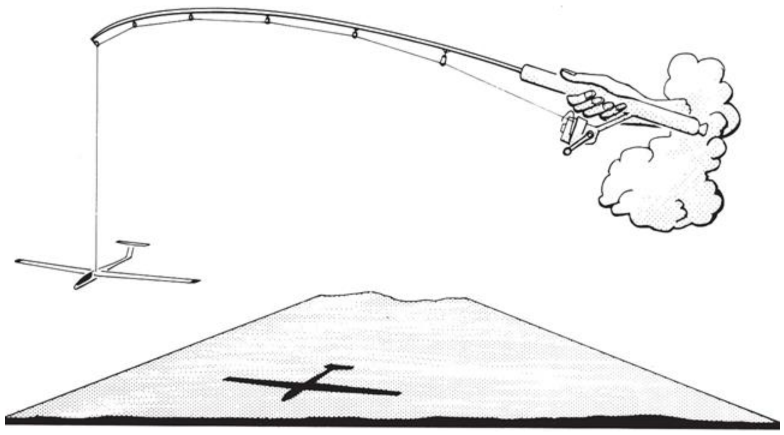
WHAT MAKES A GLIDER FLY?



In this chapter we are not dealing with "soaring" or "staying up". Soaring is the art of using the energy of the atmosphere in such a way that the glider will remain airborne, climb, and travel across country as required. We are only concerned here with the manner in which you can control the various aerodynamic forces to make the aircraft behave in the way you wish. The same principles apply whether the glider is soaring or descending in non-rising air. Soaring is made possible by the fact that the air around the glider is moving upwards.

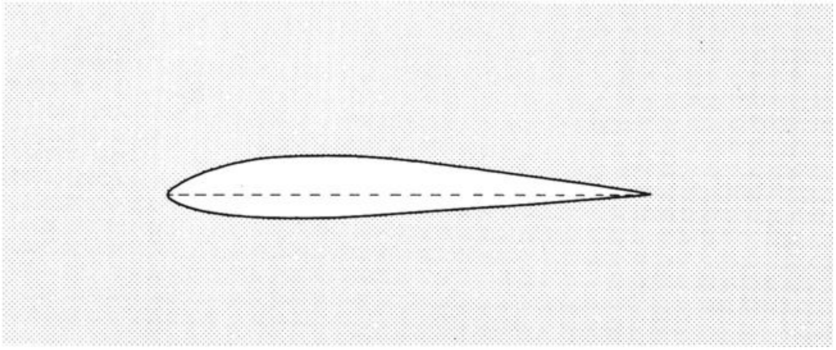
Airspeed

In later paragraphs it will be seen how the movement of a glider through the air produces the forces which keep it up and enable it to manoeuvre. The behaviour of the aircraft is determined by its rate of movement through the mass of air in which it is travelling, i.e., by its "air speed". If a wind is blowing, this mass of air will itself be moving over the ground but the only effect this has on the aircraft (as long as the wind is steady) is to alter its position with respect to the ground. The airspeed, which causes the airflow, which you would feel on your face in an open cockpit, depends only on the manner in which the controls are manipulated, and is not influenced by the wind.

For navigational purposes we may think in terms of the "groundspeed" and take the wind into account. Here, we are concerned with controlling and manoeuvring the aircraft and need only consider the airspeed. However, the wind will be relevant later when we deal with judgement considerations.

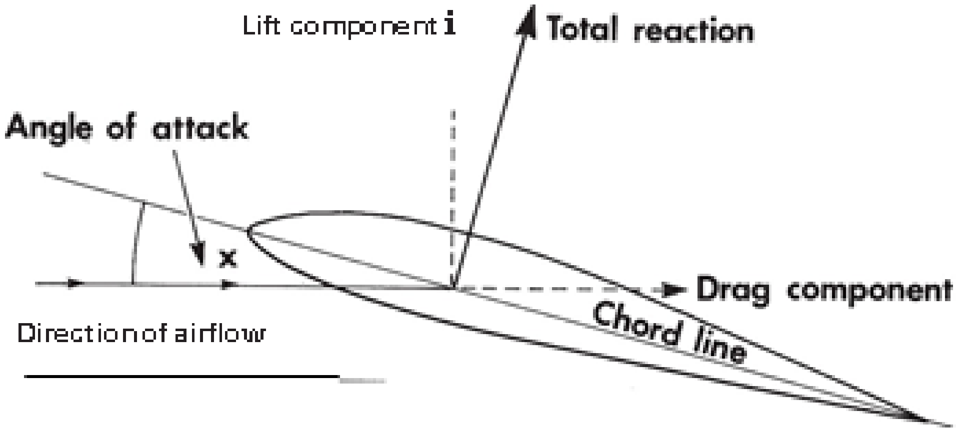
Aerofoils

The wings, tailplane, elevator, fin and rudder, which are known as "aerofoils", are constructed with "streamline" sections so that the air flows smoothly over them and sets up little resistance. A typical wing section is something like this:



Lift and Drag

If a wing is placed in a wind tunnel at a slight angle to a moving stream of air, as shown below, the reaction due to the air acts upwards and backwards. This total reaction can be represented by two components at right angles:



In the diagram here we represent each force by a line in the direction in which the force is working. The length of the line represents the strength of the force involved.

The upward component, called Lift, is always considered as acting at right angle to the airflow; the backward component, called Drag, is parallel to the airflow . The combined effect of lift and drag is the Total Reaction.

In steady flight the total reaction is equal to the weight. Because of the shallow glide angle the lift is only a little less than the total reaction.

Drag is a hindrance, acting opposite to the direction of flight. It can be minimised in various ways, but some drag is inevitably associated with lift.

The proportion of lift and drag. varies according to the angle at which the airflow meets the aerofoil. This angle, between the direction of the airflow and the chord line, is called the Angle of Attack. If the aerofoil is at a large angle to the airflow a considerable part of the force of the air is drag.

By measurements on a wing in a wind tunnel it can be shown that the value of the lift and drag force rise as the angle of attack is increased but only up to a certain point. When the "critical" or "stalling angle" is reached the drag force continues to increase but there is a marked decrease in lift. This is explained later under "stalling".

Measurements of the drag force show that as the angle of attack is increased the drag goes on increasing; there is no "critical angle".

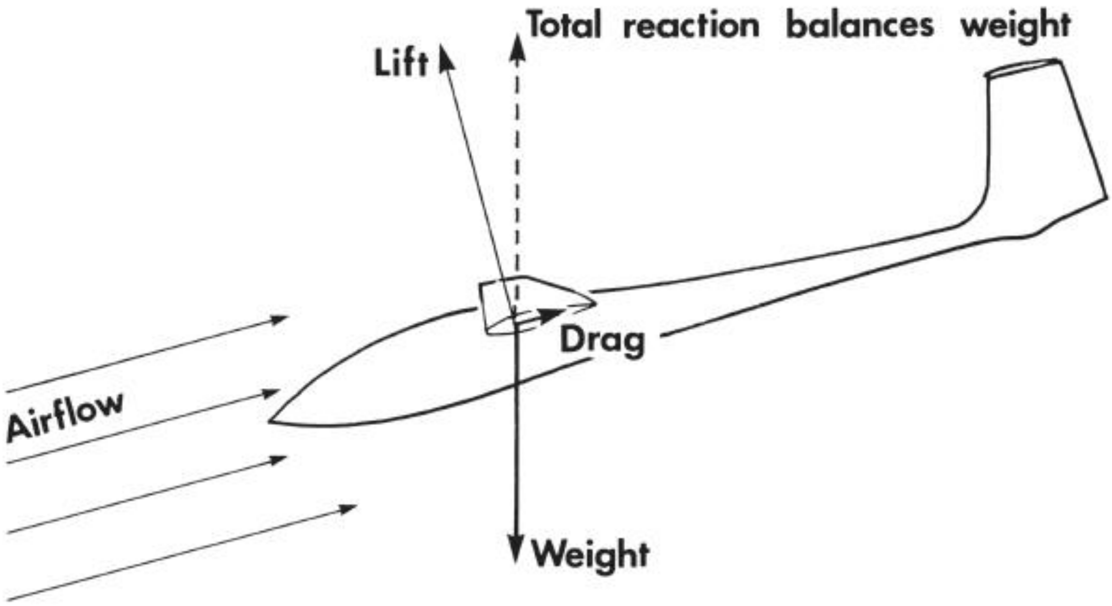
The actual value of lift (and drag) force for a wing depends upon the airspeed, as well as on the angle of attack. If the speed of the airflow is increased, both lift and drag are increased.

When a glider is in steady flight the values for airspeed and angle of attack are such that the lift force is always equal to the all up weight of the aircraft. If the speed is increased the aircraft is automatically flown at a smaller angle of attack so that the balance is maintained. If we wish to carry out a manoeuvre, such as a turn, in which extra lift is required, we may obtain this lift either by increasing the angle of attack (up to the critical angle) or by increasing the speed, or by doing both.

To get some idea of the magnitude of the quantities involved, let us take the case of typical glider. In normal flight this aircraft might be flying at about 45 knots (kts). At this speed the angle of attack is about 7 degrees, and this combination produces a lift force equal to weight (say 650 lb.). The drag force is about 201b.

The forces on a glider

The movement of a glider through the air is derived from the pull of gravity, in that the weight of the aircraft acting downwards provides a forward component in the direction of motion. We have shown how the other forces, lift and drag, are produced. When a glider is in steady flight the three forces balance as shown overleaf. The force shown as weight represents the total weight of the aircraft. Although the weight is distributed over the entire structure and acts vertically downwards all along it there will be a point about which the aircraft, if placed on a pivot, would balance. This is the centre of gravity and the weight can be thought of as a single force, represented by a line, acting through that point.



Similarly, the lift of the aerofoil is obtained from all over the wing, but the total effect can be represented as one force passing through the Centre of Pressure. The Centre of Pressure bears the same relationship to lift as the centre of gravity does to weight but while the Centre of Gravity remains fixed, the centre of pressure 's position varies depending on the angle of attack and the distribution of lift over the wing.

Similarly, drag is shown as one straight line which represents the resultant effect of all the drag.

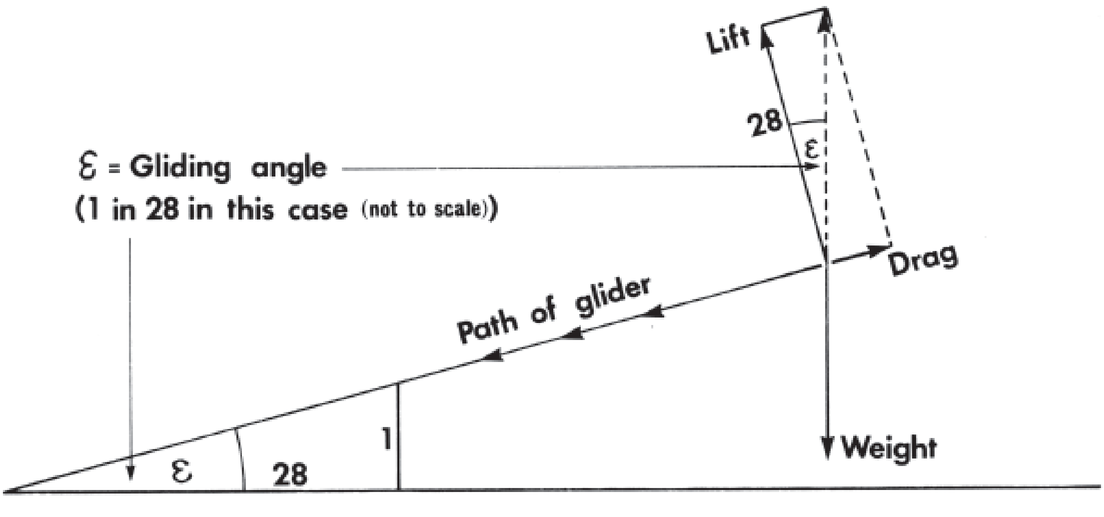
Throughout this book we have stated that the lift is equal to the weight in steady flight. We now see from the disposition of the forces above that the weight of the aircraft is actually counter-balanced by the resultant of the lift and drag forces, i.e. by the total reaction. In practice, however, the lift is very nearly equal to the total reaction, since the component of drag is small for flat gliding angles, and the effect of drag in this connection can be ignored.

By the use of the controls the pilot may alter the equilibrium; it will be seen later that the use of the elevator alters the attitude of the glider with respect to the airflow, i.e., alters the angle of attack. If the angle of attack is decreased, for

. example, the values for lift and drag are altered and the forces no longer balance. As there is an unbalanced force a change occurs, and this continues until a new equilibrium is set up.

If we draw out the forces in relation to the path of the glider we see that the "gliding angle" (height lost/horizontal distance covered) is equal to the ratio of drag force divide by lift force. Thus, the angle of glide is flattest when the ratio L/D is a maximum.

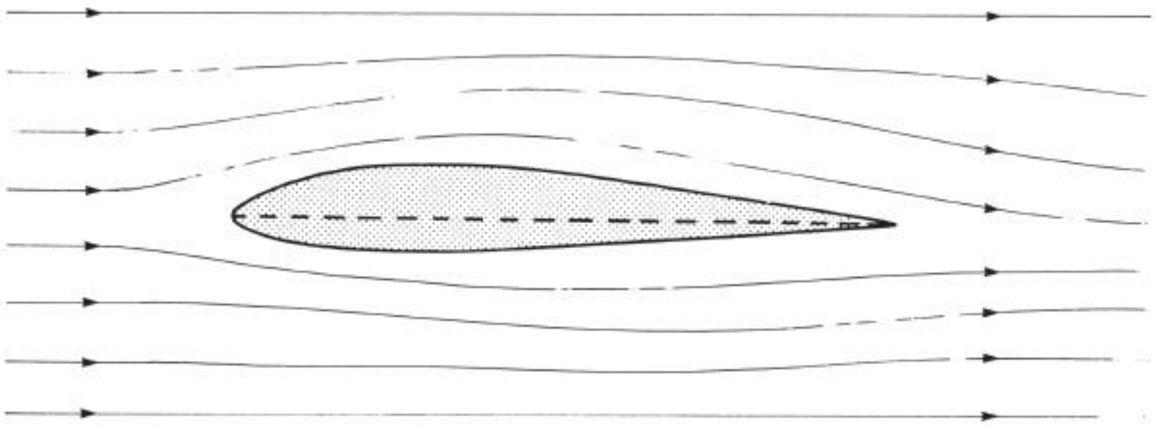
This maximum corresponds to a definite angle of attack (see Appendix). Therefore, in order to cover the largest amount of ground, in still air, we must fly at this angle of attack (about 7 degrees for most gliders). In practice the pilot



selects a speed not an angle of attack. The gliding angle is usually expressed as a ratio, e.g., 1 in 30. It should be noted that in the example above the angles are exaggerated for the sake of clarity (and, therefore the ratio of the forces is not representative).

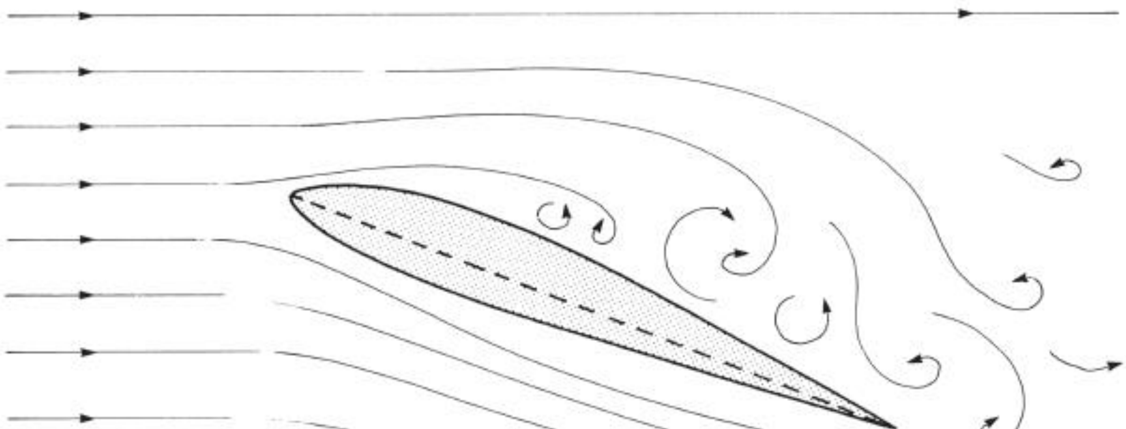
Stalling

It was mentioned earlier that if the angle of attack is increased beyond a certain point, the value of the lift rapidly decreases; the wing is then said to be "stalled". In order to explain this fact, we must consider what happens to the airflow passing over the wing. Normally the flow is smooth like this:



The result is that the air passing under the aerofoil increases in pressure and exerts an upward force on it, while the pressure of air passing over the top of the aerofoil is reduced and this exerts an upwards 'sucking' effect. These changes in pressure are actually quite small but both the air passing over and the air passing under have a lifting action.

In fact, the amount of lift provided by the sucking effect is greater than that provided by the pressure on the under surface. The upward, sucking effect is only maintained so long as the airflow over the top of the aerofoil remains smooth. If the flow becomes disturbed, the effect is very greatly reduced, the greater the disturbance the greater the loss of lift. Such a turbulent airflow can be shown diagramatically:



It is when the air over the aerofoil is in this turbulent state that the aerofoil is said to be stalled. Stalling occurs when the angle of attack is increased beyond the "stalling angle". The value of this angle depends on the design of the particular aerofoil. Stalling always occurs when the angle of the aerofoil relative to the airflow is increased beyond this value, and it cannot occur unless the angle is reached. Let us consider a set of circumstances in which the aircraft is stalled.

The wings of most gliders will stall at an angle of attack of about 15°. Suppose we are flying at 50 kt. and 6° angle of attack. This means that the lift (strictly total reaction) provided by the wings is equal to the weight of the aircraft (say 630Ib wt). By gently moving the elevator, so as to increase the angle of attack, we disturb the balance and bring the aircraft to level flight. In this condition the aircraft will be flying at a slightly greater angle of attack and at a slower airspeed than previously, and the lift produced will still be equal to the weight of the aircraft.

However, in level flight we no longer have a 'forward' component of lift to maintain forward motion (lift and weight are directly in line) and the drag force causes the speed to reduce. This also means a steady loss of lift, and the state of level flight can only be maintained by increasing the angle of attack still further so as to keep the lift constant. Again, drag is also increased by this procedure, so that the speed falls off more rapidly, and finally in an attempt to maintain adequate lift the angle of attack is brought to the stalling point (15°). At this point the wings lose a large part of their lift and the nose usually drops; the aircraft loses height rapidly and is not under the normal control of the pilot until recovery has been made.

When a stall is performed gently as described above, the speed at the stall will be at a certain value known as the "stalling speed" of the aircraft (typically in the order of 34 or 35 kt. for the modern glider). The stall will always take place if the airspeed is allowed to fall to this value. However, it is misleading to think of the occurrence of the stall as being dependent on speed. A glider may be made to stall at higher speeds, as will be seen, and the so-called stalling speed is merely the speed at which the aircraft stalls when an attempt is made to fly level by the gentle use of the controls.

Airspeed and Angle of Attack

In flying the glider, we are concerned with a number of factors, the angle of attack of the wings being the most important as regards performance. A glider is not normally equipped with an instrument which indicates the value of the angle of attack, so that you are taught to interpret, from the value of the airspeed and the behaviour of the aircraft, when the angle of attack is approaching that of the stall. You are able, by using the airspeed as a guide, to adjust the angle of attack to the most favourable value for a particular circumstance. It is important, however, that you should realise that this relationship is not precisely fixed, and we shall now go into this in a little more detail.

Consider once more the gentle stall described; by increasing the angle of attack as the airspeed fell off we kept the lift equal to the weight until the stalling angle of attack was reached. It follows that the Stalling Speed is that speed required to make the lift equal to the weight when the angle of attack is the "stalling angle".

It is apparent from the above considerations that the relation between the airspeed and the angle of attack will vary with the load carried by the aircraft. If our glider is carries a heavy pilot and we carry out a gentle stall, more lift is required to balance the increased weight, and the stalling angle is reached at a higher speed. The stalling speed is therefore increased by the extra load but the stalling angle remains the same.

Load Factor

When an aircraft is performing manoeuvres (i.e. is not in steady flight) the lift which the wings are required to produce varies. For instance, during a turn part of the lift is used to cause the aircraft to turn (to provide the necessary inward force in the direction of the turn), and as the weight still has to be supported, this means that the total lifting force provided by the wings must be increased. This state of affairs is equivalent to a temporary increase in the weight of the aircraft and contents, and it is expressed by the load factor, which is the ratio between the apparent weight of the aircraft during the manoeuvre and its normal weight under gravity. A pilot may speak of carrying out a steep turn, for example, with a "load" or "load factor" of "2g", which means that the aircraft and contents including the pilot, apparently weigh twice as much as they do under gravity alone (1'g'), and the lift produced by the wings is equal to twice the ordinary weight. To the pilot, therefore, the parts of his body and anything that he tries to pick up appear to have doubled in weight.

Such an increased loading occurs to some extent in all manoeuvres involving change of direction, such as looping, pulling out of dive, turning and so on. It is caused as a result of manipulation of the controls by the pilot.

The increased lift required by the increased load factor can be obtained either by increasing the angle of attack (up to the angle of maximum lift) or by increasing the airspeed, or by a combination of both. If the airspeed is kept at some constant figure, the angle of attack must be increased; it is therefore brought closer to the stalling angle, and in this way the aircraft may actually be stalled in a manoeuvre although the airspeed is well above the usual "stalling speed". You must bear in mind, therefore, that increased loading means **increased stalling speed.**