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Design and Heat Transfer Performance of Shell and Tube Heat Exchanger by using Nano Fluids

V. Ashok Kumar [1], K. Upender [2]

Associate Professor, Mechanical Engineering, Mother Theressa College of Engg & Tech. Peddapalli, Telangana[1]

M. Tech, Student, Mechanical Engineering, Mother Theressa College of Engg. & Tech. Peddapalli, Telangana[2]

Abstract: Heat exchanger is a device used to transfer heat between one or more fluids. In this thesis, different nano fluids mixed with base fluid water are analyzed for their performance in the radiator. The nano fluids are Aluminum Oxide, Silicon Oxide and Titanium carbide for two volume fractions 0.7, 0.8. 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 tube heat exchanger is done in Pro/Engineer. CFD analysis is done on the shell and tube heat exchanger for all nano fluids and volume fraction and thermal analysis is done in Ansys for two materials Aluminum and Copper for better fluid at better volume fraction from CFD analysis.

Key words: Finite element analysis, steam boiler, CFD analysis, thermal analysis.

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.

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

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.

II. LITERATURE REVIEW

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.

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/CAE

Computer-aided design (**CAD**), also known as **computer-aided design and drafting** (**CADD**), is the use of computer technology for the process of design and design-documentation.

INTRODUCTION TO PRO-ENGINEER

Pro/ENGINEER Wildfire is the standard in 3D product design, featuring industry-leading productivity tools that promote best practices in design while ensuring compliance with your industry and company standards. Integrated Pro/ENGINEER CAD/CAM/CAE solutions allow you to design faster than ever, while maximizing innovation and quality to ultimately create exceptional products.

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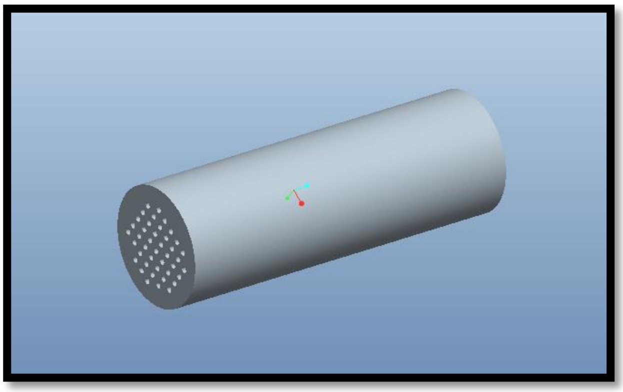
Different modules in pro/engineer
Part design, Assembly, Drawing& Sheet metal.

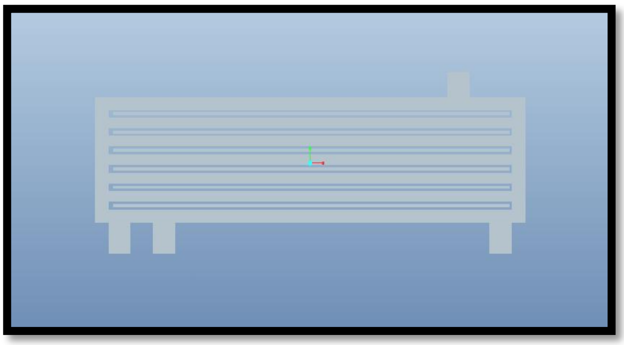
INTRODUCTION TO FINITE ELEMENT METHOD:
Finite Element Method (FEM) is also called as Finite Element Analysis (FEA). Finite Element Method is a basic analysis technique for resolving and substituting complicated problems by simpler ones, obtaining approximate solutions Finite element method being a flexible tool is used in various industries to solve several practical engineering problems. In finite element method it is feasible to generate the relative results.

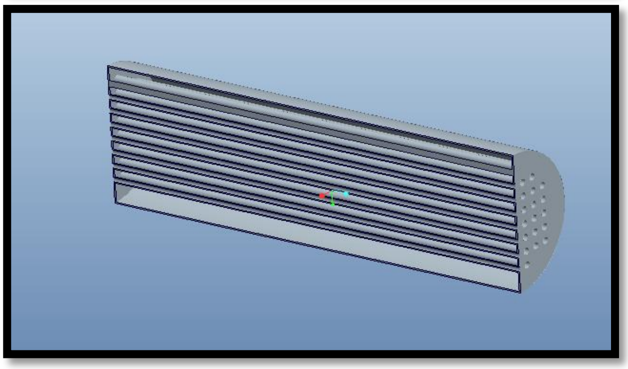
V. MODELING AND ANALYSIS

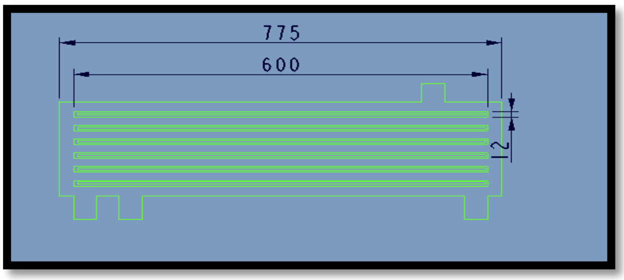
3D MODEL OF SHELL AND TUBE HEAT EXCHANGER



CUT SECTION
2D MODEL OF SHELL AND TUBE HEAT EXCHANGER







CALCULATIONS TO DETERMINE PROPERTIES OF NANO FLUID BY CHANGING VOLUME FRACTIONS

Volume fraction= 0.7 & 0.8(taken from journal paper)
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

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

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

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	0.7	15.31	1630.24	3015.46	0.0028325
	0.8	99.67	1434.59	3303	0.00309
SILICON OXIDE	0.7	1.2353	2113.24	2154.46	0.0028325
	0.8	1.3646	1923.91	2319.64	0.00309
TITANIUM CARBIDE	0.7	23.33	1309.32	3750.46	0.0028325
	0.8	31.701	1142.789	4143.64	0.00309

CFD ANALYSIS OF SHELL AND TUBE HEAT EXCHANGER

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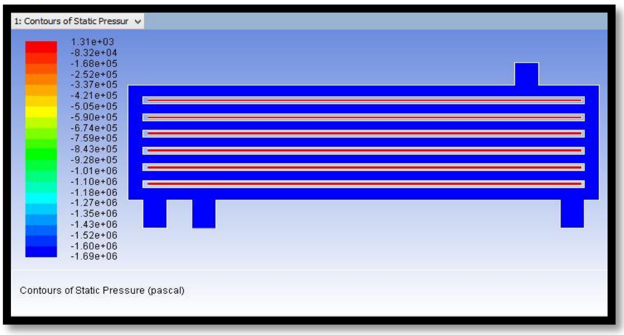
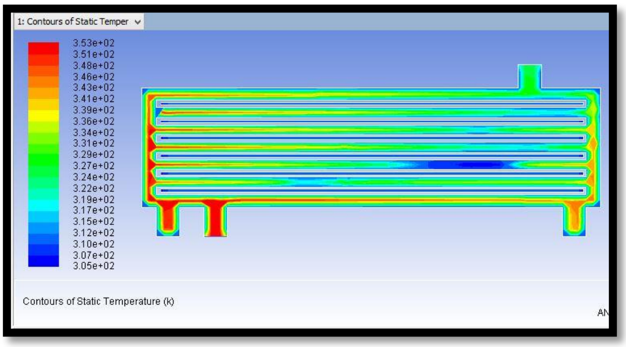
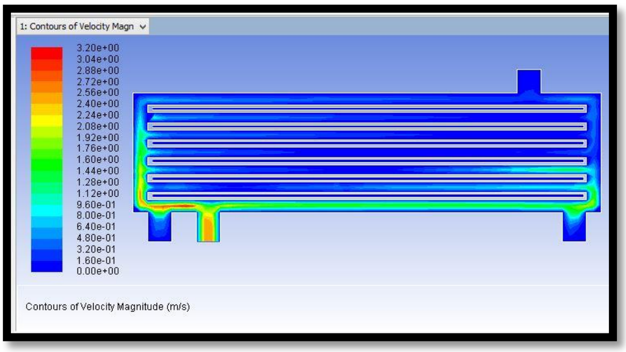
ALUMINUM OXIDE NANO FLUID VOLUME FRACTION - 0.7 STATIC PRESSURE



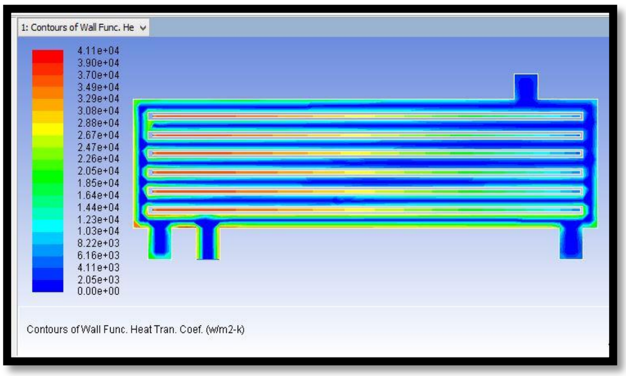
STATIC TEMPERATURE



VELOCITY MAGNITUDE



HEAT TRANSFER CO-EFFICIENT

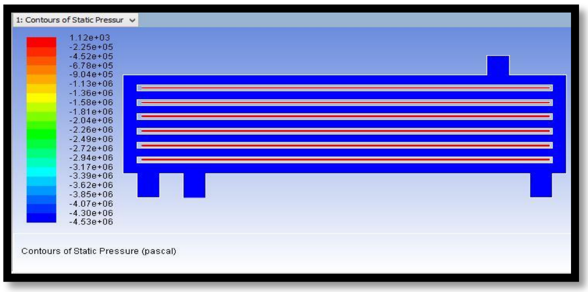


Mass Flow Rate	(kg/s)
ci	180.92766
co	0
hi	301.54593
ho	0
interior-_trm_srf	-610.22369
wall-_trm_srf	0
Net	482.47359

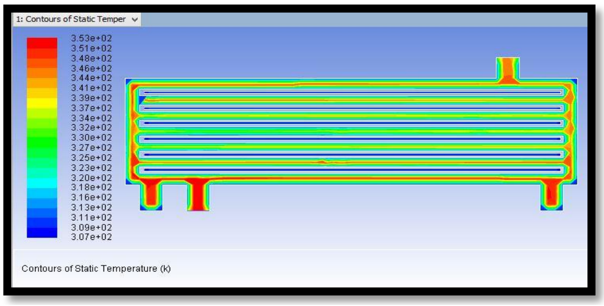
Total Heat Transfer Rate (w)

Total Heat Transfer Rate	(w)
ci	1430326.9
co	0
hi	26964406
ho	0
wall-_trm_srf	-4972388
Net	23422345

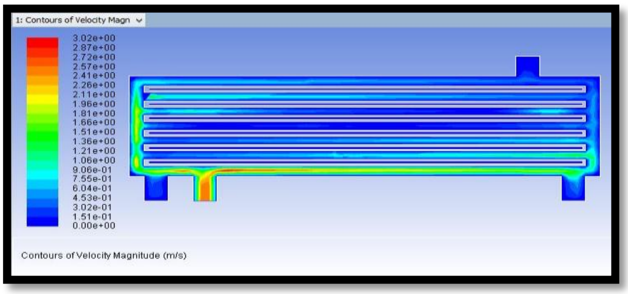
SILICON OXIDE NANO FLUID VOLUME FRACTION - 0.7 STATIC PRESSURE



STATIC TEMPERATURE



VELOCITY MAGNITUDE



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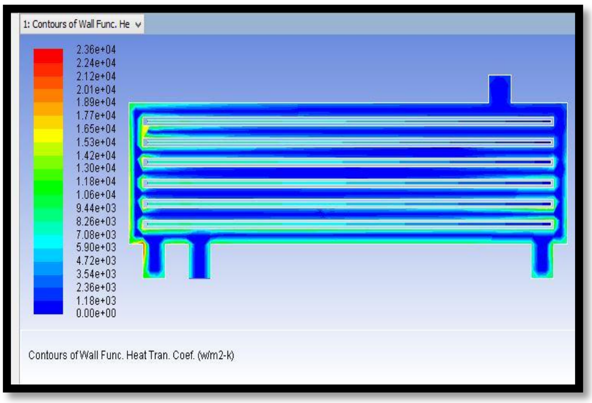
HEAT TRANSFER CO-EFFICIENT

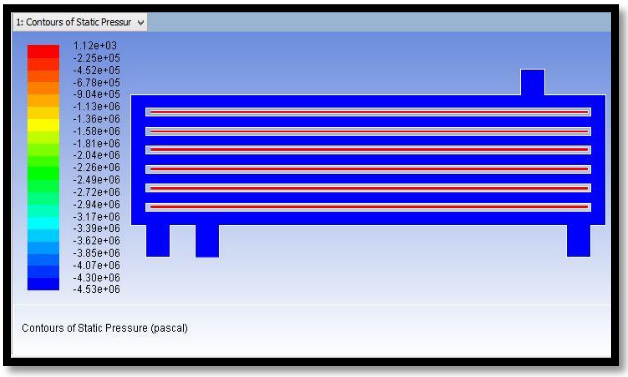


Mass Flow Rate	(kg/s)
ci	129.26764
co	0
hi	215.44594
ho	0
interior-_trm_srf	368.86679
wall-_trm_srf	0
Net	344.71358

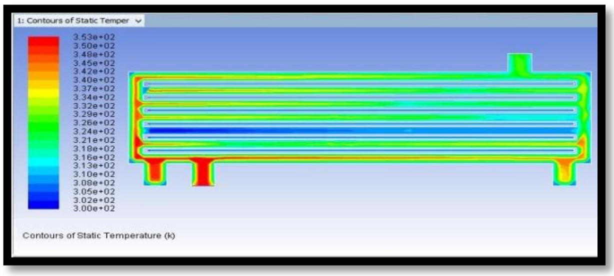
Total Heat Transfer Rate	(w)
ci	1324846.9
co	0
hi	24972764
ho	0
wall-_trm_srf	-2280731
Net	24016880

TITANIUM CARBIDE NANO FLUID VOLUME FRACTION - 0.7

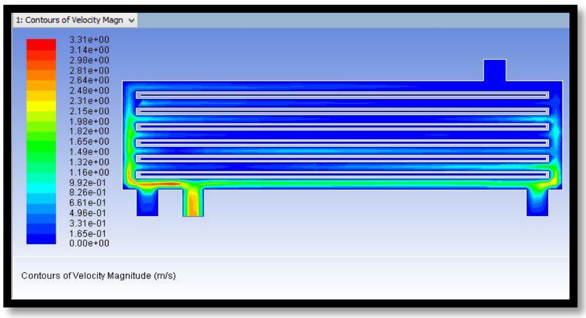
STATIC PRESSURE



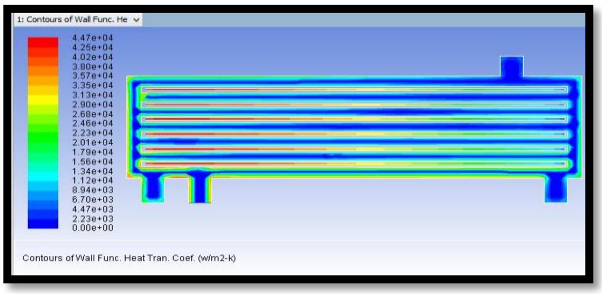
STATIC TEMPERATURE



VELOCITY MAGNITUDE



HEAT TRANSFER CO-EFFICIENT



REPORTS

Mass Flow Rate	(kg/s)
ci	225.02768
co	0
hi	375.0459
ho	0
interior-_trm_srf	2279.7739
wall-_trm_srf	0
Net	600.07358

Total Heat Transfer Rate	(w)
ci	1428730.8
co	0
hi	26934992
ho	0
wall-_trm_srf	-4784658
Net	23579065

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VI. RESULTS AND DISCUSSIONS

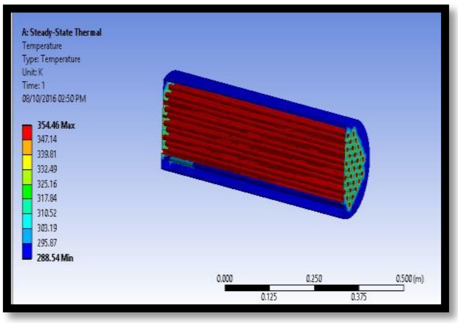
CFD ANALYSIS RESULTS

Nano fluid	Volu-me fract-ion	Pressure (pa)	Velocity (m/s)	Temperature (k)	Heat transfer coefficient (W/mm²k)	Mass flow rate (Kg/sec)	Heat transfer rate (w)
Aluminu-m oxide	0.7	1.31e+03	3.20	3.53e+02	41097.48	482.47	23422345
	0.8	1.30e+03	3.05	3.53e+02	121960.9	528.47	188877561
Silicon oxide	0.7	1.12e+03	3.02	3.53e+02	23593.3	344.713	24016880
	0.8	9.73e+02	3.04	3.53e+02	10299.48	371.14	24214383
Titanium carbide	0.7	1.16e+03	3.31	3.53e+02	44687.49	600.073	23579065
	0.8	1.24e+03	2.85	3.53e+02	89309.43	662.982	19497013

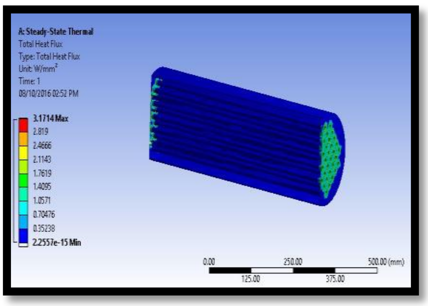
THERMAL ANALYSIS RESULTS

Aluminum alloy				Copper	
Nano fluid	Volume fraction	Temperature (K)	Heat flux (W/mm²)	Temperature (K)	Heat flux (W/mm²)
Aluminum oxide	0.7	354.46	3.17	354.13	5.7638
	0.8	354	2.03	353.71	3.692
Silicon oxide	0.7	354.25	2.5811	353.45	4.6693
	0.8	353.94	1.911	353.66	3.5042
Titanium	0.7	354.5	3.2581	354.16	5.94

THERMAL ANALYSIS OF SHELL AND TUBE HEAT EXCHANGER
MATERIAL-ALUMINUM ALLOY
ALUMINUM OXIDE NANO FLUID AT VOLUME FRACTION - 0.7
MATERIAL-COPPER ALLOY
TEMPERATURE

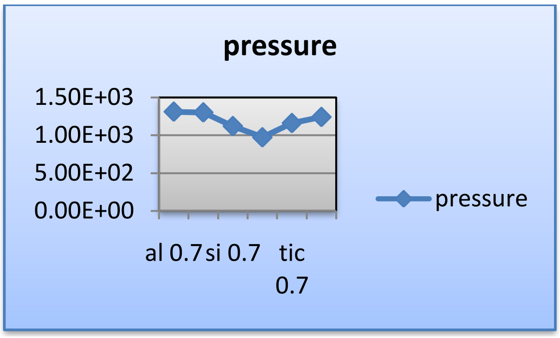


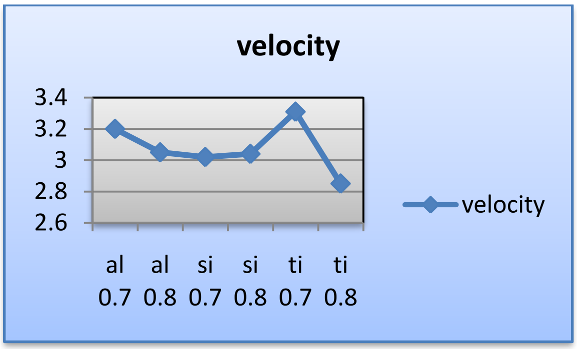
HEAT FLUX

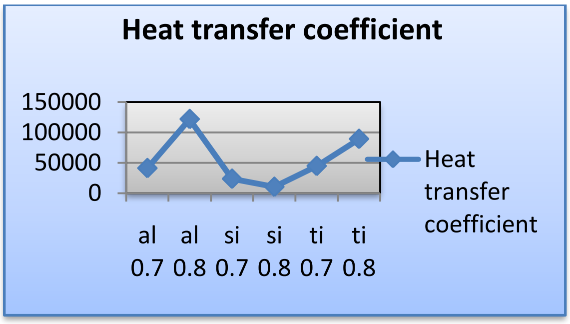


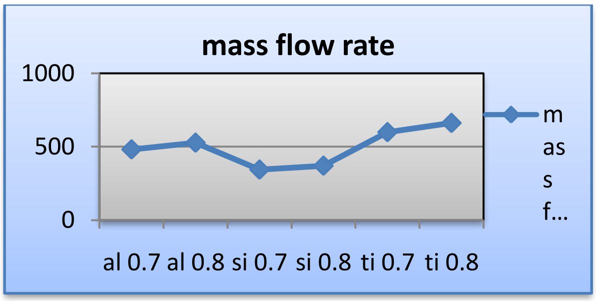
GRAPHS

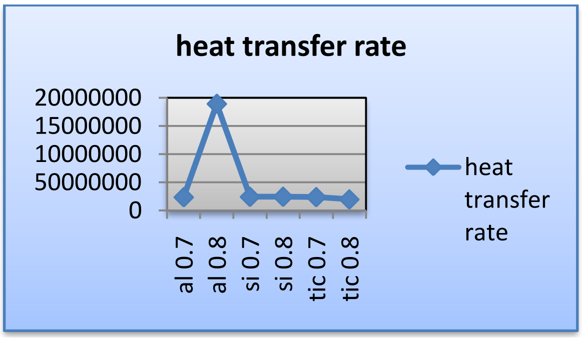
CFD analysis Graphs











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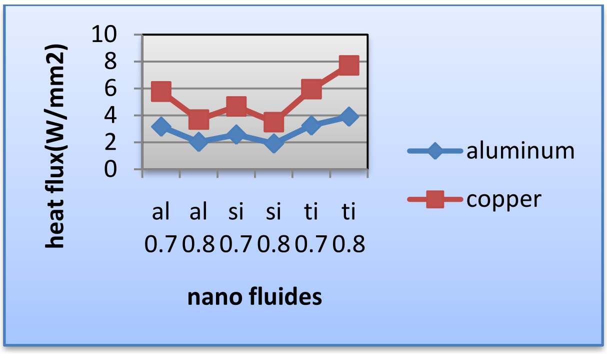
THERMAL ANALYSIS GRAPHS



VII. CONCLUSION

3D model of the shell and tube heat exchanger is done in Pro/Engineer. CFD analysis is done on the shell and tube heat exchanger for all nano fluids Aluminum Oxide, Silicon Oxide and Titanium Carbide and at different volume fractions 0.7, 0.8. By observing the CFD analysis results, the pressure are more for aluminum oxide at volume fraction of 0.7 and mass flow rate is more for titanium carbide at volume fraction of 0.8. The heat transfer coefficient and heat transfer rate are s more for Aluminum oxide at volume fraction of 0.8. Thermal analysis is done for two materials Aluminum and Copper taking heat transfer coefficient value of Aluminum oxide at 0.8 volume fractions from CFD analysis. By observing thermal analysis results, heat flux is more when Copper is used than Aluminum alloy.

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