Light Aircraft Structures
Idealised Multi-Cell Sections – Torsion

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04 February 2019

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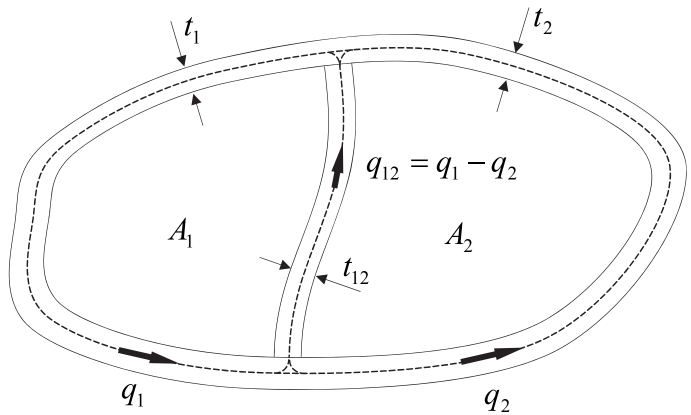
- Recalling the *Bredth-Batho equations*:

$$\left(\frac{\theta}{L}\right)_1 = \underbrace{\frac{q_1}{2\,A_1\,G}\oint_1 \frac{\mathrm{d}s}{t}}_{\text{Cell 1 as a closed cell}} - \underbrace{\frac{q_2}{2\,A_1\,G}\int_{12} \frac{\mathrm{d}s}{t}}_{\text{Contribution of cell 2 along adjacent wall}}$$

$$\left(\frac{\theta}{L}\right)_2 = \underbrace{\frac{q_2}{2\,A_2\,G}\oint_2 \frac{\mathrm{d}s}{t}}_{\text{Cell 2 as a closed cell}} - \underbrace{\frac{q_1}{2\,A_2\,G}\int_{12} \frac{\mathrm{d}s}{t}}_{\text{Contribution of cell 1 along adjacent wall}}$$

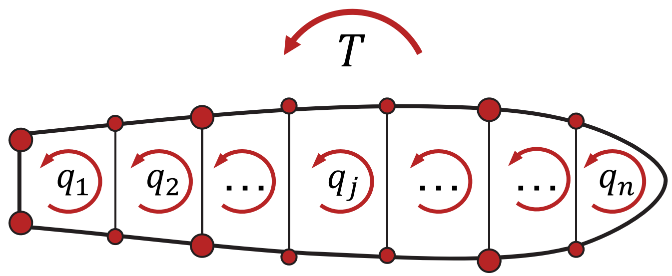


- And since the twist rate is constant:

$$\left(\frac{\theta}{L}\right)_1 = \left(\frac{\theta}{L}\right)_2$$

Torsional Moments

- Consider an n-cell wing section subjected to pure torque T
- Each cell i develops a constant shear flow q_i and:

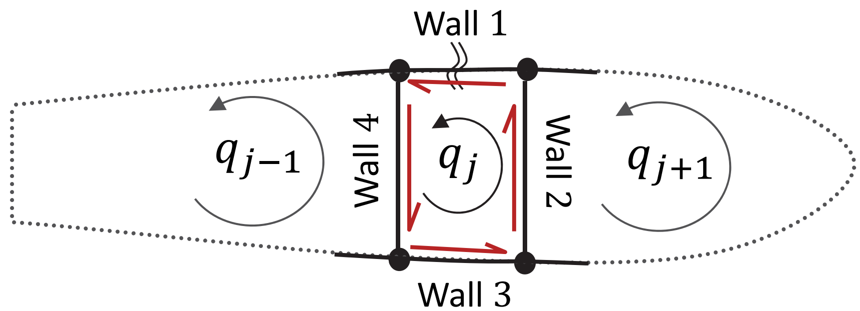


$$T = \sum_{j=1}^{n} 2\, A_j\, q_j$$

- A single-cell section is statically determinate, but a multi-cell section is **statically indeterminate** – the n-cell section will have:
  - n unknown shear flows
  - One unknown angle of twist (assumed to be the same for all cells)
- Therefore $n + 1$ independent equations are required to solve

- We generate n equations by considering the rates of twist:

$$\left(\frac{\mathrm{d}\theta}{\mathrm{d}z}\right)_j = \frac{1}{2\,A_j}\int_j q\,\frac{\mathrm{d}s}{t\,G}$$



Open-section shear flows at the j-th cell of an n-cell section subjected to torsion

$$\left(\frac{\mathrm{d}\theta}{\mathrm{d}z}\right)_j = \frac{1}{2\,A_j}\sum_{i=1}^{4}\left(q_i\,\frac{b_i}{t_i\,G_i}\right)$$

$$\left(\frac{\mathrm{d}\theta}{\mathrm{d}z}\right)_j = \frac{1}{2\,A_j}\left[\overbrace{q_j\,\frac{b_1}{t_1\,G_1}}^{\text{Wall 1}} + \overbrace{(q_j - q_{j+1})\,\frac{b_2}{t_2\,G_2}}^{\text{Wall 2}} + \overbrace{q_j\,\frac{b_3}{t_3\,G_3}}^{\text{Wall 3}} + \overbrace{(q_j - q_{j-1})\,\frac{b_4}{t_4\,G_4}}^{\text{Wall 4}}\right]$$

- And finally:

$$T = \sum_{j=1}^{n} 2\,A_j\,q_j$$