GLIDER WING DESIGN – PART 2 by Martyn Pressnell, FRAeS.

Due to typographical problems the printed article on page 63 in AeroModeller 942 November 2015 has mislaid or corrupted the Greek pi (π) symbol. The corrected section is below.

Demon Drag

Clearly drag must be understood and reduced so far as possible. If we consider a glider in which the incidence is slowly being increased by re-trimming it nose up, the first milestone reached is the maximum lift to drag ratio $(C_L/C_D)_{max}$, this is the condition in which the glider would achieve the greatest range, a good condition for flying between thermals, and most significant for height stability. Slowing the glide a little further achieves a condition of $(C_L{}^{3/2}/C_D)_{max}$, sometimes called the power factor, which is the condition for minimum rate of descent. Slowing the model further induces the stall as mentioned above.

Now drag is composed of several parts which may be familiar, essentially form drag (C_{Do}) and induced drag (C_{Di}). The form drag includes skin friction due to the viscous forces in the airflow, excrescence drag related to such items as pegs, elastic bands, timers and recovery devices, aerials and cameras protruding from the surface of the model. Also there is interference drag, such as interference between the airflow around the fuselage and wing or other components, requiring good fairings to minimise the drag that are not always seen on models.

Induced drag is very important for slow gliding models and can be described as a drag penalty for producing lift and casting off a vortex system behind the model, particularly at the wing tips. This vortex system induces a downwash between the wings and over the tail-plane. The wing then is not flying in a simply plane airflow but in a distorted airflow. The effect of this is that the lift force is canted backwards producing a drag force component. Lift can't be produced without this vortex system and the inevitable induced drag. Induced drag depends twice on the lift because it affects the downwash angle as well as the drag-wise component. In general we can write the drag coefficients as:

$\mathbf{C_D = C_{Do} + C_{Di}}$ where the induced drag: $\mathbf{C_{Di} = k\,C_L^2 / (\pi\ a)}$

The aspect ratio (a) represents the slenderness of the wing usually found as span/mean chord (s/c) or span squared divided by area (s^2/A), whilst the wing efficiency factor (k) depends largely on the plan-form shape of the wing. Thus we have:

$\mathbf{C_D = C_{Do} + k\,C_L^2 / (\pi\ a)}$ and dividing by C_L $\mathbf{C_D/C_L = C_{Do}/C_L + k\,C_L / (\pi\ a)}$

Here we have one term reducing with C_L and one term increasing with C_L so that we need to find the condition producing the maximum lift/drag ratio C_L/C_D. The maximum is found when the two drag terms are equal, so that:

$\mathbf{C_{Do} = k\,C_L^2 / (\pi\ a)}$ and extracting the optimum aspect ratio it becomes $\mathbf{a_{opt} = k\,C_L^2 / \pi\,C_{Do}}$

The terms C_L and C_{Do} can be estimated from wind tunnel test results or from rather complex computer fluid dynamics (CFD) evaluations. Using an aerofoil's lift and drag characteristics, this formula is an important design tool in giving the optimum aspect ratio.

One further principle is also revealed. If the model is trimmed and flying close to its maximum Lift/Drag ratio, a change of trim to fly faster or slower causes the drag to increase. If the speed increases a rising drag is expected and stabilises the flight. However if the speed is reducing a reducing drag encourages even slower flight. This latter condition is not stable and level flight can't be maintained automatically. A radio control pilot can enforce the stability, but it requires continuous attention and makes for uncomfortable flying. The free-flight model is likely to wallow down effectively out of control. Thus the condition for maximum lift/drag ratio or a little faster, effectively designates the optimum flying speed.