Lab: Flow of Compressible Fluids

Experimental set up

The test rig is called the Compressible Flow Rig and can be used to do a number of experiments. The rig comprises a flow bench with various flow conduits made up of Perspex. Flow enters into the conduit through a converging nozzle and the pressure drop at the entrance can be used to find out the air velocity directly. The fact that the flow rig is attached to the suction side allows the flow to be free from swirl and undue fluctuation. The following two figures show the test rig.

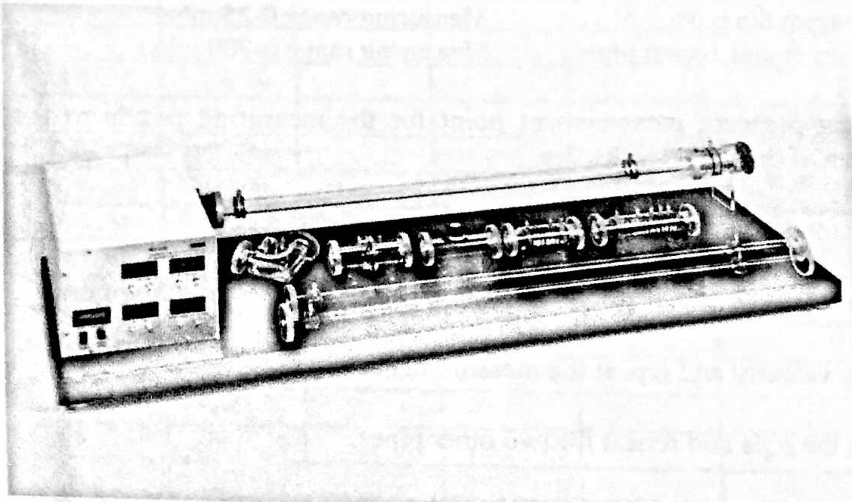


Fig. 1 Picture of the Compressible Flow Unit.

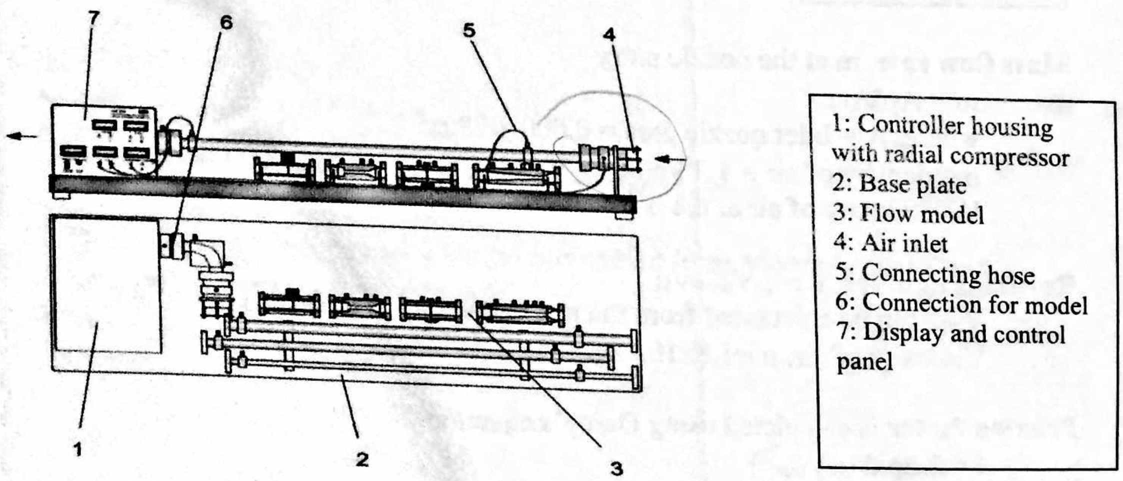


Fig. 2: Components of the flow unit.

PART 1: Friction in Pipe

Objective:

- To investigate the relationship between friction factor and Reynolds number for flow through smooth pipes
- To ascertain whether the flow is laminar or turbulent and compare the friction factors with those from Moody diagrams.

Experimental procedure

1. Attach the pipe section to the measuring nozzle and the intake connection using union nuts. Note: the longer end is the abatement section for the inlet and must be connected to the measuring nozzle.

2. Connect the pressure measurement points to the differential pressure manometer as shown:

34mm dia pipe	:	Measuring range 0-25 mbar
24mm and 16mm pipe:		Measuring range 0-200 mbar

3. Connect pressure measurement point for the measuring nozzle to the negative connection of the velocity display.

4. Switch on compressor and set the desired speed.

5. Record the velocity V_o from the nozzle and the pressure loss Δp in the data sheet.

6. Set new velocity and repeat the measurements.

7. Change the pipe and repeat for two other pipes.

Note 1: The minimum velocity should be about 6 and maximum just above 60 m/s
Note 2: **Do not run the compressor more than about 30,000 rpm.**

Formulas to be used

Mass flow rate, m at the nozzle entry

$m = A\rho Vo$,
where, A = Inlet nozzle area = 0.0009078 m^2
ρ = density of air = 1.2 kg/m^3
V_o= velocity of air at the nozzle.

Reynolds number, $Re = \rho V_{pipe} d/\mu$

V_{pipe} can be calculated from the mass flow rate and the area of the pipe.
Viscosity of air, $\mu = 1.8 \times 10^{-5}$ kg/m.s

Friction factor is calculated using Darcy's equation.

$f = 2.\Delta p.d/(\rho V_{pipe}^2)$

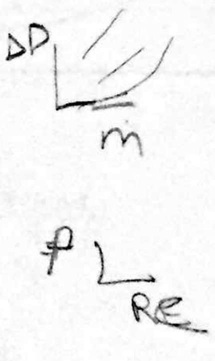
h is the pressure drop in terms of 'head loss in metres of the fluid' , $h = \Delta p/(\rho g)$

Data sheet

Pipe diameter	V_o m/s	Δp mbar	m kg/s	V_{pipe} m/s	Re	f	h metre of air
34 mm	53.2	10.4	0.058	53.26	120722.6	0.021	88.3
Measuring range 0-25 mbar	50.6	9.7					
	46.1	8.7					
	43.1	7.1					
	35.2	5.0					
	30.9	4.1					
	25.3	2.9					
	20.1	2.0					
	14.7	1.3					
	6.3	0.5					
24 mm	40.8	21.6					
Measuring range 0-200 mbar							
	35.8	13.5					
	30.1	7.1					
	25.7	2.6					
	20.1	0.3					
	15.4	0.2					
	10.5	0.2					
16 mm	27.0	64.4					
Measuring range 0-200 mbar							
	20.4	54.4					
	18.2	40.8					
	15.9	27.5					
	13.6	15.5					
	11.7	6.1					
	8.3	0.2					

Calculations and results

- Complete the above table.
- Draw the following curves
  - Δp vs. m for all three pipes on the same graph
  - f vs Re
- Compare the friction factors with those obtained from Moody's charts and comment on your observations.
- Discuss the results.



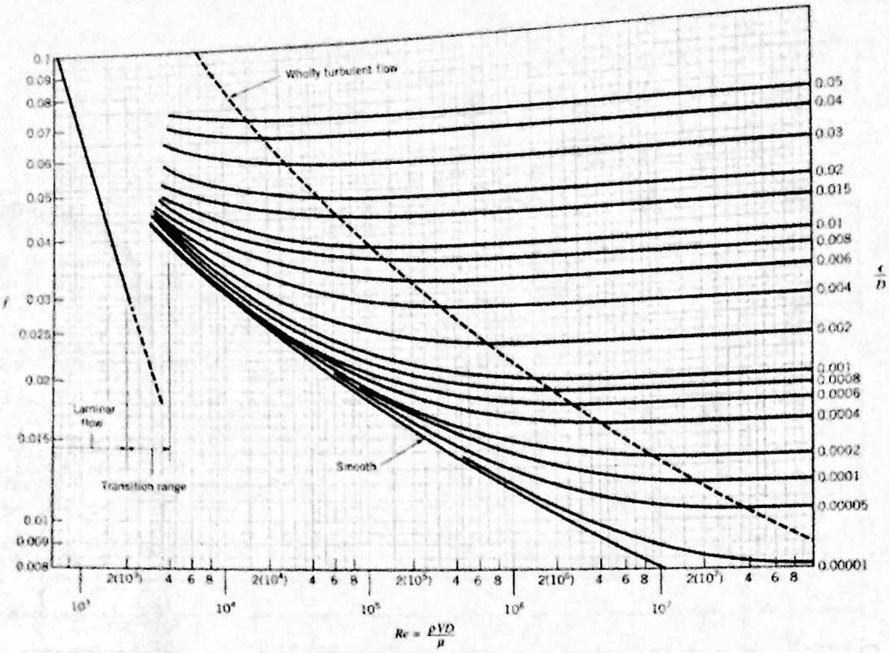


Fig. 3: Moody's chart for pipe.

PART 2: Pressure Distribution in the Bend

Objective:

To determine the pressure distribution in a bend at a fan speed of about 30,000 min^{-1}.

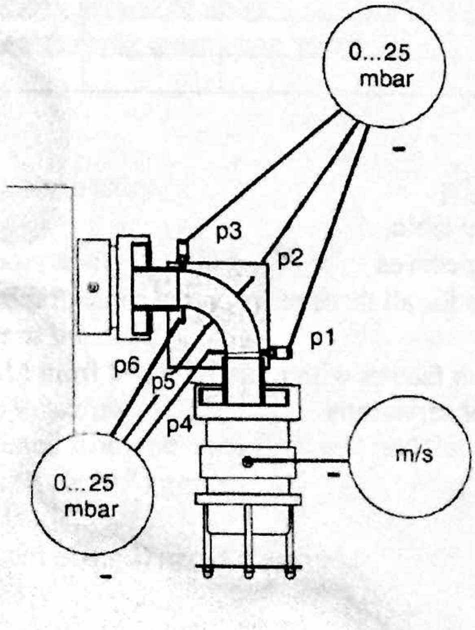


Fig. 4: Experiment Set-up.

Experimental procedure

1. Use the union nuts to attach the bend and measuring nozzle to the intake connection.
2. Connect pressure measurement point for the measuring nozzle to the negative connection of the velocity display.
3. Switch on the fan and adjust speed to 30,000 min^{-1}.
4. Connect the manometer 0...25 mbar in sequence to the pressure measurement points p1 to p6.
5. Record pressures p1 to p6.

Experimental Results

1. The measured pressure levels are listed in the following table.

Negative pressure in mbar, Speed 30,000 min^{-1}					
Outer bend			Inner bend		
0°	45°	90°	0°	45°	90°
p1	p2	p3	p4	p5	p6
-15.0	-11.4	-14.6	-22.9	-29.2	-23.6

It is clear that there is a lower pressure level on the inner surface of the bend than on the outer surface. This is caused by the centrifugal force resulting from the circular movement.

Plot the distribution of the pressure as follow:

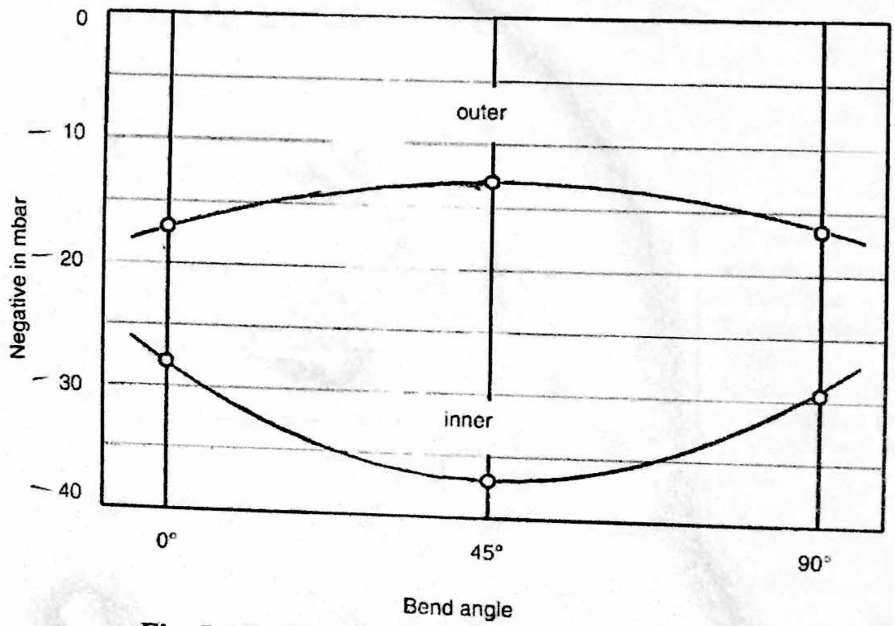


Fig. 5: Pressure distribution in a bend.

0	P_1	P_4
45	P_2	P_5
90	P_3	P_6