CFD ANALYSIS OF SHELL AND TUBE HEAT EXCHANGER WITH AND WITHOUT BAFFLES BY USING 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. In this work, different NANO fluids mixed with base fluid water are analysed for their performance in the shell and tube heat exchanger without baffle and with baffle(90^0,30^0 and helical type baffle). The NANO fluids are Aluminium Oxide and Titanium carbide for two volume fractions 0.4, 0.5. Theoretical calculations are done determine the properties for NANO fluids and those properties are used as inputs for analysis. 3D model of the shell and elliptical tube heat exchanger is modelling in CREO parametric software. CFD analysis is done by ANSYS software.*

KEYWORDS*: Heat exchanger, shell and tube heat exchanger, CREO software, CFD analysis, NANO fluids.*

I. 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.

Factors Affecting the Performance of Shell and Tube Heat Exchanger

For a given shell geometry, the ideal configuration depends on the baffle cut, the baffle spacing, and baffle inclination angle. Even after fixing the right baffle cut and baffle space the performance can be still improved by varying baffle inclination angle. Having lower inclination angle, increases heat transfer at the cost of increased shell side pressure drop. On the other hand increasing angle beyond value might result in reduced pressure drop but with lesser heat transfer. So it is very important to have an optimum baffle angle to give minimum pressure drop with maximum heat transfer. Also determining effective baffle spacing and tube diameter for optimum baffle inclination.

Heat transfer surfaces are plain or enhanced tubes. Additionally, shell-and-tube heat exchangers can contain multiple pass 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.

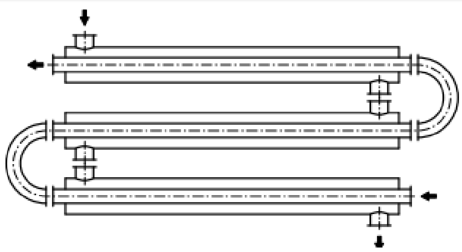


Fig: 1 Counter current double-pipe heat exchanger

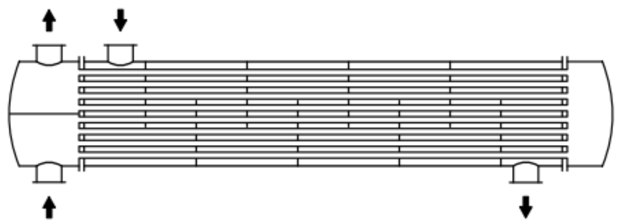
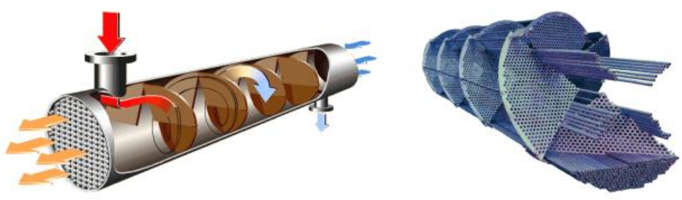


Fig:2 Segmental baffled one-pass shell and two-pass tube shell-and-tube heat exchanger

Flow in shell-side can be improved by suitable adjustments of baffle design as is done in helix changers (Král et al., 1996) – see Figure 1.2. Such an arrangement also increases the heat transfer rate vs. pressure drop ratio, reduces leakages (baffle bypass effect), flow-induced vibrations, and limits creation of stagnation zones thus decreasing fouling rate (CB&I Lummus Technology, 2012).



(a) scheme (b) tube bundle

Fig: 3 Helix changer: shell-and-tube heat exchanger with helical baffles

II. LITERATURE REVIEW

Shell-and-Tube Heat Exchangers

R. Shankar Subramanian

Shell-and-tube heat exchangers are used widely in the chemical process industries, especially in refineries, because of the numerous advantages they offer over other types of heat exchangers. A lot of information is available regarding their design and construction. The present notes are intended only to serve as a brief introduction.

Experimental study on thermal and flow processes in shell and tube heat exchangers - influence of baffle cut on heat exchange efficiency - Nenad Radojković, Gradimir Ilić, Žarko Stevanović, Mića Vukić, Dejan Mitrović, Goran Vučković

Experimental investigations were done to identify influence of thermal and flow quantities and shell side geometry on STHE's heat exchange intensity. In thismpaper special attention was paid to segmental baffle cut influence on apparatus efficiency.

Design and Thermal Performance Analysis of Shell and Tube Heat Exchanger by Using CFD-A Review

Abstract: This paper is concerned with the study of shell and tube heat exchanger. Also the factors affecting the performance of shell and tube heat exchanger is studied and its details discussion is given. this paper focuses on the designing of small shell and tube heat exchanger with counter flow arrangement. Thermal analysis is carried out considering various parameters such as baffle spacing, baffle inclination, flow rates of hot and cold fluids, tube diameter etc. by using CFD. Some research papers are studied in details and then review from those papers is described in the paper.

III. RESEARCH GAP & PROBLEM DESCRIPTION

In the research by **R. Shankar Subramanian**, the shell and tube heat exchanger is taken in the water with various temperatures. In this thesis, along with water Aluminum Al_2O_3, silicon oxide and titanium carbide nano fluid at different volume fractions (0.7 and 0.8) of the shell and tube heat exchanger is analyzed for heat transfer properties, temperature, pressure ,velocity and mass flow rates in CFD analysis. In thermal analysis, two materials Copper and Aluminum are considered for heat exchanger. Modeling is done in Pro/Engineer, Thermal analysis and CFD analysis is done in Ansys. The boundary conditions for thermal analysis are temperatures, for CFD analysis is pressure, velocity and temperature.

IV. INTRODUCTION TO CAD

Computer-aided design (**CAD**) is the use of computer systems (or workstations) to aid in the creation, modification, analysis, or optimization of a design. CAD software is used to increase the productivity of the designer, improve the quality of design, improve communications through documentation, and to create a database for manufacturing. CAD output is often in the form of electronic files for print, machining, or other manufacturing operations. The term **CADD** (for Computer Aided Design and Drafting) is also used.

INTRODUCTION TO CREO

PTC CREO, formerly known as Pro/ENGINEER, is 3D modeling software used in mechanical engineering, design, manufacturing, and in CAD drafting service firms. It was one of the first 3D CAD modeling applications that used a rule-based parametric system. Using parameters, dimensions and features to capture the behavior of the product, it can optimize the development product as well as the design itself.

ADVANTAGES OF CREO PARAMETRIC SOFTWARE

1. Optimized for model-based enterprises
2. Increased engineer productivity
3. Better enabled concept design
4. Increased engineering capabilities
5. Increased manufacturing capabilities
6. Better simulation
7. Design capabilities for additive manufacturing

CREO parametric modules:

- Sketcher
- Part modeling
- Assembly
- Drafting

3D MODEL OF SHELL AND TUBE HEAT EXCHANGER

- Tube outer dia. = 23 mm
- Tube inner dia. = 17 mm
- Number of tube = 9
- Shell inner dia. = 136 mm
- Shell outer dia. = 142 mm
- Number of baffles = 5
- Diameter of baffles = 136 mm
- Distance between baffles B = 300 mm

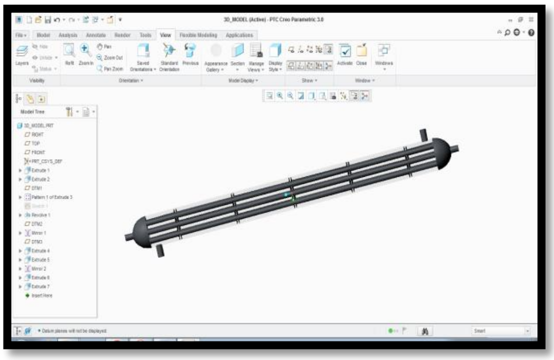


Fig: 4 3d model

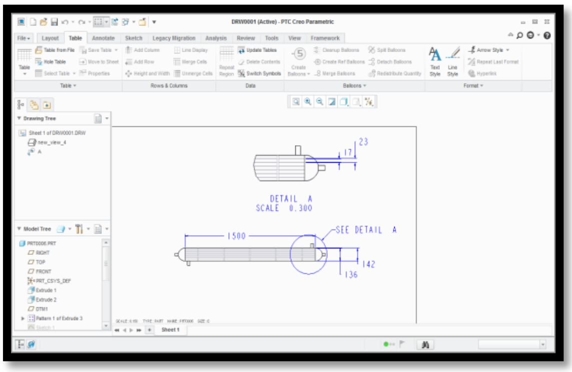


Fig 5: drafting

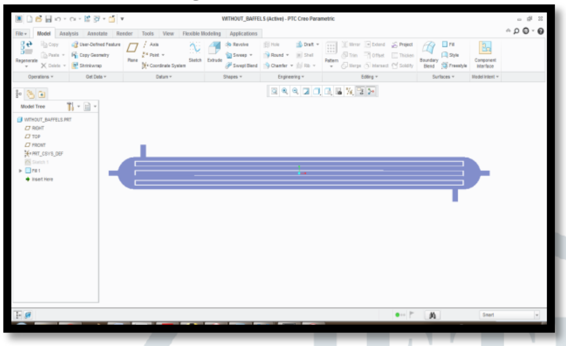


Fig:6 Without baffles

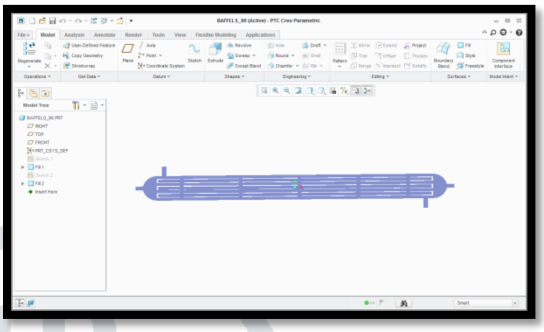


Fig:7 Baffles with 90^0

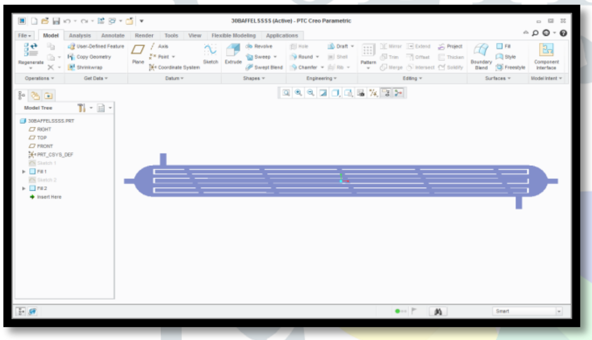


Fig: 8Baffle with 30^0

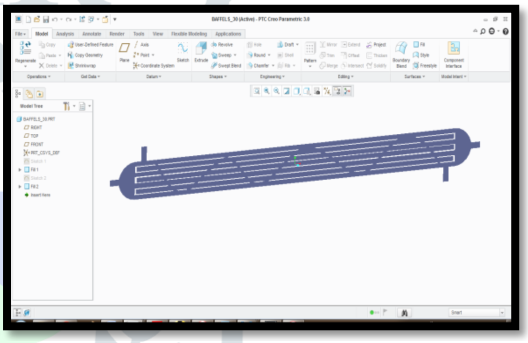


Fig:9 Helix type baffle

INTRODUCTION TO FEA

Finite Element Analysis (FEA) was first developed in 1943 by R. Courant, who utilized the Ritz method of numerical analysis and minimization of variational calculus to obtain approximate solutions to vibration systems. Shortly thereafter, a paper published in 1956 by M. J. Turner, R. W. Clough, H. C. Martin, and L. J. Top established a broader definition of numerical analysis. The paper centered on the "stiffness and deflection of complex structures".

INTRODUCTION TO ANSYS

ANSYS 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.

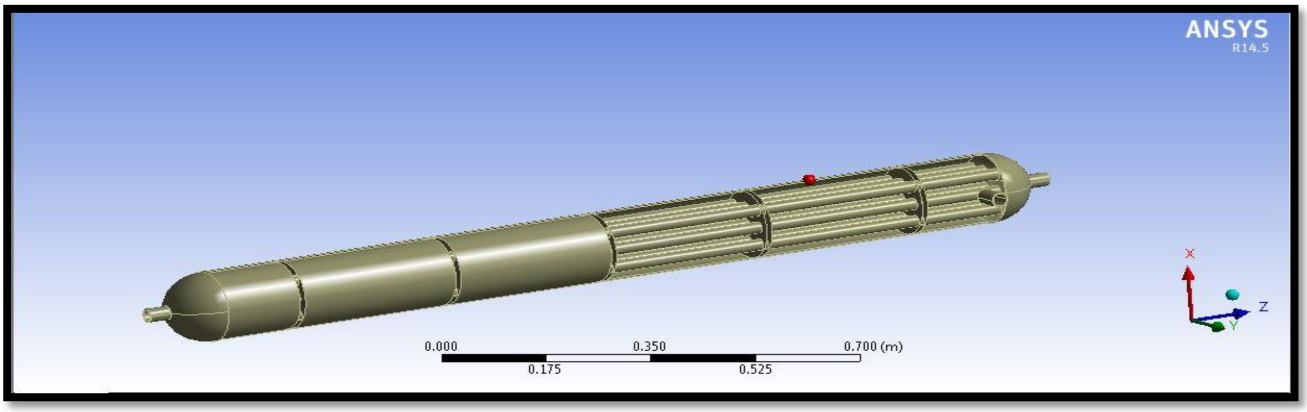
INTRODUCTION TO CFD

Computational fluid dynamics, usually abbreviated as CFD, is a branch of fluid mechanics that uses numerical methods and algorithms to solve and analyse problems that involve fluid flows.

NANO FLUID PROPERTIES

FLUID	Volume fraction	Thermal conductivity (w/m-k)	Specific heat (J/kg-k)	Density (kg/m^3)	Viscosity (kg/m-s)
ALUMINUM OXIDE	**0.4**	2.647	1809	2150.92	0.002006
	0.5	4.17	1570.9	2439.1	0.002256
TiC	**0.4**	2.625	5357.01	2570.92	0.002006
	0.5	4.12	4069.1	2964.1	0.002256

CFD ANALYSIS OF SHELL AND TUBE HEAT EXCHANGER



FLUID- WATER

ALUMINUM OXIDE NANO FLUID VOLUME FRACTION - 0.4

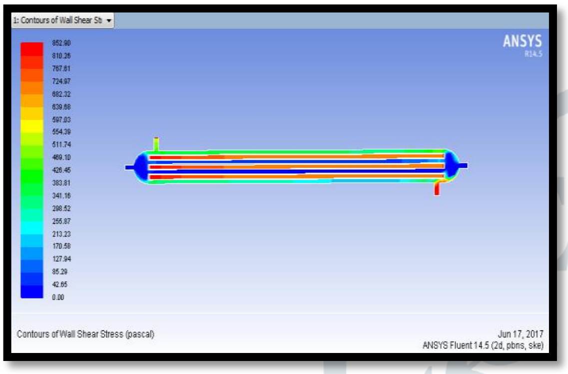


Fig 9: heat transfer coefficient

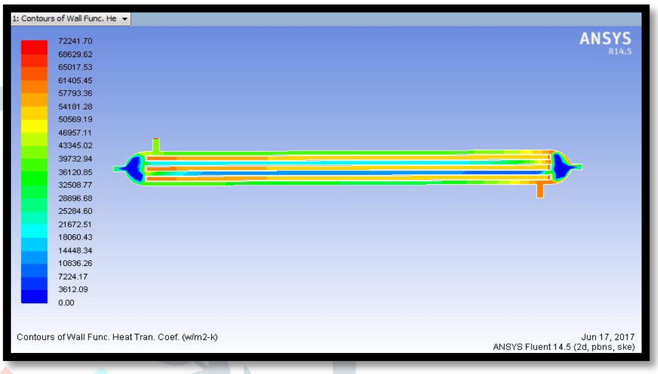


Fig 10: heat transfer coefficient

VOLUME FRACTION - 0.5

TITANIUN CARBIDE NANO FLUID VOLUME FRACTION - 0.4

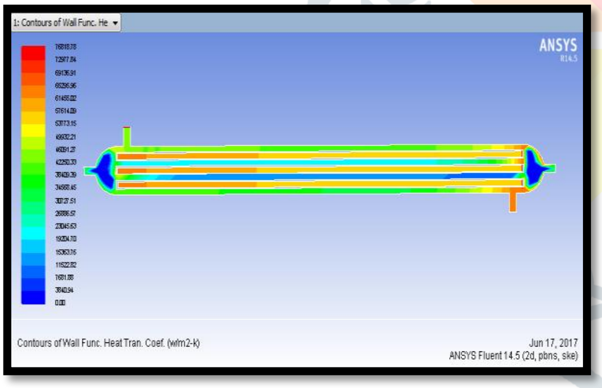


Fig 11: heat transfer coefficient

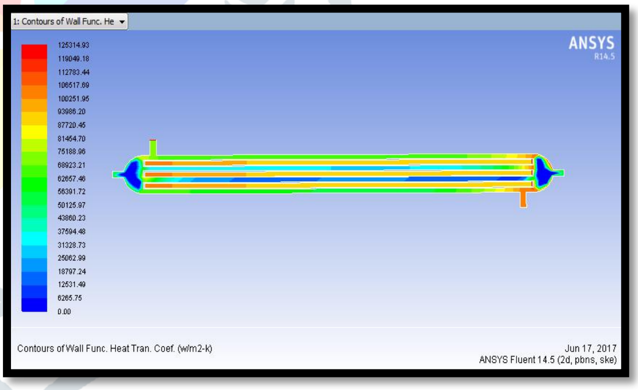


Fig 12: heat transfer coefficient

VOLUME FRACTION - 0.5

SHELL AND TUBE HEAT EXCHANGER WITH BAFFLES
BAFFLE AT 90^0
FLUID- TITANIUM CARBIDE
VOLUME FRACTION AT 0.4

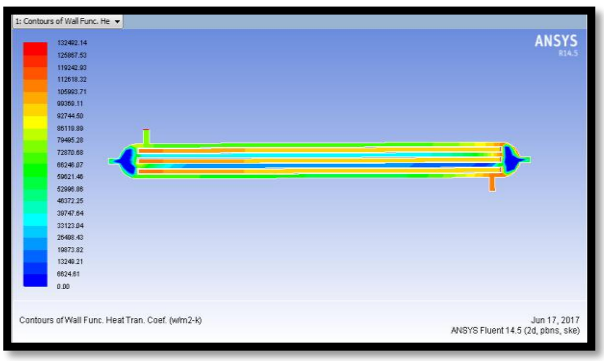


Fig 13: heat transfer coefficient

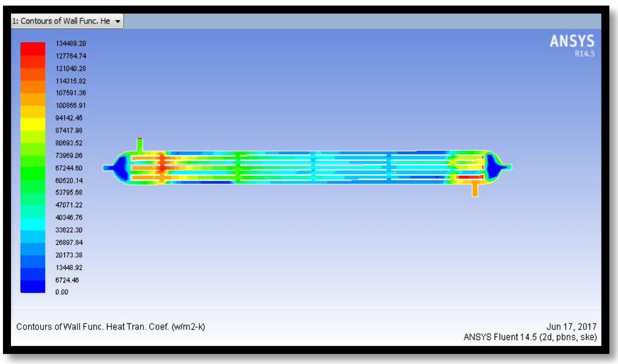


Fig 14: heat transfer coefficient

FLUID- TITANIUM CARBIDE VOLUME FRACTION AT 0.4

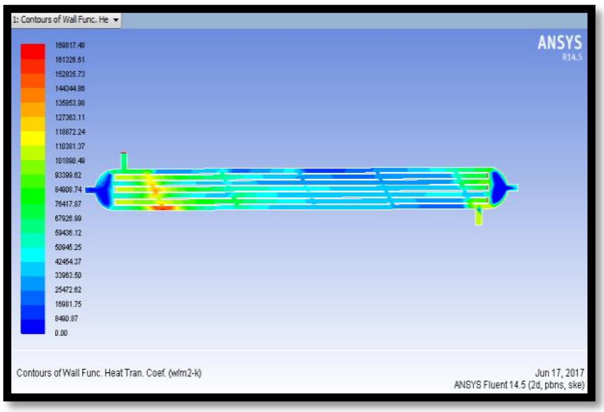


Fig 15: heat transfer coefficient

HELIX TYPE BAFFLE FLUID- TITANIUM CARBIDE VOLUME FRACTION AT 0.4

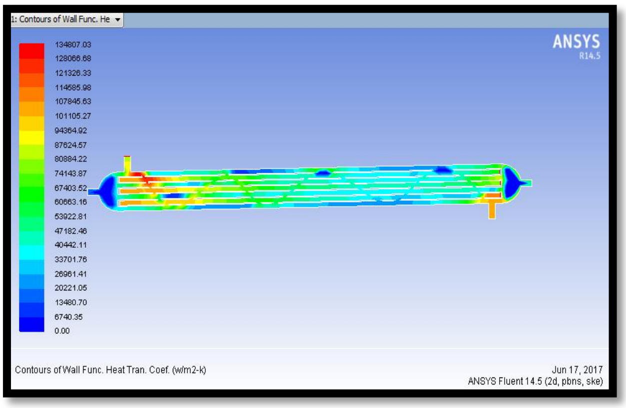


Fig 16: heat transfer coefficient

RESULTS AND DISCUSSION

Without baffles

Fluid	Pressure (pa)	Velocity (m/s)	Heat transfer co-effient (w/mm2)	Mass flow rate(kg/s)	Heat transfer rate(w)
Water	1888796.58	16.47	852.9039	2.8782	114868
Al_2O_3 (ϕ=0.4)	879568	7.65	7224170	3.249939	39747
Al_2O_3 (ϕ=0.5)	783056.75	6.75	76818.78	9.56622	63635
TiC (ϕ=0.4)	735876.00	6.40	125314.93	3.247	117724
TiC (ϕ=0.5)	644358.94	5.55	132492.14	9.56988	164684

With baffles: Angle 90^0

Fluid	Pressure (pa)	Velocity (m/s)	Heat transfer co-effient (w/mm2)	Mass flow rate(kg/s)	Heat transfer rate(w)
Water	1182148.25	15.20	12928.53	36.38739	3650804
Al_2O_3 (ϕ=0.4)	545987.94	7.06	7654.60	23.547791	1091974
Al_2O_3 (ϕ=0.5)	481508	6.24	81300.73	23.543701	955547
TiC (ϕ=0.4)	456789.50	5.91	134489.20	23.548645	3234044
TiC (ϕ=0.5)	396219	5.13	141271.55	23.543884	2474464

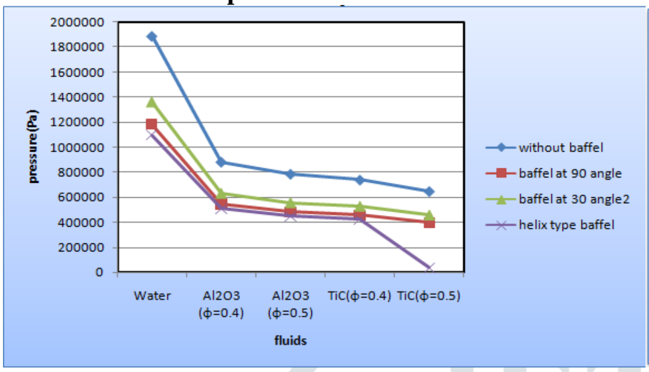
With baffles: Angle 30^0

Fluid	Pressure (pa)	Velocity (m/s)	Heat transfer co-effient (w/mm2)	Mass flow rate(kg/s)	Heat transfer rate(w)
Water	1362678.13	25.89	93815.60	9.89489	3980
Al_2O_3 (ϕ=0.4)	631890.00	12.02	96500.55	9.0525513	36144
Al_2O_3 (ϕ=0.5)	556330.81	10.60	101651.22	6.8190308	196701
TiC (ϕ=0.4)	528660.31	10.06	169817.48	9.050293	89132
TiC (ϕ=0.5)	457794.00	8.72	177823.98	6.8195801	508648

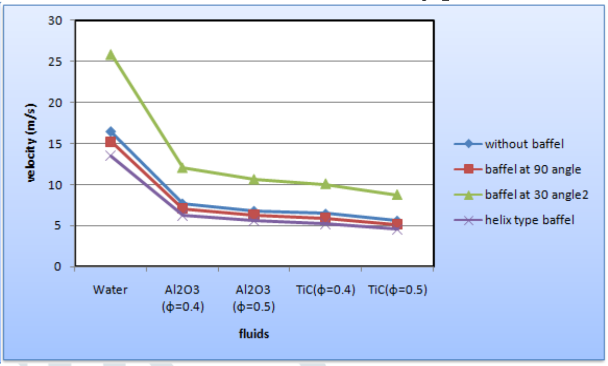
Helix type baffle

Fluid	Pressure (pa)	Velocity (m/s)	Heat transfer co-effient (w/mm2)	Mass flow rate(kg/s)	Heat transfer rate(w)
Water	1096997.63	13.44	73268.48	27.996277	3798898
Al_2O_3 (ϕ=0.4)	508751.00	6.27	77234.03	26.3483	1599823
Al_2O_3 (ϕ=0.5)	448680.88	5.54	8210213	26.182495	1384975
TiC(ϕ=0.4)	425639	5.25	134807.03	26.348969	4737586
TiC(ϕ=0.5)	36920.69	4.56	141917.66	26.180847	3587748

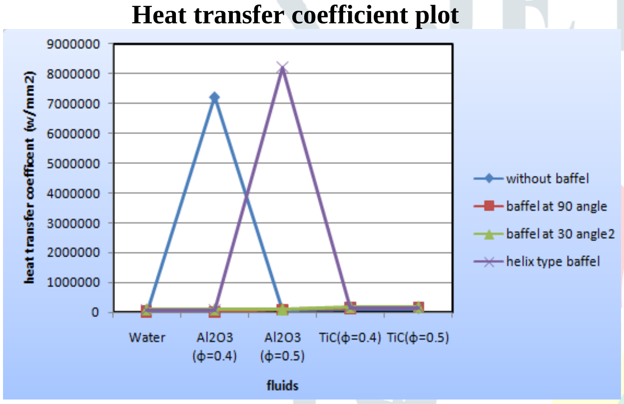
Pressure plot



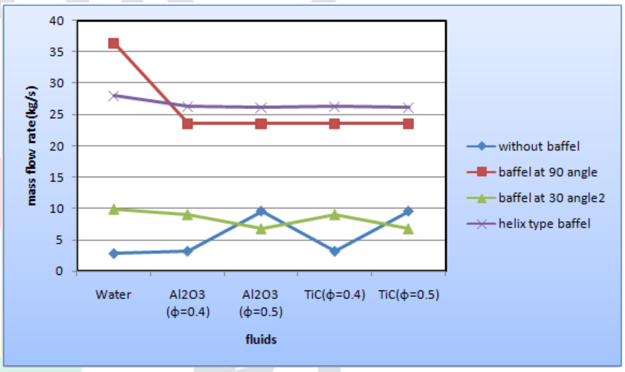
Velocity plot



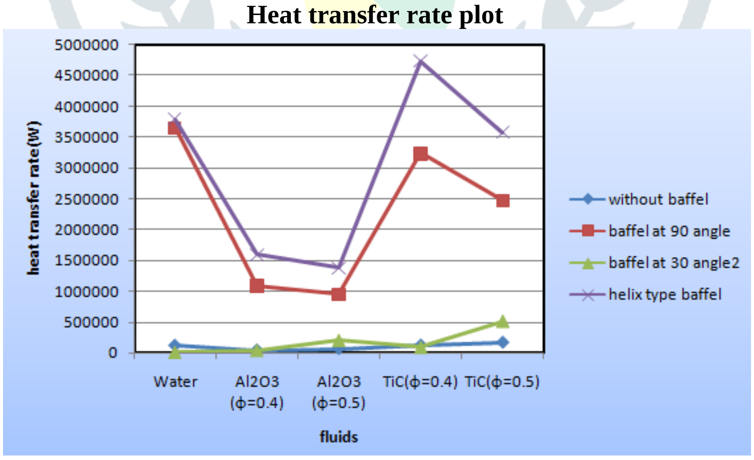
Heat transfer coefficient plot



Mass flow rate plot



Heat transfer rate plot



CONCLUSION

In this work, different nano fluids mixed with base fluid water are analyzed for their performance in the shell and tube heat exchanger without baffle and with baffle(90^0,30^0 and helical type baffle). The nano fluids are Aluminum Oxide and Titanium carbide for two volume fractions 0.4, 0.5. Theoretical calculations are done determine the properties for NANO fluids and those properties are used as inputs for analysis.

3D model of the shell and elliptical tube heat exchanger is done in CREO parametric software. CFD analysis is done in ANSYS software. By observing the CFD analysis the heat transfer rate increases for titanium carbide at volume fraction 0.4 when compare with aluminum oxide and water.

So it can be conclude the shell and tube heat exchanger with helix type baffle is the better model because the more heat transfer rate for helical type baffle shell and tube heat exchanger whe we compare the without baffle,with baffle at angle 90^0 and baffle with angle 30^0 .

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