ASD2 DBT Wing initial sizing - overview

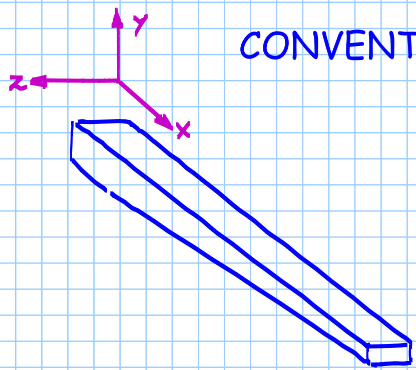
I2F

26.9.2017

These notes provide a brief overview of the initial sizing of the AVD2 wing box-spar 1.

STRUCTURE

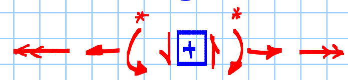
Box spar
semi-monocoque
cantilever



CONVENTIONS

Axes:
spanwise = x
chordwise = z
Through = y

Internal sign convention:

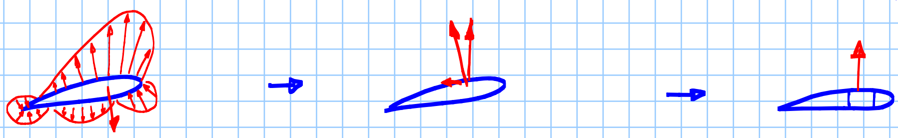


Yr2 +ve moment different to Yr1

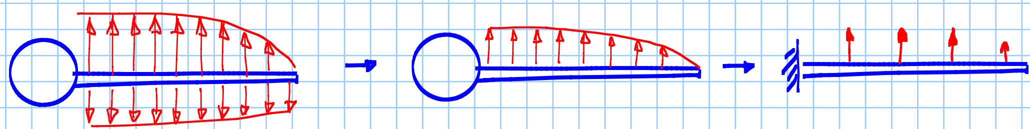
LOADING

Critical manoeuvre load case

Chord-wise



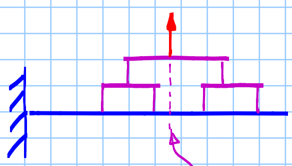
Spanwise:

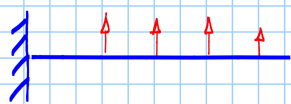


Aero pressure + inertia. Nett loading Idealised

PART MODEL 2.

1. Consider the box-spar as a cantilevered beam carrying the compiled loading from the aerofoil - simplified for test application as a wiffle tree loading.

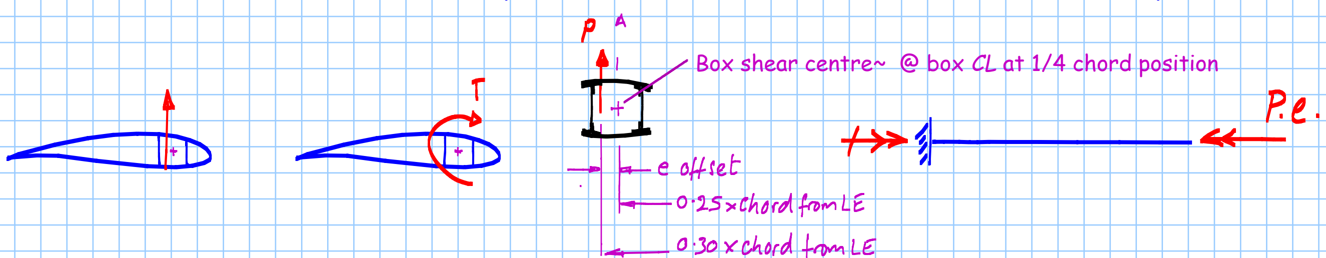




For initial root and inboard sizing we can simply consider the total whiffle tree loading at the point of application.

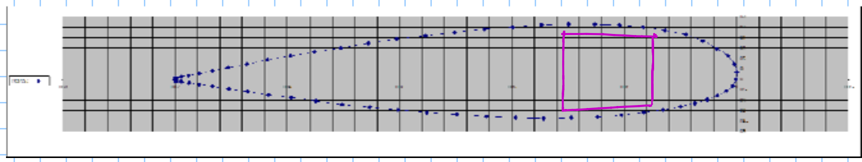
*NOTE, in this exercise we will design for the idealised test loading.

2. Consider the box spar as a shaft carrying offset loading as a torque. Allow for a variation in resultant lift position between 30% and 25% chord position.



For the specified geometry the box spar centre is at the 25% chord position.
So consider a maximum offset = (0.3 - 0.25) x wing chord.

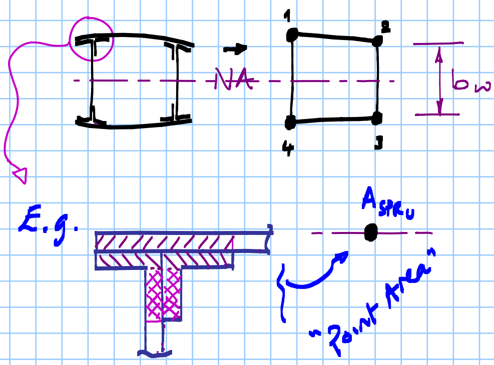
SECTION MODEL



3.

Considering the box-spar as the main structural element

Model the thin-wall "semi-moncoque" structure as an end-load carrying boom idealisation based on effective areas. Assume the remaining skin carries only shear when buckled.



Assuming panels will buckle before reaching ultimate, we will claim only the skin areas stabilised by connection to the corner angle flanges when estimating the effective end load carrying boom areas.

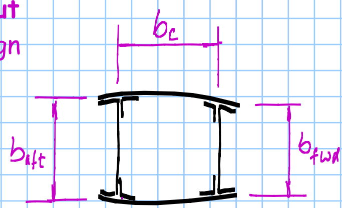
This is a reasonable conservative simplification for the DBT box-spar initial sizing.

Assuming the effective boom area acts on the outer skin-line, we need to reduce the spar web and angle blade area contributions to avoid overestimating their 2nd mmt of area contributions to the box. For our DBT box-spar a reduction of the stabilised web and angle blade areas by one third should be reasonable.

SCHEMES:

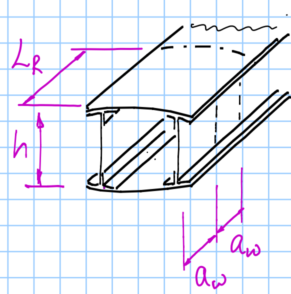
4.

*** Note sketches show curved skins **but** for the latest embedded box-spar design the skins can be flat!



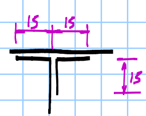
Configuration:
Channel section spars + support angles + skins

Box-spar chord b_c = 75mm*



Section height, b_{aft}, b_{fwd} according to chosen h/c% and aerofoil coordinates for a wing chord of 450mm*

All angles and flanges = 15mm*



Skin, spar and angle thicknesses t = 0.4, 0.5, 0.6, 0.7, 0.9, 1.0mm
Rib pitch, L_R
Web stiffener pitch, a_w

Thicker gauges required on upper surface for stability in compression.

Note, for efficiency you should reduce thicknesses outboard along the span

Team Comms groups should investigate different trial schemes.

The Root end of the box-spar skins must allow for fixture attachment - further details tba.

*Compulsory dims

CHECKS: Stiffness, Strength + Stability.

Initially check the most critical inboard stations, e.g. near the root.
Then check further stations outboard, e.g. where loading and section depth is reduced.

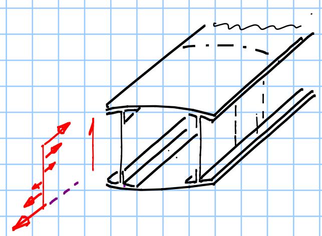
<u>Stiffness</u>:
check deflection of wing tip at limit using an incremental beam model

<u>Strength</u>:
check <u>lower surface boom / skin</u> tension/shear material failure at ultimate

<u>Stability</u>:
check <u>upper boom</u> compression column buckling at ultimate
check <u>upper skin</u> compression panel buckling at at limit and ultimate
check <u>rear spar web</u> panel in-plane bending + shear buckling at limit and ultimate
check <u>upper spar cap "blade"</u> panel compression buckling at ultimate

<u>Joints</u>:
check <u>spar-skin</u>, <u>skin-skin</u>, <u>web-web</u> and <u>root fixture</u> joint fastener/plate bearing, shear and tension failure modes at ultimate

E.g.:



For item # @ station x

Design for: $\underset{\text{Applied}}{\sigma, \tau} < \underset{\text{Allowable}}{\sigma^*, \tau^*}$ at LIM or ULT → **RF = ##**

Note, we will:
- Neglect non-unifrom stress distributions due to shear lag
- Neglect local stress distributions at details
  (apart from lower surface inspection holes).
- Correct elastic buckling estimates for plastic buckling
- Neglect local/global buckling interaction

TRIAL SCHEME CHECK RESULTS

Working in your Comms groups check a trial scheme by performing the calculations given in the "calc illustration" document. Compare results between Comms group members and with other Comms groups within your team then create a spreadsheet to automate your checks, including further critical stations along the wing and refining your methods. **Check your results against your original hand calcs and team mates' calcs to identify any errors before relying on your automated xls results! "Check stress!"**

Finally:

TRADE-OFF checked schemes - according to fitness for purpose.

i.e.: consider RF's, weight, manufacturing ease, cost for each trial scheme and of course the aero performance for the flight phases!

... then commit to a chosen scheme for your team and order materials!

A list of calcs in the illustration doc. is given below

1. SCHEME
2. PART MODEL
3. SECTION MODEL
   a. Boom area properties
   b. Box section area properties
4. STRESS
   a. Direct stress due to bending
   b. Shear stress due to transverse load
   c. Shear stress due to torsion
   d. Transverse + torsional shear stress by superposition

   } @ Station x ...
5. CHECK: STIFFNESS
   Tip deflection at limit
6. CHECK: STRENGTH - at ultimate
   a.(i) Tension/shear material failure in lower aft boom (at ult)
   a.(ii) Tension stress concentration material failure in lower skin (at ult)
7. CHECK: STABILITY - at limit or ultimate
   a. Compression column buckling in upper boom (at ult)
   b. (i) Compression panel buckling in upper skin (at lim)
   b.(ii) In-plane bending/shear panel buckling in rear spar web (at lim)
   b.(iii) Compression panel "blade" buckling in upper aft spar flange (at ult)

.... Further items on Joint calcs, etc.

Note, the listed checks are not exhaustive!