Velocity Measurement in Free Surface Flows

Generally, the flow is assumed as one dimensional and standard. Pitot tube is used for measurement of velocity using either an inclined manometer or other type of manometer. One of the means of measuring of the local velocity \( \nu \) in a flowing fluid is the Pitot tube named after Henri Pitot who used a bent glass tube in 1730 to measure velocity in the river Seine.

Considering two dimensional flow of a frictionless fluid past a solid body (a combination of a source and uniform flow equal to half body - The point at which the pressure equals \( p_0 \) is located at \( 113.3^\circ \)) indicates that at stagnation point the velocity is zero. If \( \frac{p_0}{\gamma} \) denotes the static pressure head at some distance away from the velocity is \( v_0 \), while \( \frac{p_0}{\gamma} \) denotes the pressure head at the stagnation point, then applying the Bernoulli's equation,

\[
\frac{p_0 + \frac{v_0^2}{2g} + z}{\gamma} = \frac{p_s + \frac{v_0^2}{2}}{\gamma}
\]

\[
\therefore p_s = p_0 + \frac{\rho v_0^2}{2}
\]

Thus \( \frac{\rho v_0^2}{2} \) or \( \frac{\gamma v_0^2}{2g} \) is the dynamic pressure.

Rewriting the above equation,

\[
\frac{\gamma v_0^2}{2g} = p_s - p_0
\]

or \( v_0 = \left[ \frac{p_s - p_0}{\frac{\gamma}{2g}} \right]^{\frac{1}{2}} \)

If \( \frac{p_s - p_0}{\gamma} \) is measured then the local velocity \( v \) could be determined using manometer.
The static pressure can be determined accurately when the measuring device shape matches with the streamline such that no disturbance is created. Piezometer is attached to the pipe boundary either with the U-tube Manometer, or a pressure gauge, transducer. The Piezometer should be flush with the inside boundary. A small projection (2.5mm) of Piezometer inside the boundary can cause a measuring error of 16%. Piezometer ring is used to average the pressure over the boundary.

The static pressure is measured using Static tube. The pressure is transmitted to the Manometer or Gauge through the holes provided on the circumference of the tube. Actually the mean velocity past the Piezometer holes will be slightly larger than that of
the undisturbed flow field, hence the pressure at the holes will be slightly lower than the actual pressure of the undisturbed fluid. The error could be reduced by making the tube as small as possible. Thus the stagnation pressure could be measured.

The equation derived earlier is for ideal velocity of flow at the point of measurement. The correcting factor (co-efficient of Pitot tube) of 0.98 to 0.995 is used for obtaining the true velocity. In view of the velocity fluctuation due to turbulence this correction is necessitated. Pitot tube cannot measure the turbulent fluctuation in the flow.

Combined Pitot - static tube is used for measuring the velocity. Further positioning of the holes and the size must be precisely located and drilled. Otherwise it introduces an error. Hence a correction factor is required to be used.

**PRANDTL TUBE**

Prandtl tube is used to measure the velocities in the axial direction. It consists of a hollow stream lined brass body of 19 mm diameter. There are two holes corresponding to stagnation point, where it can be unscrewed to find an inductance type pressure pick-up. The pressure differential corresponding to the velocity head in the flowing water can be sensed accurately by the pick-up and shown as an analogous quantity on the dial of the amplifier. The minimum and maximum velocities that can be safely measured by the instrument are 1.5 m/s with accuracy in the measurement of head.
PRANDTL TUBE

1. Static hole
2. Total head hole

To manometer

Total Head

Static Head

Pitot Static Tube

0.3 d

3 d

8 to 10 d
The Pitot Static tube with blunt nose is known as Prandtl tube. The Pitot tube requires calibration. In order to measure the correct velocity component, a protractor can be attached to notice the angle of the approaching streamline. One of the disadvantages with the Pitot tube is that it is insensitive to directional components of velocities in the flow system (i.e.) it will not show any applicable difference in reading even it is inclined to the direction of the flow upto 17° nearly. In otherwords it can measure only the velocity component. The Pitot tube is insensitive to the direction of flow and only the velocity component is measured.

Further, improvement is the Pitot cylinder, using which the direction of velocity could be determined. Two holes are provided at an angle of 39.25° from the centre line of the tube.

Pitot meter consists of two tubes placed behind each other. Further, it is modified to measure shear stress and is called Preston tube or Stanton tube.
Other devices used for measuring the flow field is the **Current Meter**, Anemometer (Wind field). Instantaneous Turbulence velocity can be measured using hot film anemometer. Floats are used for estimating the surface velocity. The surface wind influences the velocity measured. Generally 0.85 ± 0.05 times the float velocity is the surface velocity.

Photographic method is another technique to measure the surface velocity. Hydrogen bubble technique can be used for measuring the flow in laboratory.