IOWA STATE UNIVERSITY

MEASUREMENTS OF THE BOUNDARY LAYER OVER A FLAT PLATE PRE-LABORATORY

AER E 344 - PRE-LAB 08 - MEASUREMENTS OF THE BOUNDARY LAYER OVER A FLAT PLATE

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:

$$
\begin{aligned}
Re &= \frac{\rho V_\infty^2 L}{\mu} && (1.1)\\
x &= \frac{Re \cdot \mu}{\rho V_\infty^2}\\
x &= \frac{1 \times 10^5 \cdot 1.8 \times 10^{-5}\,\mathrm{N\,s/m^2}}{1.225\,\mathrm{kg/m^3} \cdot 12.8\,\mathrm{m/s}}\\
x &= 11.5\,\mathrm{cm}\\
x &= 4.52\,\mathrm{inch}
\end{aligned}
$$

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:

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

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

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 30 inch from the leading edge of the airfoil, the boundary layer will be approximately 0.763 inch or 19.4 mm. For this boundary layer width, we should take measurements

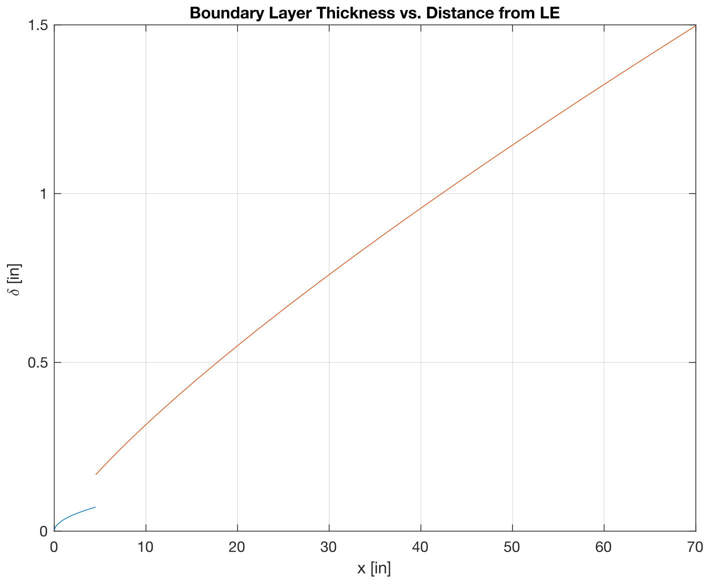

Figure 1.1: *A plot of the boundary layer thickness, δ, as a function of the distance from the leading edge of a theoretical flat plate, x.*

every 2 mm to 3 mm—starting approximately 10 mm below the airfoil and ending approximately 10 mm above the airfoil. This scale will vary depending on the x distance of the probe.

1.2 PreLab08.m

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

u = symunit;

%% 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_transition = ...
    double(separateUnits(unitConvert(x_transition * u.m, u.in))); % [in]
x_laminar = 0 : 0.01 : x_transition; % [in]
x_turbulent = x_transition : 0.01 : 70; % [in]
```

```
Re_laminar = rho * V_inf ...
    * double(separateUnits(unitConvert(x_laminar * u.in, u.m))) ...
    / mu; % []
Re_turbulent = rho * V_inf ...
    * double(separateUnits(unitConvert(x_turbulent * u.in, u.m))) ...
    / mu; % []

boundary_layer_laminar = ...
    5.0 * x_laminar ./ sqrt(Re_laminar); % [in]
boundary_layer_turbulent = ...
    0.37 * x_turbulent ./ Re_turbulent.^(1 / 5); % [in]

%% Output
fprintf( ...
    "x_transition = %g in\n", ...
    x_transition);

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