USING AIRSCREW

We are going to get started on your homework by modeling one of the turbines from Problem 1 in Chapter 7 of the White Book. The turbine we will model in class has the following parameters:

- Blade radius = 10cm
- Number of blades = 3
- Pitch angle = 12 degrees
- No twist
- Hub radius = 2.9 cm
- Hub height = 20.3 cm
- Blade chord (width) = 2.5 cm (no trimming)
- Wind Speed = 4.8 m/s
- Air Density = 1.07 kg/m^3 -- to complete the hw, use Eqn. 9 to determine P_{wind}

We want to determine the speed at which this turbine will spin, the kinetic power of the turbine, and the electric power generated by the generator.

1) Open the Airscrew program. Double click on introduction screen to close it.
2) Select FILE>OPEN *.IPT INPUT FILE and choose to open *Example.ipt*
3) The turbine blade that you want to analyze is built in Airscrew using the BUILDAIRSCREW Menu.
   a) Click on that menu and then put the mouse over DIMENSIONAL UNITS. Click to accept the units. You could change any of these units if you wanted, but we don't need to for the ENGR102 project
4) Go back to the BUILDAIRSCREW menu and notice that BASIC DATA can now be selected. Put your mouse over BASIC DATA and then click on NUMBER OF BLADES.
   a) A large dialog box opens where you can enter the number of blades and other basic dimensions.
   b) Enter the appropriate data from above. Many of the fields will not need to be changed.
   c) Click DONE when done entering data.
5) Go back to the BUILDAIRSCREW menu and notice that BLADE CHORD AND TWIST can now be selected. Click on BLADE CHORD AND TWIST.
   a) Read the text box and then double-click it to close it.
   b) For our design being modeled, there is no twist and the blade chord is constant, so nothing needs to be entered. As we will see later, however, you are able to enter the blade chord and the twist angle for 10 sections of your turbine blade (each being 1/10 of the overall length of the blade).
   c) Click DONE.
6) Go back to the BUILDAIRSCREW menu and notice that ANALYSIS OPTIONS can now be selected. Put your mouse over ANALYSIS OPTIONS and then click on BLADE PITCH>SMALLEST PITCH ANGLE.
   a) Here, you are able to enter a range of pitch angles for you turbine blade and have the program calculate results for all pitch angles within your range. For now, we are only interested in a pitch angle of 12 degrees. Therefore, enter 12 degrees for both the smallest and largest pitch angles.
   b) Notice that you can do other things in this dialog box.
      i) You can enter the wind speed.

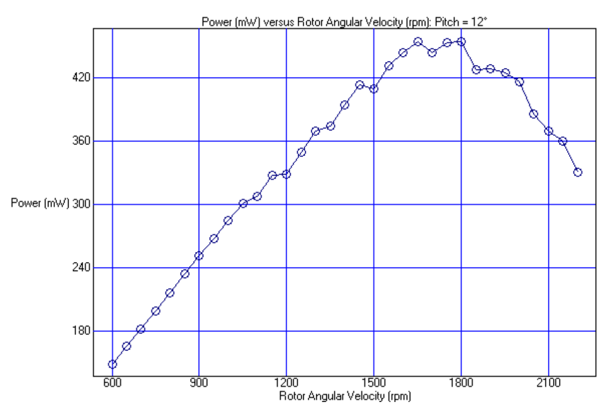
   ii) You can make calculations for either constant angular velocity or constant wind speed (we want constant wind speed)
   iii) You can enter the range of angular velocities over which to evaluate the performance of the turbine.
  c) Click DONE.

7) Go back to the BUILDAIRSCREW menu and notice that START ANALYSIS can now be selected. Click on START ANALYSIS.
   a) You should see a table of data now. This data shows the torque and power (among other things) for your turbine for different angular velocities.
   b) If you click on SHOW GRAPHICAL, you will see a graph of the results. Note that the origin is NOT (0,0).
   c) With this graph of torque vs. angular velocity for the turbine and the graph of torque required to turn the generator, you can determine the speed that your turbine will turn.
8) One problem you may find is that there are not enough points plotted on the graphs. It is easy to fix this.
   a) Go back to the BUILDAIRSCREW menu, put your mouse over ANALYSIS OPTIONS and then click on VARIABLE ROTOR ANGULAR VELOCITY>ANALYSIS INCREMENT.
   b) Change the angular velocity increment from 200 to 50
   c) Click DONE
   d) Run the analysis again by clicking on START ANALYSIS on the BUILD AIRSCREW menu.
   e) Now you should be able to get a pretty accurate value for the angular velocity where the torque of the wind turbine equals the torque required to turn the generator. You can further change the range or increment of angular velocities checked if needed. The graph is a good place to start, but using the numbers in the table can be more precise.

Angular Velocity

9) Once we know the angular velocity of the windmill, we can determine the power of the turbine and of the electric generator.
   a) To determine the power generated by the turbine, make the graphical plot the top window on your desktop.
   b) Click on SELECT PLOT. Put your mouse over ORDINATE (Y-AXIS) and then select POWER from the list.
   c) The plot shown now is the plot of turbine power versus angular velocity. It should look like the figure below.

Turbine Power



Under the FILE menu in the window with the plot, you can select to COPY TO CLIPBOARD, which will then allow you to paste these plots into Word documents. You will need to do this to complete the homework assignment.

Electric Power

   d) To determine the power generated by the electric generator, use Figure 11 from the White Book.

10) One method you will find useful in designing your turbine is to allow AIRSCREW to model several different pitch angles during one analysis.
   a) To do this, go back to the ANALYSIS OPTIONS dialog box from the BUILDAIRSCREW menu.
   b) Instead of entering the max and min pitch angles as the same value, enter the min pitch angle as 12 and the max as 36. Next, enter the increment to be 12.
   c) Run the analysis again by clicking on START ANALYSIS on the BUILD AIRSCREW menu
   d) Look at the plots and notice that torque and power curves for 3 different pitch angles are shown on the same graph. Because the scale is so different for the 3 pitch angles, this plot is not effective for completing this homework…. but it could be good when you are designing your turbine. For instance, you could quickly determine which pitch angle between 5 and 14 degrees gives you the highest efficiency.
11) So, now you know the basics of AIRSCREW. One last important topic is how to account for twist in your turbine blade.
   a) These next few steps are here to provide you with insight as to how to enter blade twist into AIRSCREW.
   b) First, go to BLADE CHORD AND TWIST under the BUILDAIRSCREW menu. Close the text pop-up box.
   c) When the figure in the top right hand corner of the box gets to Figure 2, right click on the figure. Examine this figure to familiarize yourself with what blade twist is. This is the same way that blade twist was defined in class.
   d) Next, enter 90 degrees into each of the 10 BLADE TWIST boxes and watch the figure on the left change. Notice how each section turns so that the wind is blowing straight into it.
   e) To see the relationship between pitch and twist angles, enter 12 degrees into each of the 10 BLADE TWIST boxes. Click DONE.
      i) Go to the ANALYSIS OPTIONS dialog box and enter both the max and min pitch angles as zero.
      ii) What do you expect? Run the analysis again by clicking on START ANALYSIS on the BUILD AIRSCREW menu.
      iii) Because $\theta_{total}=\theta_{twist}+\theta_{pitch}$, (1) setting all twist angles to 12 degrees with pitch at zero and (2) setting all twist angles to zero with pitch at 12 degrees, results in the same turbine angle! So the results from this turbine blade and the first one we did are exactly the same!
      iv) A common desire is to set the pitch to a certain positive angle (for this example, let's say θ_{pitch}=12 degrees) and then twist the blade so that the total angle as you move out towards the tip of the blade is less than the total angle at the hub (for the example. let's say the total angle at the tip of the blade is 4 degrees). At the tip, if the pitch is 12 degrees and the total angle is 4 degrees, then the twist angle is –8 degrees. The reason we point this out is to show that the twist is entered as a negative number.
12) When you enter blade twist angles in your homework, you will have to also account for the narrow blade chord as you trim your venetian blind. This is done in the BLADE TWIST AAND CHORD dialog box.
13) You now know how to use Airscrew! I encourage you to be creative in how you use it to find the best turbine design. I suggest that you use Airscrew to find small ranges for your pitch and twist angles, your blade radius, and your number of blades. Then, build and test several of these alternatives – keeping in mind limitations on the amount of material you have to use.