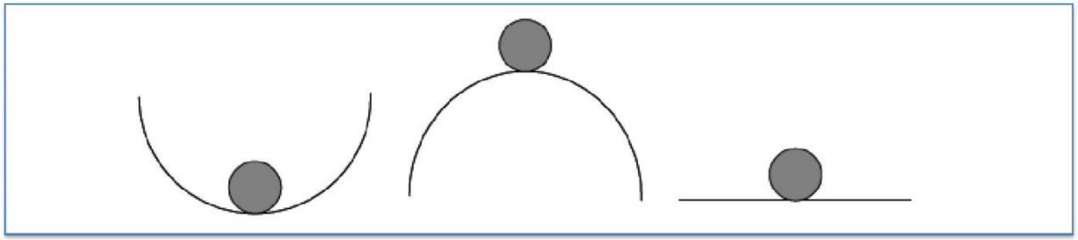
ESTABILIDAD DEL AVIÓN
1ra CLASE

ESTABILIDAD DEL AVIÓN

Estados de Equilibrio

Al aplicar un fuerza a la esfera que la hace moverse de su posición de equilibrio por su propio peso puede suceder:



Equilibrio ESTABLE:
La esfera vuelve a su posición original

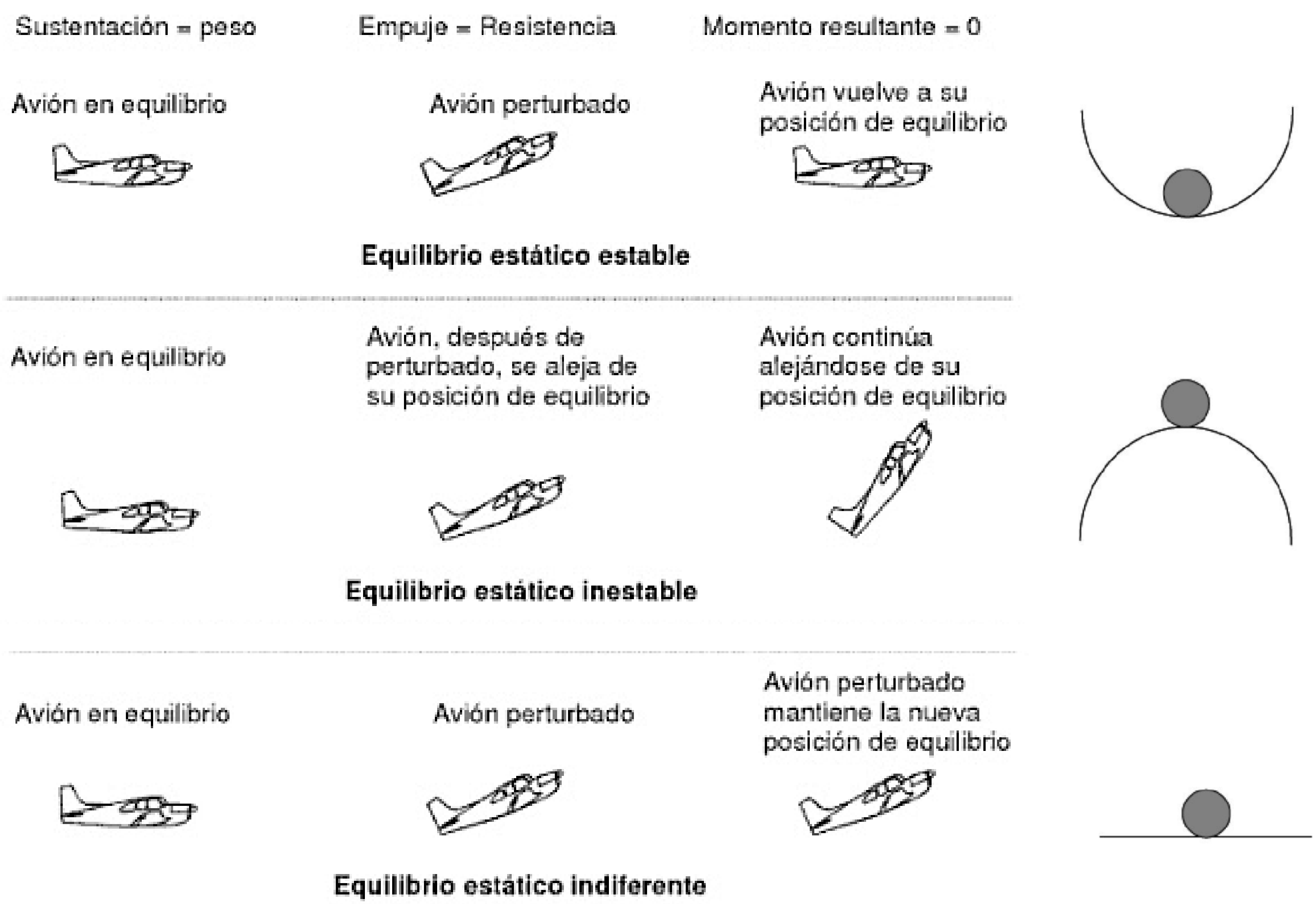
Equilibrio INESTABLE
La esfera se aleja de su posición de origen

Equilibrio NEUTRO O INDIFERENTE
La esfera no se mueve por sí misma luego de retirada la fuerza

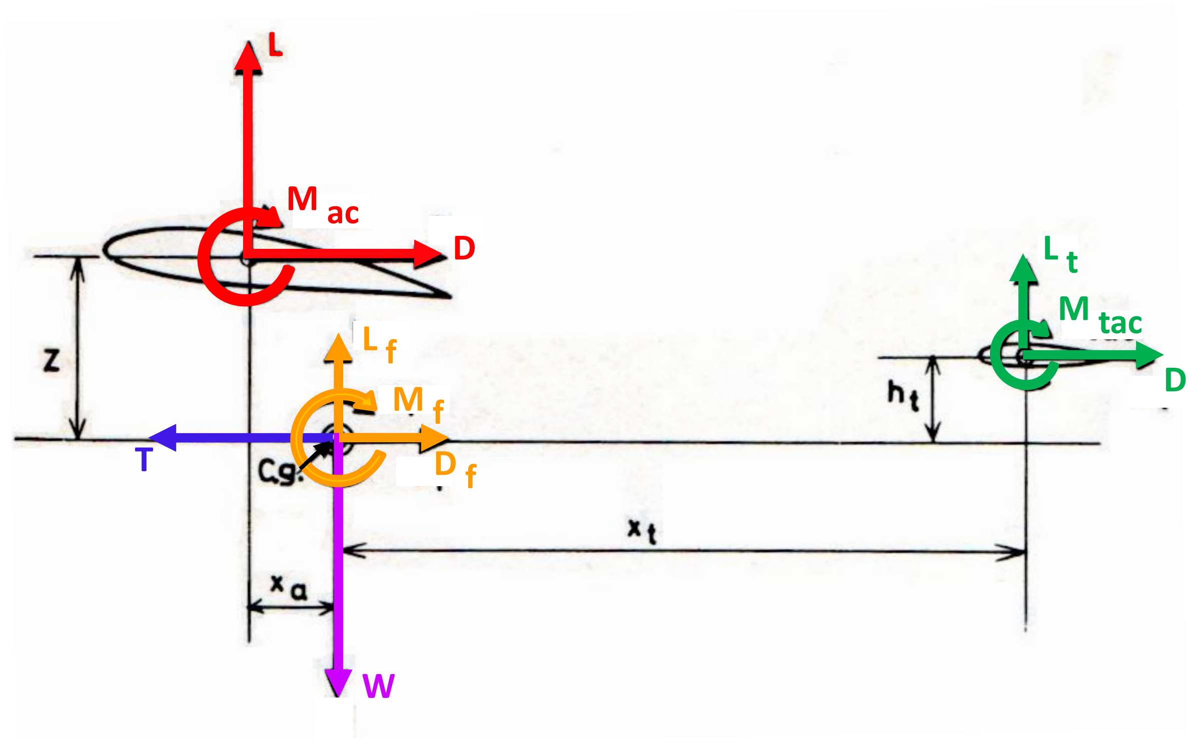
ESTABILIDAD ESTÁTICA LONGITUDINAL

Primary Control Surface	Airplane Movement	Axes of Rotation	Type of Stability
Elevator/ Stabilator	Pitch	Lateral	Longitudinal

ESTABILIDAD ESTÁTICA LONGITUDINAL



ESTABILIDAD ESTÁTICA LONGITUDINAL



+ ← $\Sigma F_x = 0$ $\Sigma F_x = T - D - D_f - D_t = 0$

+ ↑ $\Sigma F_z = 0$ $\Sigma F_z = L + L_f + L_t - W = 0$

+ ↻ $\Sigma M_{cg} = 0$ $\Sigma M_{cg} = M_{ac} + L \cdot x_a + D \cdot z + M_f + M_{tac} - L_t \cdot x_t + D_t \cdot h_t = 0$

ESTABILIDAD ESTÁTICA LONGITUDINAL

$$M_{cg} = M_{ac} + L \cdot x_a + D \cdot z + M_f + \cancel{M_{ac_t}} - L_t \cdot x_t + \cancel{D_t}\, h_t = 0$$

$$M_{cg} = M_{ac} + L \cdot x_a + D \cdot z + M_f - L_t \cdot x_t = 0$$

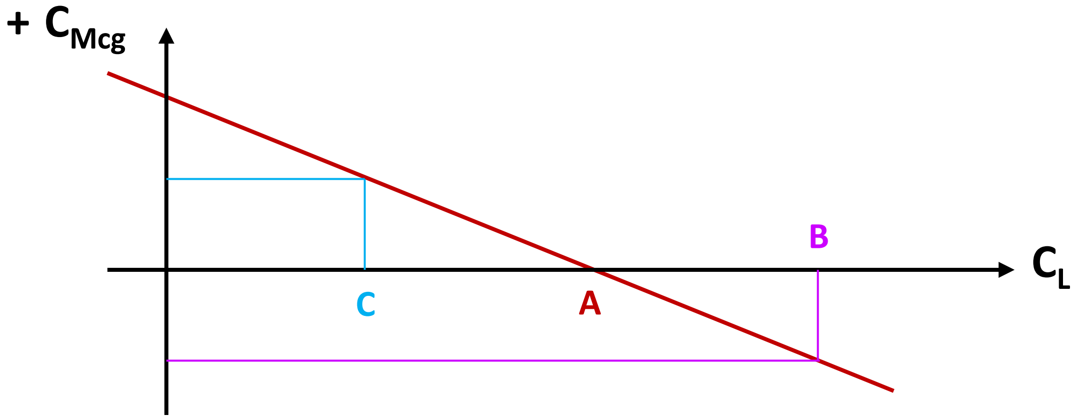
$$M_{cg} = C_{Mac} \cdot q \cdot S \cdot c + C_L \cdot q \cdot S \cdot x_a + C_D \cdot q \cdot S \cdot z + C_{Mf} \cdot q \cdot S \cdot c - C_{Lt} \cdot q_t \cdot S_t \cdot x_t = 0$$

Dividiendo miembro a miembro por $q \cdot S \cdot c$

$$C_{Mcg} = C_{Mac} + C_L \cdot \frac{x_a}{c} + C_D \cdot \frac{z}{c} + C_{Mf} - C_{Lt} \cdot \frac{q_t}{q} \cdot \frac{S_t}{S} \cdot \frac{x_t}{c} = 0$$

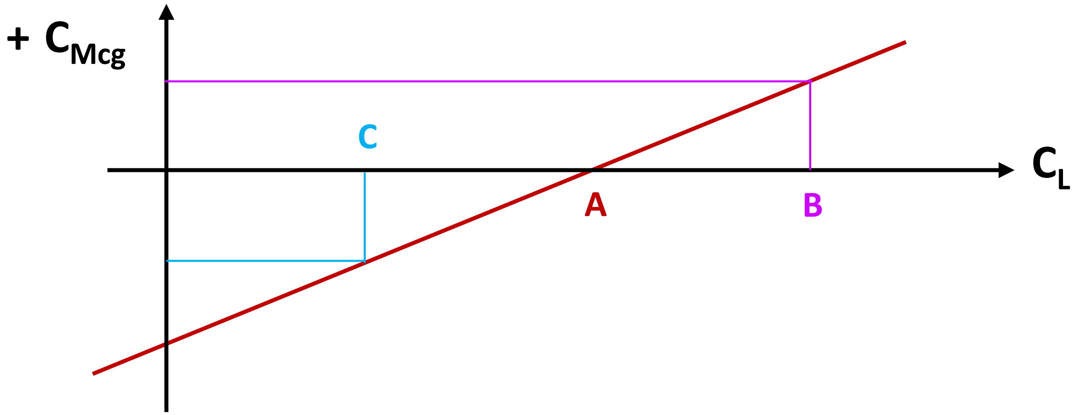
$$C_{Mcg} = C_{Mac} + C_L \cdot \frac{x_a}{c} + C_D \cdot \frac{z}{c} + C_{Mf} - C_{Lt} \cdot \eta_t \cdot \bar{V} = 0$$

ESTABILIDAD ESTÁTICA LONGITUDINAL



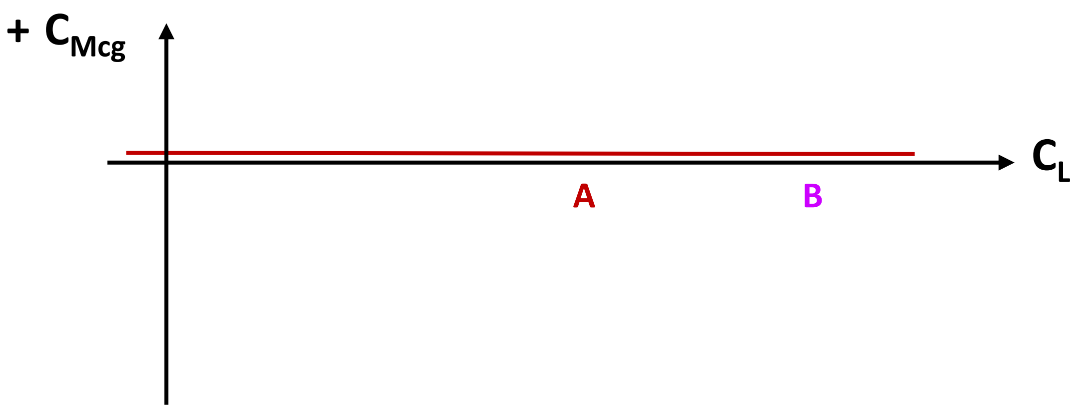
$$\frac{dC_{Mcg}}{dC_L} < 0$$

ESTABLE



$$\frac{dC_{Mcg}}{dC_L} > 0$$

INESTABLE



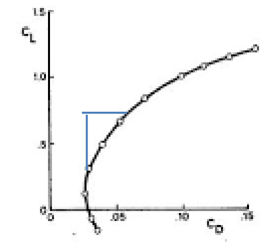
$$\frac{dC_{Mcg}}{dC_L} = 0$$

NEUTRO

ESTABILIDAD ESTÁTICA LONGITUDINAL

$$C_{Mcg} = C_{Mac} + C_L \cdot \frac{x_a}{c} + C_D \cdot \frac{z}{c} + C_{Mf} - C_{Lt} \cdot \eta_t \cdot \overline{V} = 0$$

$$\frac{dC_{Mcg}}{dC_L} = \cancel{\frac{dC_{Mac}}{dC_L}} + \frac{dC_L}{dC_L} \cdot \frac{x_a}{c} + \cancel{\frac{dC_D}{dC_L}} \cdot \frac{z}{c} + \frac{dC_{Mf}}{dC_L} - \frac{dC_{Lt}}{dC_L} \cdot \eta_t \cdot \overline{V}$$



$$\frac{dC_{Mcg}}{dC_L} = \frac{x_a}{c} + \frac{dC_{Mf}}{dC_L} - \frac{dC_{Lt}}{dC_L} \cdot \eta_t \cdot \overline{V}$$

ALA

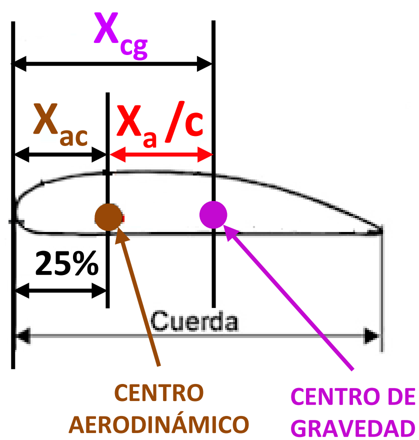
FUSELAJE

EMPENAJE HORIZONTAL

CONTRIBUCIÓN DEL ALA

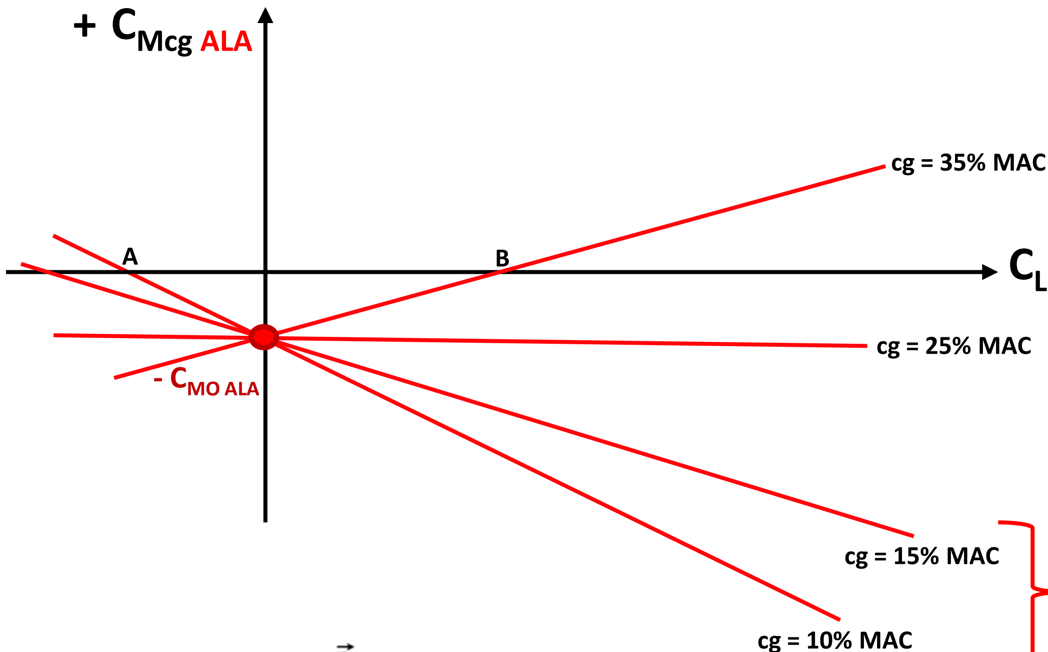
$$\left[\frac{dC_{Mcg}}{dC_L}\right]_{ALA} = \frac{X_a}{c} = X_{cg} - X_{ac}$$

- > 0 INESTABLE
- < 0 ESTABLE
- = 0 NEUTRO



CONTRIBUCIÓN DEL ALA

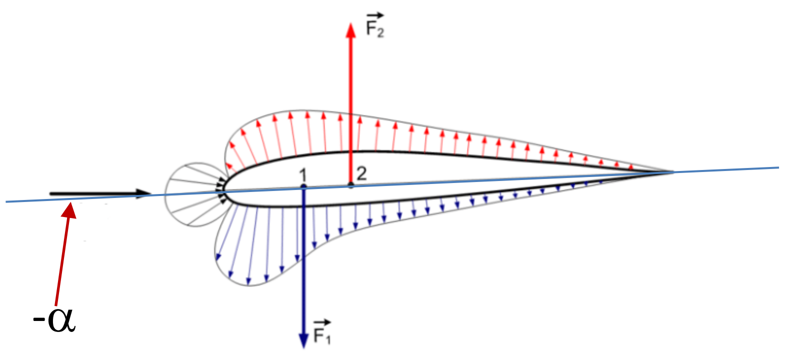
$$\left[\frac{dC_{Mcg}}{dC_L}\right]_{ALA} = \frac{X_a}{c} = X_{cg} - X_{ac}$$



$$\frac{dC_{Mcg}}{dC_L} = X_{cg} - X_{ac} > 0 \text{ INESTABLE}$$

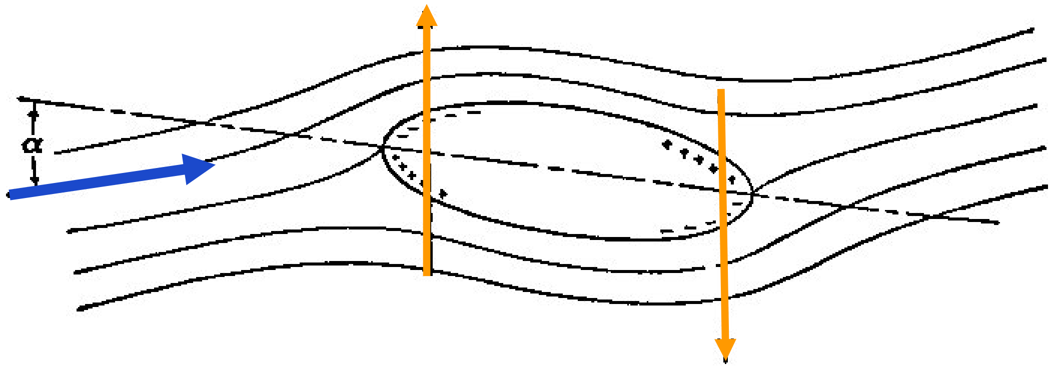
$$\frac{dC_{Mcg}}{dC_L} = X_{cg} - X_{ac} = 0 \text{ NEUTRO}$$

$$\frac{dC_{Mcg}}{dC_L} = X_{cg} - X_{ac} < 0 \text{ ESTABLE}$$



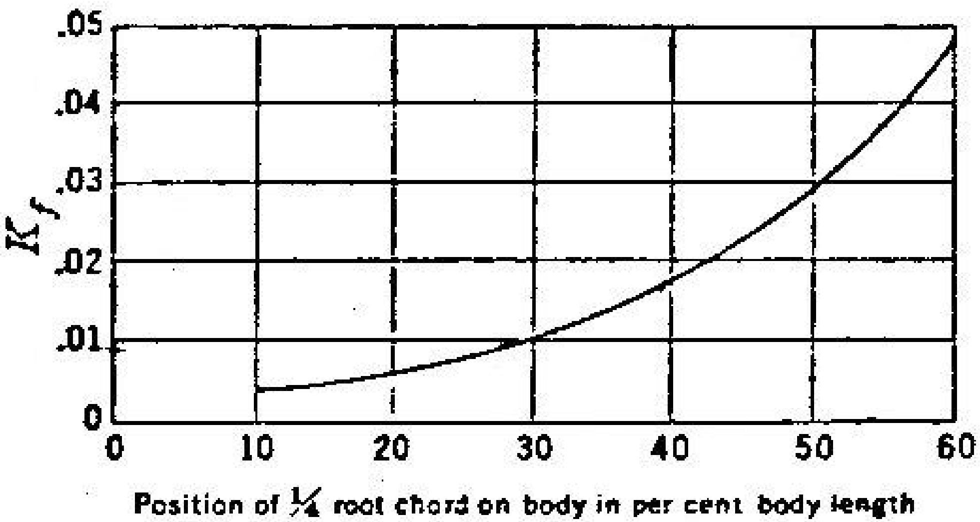
$$\vec{F}_1 = \vec{F}_2$$

CONTRIBUCIÓN DEL FUSELAJE

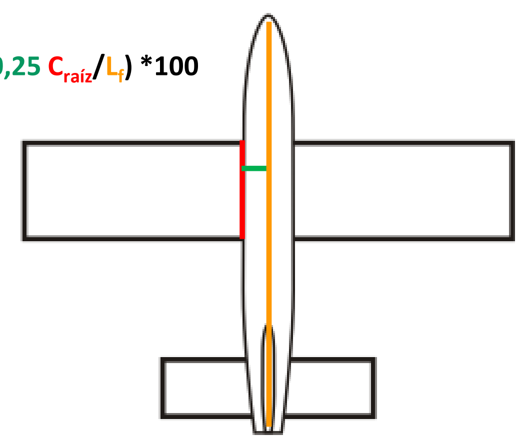


$$\left[\frac{dC_{Mcg}}{dC_L}\right]_{FUS} = \frac{K_f \cdot w_f^{\,2} \cdot L_f}{S_w \cdot c \cdot a_w}$$

> 0 INESTABLE

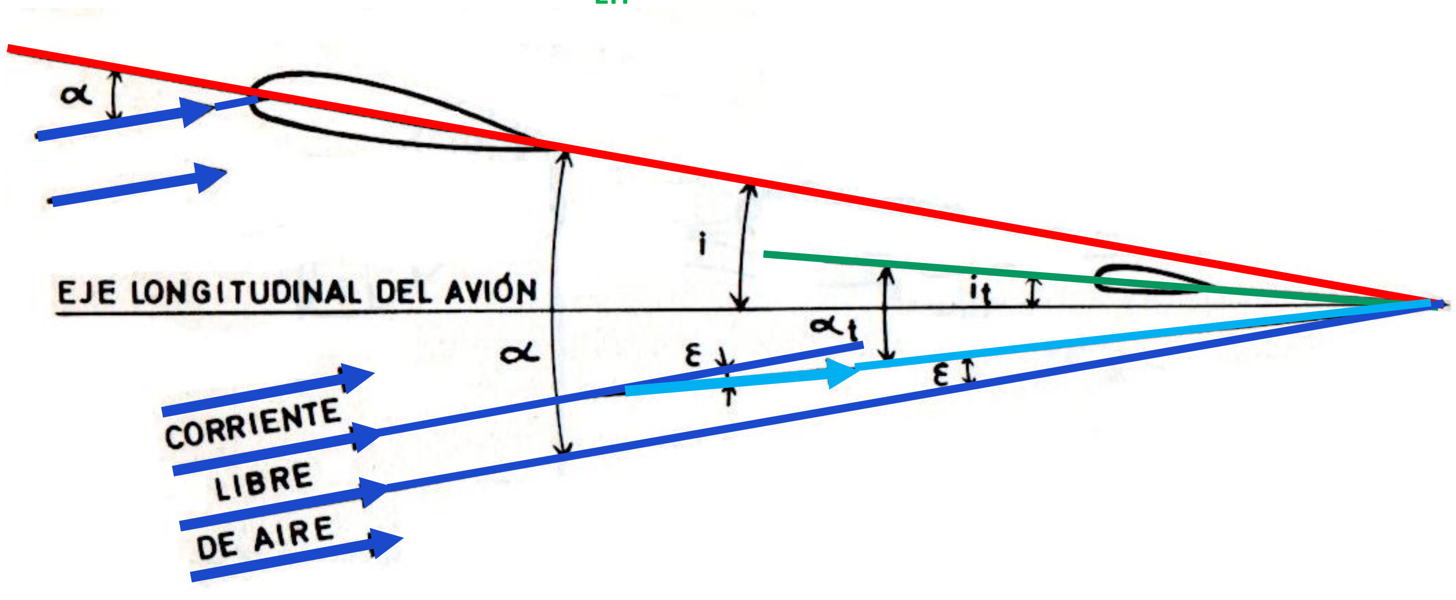


$(0{,}25\ C_{raíz}/L_f)\ {*}100$



CONTRIBUCIÓN DEL EMPENAJE HORIZONTAL

$$\left[\frac{dC_{Mcg}}{dC_L}\right]_{EH} = -\frac{dC_{Lt}}{dC_L} \cdot \eta_t \cdot \overline{V}$$



$$\alpha_t = \alpha - i + i_t - \varepsilon$$

CONTRIBUCIÓN DEL EMPENAJE HORIZONTAL

$$\left[\frac{dC_{Mcg}}{dC_L}\right]_{EH} = -\frac{dC_{Lt}}{dC_L} \cdot \eta_t \cdot \overline{V}$$

$$\alpha_t = \alpha - i + i_t - \varepsilon$$

$$C_{Lt} = a_t \cdot \alpha_t = a_t \cdot (\alpha - i + i_t - \varepsilon)$$

$$\frac{dC_{Lt}}{dC_L} = a_t \cdot \left[\frac{d\alpha}{dC_L} - \frac{d\varepsilon}{dC_L}\right]$$

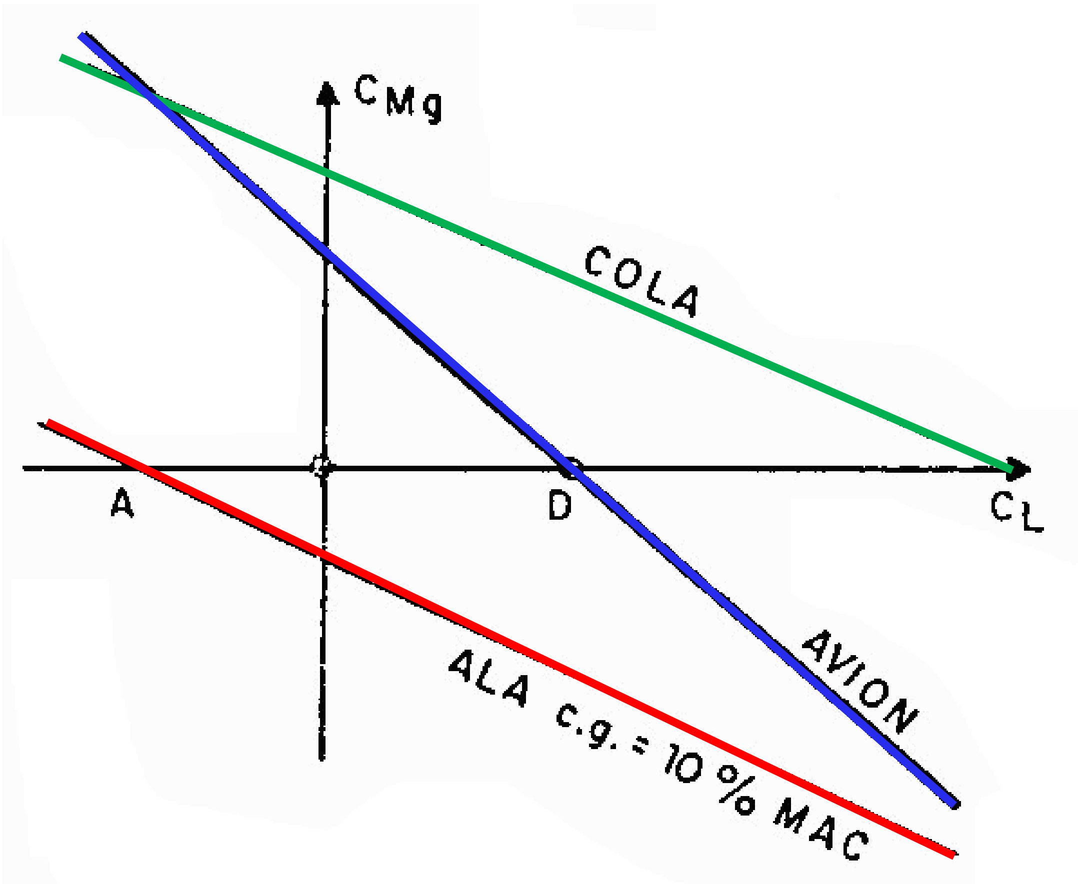
$$\frac{dC_{Lt}}{dC_L} = \frac{a_t}{a} \cdot \left[1 - \frac{d\varepsilon}{d\alpha}\right]$$

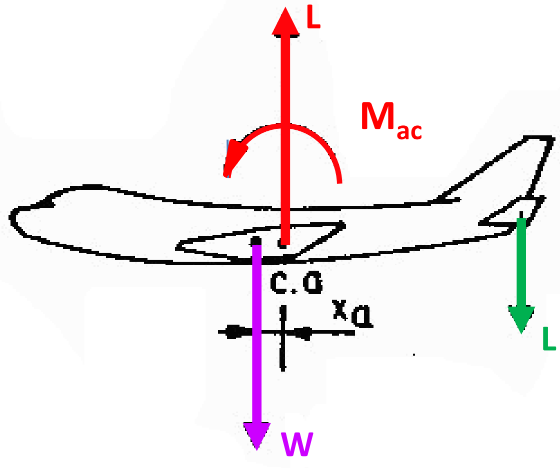
$$dC_L = a \cdot d\alpha$$

$$d\alpha = \frac{dC_L}{a}$$

$$\left[\frac{dC_{Mcg}}{dC_L}\right]_{EH} = -\frac{a_t}{a} \cdot \left[1 - \frac{d\varepsilon}{d\alpha}\right] \cdot \eta_t \cdot \overline{V}$$

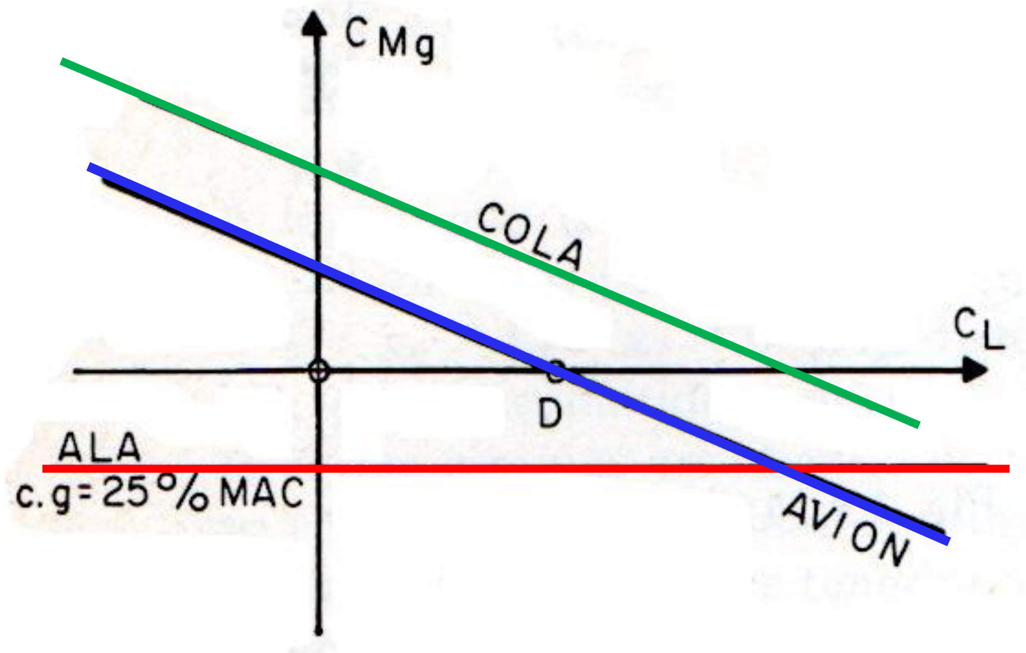
ESTABILIDAD ESTÁTICA DEL AVIÓN

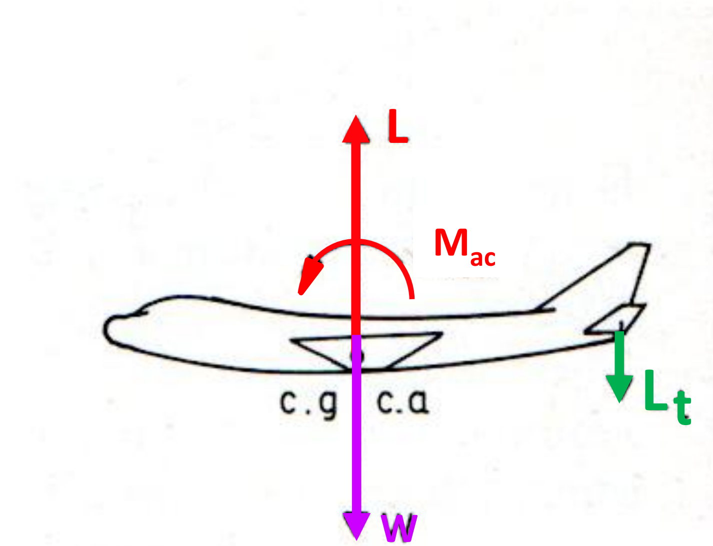




$$\Sigma M_{cg} = -M_{ac} - L \cdot x_a + L_t \cdot x_t = 0$$

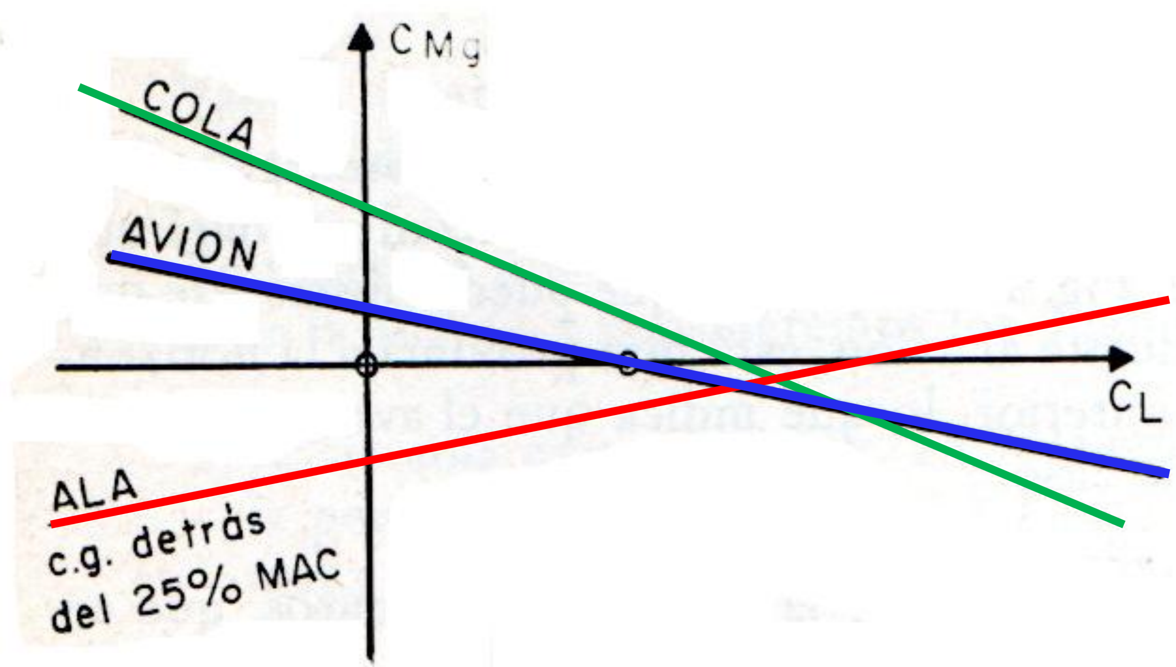
ESTABILIDAD ESTÁTICA DEL AVIÓN

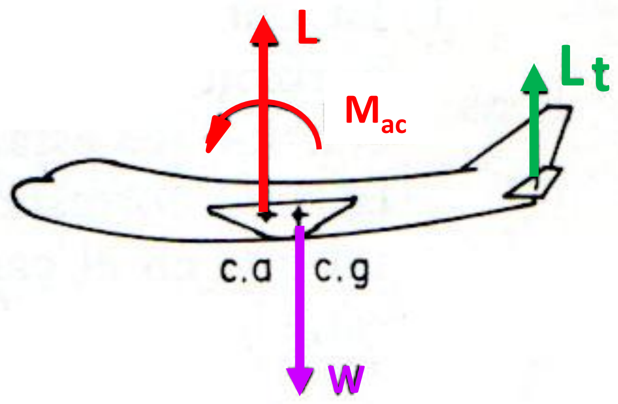




$$\Sigma M_{cg} = - M_{ac} - L \times x_a + L_t \cdot x_t = 0$$

ESTABILIDAD ESTÁTICA DEL AVIÓN





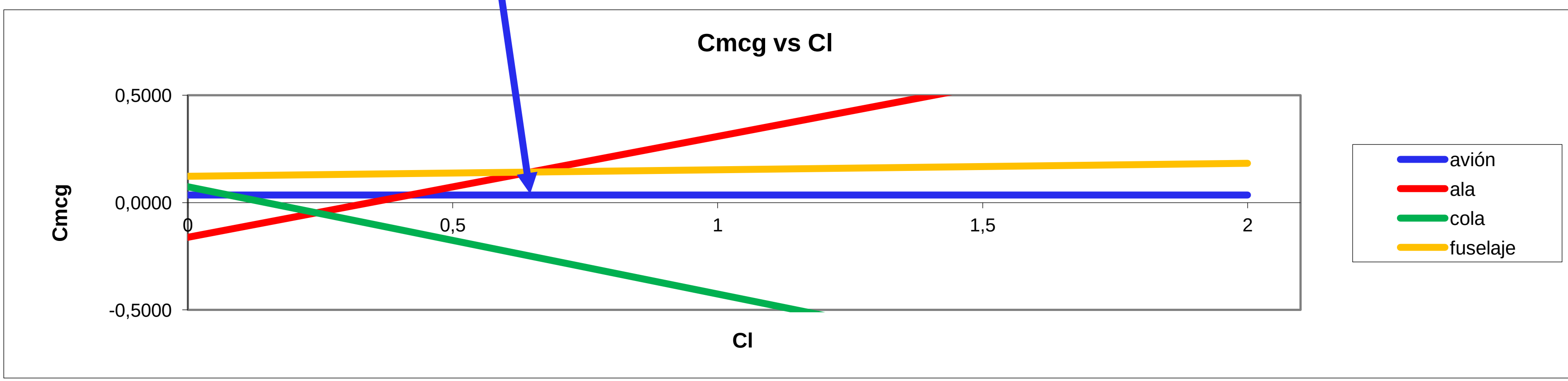
$$\Sigma M_{cg} = - M_{ac} + L \cdot x_a - L_t \cdot x_t = 0$$

PUNTO NEUTRO CON MANDOS FIJOS

$$\frac{dC_{Mcg}}{dC_L} = \frac{x_a}{c} + \frac{dC_{Mf}}{dC_L} - \frac{dC_{Lt}}{dC_L} \cdot \eta_t \cdot \overline{V}$$

$$\frac{dC_{Mcg}}{dC_L} = X_{cg} - X_{ac} + \frac{dC_{Mf}}{dC_L} - \frac{dC_{Lt}}{dC_L} \cdot \eta_t \cdot \overline{V}$$

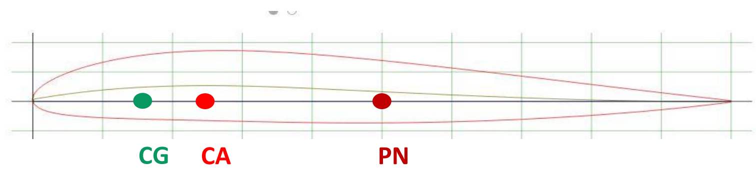
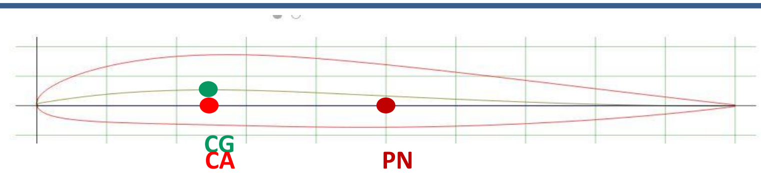
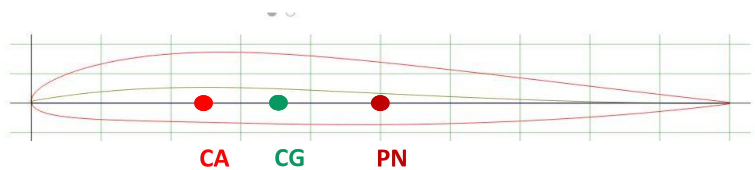
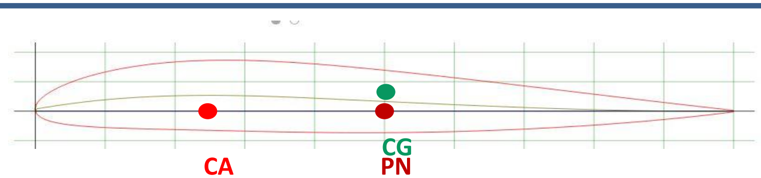
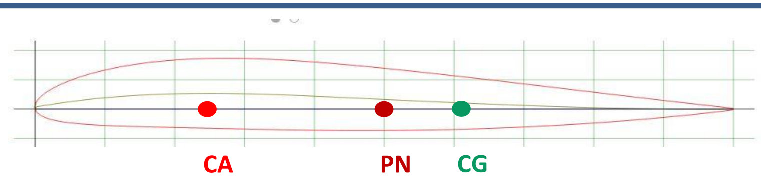
$$0 = N_o - X_{ac} + \frac{dC_{Mf}}{dC_L} - \frac{dC_{Lt}}{dC_L} \cdot \eta_t \cdot \overline{V}$$



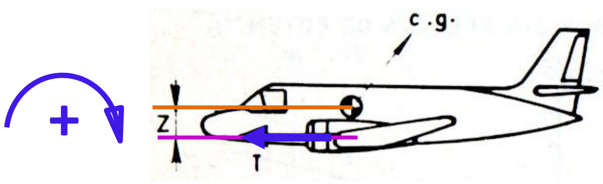
$$\left(\frac{dC_{Mcg}}{dC_L}\right)_{\text{AVIÓN}} = X_{cg} - N_o$$

- < 0 ESTABLE
- = 0 NEUTRO
- > 0 INESTABLE

CONTRIBUCIÓN DEL ALA Y ESTABILIDAD DEL AVIÓN

	CONTRIBUCIÓN DE ALA	ESTABILIDAD AVIÓN
	ESTABLE O POSITIVA	ESTABLE O POSITIVA
	INDIFERENTE O NEUTRA	ESTABLE O POSITIVA
	INESTABLE O NEGATIVA	ESTABLE O POSITIVA
	INESTABLE O NEGATIVA	INDIFERENTE O NEUTRA
	INESTABLE O NEGATIVA	INESTABLE O NEGATIVA

CONTRIBUCIÓN DE LA TRACCIÓN / EMPUJE



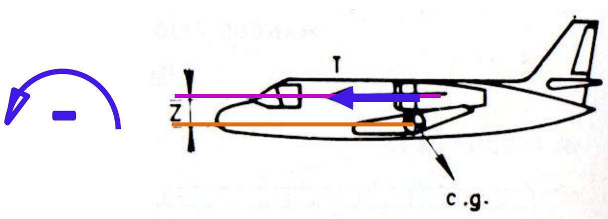
$$T \cdot Z = C_{Mcg} \cdot q \cdot S \cdot C$$

$$C_{Mcg} = \frac{T \cdot Z}{q \cdot S \cdot c} \qquad W = q \cdot S \cdot C_L$$

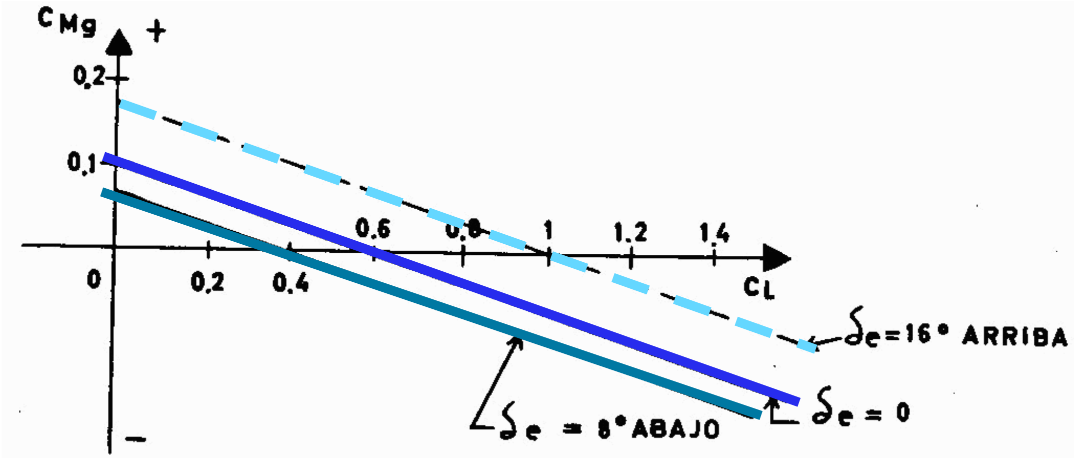
$$C_{Mcg} = \frac{T \cdot Z \cdot C_L}{W \cdot c}$$

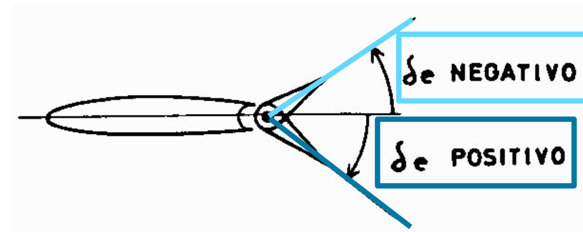
$$\left[\frac{dC_{Mcg}}{dC_L}\right]_T = \frac{T \cdot Z}{W \cdot C} \quad > 0 \text{ INESTABLE}$$

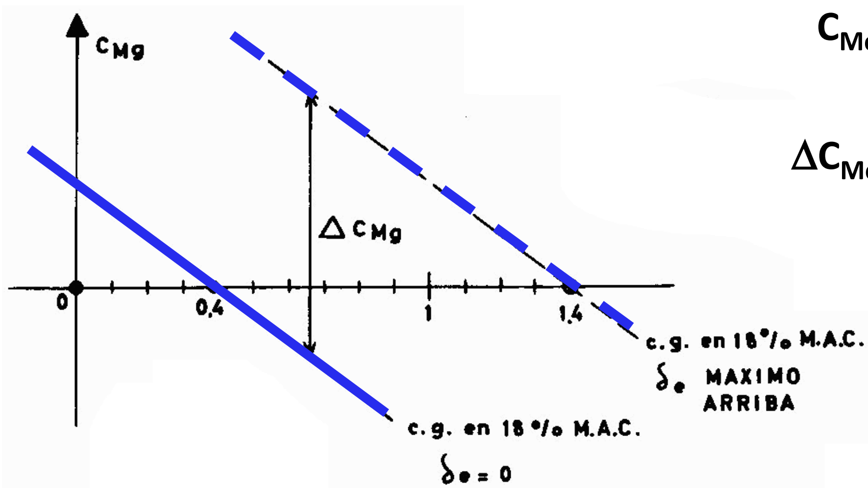
$$\left[\frac{dC_{Mcg}}{dC_L}\right]_T = -\frac{T \cdot Z}{W \cdot C} \quad < 0 \text{ ESTABLE}$$



CONTROL LONGITUDINAL



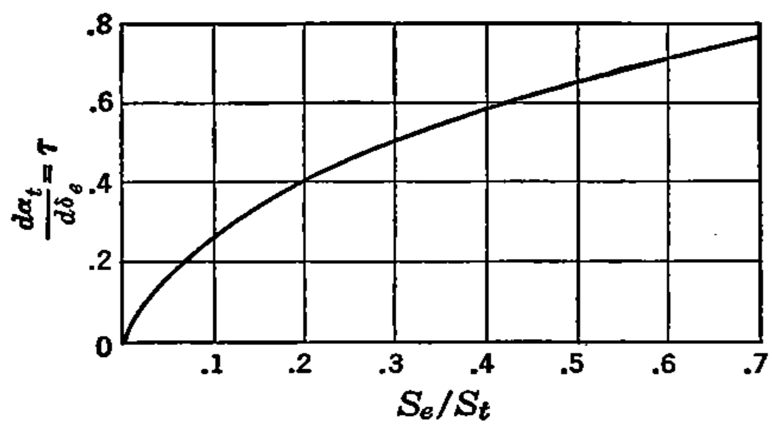




$$C_{Mcg} = C_{Mac} + C_L \cdot \frac{x_a}{c} + C_{Mf} - C_{Lt} \cdot \eta_t \cdot \overline{V} = 0$$

$$\Delta C_{Mcg} = C_{Mac} + C_L \cdot \frac{x_a}{c} + C_{Mf} - a_t \cdot (\alpha - i + i_t - \varepsilon + \boxed{\tau \cdot \delta_e}) \cdot \eta_t \cdot \overline{V}$$

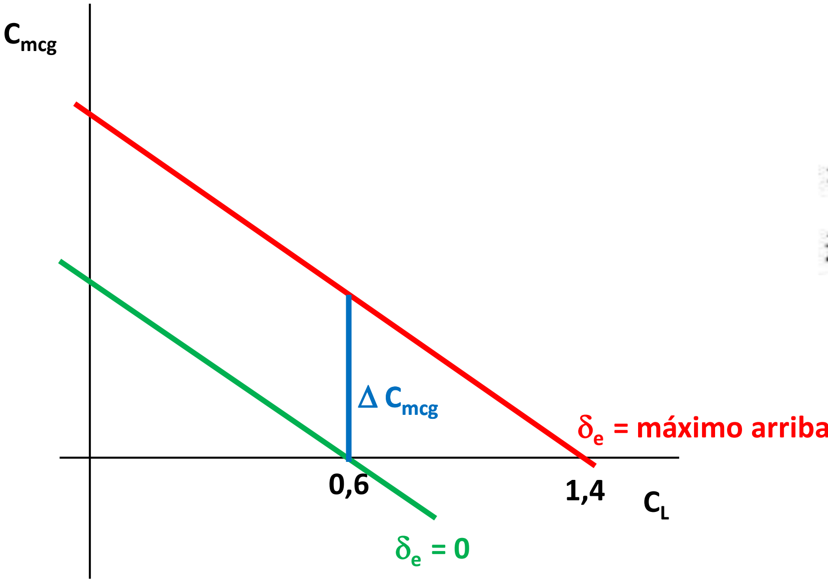
$\tau = \frac{d\,\alpha_t}{d\,\delta_e}$ = EFECTIVIDAD DEL TIMÓN

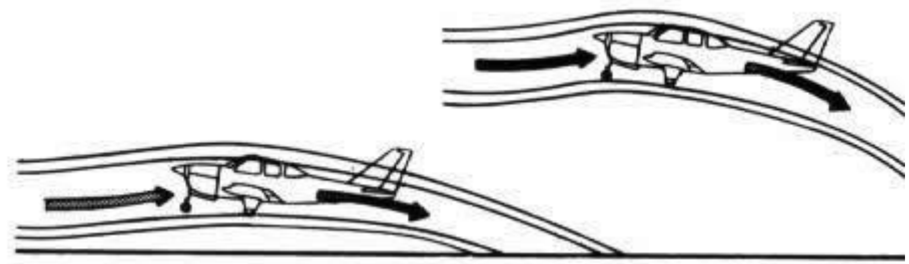


Límites posición delantera C.G.:

1) La deflexión total disponible del timón de profundidad.
2) La capacidad de aterrizar con efecto suelo.
3) La capacidad de maniobra en la configuración de aterrizaje.

CONTROL LONGITUDINAL





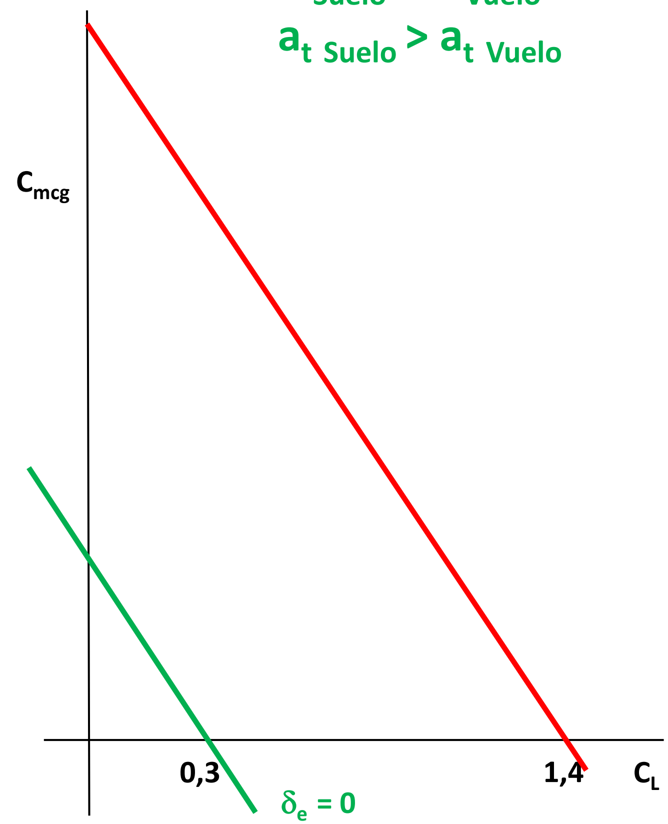
$\varepsilon_{\text{Suelo}} < \varepsilon_{\text{Vuelo}}$

$a_{\text{Suelo}} > a_{\text{Vuelo}}$

$a_{t\ \text{Suelo}} > a_{t\ \text{Vuelo}}$

$$\left[\frac{dC_{Mcg}}{dC_L}\right]_{EH} = -\frac{a_t}{a}\cdot\left[1-\frac{d\varepsilon}{d\alpha}\right]\cdot\eta_t\cdot\overline{V}$$

$$\left[\frac{dC_{Mcg}}{dC_L}\right]_{EH\ Suelo} > \left[\frac{dC_{Mcg}}{dC_L}\right]_{EH\ Vuelo}$$



ESTABILIDAD DEL AVIÓN