Mesurement of Lift and Drag – SP3

Objective :
Determination of lift and drag coefficients of a turbine blade

Apparatus:
Electric blower, Wind tunnel, pitot tube, water manometer, turbine blade models.

Experimental Setup:
A schematic of the test section is shown in the Fig. 1. The exhaust of a 10 hp blower is connected to a large plenum chamber to remove the disturbances in the flow at the blower exit. A smooth entry is provided from the plenum chamber to a 227 mm X 100 mm rectangular cross-section duct. A 200 mm length is provided for development of the flow before the flow encounters the blade cascade. The blade has a turning angle of 107^o . The blades are cast with fine 2 mm diameter holes within the body of the blade which act as the static pressure taps. These holes communicate with the surface of the blade and also to a manometer and the locations of the pressure measurement locations are shown in the Fig. 1.

Test procedure:
1. The manometer assembly consists of a large number of vertical glass tubes connected to a single large glass reservoir that can be moved up and down. Move the glass reservoir up and down by a few centimeters and note the change in the levels of the glass tubes. Within a few seconds the levels in all the glass tubes should become equal. The tubes in which this does not happen can be considered to have a partial/full blockage and the data from these taps are to be ignored in the calculations. Lock the glass jar at some convenient location and note down the initial reading.

2. Make sure that the blower inlet valve is fully closed. Start the motor connected to the blower. After the blower has picked up full speed (typically a few seconds after start up) open the inlet valve completely.

3. Adjust the position of the movable pitot tube at the exit to give maximum deflection and note down the manometer readings from the blade static pressure taps and the pitots.

4. Perform the necessary computations.

Observations:
Stagnation pressure at inlet pitot tube:
Stagnation pressure at exit pitot tube:

Location of Pressure tap	Pressure in mm water
1	....
2	....
..	....
20	....

Theory:

A simplistic approach to determining the lift and drag forces acting on a blade in the cascade is to use the change of momentum principle. The flow in between two blades is assumed to be frictionless and the inlet and exit velocities are assumed uniform. Consider the two blades shown in the Fig. 2. The flow is assumed to enter the passage in between the blades at the blade inlet angle. The flow is assumed to exit the passage at the blade exit angle. The force on the blade (per unit depth)in the direction of rotation(Y_n), Lift, due to the change of direction of the flow is given by:

$F_L = \rho * S * C_1 * \text{Cos } \alpha_1 * (C_1 \text{Sin } \alpha_1 + C_2 \text{Sin } \alpha_2)$ (1)

where,(see Fig. 2)

ρ= density of air at the inlet

C_1 = velocity of air into the cascade

C_2 = velocity of air at exit from the cascade

α_1 = angle with which the air enters the passage (= blade angle here)=44.3^0

α_2 = angle with which the air leaves the passage (= blade exit angle here)=62.7^0

S = distance between the blades along the Y axis (S = 0.085 m)

The lift coefficient is defined as

$C_L = F_L/(\text{area normal to the lift force}*.5*\rho*C_1^2)$

Here area normal to lift force is the product of the length of blade in X_n direction (=97mm) and height (=unity) of the blade.

Similarly the drag force per unit depth on the blade due to change of fluid momentum is given by:

$F_D = \rho * S * C_1 * \text{Cos } \alpha_1 * (C_1 \text{Cos } \alpha_1 - C_2 \text{Cos } \alpha_2)$ (2)

and the drag coefficient defined as:

$C_D = F_D /(\text{area normal to drag force}*.5*\rho*C_1^2)$

Here area normal to drag force is the product of the width of blade in Y_n direction (=58mm) and height (=unity) of the blade.

Results and Discussions:

1. Compute the inlet and exit velocity from pitot tube readings

2. Plot the pressure distribution of gauge pressure versus distance along X_n for the pressure and suction surfaces on the same graph. Draw a smooth curve through the points obtained. The area under the curve will give the lift experienced by the blade. Compute the area using the trapezoidal rule. The normalised coordinates of the pressure taps are given in Fig. 2. The reference length for non-dimensionalisation is 97 mm.

3. Similarly obtain drag force (Force in X_n direction)

4. Compute drag and lift using the expressions in equations (1) and (2) and compare C_L and C_D with 6. Perform an uncertainty analysis for your results.
that obtained in steps 2 and 3.

5. Discuss the nature of the pressure variation plotted in steps 2 and 3.

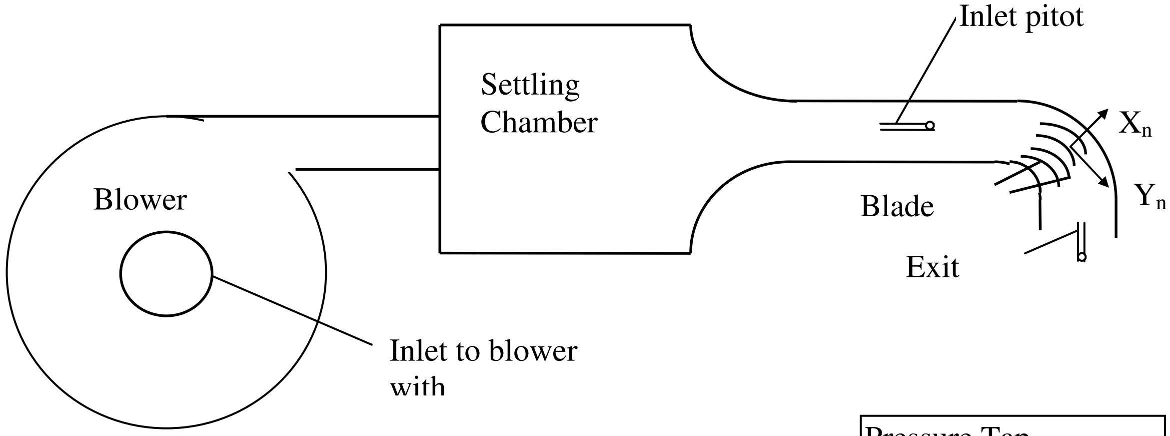
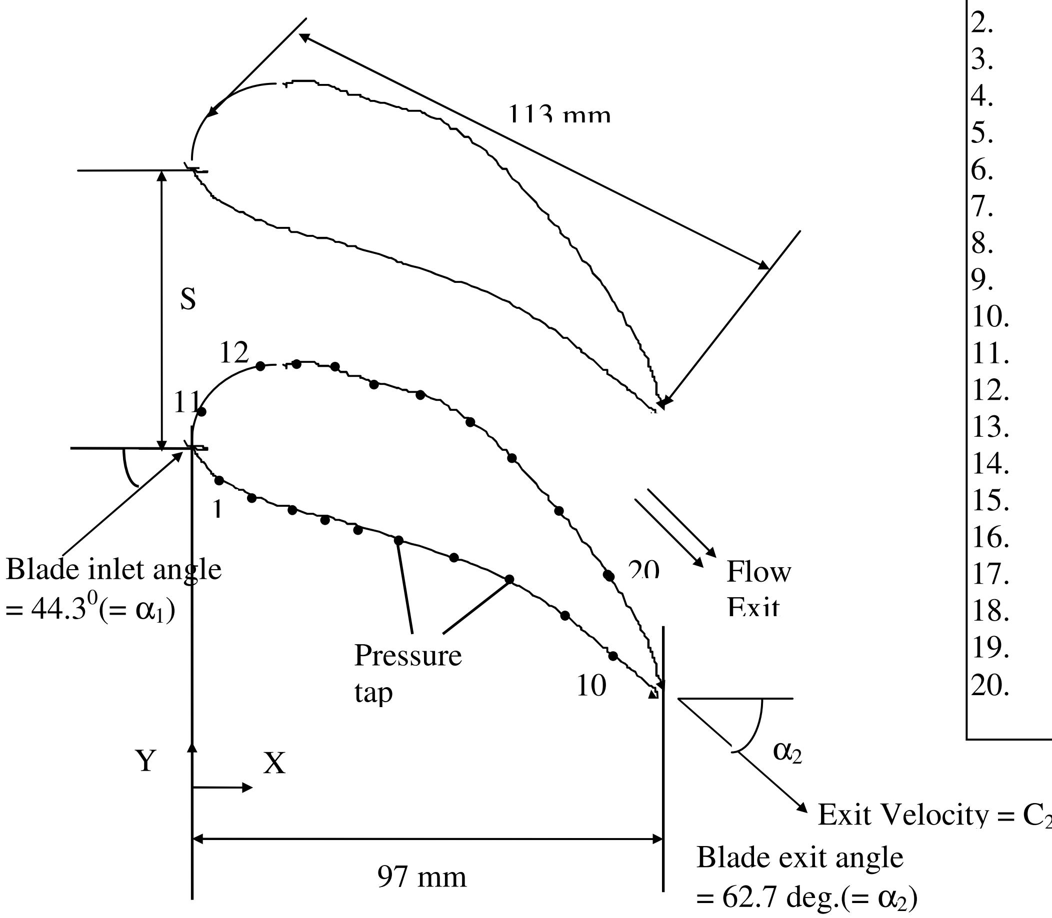


Fig. 1 Schematic of experimental setup



Pressure Tap Locations

Sl. No.	X	Y
1.	.0909	.5241
2.	.1818	.5577
3.	.2727	.5679
4.	.3636	.5576
5.	.4545	.5287
6.	.5455	.4864
7.	.6364	.4133
8.	.7273	.3126
9.	.8182	.2051
10.	.9091	.0722
11.	.0200	.6680
12.	.1548	.7661
13.	.2308	.7906
14.	.3077	.8000
15.	.3846	.7938
16.	.4615	.7732
17.	.6154	.6854
18.	.7692	.5112
19.	.8462	.3793
20.	.9231	.2172

Fig. 2 Locations of pressure taps on blade profile and nomenclature