CL254 - Process Fluid Mechanics
Project Report 2022

Flow pattern in a diverging channel under laminar conditions

GROUP 7

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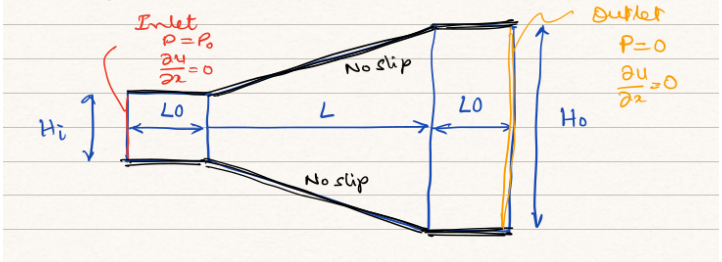
Problem Statement

Flow pattern in a diverging channel under laminar conditions.



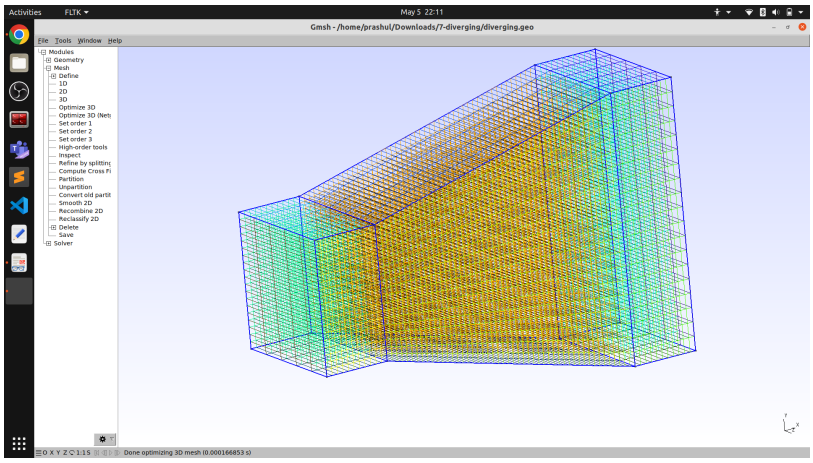
Analyse the problem according to the given pathway :

- For a given geometry, use a δt that gives a stable flow i.e. velocity profile does not change and a mesh that is fine enough so that the flow is mesh independent.
- For a given geometry use different values of P_o to obtain ΔP v/s flow rate curves for the flow.
- For a fixed value of P_o use different values of H_i to study how the flow rate varies. Use a large enough value of P_o so that $R_e >> 1$ but the flow is laminar.
- Obtain streamlines for the flow and check for boundary layer separation.

NOTE: p in the simulations is P/ρ

Solution

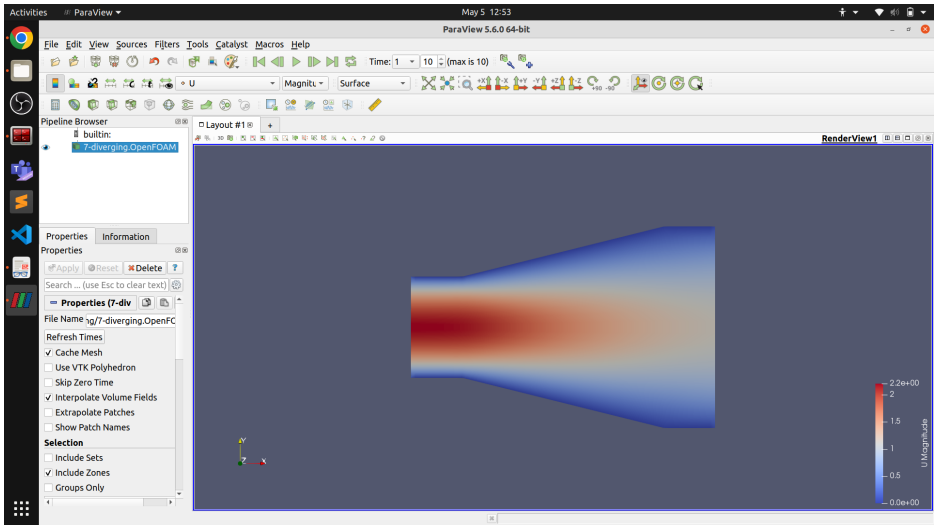
We were given the following geometry to solve the flow and analyse the flow



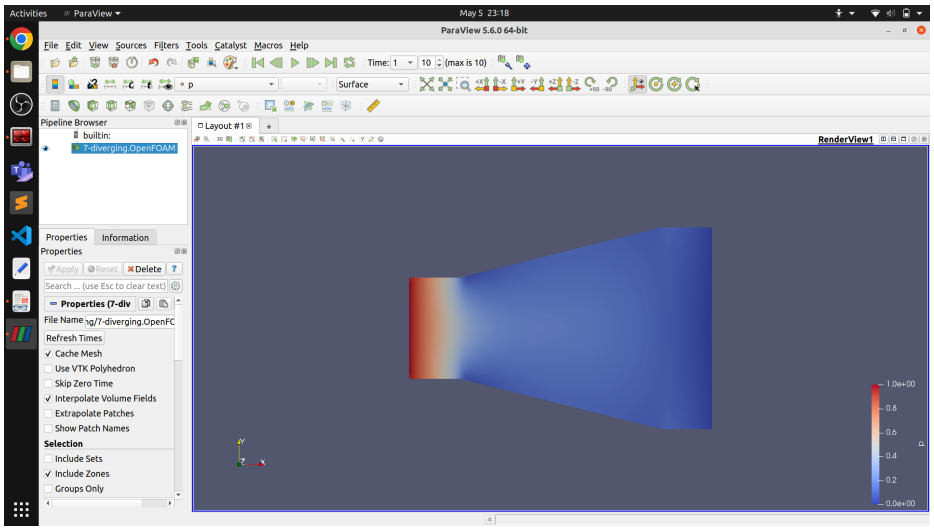
a).

We have used icoFoam command to solve for the flow and therefore we got the following velocity profile of the flow.

Velocity variation :



Pressure variation :

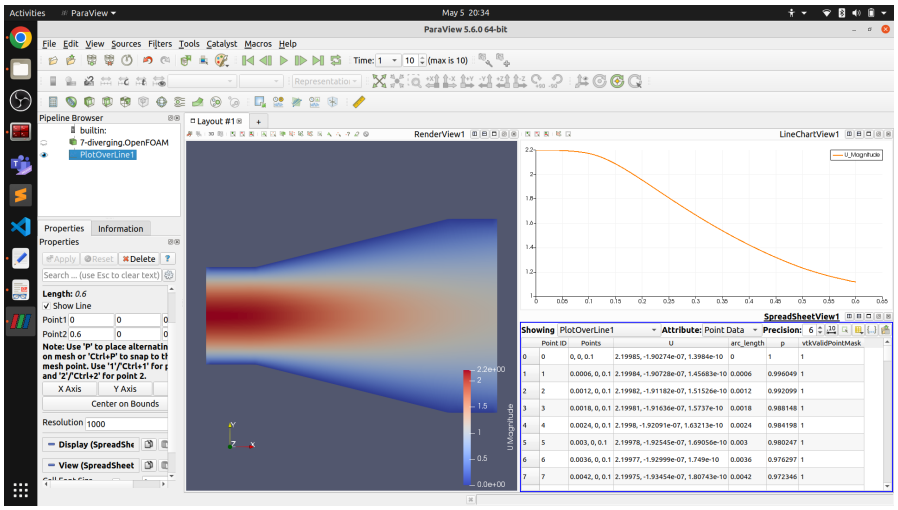


b).

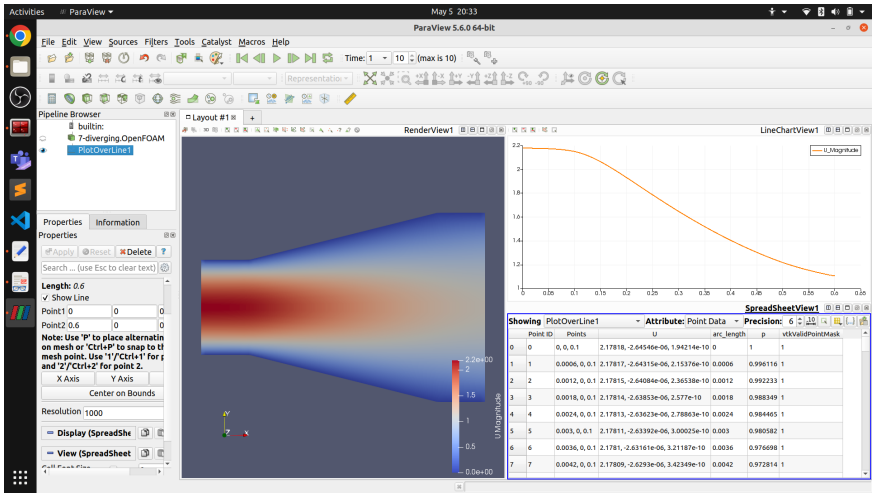
We have to use a δt that gives a stable flow i.e. velocity profile does not change. Therefore we plotted the velocity curve for different value of δt and plotted all those curve on excel plot, to compare when the curves overlaps.

Therefore the velocity profile we got for each value of δt is :

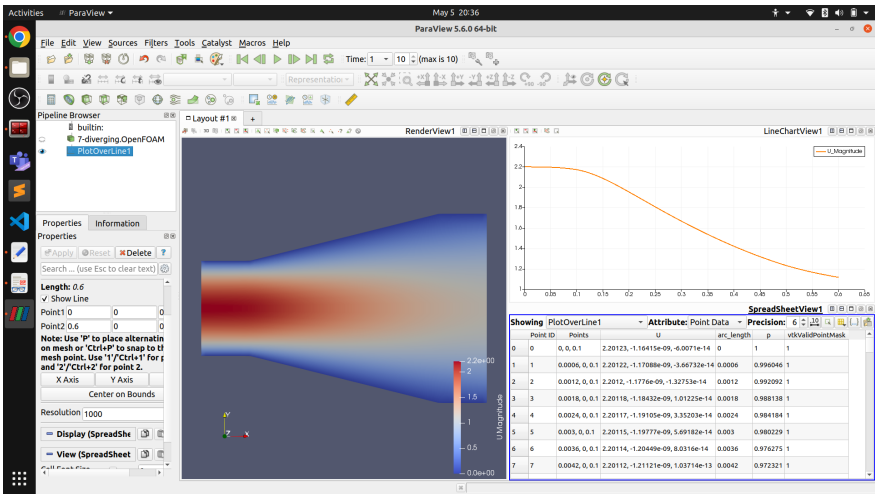
- δt =0.01



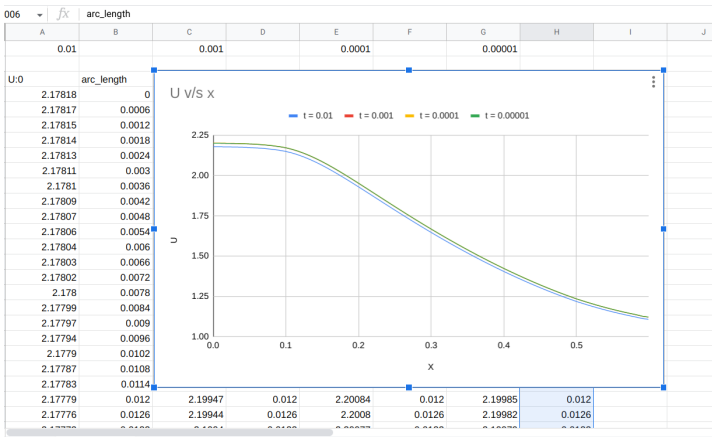
- δt =0.001



- δt =0.0001



Therefore on plotting all these velocity curves on the same graph we got this,



Since, we can observe that after δt =0.001 that velocity profile overlaps, Therefore we will be using this value of δt further.

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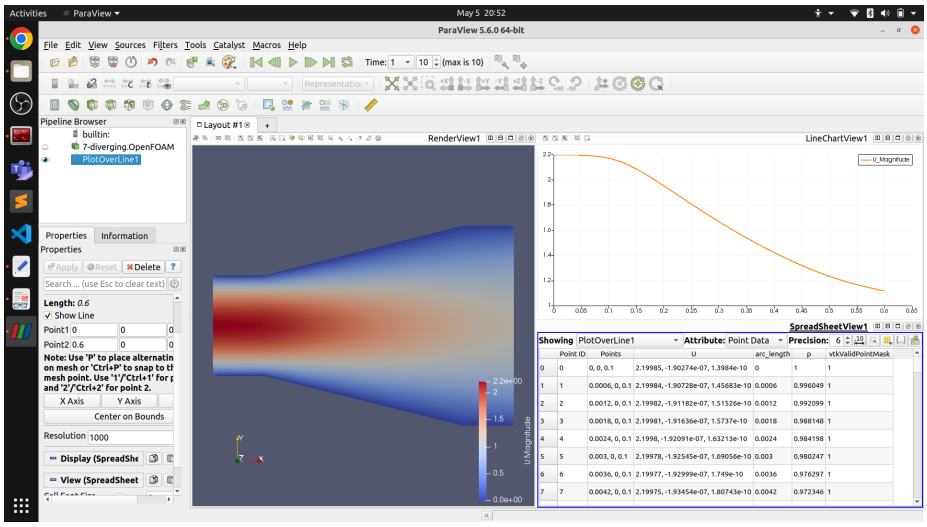
b).
Now we have to use a mesh that is fine enough so that the flow is mesh independent i.e. if we further increase the finess of the mesh, the velocity profile do not change.
For this again we plotted the velocity profile for different mesh refines and then plotted them on the same graph.

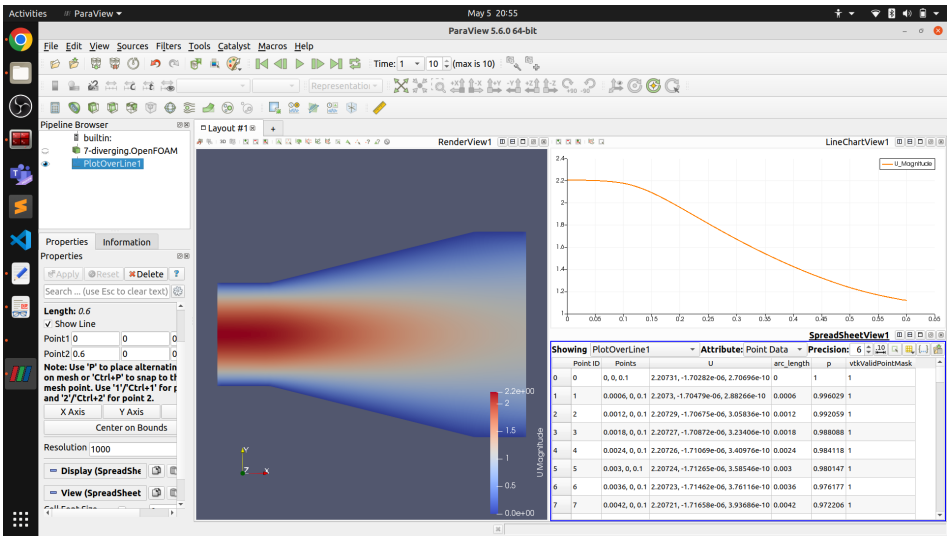
In the .geo file, the following parameters were changed
NH=20;
NL=50;
Transfinite Curve {8, 9, 10, 4} = NH Using Progression 1;
Transfinite Curve {6, 2} = NL Using Progression 1;

So the velocity curve for different mesh finements are :

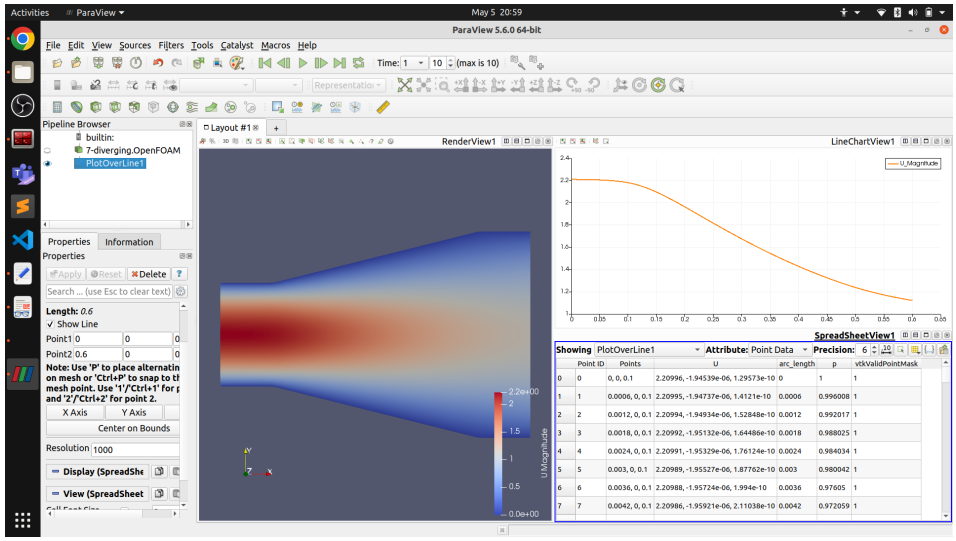
- NH=20;
  NL=50;



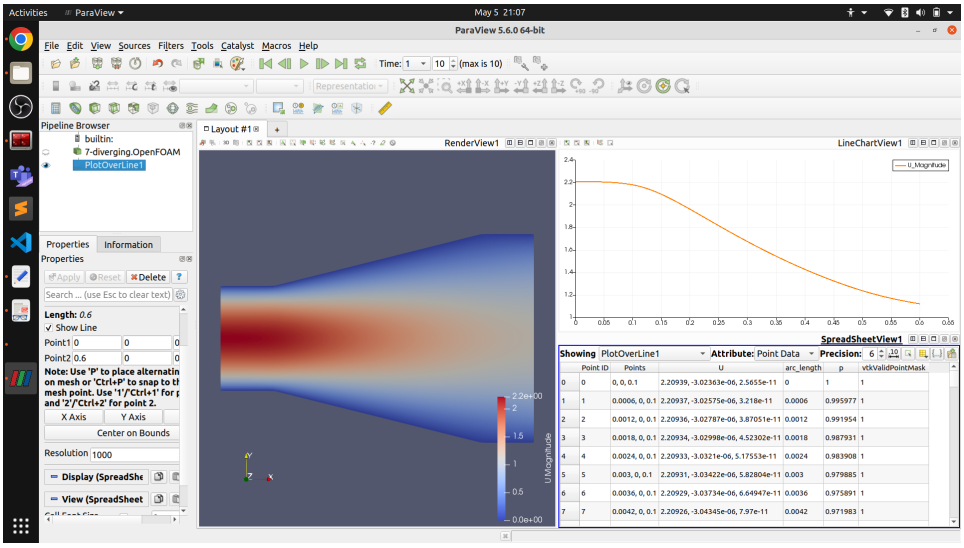
- NH=30;
  NL=60;



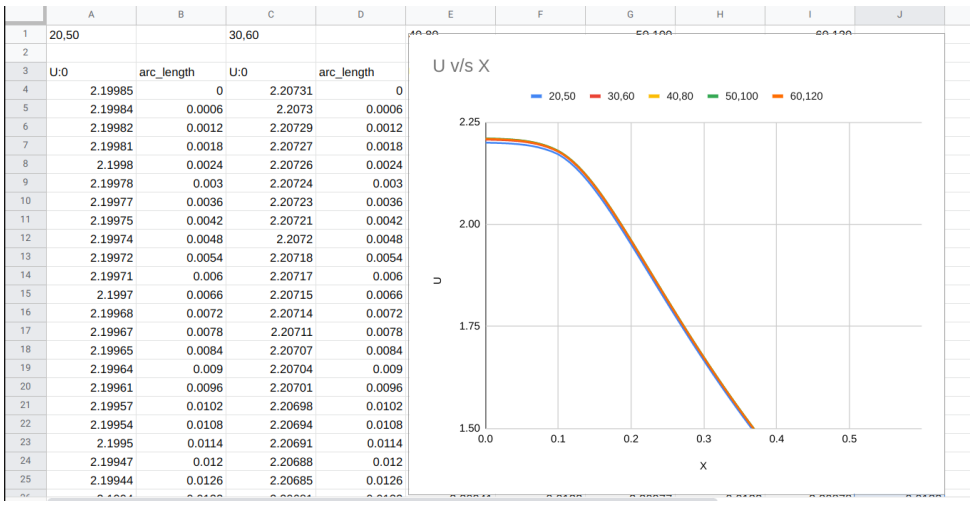
- NH=40;
  NL=80;



- NH=60;
  NL=120;



Therefore, if we plot these curves on the same graph we get the following curve.



	A	B	C	D
1	20,50		30,60	
2				
3	U:0	arc_length	U:0	arc_length
4	2.19985	0	2.20731	0
5	2.19984	0.0006	2.2073	0.0006
6	2.19982	0.0012	2.20729	0.0012
7	2.19981	0.0018	2.20727	0.0018
8	2.1998	0.0024	2.20726	0.0024
9	2.19978	0.003	2.20724	0.003
10	2.19977	0.0036	2.20723	0.0036
11	2.19975	0.0042	2.20721	0.0042
12	2.19974	0.0048	2.2072	0.0048
13	2.19972	0.0054	2.20718	0.0054
14	2.19971	0.006	2.20717	0.006
15	2.1997	0.0066	2.20715	0.0066
16	2.19968	0.0072	2.20714	0.0072
17	2.19967	0.0078	2.20711	0.0078
18	2.19965	0.0084	2.20707	0.0084
19	2.19964	0.009	2.20704	0.009
20	2.19961	0.0096	2.20701	0.0096
21	2.19957	0.0102	2.20698	0.0102
22	2.19954	0.0108	2.20694	0.0108
23	2.1995	0.0114	2.20691	0.0114
24	2.19947	0.012	2.20688	0.012
25	2.19944	0.0126	2.20685	0.0126

As you can see that after,NH=40;NL=80; the curves tend to overlap each other. Therefore the

Flow becomes independent of the mesh after NH=40;NL=80;

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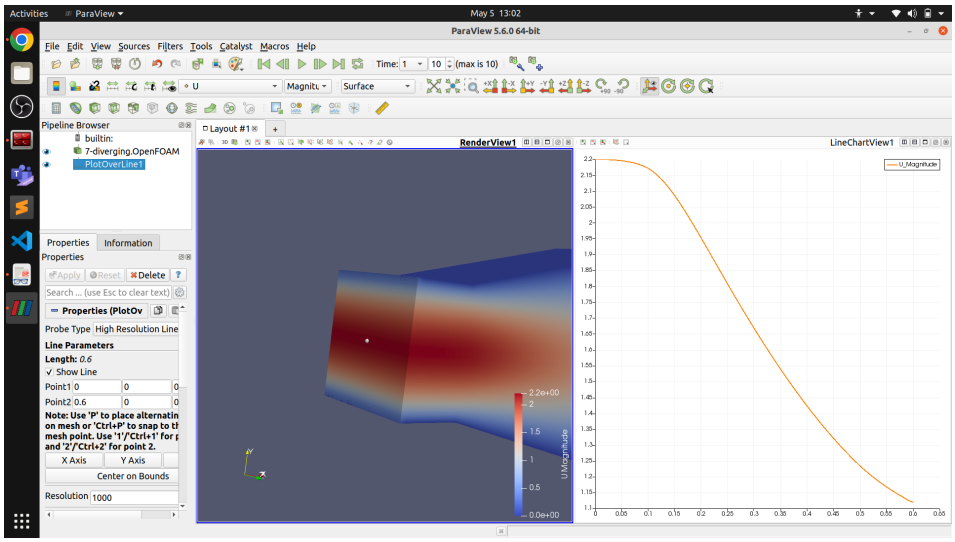
c).

We have to use different values of P_o to obtain ΔP v/s flow rate curves for the flow. Therefore staring from $P_o = 1$ till $P_o = 2.1$, we have plotted the velocity profile of the flow. Then since flowrate is always same for a given parameter, we extracted the value of U(x=0) and multiplied it with the area of cross section at x=0 (i.e. Hi*Hi) which gives us the flow rate of the system.

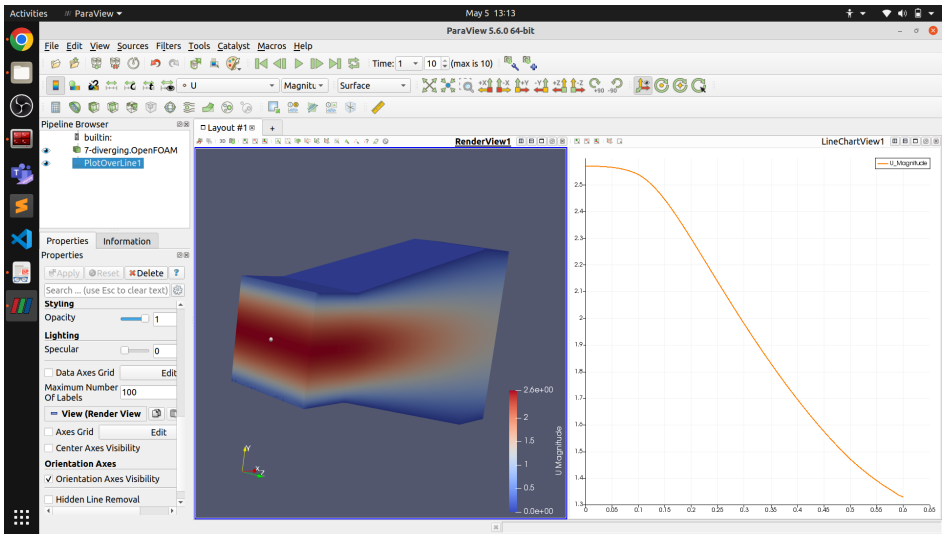
We then plotted the ΔP and Q (flow rate) value on a graph and analysed its behaviour.

Therefore the velocity profile for different value of P_o is

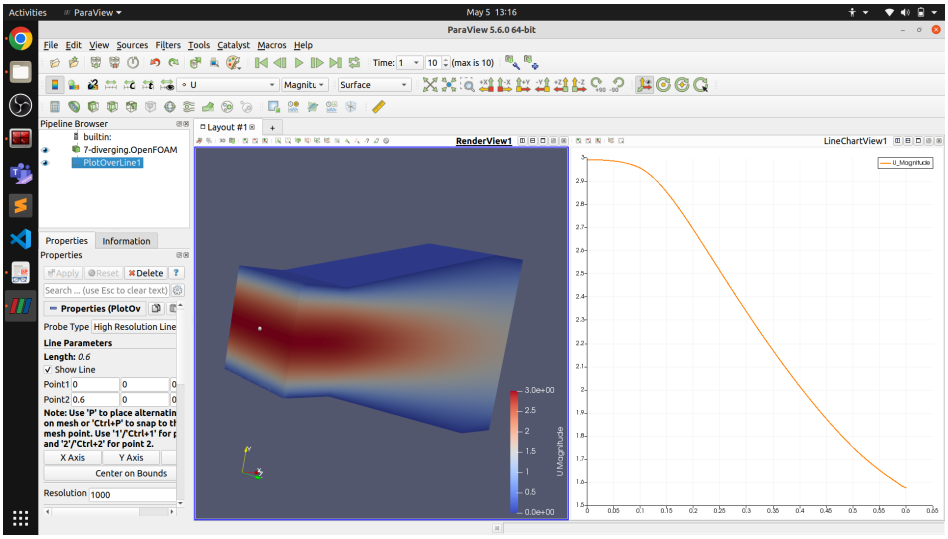
- Po = 1 (m/s)^2



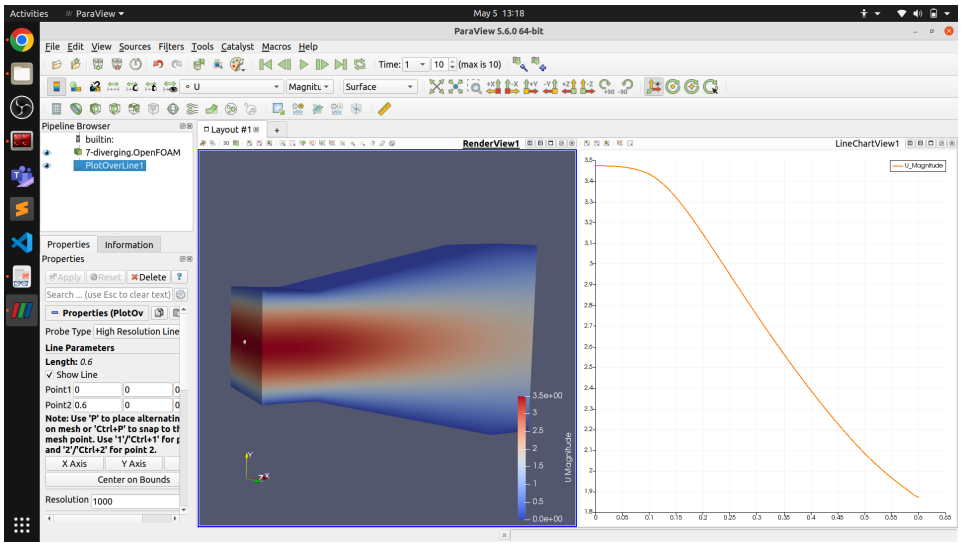
- Po = 1.1 (m/s)^2



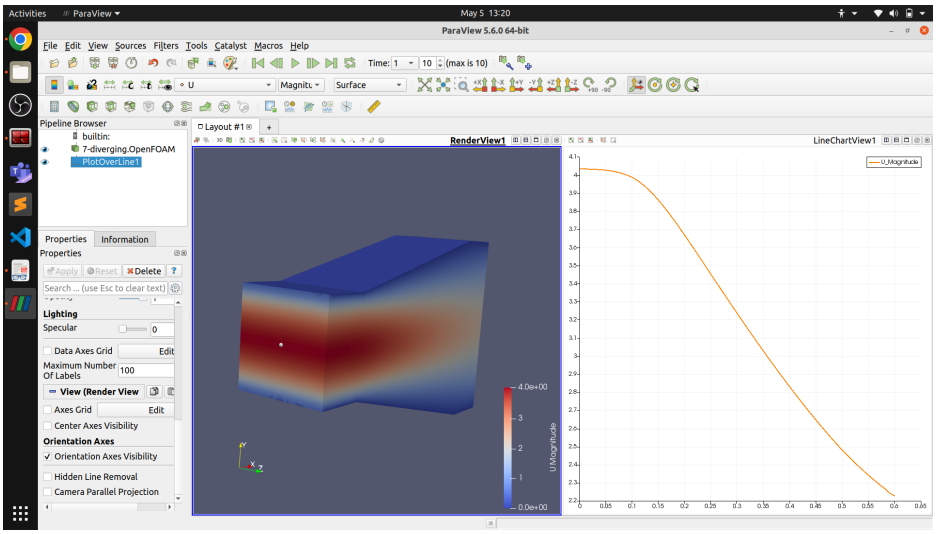
- Po = 1.2 (m/s)^2



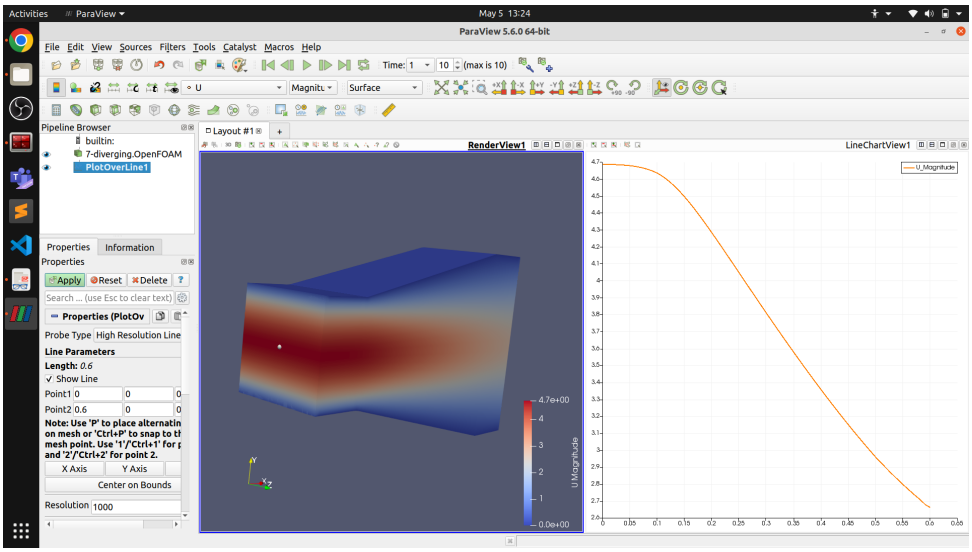
- Po = 1.3 (m/s)^2



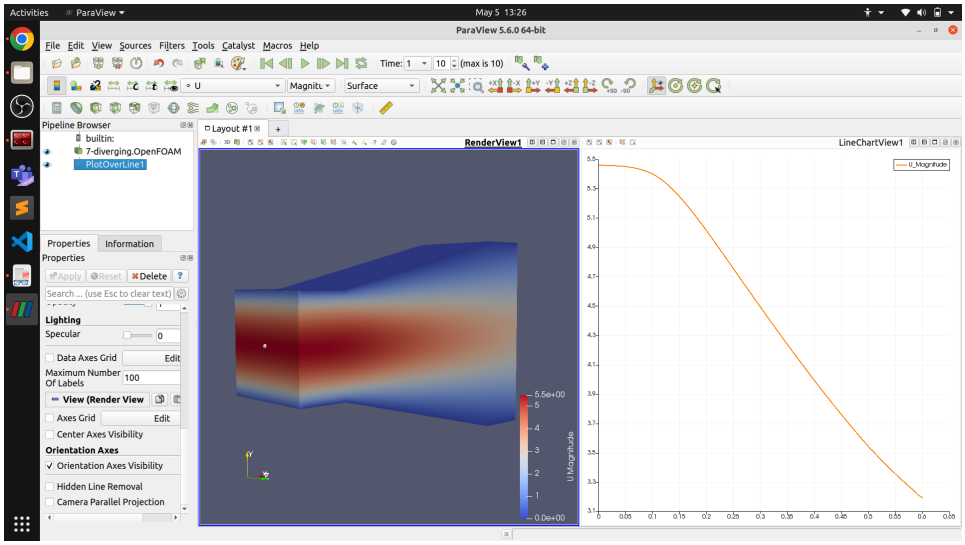
- Po = 1.4 (m/s)^2



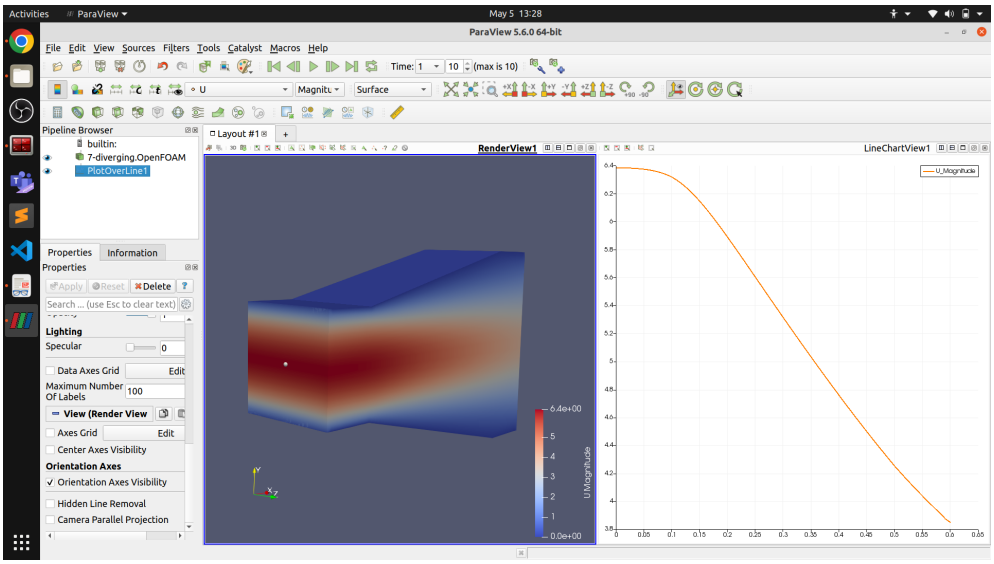
- Po = 1.5 (m/s)^2



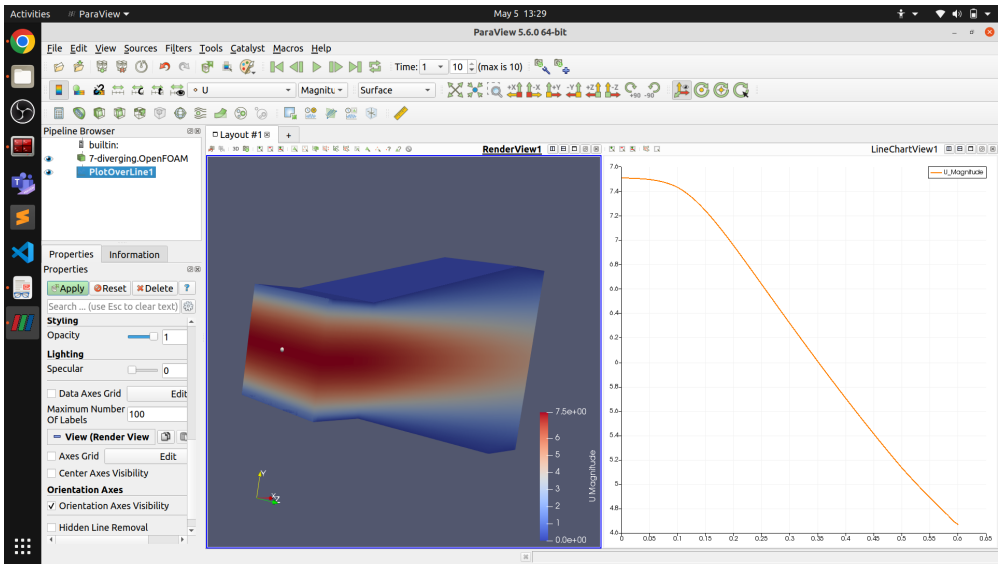
- Po = 1.6 (m/s)^2



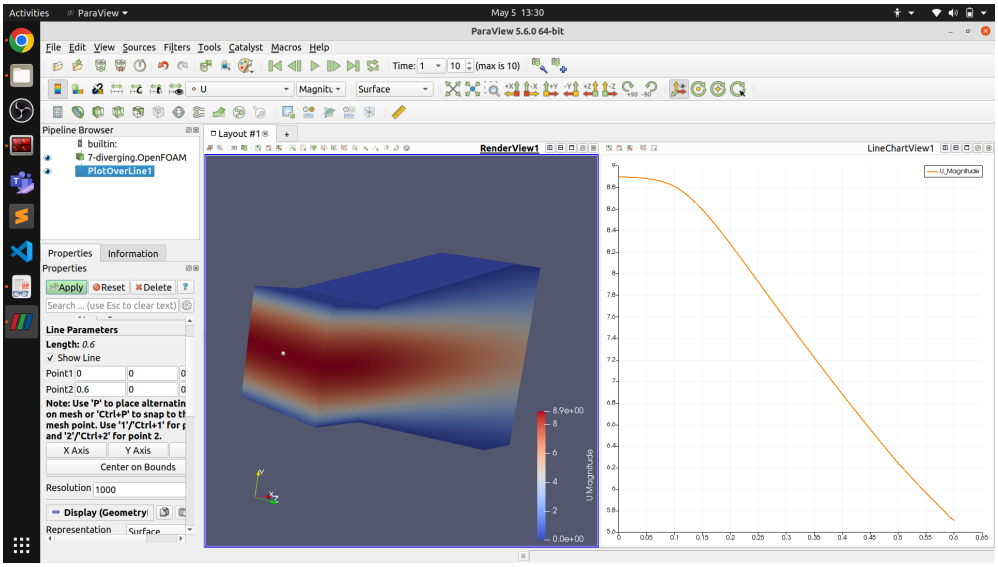
- Po = 1.7 (m/s)^2



- Po = 1.8 (m/s)^2

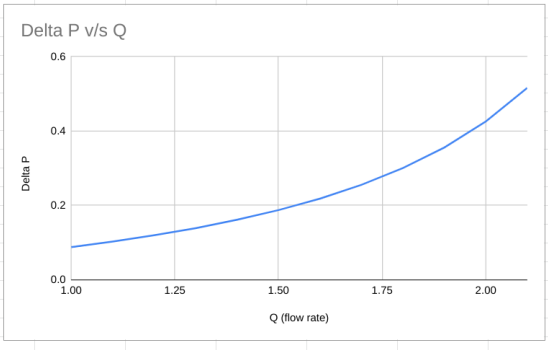


- Po = 1.9 (m/s)^2



Now extracting the value of U and then calculating the value of Q, then plotting the curve on the graph, we get the following curve.

	Po	U_x (x=0)	Hi	Q
1				
2	1	2.2	0.2	0.088
3	1.1	2.57	0.2	0.1028
4	1.2	2.99158	0.2	0.1196632
5	1.3	3.474	0.2	0.13896
6	1.4	4.034	0.2	0.16136
7	1.5	4.687	0.2	0.18748
8	1.6	5.46	0.2	0.2184
9	1.7	6.385	0.2	0.2554
10	1.8	7.508	0.2	0.30032
11	1.9	8.896	0.2	0.35584
12	2	10.6457	0.2	0.425828
13	2.1	12.9	0.2	0.516
14				
15				
16				
17				
18				
19				
20				



So as we observed that the ΔP v/s Q is increasing but the curve is not linear.

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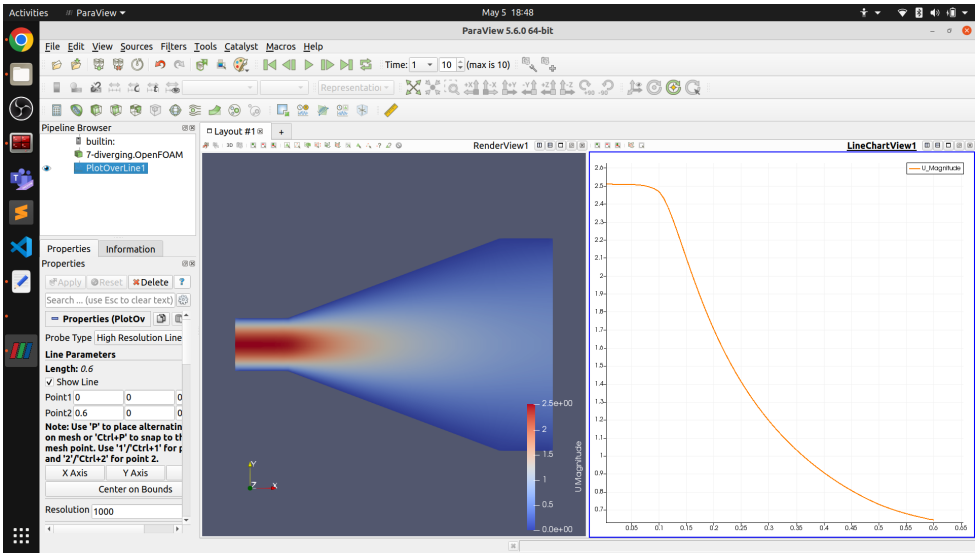
d).

Now for a fixed value of P_o we have to use different values of H_i to study the variation of flow rate. Here we are using Po = 1.9 (m/s)^2.

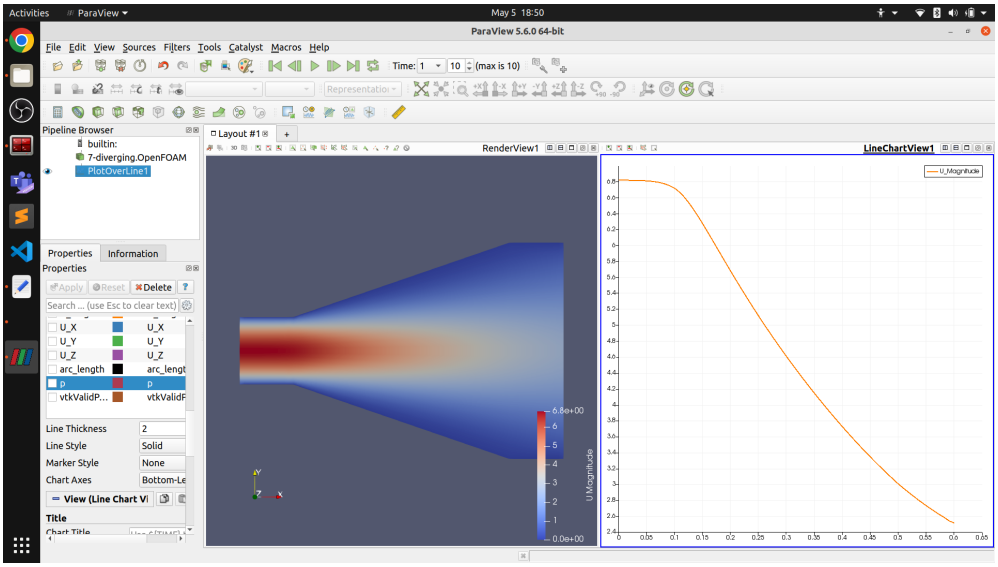
So we took different values of Hi varying from 0.1 to 0.375 (the value of Hi should necessarily be less than Ho = 0.4, since the pipe is diverging one). So we plot the the velocity profile at different value of Hi and similar to the previous solution extracted the value of U to calculate the value of Q (flow rate).

The velocity profile at different value of Hi is given by :

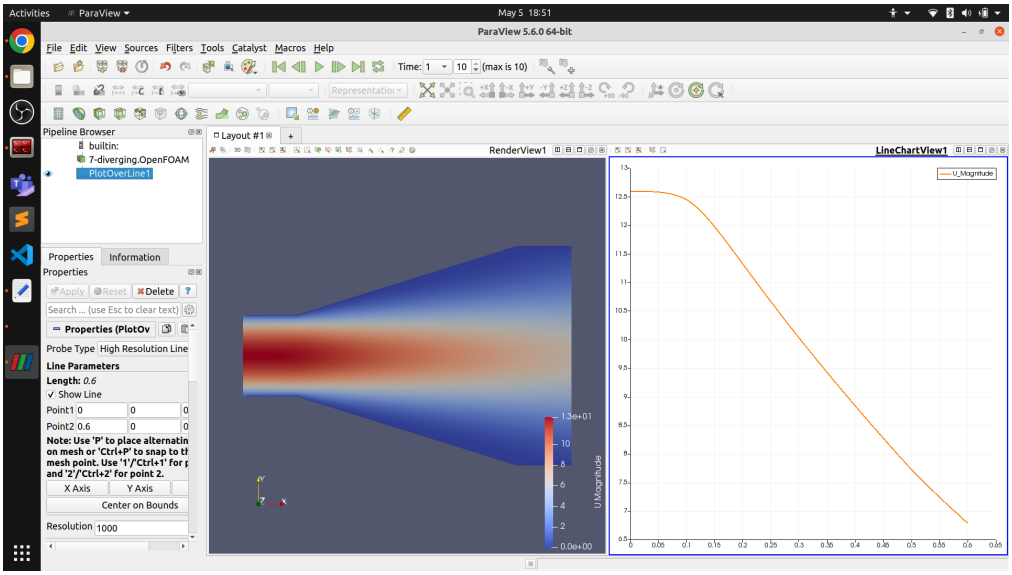
- H_i = 0.1 m



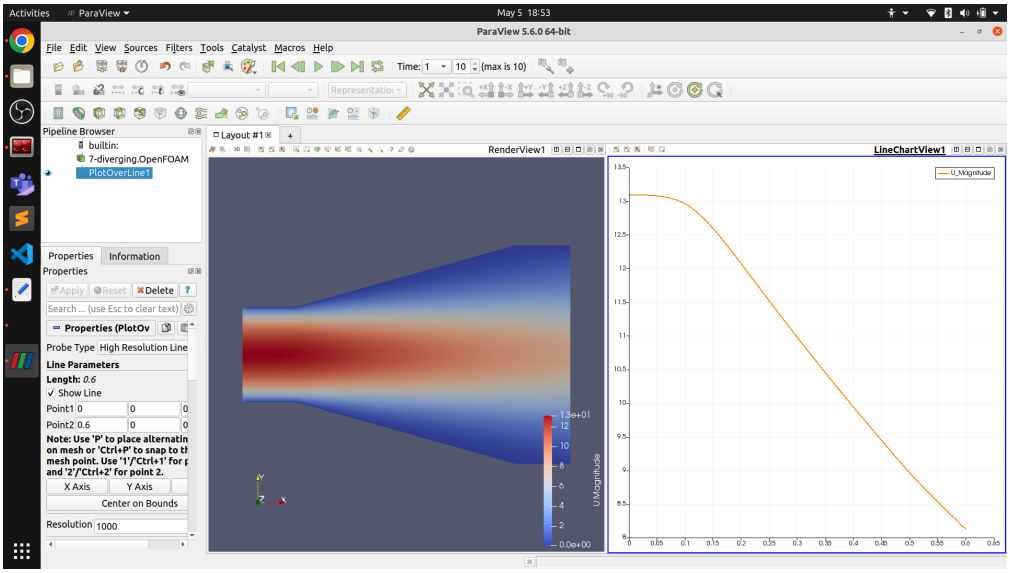
- H_i = 0.125 m



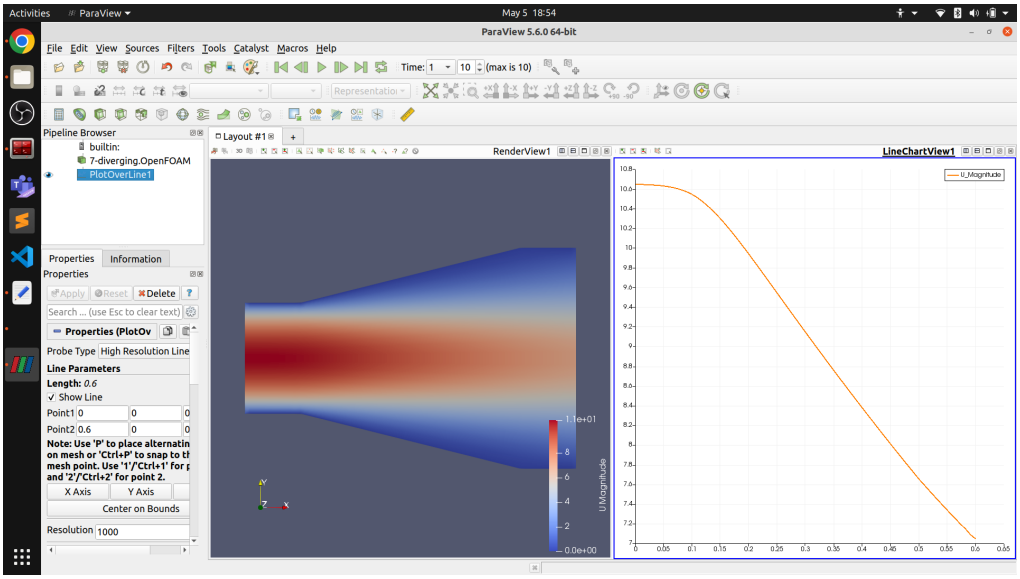
- H_i = 0.15 m



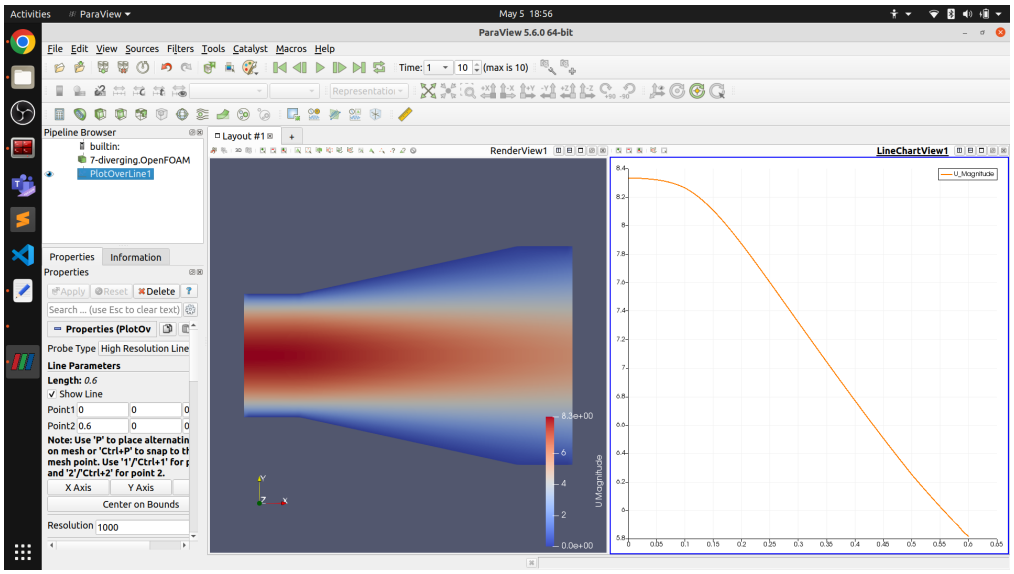
- H_i = 0.175 m



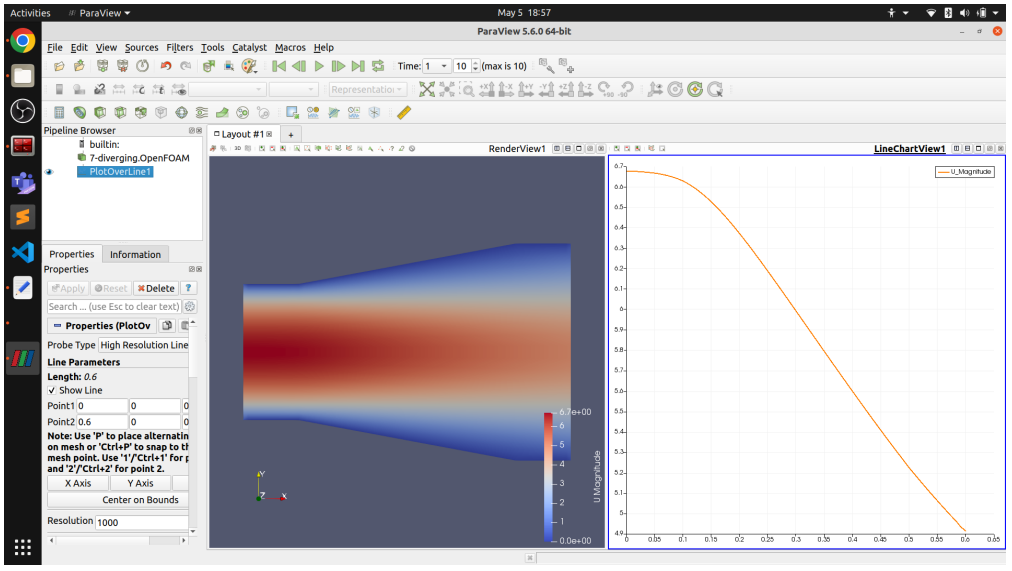
- H_i = 0.2 m



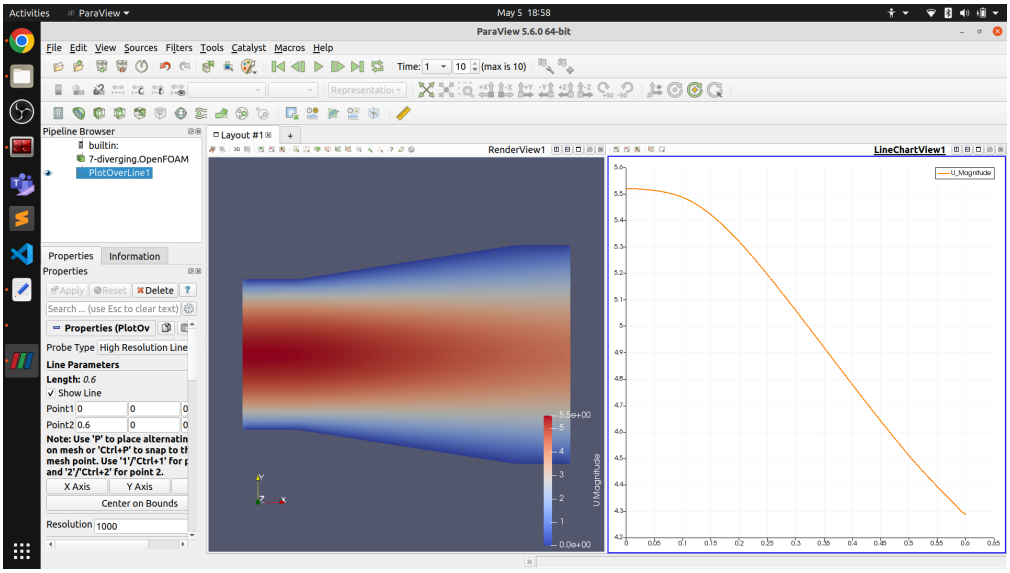
- H_i = 0.225 m



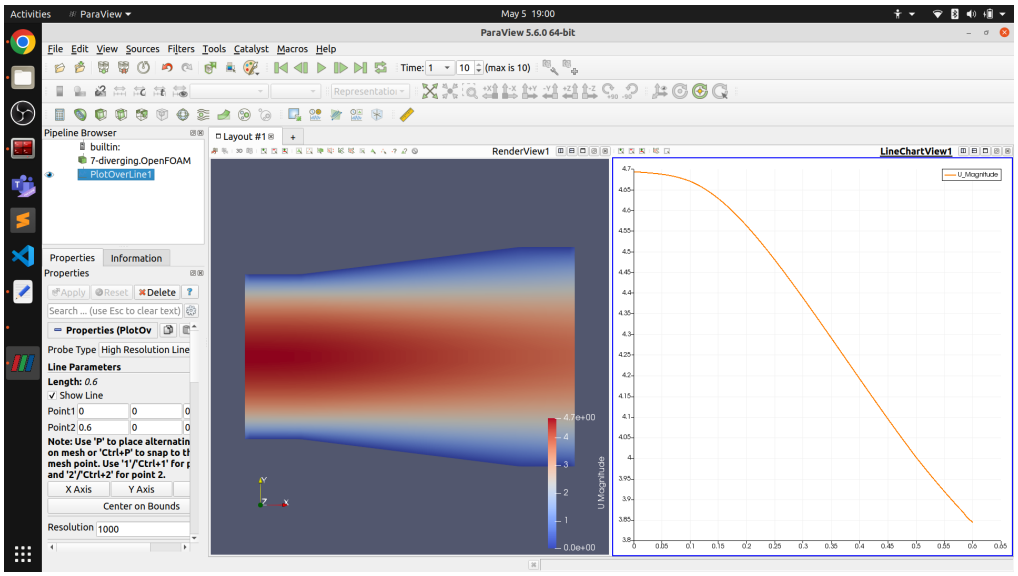
- H_i = 0.25 m



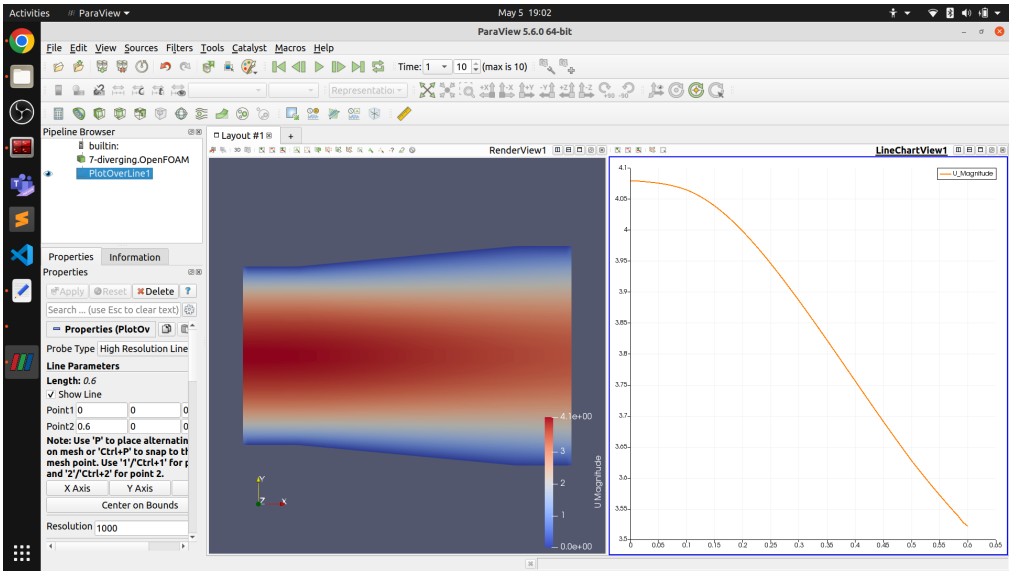
- H_i = 0.275 m



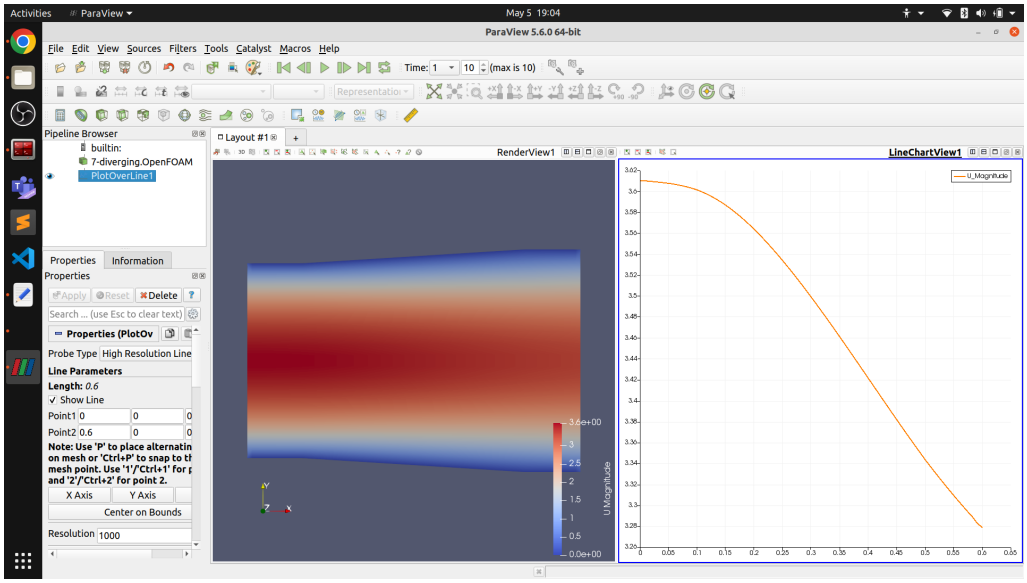
- H_i = 0.3 m



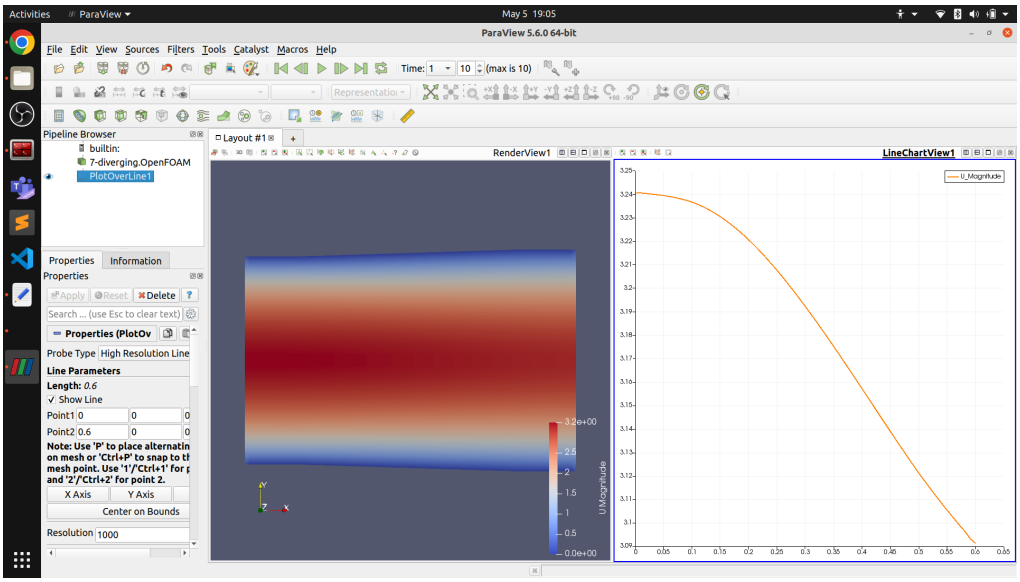
- H_i = 0.325 m



- H_i = 0.35 m

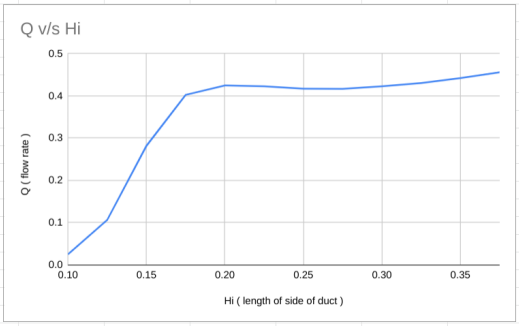


- $H_i = 0.375$ m



Now extracting the value of U and then calculating the value of Q, then plotting the curve on the graph, we get the following curve.

	Hi	U_x	Q	Po=2
1				
2	0.1	2.51	0.0251	
3	0.125	6.81	0.10640625	
4	0.15	12.52	0.2817	
5	0.175	13.14	0.4024125	
6	0.2	10.62	0.4248	
7	0.225	8.35	0.42271875	
8	0.25	6.675	0.4171875	
9	0.275	5.51	0.41669375	
10	0.3	4.695	0.42255	
11	0.325	4.075	0.430421875	
12	0.35	3.61	0.442225	
13	0.375	3.24	0.455625	



So we got this curve of Q (flow rate) v/s Hi.

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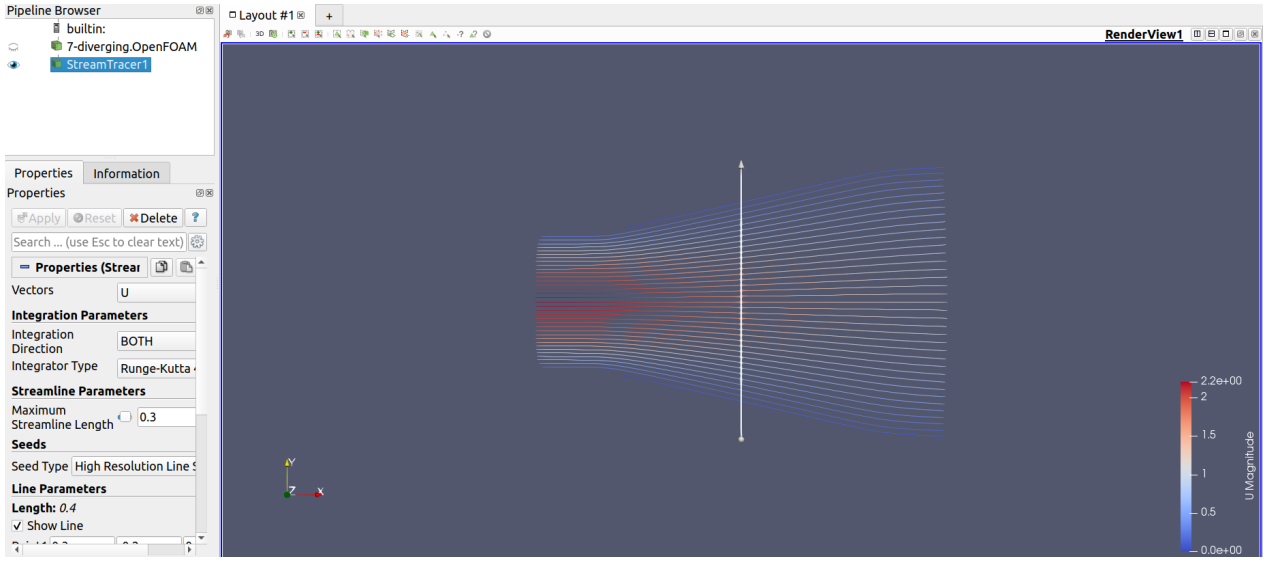
e).

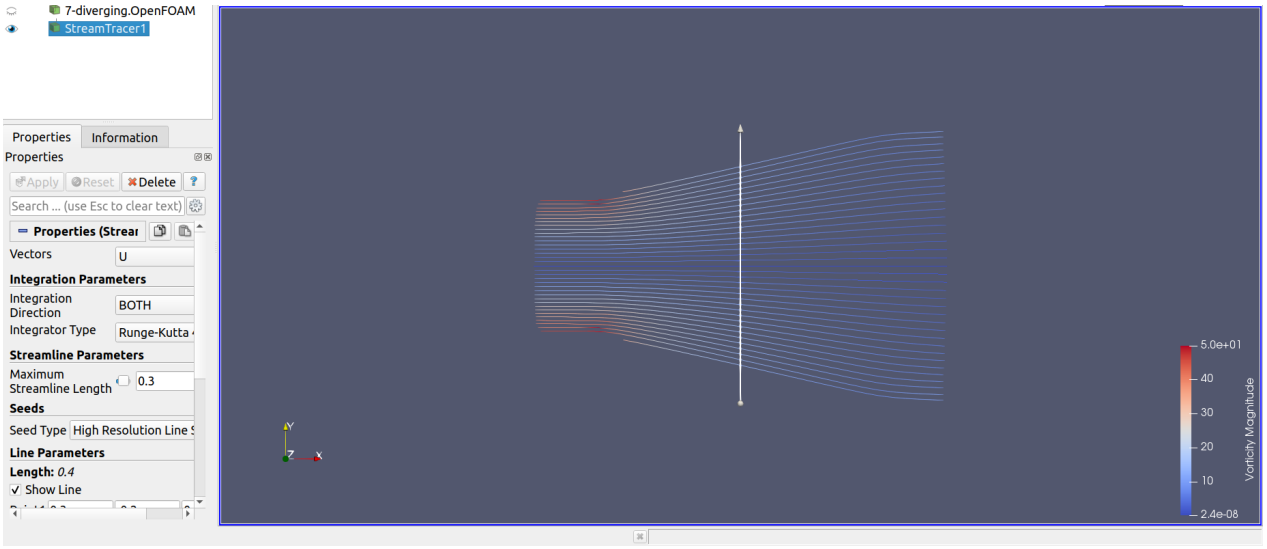
We have to obtain streamlines for the flow and check for boundary layer separation. Now notice that if the pressure is negative there will be formation of boundary layer, therefore for the conclusion of boundary layer formation we will observe the pressure profile.

Streamlines

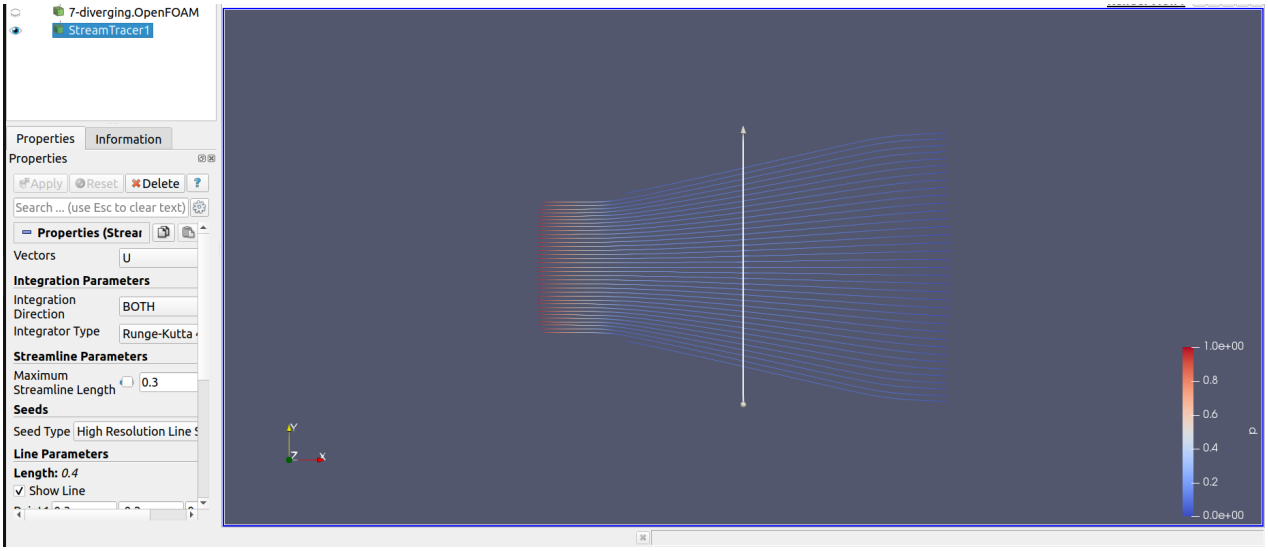
With velocity profile :



With vorticity profile :



With pressure profile :



Note that here pressure does not get negative at any point in the flow. Therefore there is no formation of boundary layer.

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Appendix

1.The plot used in the report is plotted using excel whose sheet is attached below : https://docs.google.com/spreadsheets/d/1GjBBH66phEngnkvFRCNK_q4gripdQo26IxjH2R1E0Qw/edit?usp=sharing

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End of Report