HW #3
Due 2 October 2015 in class

Note: This HW concerns predicting the propulsive performance of the APC 10×5 propeller. You will find all of the data you need in the AIAA Conference Paper “Blade element momentum modeling of low-Re small UAS electric propulsion systems”, by M. H. McCrink and J. W. Gregory (AIAA Paper 2015-3296). This paper is on the class website as item #12; you must read the paper for this HW to make sense.

The APC 10 × 5 propeller is used to propel small remotely piloted vehicles like RC airplanes. The nomenclature 10 × 5 refers to the diameter (\(d = 10\) inches) and the nominal pitch (5 inches, usually measured at the radius \(r = 3d/8\)). The propeller is comprised of a NACA 4412 airfoil section from the 5% radius to the tip.

Problem 1 Using the \(c_\ell\) and \(c_d\) data shown in Figure 4, and the propeller geometry given in the paper, compute the thrust coefficient, power coefficient, and efficiency curves as functions of \(J\) using simple blade element theory. Compare your predictions to the measured data presented in Figures 14, 17, and 19 at full power (max RPM). Comment on your results. You will need to digitize the experimental data to make the comparisons.

Problem 2 Using your code from problem #1, implement the Prandtl-Glauert correction for \(c_\ell\) and recompute the \(C_T\), \(C_P\), and \(\eta\) versus \(J\) figures. Describe what you see and whether the correction was important.

Problem 3 Combine your blade element code from #2 with the momentum theory to deduce the inflow factors \(a\) and \(b\) (denoted \(a_0\) and \(a_1\), respectively, in the AIAA paper) as functions of \(r\) and recompute the \(C_T\), \(C_P\), and \(\eta\) versus \(J\) figures. Describe what you see and whether the momentum theory estimate of the induced flow was important.

Problem 4 (25 pts. extra credit) Implement the tip loss factor and three-dimensional flow corrections and recompute the \(C_T\), \(C_P\), and \(\eta\) versus \(J\) figures. Describe what you see and whether the corrections were important.

Problem 5 Look back over your results from problems 1–3 (and 4 if you did it) and answer the question: is blade element momentum theory useful? Explain why you believe this.