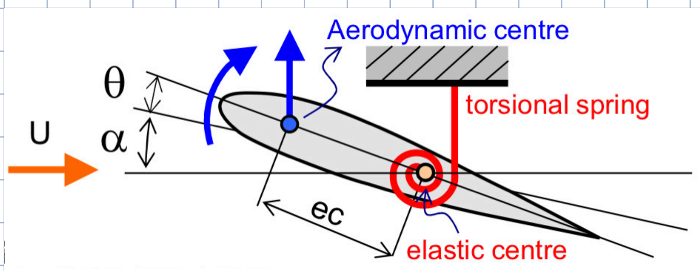
Assumptions for study of flexible aircraft under aerodynamic loads:

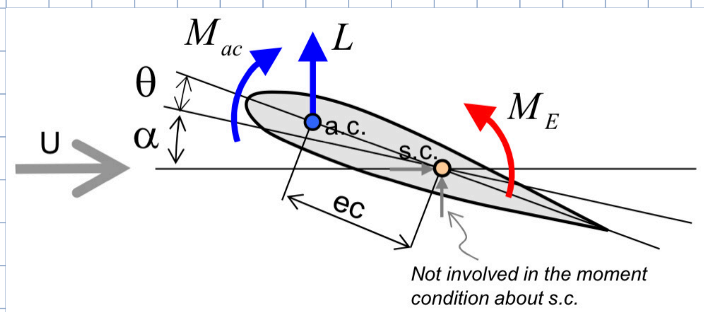
- Aero loads influence structural shape and vice versa
- Forces and moments are independent of time
- Only steady aerodynamics are considered

Static Aeroelastic Response:



Assumptions:

- ∞ long wing
- uniform section
- linear springs
- linear aerodynamics



Static aeroelasticity - aerofoil always in state of static equilibrium (if possible) between aerodynamic and elastic (restoring) effects:

Aero moment = Elastic moment

Moment equilibrium about shear centre:

$$\sum_i M_{e.c.,i} = 0$$

$$M_{AC} + L.ec - M_E = 0$$

Lift $= qSC_L = qSC_{L,\alpha}(\alpha + \theta)$

Aero Moment $M_{AC} = qScC_{M_{AC}}$

Elastic Moment $M_E = k\theta$

$$qScC_{M_{AC}} + ec.qSC_{L,\alpha}(\alpha+\theta) = k\theta$$

$$\therefore \theta = \frac{qS(cC_{M_{AC}} + ec.C_{L,\alpha}\alpha)}{k - ec.qSC_{L,\alpha}}$$

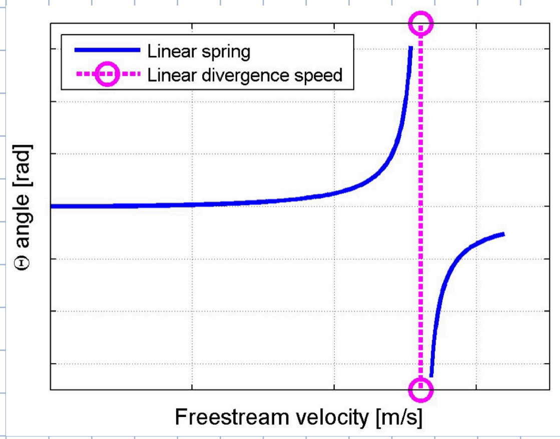
- $\theta \uparrow$ as $q \uparrow$
- $\theta \to \infty$ as $k - ec.qSC_{L,\alpha} \to 0$
  - → divergent aerofoil
  - → defines q_D & U_D when divergence occurs
  - → divergence only occurs when $e > 0$
    - ↳ ec forward of ac

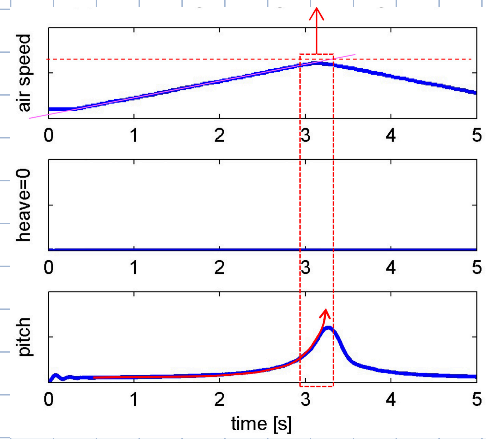
Aircraft should be designed to operate well below divergence speeds for all lifting surfaces:

Divergence condition: $k - ec.qSC_{L,\alpha} = 0$

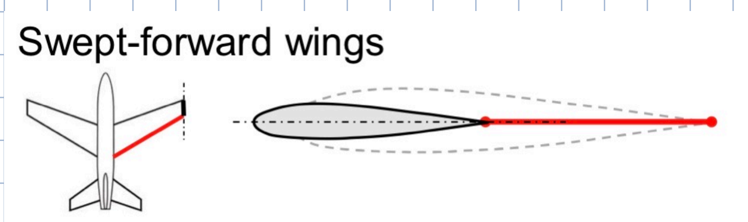
$$q_D = \frac{k}{ec.SC_{L,\alpha}} \longrightarrow U_D = \sqrt{\frac{2k}{ec.SC_{L,\alpha}\rho}}$$

Divergence occurs when aero moment too large for elastic moment to balance :

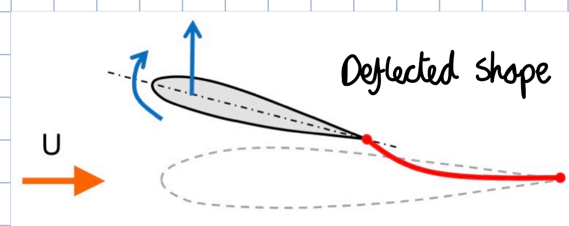


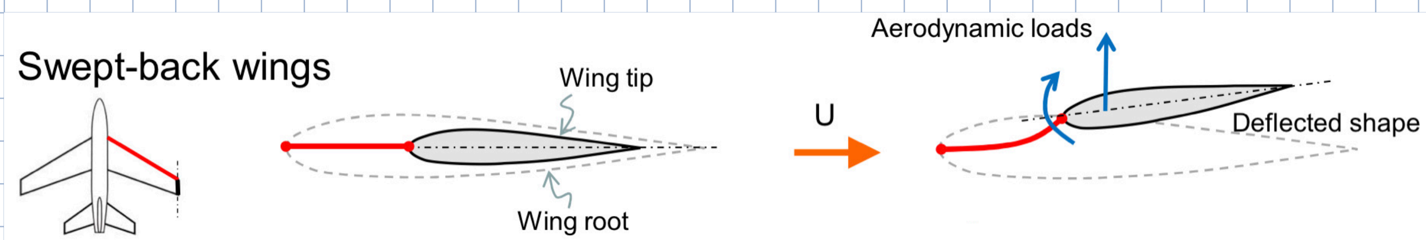


Wing Sweep Effects :



Aero loads





Divergence Speed :

↑ w. Swept back
↓ w. swept forward

- ↑AR ↓ U_D (↓ torsional stiffness)
- ↑ec offset ↓U_D

For swept-forward wings :

- U_D becomes limiting case
- Need to use aero tailoring to counteract effect

Other Effects :

Non-linear effects of ↑ angles :

- → non-linear aerodynamics (↑α)
- → non-linear elasticity (e.g non-linear springs)