Given: Plate with orifice struck concentrically by water jet as shown.

Find: (a) Expression for force needed to hold the plate.
(b) Value of force for \( V = 5 \text{ m/s} \), \( D = 100 \text{ mm} \), and \( d = 25 \text{ mm} \).

Plot: required force as a function of diameter ratio \( d/D \).

Solution:

Apply the \( x \) component of the momentum equation to the
inertial CV shown.

Basic equation:
\[
F_{x, i} + F_{x, a} = \frac{\partial}{\partial t} \int_{CV} u_p dA + \int_{CV} u_p dA
\]

Assumptions:
1. Atmospheric pressure surrounds CV
2. \( F_{x, i} = 0 \)
3. Steady flow
4. Uniform flow at each section
5. Incompressible flow

Then,
\[
R_x = u_x \left[ -p_{A_1} \frac{A_1}{A_2} + u_{2x} \left( u_{2x} - u_{A_2} \right) + u_{3x} \left( u_{3x} - u_{A_3} \right) \right] - u_{A_1} \frac{A_1}{A_2} + u_{A_2} \frac{A_2}{A_3} + u_{A_3} = 0
\]

and
\[
R_x = \frac{\rho u_x^2}{2} \left( A_1 - \frac{A_2}{A_3} \right)
\]

Evaluating for \( d = 25 \text{ mm} \):
\[
R_x = \frac{\pi}{4} \times 998 \frac{\text{N}}{\text{m}^2} \left( 5 \text{ cm} \right)^2 \times \left( 0.10 \text{ m} \right)^2 \times \left( 1 - \left( \frac{25 \text{ mm}}{100 \text{ mm}} \right)^2 \right) \times 5^2 \frac{\text{m}}{\text{s}} \times 2 \frac{\text{m}}{\text{s}} = -184 \text{ N}
\]

Since \( R_x \neq 0 \), it must be applied to the left. \( R_x \) is plotted as a function of \( d/D \).

Force to Hold Plate vs. Diameter Ratio

- \( D = 100 \text{ mm} \)
- \( V = 5 \text{ m/s} \)