

EAE 127 - MIDTERM 11/02/04

(Open Notes, open Book)

(Give unambiguous answers. Use results derived in Class)

1. Inviscid, Incompressible Flow (20 points)

1.1 Design of a Thin Cambered Plate

What does *leading edge adaptation* mean in thin airfoil theory? How does it translate in terms of the Fourier coefficients in the expansion of the vorticity $\Gamma'[x(t)]$?

In thin airfoil theory, a thin cambered plate is designed to have the following aerodynamic characteristics *at the angle of adaptation*:

$$C_{m,o} = -\frac{1}{2}C_l.$$

Find the simplest cambered plate which satisfies this design requirement and give all the Fourier coefficients at adaptation. Check your calculation carefully.

Use the equation

$$d'[x(t)] = \alpha - A_0 + \sum_{n=1}^{\infty} A_n \cos nt,$$

to find the equation of the camberline and to solve for $A_0(\alpha)$. (Hint: eliminate the cosines in terms of x/c , and enforce the conditions $d(0) = d(c) = 0$.)

What is the angle of adaptation α_a ?

Sketch the plate and, qualitatively, the flow at the incidence of adaptation, in particular the streamlines near the leading edge and the trailing edge.

1.2 Global Coefficients

Give the value of the aerodynamic coefficients C_l , C_d and $C_{m,o}$ at that particular value $\alpha = \alpha_a$. Check that you satisfy the design requirement.

Where is the center of pressure at adaptation?

If α varies, how do these coefficients vary?

If thickness is added to the thin cambered plate, how will these coefficients be affected?

1.3 Aerodynamic Center

Give the definition of the *aerodynamic center*.

Find the moment at the aerodynamic center.

1.4 Result

Sketch the vorticity $\Gamma'[x(t)]$ at ideal angle of attack.

2. Linearized Supersonic Flow (10 points)

Consider the parabolic plate of equation $d(x) = A_1 c \frac{x}{c} (1 - \frac{x}{c})$ which represents the mean camberline of the wing of a supersonic aircraft flying at $M_0 > 1$. Let $\beta = \sqrt{M_0^2 - 1}$.

2.1 Global Coefficients at $\alpha = 0$

Calculate the aerodynamic coefficients C_l , C_d and $C_{m,o}$, in terms of β and A_1 , at $\alpha = 0$.

2.2 Global Coefficient at $\alpha \neq 0$

Give the expression of C_l , C_d and $C_{m,o}$ for arbitrary α .

If thickness were added to the cambered plate, which of these coefficients, C_l , C_d and $C_{m,o}$, would be affected?

Find the maximum “finesse”, i.e. $f_x = (\frac{C_l}{C_d})_{max}$ if $A_1 = 0.1$.