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Analysis of Shell and Tube Heat Exchanger Using Different Nano Fluids

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Abstract: Heat exchanger is a device used to transfer heat between one or more fluids. The fluids may be separated by a solid wall to prevent mixing or they may be in direct contact. They are widely used in space heating, refrigeration, air conditioning, power stations, chemical plants, petrochemical plants, petroleum refineries, natural-gas processing, and sewage treatment. These exchangers provide true counter-current flow and are especially suitable for extreme temperature crossing, high pressure, high temperature, and low to moderate surface area requirements. In this thesis, four Nano fluids mixed with base fluid (water) are analyzed for their performance in the shell and tube heat exchanger. 3D model of the shell and tube heat exchanger is designed using catia v5. Four Nano fluidsconsidered are Aluminum Oxide, copper oxide, Silicon Oxide and Titanium carbide. The values of Density,Specific heat, Thermal conductivity,viscosity are theoretically. CFD analysis is done on the shell and tube heat exchanger for four nano fluids and five volume fractions 0.5, 0.6, 0.7, 0.8, 0.9considering the above obtained values. Variations in velocity magnitude, dynamic pressure and heat transfer rate and mass flow rate are calculated from CFD and the comparisons are made

I. INTRODUCTION

A Shell and tube heat exchanger is a class of heat exchanger. It is the most common type of heat exchanger in oil refineries and other large chemical processes. As its name implies, this type of heat exchanger consists of a shell (a large vessel) with a bundle of tubes inside it. Thermal design of shell-and-tube heat exchangers (STHEs) is done by sophisticated computer software. However, a good understanding of the underlying principles of exchanger design is needed to use this software effectively. This article explains the basics of exchanger thermal design, covering such topics as: STHE components; classification of STHEs according to construction and according to service; data needed for thermal design; tube side design; shell side design, including tube layout, baffling, and shell side pressure drop; and mean temperature difference. The basic equations for tube side and shell side heat transfer and pressure drop are well known; here we focus on the application of these correlations for the optimum design of heat exchangers. A follow-up article on advanced topics in shell-and-tube heat exchanger design, such as allocation of shell side and tube side fluids, use of multiple shells, overdesign, and fouling, is scheduled to appear in the next issue.

A. *Thermal Design Considerations*

The flow rates of both hot and cold streams, their terminal temperatures and fluid properties are the primary inputs of thermal design of heat exchangers.

B. *Thermal design considerations*

Thermal design of a shell and tube heat exchanger typically includes the determination of heat transfer area, number of tubes, tube length and diameter, tube layout, number of shell and tube passes, type of heat exchanger (fixed tube sheet, removable tube bundle etc), tube pitch, number of baffles, its type and size, shell and tube side pressure drop etc.

C. *Shell*

Shell is the container for the shell fluid and the tube bundle is placed inside the shell. Shell diameter should be selected in such a way to give a close fit of the tube bundle. The clearance between the tube bundle and inner shell wall depends on the type of exchanger ([2]; page 647). Shells are usually fabricated from standard steel pipe with satisfactory corrosion allowance. The shell thickness of 3/8 inch for the shell ID of 12-24 inch can be satisfactorily used up to 300 psi of operating pressure.

D. *Tube*

Tube OD of ¾ and 1 are very common to design a compact heat exchanger. The most efficient condition for heat transfer is to have the maximum number of tubes in the shell to increase turbulence. The tube thickness should be enough to withstand the internal pressure along with the adequate corrosion allowance. The tube thickness is expressed in terms of BWG (Birmingham Wire Gauge) and true outside diameter (OD). The tube length of 6, 8, 12, 16, 20 and 24 ft are preferably used. Longer tube reduces shell diameter at the expense of higher shell pressure drop. Finned tubes are also used when fluid with low heat transfer coefficient flows in the shell side. Stainless steel, admiralty brass, copper, bronze and alloys of copper-nickel are the commonly used tube materials:

E. Classification based on construction

Fixed tube sheet: A fixed-tube sheet heat exchanger has straight tubes that are secured at both ends to tube sheets welded to the shell. The construction may have removable channel covers (e.g., AEL), bonnet-type channel covers (e.g., BEM), or integral tube sheets (e.g., NEN). The principal advantage of the fixed tube sheet construction is its low cost because of its simple construction. In fact, the fixed tube sheet is the least expensive construction type, as long as no expansion joint is required.

II. LITERATURE REVIEW

Eastman et al. [1] focused on the thermal conductivity of nanofluids. Many researchers have conducted studies on the thermal properties of nanofluids such as thermal conductivity and rheological behaviour that affect their performance. Said et al. [2] conducted a study on the thermo-physical properties of Al2O3 in EG/water mixture (by mass) nanofluids. They showed that thermal conductivity linearly increased with concentration of nanofluid.Sundar et al. [3] used a mixture of ethylene glycol and water with Fe3O4nanoparticles and found that the thermal conductivity of nanofluids increased as the concentration and temperature of the nanofluids increased. Javadi et al. [4] found that the types of nanoparticles used also contributed to the thermal conductivity enhancement whereby Al2O3 and TiO2 were found to have higher enhancement than SiO2. Also, thermal conductivity was affected by particle size and the stability of the nanofluid [13-16].Sharma and SyamSundar [5] found that the twisted tape inserts contributed to the enhancement of the heat transfer of the applied nanofluid in the system.

III. CATIA

CATIA which stands for Computer Aided Three Dimensional Interactive Application is CAD software owned and developed by Dassault Systems and marketed worldwide by IBM. It is the world’s leading CAD/CAM software for design and manufacturing. CATIA supports multiple stages of product development through conceptualization, design, engineering and manufacturing.

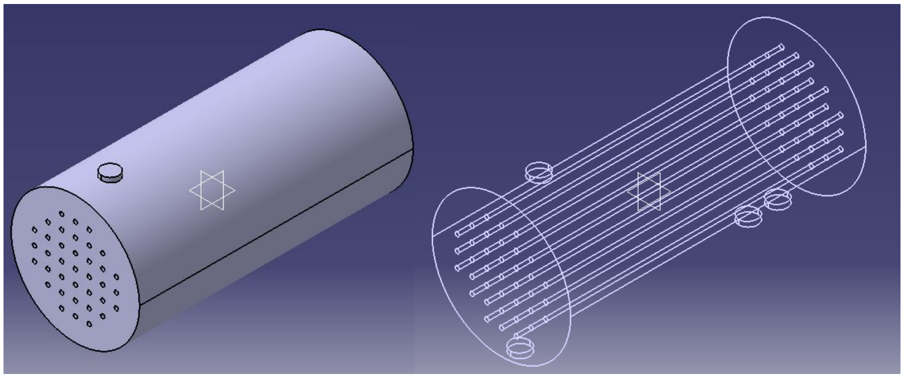

Fig:1 Solid viewFig:2 Wireframe view

IV. PROBLEM DESCRIPTION

Four Nano fluids considered are Aluminum Oxide, copper oxide, Silicon Oxide and Titanium carbide. The properties values of Density, Specific heat, Thermal conductivity,viscosity are calculated using manual calculations.

A. AluminiummOxid

Al_2O_3 is an electrical insulator but has a relatively high thermal conductivity (30 Wm^{-1}K^{-1})[3] for a ceramic material. Aluminium oxide is insoluble in water. In its most commonly occurring crystalline form, called corundum or α-aluminium oxide, its hardness makes it suitable for use as an abrasive and as a component in cutting tools

B. Copper oxide

copper oxide is the inorganic compound with the formula Cu_2O. It is one of the principal oxides of copper, the other being CuO or cupric oxide. This red-coloured solid is a component of some antifouling paints. The compound can appear either yellow or red, depending on the size of the particles.[2] Copper(I) oxide is found as the reddish mineral cuprite.

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C. Silicon dioxide, also known as silica

(from the Latin silex), is an oxide of silicon with the chemical formula SiO_2, most commonly found in nature as quartz and in various living organisms.[5][6] In many parts of the world, silica is the major constituent of sand. Silica is one of the most complex and most abundant families of materials, existing as a compound of several minerals and as synthetic product. Notable examples include fused quartz, fumed silica, silica gel, and aerogels. It is used in structural materials, microelectronics, and as components in the food and pharmaceutical industries.Inhaling finely divided crystalline silica is toxic and can lead to silicosis, bronchitis, lung cancer, and systemic autoimmune diseases, such as lupus and rheumatoid arthritis.

D. Titanium carbide

Titanium carbide is used in preparation of cermets, which are frequently used to machine steel materials at high cutting speed. It is also used as an abrasion-resistant surface coating on metal parts, such as tool bits and watch mechanisms.[*citation needed*] Titanium carbide is also used as a heat shield coating for atmospheric reentry of spacecraft.

E. Calculation for finding material properties for aluminum oxide at different volume fractions

1) Problem

Density of NANO fluid $\rho_{nf=}\quad \emptyset \times \rho s + [(1-\emptyset)(\rho w)]$

Specific heat of NANO fluid $C_{pnf=}\frac{\emptyset\times\rho s\times cps+(1-\emptyset)(\rho w\times cpw)}{\emptyset\times\rho s+(1-\emptyset)\times\rho w}$

Viscosity of NANO fluid $\mu_{nf=}\mu_w(1+2.5\times\emptyset)$

Thermal conductivity of NANO fluid $k_{nf=}k_w\left[\frac{ks+2kw+2(kw-ks)\emptyset}{ks+2kw-(kw-ks)\emptyset}\right]$

$$\rho_w=1000,\ C_{pw}=4185.5,\ \mu_w=0.001002,\ K_w=0.591$$

2) Aluminium oxide:

$$\rho_s=3890\text{ kg/m3, Cps}= 880\ Ə/(kg-k),\ K_s= 38.5\text{ w/m.k}$$

$$\rho_w=1000,\ C_{pw}=4185.5,\ \mu_w=0.001002,\ K_w=0.591$$

3) Density of Aluminium oxide at volume fractions (0.5; 0.6; 0.7; 0.8; 0.9)

Now $\rho_{nf=}\quad \emptyset \times \rho s + [(1-\emptyset)(\rho w)]$

$\therefore\quad \rho_{nf0.5=}\quad 0.5\times 3890 + [(1-0.5)(1000)]$

$$\rho_{nf(0.5)=}2445;\ \rho_{nf(0.6)=}2734;\ \rho_{nf(0.7)=}3023;\ \rho_{nf(0.8)=}3312;\ \rho_{nf(0.9)=}3601$$

4) Specific heat of Nano fluid at volume fractions (0.5; 0.6; 0.7; 0.8; 0.9)

Now $C_{pnf=}\frac{\emptyset\times\rho s\times cps+(1-\emptyset)(\rho w\times cpw)}{\emptyset\times\rho s+(1-\emptyset)\times\rho w}$

$$\therefore C_{pnf\,0.5=}\frac{0.5\times2615\times877.8+(1-0.5)(1000\times4185.5)}{0.5\times2615+(1-0.5)\times1000}$$

$$C_{pnf(0.5)=}1555.9;C_{pnf(0.6)=}1363.6;C_{pnf(0.7)=}1208;C_{pnf(0.8)=}1079.6;\ C_{pnf(0.9)=}971.7$$

5) Viscosity of Nano fluid at volume fractions (0.5; 0.6; 0.7; 0.8; 0.9)

Now $\mu_{nf=}\mu_w(1+2.5\times\emptyset)$

$\therefore\quad \mu_{nf}0.5_{=}0.001002(1+2.5\times0.5)$

$\mu_{nf}(0.5)_{=2.2545*10}{}^{-3}\mu_{nf}(0.6)_{=2.505*10}{}^{-3}\mu_{nf}(0.7)_{=2.7555*10}{}^{-3}\mu_{nf}(0.8)_{=3.006*10}{}^{-3;}$

$\mu_{nf}(0.9)_{=3.2565*10}{}^{-3}$

6) Thermal conductivity of nano fluid at volume fractions (0.5; 0.6; 0.7; 0.8; 0.9)

Now $$\mathbf{k_{nf}} = k_w\left[\frac{ks+2kw+2(kw-ks)\emptyset}{ks+2kw-(kw-ks)\emptyset}\right]$$

$$\therefore \qquad k_{nf}0.5 = 0.591\left[\frac{38.5+2(0.591)+2(0.591-38.5)0.5}{38.5+2(0.591)-(0.591-38.5)0.5}\right]$$

$k_{nf}(0.5) = 11.938$; $k_{nf}(0.6) = 2.212$; $k_{nf}(0.7) = 2.972$; $k_{nf}(0.8) = 6.3386$;

$k_{nf}(0.9) = 11.463$;

V. ANALYSIS

The properties values of Density, Specific heat, Thermal conductivity,viscosity are calculated by using manual calculations .this values used for CFD analysis.Thecfd analyses is done in ansysfluent on the shell and tube heat exchanger for four nano fluids and five volume fractions 0.5, 0.6, 0.7, 0.8, 0.9.at every volume fraction finite element analysis was generated five results ,these are Velocity magnitude, dynamic pressure, total heat transfer, mass flow rate. This simulation was conducted on Four Nano fluids considered are Aluminum Oxide, copper oxide, Silicon Oxide and Titanium carbide. Taken major perameters wasDensity, Specific heat, Thermal conductivity,viscosity of the above four nano fluids .finally the simulated graphical result and graphs generated at each and every volume fraction

A. CFD analysis of silicon oxide at 0.6 volume fraction

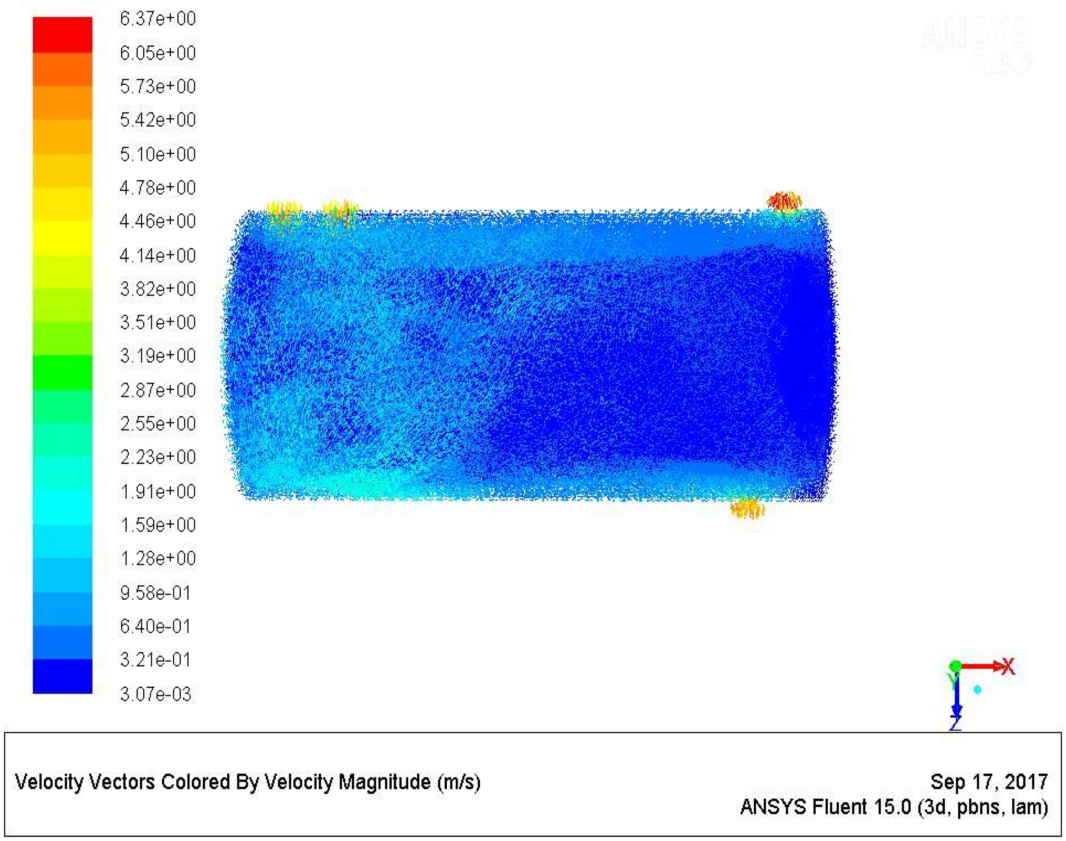


Fig: 3 pictorial graph representing velocity vector

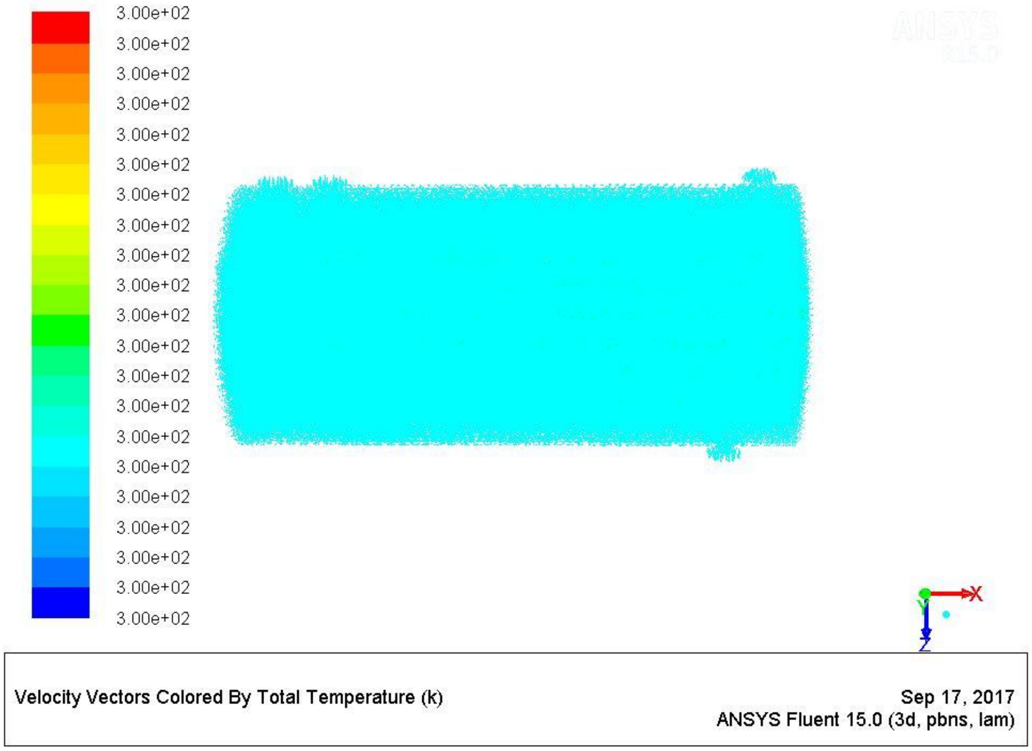


Fig: 4 pictorial graph representing total temperature

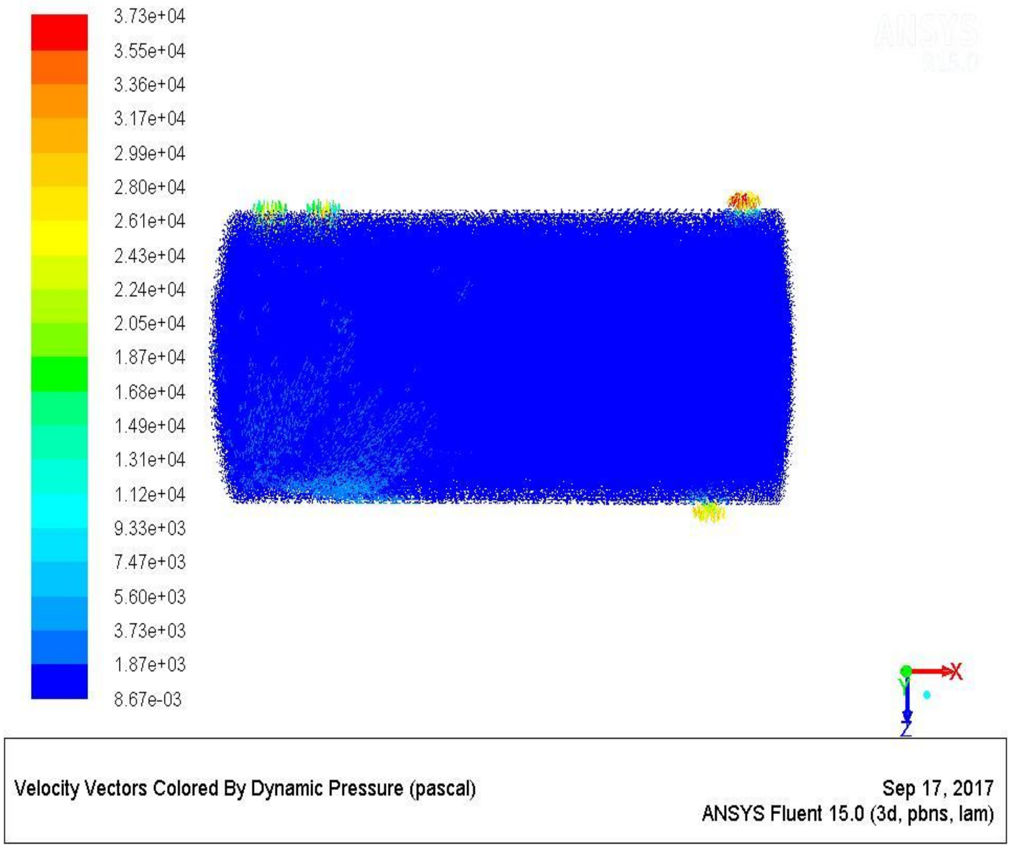


Fig: 5 pictorial graph representing dynamic pressure

TABLE1. Velocity magnitude for different materials

Velocity magnitude	Aluminum oxide	copper oxide	silicon oxide	titanium carbide
0.5 volume fraction	6.40E+00	6.37E+00	6.35E+00	6.37E+00
0.6 volume fraction	6.74E+00	6.37E+00	6.37E+00	6.36E+00
0.7 volume fraction	6.37E+00	6.37E+00	6.39E+00	6.33E+00
0.8 volume fraction	6.39E+00	6.46E+00	6.36E+00	6.37E+00
0.9 volume fraction	6.37E+00	8.22E+00	6.35E+00	6.36E+00

TABLE2. Dynamic pressure for different materials

dynamic pressure	Aluminum oxide	copper oxide	silicon oxide	titanium carbide
0.5 volume fraction	5.01E+04	7.41E+04	3.43E+04	5.30E+04
0.6 volume fraction	6.20E+04	8.50E+04	3.73E+04	5.94E+04
0.7 volume fraction	6.13E+04	9.58E+04	3.94E+04	6.54E+04
0.8 volume fraction	6.75E+04	1.10E+05	4.28E+04	7.26E+04
0.9 volume fraction	7.30E+04	1.95E+05	4.56E+04	7.91E+04

TABLE3. Total heat transfer for different materials

total heat transfer	Aluminum oxide	copper oxide	silicon oxide	titanium carbide
0.5 volume fraction	-2334.04	-2459.225	-2304.68	-2429.142
0.6 volume fraction	-2341.66	-2469.733	-2317.28	-2459.186
0.7 volume fraction	-2373.65	-2492.096	-2326.53	-2488.031
0.8 volume fraction	-2398.05	-2506.97	-2352.84	-2501.273
0.9 volume fraction	-2402.78	-2517.997	-2366.16	-2518.611

TABLE4. Mass flow rate for different materials

mass flow rate	Aluminum oxide	copper oxide	silicon oxide	titanium carbide
0.5 volume fraction	-0.15676	-0.179459	-0.18315	-0.407652
0.6 volume fraction	-0.50253	-0.625134	-0.1766	-0.407902
0.7 volume fraction	-0.48562	-0.706615	-0.14625	-0.593218
0.8 volume fraction	-0.43289	-0.789902	-0.29796	-0.519287
0.9 volume fraction	-0.58279	-0.870258	-0.30484	-0.483673

Graphs**:**

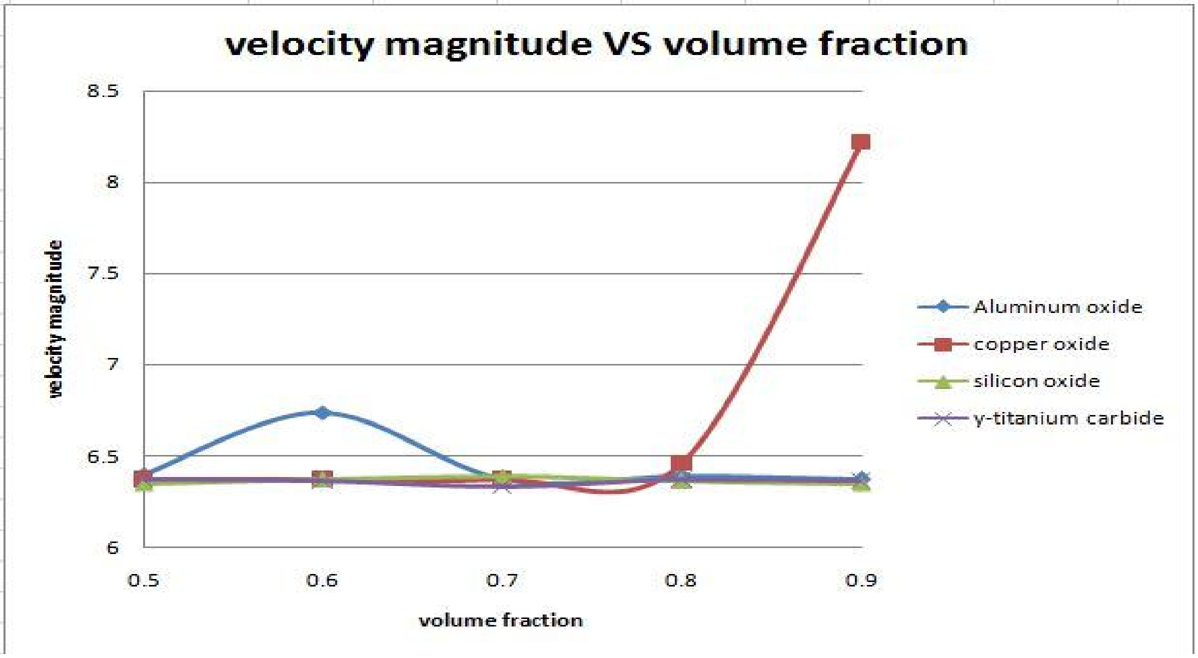


Fig:6.Graphical representation for velocity magnitude VS volume fraction

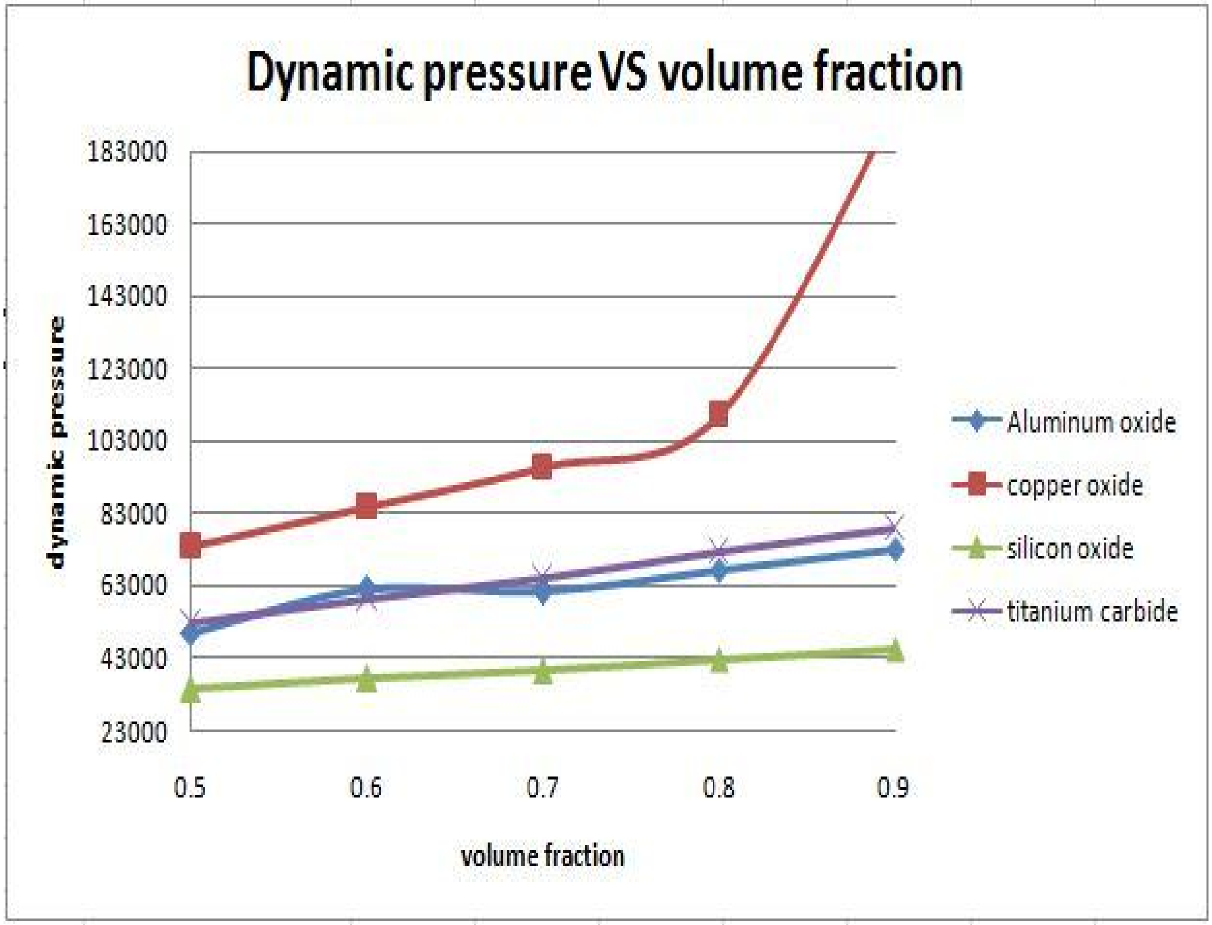


Fig:7. Graphical representation for dynamic pressure VS volume fraction

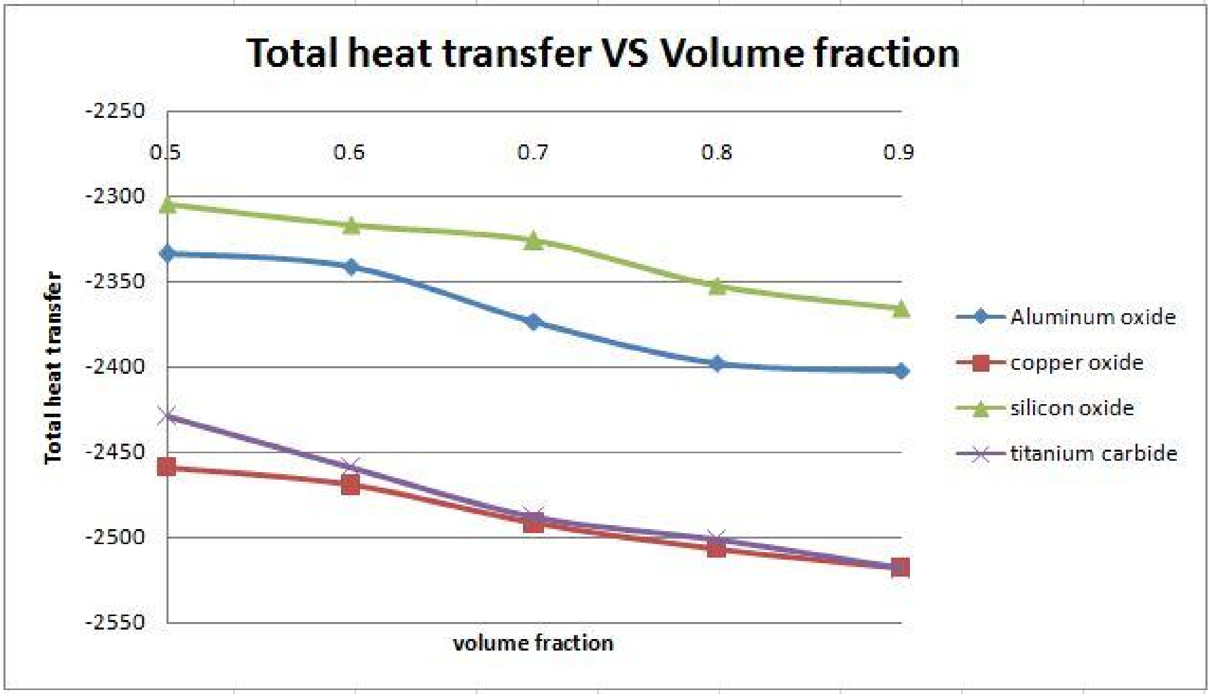


Fig:8.Graphical representation for total heat transfer VS volume fraction

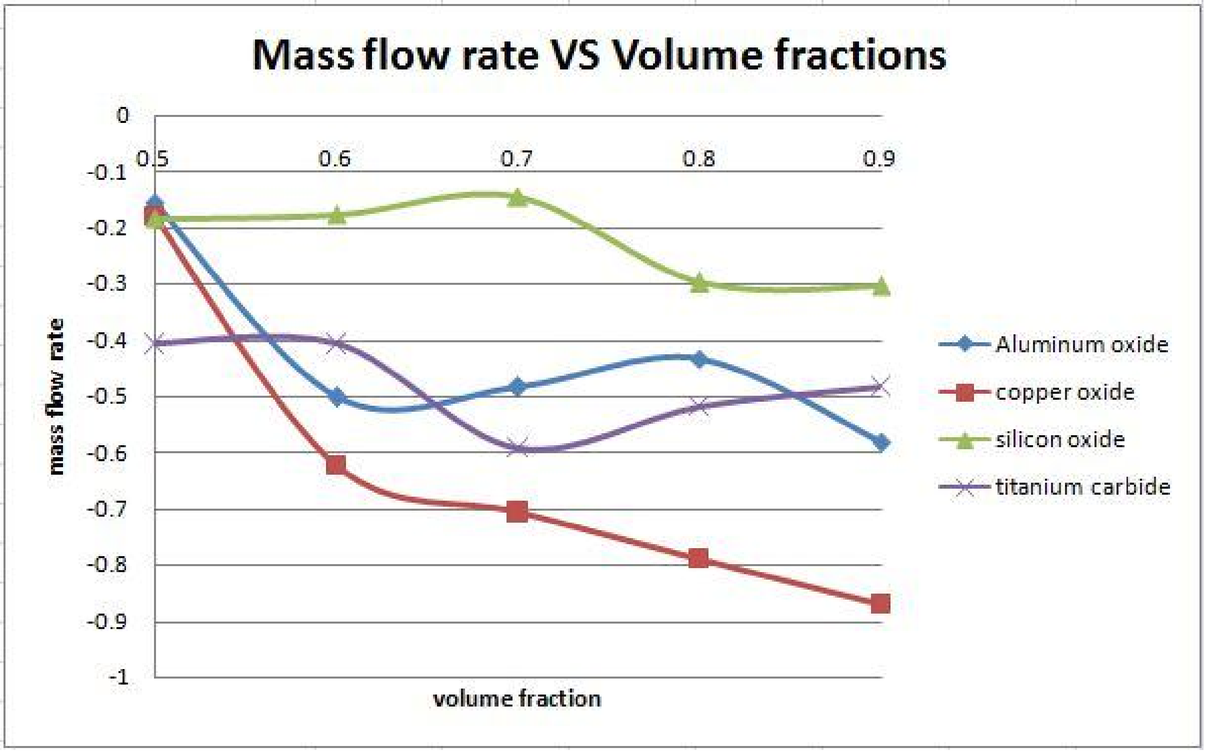


Fig: 9. Graphical representation for mass flow rate VS volume fractions

1) From Fig: 6 It was found thatvelocity magnitude VS volume fraction at 0.6 aluminum oxide gives best result and at volume fraction at 0.85 copper oxide gives best velocity magnitude
2) From Fig: 7 It was found that dynamic pressure VS volume fraction at 0.5 to 0.9 copper oxide gives best results.
3) From Fig: 8 It was found that total heat transfer VS volume fraction at 0.5 to 0.9copper oxide gives best results.
4) From Fig:9 It was found that mass flow rate VS volume fraction at 0.5 to 0.9copper oxide gives best results.

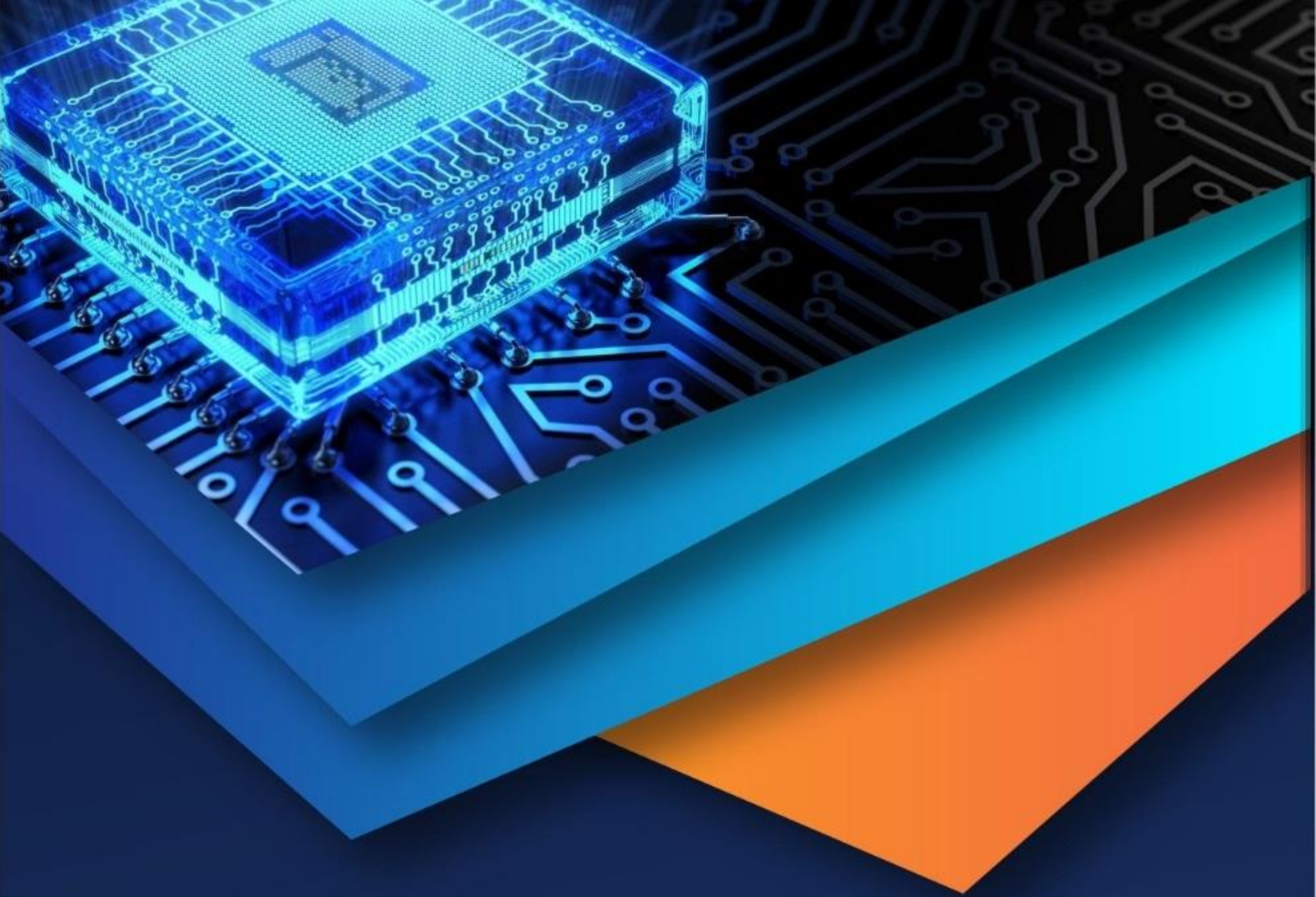
5) Highest heat velocity magnitude is noticed in copper oxide and aluminum oxide in higher volume fractions, in lower volume fractions aluminum oxide has the higher velocity magnitude silicon oxide recorded lowest velocity magnitude.
6) Highest heat dynamic pressure is noticed in copper oxide and titanium oxide in higher volume fractions, in lower volume fractions copper has the higher dynamic pressure silicon oxide recorded lowest dynamic pressure.
7) Highest heat transfer rate is noticed in copper oxide and titanium oxide in higher volume fractions, in lower volume fractions copper has the higher heat transfer rate silicon oxide recorded lowest heat transfer rate in all volume fraction an average of 150w variation is observed when compared with copper oxide.
8) Mass flow rate increases in the order silicon oxide, aluminum oxide, titanium oxide and copper got the highest flow rate in all volume fractions and the reason behind this could be its high density

VI. CONCLUSIONS

In this study material properties of various Nano fluids are calculated at different volume fractions and compared. Performance of these Nano fluids are evaluated using computational fluid dynamics with the help of Ansys fluent module Hear the 3d model of hot water flow volume is developed using Catia v5 and is analyzed using different volume fractions of four different Nano fluids which are aluminum oxide, copper oxide, silicon oxide and titanium oxide From the results copper oxide showed the best performance in all volume fraction and titanium oxide followed copper oxide. On an average the thermal gradient is around 3^{o}K, as we are doing a static analysis the variations in temperature drop is not pronounceable. The performance of aluminum oxide and silicon oxide is much lower than the copper oxide and titanium oxide.One can estimate the performance of a Nano fluid by studying its properties .Viscosity of the Nano fluid only changes with volume fraction but don’t depend on the Nano particle constituents in the Nano fluid. But, as the viscosity increases mass flow rate increases and with increase in volume fraction of Nano particles in Nano fluid its specific heat decreases and thermal conductivity increaes

VII. REFERNCES

[1] Eastman JA, Choi SUS, Li S, Thompson LJ, Lee S.” Enhanced Thermal Conductivity through the Development of Nanofluids”,Proc Symposium Nanophase and Nanocomposite Materials II. Boston, MA: Materials Research Society. 1997:pp 3–11.
[2] Said Z, Sajid MH, Alim MA, Saidur R, Rahim NA. “Experimental investigation of the thermo physical properties of AL2O3-nanofluid and its effect on a flat plate solar collector”, International Communications in Heat and Mass Transfer. 2013; 48: pp 99-107.
[3] International Communications in Heat and Mass Transfer. 2013; 49:pp17-24.
[4] thermophysical properties and heat transfer characteristics of a plate heat”,International Communications in Heat and Mass Transfer 44 (2013); pp 58–63.
[5] SyamSundar L, Sharma KV. “An experimental study on heat transfer and friction factor of Al2O3 nanofluid”, Journal of Mechanical Engineering and Sciences. 2011; 1: pp 99-112.



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