DESIGN AND CFD ANALYSIS OF DOUBLE PIPEHELICAL HEAT EXCHANGER AT DIFFERENT NANO FLUIDS

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, different nano fluids mixed with base fluid water are analyzed for their performance in the double pipe helical heat exchanger. The nano fluids are magnesium Oxide and Titanium nitride for two volume fractions 0.15, 0.25. Two materials copper and aluminium alloy are tested. Theoretical calculations are done determine the properties for nano fluids and those properties are used as inputs for analysis.

3D model of the double pipe helical heat exchanger is done in CREO parametric software. CFD analysis is done on the double pipe helical heat exchanger for all nano fluids and volume fraction.

Based on the experimental results titanium nitride nano fluid at volume fraction 0.25 gives the better heat transfer rate and the material is copper.

INTRODUCTION

Heat exchangers are one of the mostly used equipment in the process industries. Heat Exchangers are used to transfer heat between two process streams. One can realize their usage that any process which involve cooling, heating, condensation, boiling or evaporation will require a heat exchanger for these purpose. Process fluids, usually are heated or cooled before the process or undergo a phase change. Different heat exchangers are named according to their application. For example, heat exchangers being used to condense are known as condensers, similarly heat exchanger for boiling purposes are called boilers. Performance and efficiency of heat exchangers are measured through the amount of heat transfer using least area of heat transfer and pressure drop. A better presentation of its efficiency is done by calculating over all heat transfer coefficient. Pressure drop and area required for a certain amount of heat transfer, provides an insight about the capital cost and power requirements (Running cost) of a heat exchanger. Usually, there is lots of literature and theories to design a heat exchanger according to the requirements.

Heat exchangers are of two types:-

Where both media between which heat is exchanged are in direct contact with each other is called Direct contact heat exchanger, Where both media are separated by a wall through which heat is transferred so that they never mix, Indirect contact heat exchanger.

A typical heat exchanger, usually for higher pressure applications up to 552 bars, is the shell and tube heat exchanger. Shell and tube type heat exchanger, indirect contact type heat exchanger. It consists of a series of tubes, through which one of the fluids runs. The shell is the container for the shell fluid. Generally, it is cylindrical in shape with a circular cross section, although shells of different shape are used in specific applications. For this particular study shell is considered, which a one pass shell is generally. A shell is the most commonly used due to its low cost and simplicity, and has the highest log-mean temperature-difference (LMTD) correction factor. Although the tubes may have single or multiple passes, there is one pass on the shell side, while the other fluid flows within the shell over the tubes to be heated or cooled. The tube side and shell side fluids are separated by a tube sheet.

Baffles are used to support the tubes for structural rigidity, preventing tube vibration and sagging and to divert the flow across the bundle to obtain a higher heat transfer coefficient. Baffle spacing (B) is the centre line distance between two adjacent baffles, Baffle is provided with a cut (Bc) which is expressed as the percentage of the segment height to shell inside diameter. Baffle cut can vary between 15% and 45% of the shell inside diameter. In the present study 36% baffle cut (Bc) is considered. In general, conventional shell and tube heat exchangers result in high shell-side pressure drop and formation of recirculation zones near the baffles. Most of the researches now a day are carried on helical baffles, which give better performance then single segmental baffles but they involve high manufacturing cost, installation cost and maintenance cost. The effectiveness and cost are two important parameters in heat exchanger design. So, In order to improve the thermal performance at a reasonable cost of the Shell and tube heat exchanger, baffles in the present study are provided with some inclination in order to maintain a reasonable pressure drop across the exchanger.

TUBULAR HEAT EXCHANGERS:

A tubular heat exchanger can either consist of a smaller-diameter tube mounted inside a larger diameter tube (“double-pipe exchanger”, see Figure 1) or, more commonly, a tube bundle inside a shell (“shell-and-tube exchanger”, see Figure 1.1). Thus, heat transfer surfaces are plain or enhanced tubes. Additionally, shell-and-tube heat exchangers can contain multiplepass tube bundles, i.e., for double-pass we have a bundle of U-tubes, for triple-pass the tubes in the bundle bend twice, etc. Multiple-pass shells are common as well. Baffles, either segmental or doughnut and disc ones, present in the shell direct fluid flow in shell-side, support the tubes, and limit possible tube vibrations.

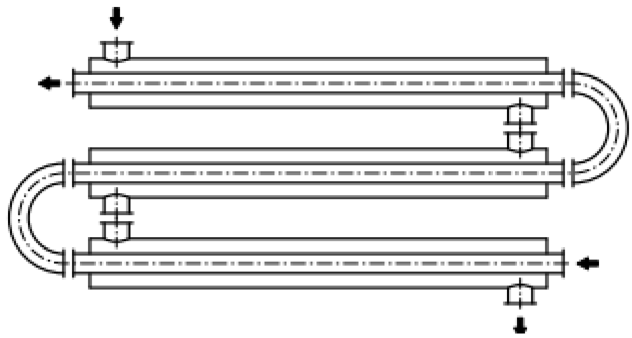


Figure 1.1: Countercurrent double-pipe heat exchanger

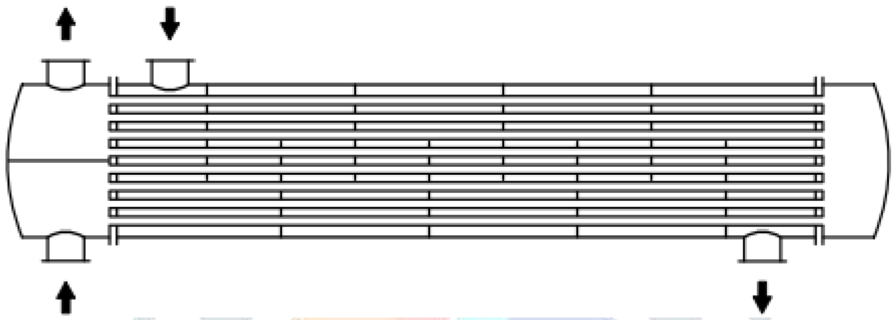


Figure 1: Segmentally baffled one-pass shell and two-pass tube shell-and-tube heat exchanger

LITERATURE REVIEW

1. Jibin Johnson **,** Abdul Anzar V M, Abith Shani. In this paper heat transfer equipment is defined by the function it fulfills in a process. On the similar path, Heat exchangers are the equipment used in industrial processes to recover heat between two process fluids. They are widely used in space heating, refrigeration, air conditioning, power plants, chemical plants, petrochemical plants, petroleum refineries, and natural gas processing. The operating efficiency of these exchangers plays a very key role in the overall running cost of a plant. So the designers are on a trend of developing heat exchangers which are highly efficient compact, and cost effective. A common problem in industries is to extract maximum heat from a utility stream coming out of a particular process, and to heat a process stream. Therefore the objective of present work involves study of refinery process and applies phenomena of heat transfer to a double pipe heat exchanger. Design and anaysis of double pipe heat exchanger using computational method (international journal 0f professional engineering studies

volume v/issue2)

2. Timothy J. Rennie, Vijaya G.S. Raghavan. In this paper heat transfer characteristics of a double-pipe helical heat exchanger were numerically studied to determine the effect of fluid thermal properties on the heat transfer.

Two studies were performed; the first with three different Prandtl numbers (7.0, 12.8, and 70.3) and the second with thermally dependent thermal conductivities. Thermal conductivities of the fluid were based on a linear relationship with the fluid temperature. Six different fluid dependencies were modeled. Both parallel flow and counter flow configurations were used for the second study.

Results from the first study showed that the inner Nusselt number was dependent on the Prandtl number, with a greater dependency at lower Dean numbers; this was attributed to changing hydrodynamic and thermal entry lengths. Nusselt number correlations based on the Prandtl number and a modified Dean number are presented for the heat transfer in the annulus. Results from the second part of the study showed that the Nusselt number correlated better using a modified Dean number. The counter flow configuration had higher heat transfer rates than the parallel flow, but the ratio of these differences was not different when comparing thermally dependent properties and thermally independent properties. Effect of fluid thermal properties on the heat transfer characteristics in a double-pipe helical heat exchanger (international journal ofthermal sciences 45(2006) 1158-1165).

3. Abith Shani, Harif Rahiman p, Hashmi Hameed T S. In this paper heat exchangers are used in industrial processes tore cover heat between two process fluids. All the heat exchangers are designed based on the function it fulfills in a process. Although the necessary equations for heat transfer and the pressure drop in a double pipe heat exchanger are available, using these equations the validation of the design is laborious. In this paper the analytical design of the exchanger has been validated based on the results obtained from the CFD analysis. In this paper the CFD analysis is based on the standard k-ε modeling. The solution of the problem yields the optimum values of inner pipe diameter, outer pipe diameter and utility flow rate to be used for a double pipe heat exchanger of a given effective length, when a specified flow rate of process stream is to be treated for a given inlet to outlet temperature. CFD analysis of double pipe heat exchanger(IJSETR ISSN: 2278-7798).

4. Sk**.**M.Z.M.Saqheeb Ali,k.Mohan Krishna,s.D.V.V.S.Bhimesh reddy, sk.R.S.M.Ali. In this paper4 Heat Exchanger is a device used to exchange the heat energy between the two fluids by which increases the operating efficiency? These Efficiencies plays a major role for cost effective Operations in the process industries. While the both Fluids flow through the heat exchanger, the temperature of both fluids will exchange. The main objective of this paper is deals with the performance rate of double pipe heat exchanger By changing the materials which uses the heat input From the waste recovery of steam in refinery process. Double pipe heat exchangers are designed in CREO. CFD analysis is done by using ANSYS. Final Results are obtained with three different type of materials steel, aluminum and copper. Thermal analysis of double pipe heat exchanger by changing the materials using cfd (IJETT ISSN: 2231-5381).

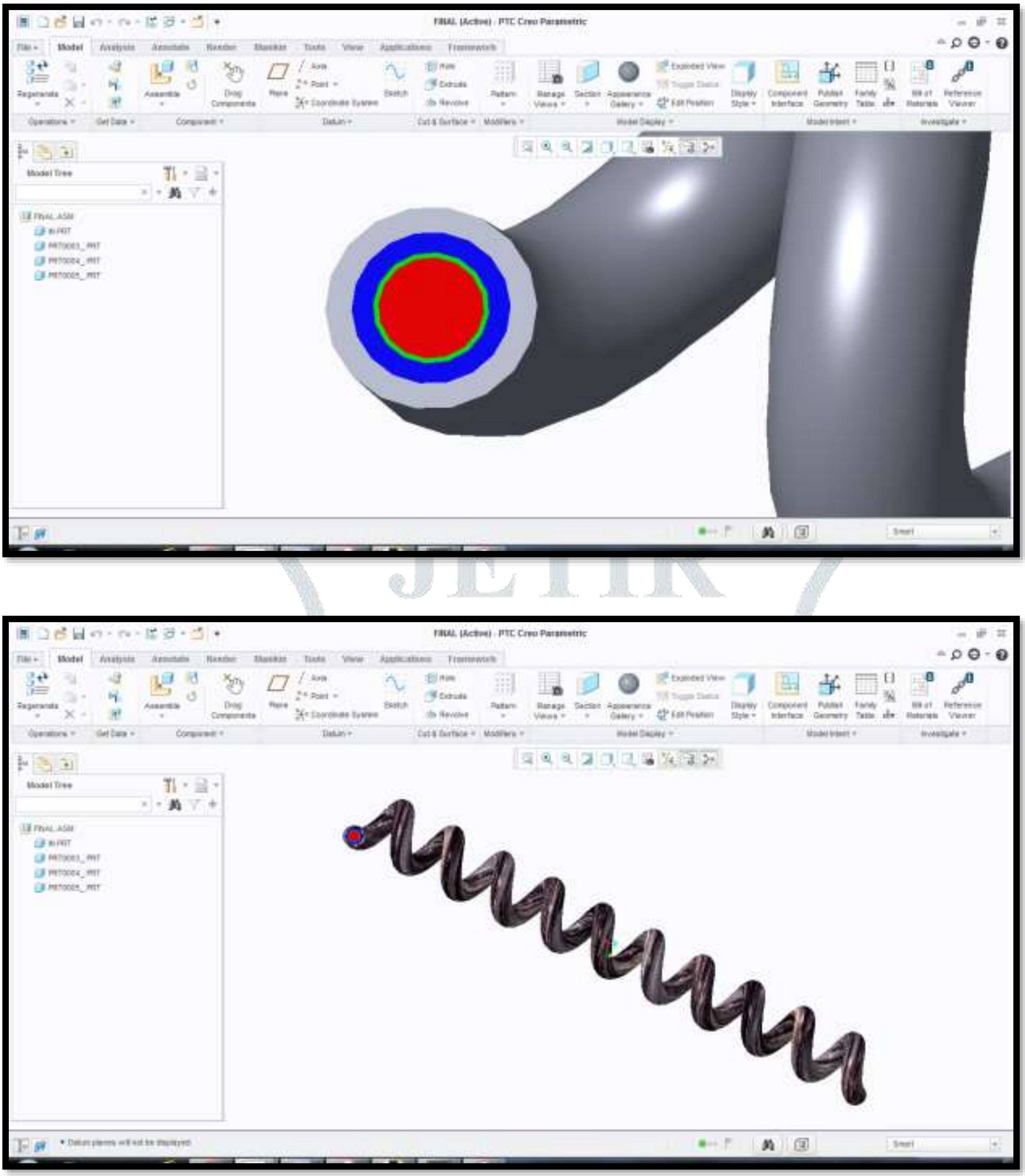


Figure 2 Design of double pipe helical heat exchanger by using CREO

INTRODUCTION TO CFD

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. Initial experimental validation of such software is performed using a wind tunnel with the final validation coming in full-scale testing, e.g. flight tests.

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 behaviour 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.

CALCULATIONS TO DETERMINE PROPERTIES OF NANO FLUID BY CHANGING VOLUME FRACTIONS

Volume fraction= 0.15& 0.25(taken from journal paper)

MATERIAL PROPERTIES

MEGNESIUM OXIDE

Density = 3880 kg/m^3

Thermal conductivity =40 W/m-k

Specific heat = 910J/kg-k

TITANIUM NITRIDE

Density = 4930 kg/m^3

Thermal conductivity =330 W/m-k

Specific heat = 711 J/kg-k

WATER

Density = 998.2 kg/m^3

Thermal conductivity = 0.6 W/m-k

Specific heat = 4182 J/kg-k

Viscosity = 0.001003kg/m-s

NOMENCLATURE

ρ_{nf} = Density of nano fluid (kg/m^3)

ρ_s = Density of solid material (kg/m^3)

ρ_w = Density of fluid material (water) (kg/m^3)

ϕ = Volume fraction

C_{pw} = Specific heat of fluid material (water) (j/kg-k)

C_{ps} = Specific heat of solid material (j/kg-k)

μ_w = Viscosity of fluid (water) (kg/m-s)

μ_{nf} = Viscosity of Nano fluid (kg/m-s)

K_w = Thermal conductivity of fluid material (water) (W/m-k)

K_s = Thermal conductivity of solid material (W/m-k)

NANO FLUID CALCULATIONS

MEGNESIUM OXIDE

DENSITY OF NANO FLUID

$$\rho_{nf} = \phi \times \rho_s + [(1-\phi) \times \rho_w]$$

SPECIFIC HEAT OF NANO FLUID

$$C_{p\,nf} = \frac{\phi\times\rho s\times Cps+(1-\phi)(\rho w\times Cpw)}{\phi\times\rho s+(1-\phi)\times\rho w}$$

VISCOSITY OF NANO FLUID

$$\mu_{nf} = \mu_w (1+2.5\phi)$$

THERMAL CONDUCTIVITY OF NANO FLUID

$$K_{nf} = \frac{Ks+2Kw+2(Ks-Kw)(1+\beta)^3\times\phi}{K_s+2K_w-K_s-K_{w1}+\beta^3\times\emptyset} \times k_w$$

β=0.1 taken from journal

NANO FLUID PROPERTIES

FLUID	Volume fraction	Thermal conductivity (w/m-k)	Specific heat (J/kg-k)	Density (kg/m^3)	Viscosity (kg/m-s)
MEGNESIUM OXIDE	**0.15**	2.647	1809	2150.92	0.002006
	0.25	4.17	1570.9	2439.1	0.002256
TITANIUM NITRIDE	**0.15**	2.625	5357.01	2570.92	0.002006
	0.25	4.12	4069.1	2964.1	0.002256

Table 1 Nano fluid properties

CFD ANALYSIS OF DOUBLE PIPE HELICALHEAT EXCHANGER

CFD ANAIYSIS OF MAGNESIUM OXIDE NANO FLUID AT VOLUME FRACTION - 0.15:

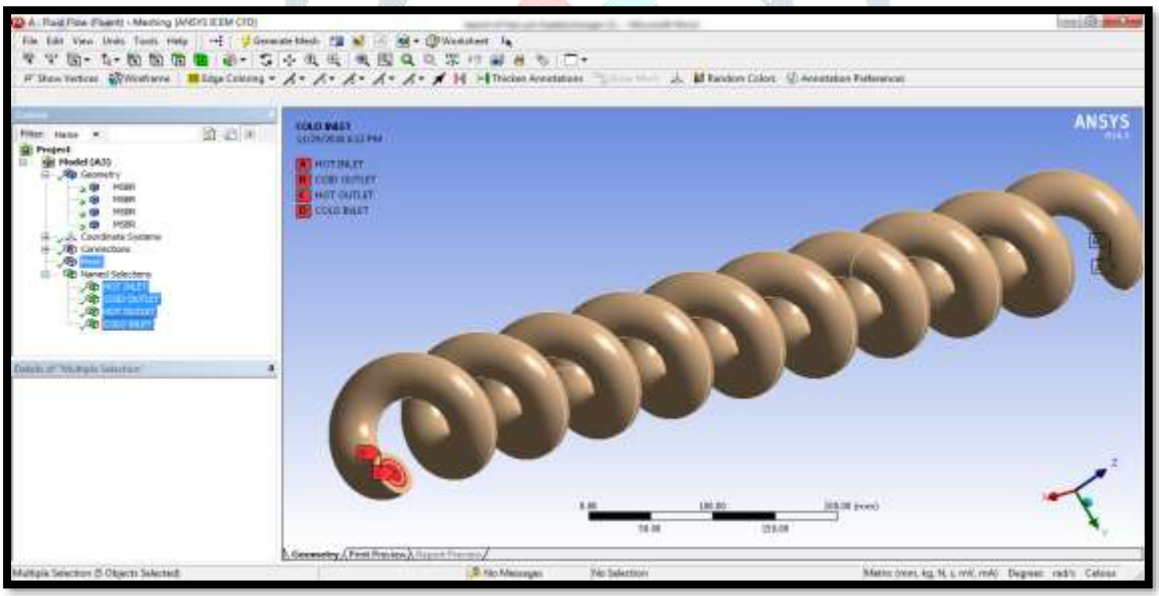
→→Ansys → workbench→ select analysis system → fluid flow fluent → double click

→→Select geometry → right click → import geometry → select browse →open part → ok

→→ select mesh on work bench → right click →edit → select mesh on left side part tree → right click → generate mesh →

The model is designed with the help of pro-e and then import on ANSYS for Meshing and analysis. The analysis by CFD is used in order to calculating pressure profile and temperature distribution. For meshing, the fluid ring is divided into two connected volumes. Then all thickness edges are meshed with 360 intervals. A tetrahedral structure mesh is used. So the total number of nodes and elements is 6576 and 3344.
Select faces → right click → create named section → enter name → water inlet

Select faces → right click → create named section → enter name → water outlet



Experimental procedure:

Model → energy equation → on.

Viscous → edit → k- epsilon

Enhanced Wall Treatment → ok

Materials → new → create or edit → specify fluid material or specify properties → ok

Solution → Solution Initialization → Hybrid Initialization →done

Run calculations → no of iterations = 50 → calculate → calculation complete

→→ **Results → graphics and animations → contours → setup**

Magnesium Oxide at 0.15

STATIC PRESSURE

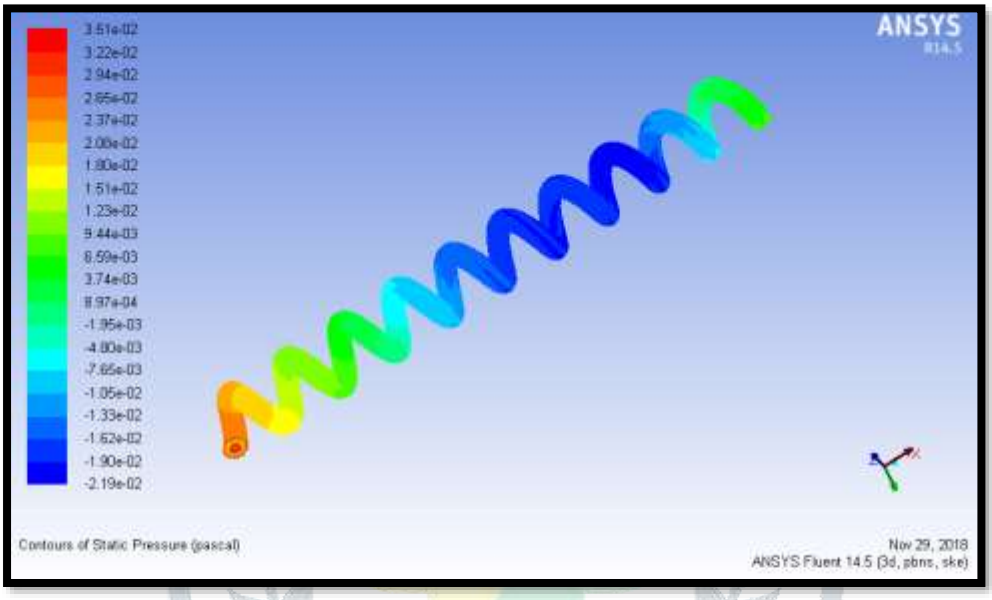


Figure 3 CFD Analysis of Magnesium oxide at volume fraction 0.15 for static pressure

VELOCITY MAGNITUDE

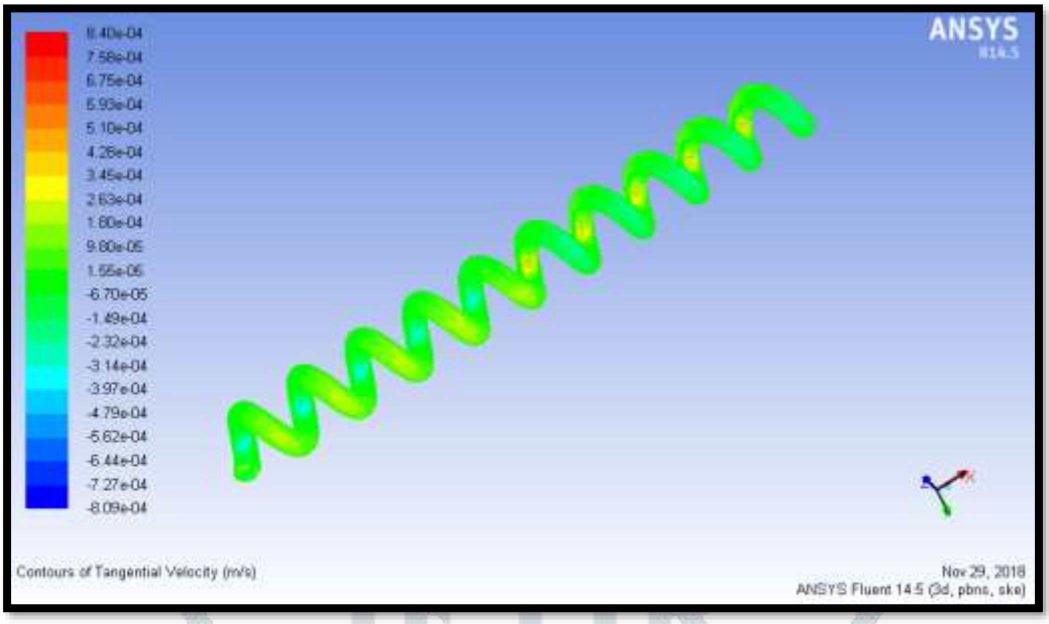


Figure 4 CFD Analysis of Magnesium oxide at volume fraction 0.15 for velocity magnitude

HEAT TRANSFER CO-EFFICIENT

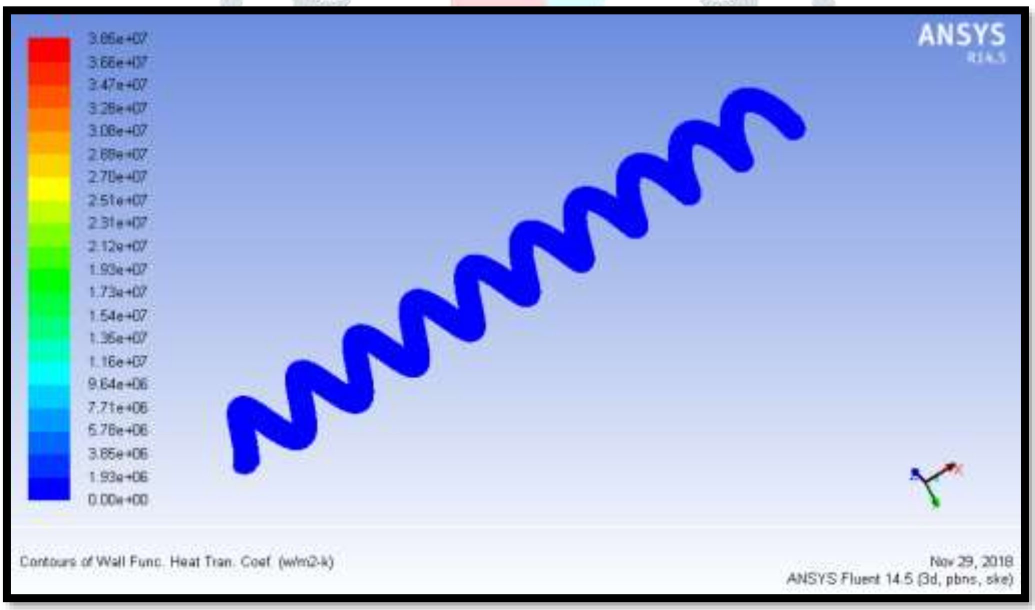


Figure 5 CFD Analysis of Magnesium oxide at volume fraction 0.15 for heat transfer co-efficient

5.2 CFD AALYSIS OF TITANIUM NITRIDE NANO FLUID AT VOLUME FRACTION - 0.15:

STATIC PRESSURE

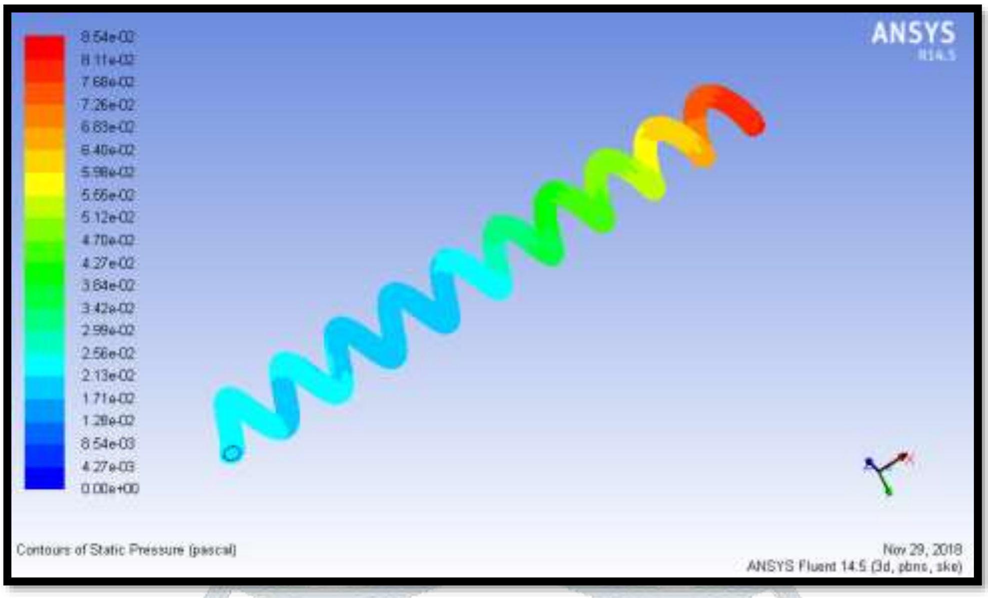


Figure 6 CFD Analysis of Titanium nitride at volume fraction 0.15 for static pressure

VELOCITY MAGNITUDE

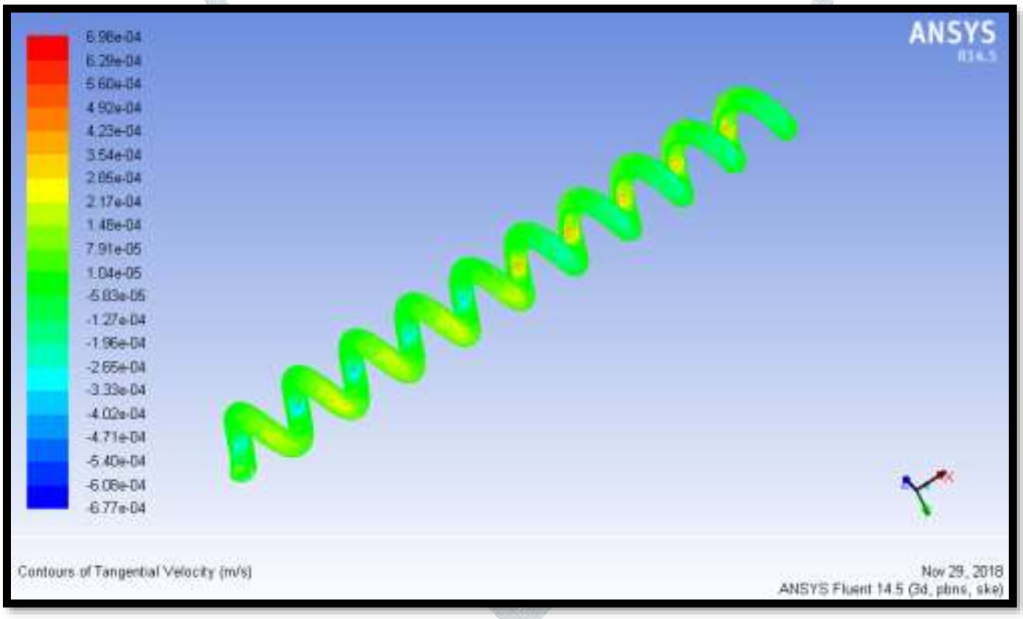


Figure 7 CFD Analysis of Magnesium oxide at volume fraction 0.15 for velocity magnitude

HEAT TRANSFER CO-EFFICIENT

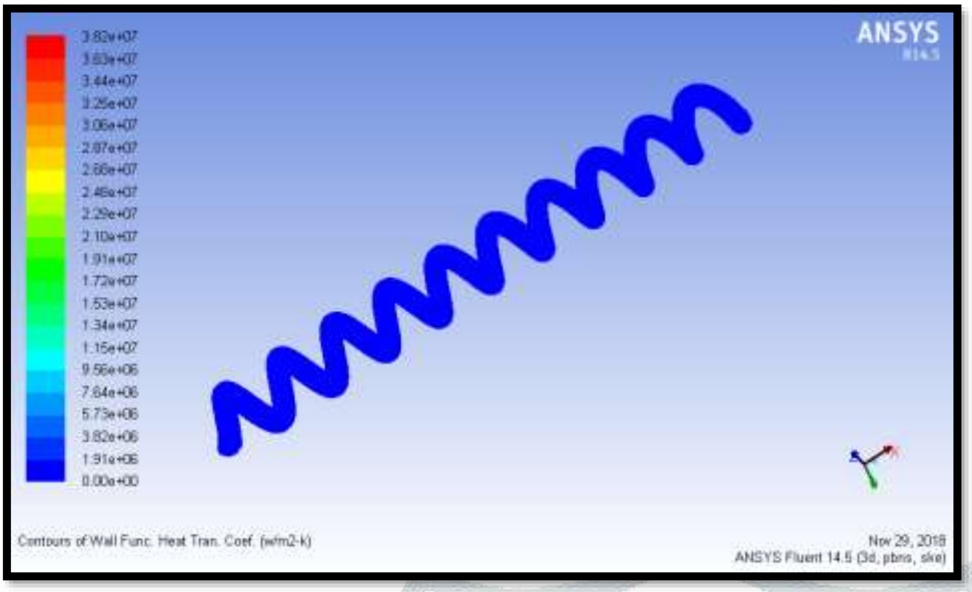


Figure 8 CFD Analysis of Magnesium oxide at volume fraction 0.15 for heat transfer co-efficient

RESULT TABLES

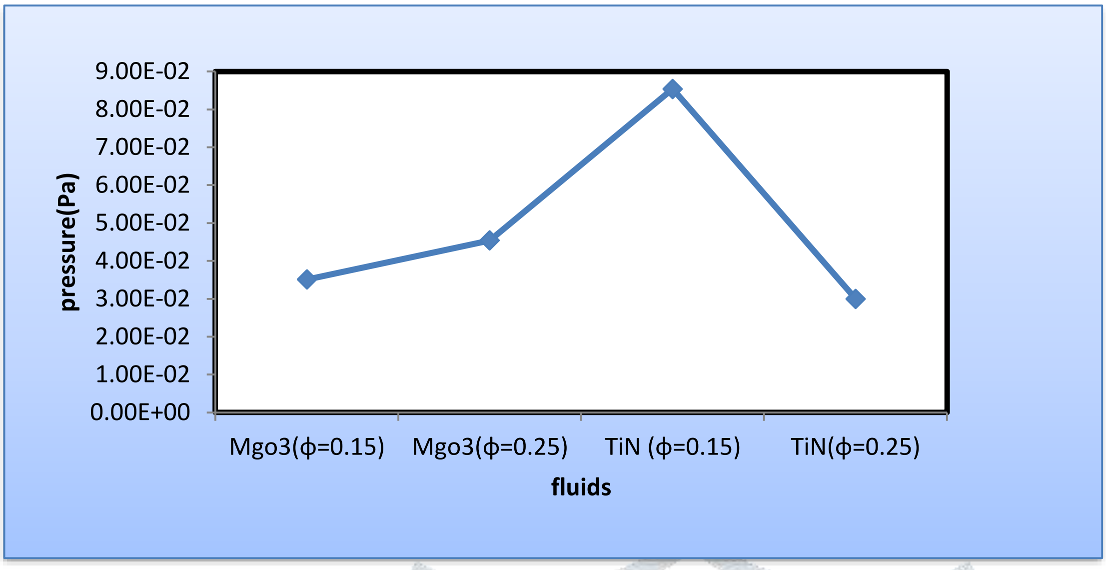
CFD RESULT TABLE

Fluid	Pressure (Pa)	Velocity (m/s)	Heat transfer coefficient (w/m2-k)	Mass flow rate(kg/s)	Heat transfer rate(W)
Mgo3(ϕ=0.15)	3.51e-02	8.40e-04	3.85e+07	0.000095061	1.9319086
Mgo3(ϕ=0.25)	4.54e-02	1.33e-03	6.07e+07	0.0004541	29.69125
TiN (ϕ=0.15)	8.54e-02	6.98e-04	3.82e+07	0.00017571	6.8591118
TiN(ϕ=0.25)	3.00e-002	2.53e-03	6.00e+07	0.00040619192	32.18376

Table 2 CFD results

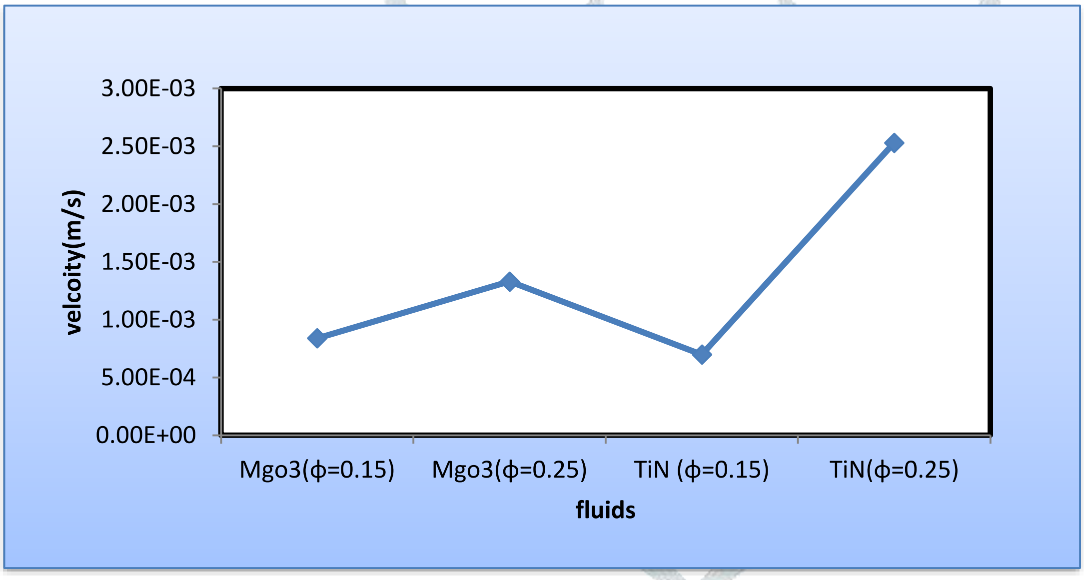
CFD analysis Graphs:

PRESSURE PLOT



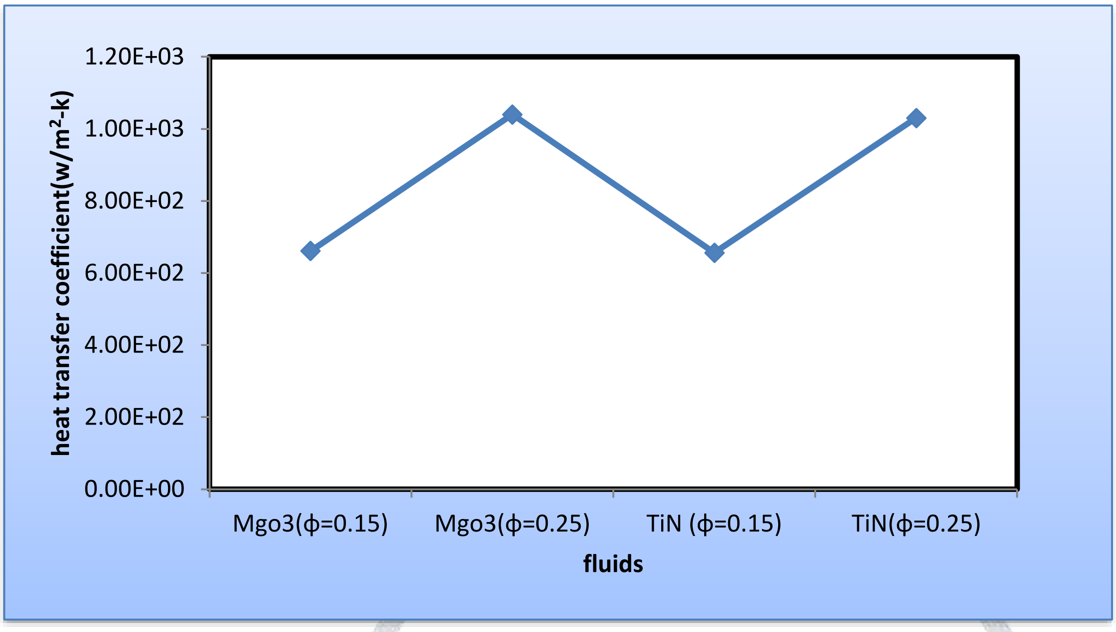
Graph1: pressure plot

VELOCITY PLOT



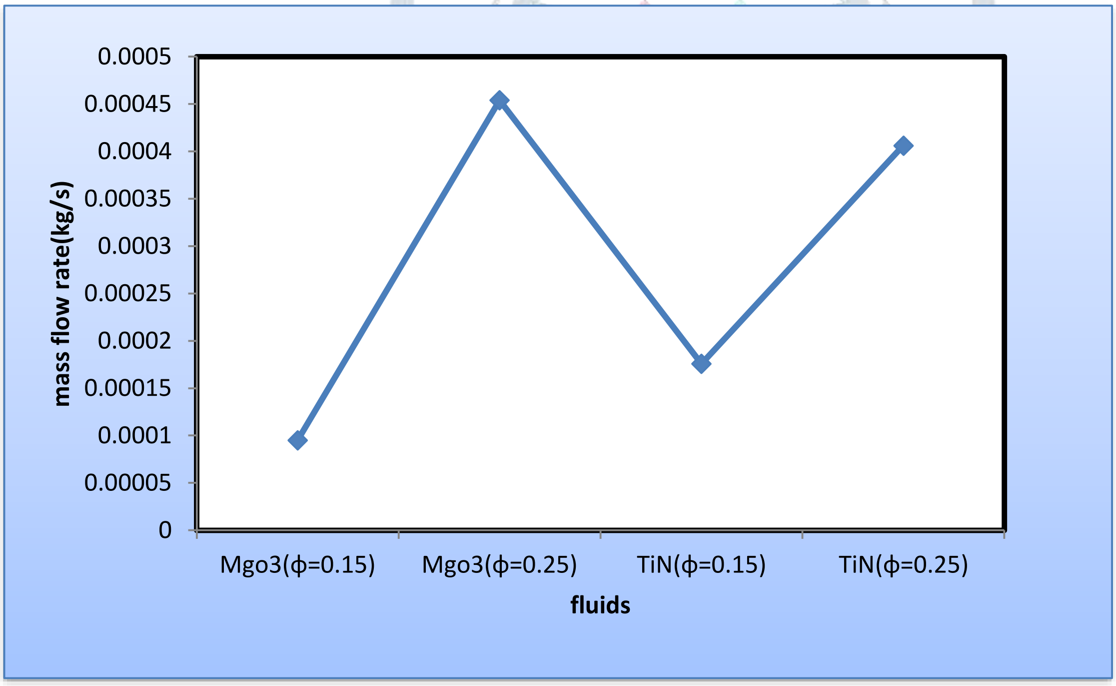
Graph2: velocity plot

HEAT TRANSFER COEFFICIENT PLOT



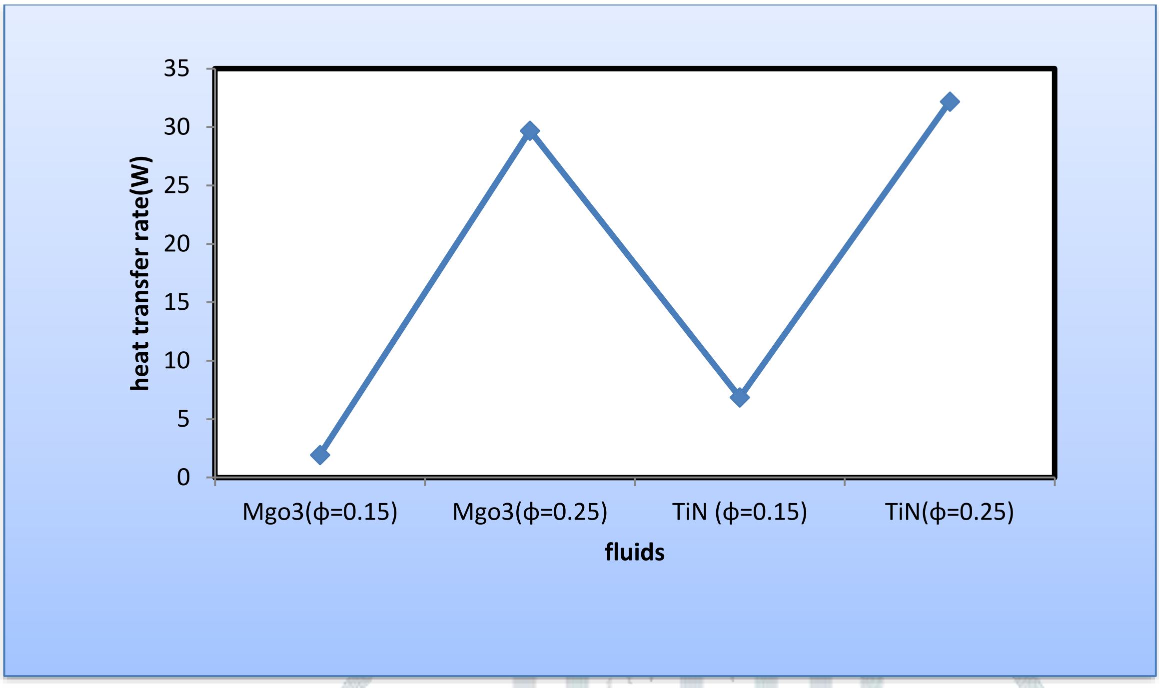
Graph3: heat transfer coefficient plot

MASS FLOW RATE PLOT



Graph4: mass flow rate plot

Heat transfer rate plot



Graph5: heat transfer rate plot

CONCLUSION

In this paper, different nano fluids mixed with base fluid water are analyzed for their performance in the double pipe helical heat exchanger. The nano fluids are megnesium Oxide and Titanium nitride for two volume fractions 0.15, 0.25. Theoretical calculations are done determine the properties for nano fluids and those properties are used as inputs for analysis.

By observing the CFD analysis results the heat transfer rate value more at titanium nitride volume fraction 0.25.

By observing the thermal analysis results the heat flux value more for copper material compare with aluminum alloy.

So it can be concluded the titanium nitride nano fluid at volume fraction 0.25 fluid is the better fluid for double pipe helical heat exchanger and material is copper.

SCOPE OF FUTURE WORK

In this project I have considered double pipe helical heat exchanger and I used two nano fluids magnesium oxide and titanium nitride, in that titanium nitride at volume fraction 0.25 have higher heat transfer rate. If different nano fluids like Sio2, CuO and so on may give the better result.

REFERENCES

1. A.O. Adelaja, S. J. Ojolo and M. G. Sobamowo, “Computer Aided Analysis of Thermal and Mechanical Design of Shell and Tube Heat Exchangers”, Advanced Materials Vol. 367 (2012) pp 731-737 © (2012) Trans Tech Publications, Switzerland.
2. Yusuf Ali Kara, Ozbilen Guraras, “A computer program for designing of Shell and tube heat exchanger”, Applied Thermal Engineering 24(2004) 1797–1805
3. Rajagapal THUNDIL KARUPPA RAJ and Srikanth GANNE, “Shell side numerical analysis of a shell and tube heat exchanger considering the effects of baffle inclination angle on fluid flow”, Thundil Karuppa Raj, R., et al: Shell Side Numerical Analysis of a Shell and Tube Heat Exchanger ,THERMAL SCIENCE: Year 2012, Vol. 16, No. 4, pp. 1165-1174.
4. S. Noie Baghban, M. Moghiman and E. Salehi, “ Thermal analysis of shell-side flow of shell-and tube heat exchanger using experimental and theoretical methods” (Received: October 1, 1998 -Accepted in Revised Form: June 3, 1999).
5. A.GopiChand, Prof.A.V.N.L.Sharma , G.Vijay Kumar, A.Srividya, “Thermal analysis of shell and tube heat exchanger using mat lab and floefd software”,Volume: 1 Issue: 3 276 –281,ISSN: 2319 – 1163.
6. Hari Haran, Ravindra Reddy and Sreehari, “Thermal Analysis of Shell and Tube Heat ExChanger Using C and Ansys”,International Journal of Computer Trends and Technology (IJCTT) –volume 4 Issue 7–July 2013.
7. Donald Q.Kern. 1965. Process Heat transfer (23rdprinting 1986). McGraw-Hill companies.ISBN 0 -07-Y85353-3.
8. Richard C. Byrne Secretary. 1968. Tubular Exchanger Manufacturers Association, INC. (8th Edition). 25 North Broadway Tarrytown, New York 10591.
9. R.H Perry. 1984. Perry's Chemical Engineer’s Handbook (6th Edition ed.). McGraw-Hill. ISBN 0-07-049479-7.
10. Ender Ozden, Ilker Tari, Shell Side CFD Analysis of A Small Shell And Tube Heat Exchanger, Middle East Technical University, 2010.