## MAE 598: Project 1: Applied Computational Fluid Dynamics

## **Geometry and Mesh:**

Base Dia: 0.6m Inlet and Outlet diameter: 0.04m Height: 1.2m Extension of inlet and outlet pipes from tank lateral surface = 0.1m. 'z' represents height of the inlet and outlet from the bottom surface. Mesh: Inflation given (5 layers)



## Task 1: Temperature at outlet in 'K'

			Z1(m)	
		0.2	0.6	1
	0.2	304.5655602	304.4315528	301.8349951
Z2(m)	0.6	305.74672	303.1190986	301.4439722
	1	305.6110803	303.6809143	301.4373442

Temp. (	К)
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Highest	305.74672
Median	303.6809143
Lowest	301.4373442

Method: Second order upwind for all equations.

**Model**: Turbulence k-eps Realizable model. (Except for task 4).

Steady flow, Pressure based

Fluid: Water with given properties.

Base Temperature: 70 degree Celsius

Calculation of Outlet Temperature on Fluent. Part of Task 1

$$T_{out} = \frac{\int \int v_n T \, dA}{\int \int v_n \, dA}$$

## Numerator of the equation:

#### Defining custom field function

# Surface Integrals under 'Reports'

Custom Field Function Calculator	Surface Integrals		×
Definition	Report Type Integral	•	Field Variable Custom Field Functions
temperature * Vx         +       -       X       /       y^x       ABS       Select Operand Field Functions from         INV       sin       cos       tan       In       log10       Field Functions         0       1       2       3       4       SQRT       Velocity         5       6       7       8       9       CE/C       X       Velocity         (       )       PI       e       .       DEL       Select	Custom Vectors Vectors of Custom Vectors Surface Types axis dip-surf exhaust-fan fan Surface Name Pattern		ustam-function-0   Surfaces Surfaces Insulated Interior-solid outlet Symm temp_wall velocity_inlet wal-solid
New Function Name custom-function-0	Save Output Parameter	Write	Highlight Surfaces Integral 0 Close Help

## **Denominator of the equation:**

Surface Integrals	
Report Type	Field Variable
Integral 🗸	Velocity
Custom Vectors	X Velocity
Vectors of	Surfaces
Custom Vectors	insulated interior-solid outlet
Surface Types	symm temp_wall velocity_inlet wall-solid
fan 🔹	
Surface Name Pattern	
Match	Highlight Surfaces Integral
Save Output Parameter	0
Compute Write	Close Help

The value obtained by dividing the numerator result and denominator result gives the required value of Temperature outlet. All the values in the table are obtained in the same procedure.

(Choosing 'mass-weighted average' gives the same result as with the above procedure probably because the density remains constant (cancels in numerator and denominator).

Report  $\rightarrow$  Surface Integrals  $\rightarrow$  Report Type: 'Mass-Weighted Average  $\rightarrow$  Variable: Temperature)

## TASK 2:

Cross-section at z = 1m

#### Z1 = 0.2m, Z2 = 0.6m; Highest Outlet Temperature Case

(i) <u>Cross-section at z = 0.2m</u>







(ii) Temperature contour at symmetry plane



## (iii) u-Velocity contour at symmetry plane



## Z1 = 0.6m, Z2 = 1m; Fifth highest outlet temperature case.

(i) Cross-section at z = 0.2m





(ii) Temperature at symmetry plane





## (iii) u-Velocity contour at symmetry plane



#### Z1 = 1m, Z2 = 1m;

# Lowest Outlet Temperature case

(i) Cross-section at z = 0.2m



Cross-section at z = 0.6m



## Cross-section at z = 1m





(ii)

U-Velocity contour at symmetry plane



## Task 3:



Inlet	Temperature
Velocity)m/s	outlet(K)
0.025	308.16656
0.05	305.74672
0.1	303.17868
0.2	301.36284

# 0.2m/s: z1=0.2m, z2 = 0.6m



Contours of Static Temperature (k)



'Local scale' was used for the cross sections z=0.2m, 0.6m, 1m. Not 'Global Scale'.

In **task 2**, from the temperature contour in symmetry plane for Z1=1m and Z2=1m, we observe that the gradient in temperature is only near the bottom surface. So, for this case, we do not expect much increase in outlet temperature. We can also say that the fluid has less time to raise to a high temperature since Z2=1m.

For the highest case: When Z1=0.2m, the inlet is close to the surface where the gradient in temperature is more. As it moves to the outlet, Z2=0.6m, the temperature raises till the highest value mentioned in the table.

Task 3 was run using 'Parametric design' approach.

Select 'New Input Parameter' from velocity inlet Magnitude as shown  $\rightarrow$  Name the parameter ('inlet\_velocity' here)  $\rightarrow$  enter the value of velocity (the current value)  $\rightarrow$  Use 'Create' icon to create an output parameter (Here 'Static Temperature' at outlet).  $\rightarrow$  We can now see a 7<sup>th</sup> row named 'Parameter' (in the current Workbench Project) as shown in the 3<sup>rd</sup> figure below).

Parameters

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			00
Momonhum rt	ation Species DPM Multiphase UDS	Input Parameters	Output Parameters
Input Parameter Properties	cation Method Magnitude, Normal to Boundary	inlet_velocity	Tempout
Name			
parameter-1	erence Frame Absolute		
Current Value (m/s)	sgnitude (m/s) 0.05 New Input Parameter		
0	ssure (pascal) 0 constant		
Used In:			
	ition Method Intensity and Hydraulic Diameter		
	Turbulent Intensity (%) 5		
OK Cancel Help	Hydraulic Diameter (m) 0.04	View Delete More	Create 💌 View More 💌
Help	OK Cancel Help		Close Help

**Duplicating 'Design Points'**: Right click on 'DP 0' and duplicate. Enter the required value of velocity in each duplicate and then click 'Update Selected Design Points'. Now, all the 4 cases will run one after the other on its own and then display the value of outlet temperature in a new column. We can then right click and export each 'DP' individually and open as a new project and edit further, if required.

1	😨 Fluid Flow (F	Fluent)
2	00 Geometry	× ,
3	Mesh	V 🖌
4	Setup	× 🖌
5	G Solution	× 🖌
6	😥 Results	2
>7	Col Deventere	
ble of	Design Points	
ble of	Design Points	B
ble of	Design Points A Name	B P1-inlet_velocity 🔻
ble of 1 2	Design Points A Name Units	B P1-inlet_velocity ▼ m s^-1
ble of 1 2 3	Design Points A Name Units DP 0 (Current)	B P1-inlet_velocity m s^-1
ble of 1 2 3 4	Design Points A Name Units DP 0 (Current) DP 1	B P1-inlet_velocity m s^-1 0.05 0.025
ble of 1 2 3 4 5	Design Points A Name Units DP 0 (Current) DP 1 DP 2	B P1 - inlet_velocity ▼ m s^-1 0.05 0.025 1
ble of 1 2 3 4 5 6	Design Points A Name Units DP 0 (Current) DP 1 DP 2 DP 3	B P1-inlet_velocity m s^-1 0.05 0.025 1 0.2

# Task 4:

Largest outlet temperature value z1=0.2, z2=0.6 case with Laminar Model

# Temperature at outlet: 303.9146 K

Running the laminar model on this turbulent flow gave an outlet temperature that is not very different from the one obtained for turbulent case. For this problem statement, the outlet temperature value is not much sensitive to the change of model. For a different problem, this might not be true. By switching to laminar model, we will not be able to capture the turbulence effects in the important areas in the domain.

When compared to the 'Turbulence model' case, the laminar model had more fluctuations in the residual curve. Owing to these fluctuations even after many iterations, it would be reasonable to take the average of the last 1000 iterations values. Further, the residual I energy curve doesn't go till e^-5 in the laminar case, even after 4000 iterations, whereas when modelled in the turbulence case, it does.

#### Laminar Model:





## Task 5:

- a) Heat Transfer Rate at the bottom surface chosen from 'Reports' → 'Fluxes' = **1009.2791 Watts** Area = Half of the base area since the geometry is symmetric.
  - $\Rightarrow$  Area = (pi/8)\*(d^2) = (pi/8)\*0.6\*0.6 = 0.14137167 m<sup>2</sup>
  - $\Rightarrow$  Heat Flux from bottom surface = (1009.2791/Area) = **7139.18923 W/m<sup>2</sup>**
- b) Temperature at outlet after replacing the boundary condition from 'Temperature' to 'Heat Flux' with the above obtained value: **305.72688** K.

This value is very close to what was observed previously. Not much difference.