IOWA STATE UNIVERSITY

QUANTIFICATIONS OF THE TURBULENCE CHARACTERISTICS IN THE WAKE OF AN AIRFOIL BY USING A HOTWIRE ANEMOMETER PRE-LABORATORY

AER E 344 - PRE-LAB 07 - QUANTIFICATIONS OF THE TURBULENCE CHARACTERISTICS IN THE WAKE OF AN AIRFOIL BY USING A HOTWIRE ANEMOMETER

SECTION 3 GROUP 3

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1 Answers

1.1 Question 1

For a 10 Hz motor frequency, the velocity is 12.8 m/s. Per the lab manual, the transition occurs at a Reynolds number of 1×10^5. Using the equation for Reynolds number, we can find the distance from the leading edge of a theoretical flat plate at which the turbulent transition occurs:

$$
\begin{aligned}
Re &= \frac{\rho V_\infty^2 L}{\mu} \qquad (1.1)\\
x &= \frac{Re \cdot \mu}{\rho V_\infty^2}\\
x &= \frac{1 \times 10^5 \cdot 1.8 \times 10^{-5}\,\mathrm{N\,s/m^2}}{1.225\,\mathrm{kg/m^3} \cdot 12.8\,\mathrm{m/s}}\\
x &= 11.5\,\mathrm{cm}
\end{aligned}
$$

Once we have the transition point, we can use the two boundary layer equations to determine the thickness of the boundary layer as a function of the distance from the leading edge of the theoretical flat plate:

$$
\frac{\delta}{x} = \frac{5.0}{\sqrt{Re_x}} \quad \text{for laminar flow} \qquad (1.2)
$$

$$
\frac{\delta}{x} = \frac{0.37}{Re_x^{\frac{1}{5}}} \quad \text{for turbulent flow} \qquad (1.3)
$$

Using the script attached to this pre-lab, we generated a graph of boundary layer thicknesses (see Figure 1.1).

We can use Figure 1.1 to determine the spacing of the measurements for a given distance from the leading edge of the airfoil. For example, if the probe is positioned 0.5 m from the leading edge of the airfoil, the boundary layer will be approximately 1.4 cm. For this boundary layer width, we should take measurements every 2 mm to

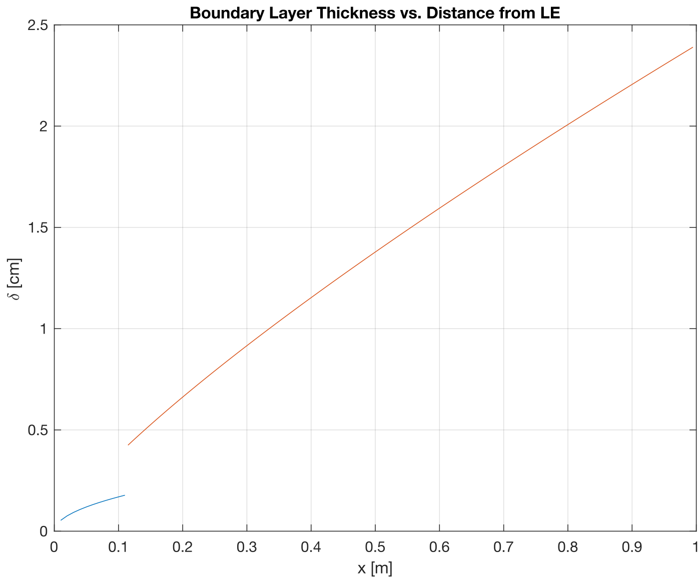

Figure 1.1: *A plot of the boundary layer thickness, δ, as a function of the distance from the leading edge of a theoretical flat plate, x.*

3 mm—starting approximately 6 mm below the airfoil and ending approximately 6 mm above the airfoil. This scale will vary depending on the x distance of the probe.

Since this lab is using an airfoil and not a flat plate, the wake may be much larger and a larger range should be used to capture the wake, especially for larger angles of attack.

1.2 PreLab07.m

```
% AER E 344 Pre-Lab 07
% Section 3 Group 3
clear, clc, close all;

%% Given
mu = 1.8e-5; % [N*s/m^2]
rho = 1.225; % [kg/m^3]
V_inf = 12.8; % [m/s] <-- this is for 10 Hz

c = 0.101; % [m]

Re_transition = 10^5; % []

%% Calculations
x_transition = Re_transition * mu / (rho * V_inf); % [m]
x_laminar = 0 : 0.01 : x_transition; % [m]
x_turbulent = x_transition : 0.01 : 1; % [m]
Re_laminar = rho * V_inf * x_laminar / mu; % []
Re_turbulent = rho * V_inf * x_turbulent / mu; % []

```

```
boundary_layer_laminar = 5.0 * x_laminar ./ sqrt(Re_laminar); % [m] <-- for laminar flow
boundary_layer_turbulent = 0.37 * x_turbulent ./ Re_turbulent.^(1 / 5); % <-- for turbulent flow

%% Output
fprintf( ...
    "x_transition = %g cm\n", ...
    x_transition * 100);

figure;
plot(x_laminar, boundary_layer_laminar * 100);
hold on;
plot(x_turbulent, boundary_layer_turbulent * 100);
hold off;
title("Boundary Layer Thickness vs. Distance from LE");
xlabel("x [m]");
ylabel("\delta [cm]");
grid on;
saveas(gcf, "boundary_layer_thickness.svg");
```