TFES Lab (ME EN 4650)
Flow Around a Circular Cylinder

Required Figures

Captions

A meaningful and comprehensive figure caption must accompany all figures. The figure caption must include the following label: Figure 1X. where X denotes the letter a – d according to the plot order listed below. Use the following guidelines when writing figure captions:

→ Ideally, the figure caption should provide a "standalone" description of the plot, and contain enough information that the reader can understand what is being shown without having to refer back to the main text of the document (report, memo, etc.).

→ The caption should start with a statement of the quantities plotted on both axes. Typically the axis labels will utilize mathematical symbols (with appropriate units) for the quantities being plotted; however, in the caption, these quantities are described in words.

→ Include relevant contextual information about the plot. For example, for the wake profile, you should state the x/D location and Re_D value at which the measurements were taken. Additionally, you should state that the measurements are for the case of flow around a two-dimensional circular cylinder. Finally, adding some text about the measurement technique used to obtain the data would be appropriate.

→ When your plot includes errorbars, it is helpful to provide information in the caption about the errorbars. For example, you should include the fact that the errorbars represent a 95% confidence interval.

→ When comparing with published data, it is appropriate to provide a reference for the publication.

→ If in doubt about what information to include in the caption, one should err on the side of providing more information, rather than less.

Plots

1a. Plot the mean horizontal velocity profile in the wake $\overline{u}/U_\infty$ (on the vertical axis) versus y/D (on the horizontal axis). Since both $\overline{u}/U_\infty$ and y/D are nondimensional, your axis labels will not have units. Use markers, such as circles, for your data. Include vertical errorbars on the data for $\overline{u}/U_\infty$ that represent the standard error in the mean to within a 95% confidence interval. That is, your errorbars should have a total length of $\pm 2\,\sigma_{\overline{u}}/U_\infty$, where $\sigma_{\overline{u}}$ denotes the standard error of the mean velocity. Note, $\sigma_{\overline{u}}$ will vary with y. For reference, include a solid black (horizontal) line corresponding to $\overline{u}/U_\infty = 1$ on your plot as well. This line represents the case where the mean velocity in the wake is equal to the freestream velocity.

1b. Plot the horizontal turbulence intensity $\sigma_u/\overline{u}$ (on the vertical axis) versus y/D (on the horizontal axis). Since both $\sigma_u/\overline{u}$ and y/D are nondimensional, your axis labels will not have units. Use markers, such as circles, for your data.

1c. Plot the pressure coefficient C_p (on the vertical axis) versus angular position θ (in degrees, on the horizontal axis). Use markers, such as circles, for your data. Include vertical errorbars on the data for C_p that represent the standard error of C_p to within a 95% confidence interval. For reference, include a solid black (horizontal) line corresponding to $C_p = 0$ on your plot as well. This line represents the case where the static pressure on the cylinder is equal to the freestream static pressure.

1d. On a single figure, plot the following as listed below. Include an appropriate legend.

- → C_D (on the vertical axis) versus Re_D (on the horizontal axis) for the published results. Use a solid black line. Both C_D and Re_D should be plotted on logarithmic coordinates, similar to Figure **??**. Include grid lines on your plot. Note, the published results can be downloaded as a text file from CANVAS.
- → C_D versus Re_D based on your analysis of the cylinder static pressure measurements. Plot your single data point using the ■ marker.
- → C_D versus Re_D based on your analysis of the conservation of mass and momentum equations. Plot your single data point using the ● marker.

Short-Answer Questions

In each of the short-answer questions below that require additional calculations, be sure to include the calculations in your Matlab code and have the results displayed to the screen.

2a. State the thickness of the wake at the x/D location of your measurements. The wake thickness should be stated in terms of the number of cylinder diameters D and not in dimensional units. Include the cylinder Reynolds number for your measurements as well. Finally, provide a technical description how you quantified the wake thickness. [2 sentences]

Your response should be of the following form, where XX denotes the values from your analysis:

> "The wake thickness behind the cylinder was found to be XXD, based on Pitot-static probe measurements taken at a downstream distance of x/D=XX and Reynolds number of Re_D=XX. The wake thickness was determined as the y-location in the wake profile where the wake velocity u reached a plateau, i.e., became independent of y."

2b. State the maximum uncertainty in $\overline{u}$ and C_p and their corresponding y/D locations. Calculate the maximum uncertainties in terms of a percentage using the following expressions:

$$\max\left(\frac{2|\sigma_{\overline{u}}|}{\overline{u}}\right)\cdot 100 \qquad \text{and} \qquad \max\left(\frac{2|\sigma_{P_r}|}{P_r}\right)\cdot 100\ , \tag{1}$$

where P_r $(= \overline{P}_{\mathrm{cyl}} - \overline{P}_\infty)$ is the average relative static pressure acting on the cylinder. Explain why the error bars on $\overline{u}/U_\infty$ are not uniform with respect to y/D, and appear larger in some regions of the wake. Similarly, explain why the error bars on C_p appear larger at some θ values but less at others. [3 sentences]

2c. State the y/D range at which $\overline{u}/U_\infty \geq 1$ for your data in the wake. In your statement, include the x/D location at which the wake profile was measured, along with the cylinder Reynolds number Re_D. Explain why there are regions of the flow in the wake where the $\overline{u}$ velocity is greater than U_∞. [2–3 sentences]

2d. State the percent difference in the drag coefficients C_D obtained from your data analysis using the two different methods, compared with the "expected value" at the same cylinder Reynolds number based on the published results,

$$\epsilon_{C_D}\,(\%) = \frac{|(C_D)_{\mathrm{Pub}} - (C_D)_{\mathrm{Data}}|}{(C_D)_{\mathrm{Pub}}} \cdot 100$$

Note, you will need to interpolate the published C_D results to find the value of C_D corresponding to the cylinder Reynolds number used in your experiment. When writing your response, explicitly state both methods used to calculate C_D. Also, in your response, explicitly state the value of the Reynolds number for your experiment. Finally, state which method yields a more accurate measure of C_D. [3 sentences]

Your response should be of the following form, where XX denotes the values from your analysis:

> "At a cylinder Reynolds number of Re_D=XX, the percent difference in C_D between the published results and the present data based on conservation of mass/momentum from the wake profile measurements is XX%. At the same Reynolds number, the percent difference in C_D between the published results and the present data based on the static pressure measurements around the cylinder is XX%. From this, it is clear that the XX method yields a more accurate measure of the drag coefficient."