THE FIRST FEW SECONDS

The article by P. J. Goulthorpe "Charlie" in last June's issue, p140, set out a simple theory to account for the performance of a glider on the winch. However, getting the best out of a winch launch depends on getting into the climb as quickly as possible. So in this article he looks at the physical limitations which apply to the start of the launch - those first few seconds. There is, of course, more to a well-executed launch than flying to absolute limits. Safety and good airmanship add their own demands, as any instructor will be quick to insist, but it helps to be clear at the outset what the glider can and cannot do and why

Waiting for a winch launch can take ages until at last your turn comes. But then matters improve and, once the "all out!" signal has been given, the business proceeds with a briskness that is sometimes alarming.

A little mental preparation is needed. To that end, the following offers some thoughts about what happens to a glider in the few seconds between departing the launch point and settling into a steady climb on the winch.

The aim

In the initial phase of the launch (Fig 1a), the aim is to join the intended launch path at a target airspeed as soon as may be done with safety. The urgency is that to reach best launch height no more cable than necessary should be wound in before the main ascent starts. The hazard is that being too precipitate risks a cable break, or a stall, in a steep climb close to the ground.

Limitations

The operating manual for the glider puts limitations on:-

- Maximum pull on the cable hook (for which the weak link should act as a fuse).
- Maximum airspeed during winching.

The ground roll

Acceleration before take-off is controlled entirely by the winch operator. Cable speed needs to increase progressively without snatch so as not to endanger the glider, over run the cable, or break the weak link.

Typically the acceleration during the ground roll is 0.5*g*, which requires a cable pull of half the glider's weight plus whatever is needed to overcome its rolling resistance - a total that should be well within the maximum pull permitted by the weak link. Gaining speed at that rate, the glider will reach flying speed within 4sec and a ground roll of 150ft; sooner, if there is a headwind and in much less distance.

At this stage the cable is sliding on the ground, its weight supported; the cable pull is horizontal and applied beneath the glider, well below its C of G, so the aircraft's inertia will cause a nose up moment. Unless anticipated by the pilot, this may cause the glider to pitch up unduly as soon as flying speed is reached. (Fig 2a.)

In an aircraft with a high C of G (*eg* a high wing, pilot-sits-upright type such as K-8), the nose up moment is especially strong. Unless its acceleration is moderated during the ground roll, the pitch up at take-off is more than can be corrected with the stick held fully forward and the glider will rotate very rapidly into the climbing attitude. Fortunately, as it does so, the cable pull aligns more nearly with the C of G, reducing the unwanted nose up moment, and the glider returns under control. (Fig 2b.)

For gliders which have a nose wheel or skid and which sit tail-up at the launch point, rapid acceleration during the ground roll can bring the tail down heavily to the ground. That can be disconcerting and is plainly an abuse of the glider.

So the winch operator needs to keep in check the rate at which the cable speed is increased until the glider is airborne. It is helpful that the cable is sliding on the ground at this stage and the frictional load provides a restraint. After the take-off, the winch operator seeks to establish and regulate a steady cable speed which he judges to be the right one for the first part of the launch.

The rotation

If the winch operator holds the cable speed steady then acceleration after take-off is in the control of the pilot. As he rotates the glider into the climb, its airspeed will increase. Moreover, as the attitude gets steeper the effect becomes more marked; when the ascent is very steep, a small change in attitude will result in a big change in speed (Fig 1c). So rotation increases the glider's speed more and more as the climb steepens.

Throughout the brief rotation the cable stays more or less horizontal. It follows that the horizontal component of the glider's airspeed will not change; it will remain equal to the steady cable speed plus any headwind. All the gain in airspeed will be a vertical addition. So, during rotation, all the glider's acceleration is in the vertical direction. The effect of a vertical acceleration is to increase the glider's weight; half a *g* vertically would make the glider weigh half as much more, for example.

Now at every point in the launch the three main forces acting on the glider, weight, pull and lift, are in balance in a triangle of forces. Weight acts vertically downwards, pull (at this initial stage) acts nearly horizontally, and the lift acts (as always) at a right angle to the flight path. (Fig 1b.) So, as the flight path steepens, the triangle changes shape and both pull and lift increase in relation to weight. It follows that whenever weight is added to by a vertical acceleration, both pull and lift at that point will be increased also, in the same proportion. (Fig 1c.)

So, during rotation, not only does cable pull increase in step with the increasing angle of climb but it increases even more because of the acceleration involved. (And the same applies to lift and wing loading). Pull becomes rapidly larger as the glider rotates and as the climb steepens pull becomes more and more sensitive to the rate of rotation.

So rapid rotation can overload the cable and break it or its weak link at an angle of climb which in itself would not require an excessive cable pull. The most critical moment in a launch is just when the attitude is steepest, at the angle chosen for the start of the climb. It is best that the rate of rotation is much reduced as this point is approached.

However, there could reasonably be a compensating increase in the speed of rotation just after take-off, when pull and lift are much less and rotation causes less acceleration. This suggests that a ski jump shape would be a good model to take for the pitch-up profile, with the rapid rotation done early. (Fig 1d.)

Fortuitously, the change in trim which occurs during rotation as the cable pull realigns towards the C of G (Figs 2a and 2b) disposes most gliders to follow such a profile naturally. The practical point for pilots is to allow the glider to pitch up quickly at first but to make sure the rotation washes out as the pitch up proceeds. Being tentative about the initial rotation and then speeding it up, as height and airspeed increase, is not the best way. It is very likely to break the weak link if the chosen climb is a steep one.

Cable breaks towards the end of the initial phase of the launch are not uncommon. When they occur it is often supposed that the cause was a drag rise induced by a rapid pitch up or by a gust. However, the drag of a modern glider in such circumstances is unlikely to exceed 5% of its weight, whereas the forces brought about by acceleration can be much greater and are much the more likely cause of failure. The remedy is to moderate the rate of rotation, especially lat-

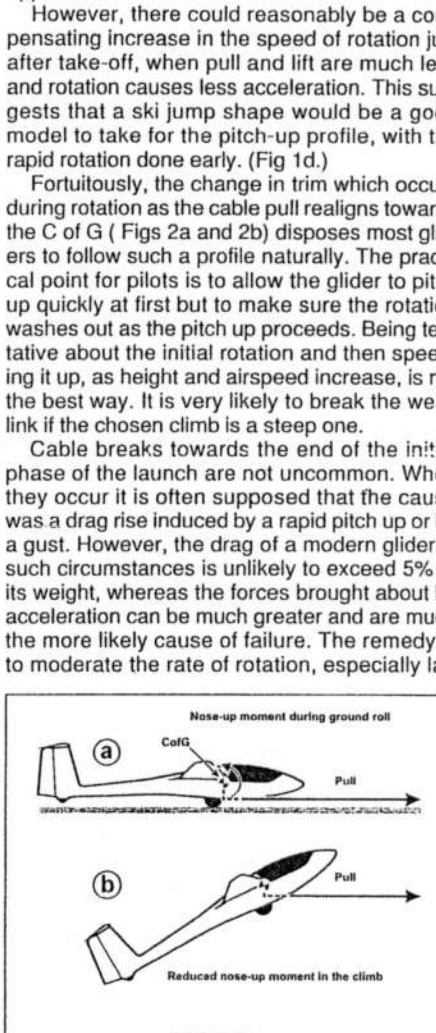
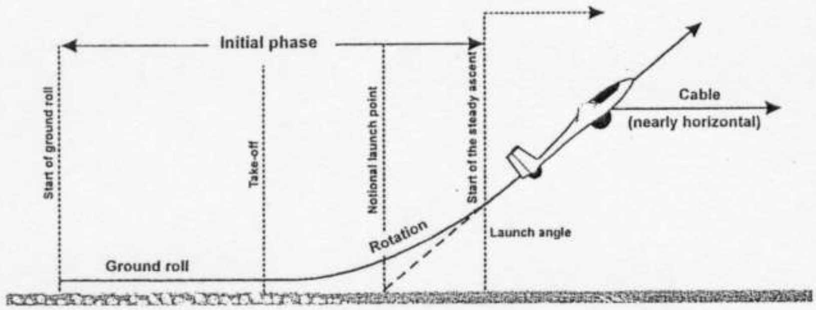
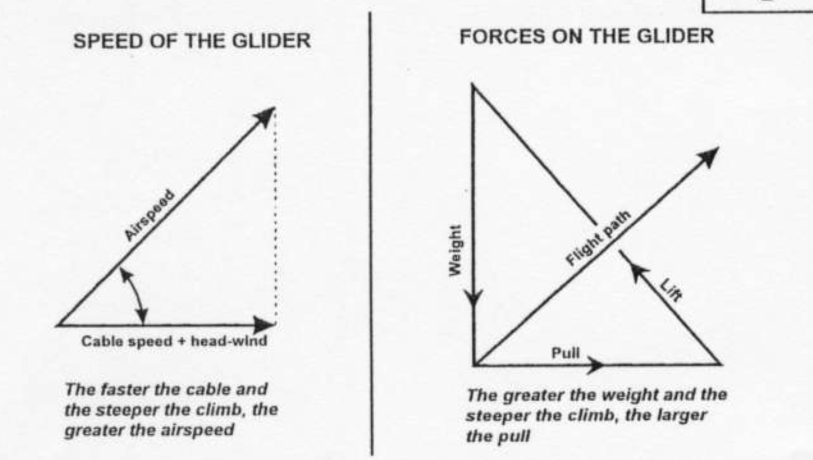


Fig 2

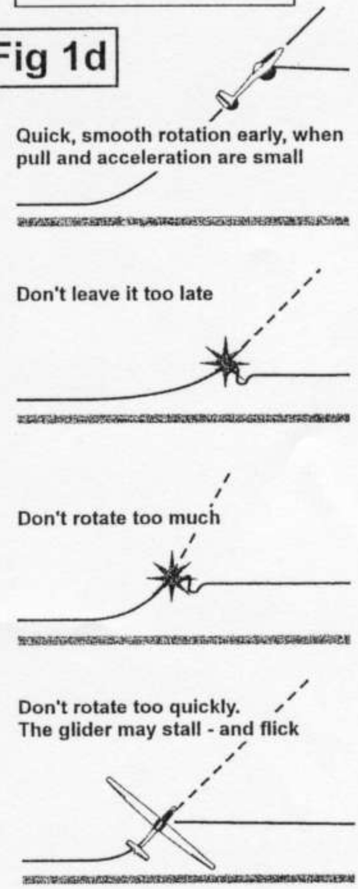
Fig 1a THE WINCH LAUNCH



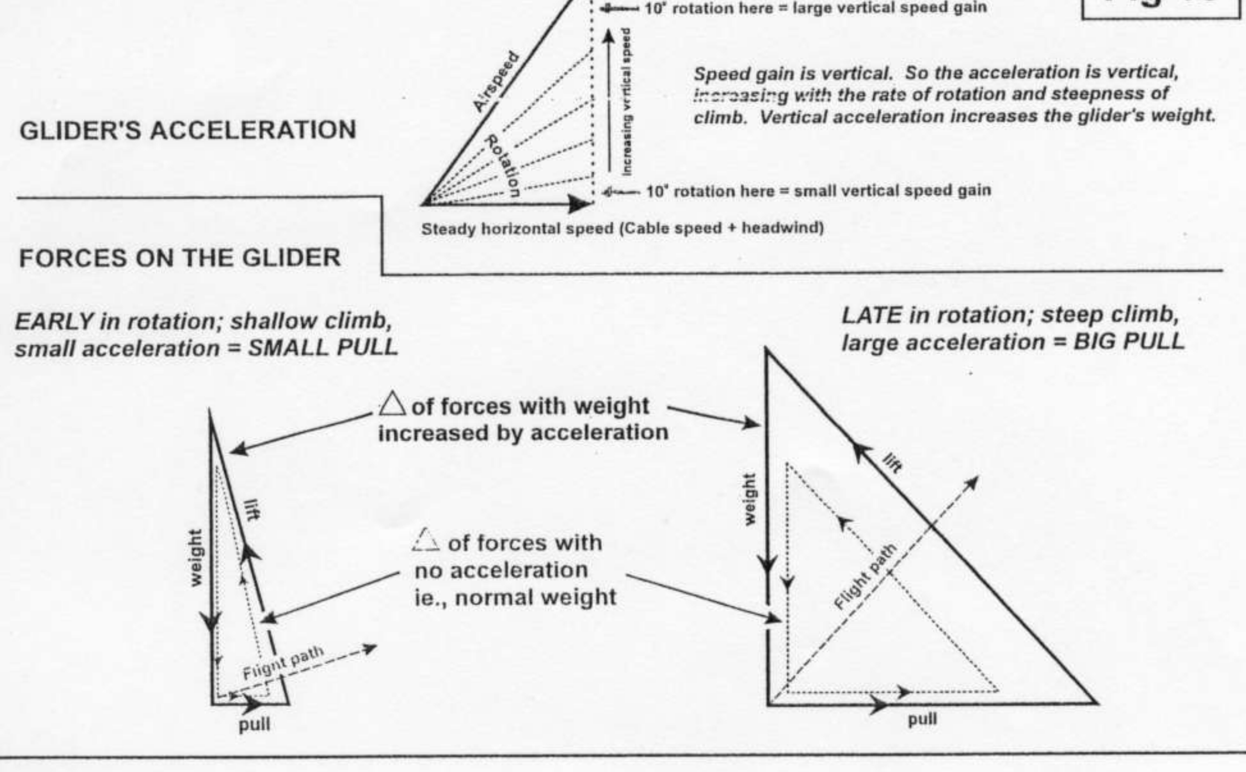
DURING STEADY ASCENT — Fig 1b



HOW TO AVOID BREAKING THE WEAK LINK — Fig 1d



DURING ROTATION — Fig 1c



terly, and if that fails, to settle in future for a less steep entry to the main ascent.

An example

Some figures may help to appreciate what has been described. Imagine a glider just airborne and level at 45kts. Suppose the pilot intends to enter the main ascent at 45°, an angle which is almost as steep as the weak link will allow. As the glider is rotated into a 45° climb, it will gain a vertical speed equal to its horizontal one, *ie* 45kts. So, if the rotation were completed in 4. 5sec (say), the glider would have a vertical acceleration averaging 10kts/sec, or a little more than 0.5*g*. That would increase the weight, and hence both pull and lift, by 50%.

But that is just an average; how the acceleration varies from point to point depends on the shape of the flight path adopted by the pilot to make the rotation. There are any number of possible paths - abruptly curved or gradual. But clearly the 0.5*g* acceleration cannot be sustained as the 45° attitude is approached because the weak link will certainly not tolerate the addition of 50% to pull at that point. So, the rate of rotation must be reduced there and, to keep up the average, made faster near the start where the pull is small enough to allow much more than a 50% increase.

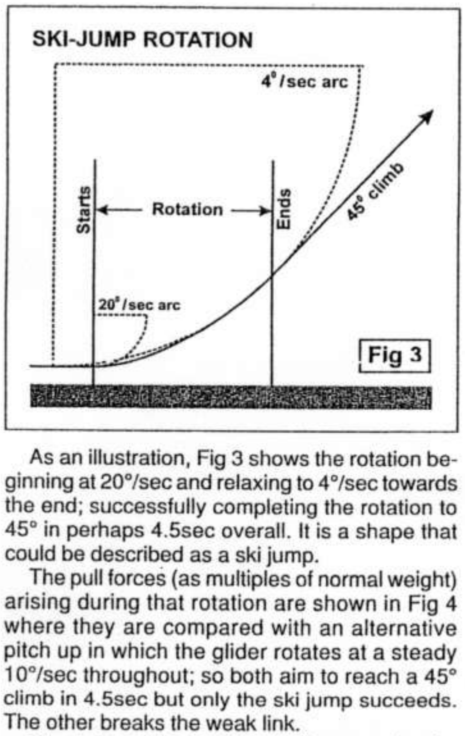


Fig 3

As an illustration, Fig 3 shows the rotation beginning at 20°/sec and relaxing to 4°/sec towards the end; successfully completing the rotation to 45° in perhaps 4.5sec overall. It is a shape that could be described as a ski jump.

The pull forces (as multiples of normal weight) arising during that rotation are shown in Fig 4 where they are compared with an alternative pitch up in which the glider rotates at a steady 10°/sec throughout; so both aim to reach a 45° climb in 4.5sec but only the ski jump succeeds. The other breaks the weak link.

The data in Fig 4 make no allowance for the weight and sag of the cable, nor the drag of the glider, so the pull forces would be a little larger in practice than those shown. Another practical point is that with the pull changing so rapidly the winch operator may not be able to hold the cable speed absolutely steady, but such variation as there is will be small compared with the 45kt gain of vertical speed; so the picture presented in Fig 4 will not be misleading in any important way. The abrupt reduction in pull as the glider reaches the 45° climb comes about because the pilot is

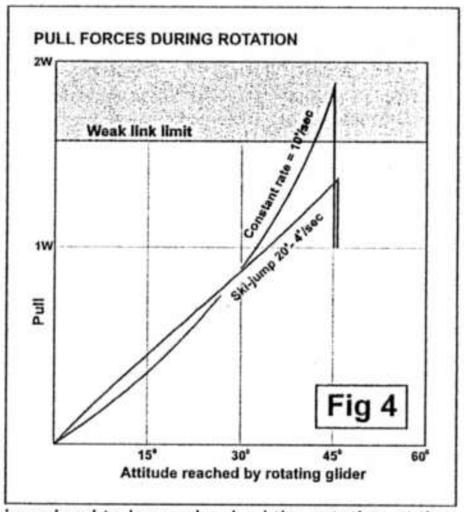


Fig 4

imagined to have checked the rotation at that point and thereby to have stopped the acceleration instantaneously. That is not entirely realistic and no doubt any practical attempt to fly the manoeuvre would produce some blunting of the peak. However, that also is a detail which does not invalidate Fig 4.

Stalling

A ski jump profile, which has a rapid rate of rotation into the climb immediately after take-off when the airspeed is low, can be expected to present some risk of stalling the glider. It is a possibility to take very seriously because such a stall might not be the gentle curtsy with which most gliders greet the stall in normal flight. Under the cable and manoeuvre loads which have been shown to arise during the rotation, a stalled glider might depart very violently from controlled flight. Indeed the BGA has in the past given publicity to catastrophic accidents which occurred in just these circumstances.

A measure of the risk can be made from the lift which is required during rotation. In normal gliding flight the lift very nearly equals the weight, so at a point in the rotation where the lift needed is more than the normal weight the stalling speed will have increased there. In the previous example the glider started to rotate at a rate of 20°/sec when its airspeed was 45kts. That can be calculated to give it a vertical acceleration of 0.82*g*. If its normal stalling speed were 33kts, then its new stalling speed would become very nearly 45kts. In short it would be just at the stall, and the proposed 20°/sec pitch up would be the fastest possible in these circumstances.

Such figures from one example have no general application, of course, but they serve to make the point that in every practical case there is the possibility of stalling the glider during the pitch up if the rotation is rapid enough. The measures to safeguard against it are to ensure that the glider is flying well above normal stalling speed before rotation is begun and to moderate the rate.

The figures in the example also suggest that, when pitching up too abruptly, the weak link is no certain protection against stalling. The 20°/sec rate produces a stall early in rotation when pull is well within the weak link limit. As the rotation progresses and the airspeed increases, the stall becomes generally less likely while the risk to the weak link grows. However, a stall can be induced at any stage if the rotation is seriously mishandled. That conclusion is in line with experience; cable breaks are much more common than stalls but the latter do sometimes occur and can proceed all the way to disaster with the weak link still unbroken.

Effect on final height

It is true, as was said at the outset, that the more quickly the rotation can be completed the more cable will remain for the main ascent and therefore the higher the launch. However, it is clear that being too precipitate risks a cable break or a stall. So it is worth assessing the trade-off between speed of rotation and final launch height

Consider the effect of a 1sec delay in completing the initial phase. If it is supposed that the cable speed is held steady at 45kts (76ft/sec), then the approximate displacement of the notional launch point (and hence the difference between the lengths of cable remaining) is 1sec at 76ft/sec, or 76ft. (Or it may be a little less than that, depending on the style of rotation the pilot uses.) Since the intended launch angle was 45°, the final height attainable will be about half the initial cable length. So each 1sec delay in completing the rotation will reduce the launch height attainable by about 38ft. If there is a headwind, the cable speed and the height foregone per second will be less.

As the climb angle is approached the loads on the glider are very sensitive to the rate of rotation. Many pilots might choose to slow down the rotation by 2 or 3sec and decide that the sacrifice of 80ft or so from the final launch height (less if there is a headwind) is worth making to enjoy a much less critical initial phase.

Although the figures used have no general application, they are not untypical. It can be instructive to time the rates of rotation in use by different pilots and to form a view of what rates are appropriate. But it needs bearing in mind that much depends on the steepness of the launch angle and the shape of the manoeuvre; the overall time taken is no measure of those aspects.

How the rotation appears to an onlooker is illustrated in Fig 5 which shows the flight paths in still air for the 20°-4°/sec ski jump and the 10°/sec constant rate examples. Both aim to reach a 45° launch angle in 4.5sec and have a constant cable speed of 45kts; so they move forward together but at different heights. It might seem that the ski jump is the more aggressive but it is the other which breaks the weak link, since it it does not reduce the rate of rota-

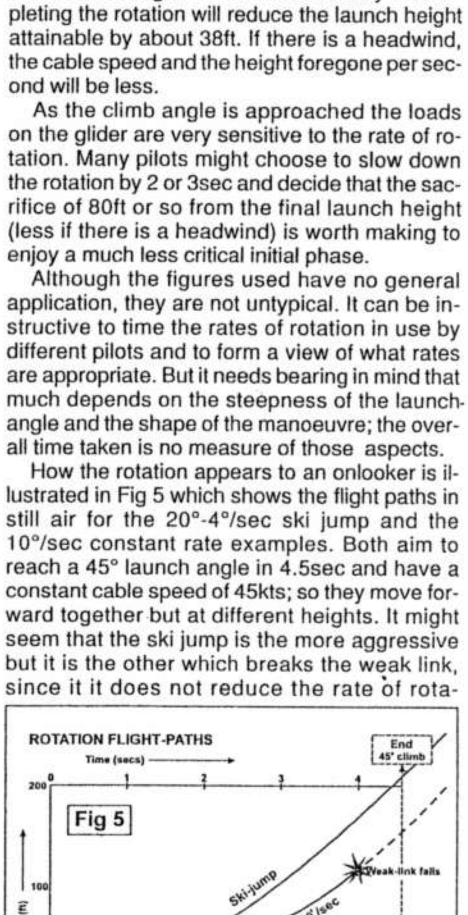


Fig 5

tion sufficiently as the climb steepens.

But it is only for the steepest launches that the rate of rotation becomes so important. As Fig 4 shows, for launch angles of 35° or less (as many club launches are), the pull forces are much the same for both examples and neither would break the weak link. Perhaps that leads to some lack of appreciation that any one technique is better than another.

Wind

Headwind benefits the launch because less cable speed is needed; so, in the ground roll and during the time taken for the rotation, less cable is wound in and more remains for the main ascent. (And that in turn gains much added height from a headwind.)

To the pilot it is apparent that the ground roll takes less time and much less distance but, once airborne, his technique in the rotation and climb needs no change on account of the headwind. He flies attitude and airspeed in the same way whether there is a headwind or not; the vertical acceleration and the forces involved are not altered, although to an onlooker the rotation may appear unusually abrupt when foreshortened by a headwind.

However, windy conditions are often gusty ones in which the entry to the main ascent will not be well controlled. So the launch angle may need to be less steep than the weak link would tolerate in smooth conditions. Crosswinds impose gusting limitations on the launch angle but without the benefits to best height, so they are wholly adverse to performance.

Summary

To reach best height from a winch launch the initial climb must be as steep as the weak link will allow and it must start as soon as possible after the launch. However, rotation into the climb accelerates the glider upwards and has the effect of increasing its weight. As a consequence, pull and wing loading are similarly increased during rotation. The effect becomes greater as the climb steepens, so the rate of rotation must be reduced to near zero as the limiting angle of climb is approached, otherwise the weak link will be broken. This suggests that a ski jump shape is a good model to take for the manoeuvre, in which the rapid rotation is done early. However, care is needed not to stall the glider by unduly rapid rates of rotation.