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Week 4 - CHT Analysis on Exhaust port

Aim: To evaluate heat transfer coefficient on the inner wall of an exhaust port. Conjugate Heat Transfer Analysis: Conjugate heat transfer analysis is a method of simulting flow where we are intrested in how Energy/Temperature is carried from fluid to the surface or surface to surface and the body of the object...

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updated on 28 Aug 2021

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Project Details

Aim: To evaluate heat transfer coefficient on the inner wall of an exhaust port.

Conjugate Heat Transfer Analysis: Conjugate heat transfer analysis is a method of simulting flow where we are intrested in how Energy/Temperature is carried from fluid to the surface or surface to surface and the body of the object in which the fluid is flowing through.

Some applications, as evident understanding CHT of ehaust port, simulating electronioc components to extract better performance, understanding the heat dessipation from a mechanical component (Engine, Heat Exchangers, etc).

Setting up problem:

As the y+ value of 1 is considered this value lies in the viscous sub-layer region. As this is a near wall region the turbulance model are not well equiped to handle it as they are more focused on resolving core turbulernt flow. Although, the K-Omega and Spalart-Allmaras models are well equiped to handle near wall functions as well.

Eventhough, K-Epsilon will give a more or less accurate result for y+ values of >30 it is to be notedd that the solution will differ slightly. And the K-Omega seems to be more accurate than K-Epsilon in this case.

Calculation of y using y+

As y+ = 1 (Using k-Omega turbulance model)

$$y+ \; = \frac{\rho \cdot U \cdot y}{\mu} => y = \frac{y+ \; \cdot \mu}{\rho \cdot U \cdot y}$$

Where,

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$$U = \sqrt{\frac{\tau}{\rho}}$$

$$\tau = 0.5 \cdot Cf \cdot \rho \cdot Un^2$$

$$Cf = 0.079 \cdot Re - 0.25$$

$$\rho(Density) = 1.225\frac{kg}{m^3}$$

Re for internal flow: $Re = \frac{\rho \cdot Un \cdot D}{\mu}$

Here,

Un = free strean Velocity,

$\tau =$ Sheer near wall,

y = distance from the solid surface.

Re = $\frac{1.225 \cdot 5 \cdot 0.15}{1.8 \cdot 10^{-5}}$ = *51041.667*

Cf = $0.079 \cdot 51041.667^{-0.25} = 0.005255$

$\tau = 0.5 \cdot 0.005255 \cdot 1.225 \cdot 25 = 0.08048$

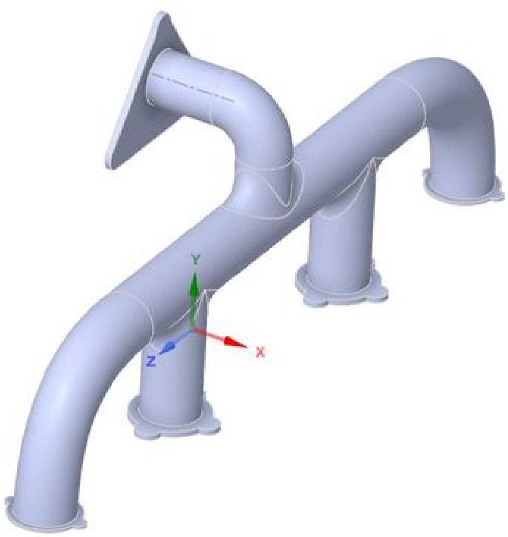
$$U = \sqrt{\frac{\tau}{\rho}} = \sqrt{\frac{0.08048074}{1.225}} = 0.256317\frac{m}{s}$$

`y = (y+ * mu)/(U*rho) = (1* 1.8*10^-5)*/(0.06569856* 1.225) = *0.0005732m*`

ie approximately **0.5mm**

This the inflation layer length for simulation with 5 layers and a growth rate of 1.2

Geomtry

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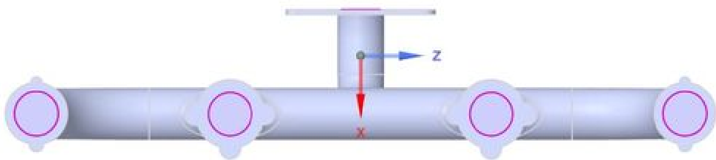

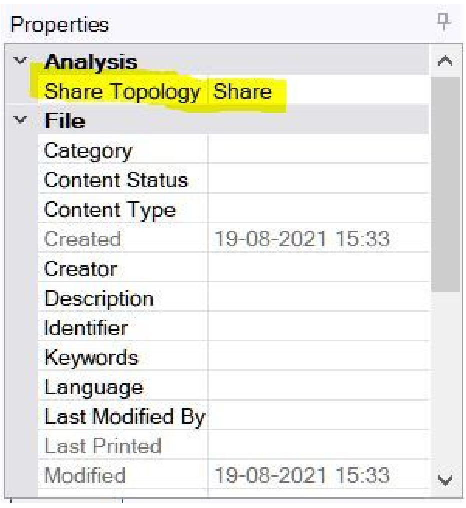
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Analysis
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File
Category
Content Status
Content Type
Created 19-08-2021 15:33
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Description
Identifier
Keywords
Language
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Modified 19-08-2021 15:33

Meshing

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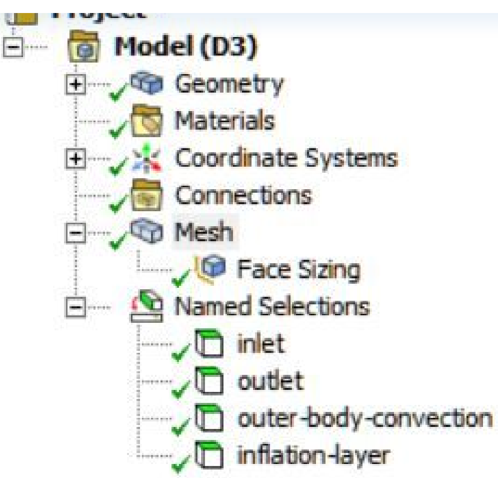

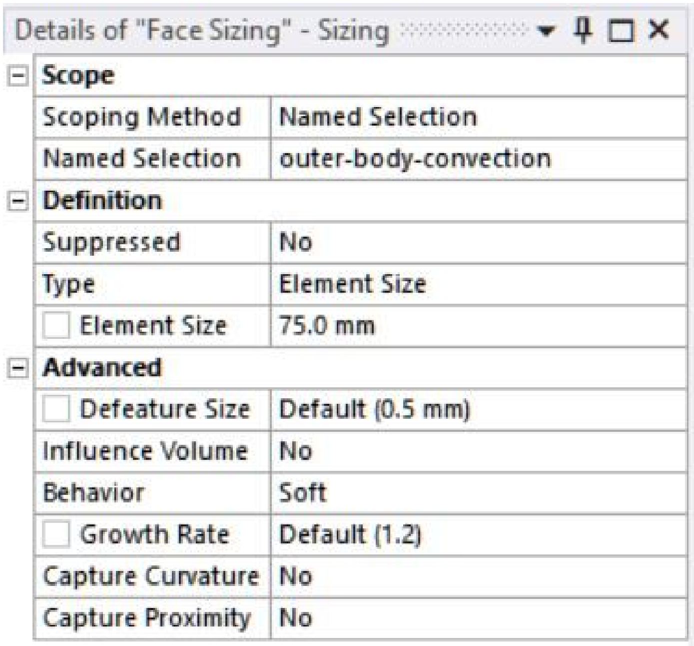

Details of "Face Sizing" - Sizing

Scope	
Scoping Method	Named Selection
Named Selection	outer-body-convection
Definition	
Suppressed	No
Type	Element Size
Element Size	75.0 mm
Advanced	
Defeature Size	Default (0.5 mm)
Influence Volume	No
Behavior	Soft
Growth Rate	Default (1.2)
Capture Curvature	No
Capture Proximity	No

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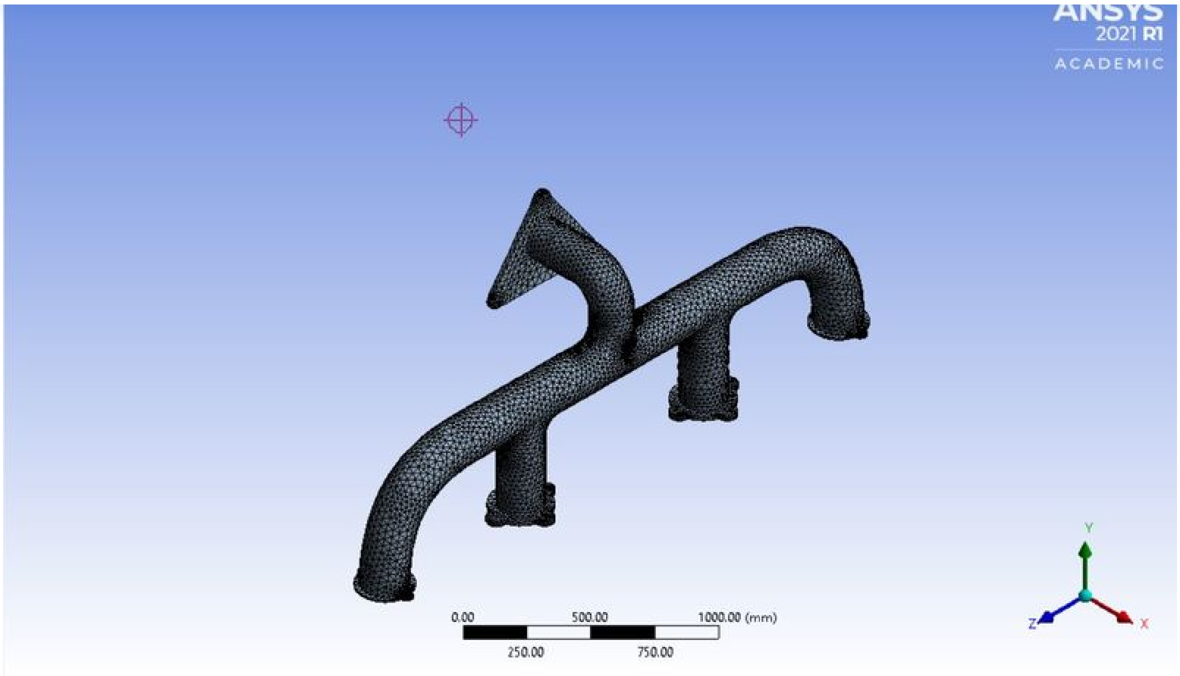
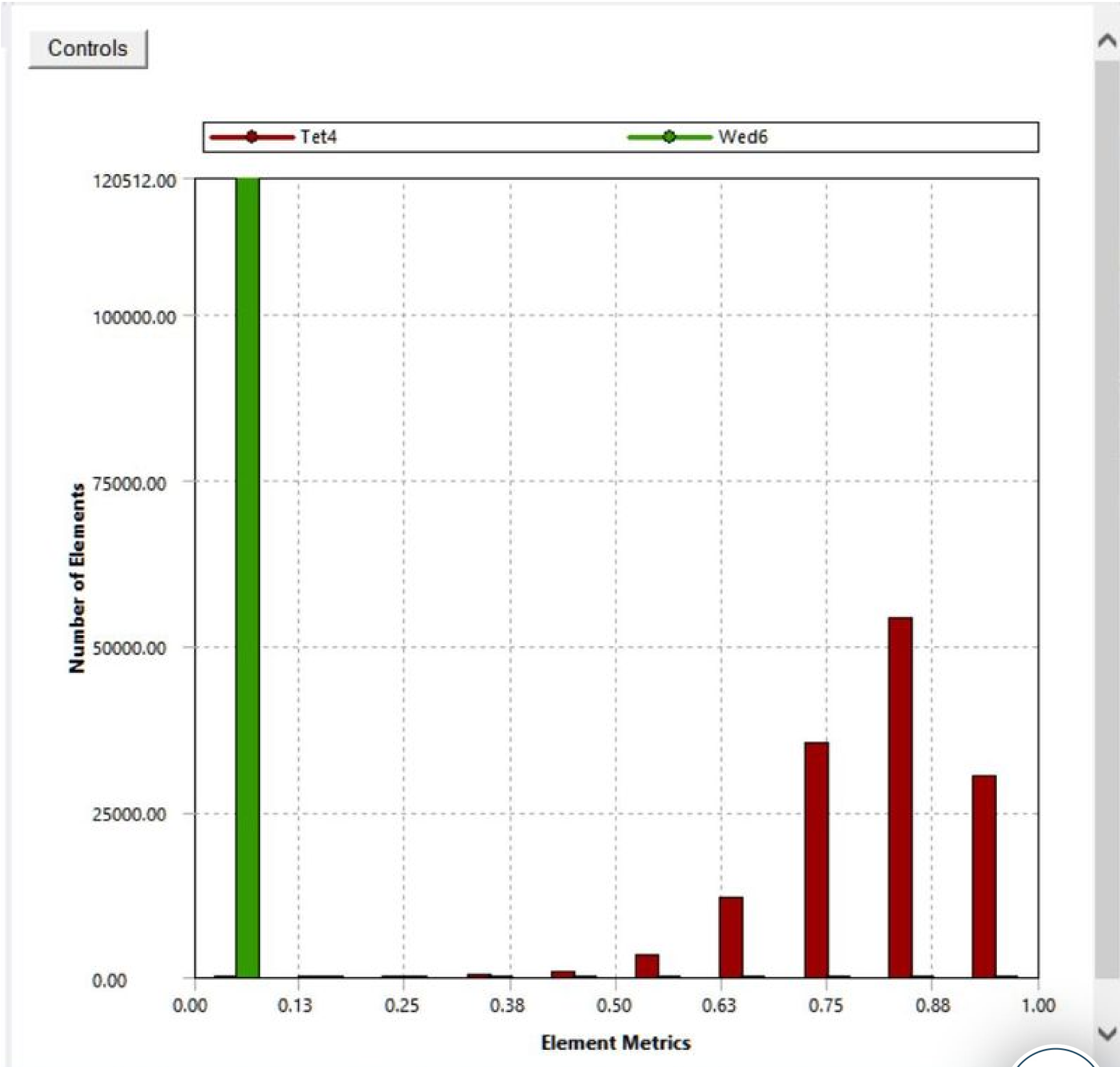
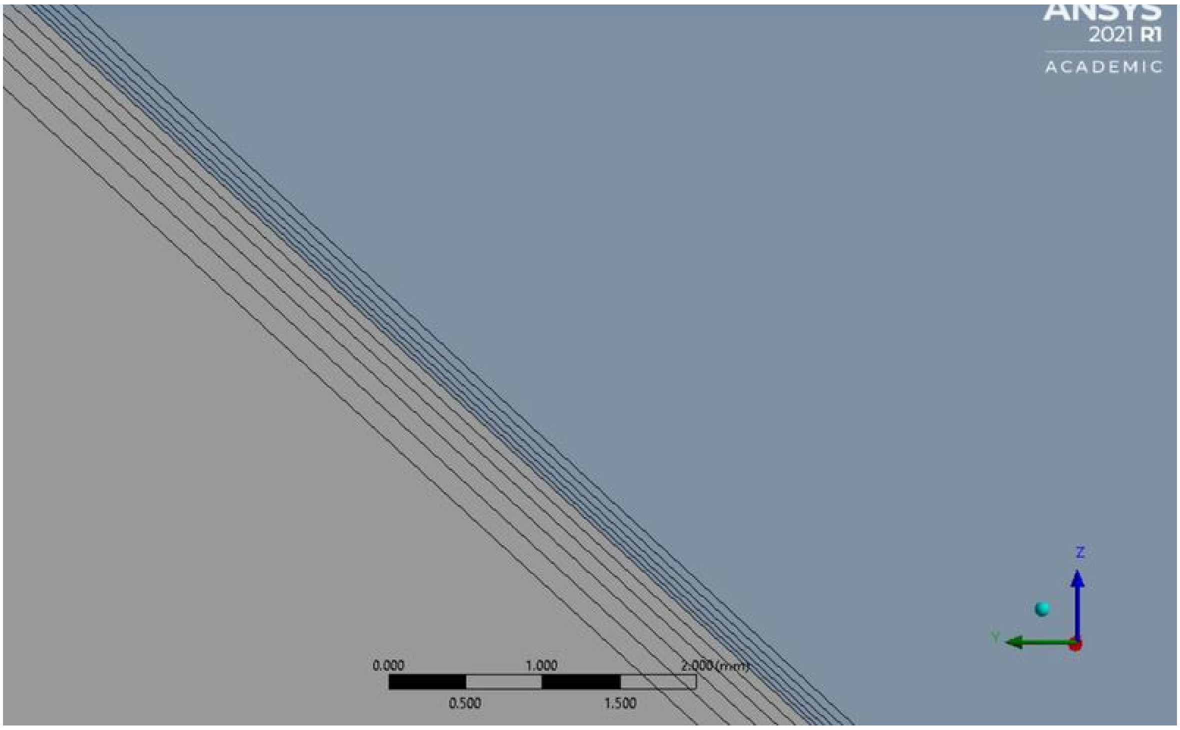




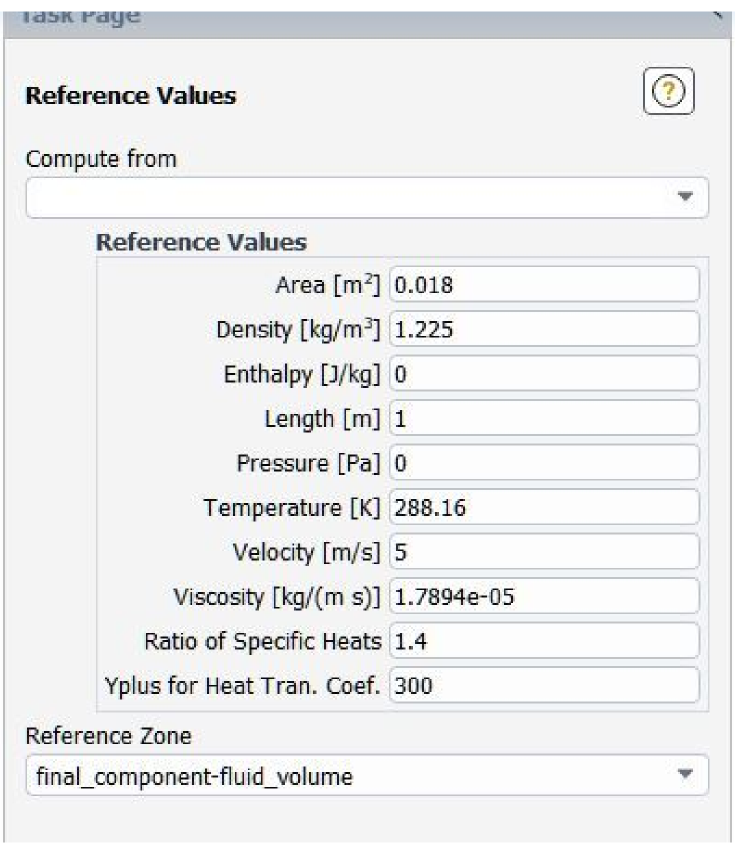
Inflation layer



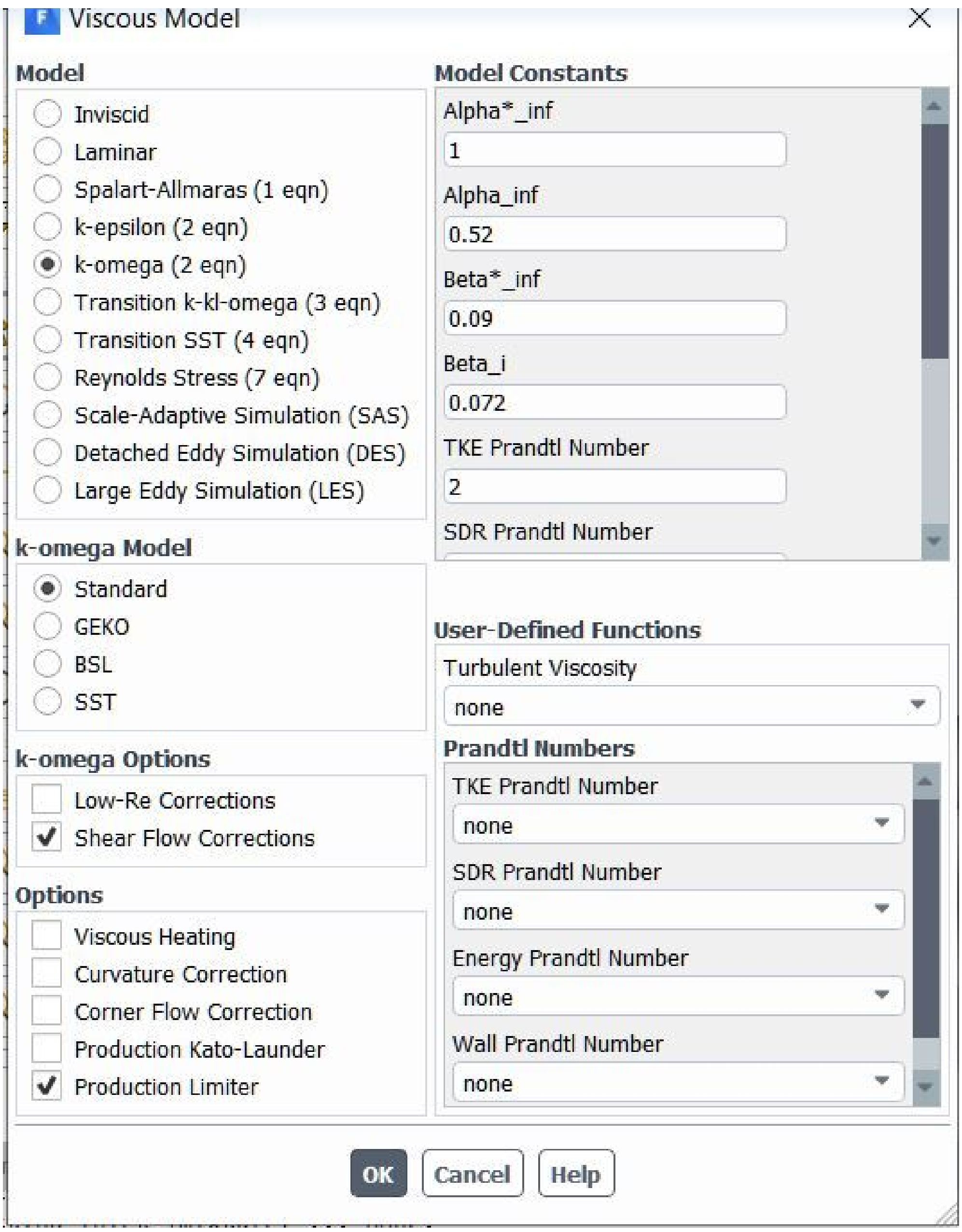
Inflation	
Use Automatic Inflation	All Faces in Chose...
Named Selection	inflation-layer
Inflation Option	Total Thickness
Number of Layers	5
Growth Rate	1.2
Maximum Thickness	0.5 mm
Inflation Algorithm	Pre
View Advanced Options	No

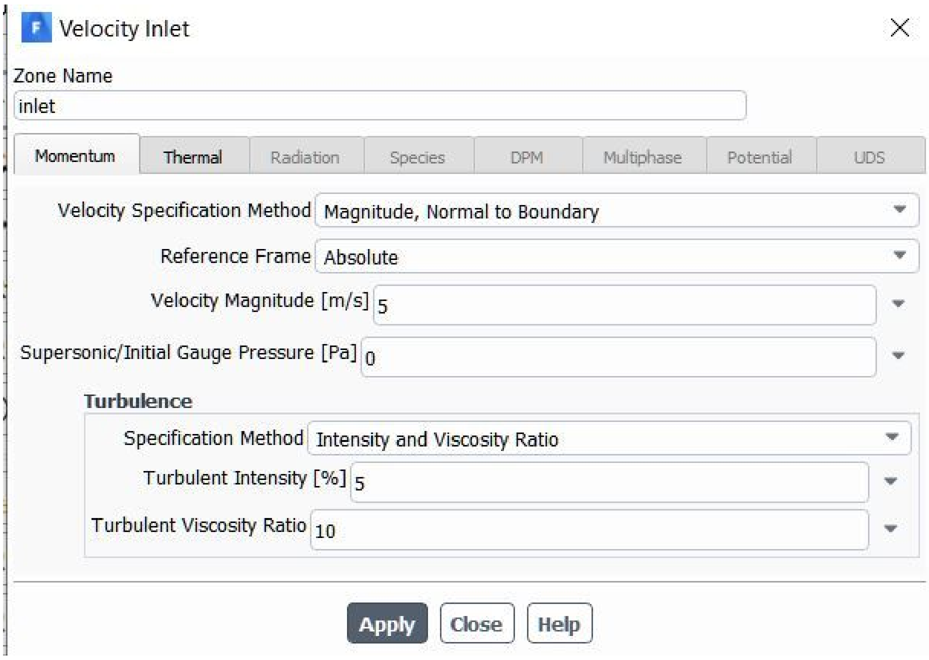
Setup

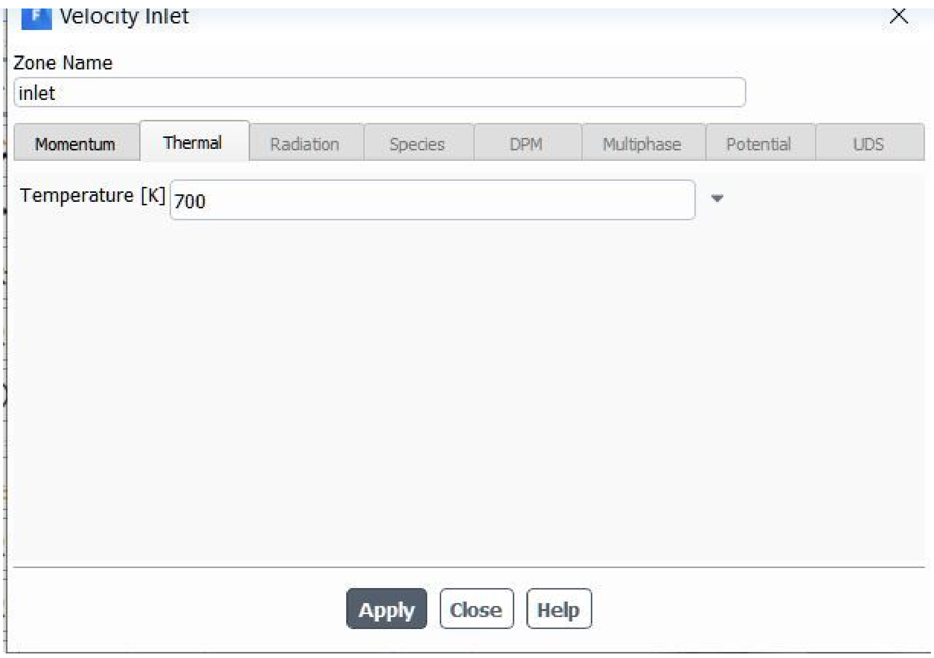
Refrence Values



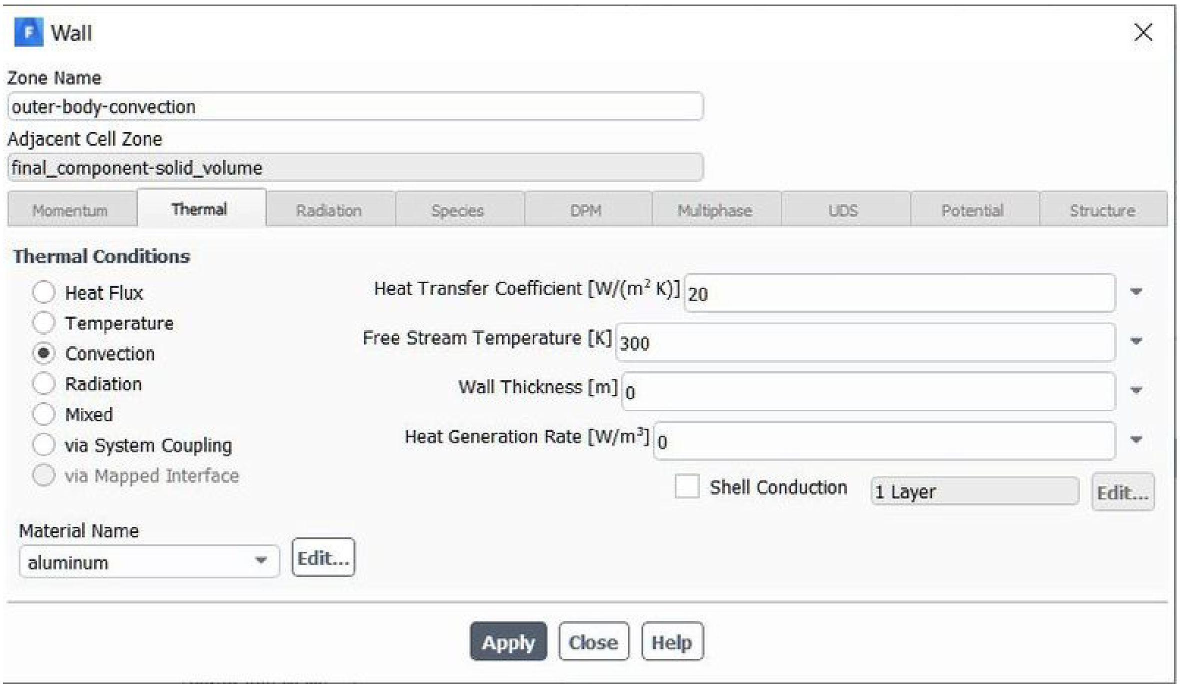
Turbulance model


Viscous Model
Model
Inviscid
Laminar
Spalart-Allmaras (1 eqn)
k-epsilon (2 eqn)
k-omega (2 eqn)
Transition k-kl-omega (3 eqn)
Transition SST (4 eqn)
Reynolds Stress (7 eqn)
Scale-Adaptive Simulation (SAS)
Detached Eddy Simulation (DES)
Large Eddy Simulation (LES)
k-omega Model
Standard
GEKO
BSL
SST
k-omega Options
Low-Re Corrections
Shear Flow Corrections
Options
Viscous Heating
Curvature Correction
Corner Flow Correction
Production Kato-Launder
Production Limiter
Model Constants
Alpha*_inf
1
Alpha_inf
0.52
Beta*_inf
0.09
Beta_i
0.072
TKE Prandtl Number
2
SDR Prandtl Number
User-Defined Functions
Turbulent Viscosity
none
Prandtl Numbers
TKE Prandtl Number
none
SDR Prandtl Number
none
Energy Prandtl Number
none
Wall Prandtl Number
none
OK
Cancel
Help


Velocity Inlet
Zone Name
inlet
Momentum
Thermal
Radiation
Species
DPM
Multiphase
Potential
UDS
Velocity Specification Method Magnitude, Normal to Boundary
Reference Frame Absolute
Velocity Magnitude [m/s] 5
Supersonic/Initial Gauge Pressure [Pa] 0
Turbulence
Specification Method Intensity and Viscosity Ratio
Turbulent Intensity [%] 5
Turbulent Viscosity Ratio 10
Apply
Close
Help

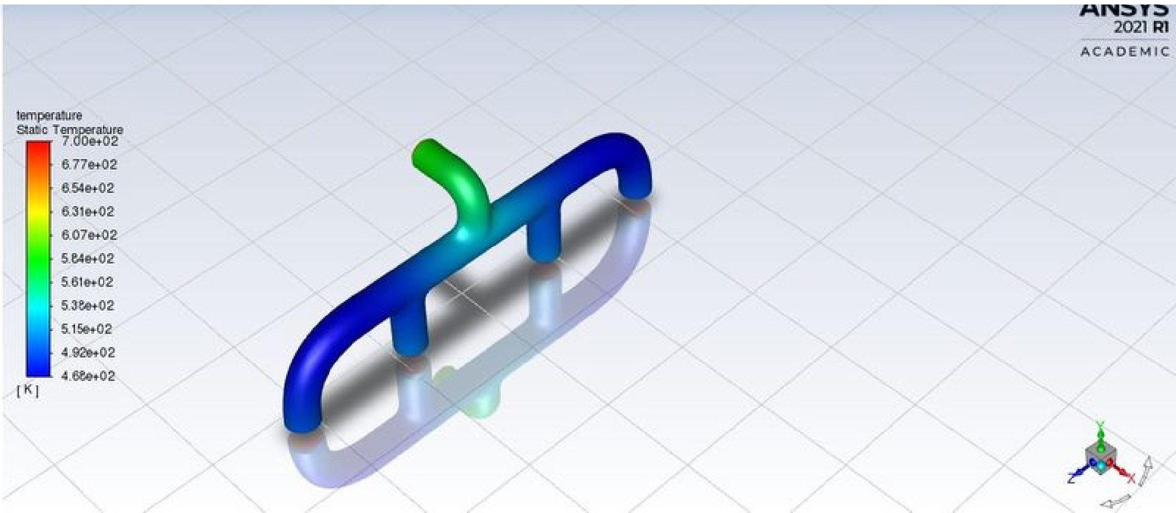


Outer wall BC:

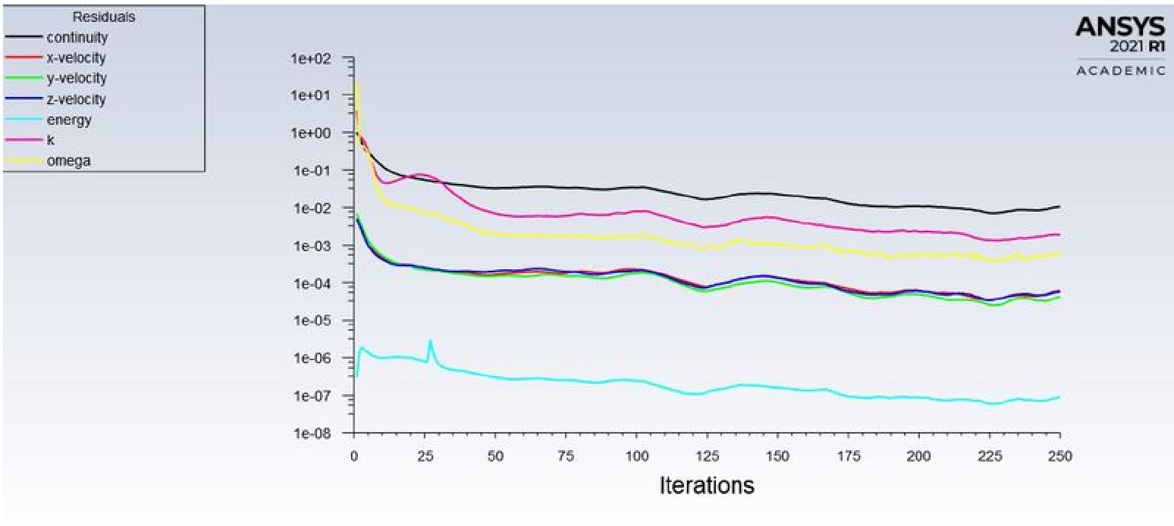


Results

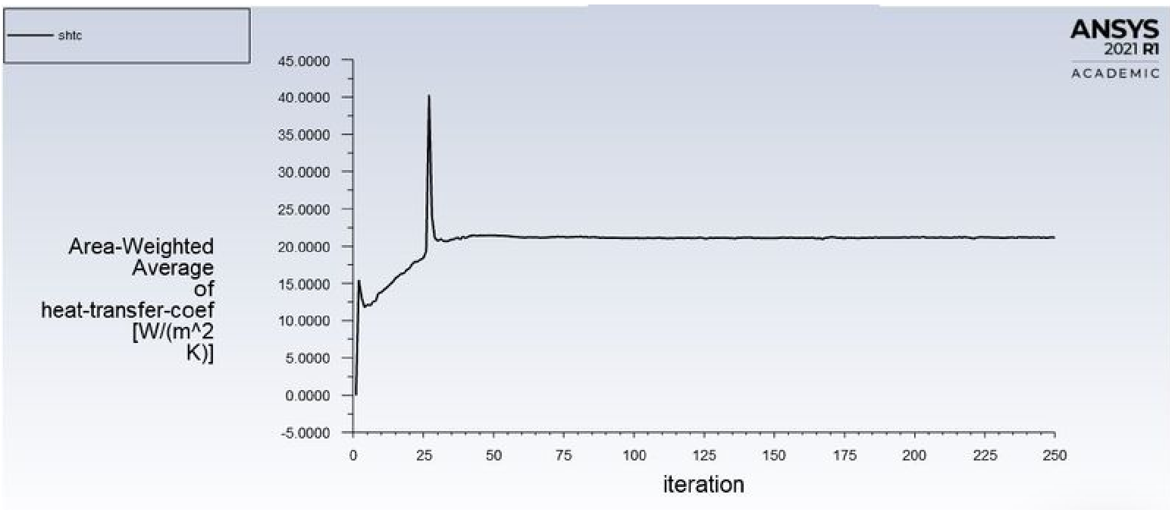
Temperature contour:



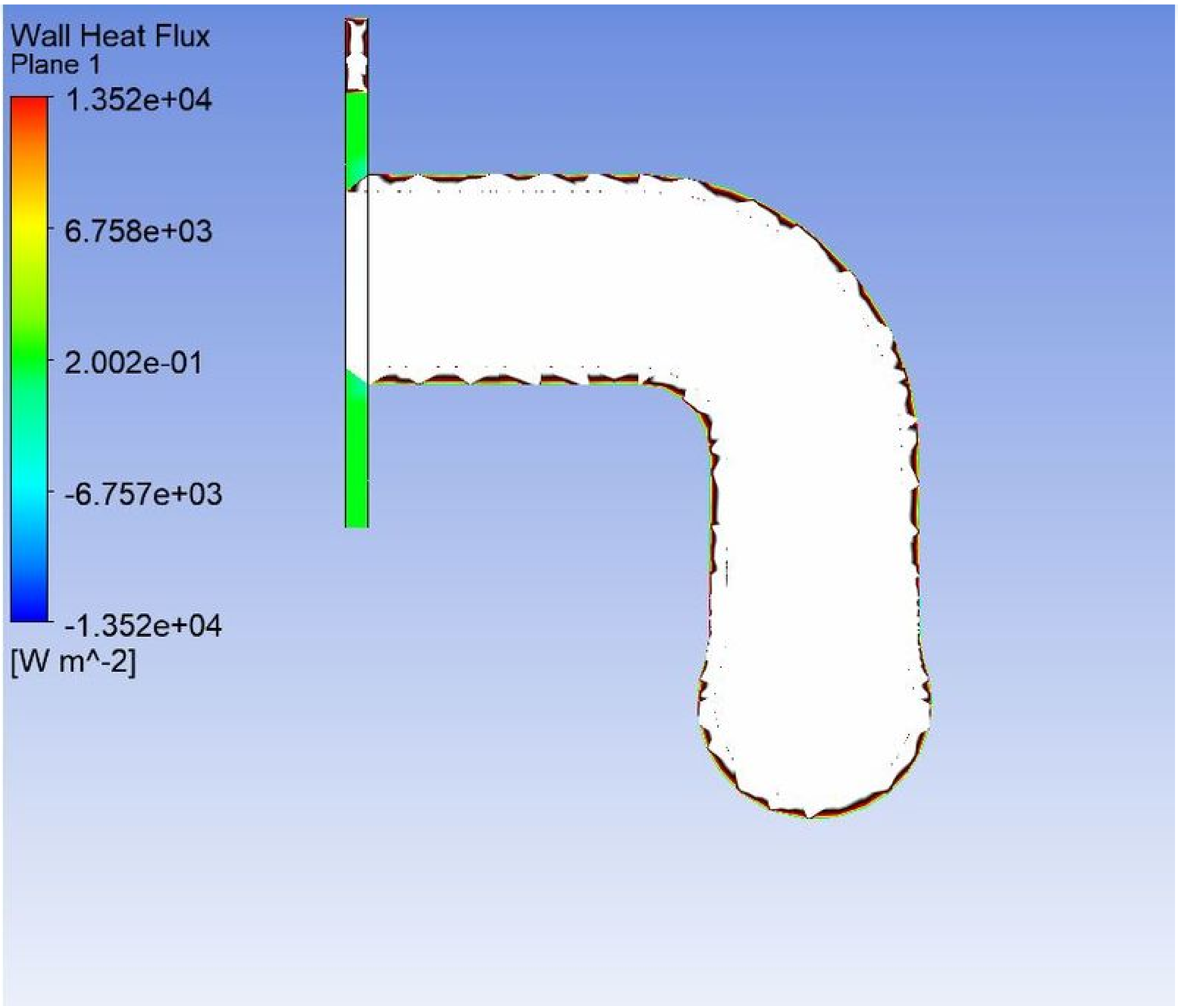
Residual



Surface heat transfer coefficient: ***21.125079 W/(m^2 K)***



PLOTS



Temperature

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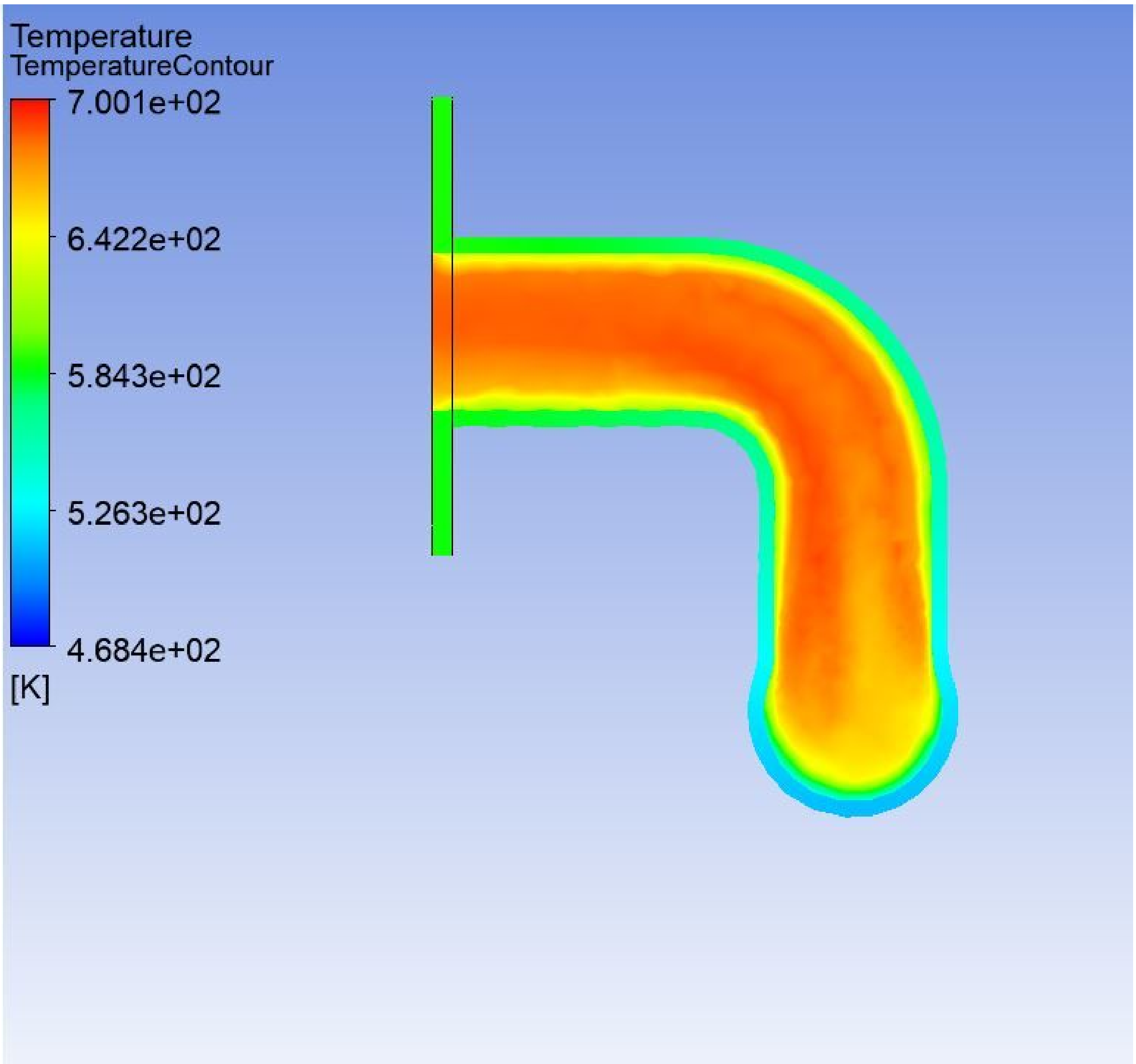
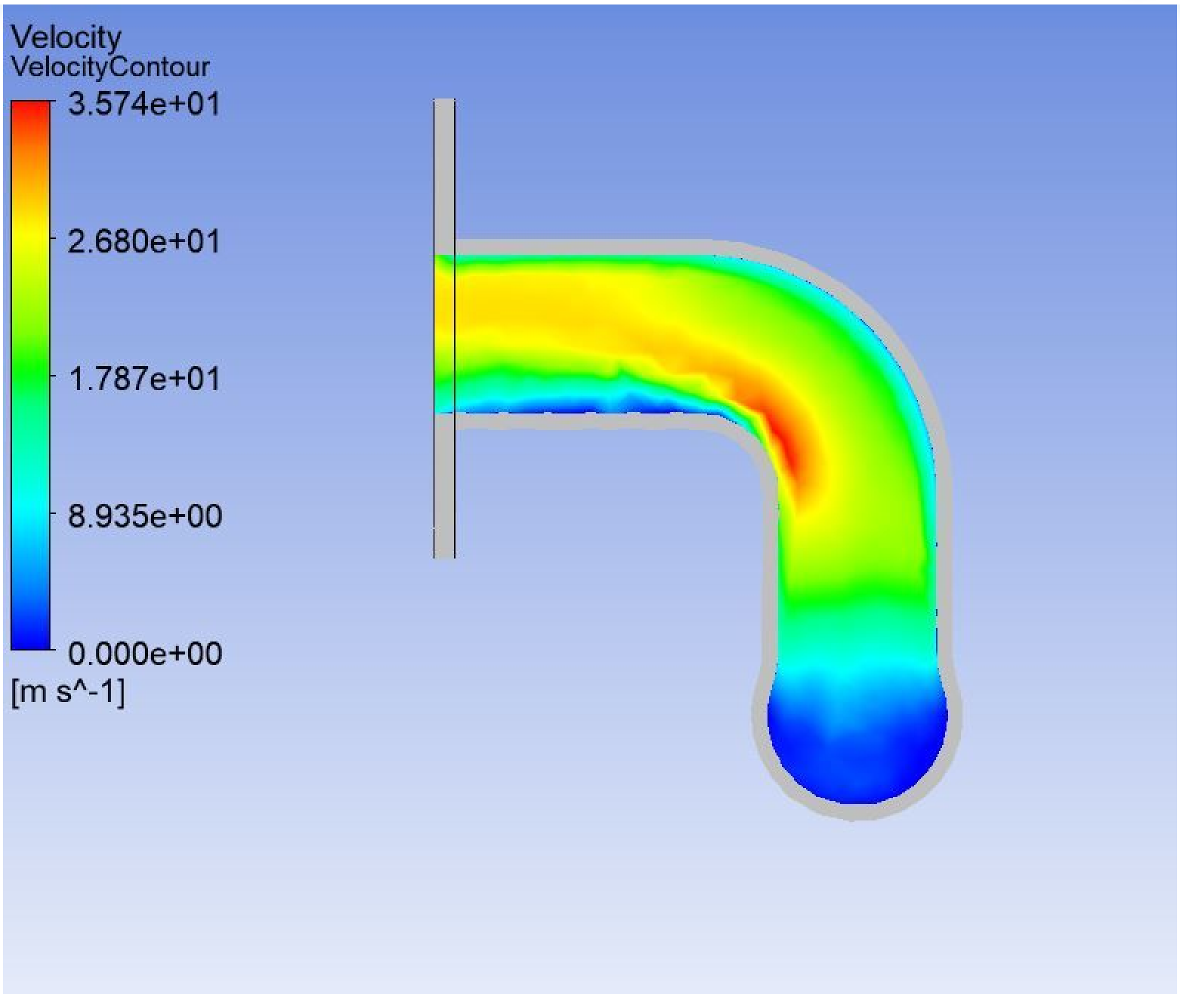
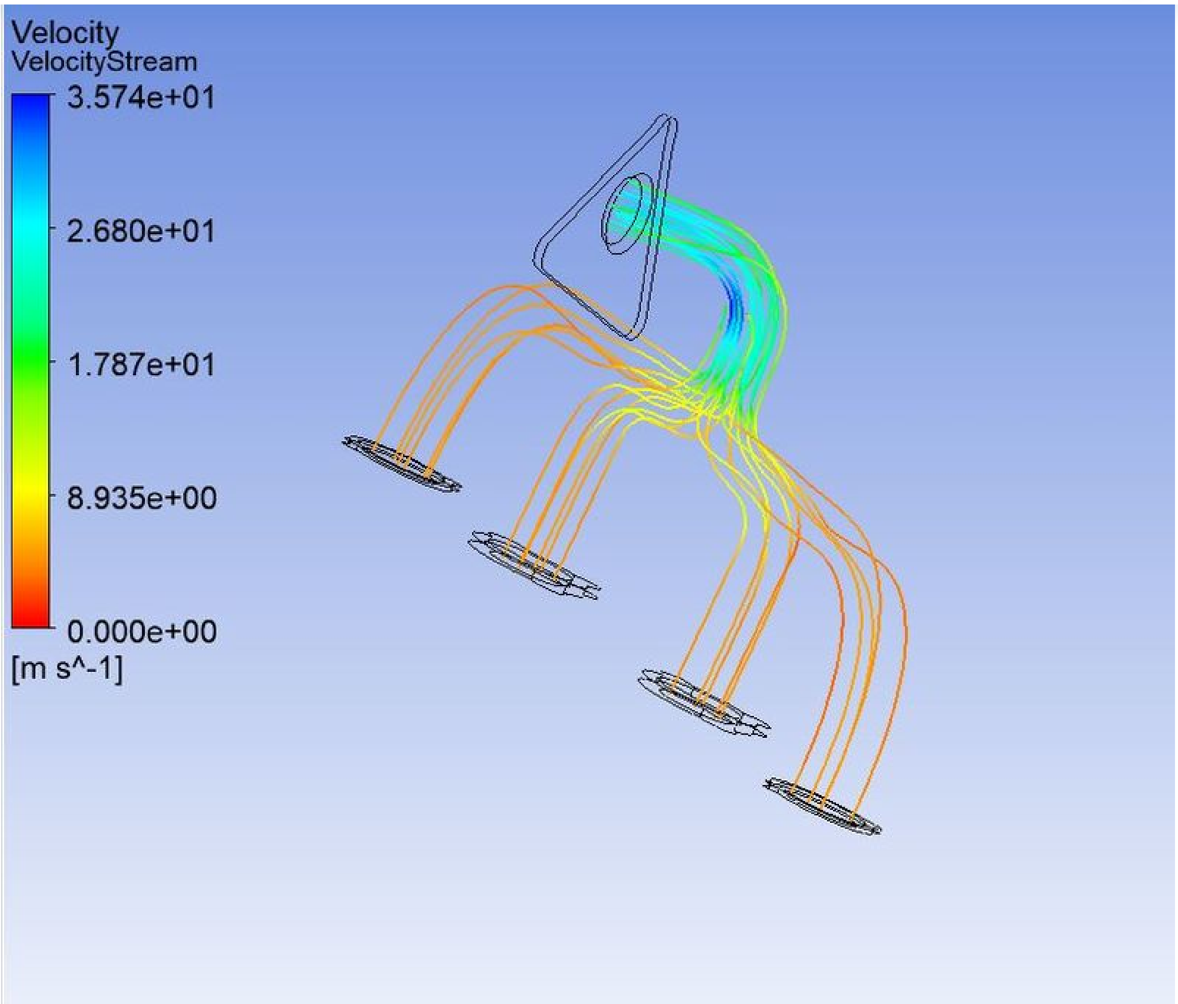


Velocity:



Velocity Streamlines:



Validation of the results:

There exist a correlation betwwen Nusslet number, Prandalt number and Reynolds number. This corellation is given

$$\mathbf{Nu}_D = \mathbf{0.023}\,\mathbf{Re}_D^{4/5}\,\mathbf{Pr}^n$$

this is a case for turbulent flow in pipes. After obtaining the Nu we can use the formula

$$Nu = \frac{h \cdot D}{k}$$

where,

h = Convective heat transfer coefficient,

D = Hydraulic diameter of pipe,

k = Thermal conductivity.

We can analytically now validate the Convective heat transfer coefficient using above steps and see if our simulation is acuurate or not.

Comments on the results and predictions on heat transfer coefficient:

As it can be seen fron the above velocity streamline plot there is increase in the ...y near the throat area. This is attributed to the fact of conservation of mass. As the hot air

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When it come to accuracy of the predictions, it can be noted that simply convergence is not criteria enough to check accuracy of Heat Transfer Coefficient. Whereas the constantly refining the mesh size will cause the element quality to deteriorate. This can be bad for accuracy as the values start to oscillate. Overall, the predictions depend upon the length of inflation layer, quality of elements, Refrence values and trbulance model as well. As a model which is good at evaluating the near wall phenomenons is generally good at predicting Heat Transfer Coefficient.

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