Flow Throw a Nozzel

University of Jordan

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Objective:

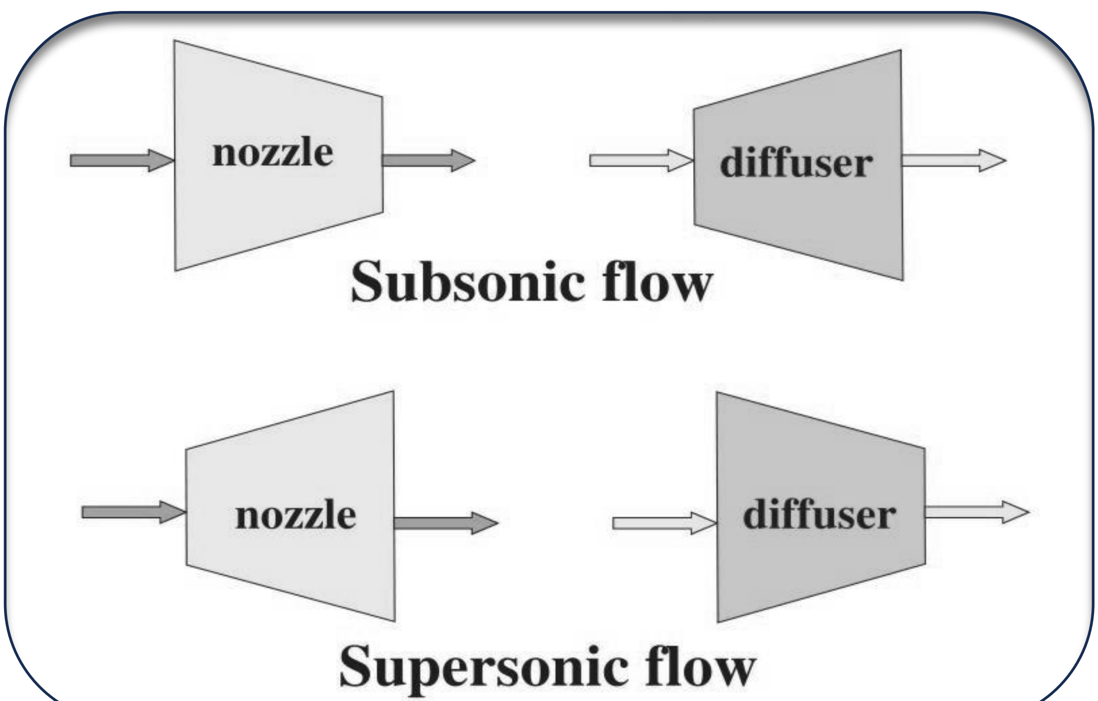
The objective of this experiment is to investigate the pressure distribution within a nozzle across various exit pressures and flow rates.

Apparatus:

The apparatus consists of a nozzle, a steady-state flow device designed to generate a high-velocity fluid stream while reducing its pressure. Air is introduced into a cast iron pressure chamber through adjustable valves. A finely crafted brass nozzle is threaded into a seat at the base of the chamber, allowing the air or steam to expand through it. The specific nozzle used in this experiment is of the convergent-parallel type.

Introduction:

A nozzle serves as a steady-state flow device aimed at producing a high-velocity fluid stream by sacrificing its pressure. For subsonic flows, the cross-sectional area of the nozzle diminishes along the flow direction, while it expands for supersonic flows.



Data Collected:

- Atmospheric pressure = 90 kPa
- Atmospheric temperature = 14℃

Position No.	X/L	P_0= 200KPa	P_0= 500Kpa
		Position Pressure Kpa	Position Pressure Kpa
7	0.00	213	500
8	0.25	210	500
9	0.50	200	490
10	0.75	190	480
11	1.00	155	440
12	1.25	148	380
13	1.50	127	370
14	1.75	127	360
15	2.00	125	360
16	2.25	120	340
17	2.50	117	340
18	2.75	110	330
19	3.00	106	320
20	3.25	106	310
21	3.50	118	300
22	3.75	108	300
23	4.00	104	290
24	4.25	100	280
25	4.50	98	280
26	4.75	95	270
27	5.00	88	260
28	5.25	81	240
29	5.50	77	230
30	5.75	63	220
31	6.00	58	200
32	6.25	20	160

- Calculate flow area of throat:

$$A_{th} = \frac{\pi}{4}\left[(dn)^2 - (dp)^2\right]$$

$$A_{th} = \frac{\pi}{4}\left[\left(\frac{4.77}{1000}\right)^2 - \left(\frac{3.33}{1000}\right)^2\right] = 9.16 \times 10^{-6} m^2$$

- Calculate sonic velocity:

$$C = \sqrt{K.R.T} = \sqrt{1.4 \times 287.1 \times 287} = 339.64\, m/s$$

- Calculate critical pressure:

$$P^* = \left[\frac{2}{k+1}^{\frac{k}{k-1}}\right] \times P_0$$

1. When Pressure equal 200 KPa:-

$$P^* = \left[\frac{2}{1.4+1}^{\frac{1.4}{1.4-1}}\right] \times 290 = 153.2017\, KPa\_abs$$

2. When Pressure equal 500 KPa:-

$$P^* = \left[\frac{2}{1.4+1}^{\frac{1.4}{1.4-1}}\right] \times 590 = 311.68\, KPa\_abs$$

- Calculate Throat Velocity:

$$V_{th} = \sqrt{\frac{2kRT_0}{k-1}\left[1 - \left(\frac{P_t}{P_0}\right)^{\frac{K-1}{K}}\right]}$$

1) When Pressure equal 200 KPa:-

$$V_{th} = \sqrt{\frac{2 \times 1.4 \times 287.1 \times 287}{1.4-1}\left[1-\left(\frac{245}{290}\right)^{\frac{1.4-1}{1.4}}\right]} = 164.7\ m/s$$

2) When Pressure equal 500 KPa:-

$$V_{th} = \sqrt{\frac{2 \times 1.4 \times 287.1 \times 287}{1.4-1}\left[1-\left(\frac{530}{590}\right)^{\frac{1.4-1}{1.4}}\right]} = 131.9\ m/s$$

- Calculate Mach number:

$$M_a = \frac{v}{c}$$

1) When Pressure equal 200 Kpa:-

$$M_a = \frac{131.9}{339.64} = 0.3884 \ < 1 \rightarrow \therefore Subsonic$$

2)When Pressure equal 500 KPa:-

$$M_a = \frac{164.7}{339.64} = 0.4849 \ < 1 \rightarrow \therefore Subsonic$$

- Calculate Mass Flow Rate at throat:

$$m_{th}^{0} = A_{th} \times P_0 \times \left(\frac{P_{th}}{P_0}\right)^{\frac{1}{K}} \times \sqrt{\frac{2k}{(k-1) \times RT_0}\left[1-\left(\frac{P_t}{P_0}\right)^{\frac{K-1}{K}}\right]}$$

1) When Pressure equal 200 Kpa:-

$$m_{th}^{0} = 4.7075 \times 10^{-6}\ kg/s$$

2)When Pressure equal 500 KPa:-

$$m_{th}^{0} = 8.0151 \times 10^{-6}\ kg/s$$

- Calculate Pressure ratio:

Pressure ratio = Back Pressure/chest Pressure

1) When Pressure equal 200 Kpa:-

Pressure ratio = 90/290 = 0.3103

2)When Pressure equal 500 KPa:-

Pressure ratio = 90/590 = 0.1525