ME 673 - Programming Assignment # 2

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Gas Dynamics (Fanno flow) Assignment

This code is written in python to numerically solve the 1D Fanno flow in both supersonic (Inlet $M = 3.0$) and subsonic (Inlet $M = 0.2$) situations. Runge Kutta (RK) methods of order 2 and 4 are used for solving the differential equations derived in the class notes.

Python Code

Initial conditions are mentioned in the beginning lines. Equations are elaborated in the first part. M,P,T are the basic properties found out. Inlet conditions are assumed, T to be 500K and Pressure to be 101 kPa. For now friction factor is assumed to not vary much and be constant. The flow is taken to be turbulent which is established by calculating the reynolds number manually.

Listing 1: Python code – Fanno flow – solving analytically.

```
#!/usr/bin/python
'''
 Python code for Numerical assignment 2, ME 678
 Written by Gowtham Kuntumalla, 140100091
 Fanno flow analysis.
 Both subsonic and supersonic inlet conditions are considered.
 M, P, T are the required properties

'''
import matplotlib.pyplot as plt
import numpy as np
import math
from scipy.optimize import fsolve


print("hey Code is running !")
# INLET CONDITIONS
gamma=1.4
R=287
T0=500 # K
P0=101000 # Pa
rho0=P0/(R*T0) #kg/m3
D = 0.05 # Pipe diameter
M0 = 0.2 # inlet mach
```

```python
h = 0.1 # x1=x0+h
fr = 0.005  # Friction factor


# Fanno flow DE #
def dlnMdx(x,M):
    return gamma * (M**2)*(2+(gamma-1)*M**2)/(1-M**2)*(fr/D)
def dlnPdx(x,M):
    return -2*gamma * (M**2)*(1+(gamma-1)*M**2)/(1-M**2)*(fr/D)
def dlnTdx(x,M):
    return -2*gamma*(gamma-1)*(M**4)/(1-M**2)*(fr/D)


# RK METHOD Functions #
def rk2(f,x,y):
    k1 = h*f(x,y)
    k2 = h*f(x+h,y+k1)
    return 0.5*(k1+k2)
def rk4(f,x,y):
    k1 = h*f(x,y)
    k2 = h*f(x+h/2,y+k1/2)
    k3 = h*f(x+h/2,y+k2/2)
    k4 = h*f(x+h,y+k3)
    return 1/6*(k1+2*k2+2*k3+k4)

if __name__ == "__main__":
    rk_method = rk2 # Use either rk2 or rk4
    x=[]; i=0
    M=[]; P=[]; T=[]; # individual lists of properties
    x.append(0);M.append(M0); P.append(P0); T.append(T0);
    while M[len(M)-1] < 0.8: # required exit mach. edit it
        M.append(M[i]*math.exp(rk_method(dlnMdx,x[i],M[i])))
        P.append(P[i]*math.exp(rk_method(dlnPdx,x[i],M[i])))
        T.append(T[i]*math.exp(rk_method(dlnTdx,x[i],M[i])))
        x.append(x[i]+h)
        i+=1
    print (M,P,T)
    # plotting
    f, (ax1, ax2, ax3) = plt.subplots(3, sharex=True)
    ax1.plot(x, M)
    ax1.set_ylabel('Mach Number')
    ax1.set_title('Variation of properties along length')
    ax2.plot(x, P, color='g')
    ax2.set_ylabel('Pressure (Pa)')
    ax3.plot(x, T, color='r')
    ax3.set_ylabel('Temperature (K)')
    ax3.set_xlabel('Distance along the pipe (m)')
```

```
    plt.show()

    print("Analysis done. Look at the plots")

#END OF PROGRAM
```

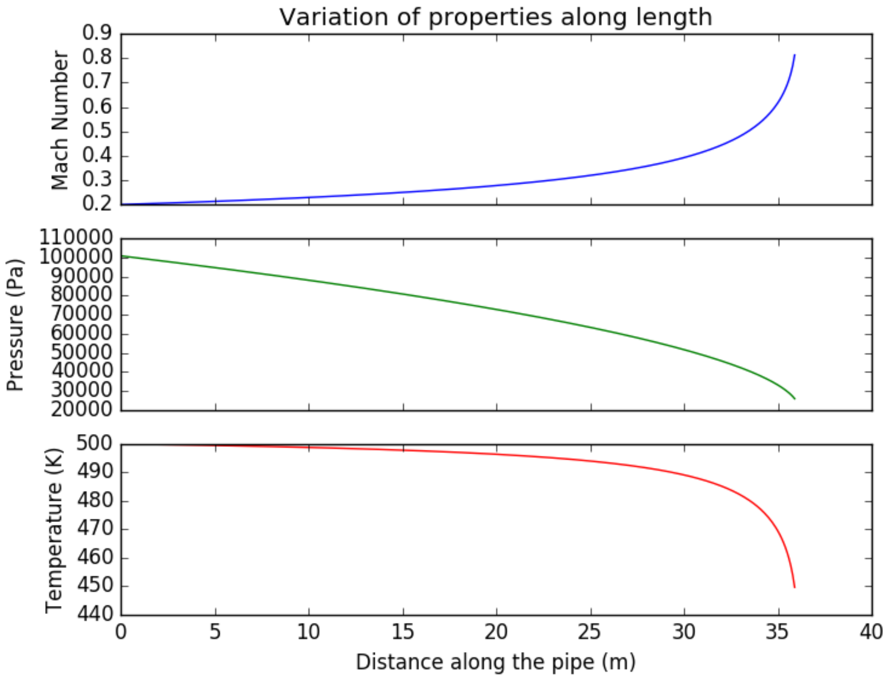
Following Listing 1... Changes are done in the code are done wherever necessary to change the initial values(subsonic or supersonic), method employed etc. We observe the following after performing some experiments by changing methods from RK 2 to RK 4 we get the results mentioned in later pages.

Figures & Conclusions

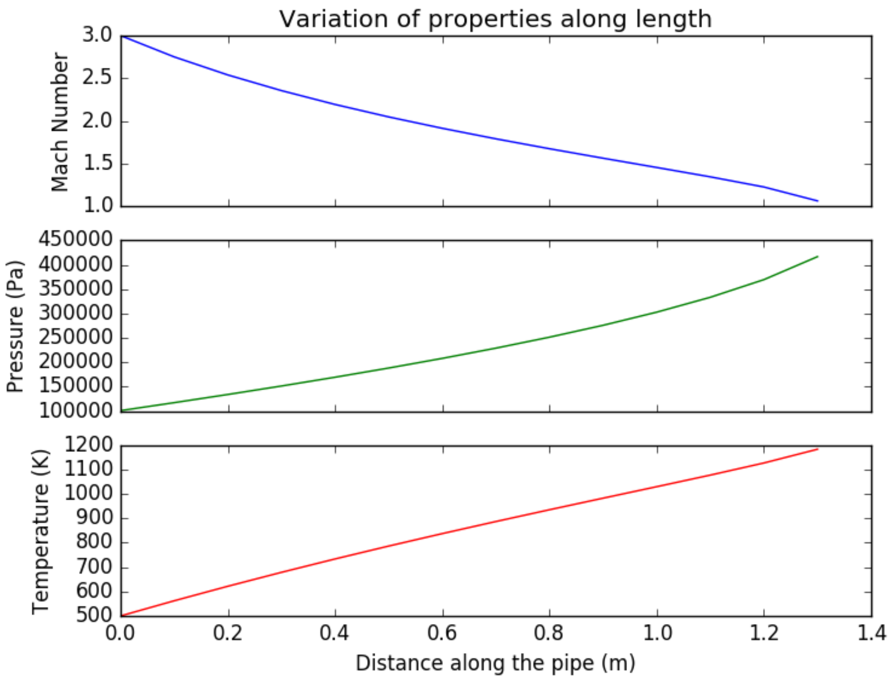
These figures are obtained directly from running the python code. Note that the step size used is $h = 0.1$. All the graphs indicate that the flow moves towards mach 1. The entropy is maximum in this case as discussed in class. Coming to pressure, Pressure decreases in subsonic flow and increases in supersonic flow conditions. Temperature follows a reverse trend.

Tables of Fanno flow have been used to verify the results of subsonic flow and the length has come out to be 37.63m for inlet mach, $M = 0.2$ and outlet mach $M = 0.8$. This number is very close the length value obtained in case of RK2 method itself (close to 37.2m).

If we use smaller step sizes better results are obtained because the system will be more close to a continuous system. In general RK4 method yields better results than RK2 owing to difference in the error orders between both methods.



(a) Subsonic inlet



(b) Supersonic inlet

Figure 1: M,P,T variation diagrams along the tube for both subsonic and supersonic conditions by RK 2 method.