26.2.2014
1

Introduction

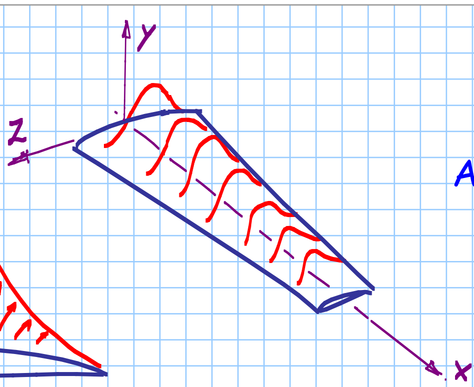
These notes provide an overview of possible modelling representations of your Flight Design Project wing.

In the FDP exercise you are only expected to use the simplest models. The more advanced models which are sketched out in these notes are intended only to illustrate the possible refinements that could be made.

Contents

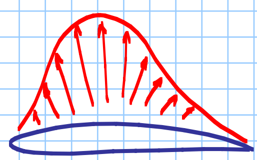
LOADS

Aerodynamic pressure distribution

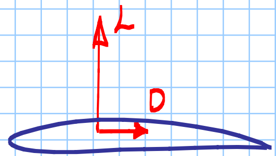


Axes!

Chordwise distribution

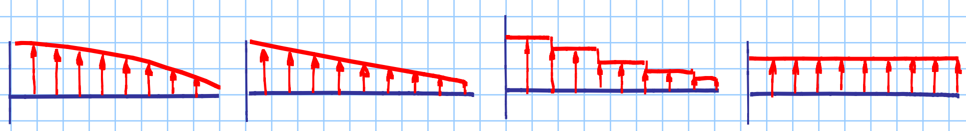


Resultant lift and drag components



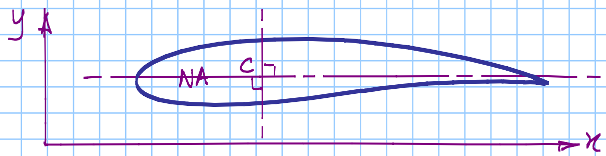
Approximation:
Orthogonal resultants

Spanwise distribution



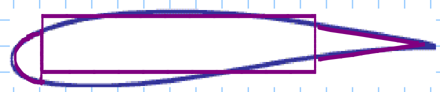
Approximations: parabolic, linear, stepped, uniform

GEOMETRY AND AREA PROPERTIES

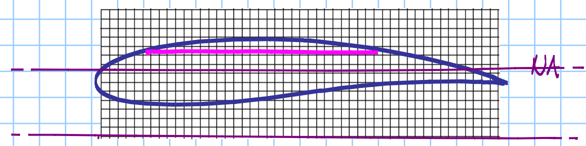


Approximations:

Compound areas:



Graphical integration:



Centre of area "Centroid" $\bar{x} = \int x\,dA \Big/ \int dA$, $\bar{y} = \int y\,dA \Big/ \int dA$

or $\bar{x} = \dfrac{\Sigma x_i A_i}{\Sigma A_i}$, $\bar{y} = \dfrac{\Sigma y_i A_i}{\Sigma A_i}$

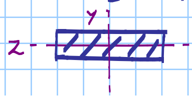
As well as the centroid there are other axis centres which are important. E.g.: **Torsional centre, Shear centre and Aerodynamic centre.** Research the deinitions of these centres and comment on them in relation to the measured behaviour of your wing.

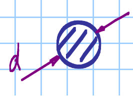
Second moment of area $I_{NA} = \int y^2\,dA$ Accounting only for vertical lift

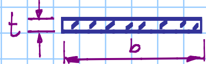
Effective shear area $A_s < A$ Just claim box area for As and for J

Torsional constant $J \rightarrow$ "I_J" = "K_T" $\approx I_{zz} + I_{yy}$ [circle: $\dfrac{\pi d^4}{32}$ thin rectangle: $\dfrac{bt^3}{3}$]

ie. for solid rectangle: $\frac{db^3}{12} + \frac{bd^3}{12} \approx$







MATERIAL PROPERTIES

The material properties of the styrofoam used to make your wings is not readily available as definitive values. Only approximate ranges of the likely properties are given here.

Revised values 14.3.2012

Density ρ = 32 - 33 kg/m^3

Youngs Modulus E = 25 * N/mm^2 tension or compression

Shear modulus G = 13.5 * N/mm ^{2}

*possible variation of 10%

Tensile strength σ_T^* = 0.45 - 0.50 ** N/mm^2

Compressive stress σ = 0.25 - 0.30 ** N/mm^2 @10% deformation

Shear strength τ^* = 0.2 - 0.25 ** N/mm ^{2}

** Conservative allowable values

④

STRUCTURAL MODELLING

Mean prismatic cantilever beam (fully fixed root end) parabolic, linear, stepped, uniform lift profile.

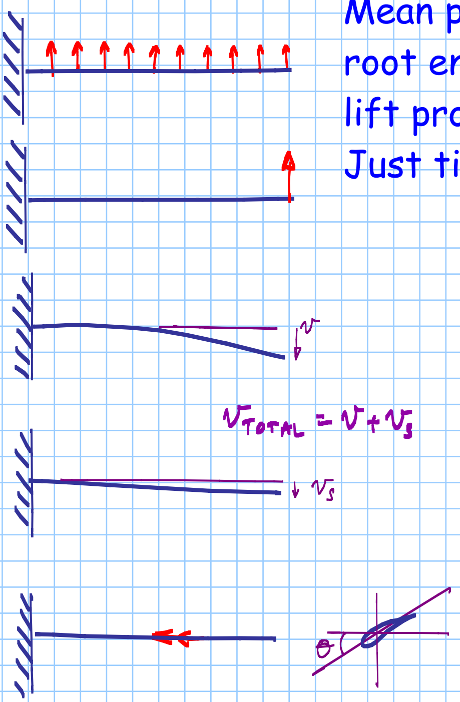
Just tip load for test configuration!

Cantilever

Bending

Shear

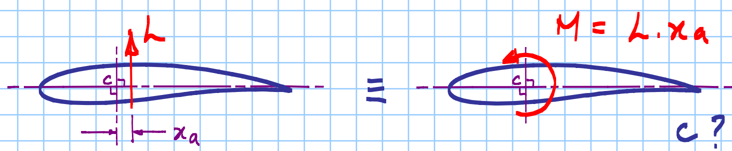
Torsion



	Deflection	Stress
Bending	$v = k\dfrac{PL^3}{EI}$,	$\sigma = \dfrac{My}{I}$
Shear	$v_s = \dfrac{PL}{GA_s}$	$\tau = \dfrac{F_y}{A_s}$
Torsion	$\theta = \dfrac{TL}{GJ}$	$\tau = \dfrac{Tr}{J}$

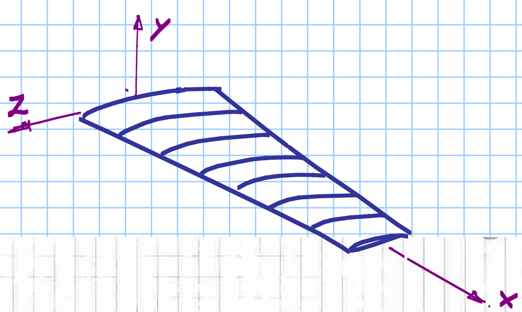
$\left\{ J \rightarrow I_J, K_T \right.$ for ▭

Note, relative postion of resultant lift and torsional axis!



⑤

Strip analysis

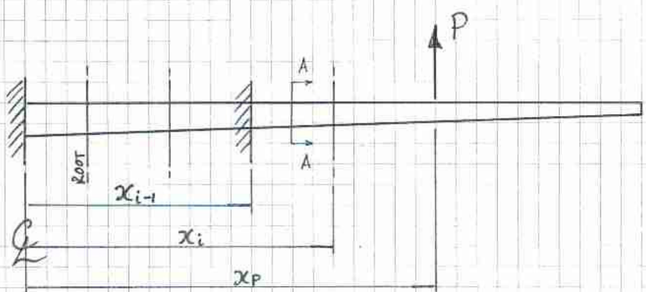


Incremental cantilever model

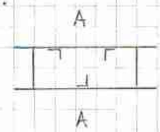
Deflection Calc.

Using "Superposition Model"

- Consider wing as system of connected cantilevers with end load and moment



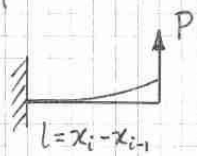
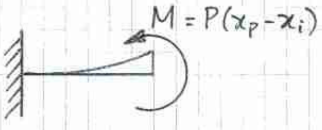
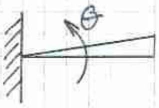
E.g.:



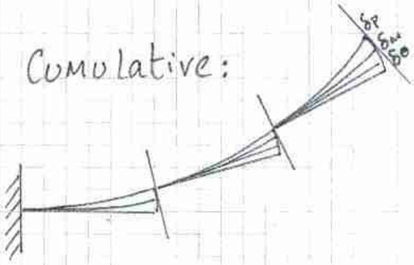
Sum the tip deflections for each cantilever due to End load, End moment + End rotation

+ Calc flexibility = δ_{tip}/P mm/N

Cantilever deflections

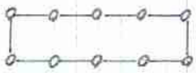
		Deflection	Rotation (rad)
End load :		$\delta_P = \frac{PL^3}{3EI}$,	$\theta_P = \frac{PL^2}{2EI}$
End moment :		$\delta_M = \frac{ML^2}{2EI}$,	$\theta_M = \frac{ML}{EI}$
End rotation :		$\delta_\theta = \theta . l$,	$\theta = \sum_{i=1 \text{ to } i-1} \theta_{P_i} + \theta_{M_i}$

Cumulative:



Model as one cantilever per rib bay

Calc average I value for each cantilever beam

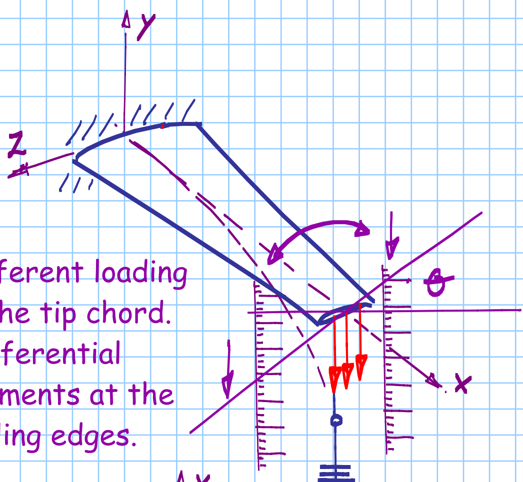


(I for booms only)

* Similarly for torque.!

TESTING

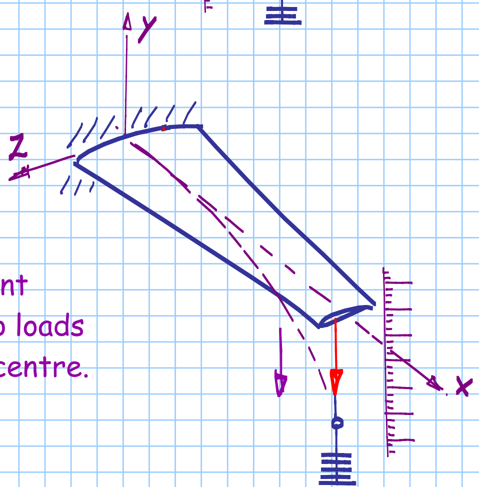
Shear centre:



Rotation for different loading positions along the tip chord. Measured by differential vertical displacements at the leadong and trailing edges.

Determination of the chordwise position of the cross-sectional centre through which a transverse load causes translation but no rotation.

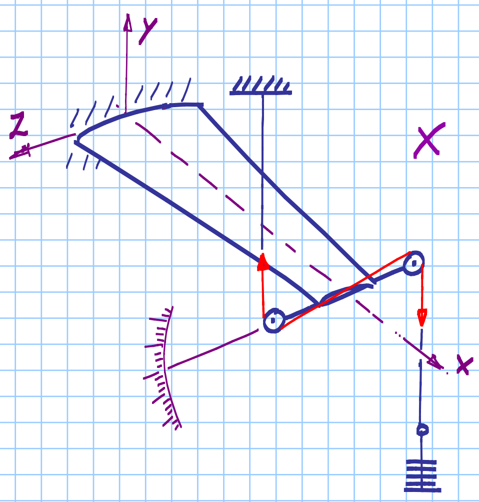
Bending:



Vertical displacement under a range of tip loads through the shear centre.

Measurement of tip displacement for tip loading at the effective shear centre.

Torsion:



A pure torsion experiment applying a torque through pulleys. Unfortunately the torsionally weak foam section is overrun by the system friction so this test has been omitted.

Compare translational and torsional results against your predicted values for the test loading configurations. I.e. as a tip loaded cantilever. For torsion assume that the applied torque is equivalent to the applied load x distance from the shear centre (referring to the shear centre test).