ME 323: FLUID MECHANICS-II

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Lecture - 08

18/11/2024

Problems on Supersonic Nozzle Operation

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Problem

Consider a rocket engine burning hydrogen and oxygen; the combustion chamber temperature and pressure are 3571 K and 25 atm, respectively. The molecular weight of the chemically reacting gas in the combustion chamber is 16 and k = 1.22, The pressure at the exit of the converging-diverging rocket nozzle is 1.174×10^{-2} atm. The area of the throat is 0.4 m^2. Assuming a calorically perfect gas, calculate:

(a) The exit Mach number

(b) The exit velocity

(c) The mass flow through the nozzle

(d) The area of the exit.

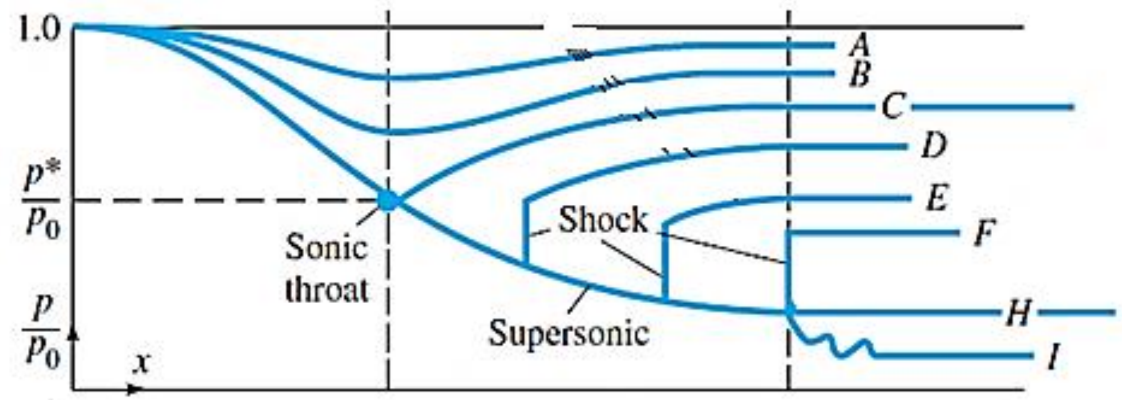
Solution:

Follow Class Note

Problem

Air flows in a converging-diverging nozzle from a reservoir maintained at 20°C and 400 kPa Gage. The throat and exit diameters are 5 cm and 15 cm, respectively. What two different back pressures will result a sonic throat if the isentropic flow occurs throughout?

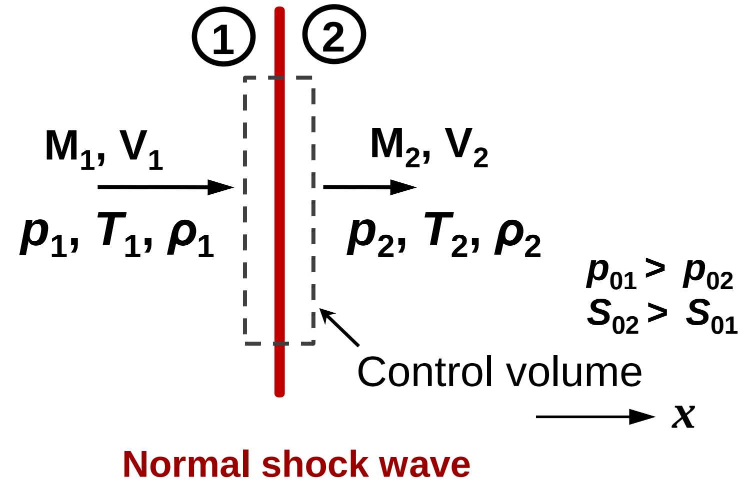
Further, determine the range of pressures for which shock will occur inside and outside the nozzle?



Solution:

Follow Class Note

Normal shock relations



① Conditions just upstream of the shock

② Conditions just downstream of the shock

$$\Rightarrow M_2^{\,2} = \frac{(k-1)M_1^{\,2} + 2}{2kM_1^{\,2} - (k-1)}$$

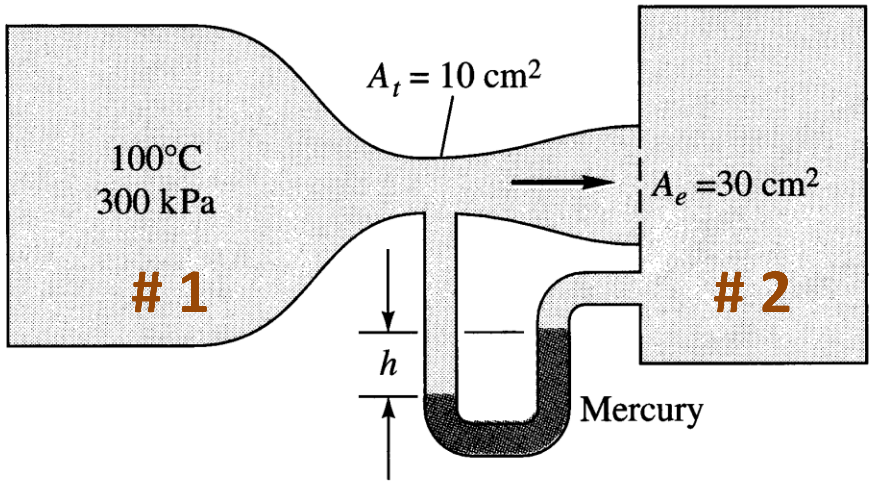
$M_2 = f(M_1)$

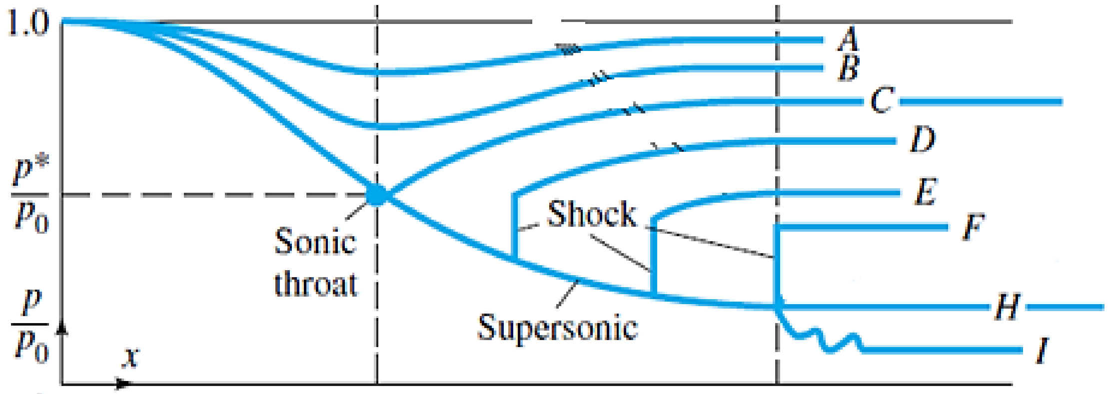
$$\Rightarrow \frac{p_2}{p_1} = \frac{2kM_1^{\,2}}{k+1} - \frac{k-1}{k+1}$$

$M_2 = f(M_1)$

Problem

Air flows through a converging-diverging nozzle between two large reservoirs, as in Fig. A mercury manometer reads *h* = 15 cm.
Estimate the downstream reservoir pressure.
Is there a shock wave in the flow? If so, does it stand in the exit plane or farther upstream?





Solution:

Follow Class Note

Problem (cont'd)

What would be the mercury manometer reading if the nozzle was operating exactly at supersonic design condition?

Solution:

Follow Class Note