Aircraft Design 1
Flying Qualities Criteria
(lateral modes)

Simplified Roll-Rate response criterion

Two factors are used to rate flying qualities in roll:

1. time constant T_R of inertial module, which describes roll characteristics using the first order transfer function:

$$G_R(s) = \frac{p(s)}{\delta_L(s)} = \frac{k_R}{T_R \cdot s + 1}$$

where:

p(t) – roll rate,

$\delta_L(t)$ – aileron deflection.

2. roll time T_φ to perform angle φ after aileron deflection δ_L

Simplified Roll-Rate response criterion

Analysis bases on the linear differential equation:

$$\dot{\Phi}(t) = -\left[\frac{L_{\delta a}\,\delta_a}{L_p}\right]\left(1 - e^{L_p t}\right)$$

where:

$$L_{\delta_a} = \frac{q\,S\,b\,C_{l_{\delta_a}}}{I_{xx}} \qquad L_p = \frac{q\,S\,b^2\,2\,C_{l_p}}{2\,I_{xx}\,V}$$

and:

$$C_{l_{\delta a}} = \frac{\partial\, C_l}{\partial\, \delta_a} \qquad C_{l_p} = \frac{\partial\, C_l}{\partial\, \frac{p\,b}{V}}$$

Simplified Roll-Rate response criterion

Roll characteristics are defined as follows:

- Time constant of roll mode $T_r = \frac{-1}{L_p}$. is time necessary to perform:

$$\left(1 - e^{-1}\right)\Phi_{ss} = 0.63\,\Phi_{ss}$$

where:

$\dot{\Phi}_{ss}$ is the steady value of roll rate

- Roll controllability:

$$T_{30} = -3\frac{b}{V}\left\{\frac{\dfrac{\partial C_l}{\partial \frac{p\,b}{V}}}{\dfrac{\partial C_l}{\partial \delta_a}}\right\}$$

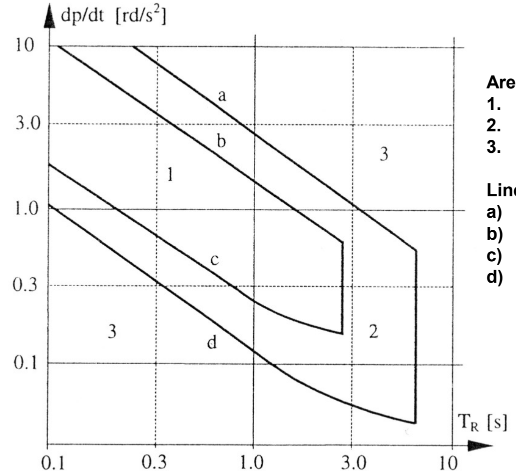
time necessary to roll from value 0° to 30° after aileron was deflected on 10°.

Simplified Roll-Rate response criterion

Roll time constant

Flight phase	Aircraft class	Acceptance level		
		1	2	3
		The biggest acceptable value T_R [s]		
A	I, IV	1.0	1.4	-
A	II, III	1.4	3.0	-
B	All	1.4	3.0	10
C	I, IV	1.0	1.4	-
C	II, III	1.4	3.0	

Simplified Roll-Rate response criterion



Areas:
1. **recommended**
2. **acceptable**
3. **unacceptable**

Lines:
a) **max roll rate 120°/s**
b) **max roll rate 60°/s**
c) **time to perform roll angle 60° - 6.5s**
d) **time to perform roll angle 60° - 10.5s**

Simplified Roll-Rate response criterion for transport aircraft

Roll controllability

Aircraft class	Flight phase	Acceptance level		
		1	2	3
		(φ-T) – roll angle φ[°] performed in time T [s]		
I	A B C	60° in 1.3 s 60° in 1.7 s 30° in 1.3 s	60° in 1.7 s 60° in 2.5 s 30° in 1.8 s	60° in 2.6 s 60° in 3.4 s 30° in 2.6 s
II	A B C	45° in 1.4 s 45° in 1.9 s 30° in 2.5 s	45° in 1.9 s 45° in 2.8 s 30° in 3.5 s	45° in 2.8 s 45° in 3.0 s 30° in 5.0 s
III	A B C	30° in 1.5 s 30° in 2.0 s 30° in 3.0 s	30° in 2.0 s 30° in 3.0 s 30° w 4.0 s	30° in 3.0 s 30° in 4.0 s 30° in 6.0 s
IV	A B C	90° in 1.3 s 60° in 1.7 s 30° in 1.0 s	90° in 1.7 s 60° in 2.5 s 30° in 1.3 s	90° in 2.6 s 60° in 3.4 s 30° in 2.0 s

Remarks:
1. In case of aircraft of IV-th class, for 1st level, stick and pedals should be free during test.
2. Otherwise rudder May be used to reduce sideslip, however only if it causes decreasing of the roll angle; any use of rudder, which increases roll angle is forbidden.

Spiral stability criterion

Spiral mode is not periodical. Unstable spiral is acceptable, however time to double initial roll angle.

Also time constant linked with time to double initial roll angle. The relation is as follows:

$$T_S = \frac{T_2}{\ln 2}$$

Spiral stability criterion

Spiral stability
Min. acceptable time to double initial roll angle

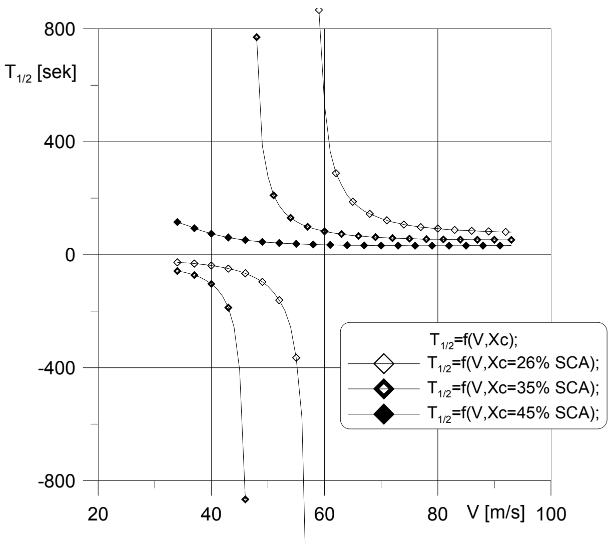
Flight phase	Acceptance level		
	1	2	3
	Double time T_2 [s]		
A i C	12	8	5
B	20	8	5
Remark: Time is measured, when controls are free after roll disturbing with angle 20°.			

Spiral stability criterion

Spiral stability – time constant T_S

Flight phase	Acceptance level		
	1	2	3
	time constant T_S [s]		
A i C	17.3	11.5	7.2
B	28.9	11.5	7.2

Spiral stability criterion



EM-11 ORKA – Spiral – time to half damping versus airspeed and CG position

Dutch-roll stability criterion

Minimum Dutch roll requirements

Acceptance level	Flight phase	Aircarft class	Dutch roll parameters		
			ω_d	ζ_d	$\zeta_d\omega_d=\xi$
1	A	I, IV	1.0	0.19	0.35
		II, III	0.4	0.19	0.35
	B	All	0.4	0.08	0.15
	C	I, IIp, IV	1.0	0.08	0.15
		IIa, III	0.4	0.08	0.15
2	All	All	0.4	0.02	0.05
3	All	All	0.4	0.02	

Remarks:

1. IIa – landing configuration.
2. IIp – cruise configuration.
3. Natural frequency ω_H [rd/s] and dimensionless damping coefficient ζ_H are derived from:

$$\omega_H \le \omega_d ; \qquad \zeta_H \ge \max\left\{\zeta_d, \frac{\xi}{\omega_H}\right\}$$

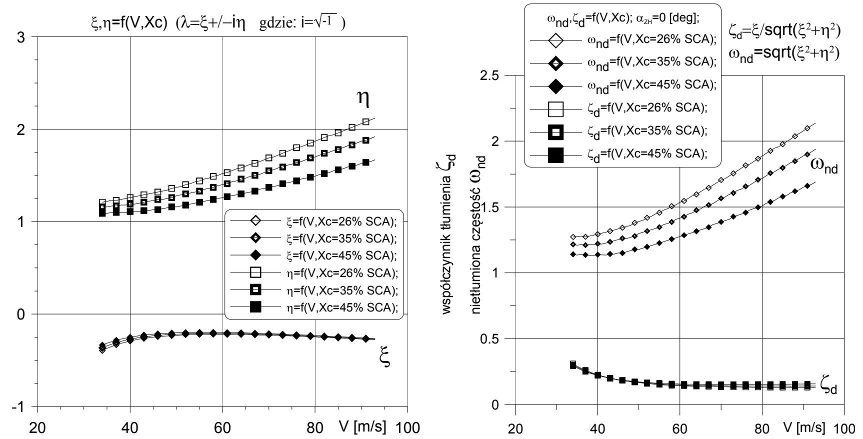
Moreover for class III aircraft condition $\zeta_H < 0.7$ should be satisfied.

Dutch-roll stability criterion

- according to CS-23 any combined lateral–directional oscillations (“Dutch roll”) occurring between the stalling speed and the maximum allowable speed appropriate to the configuration of the aeroplane must be damped to 1/10 amplitude in 7 cycles
- thus number criterion:

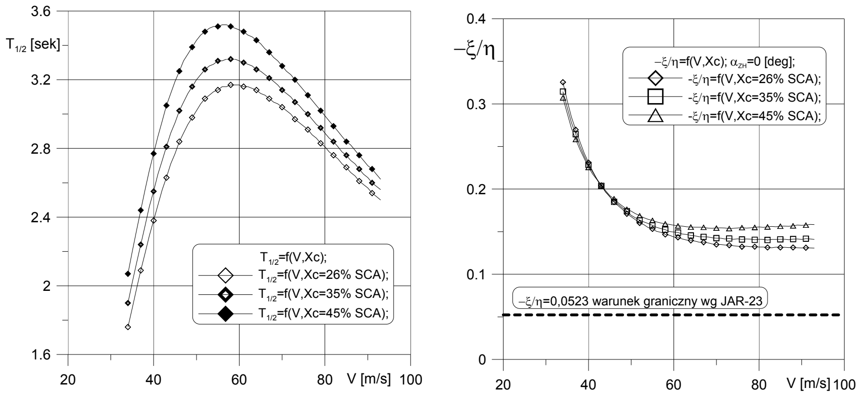
$$\frac{-\xi}{\eta} \geq 0.0523$$

Dutch-roll stability criterion



EM-11 ORKA – results of Dutch roll characteristics computation

Dutch-roll stability criterion



EM-11 ORKA – results of Dutch roll characteristics computation