SIMPLE CRITERIA FOR TOWING HOOK LOCATION

by Wielaw Stafiej, Poland

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1. INTRODUCTION

The problem of the correct behavior of a glider in towed flight is very often discussed among the designers and groups responsible for safety.

During take-off the gliders, especially those of a great span, the inertia moments of which are high, suffer troubles due to disturbance of the take-off path when catching the wing tip on the grass or other obstacle.

In such a situation a recovery moment of the towing cable is necessary to regain the initial direction of the ground run.

So for good control there must be a satisfactory arm of the towing cable force about the glider c.g. In other words the towing hook location should be as close to the fuselage nose as possible.

This requirement, however, is adverse for performance reasons, where the designers attempt to preserve the laminar flow on the fuselage front part as far as possible. The towing hook creates a source of air-stream perturbation and leads to turbulent flow, decreasing the low-drag portion of the fuselage wetted area.

The designers thus have to balance the two things – performance and safety in towed flight.

Since the problems are complex it is not possible to give a full and simple criterion for the towing hook location. Nevertheless some data based on statistics as well as the test pilots opinion can be helpful in making the choice.

2. FORM OF CRITERIA

In practice the basic characteristics of towed flight depend on the ability of the glider to stabilize the flight path. When the trajectory is disturbed the towing cable force should produce a moment to cause the glider to follow the towing airplane path.

This situation depends mainly on two factors:

- towing hook location,
- inertia characteristics of the glider.

To create a simple criterion containing both above factors it is necessary to make some assumptions:

1. For comparison purposes the cable force has been taken as equal for all the gliders compared. For simplicity of calculation it has been taken P_{cab} as 1000 N.

2. The assumed trajectory disturbance pattern follows the requirements of JAR-22. The cable is displaced:

- in vertical plane 40° downwards and forwards
- in horizontal plane 30° sidewards and forwards.

This means that a different criteria must be established for the vertical and horizontal planes.

The general shape of the criterion is proposed in the form:

$$k = \frac{P_{cab} \cdot r}{J} \qquad (1)$$

where:

P_{cab} - cable force of 1000 N
r - arm of the cable force in respect to glider c.g. and axis under consideration
J - inertia moment about glider c.g. and axis under consideration.

So the numerator reflects the stabilizing moment of the cable force and the denominator defines the glider inertia.

3. VERTICAL PLANE CRITERION

As shown on Figure 1 the towing cable arm about glider c.g. and lateral axis /"y"/ is:

$$r_y = x \sin 40^\circ - z \cos 40^\circ \qquad (2)$$

where:

x - longitudinal distance between the glider c.g. and towing hook,
z - vertical distance between above points.

For an angular displacement of 40° the formula (2) becomes:

$$r_y = 0{,}643\, x - 0{,}766\, z \qquad (3)$$

From (1) and (3) the criterion for the vertical plane is:

$$k_y = \frac{1000}{J_y} (0{,}643\, x - 0{,}766\, z) = \frac{643\, x - 766\, z}{J_y} \qquad (4)$$

where:

J_y - inertia moment about the lateral axis /"y"/ and glider c.g.

4. HORIZONTAL PLANE CRITERION

The circumstances for the horizontal plane are shown on Fig. 2.
The towing cable arm is:

$$r_x = x \sin 30^\circ \qquad (5)$$

which for the displacement of 30° becomes:

$$r_x = 0{,}5\, x \qquad (6)$$

The horizontal plane criterion is thus:

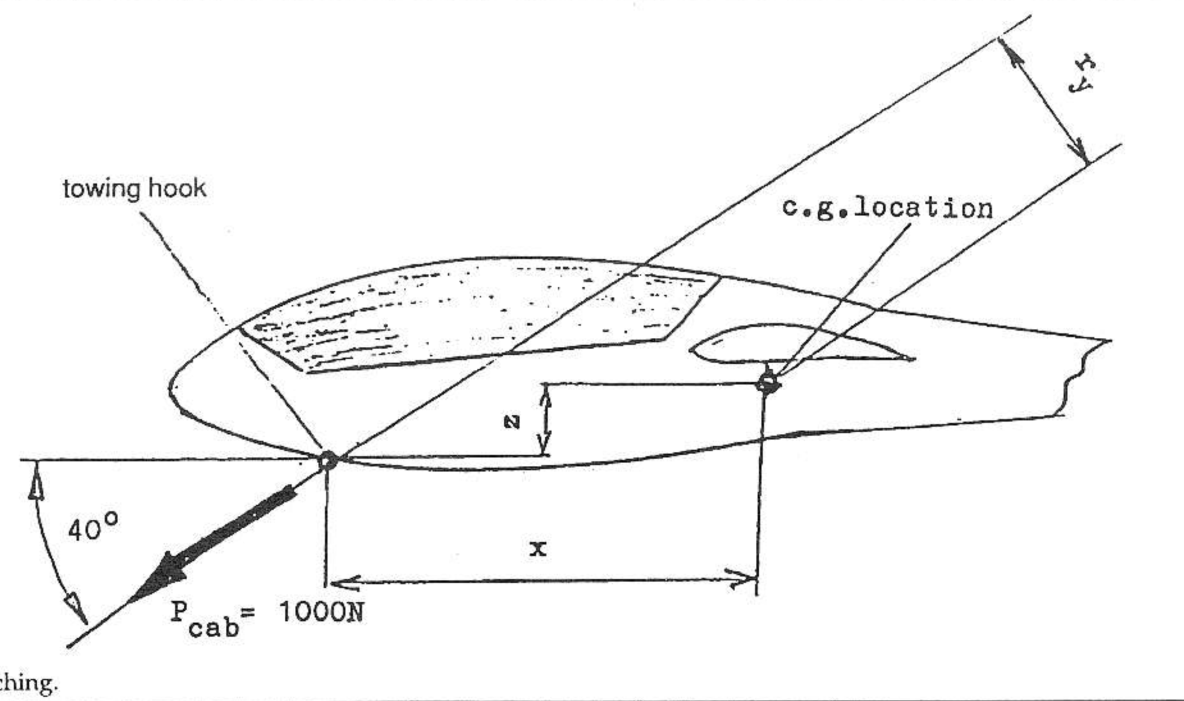

Figure 1. Pitching.

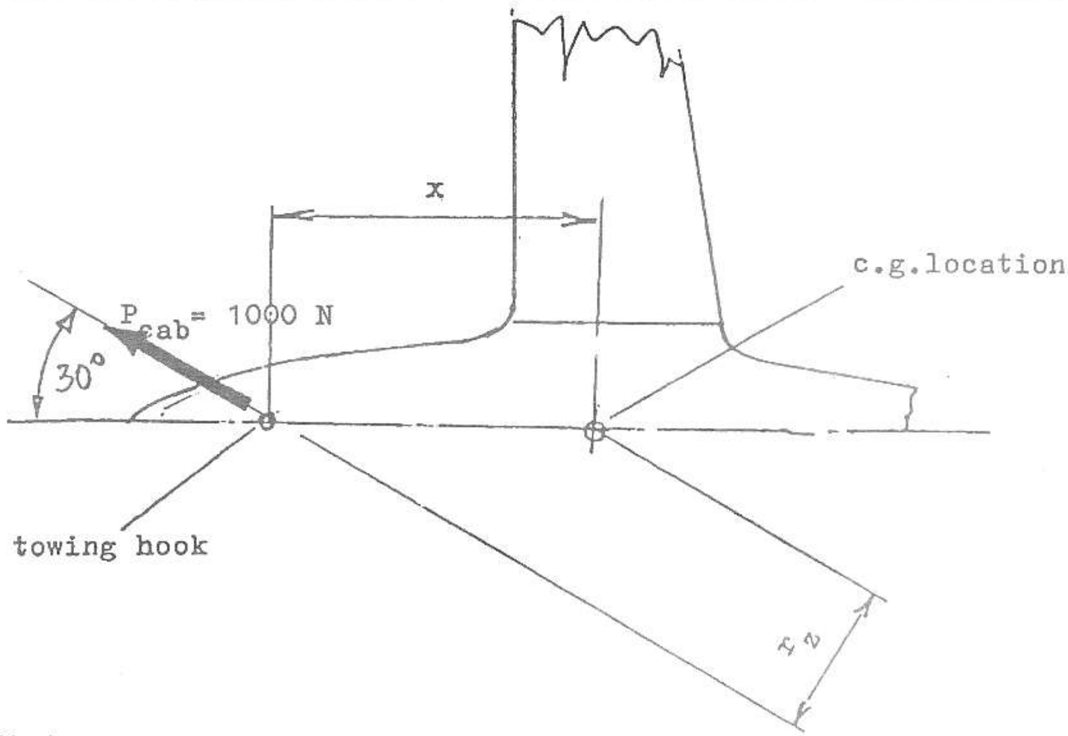

Figure 2. Yawing.

GLIDER	FRONT C.G.					
	x	z	I_y	I_z	k_y	k_z
	m		kgm²		sec⁻¹	
SZD-24 FOKA	1.290	0.520	437	2053	0.987	0.314
SZD-25 LIS	1.170	0.530	354	1784	0.977	0.327
SZD-27 KORMORAN */	2.382	0.530	1116	3988	1.008	0.299
SZD-29 ZEFIR 3	1.770	0.365	1128	5513	0.760	0.160
SZD-30 PIRAT	2.056	0.574	473	2534	1.865	0.405
SZD-31 ZEFIR 4	1.770	0.365	1344	6591	0.638	0.134
SZD-32 FOKA 5	1.246	0.474	674	2551	0.649	0.244
SZD-35 BEKAS */	2.290	0.345	1005	3774	1.202	0.303
SZD-36 COBRA	1.796	0.487	749	2653	1.044	0.338
SZD-38 JANTAR 1	1.510	0.477	625	5060	0.968	0.149
SZD-40X HALNY */	2.100	0.592	1183	8134	0.751	0.129
SZD-41 JANTAR STD. 1	1.389	0.476	548	2769	0.962	0.251
SZD-42 JANTAR 2	1.390	0.358	758	7002	0.816	0.099
SZD-42-2 JANTAR 2B	1.422	0.468	852	7786	0.652	0.099
SZD-43 ORION	1.369	0.454	760	2717	0.700	0.252
SZD-48-1 JANTAR STD.2	1.339	0.480	509	3718	0.968	0.180
SZD-50-3 PUCHACZ */	2.505	0.731	1161	4052	0.905	0.309
SZD-51-1 JUNIOR	2.107	0.716	592	2652	1.362	0.397
SZD-55-1	1.262	0.424	634	2752	0.767	0.229

*/ - two-seater

Table 1.

$$k_z = \frac{1000}{J_z} 0,5\ x = \frac{500}{J_z} x \qquad (7)$$

where:

J_z - inertia moment about the vertical axis /"z"/ and glider c.g.

5. INFLUENCE OF C.G. LOCATION

To reflect the glider c.g. location the corresponding values of distances "x" and, "z" should be taken into account for:

- front c.g. limit, and

- rear c.g. limit.

The corresponding glider masses should also be taken into account in calculating the inertia moments.

The criteria are thus established for front and rear c.g. locations.

6. CALCULATION RESULTS

To obtain a wide range of statistics the criteria calculations have been made for 19 gliders designed in Poland, including various types namely: performance, training, single and two-seater types.

For every glider model the following

GLIDER	REAR C.G.					
	x	z	J_y	I_z	k_y	k_z
	m		kgm^2		sec^{-1}	
SZD-24 FOKA	1.400	0.560	422	2021	1.116	0.346
SZD-25 LIS	1.321	0.570	343	1727	1.201	0.382
SZD-27 KORMORAN */	2.548	0.622	997	3887	1.165	0.328
SZD-29 ZEFIR 3	1.910	0.492	1025	5415	0.830	0.176
SZD-30 PIRAT	2.154	0.608	416	2639	2.209	0.408
SZD-31 ZEFIR 4	1.910	0.402	1225	6475	0.750	0.147
SZD-32 FOKA 5	1.397	0.513	613	2504	0.823	0.279
SZD-35 BEKAS */	2.500	0.440	909	3708	1.396	0.337
SZD-36 COBRA	1.916	0.515	673	2587	1.244	0.377
SZD-38 JANTAR 1	1.670	0.477	578	4640	1.225	0.180
SZD-40X HALNY */	2.222	0.610	1088	8031	0.883	0.138
SZD-41 JANTAR STD. 1	1.604	0.518	547	2475	1.158	0.324
SZD-42 JANTAR 2	1.572	0.387	731	6888	0.977	0.114
SZD-42-2 JANTAR 2B	1.605	0.495	746	6976	0.875	0.115
SZD-43 ORION	1.572	0.480	657	2583	0.919	0.293
SZD-48-1 JANTAR STD. 2	1.554	0.522	513	2592	1.167	0.300
SZD-50-3 PUCHACZ */	2.805	0.781	936	3888	1.287	0.360
SZD-51-1 JUNIOR	1.352	0.762	544	2609	1,610	0.316
SZD-55-1	1.454	0.438	580	2373	1.033	0.306

*/ - two-seater

Table 2.

entry data have been presented:

x - longitudinal position of the towing hook with respect to glider c.g.

z - vertical position of the towing hook with respect to glider c.g.

J_y - inertia moment about "y" axis and glider c.g.

J_z - inertia moment about "z" axis and glider c.g.

The results are shown in:

- front c.g. location /Tab. I/, and
- rear c.g. location /Tab. II/.

7. CONCLUSION

The gliders: SZD-31 "ZEFIR 4," SZD-32 "FOKA 5," SZD-42 "JANTAR 2" and SZD-42-2 "JANTAR 2B" are reported by the pilots to be rather difficult in aerotowing, especially during the ground run for take-off. Some troubles are met also with gliders: SZD-29 "ZEFIR 3", SZD-40X "HALNY," SZD-43 "ORION" and SZD-55-1.

Comparison of the pilot opinion with the calculation results shows that:

- In the vertical plane /pitching/ the criterion value of k_y <0,8 for the front c.g. limit and k_y <1,0 for the rear c.g. limit are within the area of poor towing behavior. For the values of k_y <0,7 for front c.g. limit and k_y <0,8 for rear c.g. limit the severe difficulty can be met, especially at the beginning of the ground run for take-off.

- In the horizontal plane /yawing/ for the criterion values k_z <0,25 for the front c.g. limit and k_z <0,20 for the rear c.g. limit the gliders are rather difficult to control on aerotowing and ground run as well.