Experiment no.: 08

Experiment name: Determination of co-efficient of discharge using orifice discharge apparatus

Objectives

The objectives of this experiment are:

1. To determine static pressure head in the tank and total pressure head in the free jet.
2. To calculate velocity coefficient (ϕ), contraction coefficient (α), and discharge coefficient (C_d).
3. To check consistency between the three coefficients.

Scopes

The scopes of this experiment includes:

1. Understanding flow characteristics through an orifice by determining velocity, contraction, and discharge coefficients.
2. Analyzing the relation between the three coefficients and determining coefficient of discharge with velocity coefficient and contraction coefficient.
3. Understanding energy losses due to frictions and conversion from pressure head to velocity head, and how these coefficients can be used to calibrate the system for practical flow measurement applications.

Datasheet

group	h_stat	h_pitot	v_theo	v_stream	phi	d_orifice	d_stream	alpha	Qa	Qt	Cd	Cd_exp
1	0.076	0.073	1.22	1.20	0.98	0.029	0.026	0.78	6.030E-04	8.062E-04	0.75	0.76
2	0.088	0.085	1.31	1.29	0.98	0.029	0.026	0.80	6.250E-04	8.675E-04	0.72	0.79
3	0.094	0.091	1.36	1.34	0.98	0.029	0.027	0.88	6.402E-04	8.966E-04	0.71	0.87
4	0.098	0.095	1.39	1.36	0.98	0.029	0.026	0.83	7.163E-04	9.154E-04	0.78	0.82
5	0.104	0.101	1.43	1.41	0.99	0.029	0.024	0.68	6.787E-04	9.430E-04	0.72	0.67
6	0.069	0.066	1.16	1.14	0.98	0.029	0.025	0.76	5.780E-04	7.681E-04	0.75	0.74

Calculation

The measured value of:

1. Static pressure head, $h_{static} = 9.4\ cm = 0.094\ m$
2. Total pressure head, $h_{pitot} = 9.1\ cm = 0.091\ m$
3. Orifice diameter, $d_{orifice} = 29\ mm = 0.029\ m$
4. Stream diameter, $d_{stream} = 27.2\ mm = 0.0272\ m$
5. For measurement of actual discharge, duration = $7.81\ s$ and volume = $5\ L$

Hence,

Theoretical velocity,

$$v_{theo} = \sqrt{2gh_{static}}$$

$$or,\ v_{theo} = \sqrt{2 \times 9.8 \times 0.094} = 1.357\ m/s$$

Stream velocity,

$$v_{stream} = \sqrt{2gh_{pitot}}$$

$$or,\ \sqrt{2 \times 9.8 \times 0.091} = 1.336\ m/s$$

Therefore, velocity coefficient,

$$\phi = \frac{v_{stream}}{v_{theo}}$$

$$or,\ \phi = \frac{1.336}{1.357} = 0.985$$

Now, contraction coefficient,

$$\alpha = \frac{A_{stream}}{A_{orifice}} = \frac{d_{stream}^2}{d_{orifice}^2}$$

$$or,\ \alpha = \frac{0.0272^2}{0.029^2} = 0.880$$

Now, actual discharge,

$$Q_a = \frac{volume}{time} = \frac{5}{7.81} = 6.402 \times 10^{-4}\ m^3/s$$

Theoretical discharge,

$$Q_t = A_{orifice} v_{theo}$$

$$or,\ Q_t = \pi(\frac{0.029}{2})^2 \times 1.357 = 8.963 \times 10^{-4}\ m^3/s$$

Therefore, coefficient of discharge,

$$C_d = \frac{Q_a}{Q_t}$$

$$or,\ C_d = \frac{6.402}{8.963} = 0.714$$

Discussion

In this experiment, three key dimensionless coefficients were determined. These are:

1. Velocity coefficient, $\phi = 0.985$,
2. Contraction coefficient, $\alpha = 0.880$, and
3. Discharge coefficient, $C_d = 0.714$

The velocity coefficient is close to 1 and falls within the expected range of 0.95 to 0.99. It indicates a minimal energy loss meaning that the actual stream velocity is nearly equal to theoretical velocity. The contraction coefficient suggests that the stream cross-section at vena contracta is 88% of orifice area implying significant contraction.

The discharge coefficient should be the product of velocity coefficient and contraction coefficient:

$$C_{d_expected} = 0.985 \times 0.880 = 0.867$$

However, the determined value of discharge coefficient is significantly lower at 0.714. This could be due to several potential errors that are listed below.

Sources of errors

The potential sources of errors include:

1. **Measurement errors:** Inaccurate measurement of stream diameter can produce a very different value of contraction coefficient. It is possible that we measured the diameter somewhere below the vena contracta where diameter was higher.
2. **Head fluctuations:** While static pressure head was fairly stable; pitot head was fluctuating and its heading can play a role for incorrect values.
3. **Pitot tube positioning:** Incorrect positioning of the pitot tube may have affected velocity measurements.
4. **Energy Losses:** Friction losses not accounted for in theoretical calculations.
5. **Human Error:** Delays in starting/stopping stopwatch or reading of manometer.