PART 1 : SECTION 1

CHAPTER 11

GLIDING AND CLIMBING

Introduction

1. This chapter deals with the basic aerodynamic considerations of the aircraft while in steady descending or ascending flight. A knowledge of these enables a pilot to obtain the maximum performance from an aircraft under widely different conditions of flight and to appreciate more quickly the effects of departure from the optimum conditions.

GLIDING

Forces in the Glide

2. For a steady glide, with the engine giving no thrust, the lift, drag, and weight forces must be in equilibrium. Fig. 1 shows that the weight is balanced by the resultant of the lift and drag; the lift vector, acting as it does at right angles to the path of flight, will now be tilted forward while the drag vector still acts parallel to the path of flight.

3. From Fig. 1 it can be seen that the geometry of the vectors is such that the angle included between the lift vector and the resultant (total reaction) is the same as that between the glide path and the horizontal. Further examination of Fig. 1 will show that the less the drag the smaller will be the gliding angle. Therefore the steepness of the glide path depends on the amount of drag. When gliding at the angle of attack for best L/D ratio, least drag is obtained and the flattest glide will result. It follows that the L/D ratio is a measure of the gliding efficiency or aerodynamic cleanliness of the aircraft.

4. During the glide a similar, although not exactly the same, relationship exists between the I.A.S. and the angle of attack as that of level flight. Therefore if the speed is adjusted to correspond to the optimum angle of attack (best L/D ratio) the best gliding performance is obtained. If the speed is changed then the angle of glide becomes steeper as the L/D ratio is reduced; a higher speed increases the profile drag and lowers the L/D ratio while a lower speed increases the induced drag (owing to the higher angle of attack) to obtain the same effect. Therefore to cover the greatest distance on the glide it is important to use the correct speed.

Effect of Wind on the Glide

5. When the glide path and angle of the aircraft is plotted by an observer on the ground it is found to vary depending on the strength and direction of the wind. However, the actual gliding angle of the aircraft through the moving air mass, measured with respect to an imaginary reference plane moving with the air mass, remains unchanged.

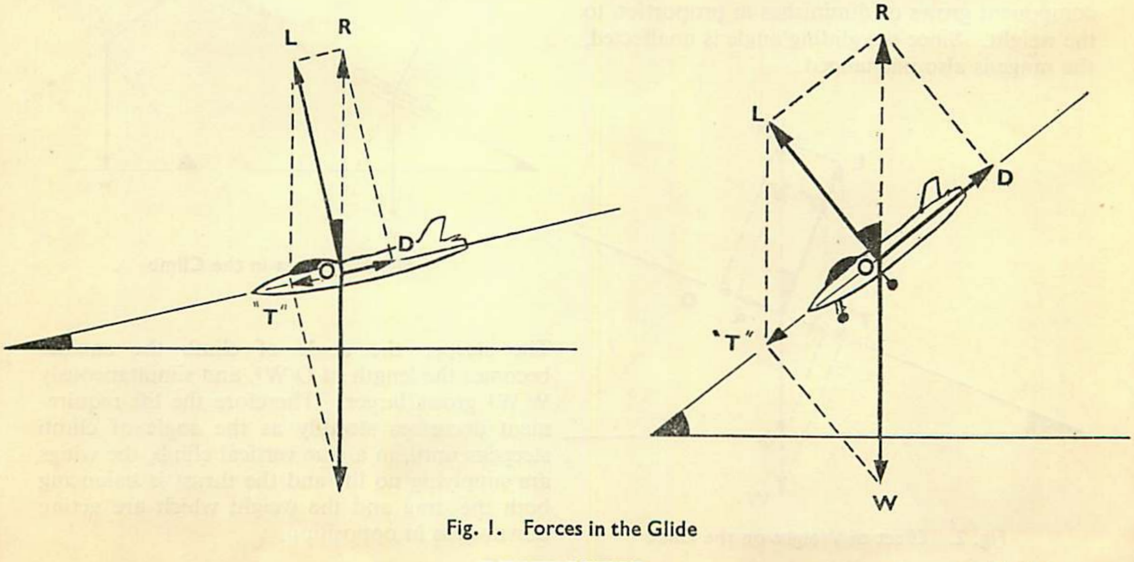

Fig. 1. Forces in the Glide

6. Starting from a given height, a glide into wind at the optimum air speed covers less distance over the ground than a glide downwind. Since in both cases the *rate* of descent, *i.e.* the time taken to lose 1,000 feet is the same, the angle as seen by a ground observer is governed only by the ground speed, being steeper at the lower ground speed when gliding into wind.

7. The effect of wind, therefore, is to decrease the range when gliding with a head-wind component and to increase it when gliding downwind. The endurance of the glide is unaffected.

Effect of Weight on the Glide

8. Variation in the weight does not affect the gliding angle *provided that the speed is adjusted to fit the A.U.W.* The best I.A.S. varies as the square root of the A.U.W. A simple method of estimating changes in the I.A.S. to compensate for changes in the A.U.W. up to about 20 per cent. is to decrease or increase the air speed by half the percentage change in the A.U.W. For example, a weight reduction of 10 per cent. necessitates a drop in air speed of 5 per cent.; an increase of weight of the same amount would entail the addition of a 5 per cent. increase.

9. Fig. 2 shows that an increase in the weight vector can be balanced by lengthening the other vectors until the geometry and balance of the diagram is restored. This is done without affecting the gliding angle. The higher speed corresponding to the increased weight is provided automatically by the larger component of the weight acting along the glide path; and this component grows or diminishes in proportion to the weight. Since the gliding angle is unaffected, the range is also unchanged.

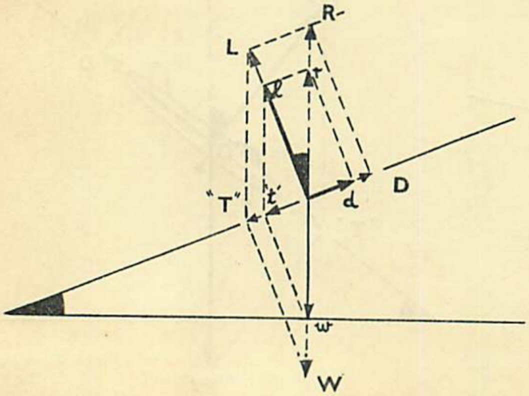

Fig. 2. Effect of Weight on the Glide

Effect of Weight on Endurance

10. Although the range is not affected by changes in weight, the endurance decreases with increase of weight and vice versa. If two aircraft having the same L/D ratio but with different weights start a glide from the same height, then the heavier aircraft gliding at a higher I.A.S. will cover the distance between the starting point and the touch-down in a shorter time; both will, however, cover the same distance. Therefore the endurance of the heavier aircraft is less.

11. Usually the exact distance covered on the glide is not vitally important; therefore the gliding speed stated in Pilots' Notes is a mean figure applying to the lower weights of a particular aircraft and giving the best all-round performance on the glide.

CLIMBING

12. The forces acting on the aircraft during a climb are shown in Fig. 3. The aircraft is in equilibrium, the weight being resolved into two components, one opposing the lift and the other acting in the same direction as the drag. The requirements for equilibrium are :—

(*a*) The thrust must equal the sum of the drag plus the opposing component of the weight (W W^1).

(*b*) The lift must equal its opposing component of the weight O W^1.

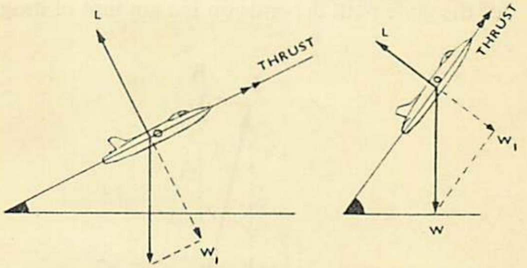

Fig. 3. Forces in the Climb

The steeper the angle of climb the smaller becomes the length of O W^1, and simultaneously W W^1 grows larger. Therefore the lift requirement decreases steadily as the angle of climb steepens until, in a true vertical climb, the wings are supplying no lift and the thrust is balancing both the drag and the weight which are acting downwards in opposition.

13. **Rate of Climb.** At a constant power setting a given rate of climb can be obtained either by climbing steeply at a low air speed or by climbing on a shallow path at a high air speed. On one extreme, if the air speed is too low the induced drag rises to a figure at which all the thrust available is required to overcome the drag and none is available for climbing, *i.e.* the rate of climb is zero. At the other extreme, if the speed is the maximum obtainable in level flight then again all the power is being used to overcome the drag, and there is no rate of climb. Between these two extremes lies a speed, or a small band of speeds, which realize the best rate of climb. The best rate of climb is achieved not at the steepest angle but at some combination of moderate angle and optimum speed at which the greatest amount of excess power is available to climb the aircraft after the drag has been balanced. A simplified explanation of what is in fact a complex subject is given below.

Power Available and Power Required

14. The power required to propel an aircraft in level flight can be found by multiplying the drag (lb.) by the corresponding T.A.S. (ft. per sec.) and dividing by 550, the lower curve of Fig. 4 being a typical curve. Note that the speed for minimum drag, although low, is not the lowest possible. The increase in power required at the lowest speeds is caused by the rapidly rising effects of induced drag. The thrust power available curve is calculated by multiplying the thrust (lb.) by the corresponding speed (ft. per sec.) and dividing by 550. The thrust power curve for a jet engine differs from that of a piston engine as shown in the upper curves of Fig. 4. The chief reason for the different shapes is that the thrust of a jet engine remains virtually constant at a given altitude, irrespective of the speed; therefore when this constant thrust is multiplied by the appropriate air speed to calculate thrust horsepower the result is a straight line. The piston engine, on the other hand, under the same set of circumstances and for a given B.H.P., suffers a gradual loss of propeller efficiency and thrust at both ends of its speed range, as indicated by the shape of the curve on the graph. The curve for the piston engine is representative of the more powerful type of piston-engine fighter and that of the jet engine of a typical jet fighter having a high subsonic performance. The power required curve is assumed to apply to both airframes, *i.e.* the airframe drag is the same irrespective of the power unit used.

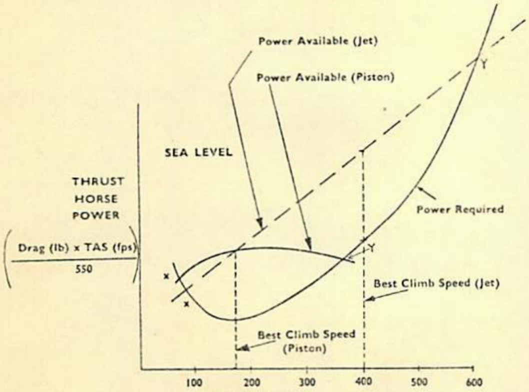

Fig. 4. Typical Power Required and Power Available Curves for Sea Level

Climbing Performance

15. The vertical distance between the power available and the power required curves represents the power available for climbing at the particular speed. The best climbing speed (highest rate of climb) is that at which the excess power is at a maximum; so that, after expending some power in overcoming the drag, the maximum amount of power remains available for climbing the aircraft. For the piston-engine aircraft the best speed is seen to be about 160 knots, and for the jet about 400 knots. Notice that in the latter case a fairly wide band of speeds would still give the same amount of excess power for the climb, but in practice the highest speed is used since better engine efficiency is obtained. At the intersection of the curves all the available power is being used to overcome drag and none is available for climbing. Points X and Y (for each engine) therefore represent the minimum and maximum speeds possible for the particular power setting.

16. If power is reduced the power available curve is lowered. Consequently the maximum speed and maximum rate of climb are reduced, while the minimum speed is increased. When the power is reduced to the point when the power available curve is tangential to the power required curve, the points X and Y coincide and the aircraft cannot climb.

Effect of Altitude on Climbing

17. The thrust horsepower of both jet and piston engines decreases with altitude. Even if it is possible to prolong sea-level power to some greater altitude by supercharging or some other method of power boosting, the power will inevitably decline when the boosting method employed reaches a height at which it can no longer maintain the set power.

18. At the highest altitudes the power available curves of both types of engine are lowered as shown in Fig. 5, and the power required curve is displaced upwards and to the right. Notice that the power required to fly at the minimum-drag speed is increased ; this effect is caused by the fact that although the minimum-drag speed, in terms of I.A.S., remains the same at all heights, the speed used in the calculation of T.H.P. is the T.A.S., which increases with altitude for a given I.A.S. Therefore the T.H.P. required to fly at any desired I.A.S. increases with altitude.

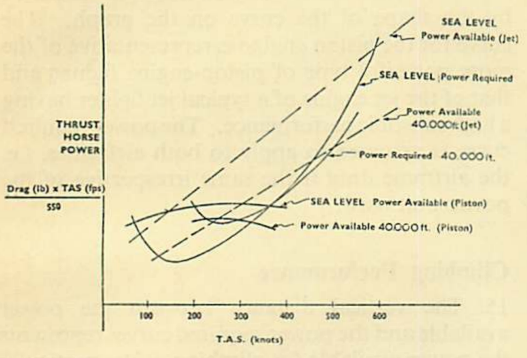

Fig. 5. Effect of Altitude on Typical Power Required and Power Available Curves

19. From Fig. 5 it can be seen that the piston-engine aircraft is almost at its ceiling whereas the jet aircraft still has power available to climb. The range of speeds between maximum and minimum level flight speeds is reduced in both examples, particularly with the piston engine. The absolute ceiling of both would be reached when the respective curves become tangential to each other. The graph shows, too, that the best climbing speeds are reduced. The T.A.S. for climbing the jet and piston are about 350 knots and 250 knots respectively, *i.e.* the jet would be climbed at about 175 knots I.A.S. and the piston aircraft at about 125 knots I.A.S. (At 40,000 feet the I.A.S. is roughly half the T.A.S.)


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