MEC 5008
Laboratory Experiments

Air flow in Pipe

Object:

To investigate the friction effects on the flow of air in a pipe, measure the velocity profile across a pipe, and find the friction factor for pipe flow..

Apparatus:

Plint centrifugal fan, driven by 3phase motor.
Motor equipped with rpm measurement, and torque arm.
Brass pipe with pressure taps for static pressure measurements, diameter 78.8mm, P_{ref} taken as distance 0mm, then 6 taps at 230mm, 1145mm, 2058mm, 2970mm, 3888mm, 4803mm.
Total pressure probe that traverses transparent section of pipe, static probe in same axial location to provide a Pitot-static type measurement.
Manometer with inclined gauge with 0.2" and 0.1" Water Gauge inclinations to provide pressure differential measurements.
Different grills to install at outlet of fan to vary the flow-rate of air.

Procedure

1. Connect the manometer to the total pressure tap and static pressure tap on the traverse setup. Start the fan and make a traverse recording the pressure across the pipe.

2. With the total pressure measured at the center line of the pipe measure the pitot-static pressure, the rpm and the force on the torque arm for different air flow rates. The flow rate is varied by using no grill, the three grills with the different holes and the blank flange.

3. For the fan without a grill or blank, measure the pressure drop at all the marked taps on the side of the pipe with reference to the P_{ref} location.

Theory

The viscosity of the air makes the air flow in the pipe have a velocity profile across the pipe. The velocity profile can be obtained from the pitot-static measurements across the pipe. The friction due to the viscosity effects generates the pressure drop along the pipe which can be measured by the static taps. The pressure drop measurement can be used to find the friction factor (the left hand side y-axis of the moody diagram) for the flow. The friction factor and the Reynolds number (x-axis on the Moody diagram) for the flow can be validated with the Moody diagram.

Restriction of the outlet of the fan changes the air flow rate of the fan and pipe setup. Furthermore the air flow rate variation has an effect on the fan in terms of mechanical load. In-fact the higher the flow the higher the mechanical work input required by the fan. This is the case even though the pressure rise across the fan is actually smaller at high flow.

For Pitot-Static measurement $$vel = \sqrt{\frac{2(p_{total} - p_{static})}{\rho_{air}}}$$

For manometer $$(p_{total} - p_{static}) = \Delta h_{water} \rho_{water} g$$

For the motor power measurement, $$power(Watts) = \frac{Force(N) \times RPM}{53.68}$$

Results

For the measured traverse pressure measurements calculate the corresponding velocities. Plot the velocity profile across the diameter of the pipe. By considering the pipe as made up of concentric annuli calculate the volume flow for the pipe. From the total volume flow calculated by summation of the discretised volume flow in the annuli, calculate the mean velocity in the pipe. Calculate the ratio of mean velocity to maximum velocity.

Calculate the power requirement and mean velocity for the power test portion of the data collected. Note from the measured pressure differentials calculate the center velocity first and then the mean velocity by applying the same ratio of mean velocity to center velocity calculated from the first portion of the results. Plot the power required (y-axis) versus flow rate (x-axis).

Using the pressure measurements along the pipe, i.e. pressure drop along the pipe with respect to the P_{ref} pressure tap, calculate the pressure drop in Pascal. Plot these pressures (y-axis) versus axial location (x-axis). Using a number of points on the pressure distribution curve that seem to follow a linear relationship with length, calculate the friction factor (left hand side y-axis of Moody chart). Also calculate the Reynolds number of the flow. Draw the point describing this flow on the Moody diagram.

Conclusions

Draw your own conclusions on the experiment and results obtained.