A PROJECT ON

Design and analysis of hair pin heat exchanger

By using different 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. 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.

In this project, nano fluid is mixed with base fluid water are calculated for their combination properties. The nano fluids are magnesium Oxide and silver nano particle volume fractions 0.35, 0.45,0.55 % at different velocities (0.5,1,1.5 m/s). Theoretical calculations are to determine the properties for nano fluids and those properties are used as inputs for analysis.

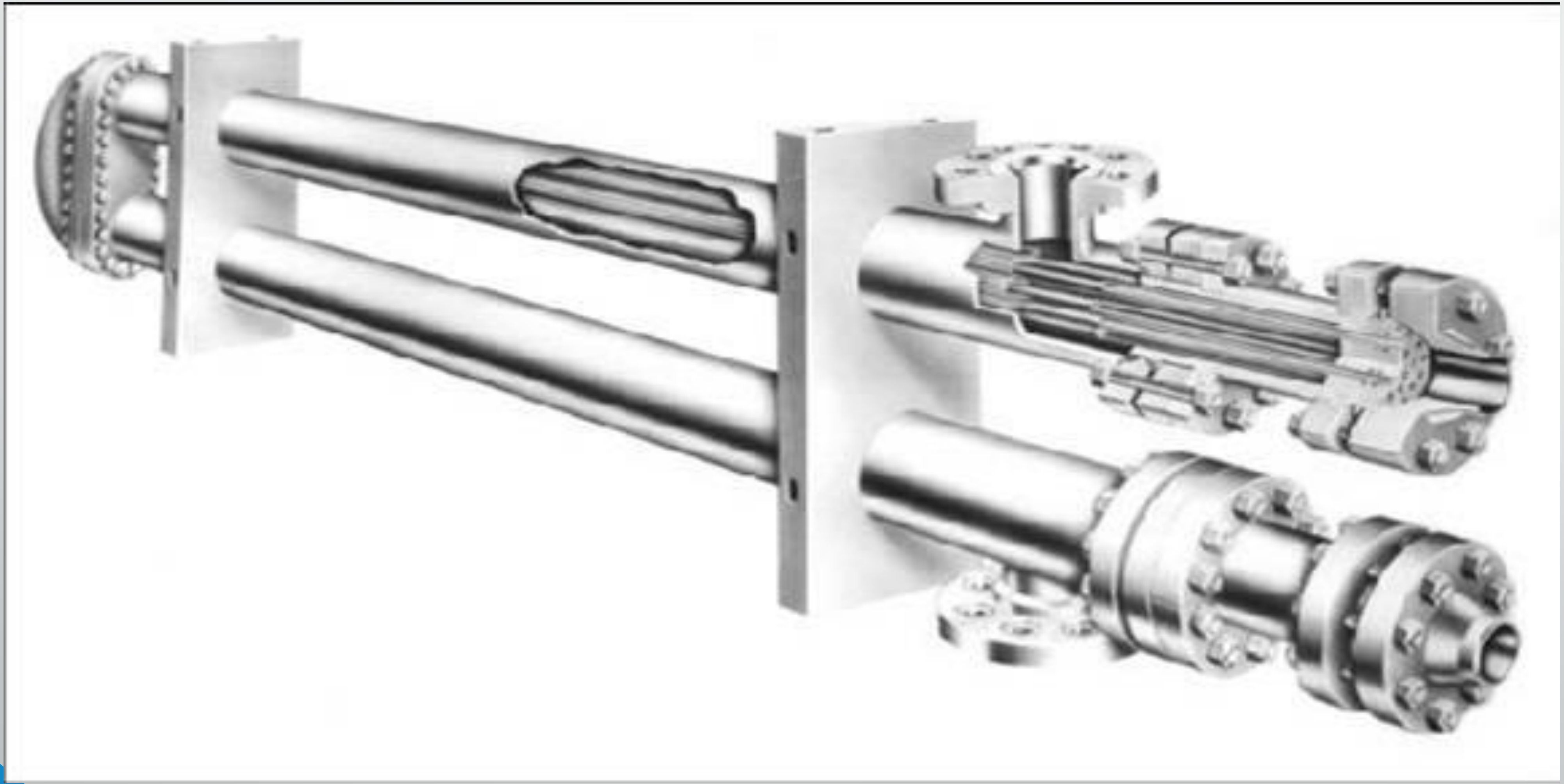
3D model of the hair pin heat exchanger with and without twisted tape model is done in CREO parametric software. CFD analysis is done on the hair pin heat exchanger at different nano fluid volume fractions. analysis is to determine the pressure drop, heat transfer coefficient .

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.

- Classifications of heat exchangers:
- Tubular heat exchangers
- Plate heat exchangers
- Air cooled heat exchangers
- Hair pin heat exchangers

HAIR PIN HEAT EXCHNAGER:



Advantages:

- The U shape bundle is free for expansion and contraction inside the Hairpin shell eliminating the need for expansion joint.
- For processes that require frequent mechanical cleaning, bare tube offers ease of cleaning and accessibility.
- Bare Multi-Tube and Double-Pipe Exchangers offer the least pressure drop among most exchangers.
- Offers a more thermally efficient design with a smaller shell than traditional shell-and-tube heat exchangers.
- It allows a good mechanical cleaning .

Advantages of hairpin-style Heat Exchangers:

- Smaller Equipment Footprint
- Differential Thermal Expansion
- High Terminal Temperature Gradients
- Thermally Efficient

HAIRPIN HEAT EXCHANGER DESIGN FEATURES

- No Removable tube bundles
- Removable Tube bundles
- Return Housing Cover design

DESCRIPTION

Heat Exchangers are primarily used for transfer the heat. Design of heat exchanger is one of the key factor for compact devices. The requirement of heat exchanger like hair pin heat exchanger is proposed where the heat transfer rate is low . Suitable applications are refrigeration, air conditioning and space heating etc. Current study presents the investigation on hairpin exchanger using two different nanofluids mixed with base fluid individually at 0.6 and 0.5 percent volume fractions and analyzed the performance using Computational Fluid Dynamics in the hair pin heat exchanger . Dispersion of nanoparticles in base fluid has emerged to enhance the thermal conductivity and rate of heat transfer. Computational fluid dynamic analysis is performed by applying the properties of nanofluids as input.

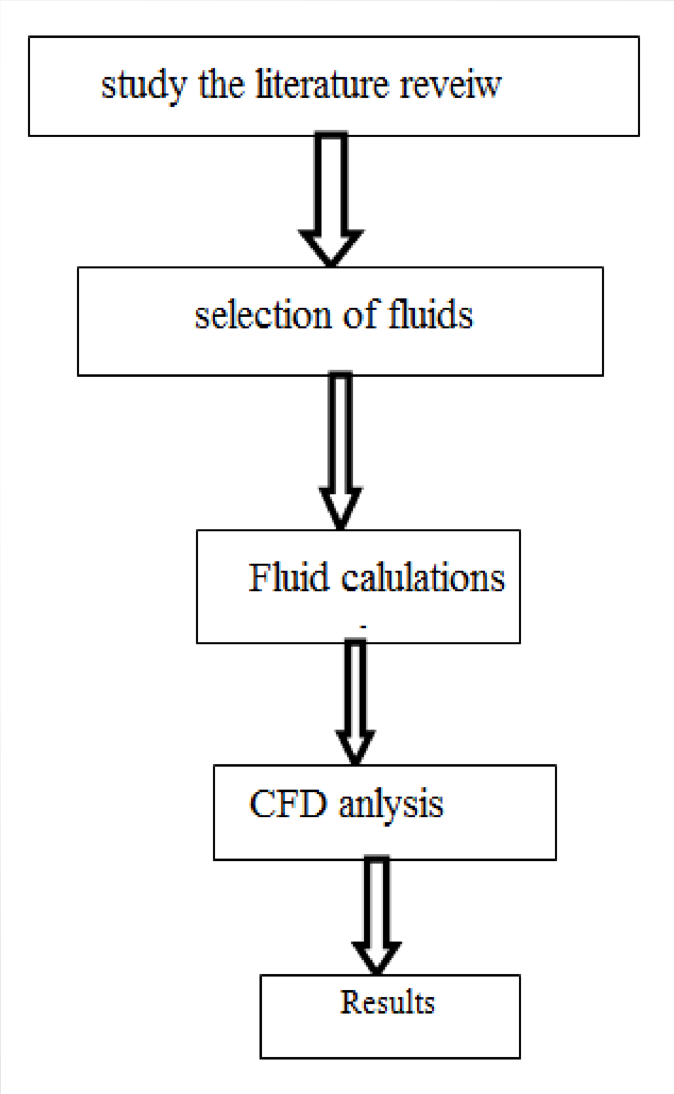
PRESENT WORK Objectives of the project:

The following are the main objectives of the present work:

- To design hair pin heat exchanger by varying the geometry such as with twisted tape and without twisted tape at different nano fluids.

- To determine the heat transfer coefficient, pressure, velocity and heat transfer rate with help of CFD analysis

- To identify suitable fluid for the based on results obtained from finite element analysis



MODELING AND ANALYSIS

CAD (Computer Aided Design) is the use of computer software to design and document a product's design process.

Engineering drawing entails the use of graphical symbols such as points, lines, curves, planes and shapes. Essentially, it gives detailed description about any component in a graphical form.

Background

Engineering drawings have been in use for more than 2000 years. However, the use of orthographic projections was formally introduced by the French mathematician Gaspard Monge in the eighteenth century.

Since visual objects transcend languages, engineering drawings have evolved and become popular over the years. While earlier engineering drawings were handmade, studies have shown that engineering designs are quite complicated. A solution to many engineering problems requires a combination of organization, analysis, problem solving principles and a graphical representation of the problem.

GEOMETRY:

I.D. of shell= 60 mm

I.D. of tube = 35 mm

O.D. of tube = 50 mm

Thermal conductivity of wall= 192 W/m-K at 25 degrees

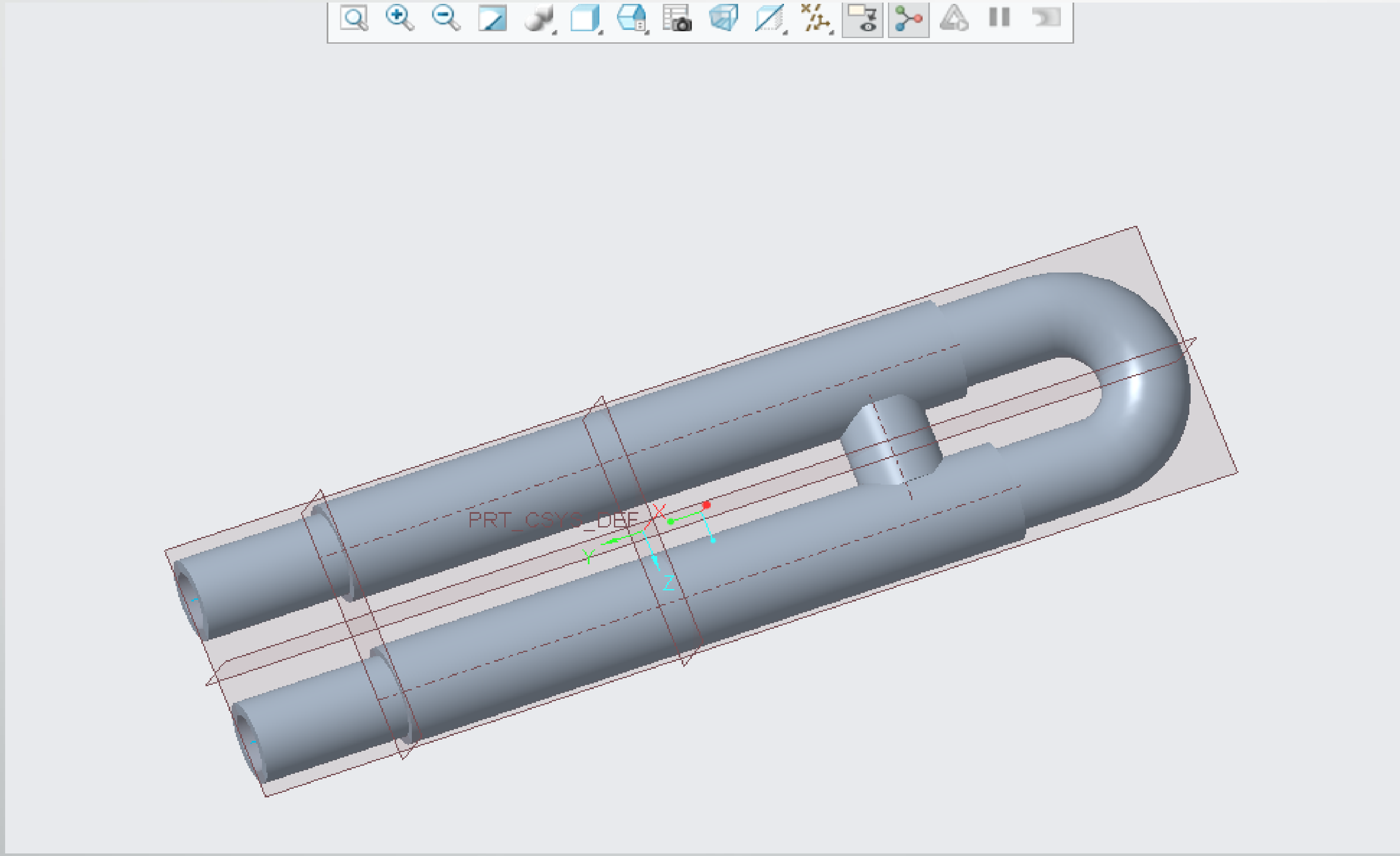
Density = 2.8 g/cm3

Melting point = 510 degree fahrenheit

Effective length of tube through which heat transfer could take place= 45 cm

Total length of the copper tube = straight part

(51cm) + U-shaped bend part (9cm) =60 cm

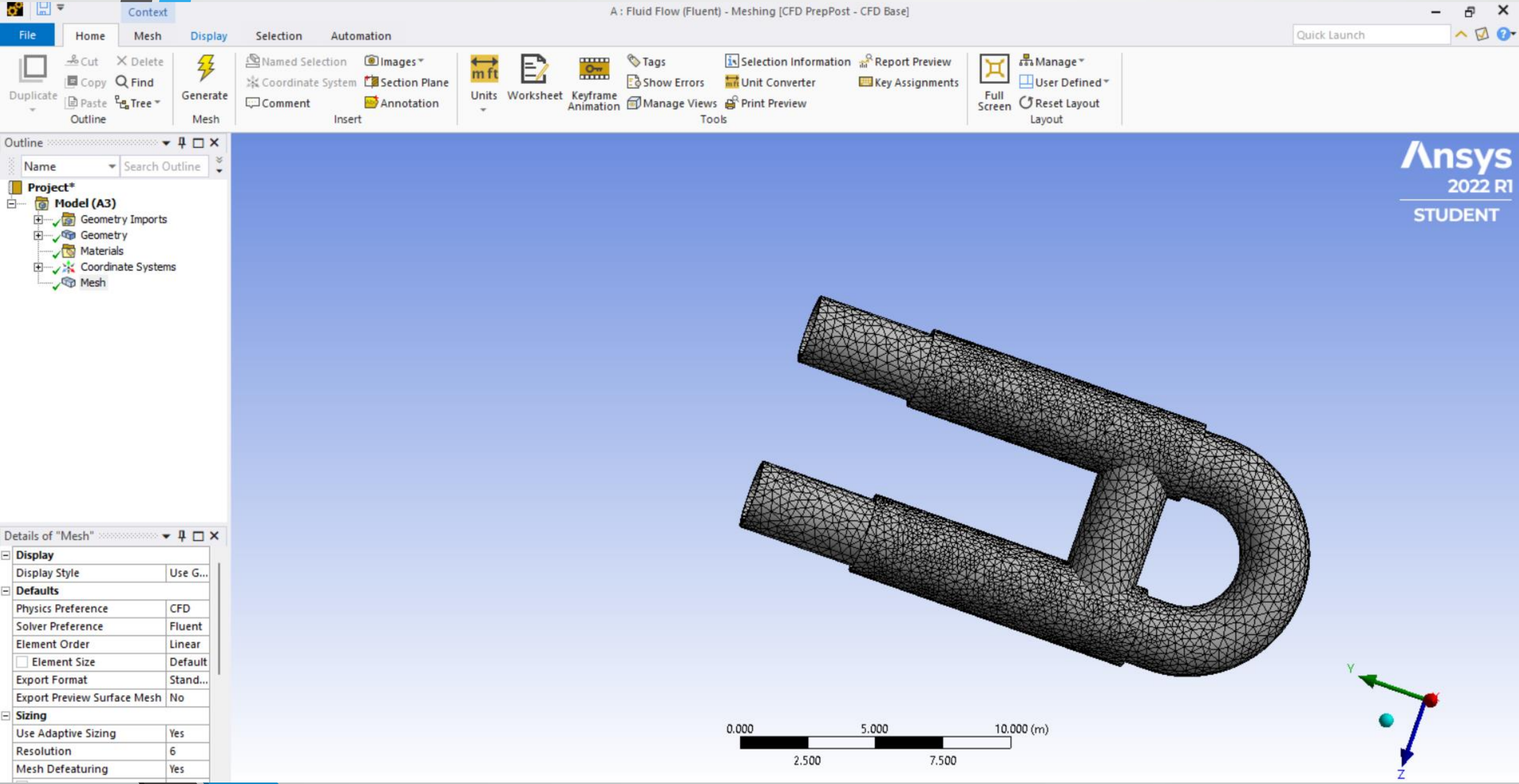

PRT_CSYS_DEF

CREATE MESH FOR THE GEOMETRY

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 16576 and 8344.

Boundary conditions

CFD technique is used to research the flow of fluid over the hair pin section through Ansys for different nanofluids. Suitable parameters were focused like pressure, velocity, heat transfer coefficient, heat and mass flow rate on each nano fluid like base fluid, magnesium oxide and silver vol fractions.


A : Fluid Flow (Fluent) - Meshing [CFD PrepPost - CFD Base]
Context
File
Home
Mesh
Display
Selection
Automation
Quick Launch
Duplicate
Cut
Copy
Paste
Delete
Find
Tree
Outline
Generate
Mesh
Named Selection
Coordinate System
Comment
Images
Section Plane
Annotation
Insert
Units
Worksheet
Keyframe Animation
Tags
Show Errors
Manage Views
Selection Information
Unit Converter
Print Preview
Report Preview
Key Assignments
Tools
Full Screen
Manage
User Defined
Reset Layout
Layout
Outline
Name
Search Outline
Project*
Model (A3)
Geometry Imports
Geometry
Materials
Coordinate Systems
Mesh
Details of "Mesh"
Display
Display Style
Use G...
Defaults
Physics Preference
CFD
Solver Preference
Fluent
Element Order
Linear
Element Size
Default
Export Format
Stand...
Export Preview Surface Mesh
No
Sizing
Use Adaptive Sizing
Yes
Resolution
6
Mesh Defeaturing
Yes
Ansys
2022 R1
STUDENT
0.000
5.000
10.000 (m)
2.500
7.500
Y
Z

CALCULATIONS TO DETERMINE PROPERTIES OF NANO FLUID BY CHANGING VOLUME FRACTIONS

MATERIAL PROPERTIES

MAGNESIUM OXIDE

Density = 3580 kg/m^3

Thermal conductivity =60 W/m-k

Specific heat = 1030 J/kg-k

Silver

Density = 10500 kg/m^3

Thermal conductivity =406.0 W/m-k

Specific heat = 233 J/kg-k

WATER

Density = 998.2 kg/m^3

Thermal conductivity = 0.6 W/m-k

Specific heat = 4182 J/kg-k

Viscosity = 0.001003 kg/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

MAGNESIUM OXIDE

DENSITY OF NANO FLUID

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

At Volume Fraction 0.45

ρ_{nf} = 2160.01 kg/m^3

SPECIFIC HEAT OF NANO FLUID

$$C_{p\ nf} = \phi \times \rho_{s\times} C_{ps+1-} \phi_{(} \rho_{w\times} C_{pw)}\ \phi \times \rho_{s+(1-} \phi_{)\times} \rho_w$$

At ϕ =0.45

$C_{p\ nf}$ = 1831.1442 j/kg-k

VISCOSITY OF NANO FLUID

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

At ϕ=0.45

μnf = 0.002131

THERMAL CONDUCTIVITY OF NANO FLUID

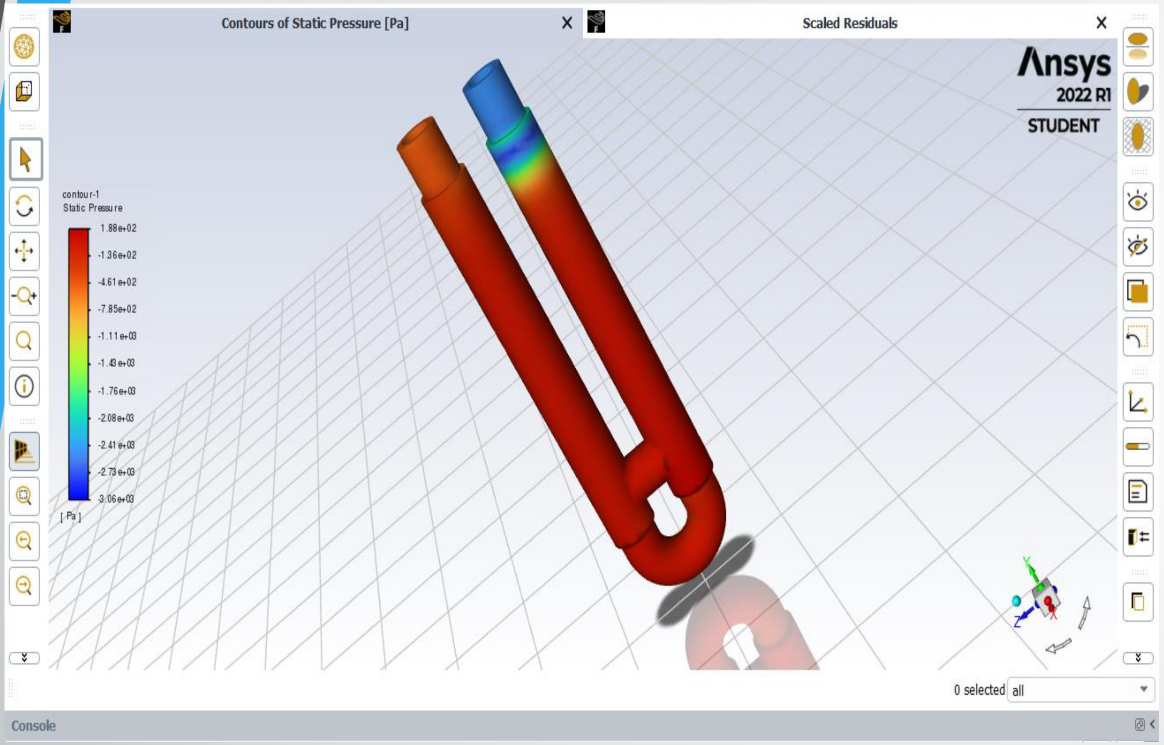
$$K_{nf} = \frac{Ks+2Kw+2(Ks-Kw)(1+\beta)^3\times\phi}{Ks+2Kw-(Ks-Kw)(1+\beta)^3\times\phi} \times k_w$$

β=0.1 At ϕ =0.45

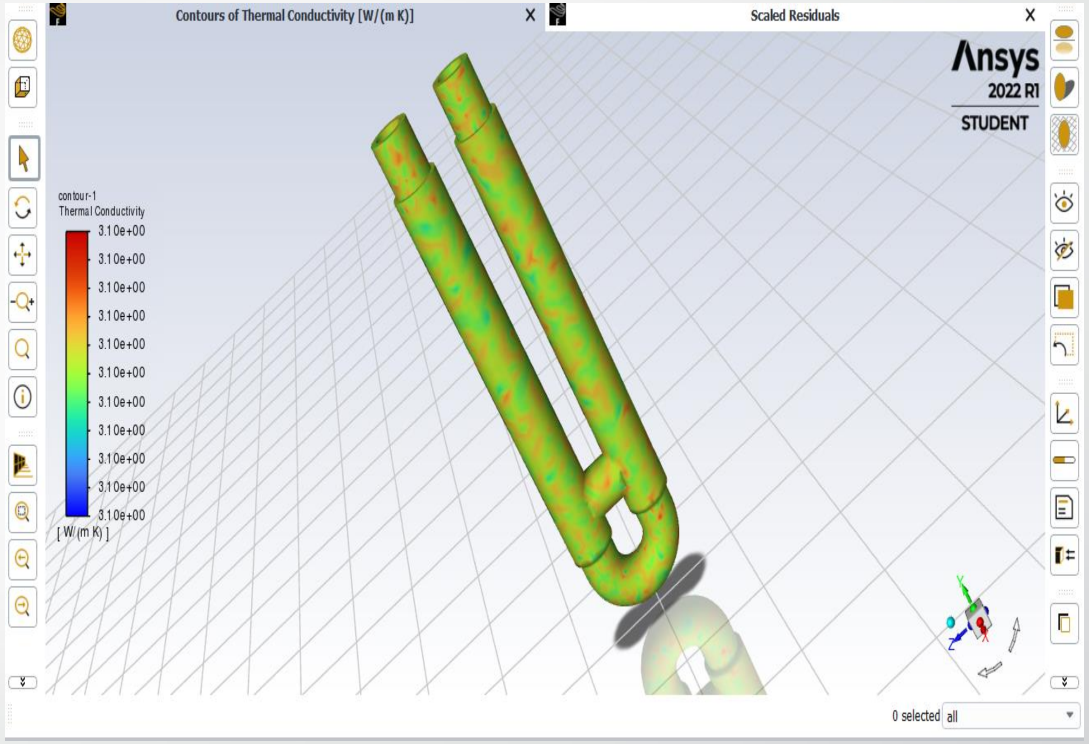
K_{nf} = 3.0993W/m-k

NANO FLUID PROPERTIES

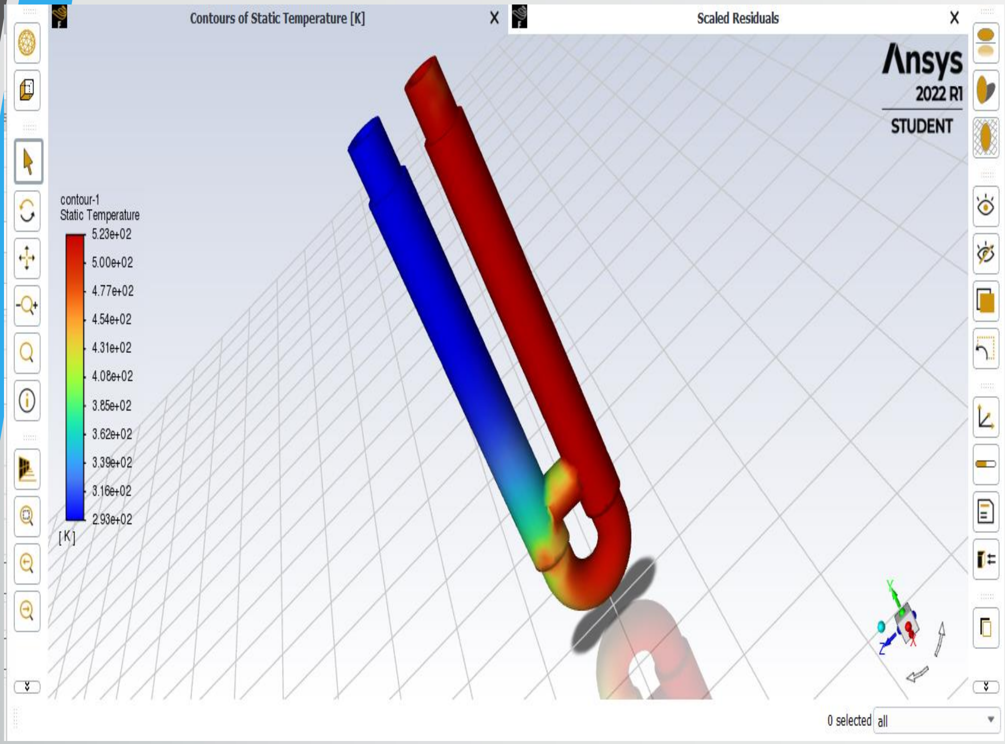
FLUID	Volume fraction	Thermal conductivity (w/m-k)	Specific heat (J/kg-k)	Density (kg/m^3)
MAGNESIUM OXIDE	0.35	2.8234	1711.2	2001.3
	0.45	3.0993	1831.14	2160.01
	0.55	3.2123	1976.12	2300.21
	0.65	3.5341	2078.34	2450.45
SILVER	0.35	3.0923	612.23	5192.37
	0.45	3.2587	682.001	5274.01
	0.55	3.4212	750.12	5356.89
	0.65	3.7561	823.45	5498.79

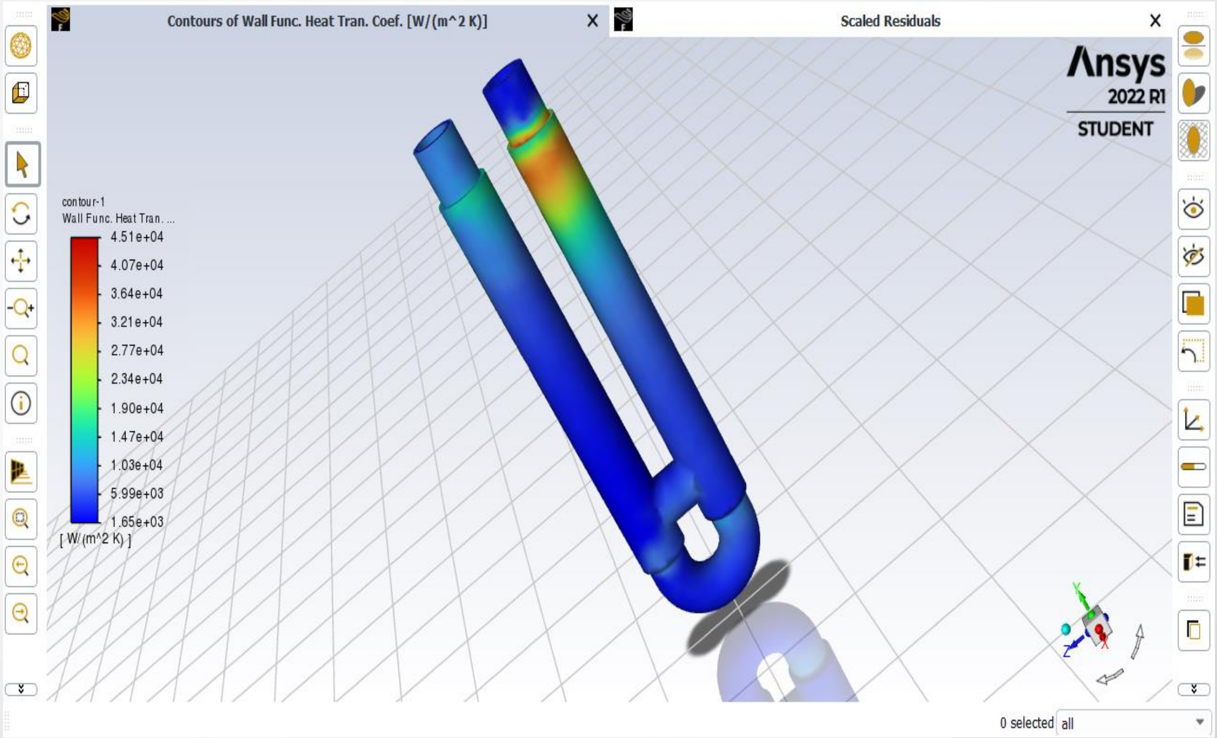


Contours of Static Pressure [Pa]
Scaled Residuals
Ansys
2022 R1
STUDENT
contour-1
Static Pressure
1.88e+02
-1.36e+02
-4.61e+02
-7.85e+02
-1.11e+03
-1.43e+03
-1.76e+03
-2.08e+03
-2.41e+03
-2.73e+03
-3.06e+03
[Pa]
0 selected
all
Console

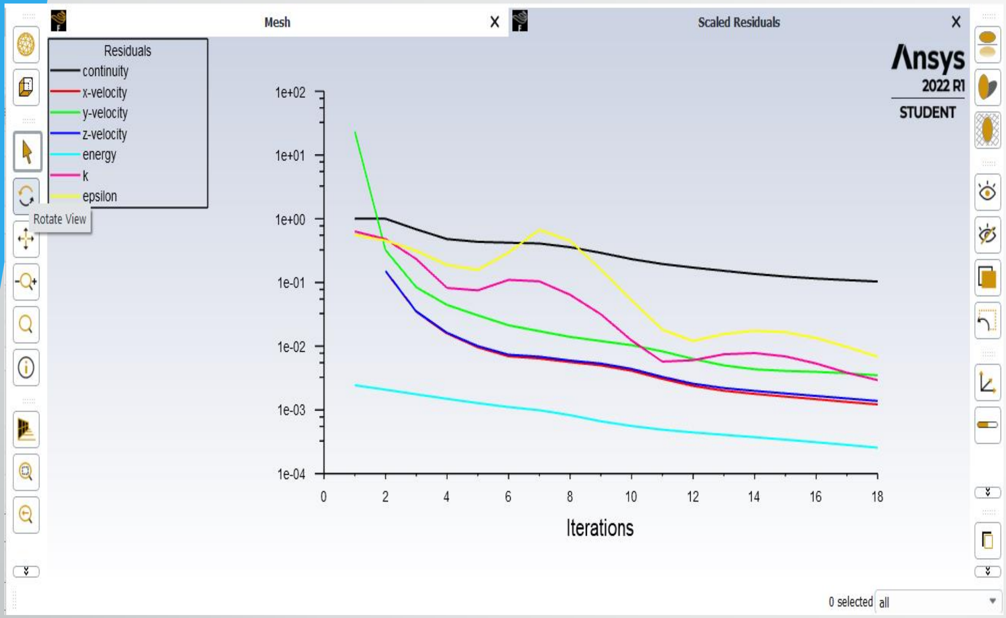


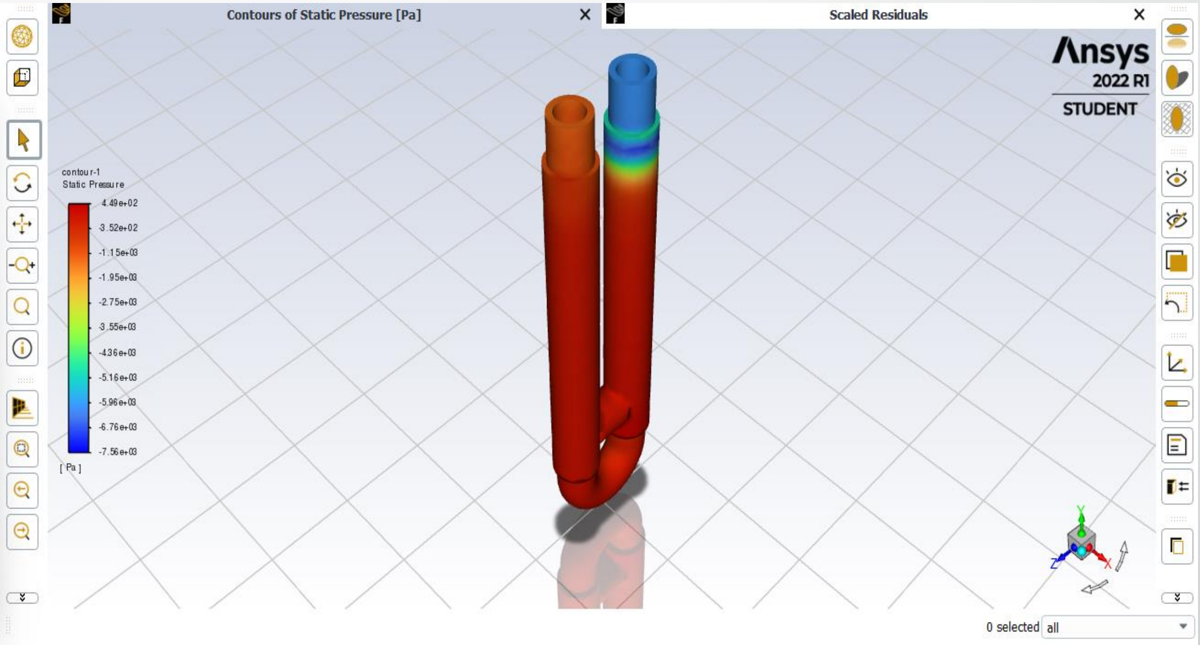
Contours of Thermal Conductivity [W/(m K)]
Scaled Residuals
Ansys
2022 R1
STUDENT
contour-1
Thermal Conductivity
3.10e+00
3.10e+00
3.10e+00
3.10e+00
3.10e+00
3.10e+00
3.10e+00
3.10e+00
3.10e+00
3.10e+00
3.10e+00
[W/(m K)]
0 selected
all

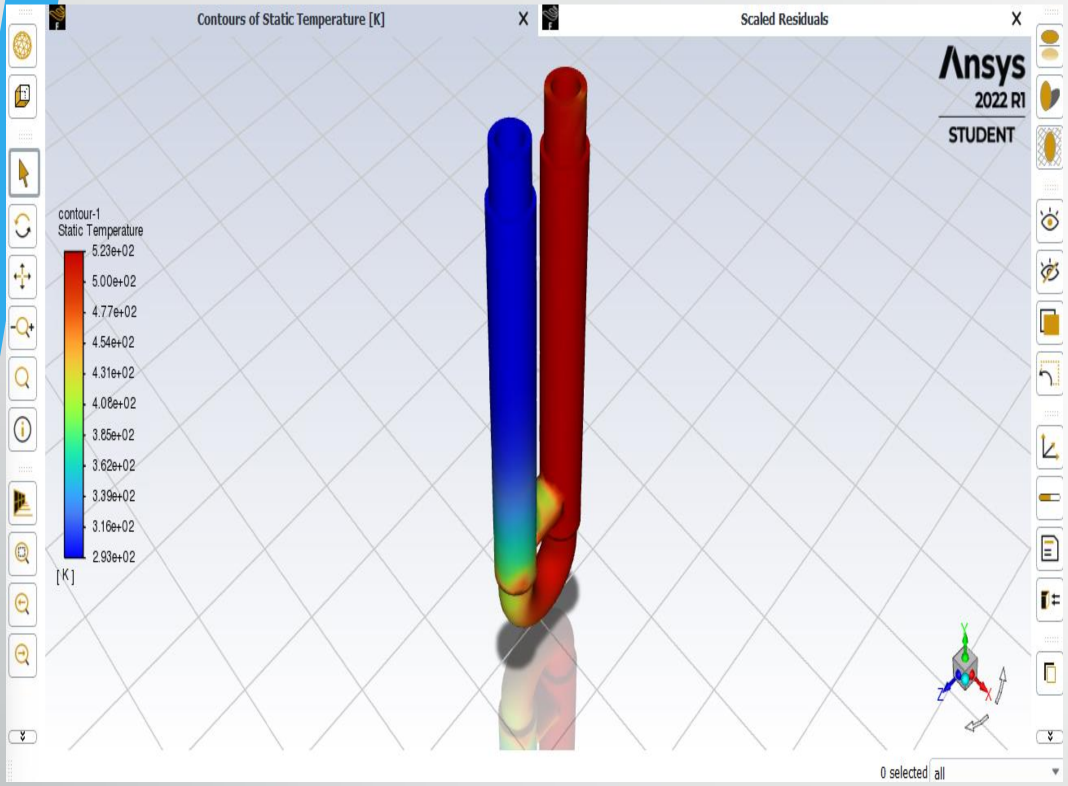

Contours of Static Temperature [K]
Scaled Residuals
Ansys
2022 R1
STUDENT
contour-1
Static Temperature
5.23e+02
5.00e+02
4.77e+02
4.54e+02
4.31e+02
4.08e+02
3.85e+02
3.62e+02
3.39e+02
3.16e+02
2.93e+02
[K]
0 selected
all


Contours of Wall Func. Heat Tran. Coef. [W/(m^2 K)]
Scaled Residuals
Ansys
2022 R1
STUDENT
contour-1
Wall Func. Heat Tran. ...
4.51e+04
4.07e+04
3.64e+04
3.21e+04
2.77e+04
2.34e+04
1.90e+04
1.47e+04
1.03e+04
5.99e+03
1.65e+03
[W/(m^2 K)]
0 selected
all

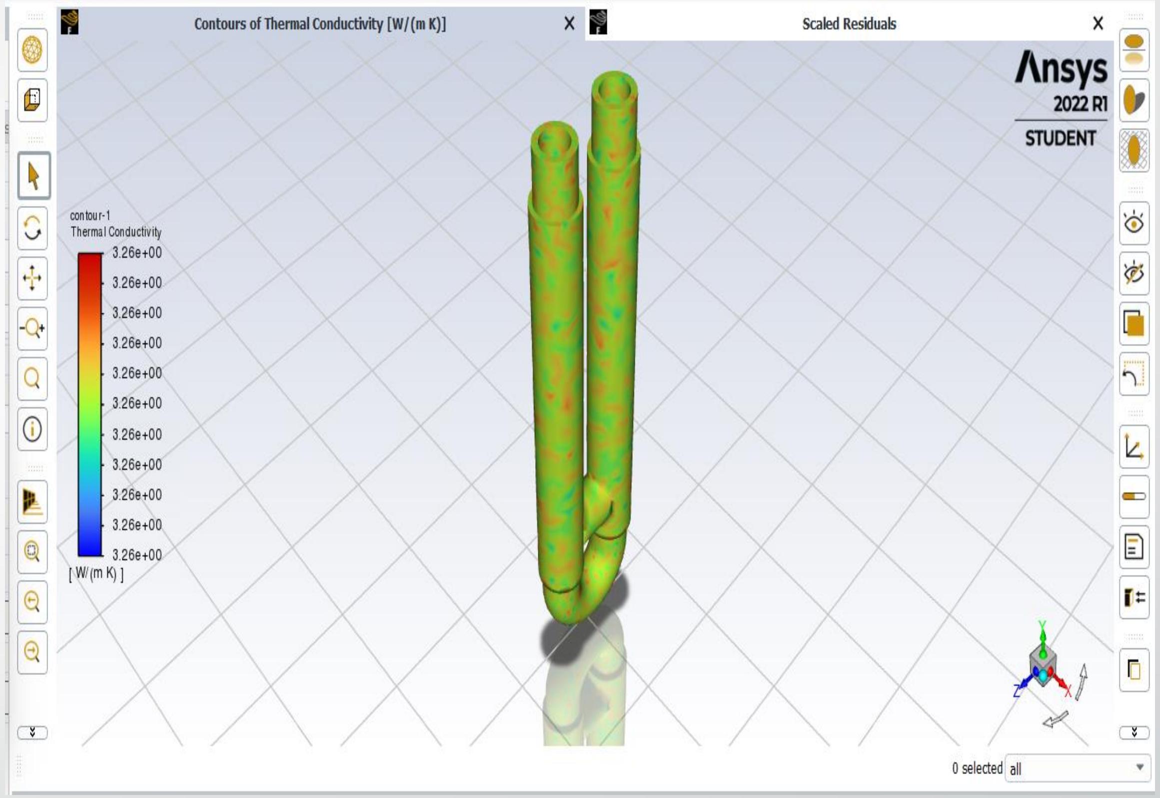
Ag : 0.45
velocity : 1 m/s



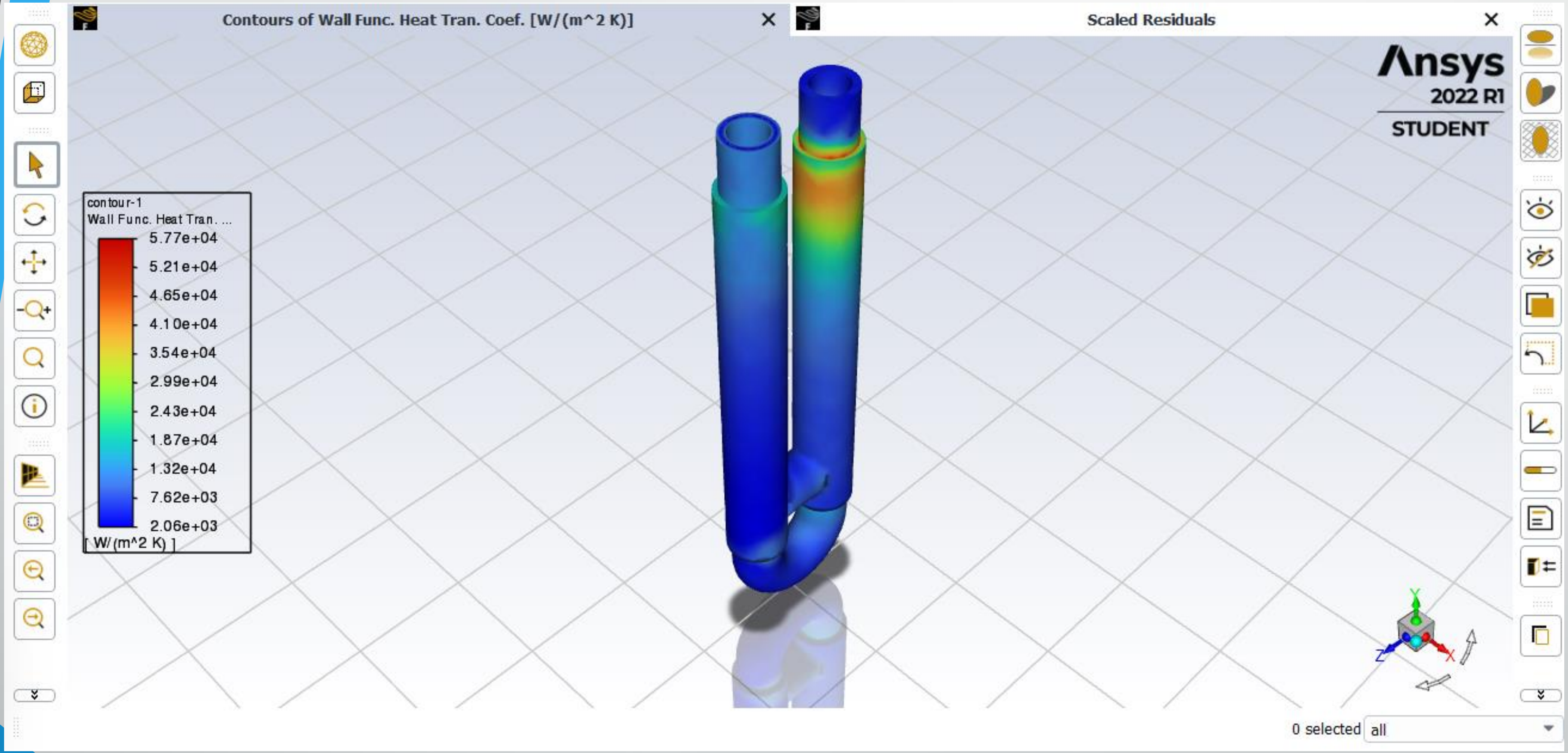




Contours of Static Temperature [K]
Scaled Residuals
Ansys
2022 R1
STUDENT
contour-1
Static Temperature
5.23e+02
5.00e+02
4.77e+02
4.54e+02
4.31e+02
4.08e+02
3.85e+02
3.62e+02
3.39e+02
3.16e+02
2.93e+02
[K]
0 selected all



Contours of Thermal Conductivity [W/(m K)]
Scaled Residuals
Ansys
2022 R1
STUDENT
contour-1
Thermal Conductivity
3.26e+00
3.26e+00
3.26e+00
3.26e+00
3.26e+00
3.26e+00
3.26e+00
3.26e+00
3.26e+00
3.26e+00
3.26e+00
[W/(m K)]
0 selected all


Contours of Wall Func. Heat Tran. Coef. [W/(m^2 K)]
Scaled Residuals
Ansys
2022 R1
STUDENT
contour-1
Wall Func. Heat Tran. ...
5.77e+04
5.21e+04
4.65e+04
4.10e+04
3.54e+04
2.99e+04
2.43e+04
1.87e+04
1.32e+04
7.62e+03
2.06e+03
[W/(m^2 K)]
0 selected
all

RESULT NANO FLUID NAME	VOLUME FRACTION	VELOCITY (m/s)	PRESSURE (Pa)	HEAT TRANSFER COEFFICIENT (w/m-k)
Mgo	0.35	0.5	1.52e+01	1.29e+04
		1.0	8.36e+01	3.28e+04
		1.5	1.35e+02	3.36e+04
	0.45	0.5	1.64e+01	1.41e+04
		1.0	6.51e+01	2.58e+04
		1.5	1.45e+02	3.69e+04
	0.55	0.5	1.75e+01	1.47e+04
		1.0	6.8e+01	2.72e+04
		1.5	1.55e+02	3.92e+04
Ag	0.35	0.5	3.89e+01	1.85e+04
		1.0	1.53e+02	3.23e+04
		1.5	3.38e+02	4.43e+04
	0.45	0.5	3.96e+01	1.98e+04
		1.0	2.20e+02	4.75e+04
		1.5	2.20e+02	4.75e+04
	0.55	0.5	4.03e+01	2.09e+04
		1.0	1.5e+02	4.86e+04
		1.5	3.54e+02	5.18e+04

CONCLUSION

In this Thesis, nano fluid is mixed with base fluid water are calculated for their combination properties. The nano fluids are magnesium Oxide and silver nano particle volume fractions 0.35, 0.45,0.55% at different velocities (0.5,1,1.5 m/s). 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 with and without twisted tape model is done in CREO parametric software. CFD analysis is done on the hair pin heat exchanger at different nano fluid volume fractions. CFD analysis is to determine the pressure drop heat transfer coefficient .

By observing the CFD analysis results the increasing the velocities increases the friction factor and heat transfer coefficient values. By observing the CFD analysis results the friction factor and heat transfer coefficient values more at silver nano particle without twisted tape model.

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THANK YOU