ME400 Mechanical Engineering Laboratory 2

(0-4-2)

LAB TIME : 9.00 – 13.00 ON MONDAYS (THAI PROGRAM)

: 8.30 – 12.30 ON TUESDAYS (TEPE)

PREREQUISITE: PASS ME 300, ME 322, ME 330 OR PERMISSION FROM INSTRUCTOR OR HEAD OF DEPARTMENT

Coordinator: Assoc.Prof. Chainarong Chaktranond

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Objectives

- To have knowledge and understanding in any measurement and basic tools in various topics, such as 1) Free and Forced vibration, Static and dynamic balancing , Strain gauge, Polariscope, Air Conditioning, Wind Tunnel, and Heat Exchangers.
- To able to apply the knowledge to real work.

Teaching Place (Thai program)

Lab	Topics	Instructor	Place
1	Free and Forced Vibration	Asst.Prof. Kiatkhajorn	Room 203 ME workshop
2	Static and dynamic balancing	Asst.Prof. Bunyong	Room 201/2 ME workshop
3	Strain gauge	Asst.Prof. Chatchai	Room 207 ME workshop
4	Polariscope	Assoc.Prof.Dulyachot	Room 201 ME workshop
5	Air Conditioning	Asst.Prof. Isares	Room 206 ME workshop
6	Wind Tunnel	Dr. Jiraprabha	Room 106 ME workshop
7	Heat Exchangers	Asst.Prof. Monchai	Room 613 Eng Bld (FL 6)
8	Basic of welding	Technician	FL 1 ME workshop
9	Basic of milling	Technician	FL1 ME workshop

Teaching Place (TEPE)

Lab	Topics	Instructor	Place
1	Free and Forced Vibration	Assoc.Prof. Thira	Room 203 ME workshop
2	Static and dynamic balancing	Asst.Prof. Bunyong	Room 201/2 ME workshop
3	Strain Gauge	Asst.Prof. Chatchai	Room 207 ME workshop
4	Polariscope	Assoc.Prof. Dulyachot	Room 201 ME workshop
5	Air Conditioning	Asst.Prof. Isares	Room 206 ME workshop
6	Wind Tunnel	Dr. Jiraprabha	Room 106 ME workshop
7	Heat Exchangers	Asst.Prof. Monchai	Room 613 Eng Bld (FL 6)
8	Compressible flow in nozzles	Prof. Somchart	
9	Journal Bearing Apparatus	Dr. Jakkrapun	Room 613 Eng Bld (FL6)

Lab schedule (Thai program)

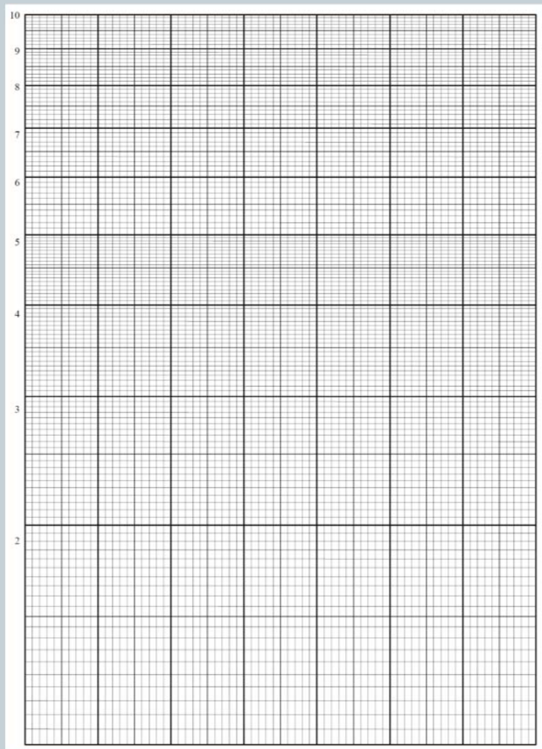
Date	Lab 1	Lab 2	Lab 3	Lab 4	Lab 5	Lab 6	Lab 7	Lab 8	Lab 9
24-Aug	Introduction to Lab by Assoc.Prof. Chainarong Chaktranond								
31-Aug	G1	G2	G3	G4	G5	G6	G7	G8	G9
7-Sep	G9	G1	G2	G3	G4	G5	G6	G7	G8
14-Sep	G8	G9	G1	G2	G3	G4	G5	G6	G7
21-Sep	G7	G8	G9	G1	G2	G3	G4	G5	G6
28-Sep	G6	G7	G8	G9	G1	G2	G3	G4	G5
19-Oct	G5	G6	G7	G8	G9	G1	G2	G3	G4
26-Oct	G4	G5	G6	G7	G8	G9	G1	G2	G3
2-Nov	G3	G4	G5	G6	G7	G8	G9	G1	G2
9-Nov	G2	G3	G4	G5	G6	G7	G8	G9	G1
16-Nov									
23-Nov									
30-Nov	**Paper exam before final exam**								

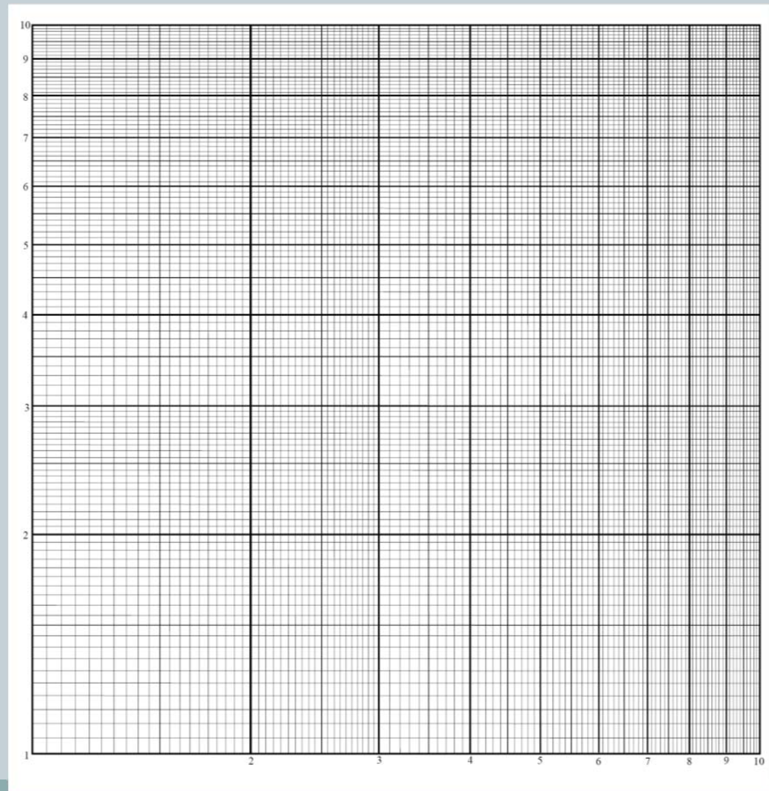
Lab schedule (TEPE)

Date	Lab 1	Lab 2	Lab 3	Lab 4	Lab 5	Lab 6	Lab 7	Lab 8	Lab 9
25-Aug	Lab introduction by Assoc.Prof. Chainarong Chaktranond								
1-Sep	G1	G2	G3	G4	G5				
8-Sep		G1	G2	G3	G4	G5			
15-Sep			G1	G2	G3	G4	G5		
22-Sep				G1	G2	G3	G4	G5	
29-Sep					G1	G2	G3	G4	G5
20-Oct	G5					G1	G2	G3	G4
27-Oct	G4	G5					G1	G2	G3
3-Nov	G3	G4	G5					G1	G2
10-Nov	G2	G3	G4	G5					G1
17-Nov									
24-Nov									
1-Dec	**Final**								

Materials

- Lab Sheet by instructor
- Graph, paper for report, calculator etc. by student





Example

Compressible Flow in Nozzles

Dr. Somchart Chantasiriwan

Objective

To study the behavior of compressible air flow past convergent nozzle and convergent-divergent nozzles.

Nozzles

Nozzle is an important component of equipment such as turbine, furnace, and rocket. Figure 1 shows two types of nozzle: the convergent nozzle and the convergent-divergent nozzle. Each type has a throat where the cross-sectional area is the minimum.

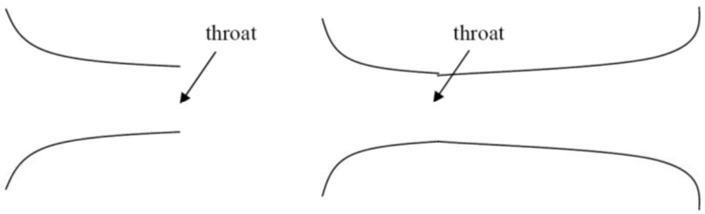


Figure 1 Convergent nozzle (left) and convergent-divergent nozzle

Nozzle is used to increase gas velocity. Initially the gas has low velocity at the entrance to the nozzle. Convergent nozzle increases the gas velocity as the gas flows along the convergent flow channel. The gas velocity will continually increase until it reaches the sound speed. This type of nozzle cannot increase the gas velocity to supersonic speed. The gas speed can be increased to supersonic speed by using convergent-divergent nozzle.

Theory

As gas flows in the convergent nozzle shown in Fig. 2, its velocity will increase as its pressure decreases. If the gas velocity is large enough, the flow becomes compressible flow of which behavior is different from incompressible flow. For isentropic flow, the energy balance equation is

$$h_i + \frac{V_i^2}{2} = h_o + \frac{V_o^2}{2} \qquad (1)$$

If gas temperature is low, gas behaves like an ideal gas ($h = c_pT$ + constant). Equation (1) becomes

$$c_pT_i + \frac{V_i^2}{2} = c_pT_o + \frac{V_o^2}{2} \qquad (2)$$

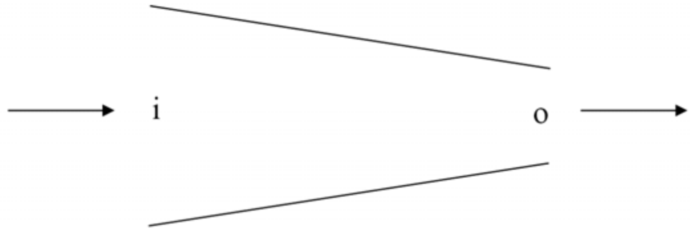


Figure 2 Isentropic flow of gas in convergent nozzle

Assume that the gas velocity at the inlet is very small ($V_i \approx 0$).

$$V_o = \sqrt{2c_pT_i\left(1-\frac{T_o}{T_i}\right)} = \sqrt{\frac{2c_p}{R}\frac{p_i}{\rho_i}\left(1-\frac{T_o}{T_i}\right)} = \sqrt{\frac{2k}{(k-1)}\frac{p_i}{\rho_i}\left(1-\frac{T_o}{T_i}\right)} \qquad (3)$$

because $c_p = kR/(k-1)$. The flow rate is given by

$$\dot{m} = \rho_oV_oA_o = A_o\sqrt{\frac{2k}{(k-1)}p_i\rho_i\left(\frac{\rho_o}{\rho_i}\right)^2\left(1-\frac{T_o}{T_i}\right)} \qquad (4)$$

If the flow inside the nozzle is isentropic, relations between gas properties at the inlet and the exit are

$$\frac{p_o}{p_i} = \left(\frac{\rho_o}{\rho_i}\right)^k \qquad (5)$$

$$\frac{T_o}{T_i} = \left(\frac{p_o}{p_i}\right)^{k-1/k} \qquad (6)$$

Substitute ρ_o/ρ_i from Eq. (5) and T_o/T_i from Eq. (6) into Eq. (4).

$$\dot{m} = A_o\sqrt{\frac{2k}{(k-1)}p_i\rho_i\left[\left(\frac{p_o}{p_i}\right)^{2/k} - \left(\frac{p_o}{p_i}\right)^{(k+1)/k}\right]} \qquad (7)$$

Equation (7) shows that if inlet pressure (p_1) is constant, but throat pressure (p_t) decrease, the flow rate will increase until the minimum value of p_t given by

$$\frac{p_t}{p_i} = \left(\frac{2}{k+1}\right)^{k/(k-1)} \quad (8)$$

At this throat pressure, the maximum flow rate is

$$\dot{m}_{max} = \frac{A_t p_i}{\sqrt{T_i}} \sqrt{\frac{k}{R}\left(\frac{2}{k+1}\right)^{(k+1)/(k-1)}} \quad (9)$$

The flow rate cannot exceed this maximum because p_t cannot be lower than the minimum. The condition in which the flow rate has reached the maximum is known as the choked condition.

Isentropic compressible flow through convergent-divergent nozzle at the maximum flow rate results in pressure profiles shown in Fig. 3. According to Eq. (7), there are two pressure profiles in the divergent section of the nozzle. The top profile represents subsonic flow, whereas the bottom profile represents the supersonic flow. Note that subsonic flow yields higher pressure at the nozzle exit than supersonic flow.

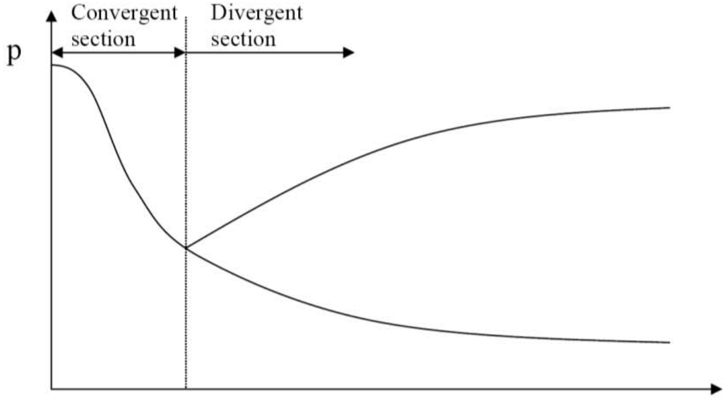


Figure 3 Pressure profiles in convergent-divergent nozzle at the maximum flow rate

Equipment

1. Nozzle Pressure Distribution Unit
2. Air compressor and accessories

Procedure

1. Convergent nozzle.

1.1 Open the discharge valve, and close the inlet valve

1.2 Install the convergent nozzle.

1.3 Close the discharge valve, and open the inlet valve.

1.4 Adjust the control so that the inlet pressure is 750 kPa.

1.5 Read back pressure gauge. If the reading is different from 750 kPa, record the reading.

1.6 Open the discharge valve slowly until the flow rate reading of the rotameter is 2 g/s. Record the value of the inlet pressure (p_i) and back pressure (p_o).

1.7 Close the discharge valve. Adjust the control so that the inlet pressure is 750 kPa.

1.8 Open the discharge valve slowly until the flow rate reading of the rotameter is 2.5 g/s. Record the value of the inlet pressure (p_i) and back pressure (p_o).

1.9 Repeat 1.7 and 1.8, but increase the mass flow rate by 0.5 g/s until the mass flow rate reaches the maximum value.

1.10 Close the discharge valve. Adjust the control so that the inlet pressure is maximum.

1.11 Open the discharge valve fully.

1.12 Record p_i, p_t and flow rate when p_i = 450, 400, 350 and 300 kPa

1.13 Put away the nozzle.

Report (example)

- Results (e.g. Table, graph, data)
- Discussions
- Example of calculation
- Conclusions

Evaluation

item	Contents	Week	Score [%]
1	• การเข้าเรียน (Attention) • ระเบียบวินัยและการแต่งกาย (Discipline) • การตรงต่อเวลา (Punctuality) • รายงาน (Report)	ทุกสัปดาห์ (All weeks)	70
2	Final exam	ก่อนสอบไล่ (Before final exam)	30

GRADE

Score	GRADE
≥80	A
76 – 79	B+
71 – 75	B
66 – 70	C+
61 – 65	C
56 – 60	D+
51 – 55	D
≤ 50	F