SESA3029 Aerothermodynamics

Class tutorial

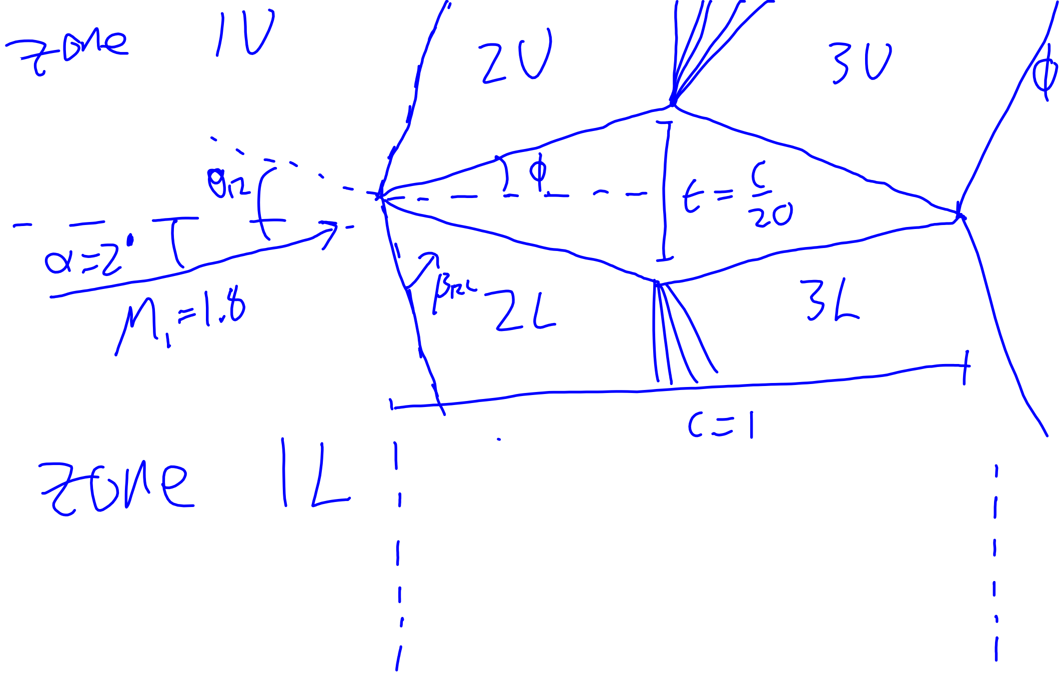
Diamond-shaped aerofoil example

A diamond shaped airfoil (with maximum thickness at the half-chord location) has a thickness-to-chord ratio of 0.05 and is placed at 2 degrees incidence in a flow at M=1.8 and p=50 kPa. Using shock-expansion theory, find:

(a) the pressure on each surface,

(b) the lift, drag and pitching moment (about the leading edge, assume chord c=1 m), and

(c) the centre of pressure.



$\phi = \tan^{-1}\left(\frac{c}{20}\right) = 2.862°$

since $\phi > \alpha$ surface 2U is experiencing compression (converging) ∴ will get oblique shock

same on region 2L.

Then region 3U and 3L have expansion fans due to divergance.

From $1L \rightarrow 2L$:

$\theta\Big|_{1L}^{2L} = \theta_{12L} = \phi + \alpha = 4.862°$

Oblique shock chart (OSC) $\rightarrow \beta_{12L} = 38.3°$

(or use shock calculator)

$M_{12L} = M_1 \sin(\beta_{12L}) = 1.1157$

M_{12L} is the mach number normal to β_{12L} before oblique

Then use NST to find M_{2L} from M_{12L} $\rightarrow M_{2L} = 0.8918$

$\rightarrow \frac{P_{2L}}{P_1} = 1.2856 \rightarrow P_{2L} = 64.28$ kPa

From $1U \to 2U$:

$\theta\Big|_{1U}^{2U} = \theta_{12U} = \phi - \alpha = 0.862^\circ$

OSC $\theta_{12U} \to \beta_{12U} = 34.51^\circ$

$M_{12U} = M_1 \sin(\beta_{12U}) = 1.02$

MISSING STEP!!

explained in lecture

NST $M_{12U} \to M_{2U} = 1.77$

$\to \frac{P_{2U}}{P_1} = 1.0471 \to P_{2U} = 52.36$ kPa

From 2L to 3L

$\theta\Big|_{2L}^{3L} = 2\phi = 5.724^\circ$ $\quad M_{2L} = 1.6324$

IFT: $M_{2L} \to \frac{P_{2L}}{P_0} = 0.2242 \quad \nu_{2L} = 15.8182^\circ$

$\nu_{13L} = \nu_{2L} + \theta = 15.8182 + 5.724 = 21.5422$

Tables: $M_{3L} = 1.8283 \quad \frac{P_{3L}}{P_0} = 0.166$

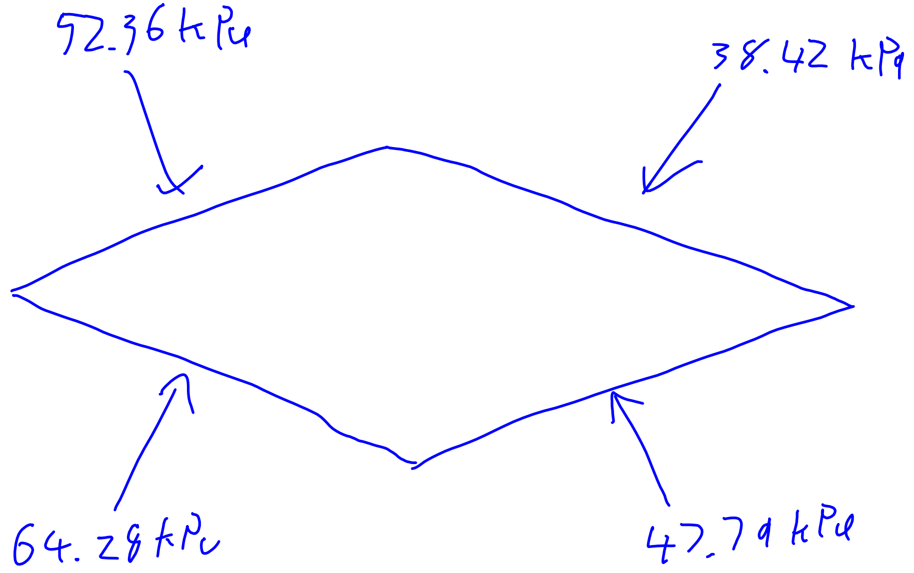
$P_{3L} = P_{2L} \frac{P_{3L}/P_0}{P_{2L}/P_0} = 47.79$ kPa

From $2U \to 3U$:

$\theta_{23L} = 2\phi = 5.724^\circ$, $M_{2U} = 1.770$

$\ldots \to P_{3U} = 38.42$ kPa (same method as $2L \to 3L$)

Can now calculate lift and drag



$L = N\cos\alpha - H\sin\alpha = 10.65$ kN/m

$D = H\cos\alpha + N\sin\alpha = 1.14$ kN/m

$$N = \left(\frac{c}{2}(64.28-52.36) + \frac{c}{2}(47.79-38.42)\right) \times 1000 = 21.33 \text{ kPa} \times \frac{c}{2}$$

$$H = \left(\frac{t}{2}(52.36-38.42) + \frac{t}{2}(64.28-47.791)\right) \times 1000 =$$

Sketch the wave pattern for the airfoil at incidences of (a) 5 degrees (b) 2.86 degrees (c) -2.86 degrees