

**DEPARTMENT OF MECHANICAL ENGINEERING
FLUID FLOW THROUGH CONVERGENT – DIVERGENT NOZZLE**

Object

The aims of the experiment are:

1. To plot the pressure variation along the nozzle for two different back pressures
2. To investigate the effect of variations in back pressure on the mass flow rate through the nozzle and
3. To compare the measured maximum mass flow rate with that predicted theoretically.

Apparatus

A small convergent – divergent nozzle (throat diameter 6.39mm) is fitted with a static pressure tube (diameter 3.33mm) which can be traversed along the nozzle centre-line (in steps of 2.5mm) to measure the pressure anywhere along the axis. This tube is fitted with a pointer which moves along a profile of the nozzle under test so as to determine the exact position of the static hole where the pressure is being measured.

An inclined tube manometer measures the pressure difference across a standard orifice plate (diameter 41.3mm) fitted to the discharge pipe (diameter 76.2mm). This is used to determine the air mass flow rate through the nozzle.

Two thermometers are fitted, one at the nozzle inlet and the other at the orifice plate exit.

A valve in the supply pipe is used to vary the supply pressure whereas another valve at nozzle exit is used to set the back pressure.

Procedure

Experiment 1:

With the pressure probe positioned at nozzle exit, used both valves to set the supply pressure to 3.5 bar and a back pressure of 2.8 bar. Traverse the probe along the nozzle in steps, each time reading the pressure while keeping the inlet pressure constant by adjusting the inlet valve.

Repeat the above procedure for a back pressure of 1 bar, keeping the supply pressure constant at 3.5bar.

Experiment 2:

Set the nozzle back pressure to 3 bar, keeping the inlet pressure at 3.5 bar. Read the inclined manometer and thermometer so as to find the mass flow rate.

Repeat the above step for back pressure of 2.8, 2.4, 2.0, 1.6, 1.2, 0.8, 0.4 and 0 bar.

Read the barometer and the thermometer in the air supply chest.

Theory

1. The maximum flow rate through the nozzle is given by:

$$m(\max) = \frac{0.685 A_t p_0}{\sqrt{RT_0}}$$

Where: A_t = nozzle throat area (allowing for the presence of the static probe), m^2
 p_0 = supply pressure in the air chest (absolute), Pa
 R = 287 J/kgK
 T_0 = Air chest temperature (absolute), K

2. For the orifice plate flow meter:

$$m = C_d A_2 \sqrt{\frac{2 p_2 \Delta \rho}{RT_2 (1 - k^2)}}$$

Where:

C_d = coefficient of discharge = 0.62

A_2 = orifice area, m^2

$\Delta \rho$ = pressure difference across the orifice (as measured by the inclined manometer), Pa

p_2 = pressure downstream of the orifice (this may be taken as atmospheric pressure, since the orifice is exhausting to atmosphere through a very small length of pipe), Pa

T_2 = temperature downstream of the orifice, K

k = orifice area/exit pipe area, m^2/m^2

R = 287 J/kgK

Results

Experiment 1:

On the same graph, plot pressure (gauge) versus static probe position for each of the two back pressures.

Experiment 2:

Plot mass flow rate vs pressure ratio (absolute) (i.e. back pressure/supply pressure).

The pressure ratio axis (x-axis) must be in the range 0 to 1.

Determine the maximum theoretical mass flow rate by the formula given above and compare it with the maximum mass flow rate measured.

Comments

Comment on the shape of the resulting curves and give reasons for any discrepancies between the measured and calculated mass flow rates.

Conversion factors

1 bar = 14.5 lb/in²

1 inch = 25.4mm