy (FTIR) spectra were observed in the range of 4000–400 cm^{-1}. The UV–Visible absorption spectra were recorded using a UV–visible spectrophotometer (JASCO 770). The Brunauer–Emmett–Teller (BET) surface area was determined by N_2 adsorption in an automated gas sorption analyzer (Micromeritics ASAP 2020 instrument). Steady-state photoluminescence (PL) spectra were determined using a fluoromax-4 spectrofluorometer (Horiba scientific Japan). XPS experiments were performed on ESCA Lab220i-XL spectrometer (VG Scientific) equipped with Al Kα radiation in twin anode at 14 kV × 16 Ma, calibrated by using the containment carbon (C 1s 284.6 eV

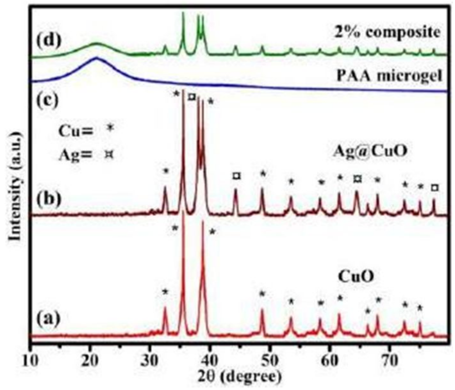

Figure 2. XRD Pattern of a CuO, b 4% Ag-doped Copper, c PAA Micro gel and d Ag @CuO/PPA Nanocomposite.

III MAIN COMPONENT

A. Radiator

Radiators are heat exchangers used to transfer thermal energy from one medium to another for the purpose of cooling and heating. The majority of radiators are constructed to function in cars, buildings, and electronics. A radiator is always a source of heat to its environment, although this may be for either the purpose of heating this environment, or for cooling the fluid or coolant supplied to it, as for automotive engine cooling and HVAC dry cooling towers. Despite the name, most radiators transfer the bulk of their heat via convection instead of thermal radiation

B. Radiation And Convection

Heat transfer from a radiator occurs by all the usual mechanisms: thermal radiation, convection into flowing air or liquid, and conduction into the air or liquid. A radiator may even transfer heat by phase change, for example, drying a pair of socks. In practice, the term "radiator" refers to any of a number of devices in which a liquid circulates through exposed pipes (often with fins or other means of increasing surface area). The term "convector" refers to a class of devices in which the source of heat is not directly exposed. To increase the surface area available for heat exchange with the surroundings, a radiator will have multiple fins, in contact with the tube carrying liquid pumped through the radiator. Air (or other exterior fluid) in contact with the fins carries off heat. If air flow is obstructed by dirt or damage to the fins, that portion of the radiator is ineffective at heat transfer. Radiators are commonly used to heat buildings on the European continent. In a radiative central heating system, hot water or sometimes steam is generated in a central boiler and circulated by pumps through radiators within the building, where this heat is transferred to the surroundings. In Israel, portable radiators are common to heat a single room, as a safer alternative to space heater and fan heater.

IV CFD THEORY AND EQUATION

The CFD approach uses numerical methods to solve the governing equations for the specified geometry and boundary conditions.
Single-phase flow was considered for analysis using ANSYS FLUENT.

1) *Continuity Equation*

$$\frac{\partial}{\partial x_i}(\rho_{nf} U_i) = 0$$

2) *Momentum Equation*

$$\frac{\partial}{\partial x_i}(\rho_{nf} U_j U_i) = \frac{\partial p}{\partial x_j} + \frac{\partial}{\partial x_i}(\mu_{n_f}(\frac{\partial U_j}{\partial x_i}))$$

3) *Energy Equation*

$$\frac{\partial}{\partial x_i}(\rho_{nf} C_{Pnf} U_j U_i) = \frac{\partial}{\partial x_i}\left(K_{n_f}\left(\frac{\partial T}{\partial x_i}\right)\right)$$

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V MODELLING AND PROCEDURE

A. Modelling

A radiator from a Tata-Indica Car, which is widely used in India was considered and the specifications.

Table 2. Speciication of radiator usage

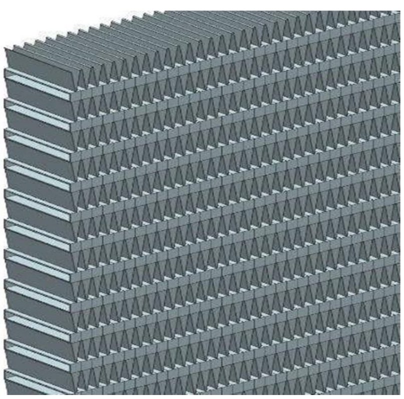
Coolant Side		Air side	
Parameter	Value	Parameter	Value
Length of the tube (L)	23.56 mm	Fin Pitch	0.7mm
Width of the tube(D)	34.64 mm	Fin Thickness	0.06mm
Thickness of the tube (d)	23.76 mm	Fin Length	21.54mm
Tube Pitch	27.9 mm	Number of fins per tube	435.4mm
Number of tubes	37	Number of rows of fins	36

However, to save time and computation the analysis was done by considering a typical element based on fin pitch and tube pitch of radiators shown in Figure 3.The model was meshed in ANSYS® Workbench. FLUENT® 16.2 was used for CFD analysis.

B. Mesh Independence Study

Meshes of varying element sizes were generated during meshing as shown in table 3. The coarse mesh had 2144005 elements, medium and fine meshes generated 2412218 and 2855211 elements respectively. The difference in fluid outlet temperatures from medium to fine type of mesh was found to be negligible. In order to save computational resources and time the medium mesh was selected and CFD analysis was carried out.

Figure 1. Model of the entire radiator generated using NX 11



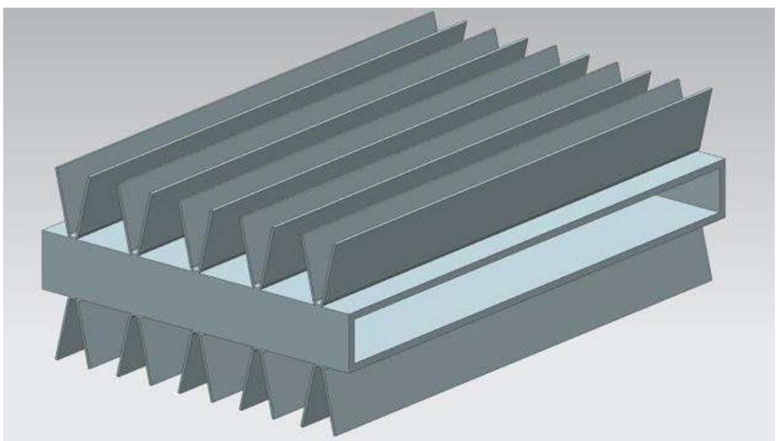


Figure 2. Enlarged view of the radiator

Figure 3. The typical element considered for analysis

Table 3.Mesh Independent Study

Mesh Type	Number of elements	Fluid Outlet Temperature (^oC)
Coarse	2144005	322.81836
Medium	2412218	322.81834
Fine	2855211	322.818342

VI CFD ANALYSIS

The Hybrid-Nanofluid is considered incompressible the flow is assumed to be laminar. A single-phase fluid approach as shown by is made use of. For the case of a viscous laminar model, the SIMPLE scheme was used. The nanofluid inlet is specified as a mass flow inlet corresponding to volume flow rates of 4, 5 and 6 LPM in the whole radiator at a temperature of 50^0C which are typical values in an automobile radiator. The air inlet is specified as a velocity inlet with velocity of 1.5m/s.

Table 4.Input Condition Considered

PARAMETERS	VALUES
Nanoparticles	Silver(Ag) and Copper Oxide(CuO)
Volume Concentration 1 %, 2%, 3% of each CG and GO	Volume Concentration 1 %, 2%, 3% of each CG and GO
Mass Flow Rates (LPM) 4,5,6	Mass Flow Rates (LPM) 4,5,6
Inlet Fluid Temperature (K) 323.15	Inlet Fluid Temperature (K) 323.15
Inlet Air Temperature (K) 298.15	Inlet Air Temperature (K) 298.15
Inlet Air Velocity (m/s) 1.5	Inlet Air Velocity (m/s) 1.5

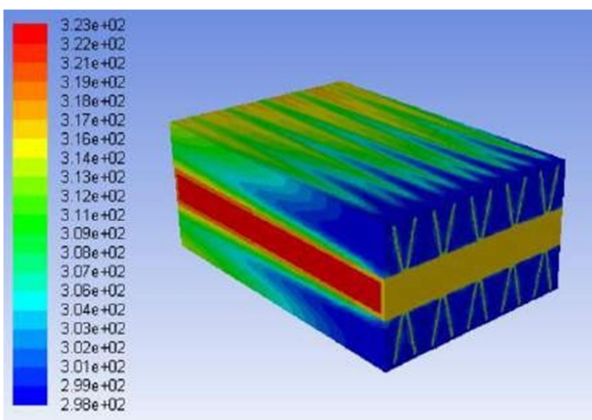


Figure 5. Contour Plot of the temperature

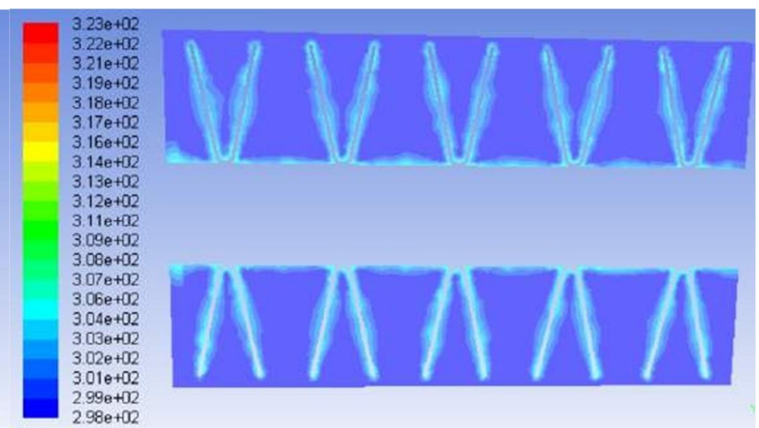


Figure 6. Temperature (in Kelvin) distribution at air inlet (in Kelvin) distribution along the region of air flow

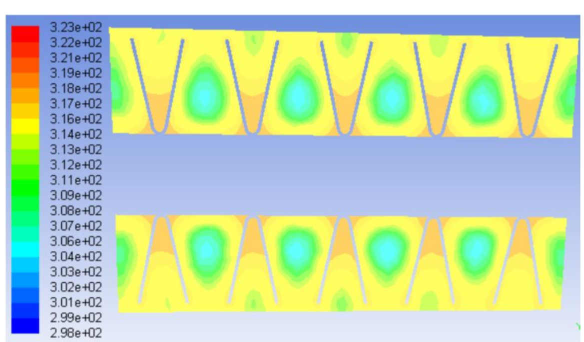


Figure 7. Temperature (in Kelvin) distribution at the air outlet

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VII USER DEFINED FUNCTION

UDF is a C/C++ Function. It is Dynamically Loaded Function with ANSYS FLUENT solver to enhance its standard features. For example Customised Boundary conditions, customised material properties, solving new scalar transport equation and computer value at the end of iteration.

A. Types Of UDF Files

1) *Interpreted:* It is used to write some small functions. Without the help of solver dynamic date.
2) *Compiled:* It is used to need a solver memory and performed a derived task .DLLS / shared object libraries are created after compilation and they are loaded where created.
3) *Program*

```
#include "udf.h"
#define k_np 36 /**thermal conductivity for nanoparticle Ag@CuO******/ #define FI 0.02 /************volume
fraction**************************/ DEFINE_PROPERTY (nanofluid_conductivity,c,t)
{
real k_f; /***thermal conductivity for fluid(water)***********/

real k_nf;          /******thermal conductivity for nanofluids*********/ real tempe = C_T(c,t);/****temperature******/
k_f= -0.000008 *(tempe *tempe) + ((0.0062 * tempe) = 0.5388);

k_nf = (((k_np + (2 * k_f) - (2 * (k_f - K_np)) * FI)/(k_np + (2 * k_f) + (k_f - k_np) * FI))) * k_f; return k_nf;
}

DEFINE_PROPERTY (nanofluids_viscosity,c,t)

{

real U_f;/***dynamic viscosity for fluid(water)***********/

real U_nf;          /******dynamic viscosity of nanofluid*********/ real tempe1 = C_T(c,t); /****temperature******/

U_f= 2.414*0.00001*pow(10,(247.8/(tempe1-140)));

U_nf = U_f/(pow((1-F1), 2.5)); return U_nf;
}

DEFINE_SPECIFIC_HEAT(nanofluid_specificheat,T, Tref, h, yi)

{

real cp, rho_w,rho;

rho_w = (-3.570*(pow(10,-3))*(pow(T,2))+(1.88*T+753.2));

rho = (FI*3970)+((1-FI)*rho_w);

cp = ((FI*3978*765)+((1-F1)*rho_w*4200))/rho; /***specific heat of nano particles = 765 j/kgk***********/

}
```

```
DEFINE PROPERTY (nanofluid_density,cell,thread)

{

real tempe, rho_w,rho; tempe = C_T(cell, thread);
rho_w = (-3.570*(pow(tempe,2))+(1.88*tempe+753.2)); rho = (F1*3970)+((1-F1)*rho_w);
return rho;

}
```

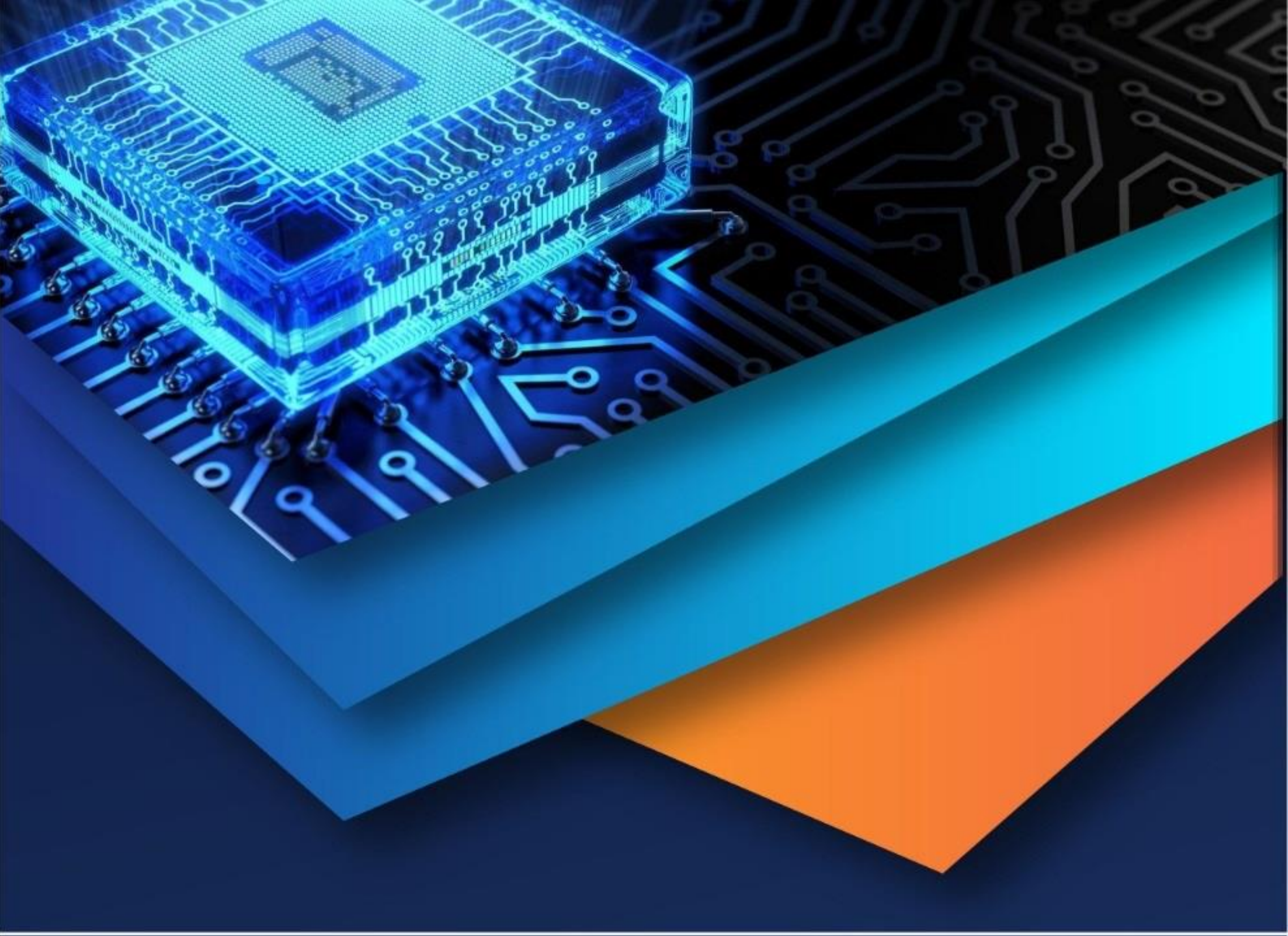
VIII CONCLUSIONS

In this work the analysis for geometry of Nanofluid was carried out using ANSYS CFD. The simulations have been carried out and familiar with UDF function. The geometry of Radiator and flow Nanofluid of Silver Doped Copper oxide was described earlier in the previous chapter with the objective to analysis the heat transfer effect of nanofluid for Ag Doped CuO and increases heat transfer effect for the fluid and increases the efficiency of the Heat transfer for using Heat exchanger. On this simulated analysis the results show the nanofluids of silver doped copper oxide is a best material for the heat transfer effect of Nanofluid.

WATER	**NANOFLUID (Ag Doped CuO)**
Inlet temperature of radiator – 63^{o}C	Inlet temperature of radiator- 70^{o}C

REFERENCES

[1] Choi Sus, Zhang ZuYuw, Lock Wood F and Grulke E A (2001), “Anamolous ThermalConductivity Enhancement in Nano Tube Suspensions”, Appl. Phys. Let., Vol. 79, p. 2252
[2] B.C. Pak, Y.I. Cho, Hydrodynamic and heat transfer study of dispersed fluids with submicron metallic oxide particles, Exp. Heat Transf. 11 (2) (1998) 151–170.
[3] Suresh, S., et al. (2011)"Synthesis of Al 2 O +–Cu/water hybrid nanofluids using two step method and its thermo physical properties." Colloids and Surfaces A: Physicochemical and Engineering Aspects 388.1 pp 41-48.
[4] SoujitSen Gupta, V. Manoj Siva, Sreenath Krishnan, T. S. Sreeprasad, Pawan K. Singh et al.(2011)"Thermal conductivity enhancement of nanofluids containing grapheme nanosheets" J. Appl. Phys. 110, 084302; doi: 10.1063/1.3650456
[5] Aravind, S. S. Jyothirmayee and Ramaprabhu, S,(2013) "Graphene-multiwalled carbon nanotube-based nanofluids for improved heat dissipation”, The Royal Society of Chemistry.SC Adv, ,3 ,13 ,pp 4199-4206
[6] Reza Davarnejad, Maryam Jamshidzadeh,2015,” CFDmodeling of heat transfer performance of MgO-water nanofluid under turbulent flow”, In Engineering Science and Technology, an International Journal,Volume 18, Issue 4, pp 536-542, ISSN 2215-0986ANSYS FLUENT 16.2, User guide,
[7] ANSYS Inc, Southpointe, Canonsburg.R.S. Vajjha, D.K. Das, P.K. Namburu, 2010“Numerical study of fluid dynamic and heat transfer.A. Akbarinia,
[8] A. Behzadmehr,2007 Numerical study of laminar mixed convection of a nanofluid in horizontal curved tubes, In Applied Thermal Engineering, Volume 27, Issues
[9] Frank P. Incropera, David P. DeWitt, Theodore L. Bergman, Adrienne S. Lavine,2006 “Fundamentals of Heat and Mass Transfer”,6th Edition.
[10] NizarAhammed, Lazarus Godson Asirvatham, Joel Titus, Jefferson Raja Bose, SomchaiWongwises, 2016, Measurement of thermal conductivity of graphene–water Nanofluid at below and above ambient temperatures,International Communications in Heat and Mass Transfer,70, pp.66–74



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