Contents

Turbulence Profiles

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```
% Paths for data loading
ROOT_DIR = "C:/Users/Trevor/Desktop/AEM 4602W/Fluids Lab/Fluids Lab Data/";
HOTWIRE_DIR = ROOT_DIR + "Hotwire Measurements/";
ANGLES = ["-5", "00", "05", "20"];
N_DATAPOINTS = [11, 10, 15, 78];
V_AVG   = 24.4247; % m/s, mean of all velocities, excluding nan
T_AVG   = 27.8641; % degrees C, mean of all temperatures
P_AVG   =   98769; % Pa, mean of all pressures, excluding nan
RHO_AVG =  1.1430; % kg/m^3, mean of all densities, excluding nan
MU_AVG  = 1.85e-5; % Pa*s, dynamic viscosity at T_AVG and ~atm pressure. Src: https://www.engineeringtoolbox.com/air-absolute-kinematic-viscosity-d_601.html

% Useful Conversions
LB_TO_N = 4.448; % lb -> N = (lb) * 4.448 N/lb
N_TO_LB = 1/LB_TO_N;
DEG_TO_RAD = pi/180; % degrees -> rad = (deg)* pi/180 rad/deg
IN_TO_M = 0.0254; % in -> m = (in) * .0254 m/in

% Base Uncertainties
F_ERR   =   0.1; % ± N, given error in sting measurements
A_ERR   =   0.2; % ± degrees, given error in sting measurements
C_ERR   = 0.001; % ± m, bias error from using a meter stick
B_ERR   = 0.001; % ± m, bias error from using a meter stick
V_ERR   =   0.4; % ± m/s, given error in pitot tube measurements
Y_ERR   =  1/16; % ± in, bias error from reading hot wire tape measure
X_ERR   =  1/16; % ± in, bias error from reading hot wire tape measure
L_ERR   =  1/16; % ± in, bias error from reading hot wire tape measure

RHO_ERR =  0.02*RHO_AVG; % *100 ± % of value, given error in pitot tube measurements
MU_ERR  =  0.01*MU_AVG; % *100 ± % of value, given error in pitot tube measurements
V_RMS_ERR = 0.2; % ± m/s, from calibration spreadsheet

F_ERR_LB  = F_ERR * N_TO_LB; % lb
A_ERR_RAD = A_ERR * DEG_TO_RAD; % rad
Y_ERR_M   = Y_ERR * IN_TO_M; % m
X_ERR_M   = X_ERR * IN_TO_M; % m
L_ERR_M   = L_ERR * IN_TO_M; % m

% Arrays to store data per angle
angle_data_arr = repmat(...
    struct(...
        "len_scale",[],...
        "v_normalized", [],...
        "v_rms", [],...
        "len_scale_ERR",[],...
        "v_normalized_ERR",[]...
    ), length(ANGLES), 1 ...
);

% Experiment properties
c =  .254; % m, airfoil chord length
x = .75*c; % m, distance from trailing edge to hot wire
L = 19.5*IN_TO_M; % m, distance from hot wire to top of tunnel

% Calibration constants: (E+offset)^2 = A + B*U^n
offset = -8.92; % V, voltage at zero flow
A      = -74.9; % constant from linear regression
B      =  53.7; % constant from linear regression
n      =  0.55; % exponent in King's Law that gave straightest fit

% Average Experiment Reynolds Number
Re_AVG = (RHO_AVG*V_AVG*c)/MU_AVG
Re_ERR = sqrt(...
    ( (RHO_ERR*V_AVG*c)/MU_AVG )^2 + ( (RHO_AVG*V_ERR*c)/MU_AVG )^2 + ...
    + ( (RHO_AVG*V_AVG*C_ERR)/MU_AVG )^2 + ( (-RHO_AVG*V_AVG*c*MU_ERR)/(MU_AVG^2) )^2 ...
)


for i = 1:length(ANGLES)
   angle = ANGLES(i);
   angle_data_arr(i) = struct(...
```

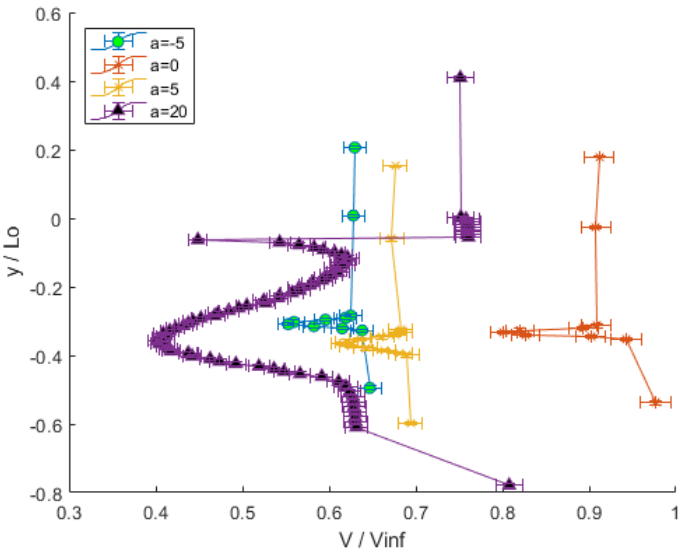
```
        "len_scale", zeros(1, N_DATAPOINTS(i)),...
        "v_normalized", zeros(1, N_DATAPOINTS(i)),...
        "v_rms", zeros(1,N_DATAPOINTS(i)),...
        "len_scale_ERR", zeros(1,N_DATAPOINTS(i)),...
        "v_normalized_ERR", zeros(1,N_DATAPOINTS(i))...
    );

    % LENGTH SCALE: the hot wire was positioned at x = .75c behind the
    % trailing edge of the airfoil, with the airfoil being L = 19.5in from
    % the top of the tunnel, as measured at zero angle of attack.
    % However, since moving the sting caused a change in the vertical
    % position of the TE, L0 was selected to be the distance from the top of
    % the tunnel to the airfoil, adjusted for angle of attack. Using trig,
    % this works out to be L - x*sin(a).
    a = str2double(angle); % deg
    L0 = L - x*sind(a); % m, height of TE adjusted for angle of attack
    L0_ERR = sqrt( (-x*sind(a)*L_ERR_M)^2 + ( (L-sind(a))*X_ERR_M )^2 + ( (L-x*cosd(a))*A_ERR_RAD )^2 ); % ± m

    for j = 1:N_DATAPOINTS(i)
        path = HOTWIRE_DIR + "a_" + ANGLES(i) + "/data_" + j + ".mat";
        data = load(path); % lab data, with P, T, rho, v, a, y, and V_arr

        % NOTE: for some reason, the pitot tube returned a speed of 'nan' for
        % all of our measurements at a = 0. This isn't a huge deal, since the
        % freestream was always set to the same speed, so a good
        % approximation for this case is to use the average of all other
        % velocities we measured
        if(isnan(data.v))
            data.v = V_AVG;
        end


        % NOTE: y as measured in the lab is the distance from the top of the
        % tunnel to the hot wire. L0, as discussed earlier, is the distance
        % from the top of the tunnel to the TE, adjusted for angle of attack.
        % To make values of y *above* the TE to be positive and *below* to be
        % negative, y was subtracted from L0 to transfrom y into the distance
        % of the hotwire above the TE. This was then nondimensionalized by L0

        % len_scale = (L0 - y) / L0
        len_scale = (L0 - (data.y * IN_TO_M)) / L0;
        len_scale_ERR = sqrt( ( (data.y*IN_TO_M*L0_ERR)/(L0^2) )^2 + (-Y_ERR_M/L0)^2 ); % unitless

        % hot wire velocity
        % from calibration: v_hotwire = (((E + offset)^2 - A)/B)^(1/n)
        v_hotwire_arr = (((data.V_arr + offset).^2 - A)./B).^(1/n);

        % v_rms = remove mean from velocities, take the average of their
        % squares, and then take the square root
        v_rms = sqrt( mean( ( v_hotwire_arr - mean(v_hotwire_arr) ).^2 ) );
        v_rms = v_rms / data.v; % normalized to be non-dimensional

        % v_hotwire / v_freestream
        v_normalized = mean(v_hotwire_arr) / data.v;
        v_normalized_ERR = sqrt( (V_RMS_ERR/data.v)^2 + ( (-V_ERR*mean(v_hotwire_arr))/(data.v^2) )^2  ); % unitless

         % Store in global arr
         angle_data_arr(i).len_scale(j) = len_scale;
         angle_data_arr(i).len_scale_ERR(j) = len_scale_ERR;
         angle_data_arr(i).v_normalized(j) = v_normalized;
         angle_data_arr(i).v_normalized_ERR(j) = v_normalized_ERR;
         angle_data_arr(i).v_rms(j) = v_rms;
    end
end
```

```
Re_AVG =

   3.8330e+05


Re_ERR =

   1.0730e+04
```

V/Vinf

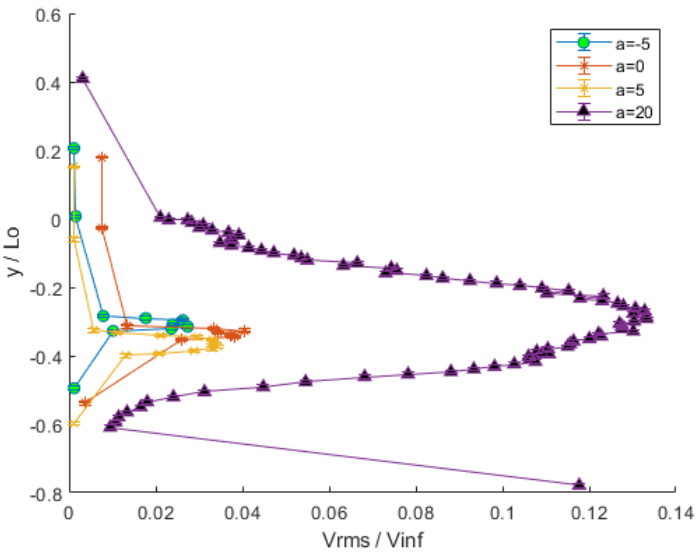
```
colors = ["green", "red", "blue", "black"];
shapes = ["-o", "-*", "-x", "-^"];
```

```
hold on
for i = 1:length(ANGLES)
    errorbar(angle_data_arr(i).v_normalized, angle_data_arr(i).len_scale,...
        angle_data_arr(i).len_scale_ERR,... % yneg
        angle_data_arr(i).len_scale_ERR,... % ypos
        angle_data_arr(i).v_normalized_ERR,... % xneg
        angle_data_arr(i).v_normalized_ERR,... % xpos
        shapes(i), 'MarkerFaceColor', colors(i)...
   )
end
xlabel("V / Vinf")
ylabel("y / Lo")
xlim([.3, 1])
legend('a=-5', 'a=0', 'a=5', "a=20", 'AutoUpdate', 'off', 'Location', 'northwest')
```



Vrms/Vinf

```
colors = ["green", "red", "blue", "black"];
shapes = ["-o", "-*", "-x", "-^"];

clf % clear previous figure
hold on
for i = 1:length(ANGLES)
    errorbar(angle_data_arr(i).v_rms, angle_data_arr(i).len_scale, angle_data_arr(i).len_scale_ERR, shapes(i), 'MarkerFaceColor', colors(i))
end
xlabel("Vrms / Vinf")
ylabel("y / Lo")
legend('a=-5', 'a=0', 'a=5', "a=20", 'AutoUpdate', 'off', 'Location', 'northeast')
```



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