VWT Diffuser for Section CD

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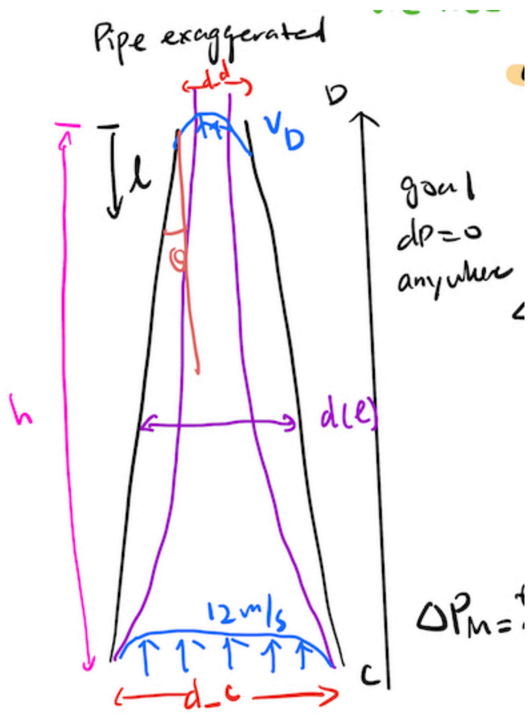
Theory and Method

The test section CD is designed to be perpendicular to the ground. Water flows throgh the section against the gravity. Therefore, if the section is straight, then the pressure cannot stay constant. To ensure a constant pressure, we must make sure that dP, or the overall change of pressure, equals to 0

To achieve that, the section wall must be angled slightly. The purpose of this script is to calculate the angle that will keep dP = 0

Here is a graph that visualizes some of the constants and variables we are using in the following script:



We define **positive** pressure change to be the increase in pressure against the flow. In other words, positive pressure or pressure change require the pump to pump **harder**. The direction of l points downward, the same direction as the gravity.

Constants

```
v_c = 12; % m/s
d_c = 0.127; % m
V = d_c^2/4*v_c; % m^3
rho = 1000; % kg/m^3
h = 1.5; % m
g = 9.81; % N/Kg
T = 20; % C
epsilon = 1.50E-05; % absolute roughness

% Pressure
P_atm = 101320; % Pa
Pa2Bar = 1/100000;
P = (P_atm+4000)*Pa2Bar;

% Reynolds Number
Re = tReynolds(V*rho,d_c,T,P);

% get the friction factor f, assuming stainless steel
f = f_Moody(d_c,Re,epsilon);
```

Symbolic relationships

```
syms theta l
% The diameter, or the width of D point using point c width and height, which
 is
% known)
d_d = d_c-h*2*theta;
% d = d_d+2*l*tan(theta); % takes too long to calculate
d = d_d+2*l*theta; % small angle approximation, tan(theta) ~= theta.
% We are ignoring displacement thickness since overall flow rate across a
 contour should be the same, so speed is only related to the size of the
 opening
v = d_c.^2.*v_c./d.^2;
v_d = d_c^2*v_c/d_d^2;
```

Pressure changes along dl

We know that:

- major loss: $\frac{\Delta p_M}{L} = \frac{f}{2}\rho\frac{v^2}{D}$
- bernoulli pressure change without considering gravity: $p_2 - p_1 = \frac{1}{2}\rho((v_1)^2 - (v_2)^2)$
- gravity: $\rho g h$

We take the derivative of each equation above with respect to l, and get the following new equations:

```
% major loss change, take negative derivative because dl is opposite to the
 actual flow of water
dP_M_dL = -diff(f/2*rho*l*v^2/d,l);
% bernoulli pressure change
dP_m_dL = diff(1/2*rho*(v_c^2-v^2),l);
% gravity pressure change, take negative derivative because dl is opposite to
 the actual flow of water
dP_h_dL = -rho*g;
```

Integration

The idea is that all three pressure changes must add up to be 0 at any given point along CD. So if we take the integration from the origin (Point D) to the entire length of H, we should still get 0.

```
dP_dl = dP_M_dL+dP_m_dL+dP_h_dL; % overall dP
f_integrate = int(dP_dl,l,0,h); % integrate and get symbolic representation

E = f_integrate == 0; % set up the equation to solve
S = solve(E,"Real",true); % solve for angle
```

Final result output

```
% angle
radian = double(S)
degree = double(S/pi*180)
% diameter of d
dd = d_c-h*2*radian
% velocity at d
v_dd = d_c^2*v_c/dd^2
```

```
radian =

    0.0031


degree =

    0.1804


dd =

    0.1176


v_dd =

   14.0057
```

Result validation

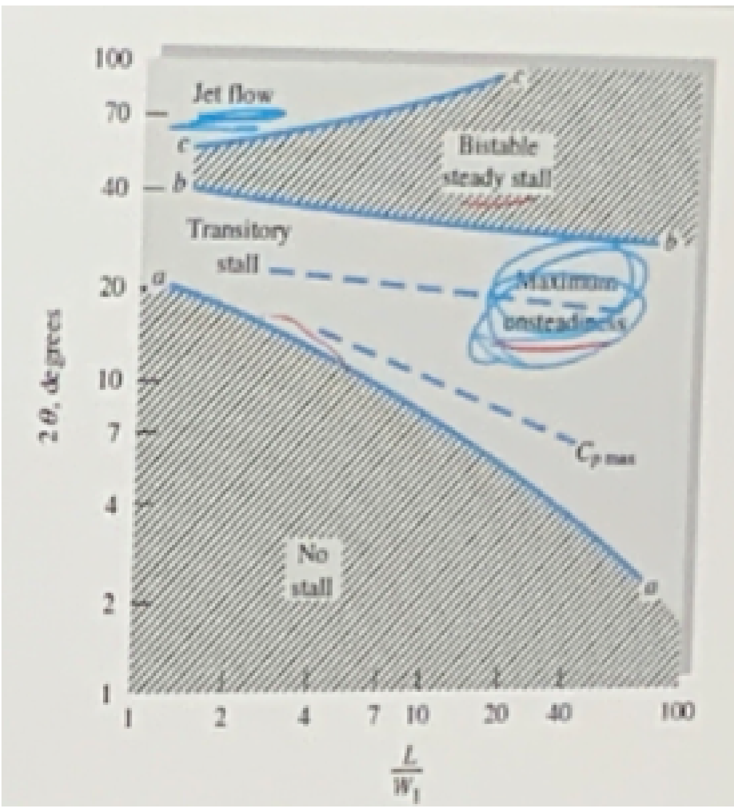
Note that

```
lengthToWidthRatio = h/dd
```

```
lengthToWidthRatio =

   12.7600
```

Substitute the result into the following graph:



$2\theta = degree \times 2$

As long as the point is in the "No stall" region, the design is valid!

```
% Other eqns for checking pressures
1/2*rho*(v_c^2-v_dd^2);
gravity = rho*g*h;
```

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