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DESIGN AND CFD ANALYSIS OF HAIR PIN HEAT EXCHANGER AT DIFFERENT NANO-FLUIDS

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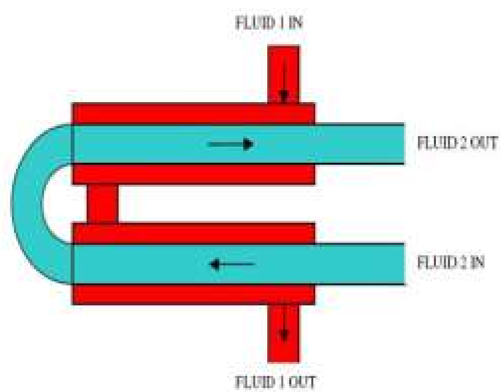
Abstract:
In this thesis, different NANO fluids mixed with base fluid water are analyzed for their performance in the hair pin heat exchanger. The NANO fluids are Aluminum Oxide and Titanium carbide for two volume fractions 0.4, 0.5. Theoretical calculations are done determine the properties for NANO fluids and those properties are used as inputs for analysis.

Keywords: *Finite element analysis, Hair pin heat exchanger, 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. 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 is 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

DESIGN AND ANAYSIS OF DOUBLE PIPE HEAT EXCHANGER USING COMPUTATIONAL METHOD 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

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ISSN: 2320-1363

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.

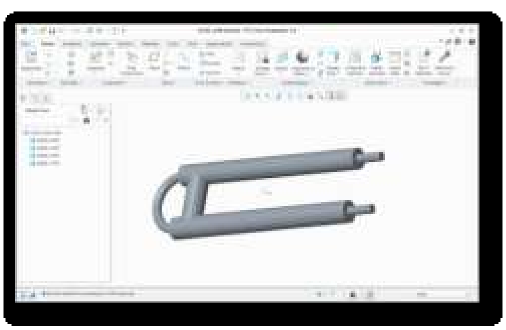
III. Dimensions of designed double tube Hair-pin heat exchanger:

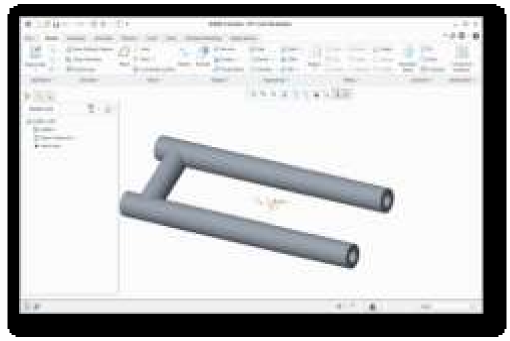
Outer pipe specification Inner tube specification

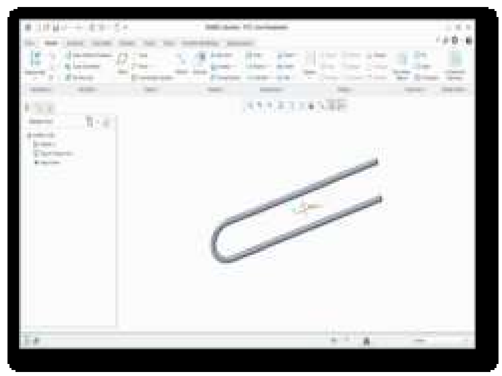
Copper tube of U bends
I.D. of shell= 19.05 mm
I.D. of tube = 8.4 mm
O.D. of shell = 22 mm
O.D. of tube = 9.5 mm
Center to center distance is taken
Wall thickness= 0.55 mm

1.5 - 1.8 times of outer dia. of shell.
Thermal conductivity of wall= 385 w/m2K
Length of each G.I. pipe =22.86cm
Effective length of copper tube through which heat transfer could take place= 45cm
Total length of the copper tube = straight part (51cm) + U-shaped bend part (9cm) =60cm

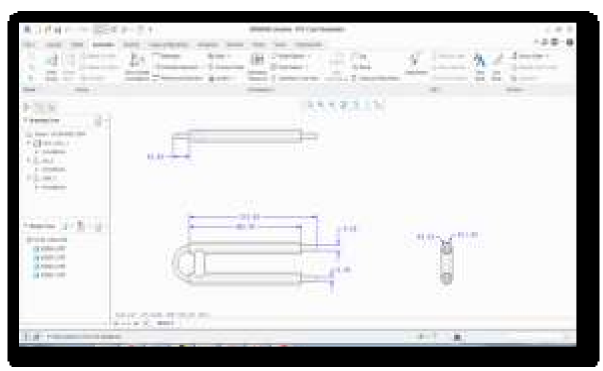
3D model of hair pin heat exchanger







2D model of hair pin heat exchanger



IV. INTRODUCTION TO FINITE ELEMENT METHOD

FEM/FEA helps in evaluating complicated structures in a system during the planning stage. The strength and design of the model can be improved with the help of computers and FEA which justifies the cost of the analysis. FEA has prominently increased the design of the structures that were built many years ago.

INTRODUCTION TO CFD

ISSN: 2320-1363

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.

CALCULATIONS TO DETERMINE PROPERTIES OF NANO FLUID BY CHANGING VOLUME FRACTIONS

NANO FLUID CALCULATIONS

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)

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

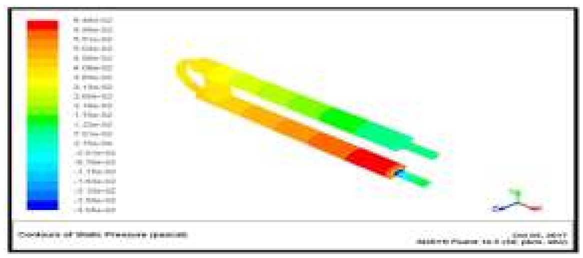
FLUID	Volume fraction	Thermal conductivity (w/m-k)	Specific heat (J/kg-k)	Density (kg/m^3)	Viscosity (kg/m-s)
ALUMINUM OXIDE	0.4	2.647	1809	2150.92	0.002006
	0.5	4.17	1570.9	2439.1	0.002256
TITANIUM CARBIDE	0.4	2.625	5357.01	2570.92	0.002006
	0.5	4.12	4069.1	2964.1	0.002256

CFD ANALYSIS OF HAIR PIN HEAT EXCHANGER

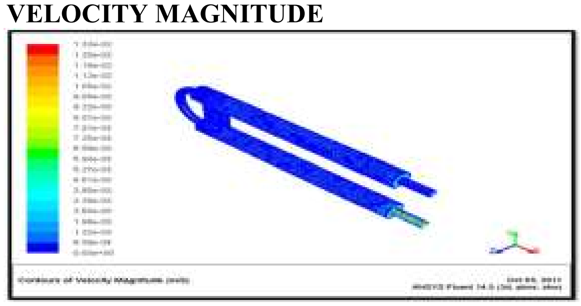
ALUMINUM OXIDE NANO FLUID

VOLUME FRACTION - 0.4

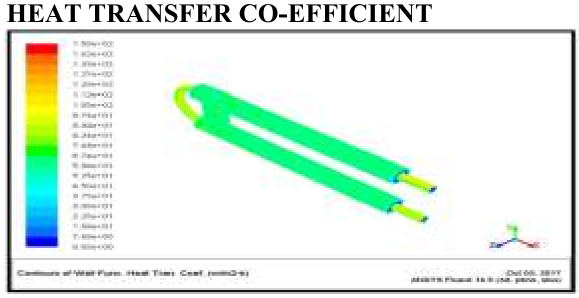
STATIC PRESSURE



VELOCITY MAGNITUDE



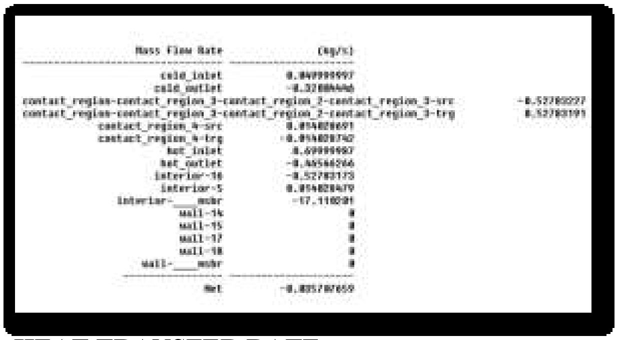
HEAT TRANSFER CO-EFFICIENT



IJMTARC – VOLUME – V – ISSUE - 19 – SEPT 2017

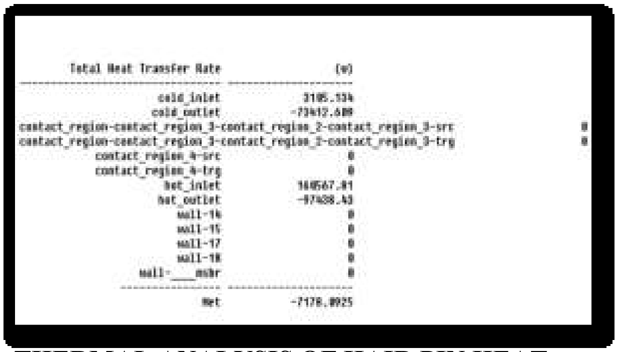
ISSN: 2320-1363

MASS FLOW RATE



Mass Flow Rate	(kg/s)
cold_inlet	0.049999997
cold_outlet	-0.32004446
contact_region-contact_region_3-contact_region_2-contact_region_3-src	-0.52703227
contact_region-contact_region_3-contact_region_2-contact_region_3-trg	0.52703191
contact_region_4-src	0.054028691
contact_region_4-trg	-0.054028742
hot_inlet	0.69999987
hot_outlet	-0.44566266
interior-16	-0.52703173
interior-5	0.054028479
interior-___msbr	-17.110201
wall-14	0
wall-15	0
wall-17	0
wall-18	0
wall-___msbr	0
Net	-0.035707659

HEAT TRANSFER RATE

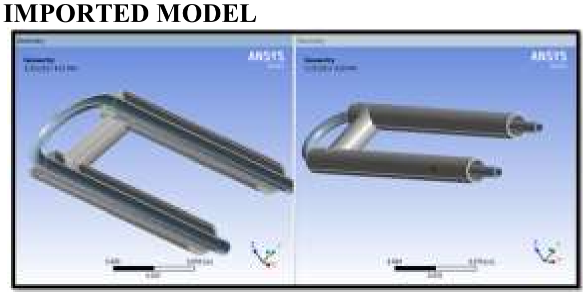


Total Heat Transfer Rate	(w)
cold_inlet	3105.334
cold_outlet	-73412.608
contact_region-contact_region_3-contact_region_2-contact_region_3-src	0
contact_region-contact_region_3-contact_region_2-contact_region_3-trg	0
contact_region_4-src	0
contact_region_4-trg	0
hot_inlet	160567.01
hot_outlet	-97438.43
wall-14	0
wall-15	0
wall-17	0
wall-18	0
wall-___msbr	0
Net	-7178.0925

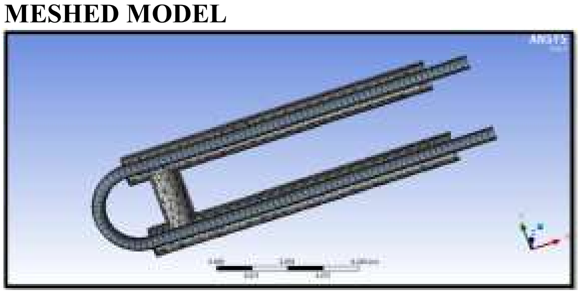
THERMAL ANALYSIS OF HAIR PIN HEAT EXCHANGER

MATERIAL-COPPER

IMPORTED MODEL

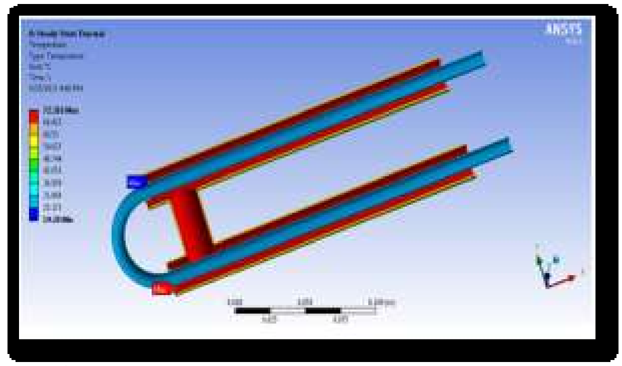


MESHED MODEL

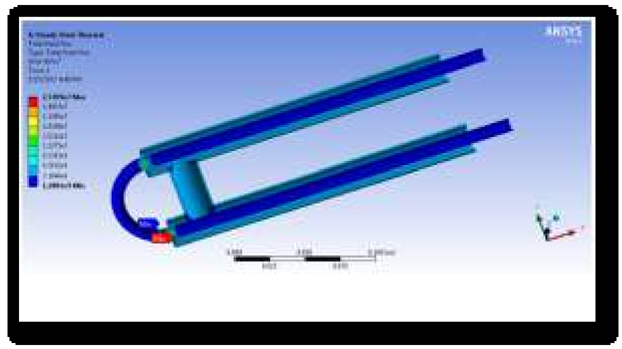


BOUNDARY CONDITIONS

TEMPERATURE



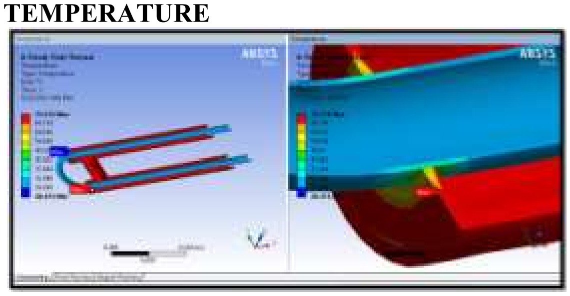
HEAT FLUX



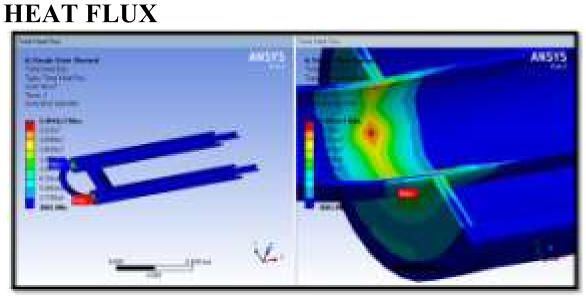
RATE THERMAL ANALYSIS OF HAIR PIN HEAT EXCHANGER

MATERIAL-ALUMINUM

TEMPERATURE



HEAT FLUX



ISSN: 2320-1363

V. RESULT TABLES

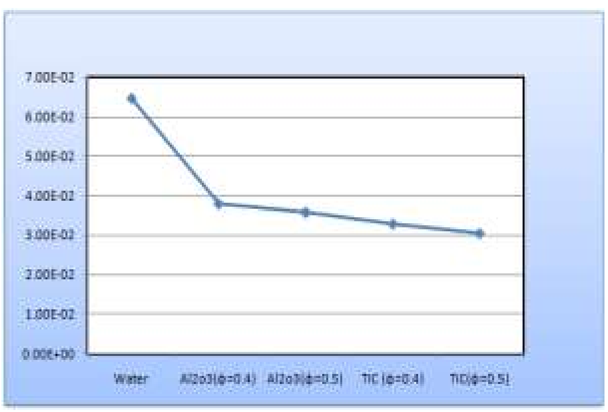
CFD RESULT TABLES THERMAL ANALSIS RESULTS TABLES

Fluid	Pressure (Pa)	Velocity (m/s)	Heat transfer coefficient (w/m2-k)	Mass flow rate(kg/s)	Heat transfer rate(W)
Water	6.46e-02	1.32e-02	1.50e+02	0.035707	7178.0925
Al2o3(ϕ=0.4)	3.79e-02	6.31e-03	6.61e+02	0.05145	4613.6967
Al2o3(ϕ=0.5)	3.58e-02	5.64e-03	1.04e+03	0.0515709	4078.4819
TiC (ϕ=0.4)	3.29e-02	5.30e-03	6.56e+02	0.0525819	14320.233
TiC(ϕ=0.5)	3.05e-02	4.62e-03	1.03e+03	0.058124	11510.686

Material	Temperature (°C)		Heat flux(w/m²)
	Min.	Max.	
Aluminum alloy	20.471	72.111	2.4941e7
copper	19.28	72.316	2.7459e7

CFD ANALYSIS GRAPHS

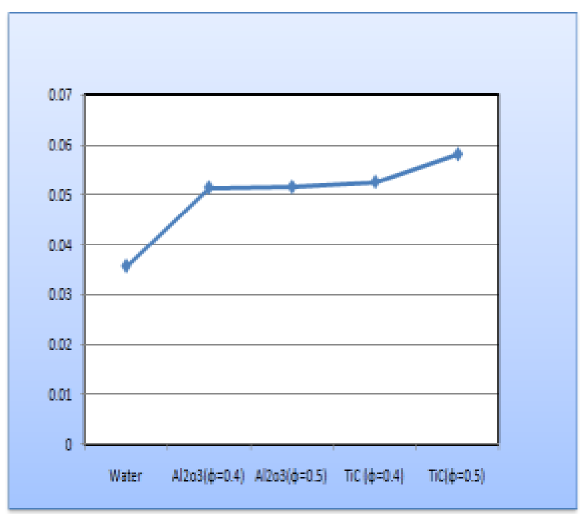
PRESSURE PLOT



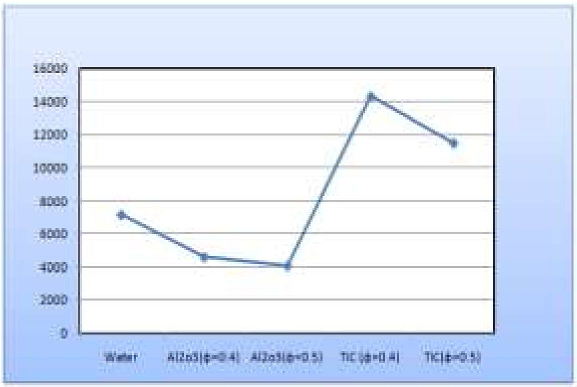
VELOCITY PLOT

HEAT TRANSFER COEFFICIENT PLOT

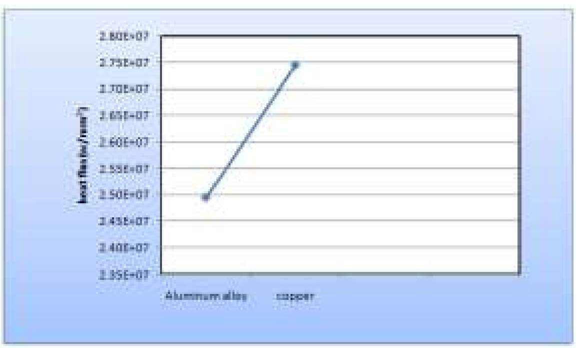
MASS FLOW RATE PLOT



HEAT TRANSFER RATE PLOT



THERMAL ANALYSIS GRAPHS



VI. CONCLUSION

Hairpin Exchangers are available in unmarried tube (Double Pipe) or a couple of tubes within a hairpin shell (Multitude), naked tubes, finned tubes, U-tubes, straight tubes (with rod-through functionality), constant tube sheets and removable package deal.

By looking at the CFD analysis results the heat transfer coefficient at titanium carbide volume fraction 0.4.

By observing the thermal analysis consequences the heat flux cost more for copper material evaluated with aluminum alloy.

So it is able to be concluded the titanium carbide nano fluid at quantity fraction 0.5 fluid is the higher fluid for hair pin warmness exchanger and material is copper.

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