Subject: Re: Sailplane performance as a function of CG
Date: Sun, 09 Jan 2000 15:49:16 GMT
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On Fri, 07 Jan 2000 19:37:23 GMT, pattist@DONTSPAMME.worldnet.att.net (Todd Pattist) wrote:

>I'd be very interested to know if there are any sailplanes
>that produce positive lift on the tail at any airspeed when
>the CG is legal but at the rearmost position. I've never
>been able to get hard facts - mostly I've heard opinions and
>a repeat of the "negative tail lift is stable" story.

The amount of lift that is actually produced by the tail (whether it is directed upwars or downwards doesn't matter) during cruise conditions (1 g) is usually very small - the CL that is needed is usually below 0.1, therefore the induced drag of the tail is low. It looks different for very high and very low speeds as well as for non-1g-conditions such as pullig up or flying non-straight.

The tail does produce no lift for only one given airspeed , CG and g-force. Shifting the CG will have the result that it does produce lift to compensate the force of the shifted CG - therefore shifting the CG backward will make the tail indeed produce some lift. But the amount of lift will usually be minimal (see numbers below).

The Longitudinal stability is defined by the Longitudinal stability coefficient (let's call it Roh).

According to JAR 22 Roh must be at least 0.05 to provide suffient longitudinal stability (Roh= 0 would make the aircraft indifferent, Roh < 0 would make it instable (and uncontrollable)).

The basic idea of this thread was to replace the aerodynamic force produced by the tail by weight-force produced by gravity. Basically this would be possible, but the slightest change in g-loading would alter the weight-force which would have to be corrected by the elevator.

[This is why planes with (too) rear CG become ...hmmm... agile ... concerning the elevator authority.]

Since a rear GC is already close to the allowed specs (Roh = 0.05) a further move backwards wouldn't make sense - any deviation form the g-load that the current CG is optimized for would make the aircraft longitudinal instable.

Here's an example for some real numbers. They are (small) part of the initial calculations for the aircraft "Impulse" (see latest issue of the German magazine "aerokurier" for the aircraft - it's some kind of lighter "Lancair"). Although it is no glider, the numbers are similar, and especially the load-distribution over different g-loadings and CG-positions follows the same principle.

For the given CG of this calculation Roh is relatively high (0.259) since the cg is about in the center of the allowed range.

Note: Positive P_0 points upwards

Note the situation at n=1 at 98,44 km/h and 64 km/h (the design minimum airspeed) - at very low speeds the tail indeed produces lift.

N = Newton
kg = Kilograms

IAS:	n [gravity]		Roh ramp weight	P_0 [tail force]
98,44 km/h	0,00	0,259	329,14 kg	-43,06 N
98,44 km/h	1,00	0,259	329,14 kg	-17,74 N
130,75 km/h	1,76	0,259	329,14 kg	-31,29 N
163,06 km/h	2,74	0,259	329,14 kg	-48,67 N
195,38 km/h	3,94	0,259	329,14 kg	-69,86 N
227,69 km/h	5,35	0,259	329,14 kg	-94,88 N
260,00 km/h	4,40	0,259	329,14 kg	-188,97 N
402,50 km/h	4,40	0,259	329,14 kg	-608,51 N
402,50 km/h	-1,50	0,259	329,14 kg	-757,95 N
156,62 km/h	-2,20	0,259	329,14 kg	-164,73 N
150,87 km/h	-1,39	0,259	329,14 kg	-136,41 N
145,12 km/h	-1,29	0,259	329,14 kg	-126,21 N
139,37 km/h	-1,19	0,259	329,14 kg	-116,41 N
133,63 km/h	-1,09	0,259	329,14 kg	-107,01 N
127,88 km/h	-1,00	0,259	329,14 kg	-98,00 N
127,88 km/h	0,00	0,259	329,14 kg	-72,67 N
64,00 km/h	0,00	0,259	329,14 kg	-18,20 N
64,00 km/h	1,00	0,259	329,14 kg	7,13 N
69,30 km/h	1,17	0,259	329,14 kg	8,36 N
74,60 km/h	1,36	0,259	329,14 kg	9,68 N
79,91 km/h	1,56	0,259	329,14 kg	11,11 N
85,21 km/h	1,77	0,259	329,14 kg	12,63 N
90,51 km/h	2,00	0,259	329,14 kg	14,25 N
160,00 km/h	2,00	0,259	329,14 kg	-63,11 N

Now the same numbers for rear CG (Roh= 0.074). The rear CG is a function of maximum cockpit load and empty fuel tanks, resulting in higher ramp weight.
Note the much higher tail loads for high g-loadings.

98,44	0,00	0,074	479,14	-43,06
98,44	1,00	0,074	479,14	279,75
130,75	1,76	0,074	479,14	493,54
163,06	2,74	0,074	479,14	767,62
195,38	3,94	0,074	479,14	1101,97
227,69	5,35	0,074	479,14	1496,61
260,00	4,40	0,074	479,14	1119,98
402,50	4,40	0,074	479,14	700,44
402,50	-1,50	0,074	479,14	-1204,18
156,62	-2,20	0,074	479,14	-819,20
150,87	-1,39	0,074	479,14	-550,49
145,12	-1,29	0,074	479,14	-509,34
139,37	-1,19	0,074	479,14	-469,79
133,63	-1,09	0,074	479,14	-431,84
127,88	-1,00	0,074	479,14	-395,49
127,88	0,00	0,074	479,14	-72,67
64,00	0,00	0,074	479,14	-18,20
64,00	1,00	0,074	479,14	304,61
69,30	1,17	0,074	479,14	357,17
74,60	1,36	0,074	479,14	413,92
79,91	1,56	0,074	479,14	474,84
85,21	1,77	0,074	479,14	539,94
90,51	2,00	0,074	479,14	609,23
160,00	2,00	0,074	479,14	531,87

Now the summarized tail loads for different airspeeds and different CG's during cruise flight (n=1) - these are the interesting numbers... ;)

Note that negative P_0 means that the tail force points downward.

The only thing you have to do now is to collect the P_0 for a given CG and Ramp weight over all the airspeeds - then you can decide whether the tail produces always lift or not.

For gliders the numbers are different, but the priciple is the same.

BTW:
This was the de-luxe version of my German article... <vbg>.

airspeed [km/h]			n	CG	Roh	ramp weight	P_0
270,00	270,00	1,00	1,842 m	0,26	329,1 kg		-298,6 N
	270,00	1,00	1,823 m	0,28	389,1 kg		-315,8 N
	270,00	1,00	1,923 m	0,18	446,6 kg		-179,6 N
	270,00	1,00	1,963 m	0,14	447,1 kg		-124,0 N
	270,00	1,00	1,924 m	0,18	439,1 kg		-180,5 N
	270,00	1,00	1,842 m	0,26	329,1 kg		-298,6 N
	270,00	1,00	1,810 m	0,29	449,1 kg		-333,0 N
	270,00	1,00	1,924 m	0,18	569,1 kg		-138,4 N
	270,00	1,00	2,038 m	0,07	479,1 kg		-1,2 N
	270,00	1,00	1,975 m	0,13	599,1 kg		-35,5 N
280,00	280,00	1,00	1,842 m	0,26	329,1 kg		-323,1 N
	280,00	1,00	1,823 m	0,28	389,1 kg		-340,2 N
	280,00	1,00	1,923 m	0,18	446,6 kg		-204,1 N
	280,00	1,00	1,963 m	0,14	447,1 kg		-148,5 N
	280,00	1,00	1,924 m	0,18	439,1 kg		-204,9 N
	280,00	1,00	1,842 m	0,26	329,1 kg		-323,1 N
	280,00	1,00	1,810 m	0,29	449,1 kg		-357,4 N
	280,00	1,00	1,924 m	0,18	569,1 kg		-162,8 N
	280,00	1,00	2,038 m	0,07	479,1 kg		-25,6 N
	280,00	1,00	1,975 m	0,13	599,1 kg		-59,9 N
290,00	290,00	1,00	1,842 m	0,26	329,1 kg		-348,4 N
	290,00	1,00	1,823 m	0,28	389,1 kg		-365,6 N
	290,00	1,00	1,923 m	0,18	446,6 kg		-229,4 N
	290,00	1,00	1,963 m	0,14	447,1 kg		-173,8 N
	290,00	1,00	1,924 m	0,18	439,1 kg		-230,3 N
	290,00	1,00	1,842 m	0,26	329,1 kg		-348,4 N
	290,00	1,00	1,810 m	0,29	449,1 kg		-382,7 N
	290,00	1,00	1,924 m	0,18	569,1 kg		-188,1 N
	290,00	1,00	2,038 m	0,07	479,1 kg		-50,9 N
	290,00	1,00	1,975 m	0,13	599,1 kg		-85,3 N
300,00	300,00	1,00	1,842 m	0,26	329,1 kg		-374,6 N
	300,00	1,00	1,823 m	0,28	389,1 kg		-391,8 N
	300,00	1,00	1,923 m	0,18	446,6 kg		-255,6 N
	300,00	1,00	1,963 m	0,14	447,1 kg		-200,0 N
	300,00	1,00	1,924 m	0,18	439,1 kg		-256,5 N
	300,00	1,00	1,842 m	0,26	329,1 kg		-374,6 N
	300,00	1,00	1,810 m	0,29	449,1 kg		-409,0 N
	300,00	1,00	1,924 m	0,18	569,1 kg		-214,4 N
	300,00	1,00	2,038 m	0,07	479,1 kg		-77,1 N
	300,00	1,00	1,975 m	0,13	599,1 kg		-111,5 N
110,00	110,00	1,00	1,842 m	0,26	329,1 kg		-28,4 N
	110,00	1,00	1,823 m	0,28	389,1 kg		-45,6 N
	110,00	1,00	1,923 m	0,18	446,6 kg		90,6 N
	110,00	1,00	1,963 m	0,14	447,1 kg		146,2 N

	110,00	1,00	1,924 m 0,18	439,1 kg	89,7 N
	110,00	1,00	1,842 m 0,26	329,1 kg	-28,4 N
	110,00	1,00	1,810 m 0,29	449,1 kg	-62,8 N
	110,00	1,00	1,924 m 0,18	569,1 kg	131,8 N
	110,00	1,00	2,038 m 0,07	479,1 kg	269,0 N
	110,00	1,00	1,975 m 0,13	599,1 kg	234,7 N
120,00	120,00	1,00	1,842 m 0,26	329,1 kg	-38,7 N
	120,00	1,00	1,823 m 0,28	389,1 kg	-55,8 N
	120,00	1,00	1,923 m 0,18	446,6 kg	80,3 N
	120,00	1,00	1,963 m 0,14	447,1 kg	135,9 N
	120,00	1,00	1,924 m 0,18	439,1 kg	79,5 N
	120,00	1,00	1,842 m 0,26	329,1 kg	-38,7 N
	120,00	1,00	1,810 m 0,29	449,1 kg	-73,0 N
	120,00	1,00	1,924 m 0,18	569,1 kg	121,6 N
	120,00	1,00	2,038 m 0,07	479,1 kg	258,8 N
	120,00	1,00	1,975 m 0,13	599,1 kg	224,5 N
130,00	130,00	1,00	1,842 m 0,26	329,1 kg	-49,8 N
	130,00	1,00	1,823 m 0,28	389,1 kg	-66,9 N
	130,00	1,00	1,923 m 0,18	446,6 kg	69,2 N
	130,00	1,00	1,963 m 0,14	447,1 kg	124,8 N
	130,00	1,00	1,924 m 0,18	439,1 kg	68,4 N
	130,00	1,00	1,842 m 0,26	329,1 kg	-49,8 N
	130,00	1,00	1,810 m 0,29	449,1 kg	-84,1 N
	130,00	1,00	1,924 m 0,18	569,1 kg	110,5 N
	130,00	1,00	2,038 m 0,07	479,1 kg	247,7 N
	130,00	1,00	1,975 m 0,13	599,1 kg	213,4 N
140,00	140,00	1,00	1,842 m 0,26	329,1 kg	-61,8 N
	140,00	1,00	1,823 m 0,28	389,1 kg	-78,9 N
	140,00	1,00	1,923 m 0,18	446,6 kg	57,2 N
	140,00	1,00	1,963 m 0,14	447,1 kg	112,8 N
	140,00	1,00	1,924 m 0,18	439,1 kg	56,4 N
	140,00	1,00	1,842 m 0,26	329,1 kg	-61,8 N
	140,00	1,00	1,810 m 0,29	449,1 kg	-96,1 N
	140,00	1,00	1,924 m 0,18	569,1 kg	98,5 N
	140,00	1,00	2,038 m 0,07	479,1 kg	235,7 N
	140,00	1,00	1,975 m 0,13	599,1 kg	201,4 N