Effect of Bank Angle on Stall Speed

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In the previous article we looked at the effect of weight on the stall speed of a glider. In this article we will consider what the effect of bank angle has on the stall speed, and other important speeds of the glider.
For a glider in straight and level flight we can regard the lift being generated by the wings as practically equal to weight. Load factor is defined as the lift being generated by the wings divided by the weight of the glider, and therefore the load factor is 1. Load factor is sometimes erroneously referred to as the ‘g’ force.

When is the load factor other than 1? There are 3 common scenarios for a glider:

- When the glider is hist by a strong gust. If the gust has an upward component, the effect on the wing loading is even more pronounced

- When flying at high speeds, if the stick is pulled back, eg to zoom climb into a thermal, the angle of attack of the wing increases, and thus the coefficient of lift. As previously shown by the equation $L=½\rho V^2SC_L$, if the coefficient of lift increases, the lift generated by the wing increases. As the sailplane weighs the same the result it that, for a short time, the sailplane climbs. As the lift generated is greater than the weight of the sailplane, the load factor increases too.

- The final, more common, scenario is that of turning. When a glider is banked, the lift generated by the wings is no longer vertical. The weight of the glider still acts vertically however, and so, to avoid a spiral dive, more lift must be generated by the wings to compensate, increasing the load factor.

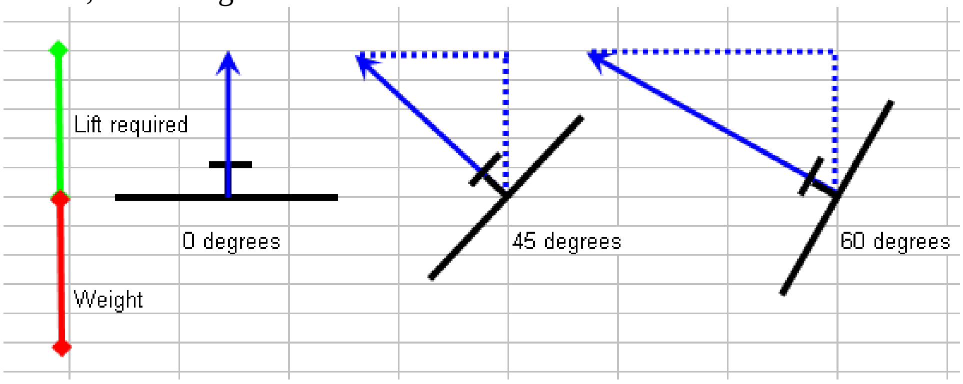

Figure 1 Additional lift required at varying angles of bank

As can be seen from the diagram above, as the bank angle increases, the load factor increases.
The load factor can be shown (not by me ☺) to be equal to the reciprocal of the cosine of the bank angle, as follows.

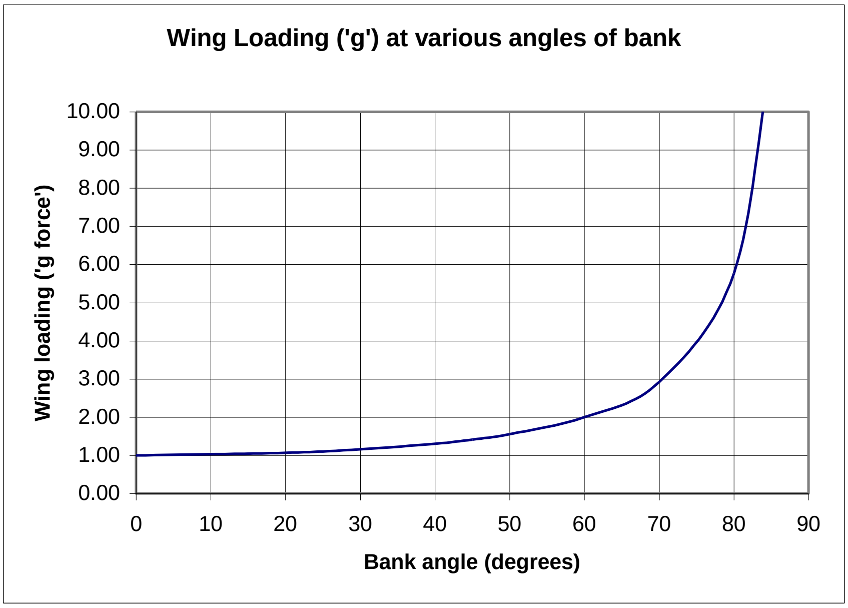

Figure 2 Load factor at varying angles of bank

Note that the load factor increases exponentially and accelerates rapidly after 45 degrees of bank, and reaches 2 at 60 degrees of bank

Degrees of bank	0	20	30	40	45	50	60	70	80	85
Load factor(g) N	1.00	1.06	1.15	1.31	1.41	1.56	2.00	2.92	5.76	11.47

Figure 3 Load factor at varying angles of bank

What is the effect of the load factor on the stall speed of a glider?
As in the previous article, it is possible to calculate the increase in stall speed; for brevity this can be described by the equation

$$Vsa = Vs \sqrt{N}$$

Where V_{sa} is the accelerated stall speed (ie the stall speed for the increased load factor), V_s is the unaccelerated stall speed and N is the load factor

Assuming a stall speed of 38 knots, such as the DG1000 flown dual, the table in figure 3 can be amended to show the stall speed at each bank angle

Degrees of bank	0	20	30	40	45	50	60	70	80	85
Load factor(g) N	1.00	1.06	1.15	1.31	1.41	1.56	2.00	2.92	5.76	11.47
Square root of N	1.00	1.03	1.07	1.14	1.19	1.25	1.41	1.71	2.40	3.39
Stall Speed (kt)	38	39	41	43	45	47	54	65	91	129

Figure 4 Stall speed at varying angles of bank

What else can this be used for? An example is to calculate the optimum speed to thermal at various angles of bank. Note: as the wing loading is increased, the induced drag also increases. This has been ignored for the purpose of this exercise.

Degrees of bank	0	20	30	40	45	50	60	70	80	85
Load factor(g) N	1.00	1.06	1.15	1.31	1.41	1.56	2.00	2.92	5.76	11.47
Square root of N	1.00	1.03	1.07	1.14	1.19	1.25	1.41	1.71	2.40	3.39
Stall Speed (kt)	38	39	41	43	45	47	54	65	91	129
Min sink speed	49	51	53	56	58	61	69	84	118	166

Figure 5 Min sink speeds at varying angles of bank

The lesson that can be learned from this exercise is that although it can be flown very slowly in thermals, the DG1000 at a bank angle of 45 degrees, should be flown at almost 60 knots to obtain the optimum climb rate. Thermalling steeply at 45 knots is not only inefficient, it is very close to the stall.

Finally, can the effect of weight and the effect of wing loading be combined? Yes it can.
If we take the speeds in figure 5 and recalculate for a wind loading of 42.8kg/sq m, i.e. maximum takeoff weight, the following speeds result

Degrees of bank	0	20	30	40	45	50	60	70	80	85
Load factor(g) N	1.00	1.06	1.15	1.31	1.41	1.56	2.00	2.92	5.76	11.47
Square root of N	1.00	1.03	1.07	1.14	1.19	1.25	1.41	1.71	2.40	3.39
Stall Speed (kt)	38	39	41	43	45	47	54	65	91	129
Min sink speed	49	51	53	56	58	61	69	84	118	166
Square root of (42.8/35)	1.106	1.106	1.106	1.106	1.106	1.106	1.106	1.106	1.106	1.106
Stall speed at 42.8kg(kt)	42	43	45	48	50	52	60	72	101	143
Min sink speed at 42.8kg	54	56	59	62	64	67	76	93	130	184

As can be seen, at a bank angle of 45 degrees, the min sink speed at max takeoff weight is 64knots, and this is the optimum thermalling speed at that weight.

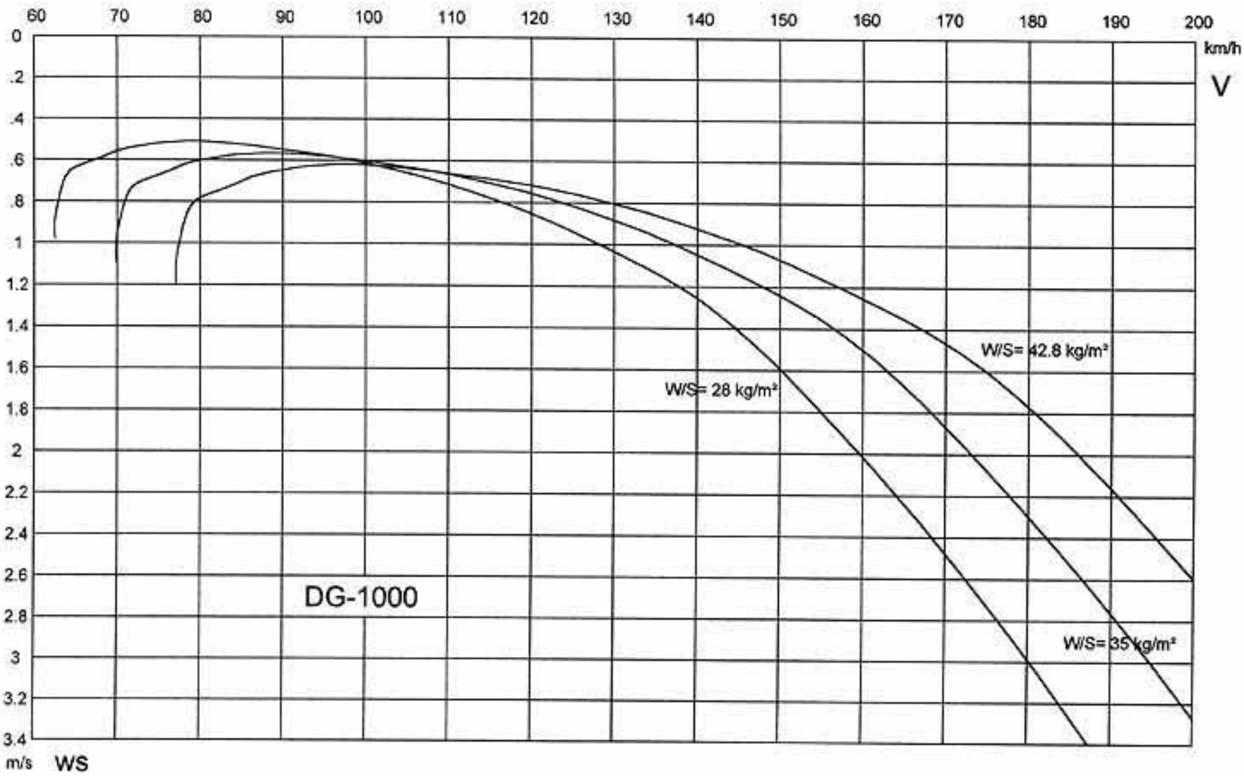

Figure 6 DG1000 Polar (20m Mode)