LIFT PRODUCTION IN FREE FLIGHT WINGS

By John O'Donnell

The following appeared in 'Free Flight Comment' in the December 1973 issue of Aero Modeller. -Ed

Some indications of the mechanism by which a wing produces lift were outlined in the June issue, The process depends on increasing the air pressure on the wing undersurface and/or simultaneously decreasing the pressure on the upper surface. Due to the shape of the wing section and the characteristics of the airflow, this pressure differential is not constant along the wing chord. Most of the wing lift is produced by the forward part .of the wing - particularly when the wing is at a high angle (of attack) to the main airstream (see figures l and 2).

Since the generation of lift usually involves flying the wing at an angle, it might well be thought that increasing the angle should increase the lift - and indeed it does at first. There are, however, other effects as well. Drag also increases with angle, whilst the lift of the wing moves even more forward. Moreover there is a very real limit to the angle of attack! Past a certain point (that varies with both section and model characteristics) the flow round the wing breaks down - often suddenly, and always with a dramatic loss of lift. This is the dreaded stall - inconvenient with models, but often disastrous with full-scale aircraft.

Figure 1
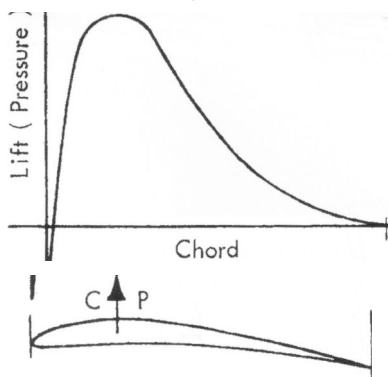
Low Angle of Attack

In flight a model is subject to various forces — such as lift, drag, weight and thrust. Normally their relationship is arranged so that they form a positively stable system — this means that the model will recover from a disturbance and resume its earlier flight path. On its own, a wing of normal section is unstable due to the fact that the forward movement of its lift with increasing angle of attack tends to increase the angle further (see figures 2 and 4). Similarly the opposite is also true!

Figure 2
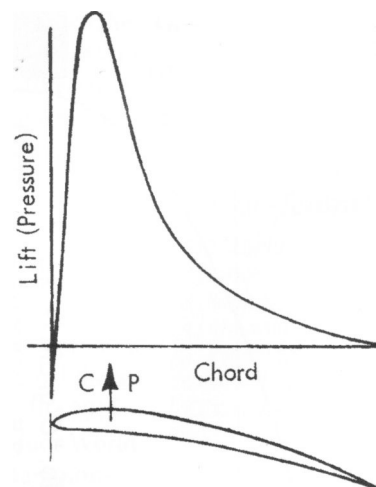
High Angle of Attack

Control of this 'pitching tendency' is the purpose and function of the tailplane - which is why our American friends call it 'stabilizer'. It also serves to ensure that the wing is indeed flown at the intended angle of attack. This is important since it usually necessary to adjust a model to fly near the stall in order to obtain good glide performance i.e. low rate of sink. Obviously this 'living dangerously' since models are subject to various disturbances, from poor launches to gusts —all of which can affect the airflow and possibly initiate a stall.

To simplify discussion it is often convenient to think of the wing lift as being concentrated at a single point - usually called the 'centre-of-pressure' or C.P. This is analogous to the way in which the mass of the model is regarded as acting at the 'balance point' or centre-of-gravity (C.G.). At the sort of angles appropriate to model glide conditions the C.P. is in the region of 30% of the wing chord measured from the leading edge (see figure 1).
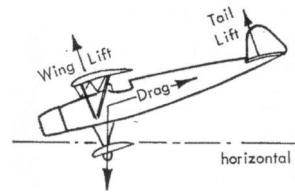
The simplest force arrangement is to have the C.P. and C.G. coincide as shown in figure 3. Note the inclusion of drag, a force that opposes motion in the same way as friction. If our hypothetical model is disturbed by, say, a gust so it tries to fly in a nose-up attitude, then the C.P. will move forward as already mentioned. However, the nose-up attitude also causes the airflow to alter over the tailplane so that it produces lift. Since the tailplane has the advantage of a long moment arm' (distance from the C.G.) the tail's corrective effect is usually sufficient to depress the model's nose and restore the 'status quo'. In a similar fashion a nose-down attitude causes the tail to 'lift' downwards and over-ride the rearward movement of the centre of pressure (See figures 4 and 5).

As the tailplane does not lift in normal flight only when disturbed - it has to be set appropriately. A symmetrical (or flat plate) tailplane would be rigged with its centre-line parallel to the' airflow. The more normal flat-bottomed-airfoil tail needs to be positioned at its 'angle of zero lift' which is usually a few degrees negative. Naturally enough a model rigged as just described has considerable 'longitudinal dihedral' or difference between wing and tail incidences ..

The end product should be stable but could well be inefficient on other counts.

High drag needs nose-down -attitude to incline lift sufficiently to balance large drag (i .e. horizontal components must balance out)
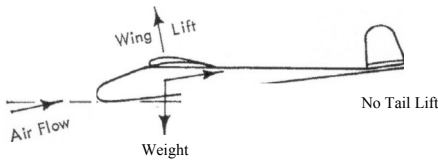
Normally a Free Flight model is rigged with its centre of gravity much farther back than the 30% wing chord associated with the centre of pressure. In fact, the usual range of C.G. locations is from 50 to 100% chord - and odd examples off the wing are sometimes encountered. The rearward C.G. merely means that the tailplane has to provide some lift in normal flight (see figure 6). Hence the tailplane has to be at some angle of attack to the air flow, with an inevitable reduction in the longitudinal dihedral. In moderation these changes have little effect on the general stability of the model - and they do produce a more efficient model. Not only does the tail contribute to the overall lift, but there seems to be some effect on the total model drag.   A secondary effect can come from the use of less nose-weight and hence the producing of a lighter model. Incidentally, the relationship between high drag and poor glide may be apparent from figure 7.

Like most techniques, that of moving the C.G. back can be overdone. With most conventional designs the symptoms are the combination of a good glide (if undisturbed) with a marked reluctance to recover from even a gentle stall. With designs featuring large tailplanes and C.G.'s around the wing's trailing edge there can be a disconcerting tendency for the model to dive-in following a stall. The methods of obtaining a stall recovery are tied-up with circling flight - a complication I have not yet mentioned and one that I intend to leave for a future column.
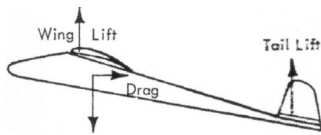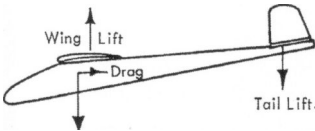
Figure 3

C.P/ and C.G. Coincident- No tail lift. Normal flight in equilibrium. Note: Lift is perpendicular to airflow and drag is parallel – they are not vertical and horizontal. Weight always acts vertically.
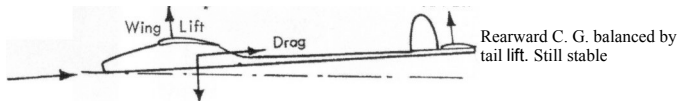
Figure 4

Model trying to f l y nose-up. Tail Lift provides nose-down (corrective) moment. Situation unstable, hence forces out of balance horizontally.

Figure 5

model trying to fly nose-down. Tail "lift " provides nose-up (corrective) moment.

Figure 6

Rearward C. G. balanced by tail lift. Still stable

Figure 7