P8 – 01 10 – 00056S
Pik 28
Stability & center of gravity limits

Sisällysluettelo

1 CALCULATION METHOD

Method is analytical analysis as described in:
Piero Morelli, Static stability and control of sailplanes, May 1976, OSTIV
This method is transferred to a spreadsheet, which can be found in:
www.HooTeeHoo.org/pik28/t1/ata01/index.html
Method is for sailplanes, but it is valid for all no-power flight conditions for Pik-28

The book has sample calculations done for a sample sailplane. Inserting these sample values in the spreadsheet, we can verify that the spreadsheet is correctly done.

2 SAMPLE DATA

SAILPLANE DATA
(used in the Sample Calculations within the text)

Sailplane total weight	W	=	300 kg
Wing loading	W/S	=	23,1 kg/m²
Induced drag effectiveness factor	e	=	0,94
Sailplane moment of inertia about X	Jz	=	157 kg•m•sec²
Allowed load factor	n	=	5,0 g
Wing:			
Wing span	b	=	15 m
Wing surface	S	=	13 m²
Wing aspect ratio	A	=	17,3
Wing lift-curve slope	a_w	=	5.4 per rad.
Wing max. lift coeff.	C_{Lmax}	=	1.35
Wing setting	i_w = 5°	=	0,087 rad
Wing m.a.c.	c	=	0,94 m
Wing zero lift moment coeff.	C_{MOW}	=	-0,1
Wing aerod. centre location (as a fraction of c)	x_a/c	=	0,25
Wing dihedral	Γ	=	2° .5
Wing root (centerline) chord	c_r	=	1,30 m
Wing tip chord	c_t	=	1,30 m
Wing taper ratio (straight tapered wing)	$r=c_t/c_r$	=	0,35
Wing section lift curve slope (per radian)	a_0	=	6,14
Fuselage:			
Fuselage length		=	4,20 m
	dC_{Mfus} / dC_{Lw}	=	0.03
	$(\Delta C_{Mow})_{fus}$	=	-0,007
Horizontal tail:			
Tail arm	l'_t	=	3,86 m
Tail span	b_t	=	3 m
Tail surface	S_t	=	1.6 m²
Tailplane surface	S_f	=	0.96 m²
Tail m.a.c	c_t	=	0,5 m

Tail m.a.c leading edge X location	X_{ct}	=	3,942 m
Downwash factor	$1 - d\varepsilon/d\alpha$	=	0,75
Elevator effectiveness	$\tau = \partial\alpha_t/\partial\delta$	=	0,58
Tab effectiveness	$\tau_{tab} = \partial\alpha_t/\partial\delta_{tab}$	=	0,02
Elevator hinge moment coefficient	b_0	=	0
Elevator surface	S_e	=	0.64 m²
Elevator mean chord	c_e	=	0.213
Elevator deflection up		=	-21 °
Tail lift curve slope	a_t	=	4.3 rad^{-1}
Tail setting	$i_t = -1°$	=	- 0.017 rad
Tail volumetric coeff.	$\overline{V'}$	=	0,506
Elevator gearing	G	=	2.5 $radm^{-1}$
Hinge moment coefficients	$b1 = \partial C_H/\partial Ms$	=	-0.010 deg^{-1}
Hinge moment coefficients	$b2 = \partial C_H/\partial\delta$	=	-0.015 deg^{-1}
Hinge moment coefficients	$b3 = \partial C_H/\partial\delta_{tab}$	=	-0.005 deg^{-1}
Landing attitude (in ground effect):			
Wing height	h_{wge}	=	3 m
Tailplane height	h_{tge}	=	3 m

3 SAMPLE RESULTS

When these were inserted in spreadsheet, results are as shown in blue cells. The values in red cells are those given as results in the book.
First three rows are for front cg limits and rest are for rear limits.

pull up, Clmax n=1	5,7%	4,3%
pull up, Clmax n=1, ground effect	6,6%	6,1%
pull up, Va, n max	9,7%	9,0%
stick free neutral point	39,7%	40%
dP/dn=-1(kg/g) pull, SL	42,9%	43%
stick free manouvring point, high altitude	49,8%	49%
stick fixed neutral point	50,1%	50%
dP/dn=-0,5(kg/g) pull, SL	51,3%	52%
stick fixed manouvring point, at high altitude	57,4%	58%
stick free manouvring point, SL	62,4%	60%
stick fixed manouvring point, SL	70,8%	68%

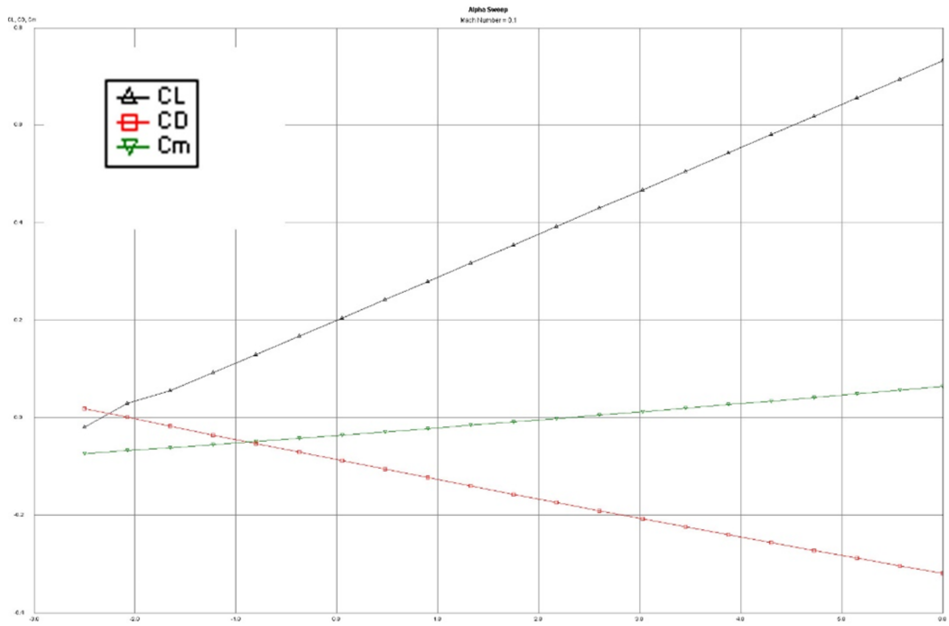
Difference in results can be traced in the fact, that book uses in its calculation two to three significant digits. Spreadsheet uses much more digits.
Values of Cessna 150 were tested and results were, that c.g range is 855 mm to 946 mm. Aircraft flight manual gives c.g. range as 829 mm to 927 mm.
Undoubtedly Cessna has been thoroughly flight tested, but taking that into account, spreadsheet gives pretty good results.

4 PIK 28 DATA

Start values are geometry dimension and some calculated values.

4.1 Wing geometry

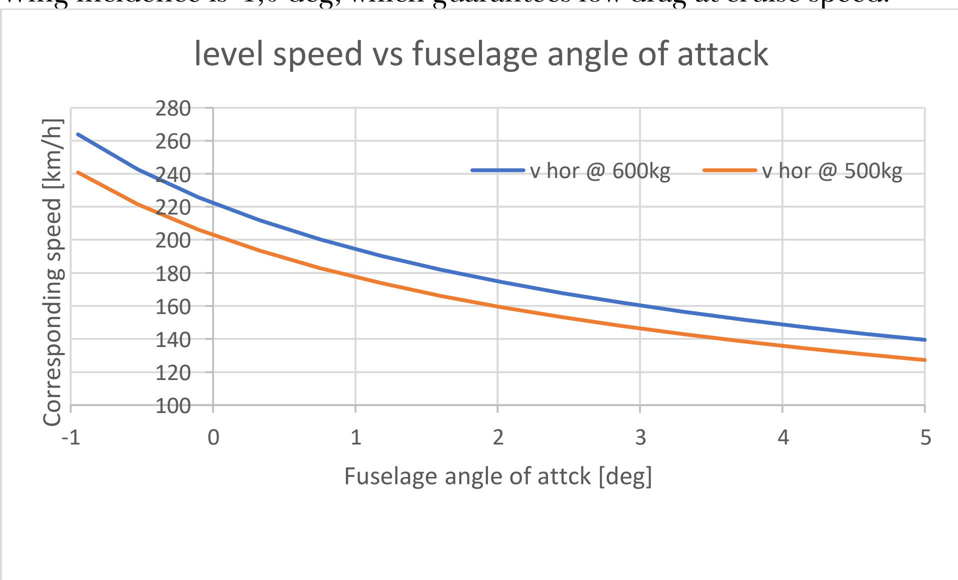
Wing geometry is taken from data sheet and 3D model.
Values were put in LinairPro 4.0 to calculate wing lift curve slope.



These are

Wing lift curve slope	5,0799 1/rad
Zero lift angle	-2,29 deg
Zero lift moment CL= 0	-0,0705
Zero lift drag CL=0	0,010034

Wing incidence is -1,0 deg, which guarantees low drag at cruise speed.



a = 5,0799 [1/rad]

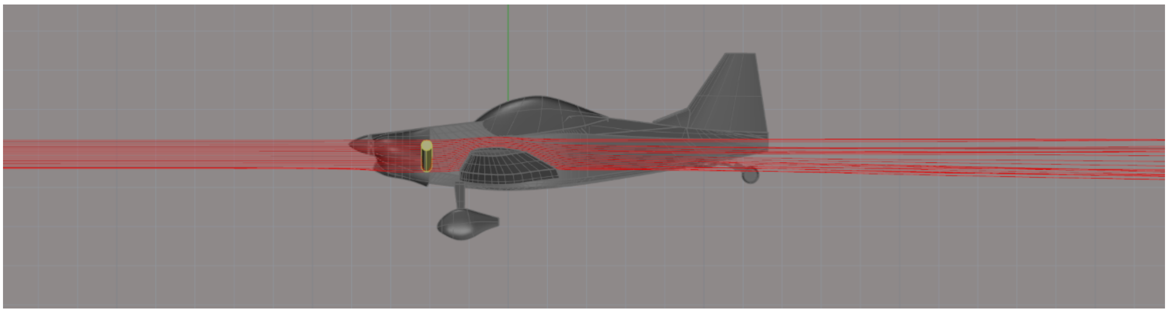
Wing aerodynamic mean chord:
Mac = 1,129 m
Winx apex X = 0,37 m
MAC LE X = 0,414

Horizontal tail values are defined in same way, and are:

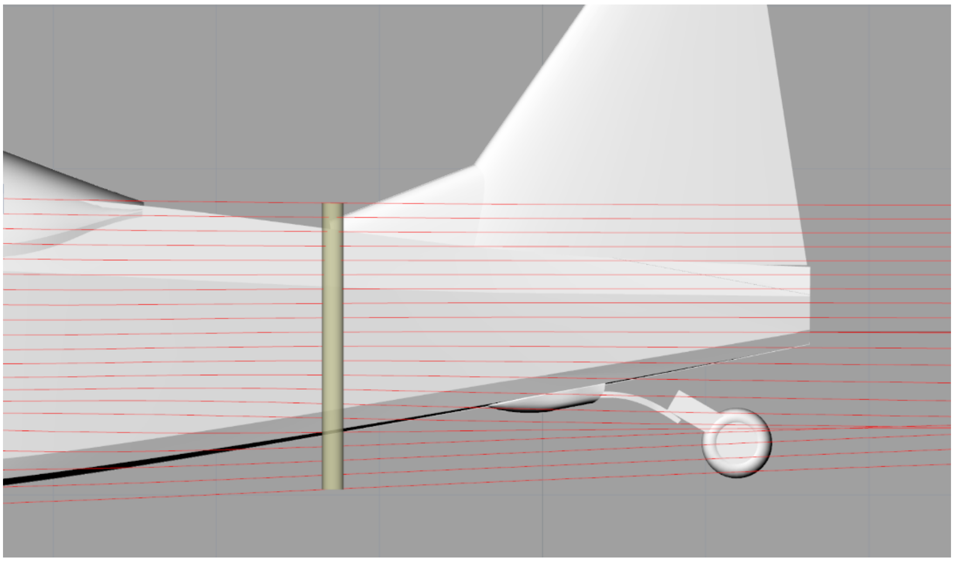
Tail MAC is
MAC t = 0,724 m
Tail lift curve slope
A = 4,6708 [1/rad]

4.2 Downwash

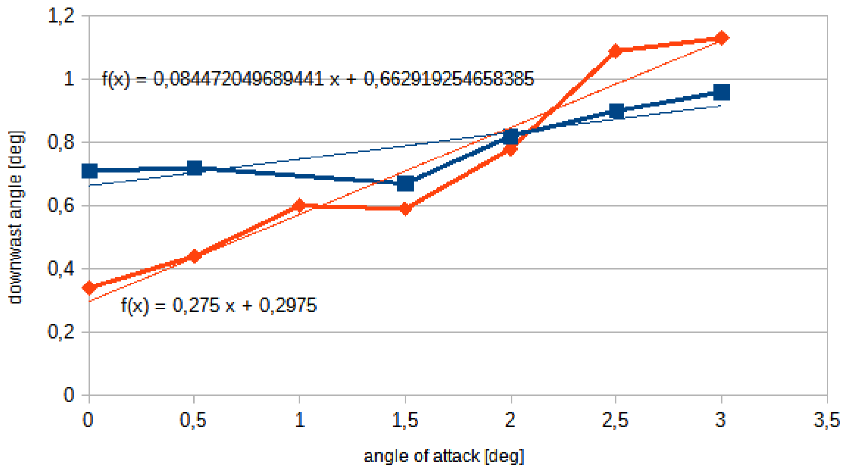
Downwash behind wing and how it changes has role in aircraft stability.
When wing produce lift, it turn flow downward (when lift is up).
This relation was determined using CFD.
See document P8-0110-00044S
In the picture below are streamlines from forward of wing at different spanwise locations.



The downwash was measured from Y locations of 0,5 and 1,0 meters at the horizontal tail location.



Measured downwash angles in graphical form are like this:



The value needed is $(1 - d\varepsilon/d\alpha)$ and its numeric value is 0,8203.

4.3 Pik 28 values

Values for calculation are:

AEROPLANE DATA

Aeroplane total weight	W	=	600 kg
Wing loading	W/S	=	68,57 kg/m²
Induced drag effectiveness factor	e	=	0,6
Aeroplane moment of inertia about X	Jz	=	18,9 kg•m•sec²
Allowed load factor	n	=	4,4 g
Wing:			
Wing span	b	=	8,14 m
Wing surface area	S	=	8,75 m²
Wing aspect ratio	A	=	7,57
Wing lift-curve slope	**a_w**	**=**	**5,0799 1/rad.**
Wing max. lift coeff.	C_{Lmax}	=	1.475
Wing setting	i_w	=	-1,02°
Wing m.a.c.	c	=	**1,129** m
Wing zero lift moment coeff.	C_{MOW}	=	-0,0705
Wing aerod. centre location (as a fraction of c)	x_a/c	=	0,25
Wing dihedral	Γ	=	3°
Wing root (centerline) chord	c_r	=	1,306 m
Wing tip chord	c_t	=	0,718 m
Wing section lift curve slope (per radian)	a_0	=	6,50
Fuselage:			
Fuselage length		=	6,61 m
	dC_{Mfus} / dC_{Lw}	=	0.03
	$(\Delta C_{Mow})_{fus}$	=	-0,007

Horizontal tail:

Tail arm	l'_t	=	**3,41** m
Tail span	b_t	**=**	**2,42** m
Tail surface	S_t	**=**	**1.83 m²**
Tailplane surface	S_f	=	0.958 m²
Tail apex X location			**3,768** m
Tail m.a.c	c_t	**=**	**0,768** m
Tail m.a.c leading edge X location	X_{ct}	**=**	**3,869** m
Downwash factor	$1 - d\varepsilon/d\alpha$	=	0,8203
Elevator effectiveness	$\tau = \partial\alpha_t/\partial\delta$	=	0,59
Tab effectiveness	$\tau_{tab} = \partial\alpha_t/\partial\delta_{tab}$	=	0,00
Elevator hinge moment coefficient	b_0	=	0
Elevator surface	S_e	=	0.835 m²
Elevator mean chord	c_e	=	0.970
Elevator deflection up		=	-35 °
Tail lift curve slope	a_t	=	4.30 rad^{-1}
Tail setting	i_t	=	+ 1,10°
Tail volumetric coeff.	$\overline{V'}$	=	0,612
Elevator gearing	G	=	2.5 radm^{-1}
Hinge moment coefficients	$b1 = \partial C_H / \partial Ms$	=	-0.010 deg^{-1}
Hinge moment coefficients	$b2 = \partial C_H / \partial \delta$	=	-0.015 deg^{-1}
Hinge moment coefficients	$b3 = \partial C_H / \partial \delta_{tab}$	=	-0.005 deg^{-1}
Landing attitude (in ground effect):			
Wing height	h_{wge}	=	0,79 m
Tailplane height	h_{tge}	=	0,6 m

5 CENTER OF GRAVITY LIMITS

5.1 Front limit

According to calculations, forward limits are

pull up, Clmax n=1	2,8 %
pull up, Clmax n=1, ground effect	13,9 %
pull up, Va, n max	-4,3 %

Test flight will define true values.
So initial forward limit is set to 14 % MAC.

5.2 Rear limit

According to calculations, forward limits are

stick free neutral point	42,4 %
dP/dn=-1(kg/g) pull, SL	41,7 %
stick free manouvring point, high altitude	44,3 %
stick fixed neutral point	51,1 %
dP/dn=-0,5(kg/g) pull, SL	44,9 %
stick fixed manouvring point, at high altitude	52,3 %
stick free manouvring point, SL	46,8 %
stick fixed manouvring point, SL	55,0 %

Neutral points looks to be fairly aft.
So initial rear limit is set to 37 % MAC, using 5% margin.

5.3 Flight limits

For initial flight testing limits are:
forward limit is set to 17 % MAC.
rear limit is set to 34 % MAC.

And in aircraft coordinates, center of gravity limits are:
571 mm - 829 mm.

6 SOURCES

/2/ Piero Morelli, Static stability and control of sailplanes, May 1976, OSTIV

— LOPPU —