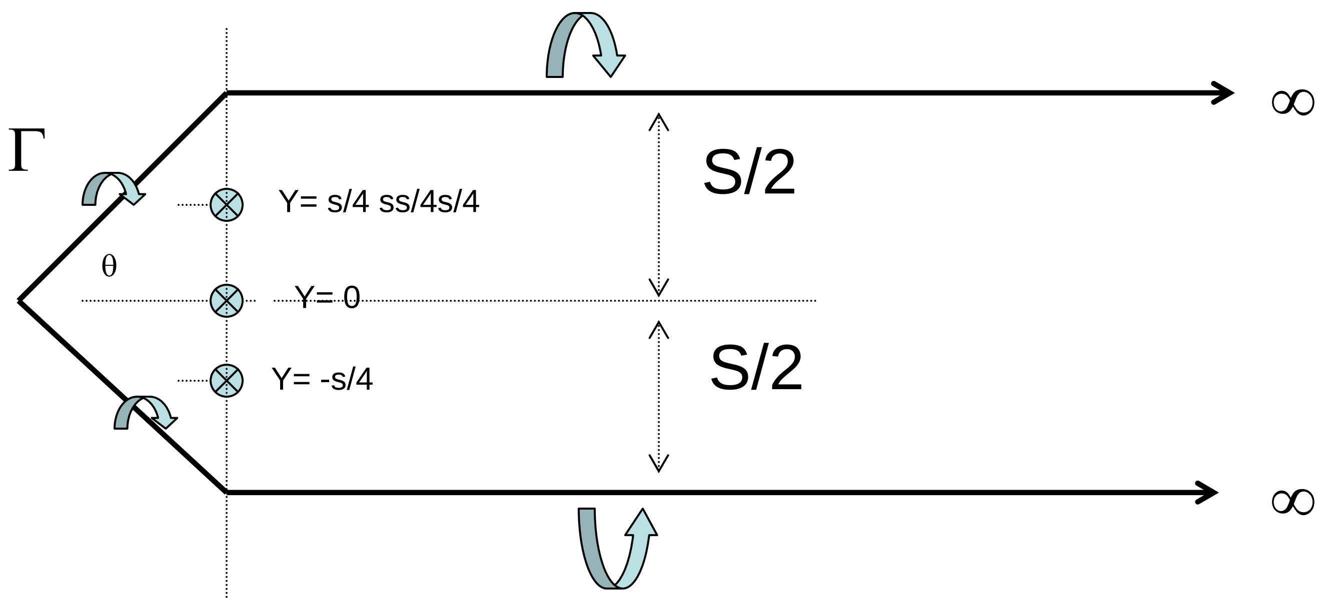
2.23 Hydrofoils & Propellers
Homework Assignment #3

Assigned: Friday March. 2, 2007

Due: Monday March 9, 2007

1) A system of straight line vortex segments is used to represent a swept wing as shown below. All vortices have the same strength Γ, with directions as shown.



Using your vortex segment function written in the last homework write a matlab code to find the total induced velocity at the three points shown above as a function of wing angle θ. Set Γ = 1 and S=1 and vary θ from 10 degrees to 60 degrees. Plot the induced velocity at these three points as a function of θfor these three points.

2) A planar foil is to be designed with spanwise circulation distribution as follows:

$$\Gamma(\tilde{y}) = 2Us(a_1 \sin(\tilde{y}) + a_3 \sin(3\tilde{y})$$

with a1 = 0.05 and a3 varies from 0.02 to -0.02

The span of the foil is 1 meter , the freestream speed U= 8m/s and the density of the water is 998 kg/m3. The aspect ratio is 3:1.

a) Plot Γ(y) and w*(y)as a function of y for a3 = 0.02, 0.01, 0, -0.01,-0.02
   Note: do not evaluate AT the tips since this may cause numerical trouble.

b) Plot the total drag on the foil as a function of a3

c) Plot the total lift on the foil

3) An elliptical foil is to be designed to the following specifications:

- Aspect ratio A= 5.0
- Span = 1 meters
- U = 7 m/s
- Required Lift = 2500N
- Density = 1000 kg/m3
- No camber or twist

a). Find the overall Lift coefficient for this foil

b) Using Prandtl's lifting line approximation find the angle of attack of this foil necessary to generate the required lift.
c) Find the induced drag coefficient and total induced drag
d) Estimate the total drag if the sectional viscous drag coef. Is Cd=0.008 where:

$$C_{d_{2Dviscous}} = \frac{Drag/span}{1/2\rho U^2 c(y)}$$

e) Describe qualitatively how the optimum foil shape would change to minimize total drag (including viscous drag). [i.e: how would the circulation loading change]

4) A 6 bladed propeller has a thrust coefficient of 0.45 and operates in uniform inflow with no swirl at an advance coefficient of J=0.9 The hub radius is 15% of the tip radius. Hint: pick a Vs=1 and diameter=1 and solve for N and Thrust;.

a) Write a matlab function called HELIX which evaluates the velocity induced on a point on a lifting line due to a helical vortex of an infinite bladed propeller (Eq's. 206 and 207 in the notes) . Note this function will require logic to determine if the helix is at a radius larger or smaller than the evaluation point. Use this function to write a code to evaluate the induced velocities at the control points in the second table below given the circulation distribution as follows:

r/R	Γ/Γo
0.15	0
0.25	0.2
0.35	0.4
0.45	0.6
0.55	0.8
0.65	1.0
0.75	0.7
0.85	0.4
0.95	0.1
1.0	0

Also compute the other velocity and angle information listed in the table below.

r/R	ωr/Va	ua*/Va	ut*/va	V*/Va	β	β_i	tan β/tan β_i
0.2							
0.3							
0.4							
0.5							
0.6							
0.7							
0.8							
0.9							
0.975							

b) At r/R=0.7, make an accurate sketch of the velocity diagram similar to figure 89 in the notes) us a chordlength of c/R = 0.1 at r/R=0.7 and assume a sectional drag coefficient of 0.008.

c) Estimate the efficiency of this propeller using the Kramer diagram. How does this compare with the Betz result at r/R=0.7, η=tan β/tan β_i ? Explain.