ASSIGNMENT-4

Computation of Compressible Flow through CD Nozzle

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Solve the quasi-1-D Euler equations for the isentropic flow of a calorically perfect gas with γ = 1.4 through a nozzle (as shown in Figure 1) having an area distribution

$$A = 1.0 + 2.0(x - 2x + 1),\ 0 \leq x \leq 2$$

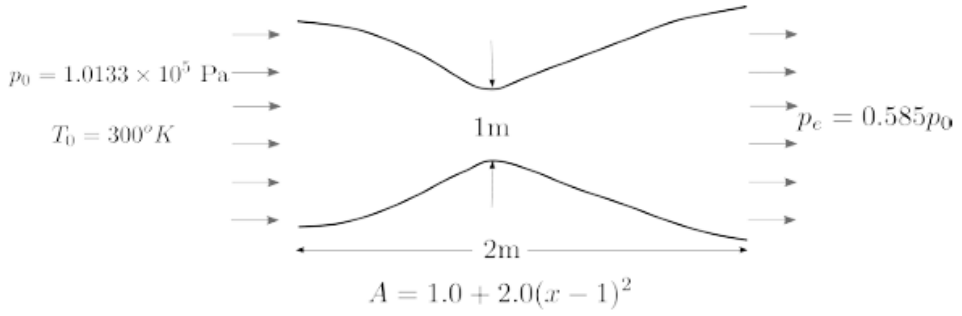


Figure 1.

Use van Leer Flux Vector Splitting method to solve the governing equations for an exit to stagnation pressure ratio, p_e/p_0, of 0.585. Use a reservoir temperature and pressure as 300 K and 1.0133×10^5 Pa respectively.

Plot

(a) the nondimensional pressure, p/p0, versus x.

(b) Mach number versus x.

(c) Use your gasdynamics knowledge to compute the exact quasi-1D results and compare with your numerical results.

<u>Solution</u>:

The inlet and outlet conditions used are as follows

γ = 1.4

R = 287.0 J/kgK

$p_0 = 1.0133 \times 10^5$ Pa

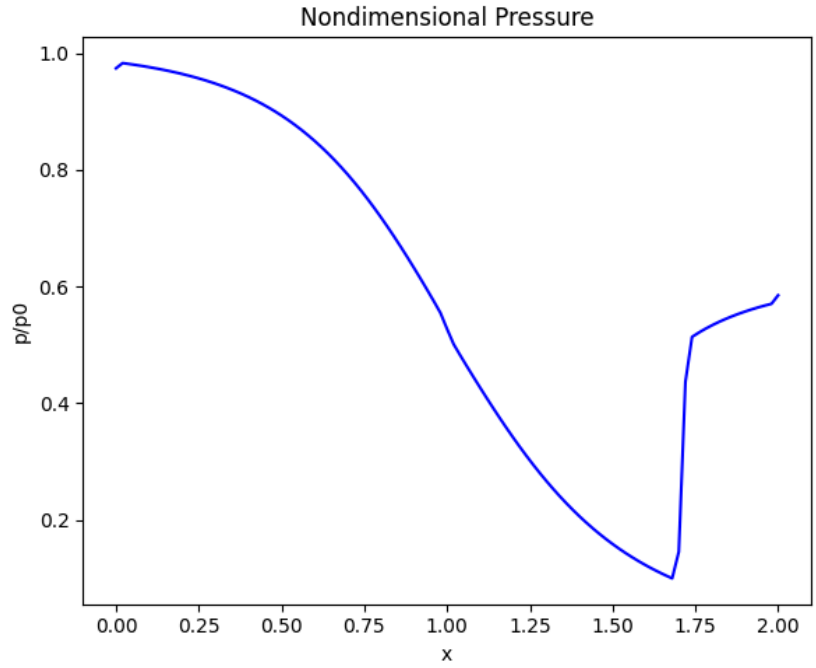
$T_0 = 300.0$

$p_e/p_0 = 0.585$

CFL = 0.5

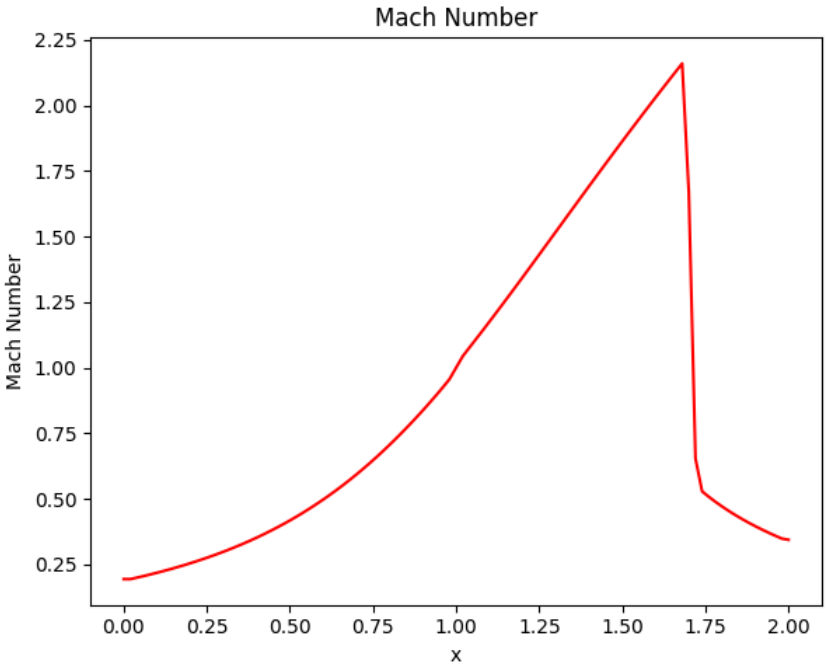
$I_{max} = 101$ parts

1) **p/p0 plot vs x**



The above plot demonstrates how pressure is decreasing axially along the nozzle flow direction. This is in direct agreement with the observation as the nozzle increases the flow velocity isentropically by reducing the static pressure. This trend can be seen till x = 1.7 m where a normal shock occurs leading to a shock formation and hence shows the sudden increase in static pressure as shown in the figure above.

2) **Mach number vs x**



The above plot demonstrates how mach number is increasing axially along the nozzle flow direction. This is in direct agreement with the observation as the nozzle increases the flow velocity isentropically by reducing the static pressure. This trend can be seen till x = 1.7 m where a normal shock occurs leading to a shock formation and hence shows the sudden decrease in mach number (from supersonic to subsonic) as shown in the figure above.

3) Comparison between Numerical and Exact solution

a) p/p0 comparison

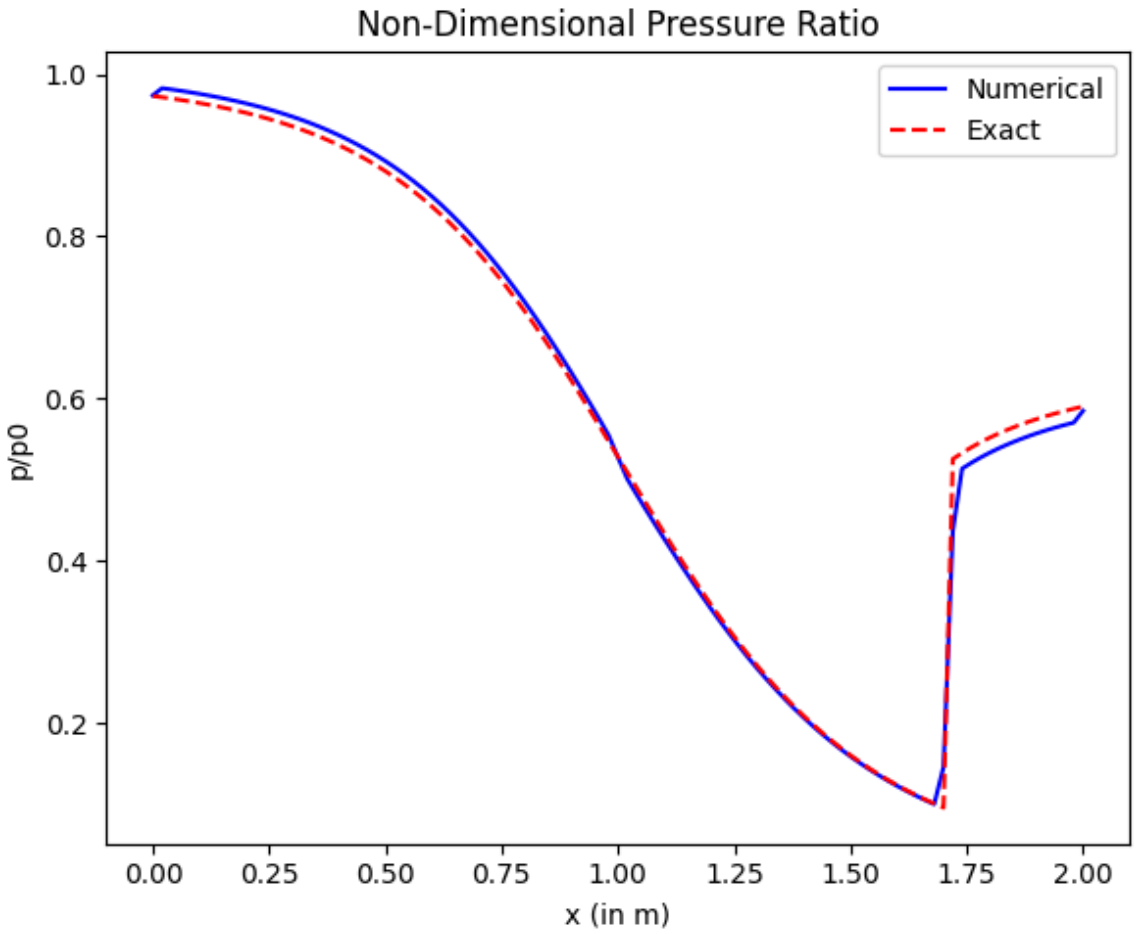
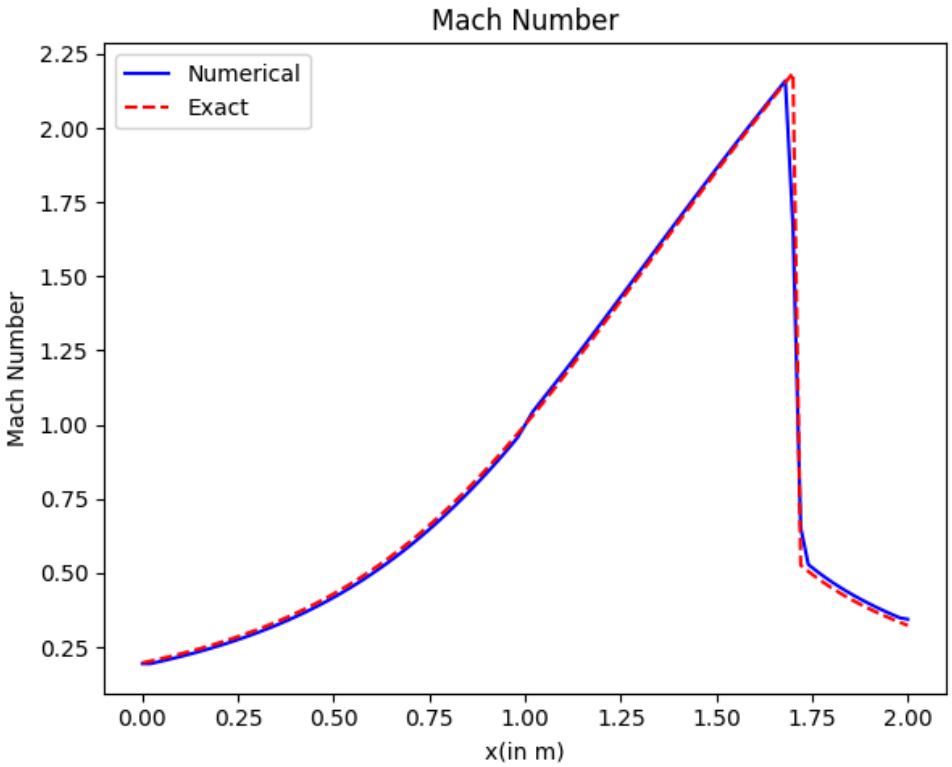


Figure 4

Clearly, the numerical and the exact solutions are in quite agreement but it can be noticed that the ratio is overestimated by the numerical method but in the supersonic regime, it followed the exact solution quite well till the flow encountered the shock. Post shock the difference between the numerical and exact solution is quite evident.

b) Mach number comparison



Clearly, the numerical and the exact solutions are in quite agreement but it can be noticed that the post shock the difference between the numerical and exact solution is quite evident.

4) Flowchart