MAE 560 – Applied CFD – Fall 2022

HW 2: Compressible Flow through a Nozzle

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Statement of Collaboration

No collaboration.

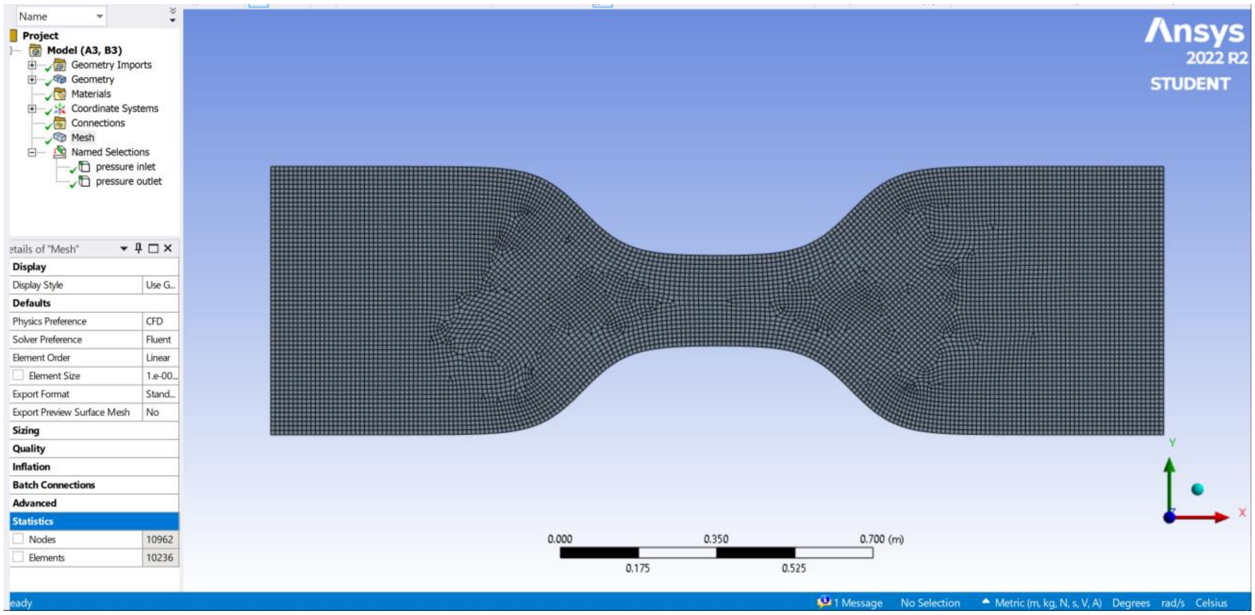

Figure 1: 2D geometry of the nozzle

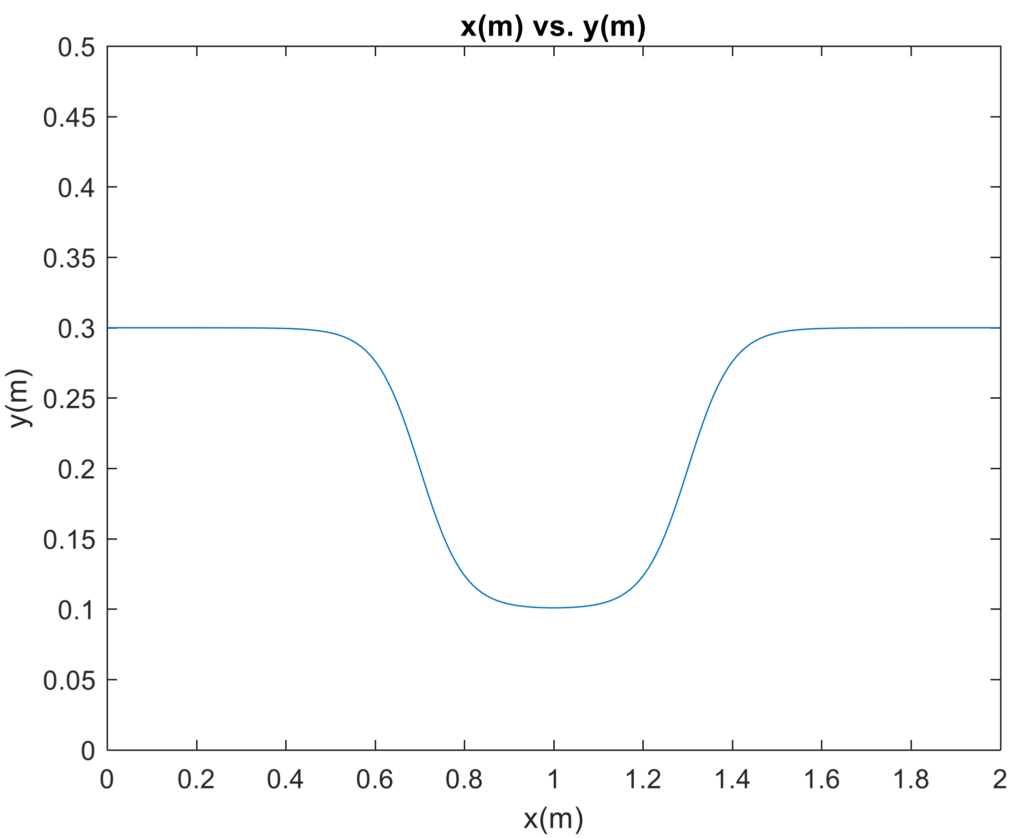

Figure 2: Profile of the symmetric nozzle wall

Objective:

Simulate two cases of a 2-D flow through a nozzle, one in the supersonic regime and the other in the subsonic regime.

Instructions:

- Consider a 2-D flow through a nozzle as illustrated in Fig. 1. The system is symmetric with respect to the x-axis. The profile of the wall of the nozzle is given by

$$F(x) = 0.3 + 0.1\,[\,tanh(10\,x - 13) - tanh(10\,x - 7)], \qquad 0 \le x \le 2, \qquad Eq.(1)$$

- as shown in Fig. 2. The unit of x and F(x) is meter. The system is filled with air. A higher pressure is imposed at the left opening and a lower pressure at the right opening. The pressure difference drives the flow through the nozzle.
- Since this is an inviscid simulation, there is no need to place highly concentrated mesh near the wall. In other words, the nodal points can be distributed more uniformly in the direction normal to the wall. You may use full-nozzle or half-nozzle geometry, the latter by invoking symmetry.

a) Supersonic Case:

Perform a simulation with the following setting:

(1) Select Density based solver and seek steady solution.
(2) Set the density of air to ideal gas to allow density to vary with pressure and temperature. Turn Energy equation on.
(3) Select Inviscid model.
(4) Set Operating pressure to 0. (This means the values of pressure imposed at the inlet and outlet are those of absolute pressure.)
(5) Set the left opening as a pressure inlet and impose
    (i) Gauge total (stagnation) pressure = 100000 Pa
    (ii) Supersonic/Initial gauge pressure = 98000 Pa
    (iii) Total temperature = 500°K.
(6) Set the right opening as a pressure outlet and impose Gauge pressure = 5000 Pa. Set the temperature of backflow to 200 K.
(7) For Reference values, choose "Compute from pressure inlet".

(8) For Initialization, choose "Standard" and "Compute from pressure inlet".

(D1)

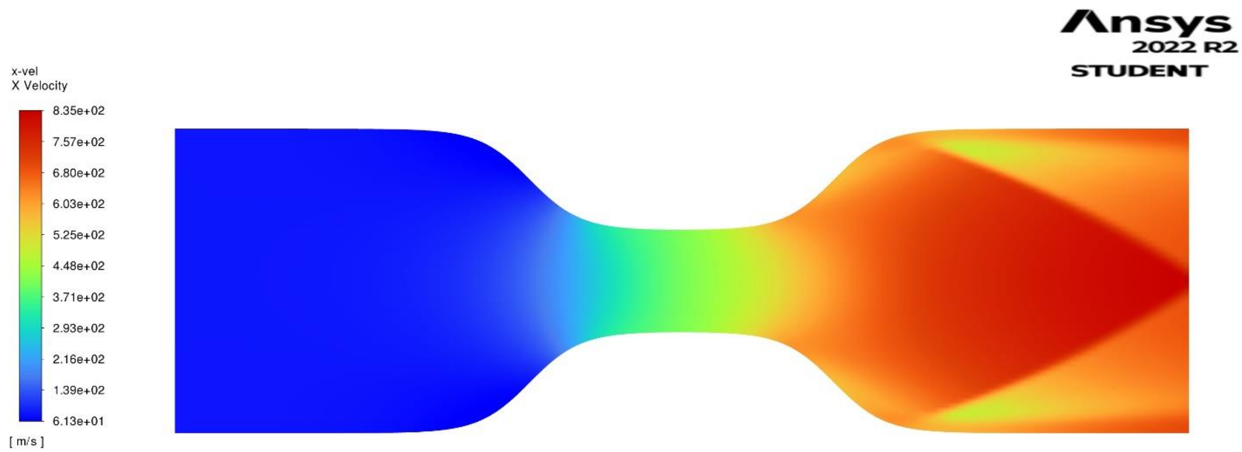

Figure 3: Contour plot of x-velocity (D1)

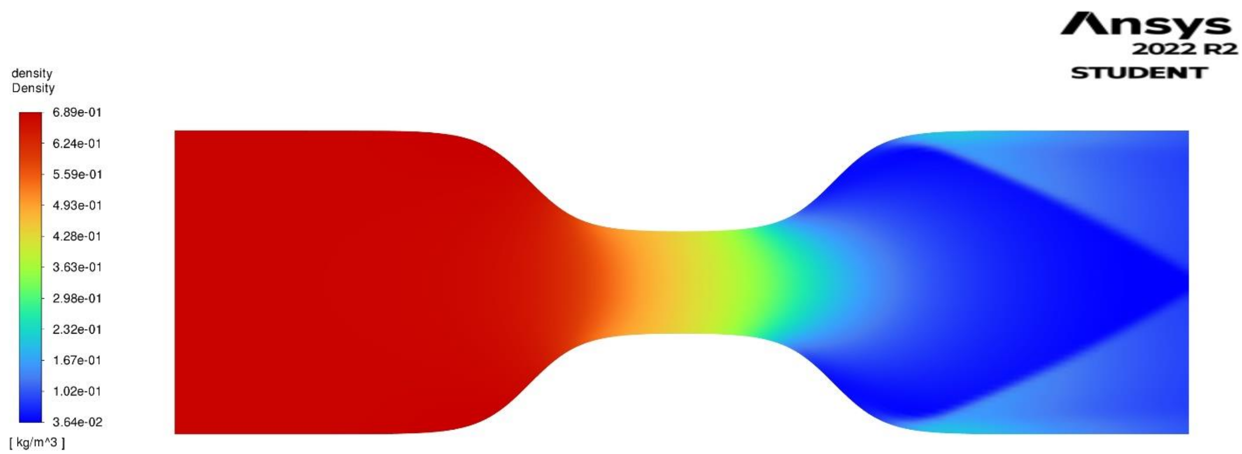

Figure 4: Contour plot of density (D1)

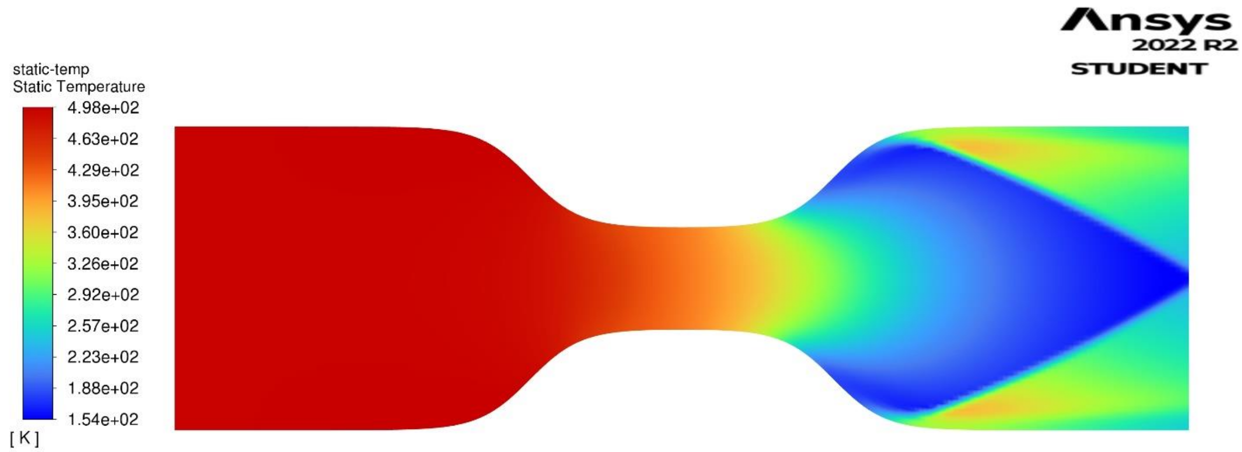

Figure 5: Contour plot of temperature (D1)

(D2)

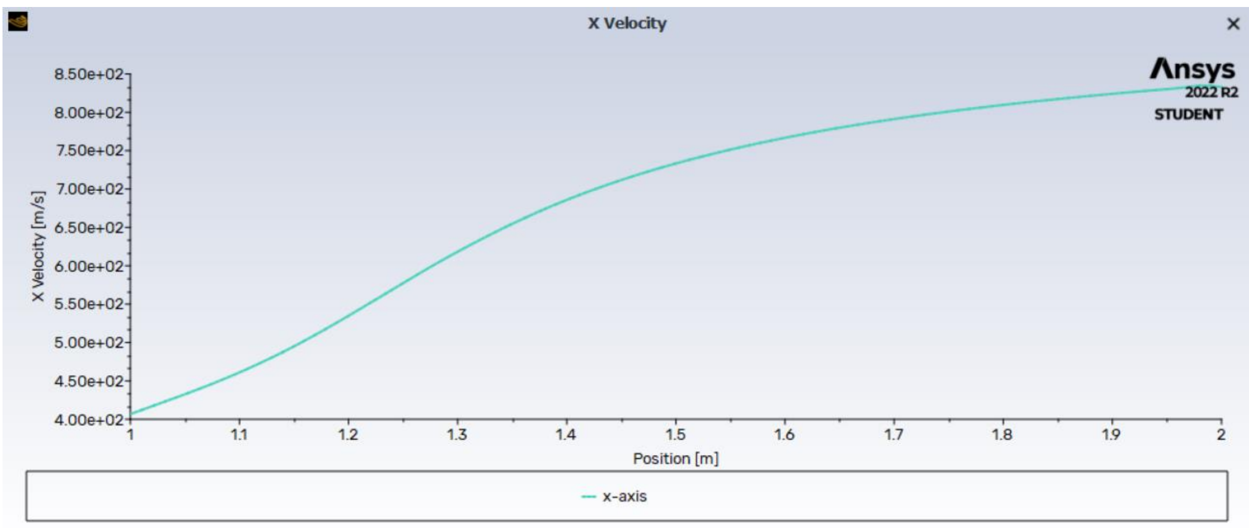

Figure 6: Line plot of x-velocity along x-axis (line of symmetry) (D2)

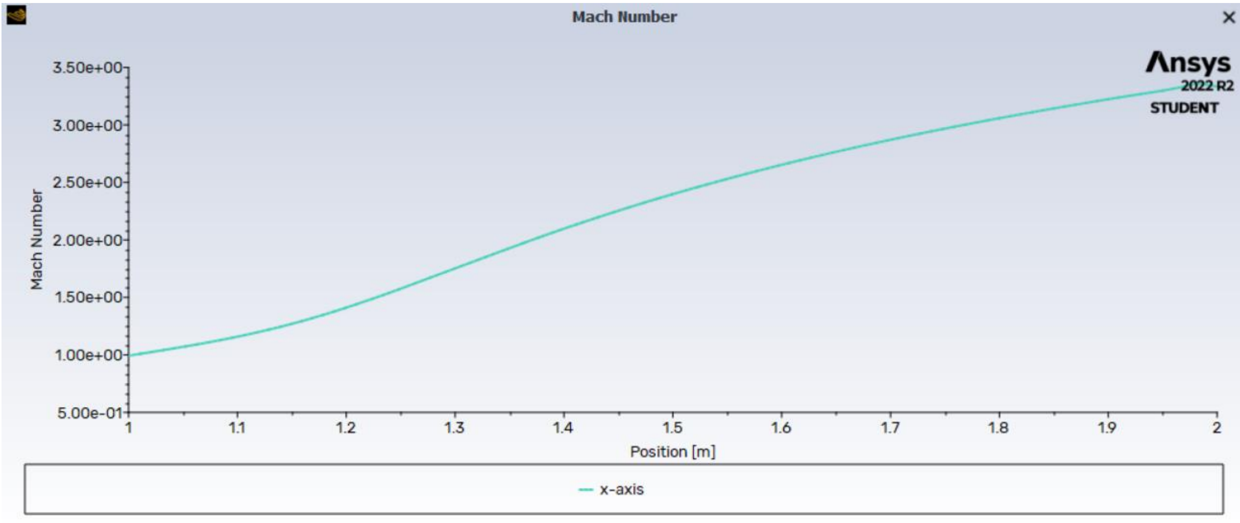

Figure 7: Line plot of Mach number along x-axis (line of symmetry) (D2)

b) Subsonic Case

Repeat Task 1a but change the boundary conditions to the following:

(5) Set the left opening as a pressure inlet and impose

(i) Gauge total (stagnation) pressure = 100000 Pa

(ii) Supersonic/Initial gauge pressure = 99900 Pa

(iii) Total temperature = 500°K.

(6) Set the right opening as a pressure outlet and impose Gauge pressure = 99500 Pa. Set the temperature of backflow to 500 K.

(D3)

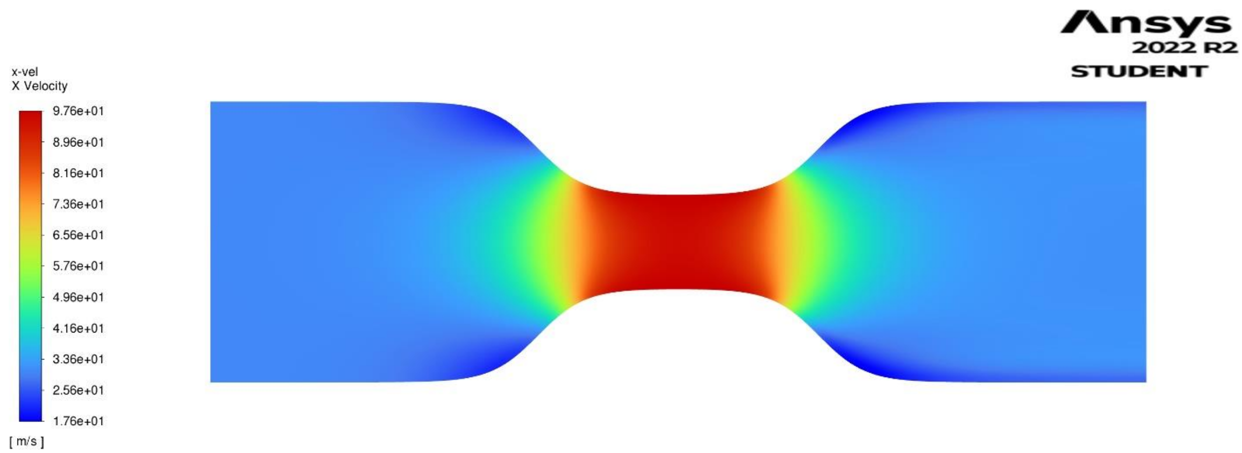

Figure 8: Contour plot of x-velocity (D3)

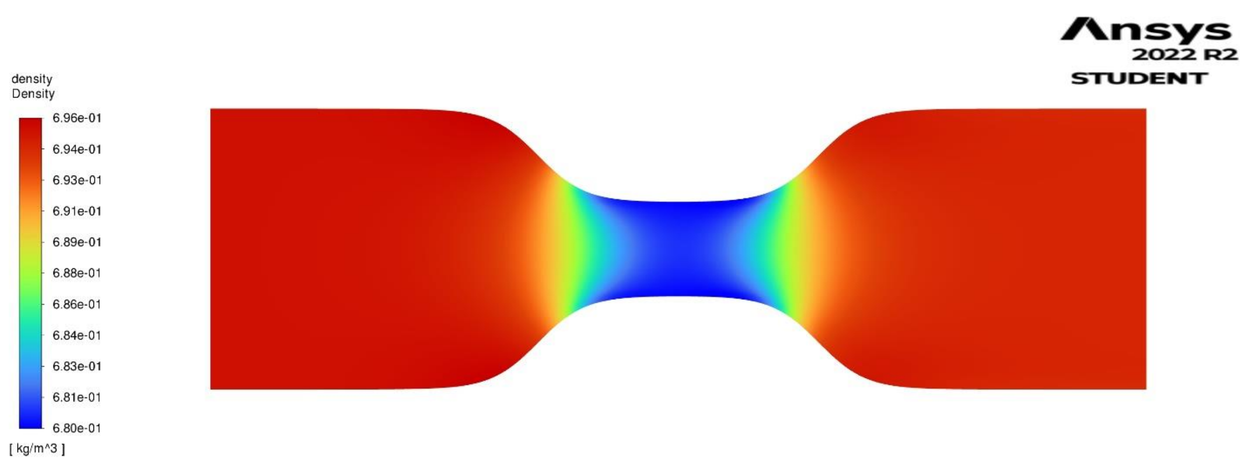

Figure 9: Contour plot of density (D3)

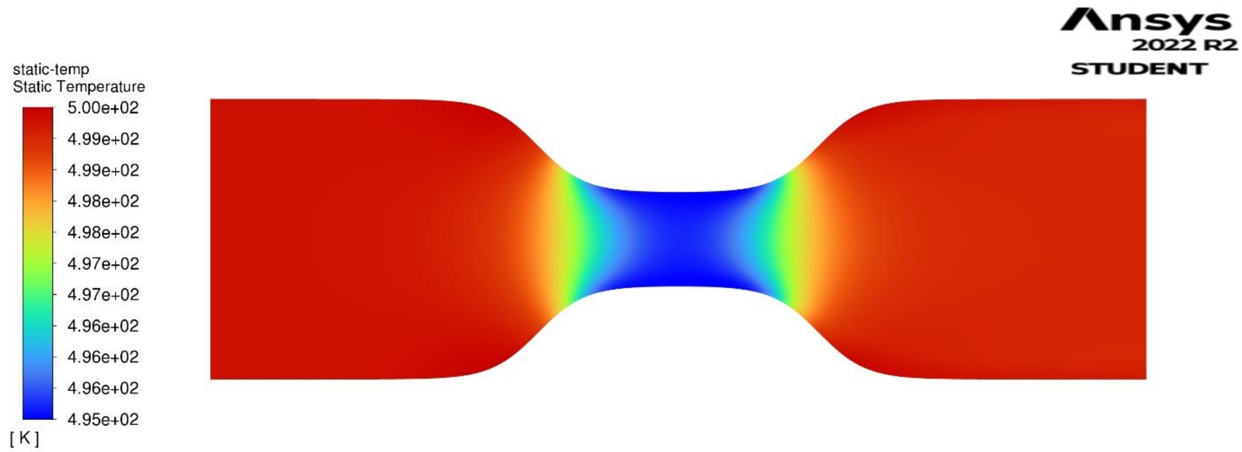

Figure 10: Contour plot of temperature (D3)

(D4)

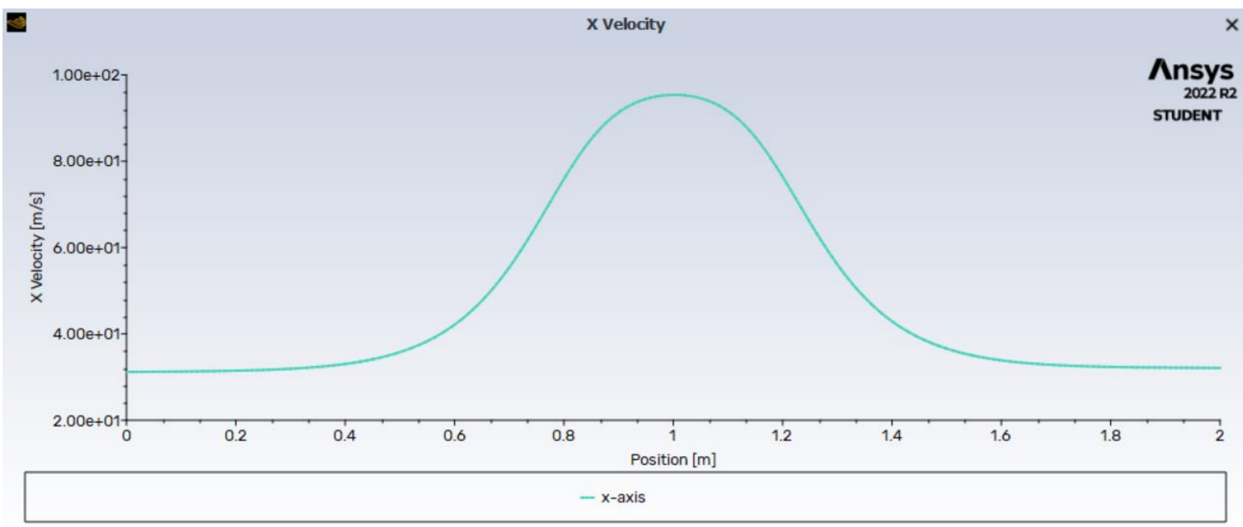

Figure 11: Line plot of x-velocity along x-axis (line of symmetry) (D4)

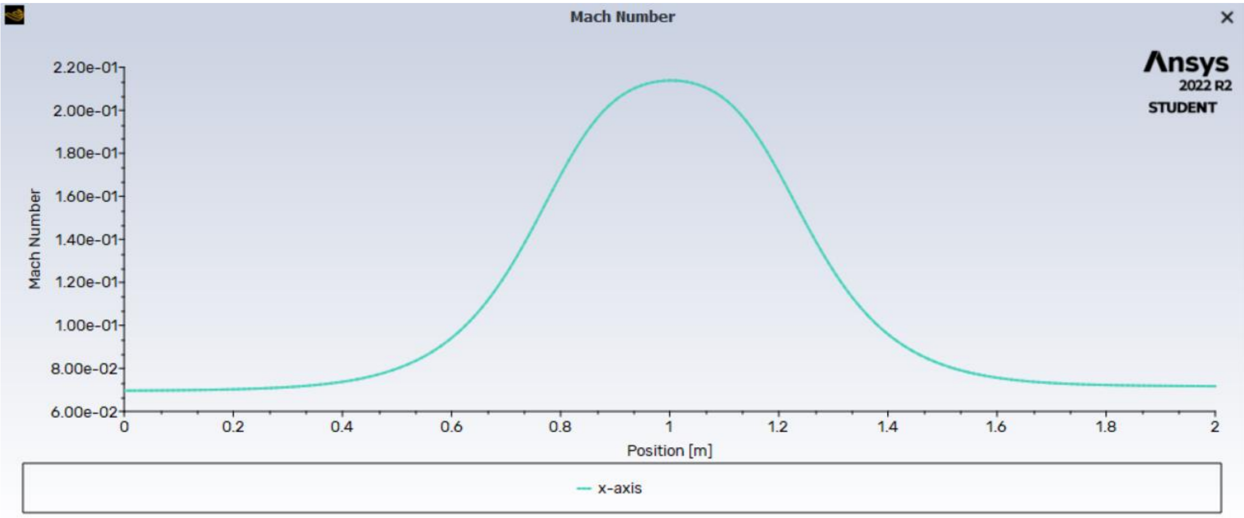

Figure 12: Line plot of Mach number along x-axis (line of symmetry) (D4)

Resources:

** *All instructions sections directly from* [1]. **

[1] MAE 560/460 Applied CFD, Fall 2022, Homework #2 Instructions

Appendix:

MATLAB Code:

```
%% MAE 560 HW 2
% Aishwarya Ledalla
clc; clear;

%%
% Data
x = [0:0.01:2]; % (m) x values
y = 0.3 + 0.1*(tanh(10*x-13) - tanh(10*x-7)); %(m) y values
z = 0; % (m) z values
i = 1; % number of curves

%%
% Text File with Data Points
fileID = fopen('nozzle_wall.txt','w'); % written text file
for n = 1:length(x) % number of points in each curve
    fprintf(fileID,'%3i %3i %9.6f %9.6f %9.6f\n',i,n,x(n),y(n),z);
end
fclose(fileID);

%%
% Plot
figure(1); plot(x,y); axis([0 2 0 0.5]); xlabel('x(m)'); ylabel('y(m)');
title('x(m) vs. y(m)')

%%
% Test Table Check
i = ones(1,length(x));
n = 1:length(x);
z = zeros(1,length(x));
Test = table(i',n',x',y',z');
```

Data from *flyingsaucer2DH.txt:*

1	1	0.000000	0.300000	0.000000
1	2	0.010000	0.300000	0.000000
1	3	0.020000	0.300000	0.000000
1	4	0.030000	0.300000	0.000000
1	5	0.040000	0.300000	0.000000
1	6	0.050000	0.300000	0.000000
1	7	0.060000	0.299999	0.000000
1	8	0.070000	0.299999	0.000000
1	9	0.080000	0.299999	0.000000
1	10	0.090000	0.299999	0.000000
1	11	0.100000	0.299999	0.000000
1	12	0.110000	0.299998	0.000000
1	13	0.120000	0.299998	0.000000
1	14	0.130000	0.299998	0.000000
1	15	0.140000	0.299997	0.000000
1	16	0.150000	0.299997	0.000000
1	17	0.160000	0.299996	0.000000
1	18	0.170000	0.299995	0.000000
1	19	0.180000	0.299994	0.000000
1	20	0.190000	0.299993	0.000000
1	21	0.200000	0.299991	0.000000
1	22	0.210000	0.299989	0.000000

1 23 0.220000 0.299986 0.000000

1 24 0.230000 0.299983 0.000000

1 25 0.240000 0.299980 0.000000

1 26 0.250000 0.299975 0.000000

1 27 0.260000 0.299970 0.000000

1 28 0.270000 0.299963 0.000000

1 29 0.280000 0.299955 0.000000

1 30 0.290000 0.299945 0.000000

1 31 0.300000 0.299933 0.000000

1 32 0.310000 0.299918 0.000000

1 33 0.320000 0.299900 0.000000

1 34 0.330000 0.299878 0.000000

1 35 0.340000 0.299851 0.000000

1 36 0.350000 0.299818 0.000000

1 37 0.360000 0.299777 0.000000

1 38 0.370000 0.299728 0.000000

1 39 0.380000 0.299668 0.000000

1 40 0.390000 0.299595 0.000000

1 41 0.400000 0.299505 0.000000

1 42 0.410000 0.299396 0.000000

1 43 0.420000 0.299263 0.000000

1 44 0.430000 0.299101 0.000000

1 45 0.440000 0.298903 0.000000

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1	66	0.650000	0.246212	0.000000
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