Efficient Light Aircraft Design – Options from Gliding

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Presentation Aims

• Recognise the convergence of interest between ultra-lights and sailplanes
• Draw on experiences of sailplane designers in pursuit of higher aerodynamic performance.
• Review several feature of current sailplanes that might be of wider use.
• Review the future for the recreational aeroplane.
Lift occurs in localised areas

A glider needs efficiency and manoeuvrability
Drag contributions for a glider

Drag at low speed dominated by Induced drag (due to lift)

\[ \frac{\nu_s}{V} = \frac{D}{W} = \frac{C_D}{C_L} \]

Glider (total) drag polar

Drag at high speeds dominated by profile drag & skin friction

\((L/D)_{\text{max}}\)
So what are the configuration parameters?

- Low profile drag: Wing section design is key
- Low skin friction: maximise laminar areas
- Low induced drag – higher efficiencies demand greater spans, span efficiency and Aspect Ratio
- Low parasitic drag – reduce excrescences such as: undercarriage, discontinuities of line and no leaks/gaps.
- Low trim drag – small tails with efficient surface coupled with low stability for frequent speed changing.
- Wide load carrying capacity in terms of pilot weight and water ballast
Progress in aerodynamic efficiency
1933 - 2010

- 1937: Wiehe (18m)
- 1957: Phoenix (16m)
- 1971: Nimbus 2 (20.3m)
- 2003: Eta (30.8m)
- 2010: Concordia (28m)

- More span & aspect ratio
- Better detail aerodynamics
- Thinner wings (carbon, flaps)
- Winglets

+ 0.66 L/D per year

Wooden gliders
Metal gliders
Composite gliders
In praise of Aspect Ratio

• Basic drag equation in non-dimensional, coefficient terms:

\[ C_D = C_{D0} f(R_e, \delta) + \frac{k}{\pi A} C_L^2 \]

• For an aircraft of a given scale, aspect ratio is the single overall configuration parameter that has direct leverage on performance. Induced drag - the primary contribution to drag at low speed, is inversely proportional to aspect ratio.

• An efficient wing is a key driver in optimising favourable design trades in other aspects of performance such as wing loading and cruise performance.

• Aspect ratio also raises vehicle overall lift curve slope providing a responsive, controllable aircraft.
Refinement of sailplane wing planforms
1922-1934

Images courtesy of Vince Cockett - scale soaring UK
Efficiency of load distribution for wings of AR=15

Induced drag additional to the ‘elliptic perfection’ of k =1
Aspect ratio – additional complexity?

- Higher stresses (eg. Root BM)
  - Leads to greater weight.
  - Limited volume for Undercarriage & fuel.
- Aero-elasticity issues (requiring analysis).
  - Torsional stiffness and control mass balance
- Control issues
  - Higher roll inertia
  - Roll control power and longer control runs
- Lower Reynolds numbers (at tip)
- Practical issues of space
  - In workshop and hanger
  - Need for transport joints?
Aero-elasticity and Flutter

- Vibrations can take many forms but most modes are 'soft' (but usually graphically reported!)
- Aero-elastic analysis is a key task in design. The only organisations fully capable are GE universities.
- The key parameter is adequate wing torsion rigidity, which, when coupled with control mass balancing can usually avoid interactions with bending or control surface modes
In flight demonstration of aileron induced flutter on a sailplane

Figure 1 and 2: Anti-symmetric wing bending oscillation $f=3.3$ Hz at $V=90$ km/h.

Figure 3 and 4: Anti-symmetric wing bending oscillations $f=5.8$ Hz at $V=140$ km/h.
Laminar aerofoils
The key to modern sailplane performance

- NACA 63-418
- FX 61-184
- FX 79-K-144 -17
● These a simple, centre-hinged flaps, for performance optimisation in fast and slow flight. They move DOWN AND UP and are often mixed in functions with aileron control.

● They are NOT normally designed for high lift. Split, Fowler, ventilated and high lift flaps are TOO DRAGGY for sailplanes

● Flap configuration can influence or limit lateral control in high lift configuration particularly if mixed with aileron function.
Relevance of thickness to sailplane wing sections

Fig. 5. Typical lift-drag polars for different low drag ranges.
Reynolds Number sensitivity of a laminar section

Figure 10: FX 66-S-196 V1 section drag characteristics.
Reynolds Number sensitivity of a laminar section

- A cross plot against ‘flight Re’ demonstrates a reduction of aerodynamic performance as airspeed and Re reduces.
- This can be accounted as an additional term in ‘lift dependent drag’
- This effect become more significant as chord reduces
Boermans T12 aerofoil characteristics
Construction of a higher aspect ratio wing in wood – finish standard required
A successful ‘mixed materials’ approach to constructing a high aspect ratio, laminar wing using small-scale, simple moulds.
Basic shell structure of a Composite Sailplane – Slingsby/Glasflugel Kestrel
Homebuilding in GRP?
Metal structure solution – HP14
Winglet Design

Figure A.19: Calculated inviscid FASD pressure distributions - final winglet design at $C_l=0.3$
Current winglet designs
Fuselage design – semi empirical approach
Corner vortex and effect on wing and fuselage flows
Fuselage design – extent of laminar flow
For the first half metre of the wing the wing section is tailored to a ‘turbulent‘ style section to accommodate better the stream-wise gradients and span-wise cross-flows that precipitate transition.
Wing to fuselage design – practical details

- Tailored wing section at root
- Contraction behind & above leading edge
- All junctions and hatches sealed
- Very limited contour filleting
Tailplane to fin junction design (1)

Tailplane max thickness well ahead of that of the fin

Narrow chord elevator and high aspect ratio tailplane

Separated and sealed control surface slots with internal mechanisms
Electric propulsion – Antares 20E

- 42kW (56hp) brushless DC motor
- 72 Li-ion batteries, 41Ah capacity, 76kg
- 52hp for 13 minutes
Typical Jet installation
Front Electric Sustainer
Convergence of interest between powered sailplane and microlight?

- Smaller number of high cost, very high performance gliders
- Emergence of cheaper self-launching (probably electrically powered) motor gliders offers autonomous operation
- Low operating cost and group ownership
Recreational Cross Country out of Lasham by an electric sustainer sailplane
Typical height profile
Lines of energy in the atmosphere
What the future holds?
- Micro-light and lighter GA aircraft are converging on the same design space.
- Limited endurance remains an issue at least for electric power in the short term.
- High efficiency design enables greater use of available energy in the atmosphere
GUIDE TO LOW LOSS RECREATIONAL AVIATION

• To harvest and store atmospheric energy one does not have to stop for thermals, BUT a flightpath strategy involving exchange of speed and height is required.
• The more efficient your airframe the easier this process becomes.
• Critically, a track must be chosen to maximise transit through areas of ‘good air’.
• While this process is weather dependent this should not constrain your recreational enjoyment. Indeed the satisfaction level should be enhanced.
• Piloting and airmanship, including lookout, must be sufficiently good to accommodate the necessary changes in heading and altitude, while complying with rules of the air in uncontrolled airspace.
• There is an emerging need to adapt response, handling and instrumentation to maximise pilot awareness.
How far can you fly on an empty tank?

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