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Heat Transfer Performance of Double Tube Hairpin Heat Exchager by Using Cfd Analysis with Mgo Nano Fluidat Different Volume Fractions

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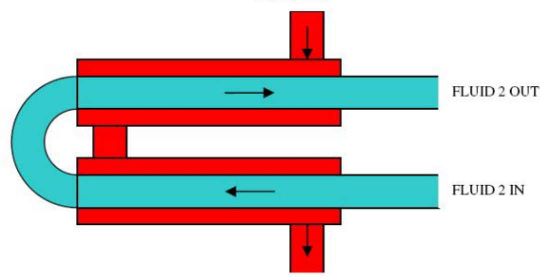
Abstract:
Heat exchanger is a device used to transfer heat between one or more fluids. The fluids may be separated by a solid wall to prevent mixing or they may be in direct contact. In this thesis, MgO nano fluid is mixed with base fluid water is analyzed for their performance in the hair pin heat exchanger. The nano fluid MgO is mixed with water at different volume fractions (0.000625, 0.00125, 0.0025, 0.005 and 0.01). Theoretical calculations are done determine the properties for nano fluids and those properties are used as inputs for analysis.

3D model of the hair pin heat exchanger is done in CREO parametric software. CFD analysis is done on the hair pin heat exchanger with MgO nano fluid at different volume fractions and thermal analysis is done in ANSYS for two materials Aluminum7085 and Copper.

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 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.

Keywords— Thermal, Heat transfer, Computational Flow Dynamics (CFD), Modeling, Heat Flux, Heat transfer Coefficient

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III. 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

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.

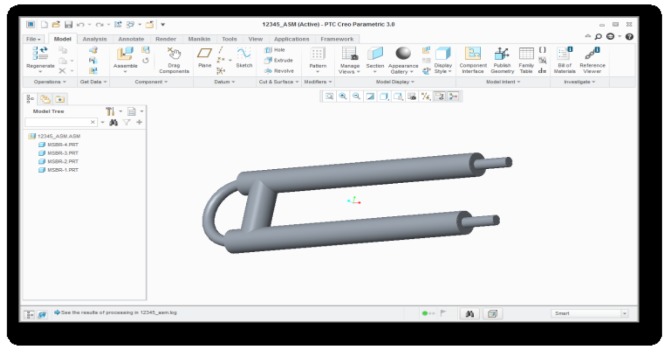
Dimensions of designed double tube Hair-pin heat exchanger:

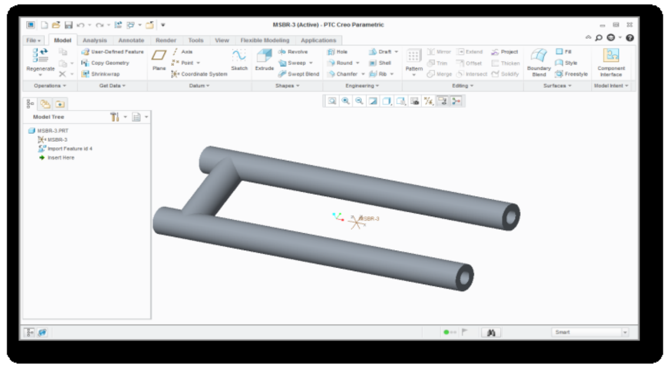
Outer pipe specification Inner tube specification

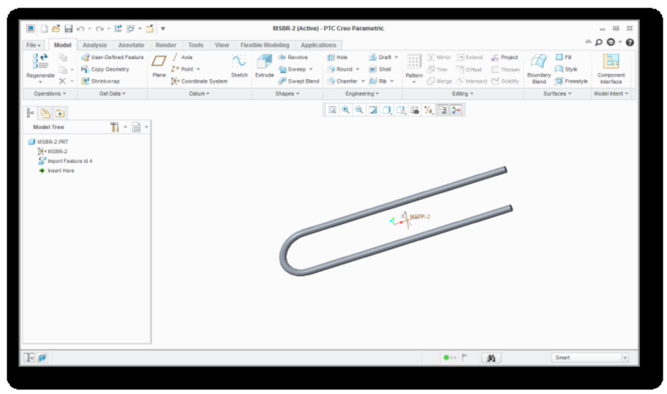
Copper tube of U bends
I.D. of shell= 19.05 mm
I.D. of tube = 8.4 mm
Copper tube of U bends
I.D. of shell= 19.05 mm
I.D. of tube = 8.4 mm
O.D. of shell = 22 mm O.D. of tube = 9.5 mm
Center to center distance is taken
Wall thickness= 0.55 mm

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

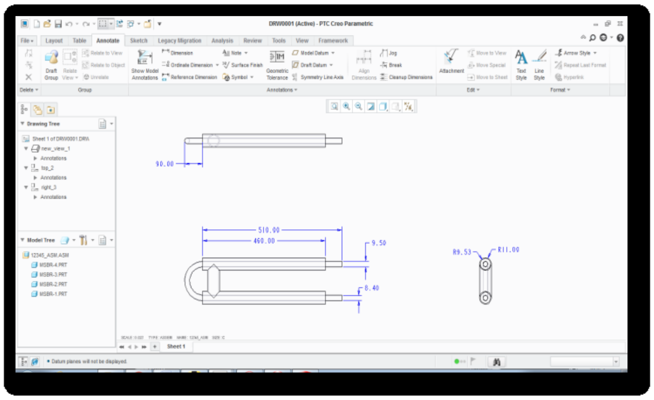
3D model of hair pin heat exchanger







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

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

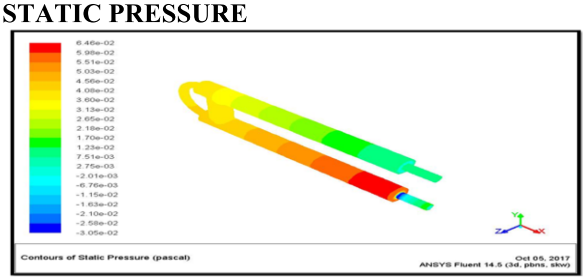
$$K_{nf} = \frac{Ks+2Kw+2(Ks-Kw)(1+\beta)^3\times\phi}{Ks+2Kw-2(Ks-Kw)(1+\beta)^3\times\phi} \times k_w$$

CFD ANALYSIS OF HAIR PIN HEAT EXCHANGER

MAGNESIUM OXIDE NANO FLUID

VOLUME FRACTION - 0.01

STATIC PRESSURE



VELOCITY MAGNITUDE

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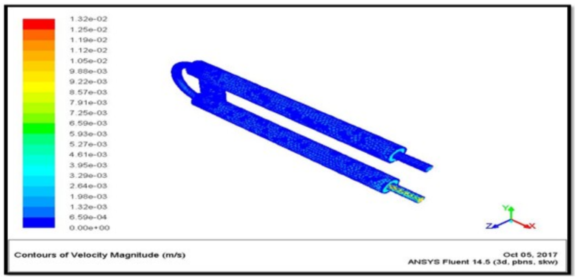
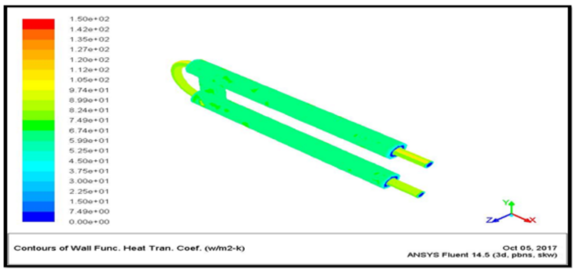
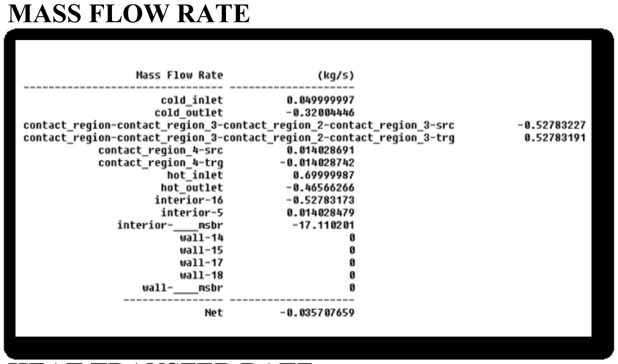


HEAT TRANSFER CO-EFFICIENT

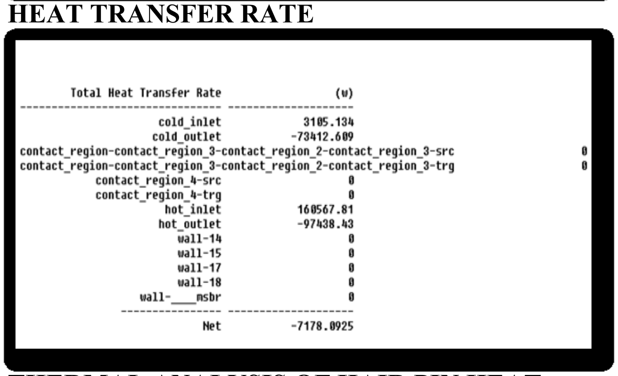


MASS FLOW RATE



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	-0.52783227
contact_region-contact_region_3-contact_region_2-contact_region_3-trg	0.52783191
contact_region_4-src	0.014028691
contact_region_4-trg	-0.014028742
hot_inlet	0.69999987
hot_outlet	-0.46566266
interior-16	-0.52783173
interior-5	0.014028479
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

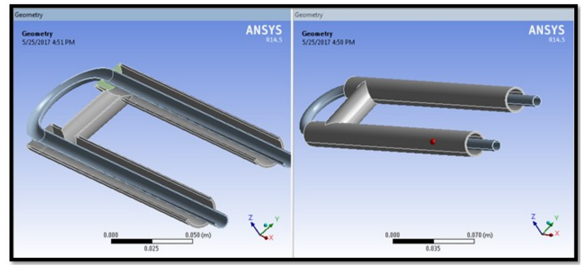


Total Heat Transfer Rate	(w)
cold_inlet	3105.134
cold_outlet	-73412.609
contact_region-contact_region_3-contact_region_2-contact_region_3-src	0
contact_region-contact_region_3-contact_region_2-contact_region_3-trg	0
contact_region_4-src	0
contact_region_4-trg	0
hot_inlet	160567.81
hot_outlet	-97438.43
wall-14	0
wall-15	0
wall-17	0
wall-18	0
wall-____msbr	0
Net	-7178.0925

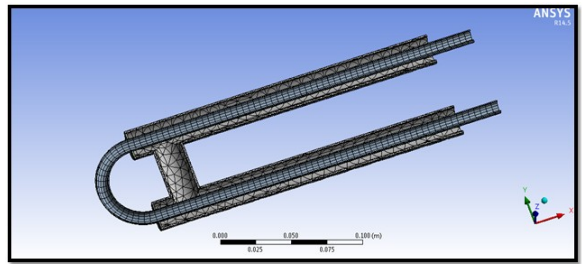
THERMAL ANALYSIS OF HAIR PIN HEAT EXCHANGER

MATERIAL-COPPER

IMPORTED MODEL

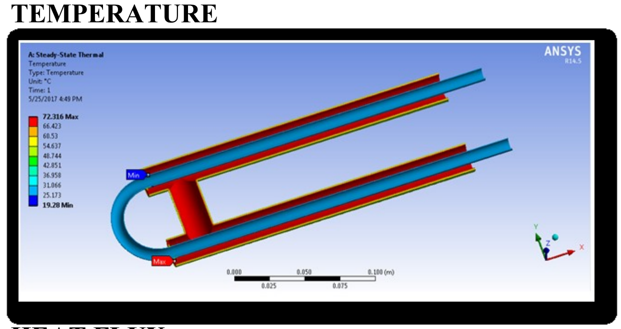


MESHED MODEL

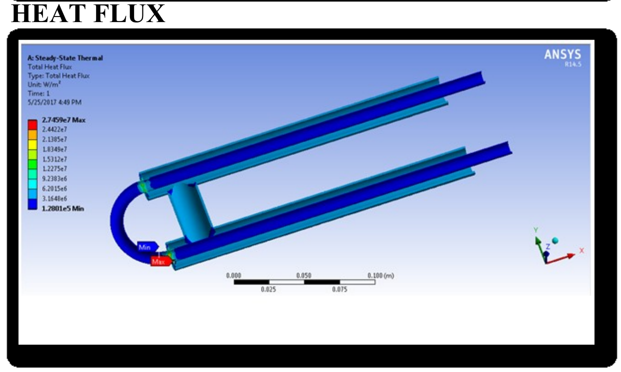


BOUNDARY CONDITIONS

TEMPERATURE



HEAT FLUX



THERMAL ANALYSIS OF HAIR PIN HEAT EXCHANGER

MATERIAL-ALUMINUM

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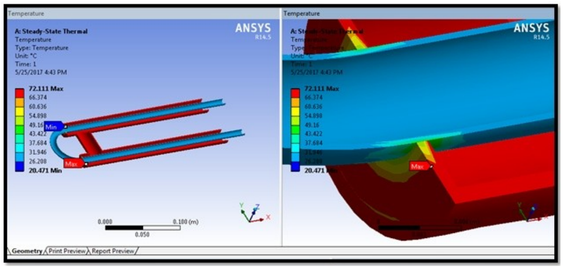
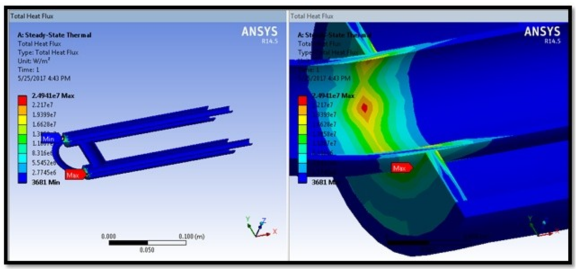
TEMPERATURE



HEAT FLUX



V.RESULT TABLES

CFD RESULT TABLES

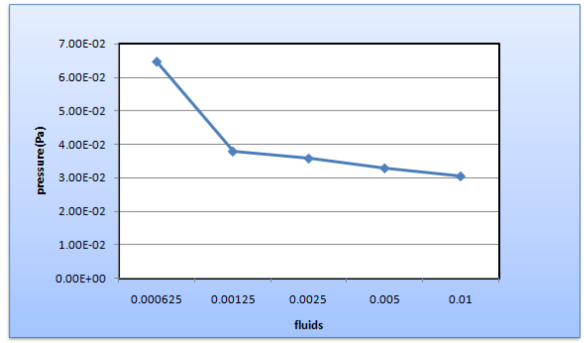
Fluid	Pressure (Pa)	Velocity (m/s)	Heat transfer coefficient (w/m2-k)	Mass flow rate(kg/s)	Heat transfer rate(W)
0.000625	6.46e-02	1.32e-02	1.50e+02	0.035707	7178.0925
0.00125	3.79e-02	6.31e-03	6.61e+02	0.05145	4613.6967
0.0025	3.58e-02	5.64e-03	1.04e+03	0.0515709	4078.4819
0.005	3.29e-02	5.30e-03	6.56e+02	0.0525819	14320.233
0.01	3.05e-02	4.62e-03	1.03e+03	0.058124	11510.686

THERMAL ANALSIS RESULTS TABLES

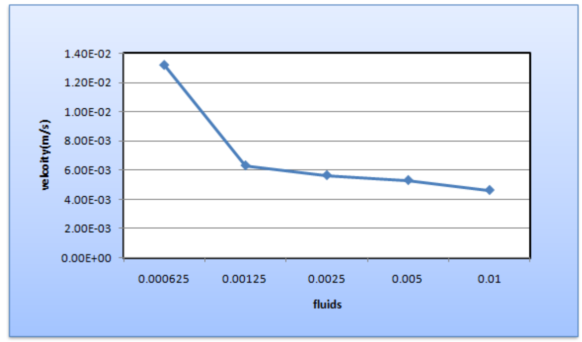
Material	Temperature (^{0}C)		Heat flux(w/m^2)
	Min.	Max.	
Aluminum alloy	20.471	72.111	2.4941e7
copper	19.28	72.316	2.7459e7

CFD ANALYSIS GRAPHS

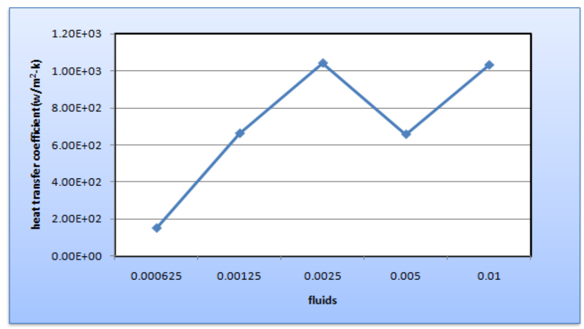
PRESSURE PLOT



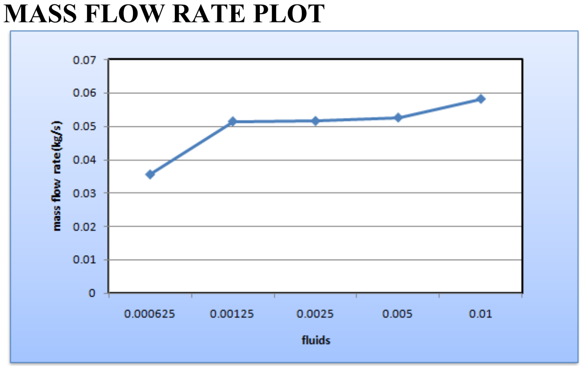
VELOCITY PLOT



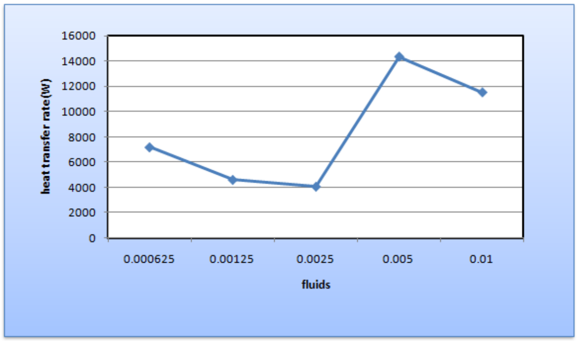
HEAT TRANSFER COEFFICIENT PLOT



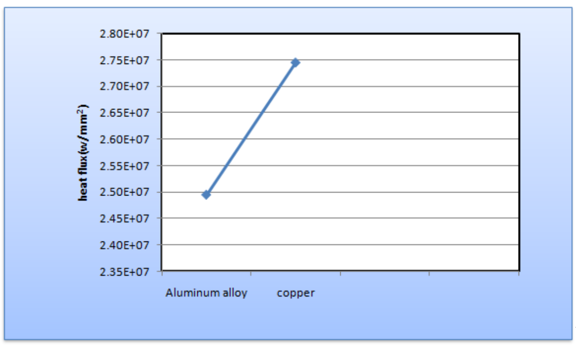
MASS FLOW RATE PLOT



HEAT TRANSFER RATE PLOT



THERMAL ANALYSIS GRAPHS



VI. CONCLUSION

In this thesis, MgO nano fluid is mixed with base fluid water are analyzed for their performance in the hair pin heat exchanger. The nano fluid is magnesium Oxide for FIVE volume fractions 0.000625, 0.00125, 0.0025, 0.005 & 0.01. Theoretical calculations are done determine the properties for nano fluids and those properties are used as inputs for analysis. Hairpin Exchangers are available in single tube (Double Pipe) or multiple tubes within a hairpin shell (Multitude), bare tubes, finned tubes, U-tubes, straight tubes (with rod-thru capability), fixed tube sheets and removable bundle.

By observing the CFD analysis results the heat transfer rate value more at magnesium oxide volume fraction 0.01.

By observing the thermal analysis results the heat flux value more for copper material compare with aluminum alloy7085.

So it can be concluded the magnesium oxide nano fluid at volume fraction 0.01 fluid is the better fluid for hair pin heat exchanger and material is copper.

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