



Dipartimento
Ingegneria Aerospaziale



Università di Napoli Federico II

ADAG
RESEARCH GROUP
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Corso Manovre e Stabilità

Stabilità LONGITUDINALE

Docente

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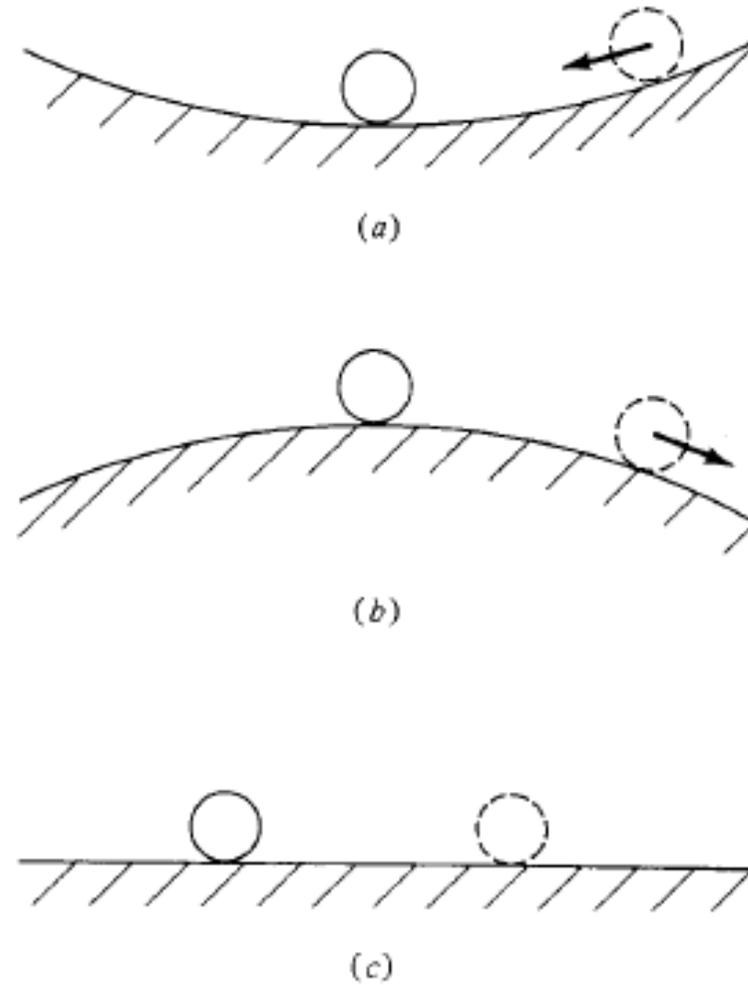


Figure 7.6 Illustration of static stability.
(a) Statically stable system. (b) Statically unstable system. (c) Statically neutral system.



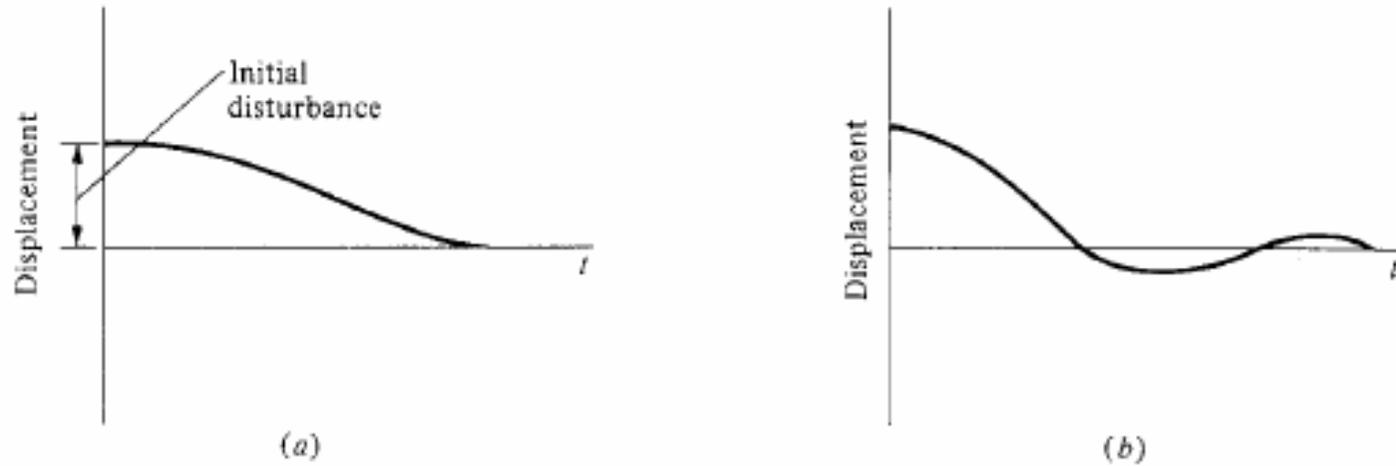


Figure 7.8 Examples of dynamic stability. (a) Aperiodic. (b) Damped oscillations.

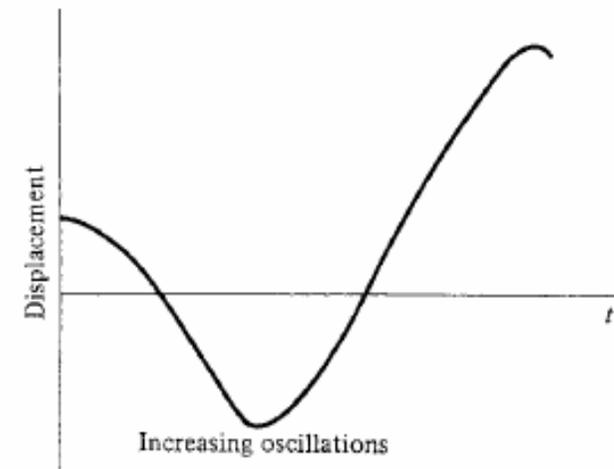


Figure 7.9 An example of dynamic instability.



Longitudinale - Momento

$$X_N = \bar{X}_{ac_A} = \frac{\bar{X}_{ac_{wf}} + \frac{C_{L\alpha_h}}{C_{L\alpha_{wf}}} \eta_h \frac{S_h}{S} \bar{X}_{ac_h} \left(1 - \frac{d\varepsilon}{d\alpha}\right)}{1 + \frac{C_{L\alpha_h}}{C_{L\alpha_{wf}}} \eta_h \frac{S_h}{S} \left(1 - \frac{d\varepsilon}{d\alpha}\right)}$$

Facendo qualche passaggio si può vedere che :

$$C_{m_\alpha} = C_{L_\alpha} (\bar{X}_{cg} - \bar{X}_{ac_A}) = C_{L_\alpha} * (X_{cg} - X_N)$$

Margine di stabilità statica :

$$MSS = dC_m / dC_L = \frac{dC_M}{dC_L} = \frac{dC_M}{d\alpha} \cdot \frac{d\alpha}{dC_L} = \frac{CM_\alpha}{CL_\alpha} = \left(\bar{X}_{cg} - \bar{X}_N \right)$$



Margine di stabilità

$$\frac{dC_M}{dC_L} = \frac{dC_M}{d\alpha} \cdot \frac{d\alpha}{dC_L} = \frac{CM_\alpha}{CL_\alpha} = \left(\bar{X}_{cg} - \bar{X}_N \right)$$

Essendo tipicamente X_{cg} avanti (verso il l.e.) al punto neutro (es. :)

$$\bar{X}_{cg} = 0.30 \quad \bar{X}_N = 0.50$$

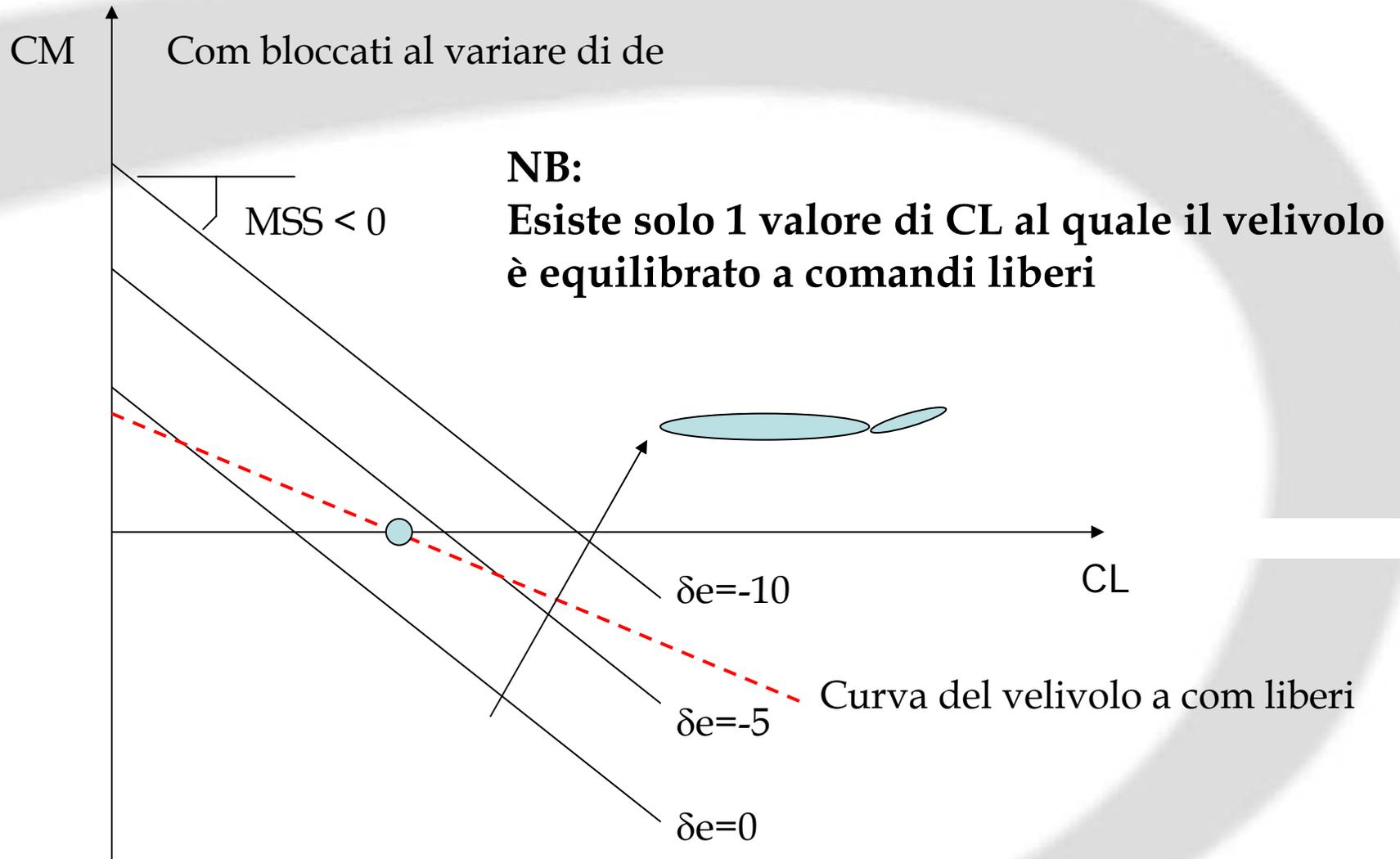
Il Margine di stabilità MSS è negativo e nel caso sopra

MSS = -0.20 (cioè 20% di stabilità statica)

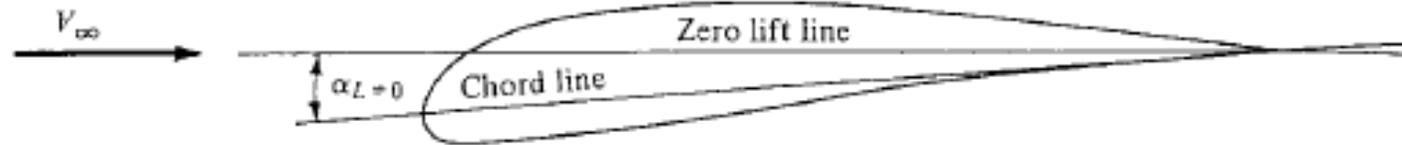
In effetti per la stabilità, come il CM_α deve essere negativo anche il

$$CM_{CL} = MSS \quad \text{deve essere negativo}$$

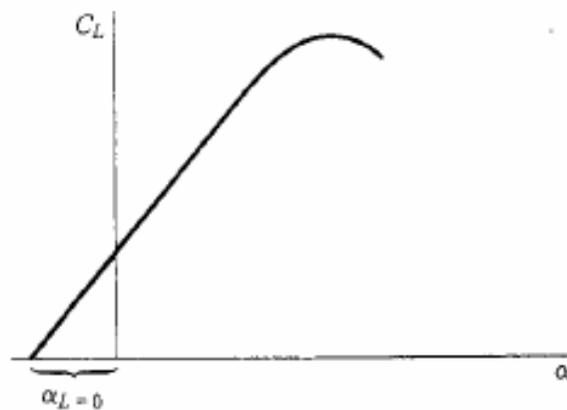
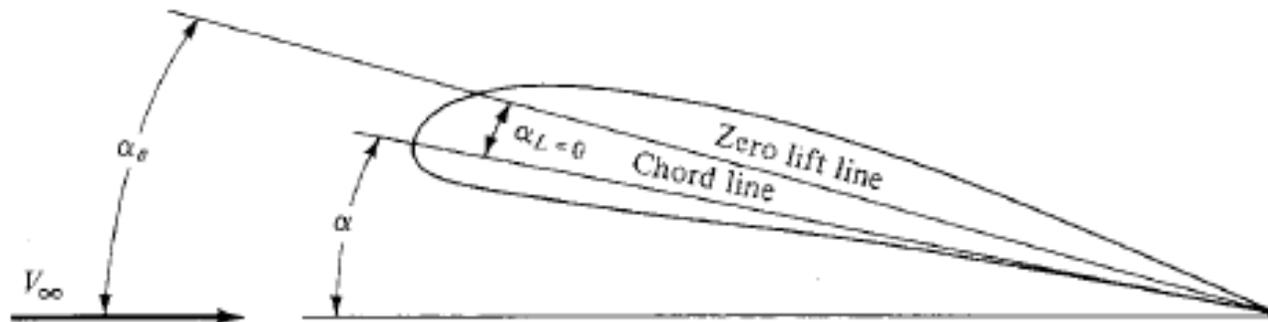




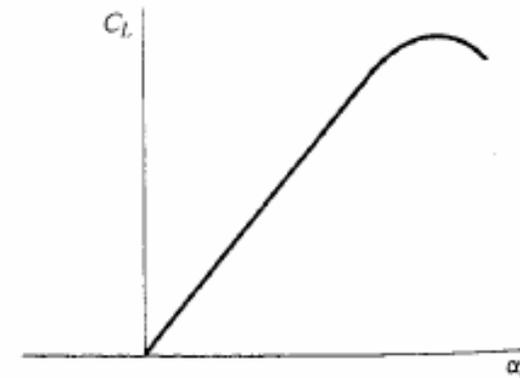
ANGOLO ATTACCO ASSOLUTO



(a)



(a)



(b)



Curva Momento Stabile

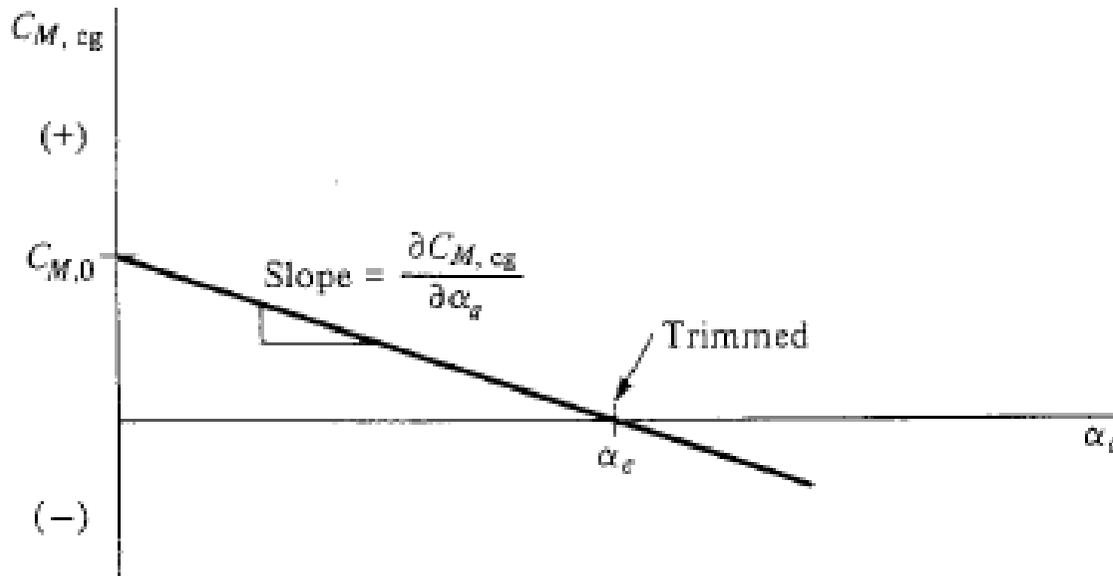
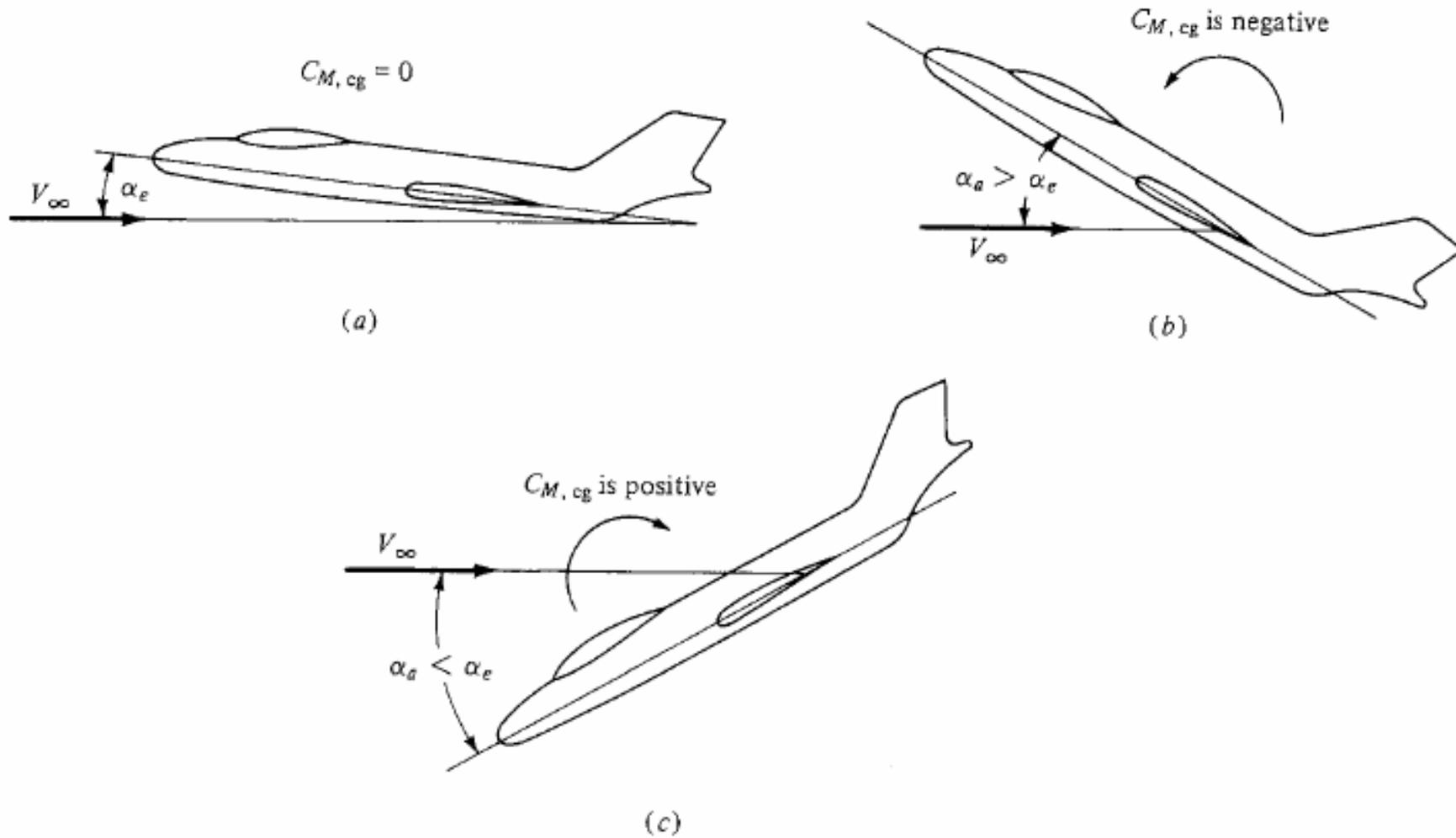


Figure 7.13 Moment coefficient curve with a negative slope.



Cosa accade



Curva mom con pendenza positiva (instabile)

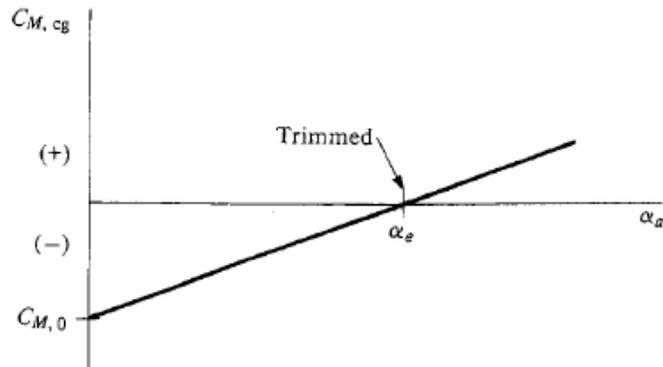
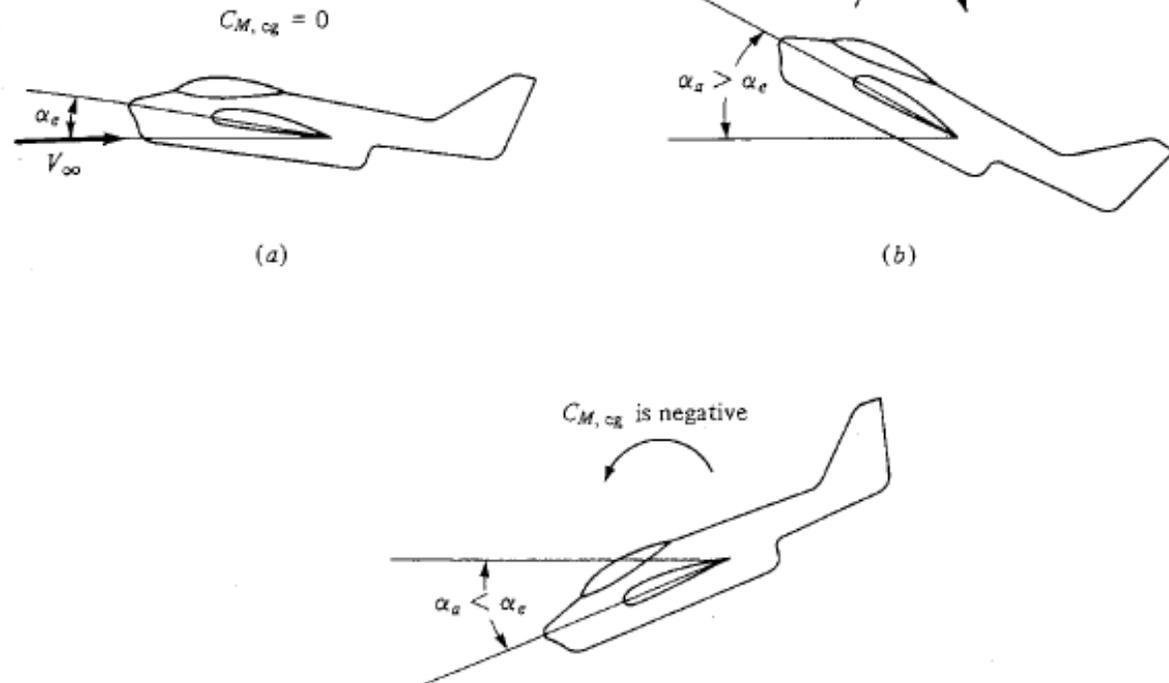
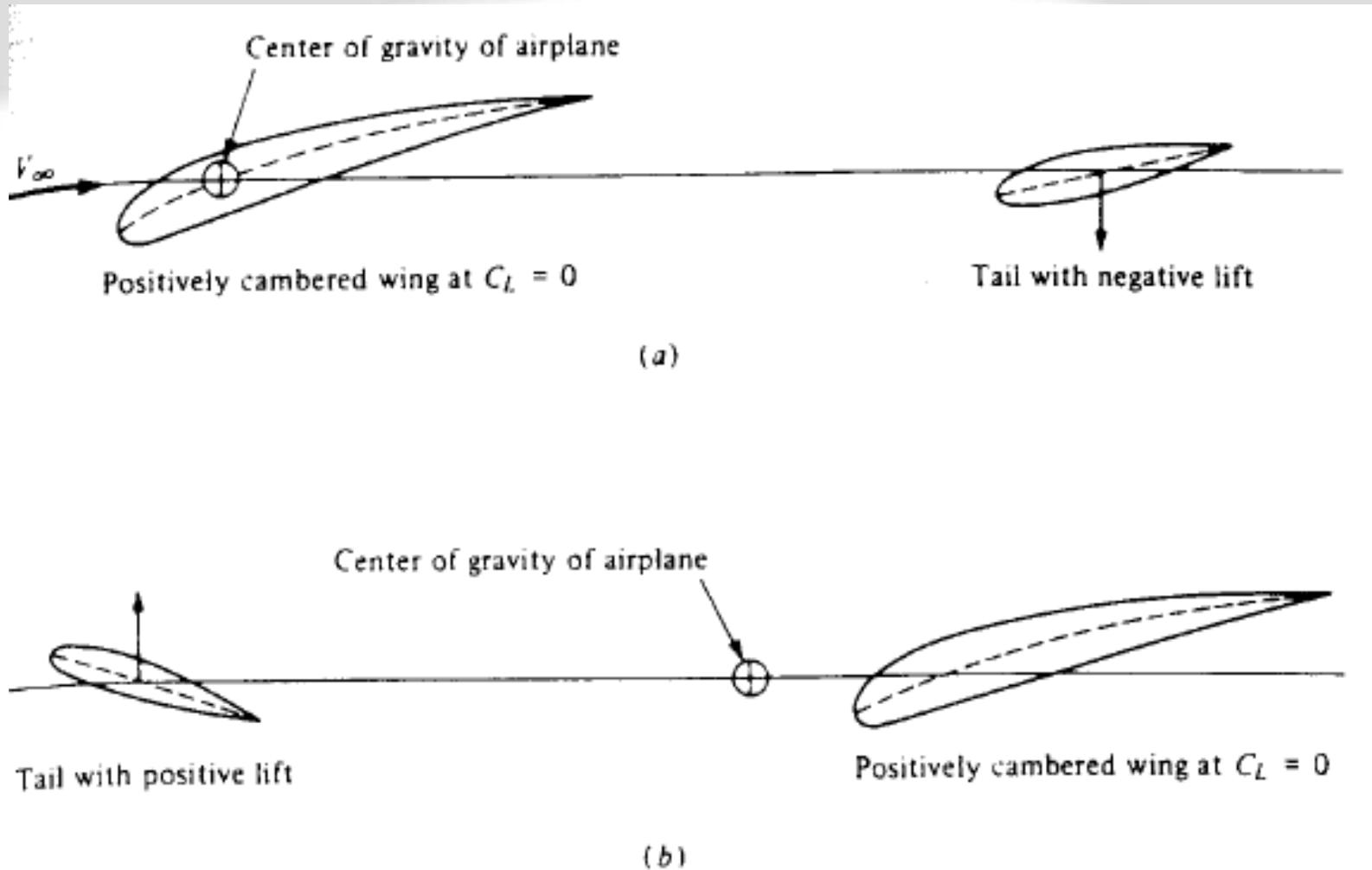


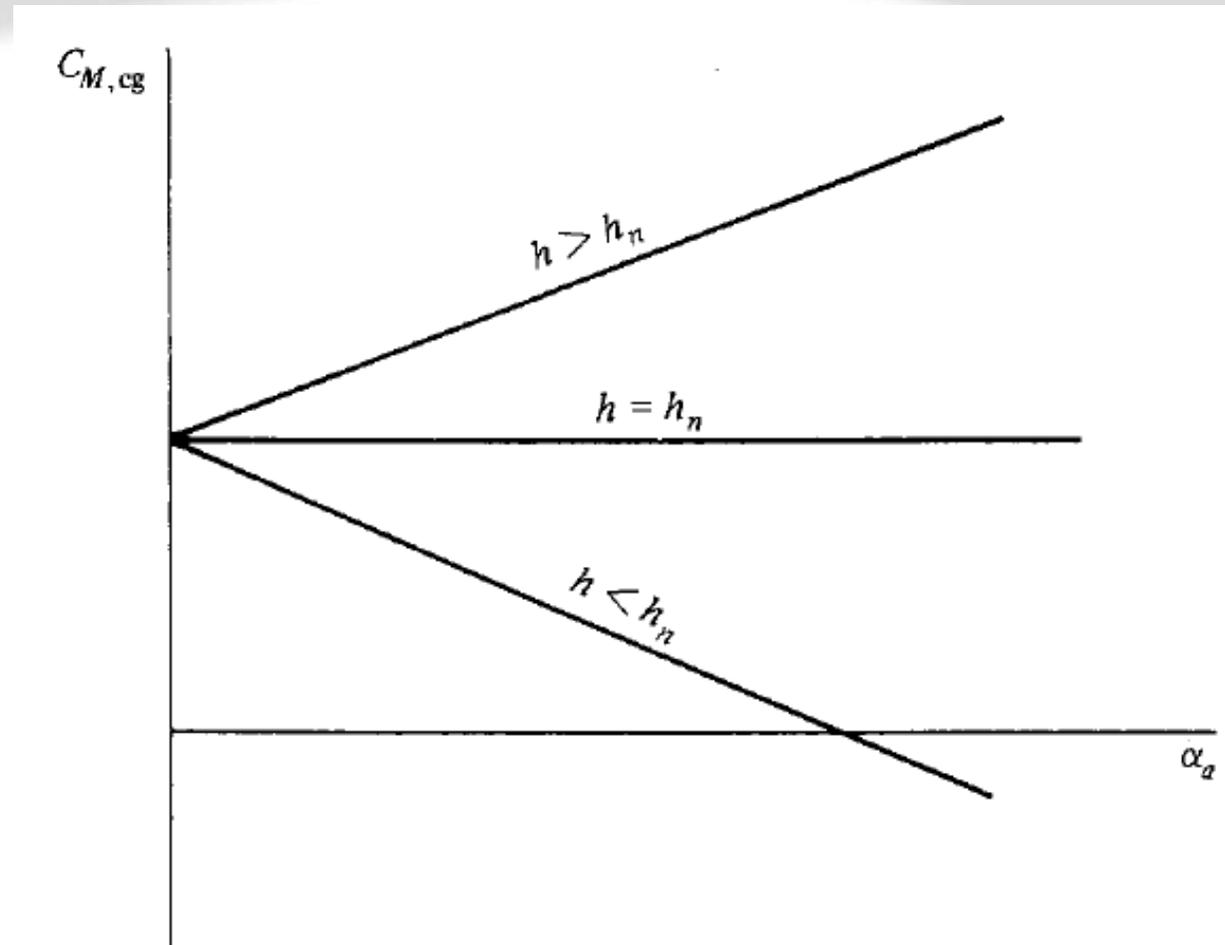
Figure 7.15 Moment coefficient curve with a positive slope.



$CM_o > 0$

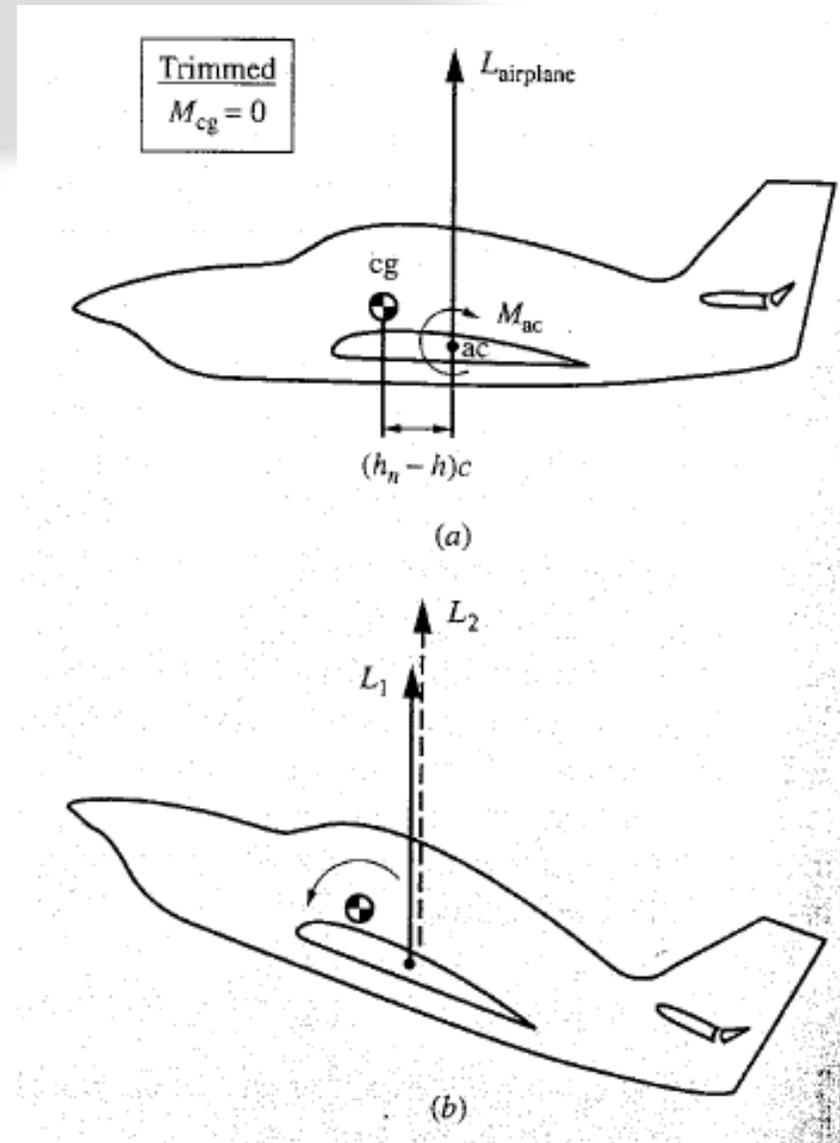


Punto neutro



Punto neutro :

Centro aerodinamico del velivolo completo



La portanza agisce sempre nel centro di pressione.

Velivolo stabile :

Il cp si sposta dietro se il velivolo cabra !

L'inverso se picchia !

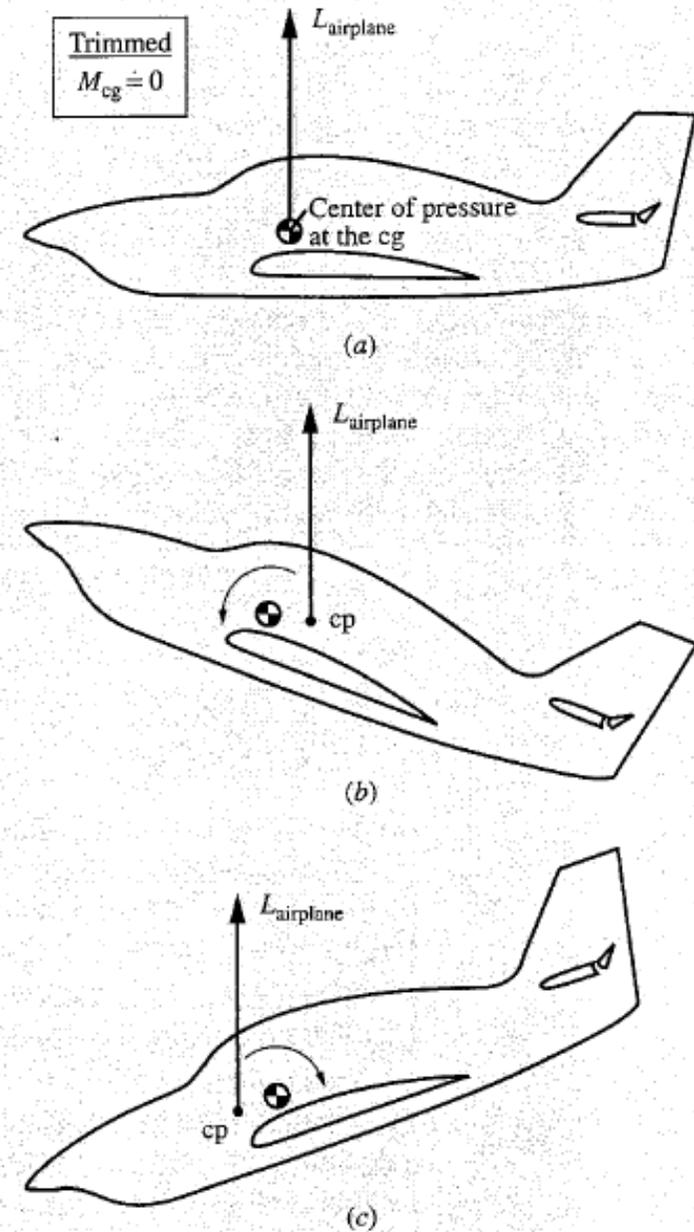
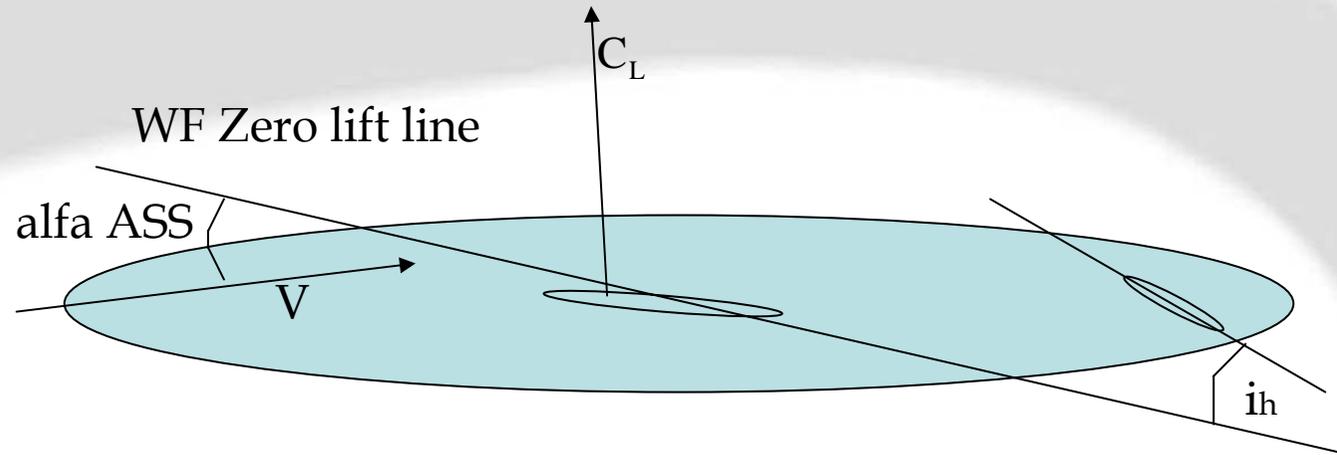


Figure 7.26 A diagram for static stability, with the lift acting at the center of pressure.



Con alfa pari all'angolo d'attacco assoluto le equazioni si semplificano:



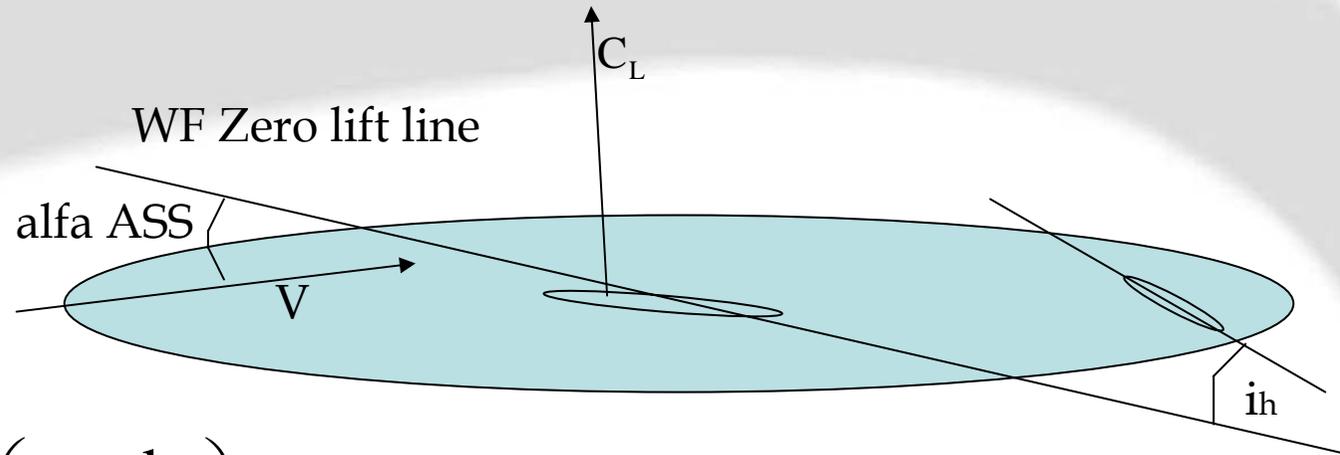
$$C_L = C_{L_{\alpha_{wf}}} \cdot \alpha + C_{L_h}$$

$$C_{L_h} = C_{L_{\alpha_h}} \cdot \alpha_h \quad \alpha_h = \alpha - \varepsilon + i_h + \tau \cdot \delta_e$$

$$\varepsilon = \frac{d\varepsilon}{d\alpha} \cdot \alpha \quad (\text{infatti } \varepsilon_0 \text{ è trascurabile})$$

$$\alpha_h = \alpha \cdot \left(1 - \frac{d\varepsilon}{d\alpha} \right) + i_h + \tau \cdot \delta_e$$

Con alfa pari all'angolo d'attacco assoluto le equazioni si semplificano:



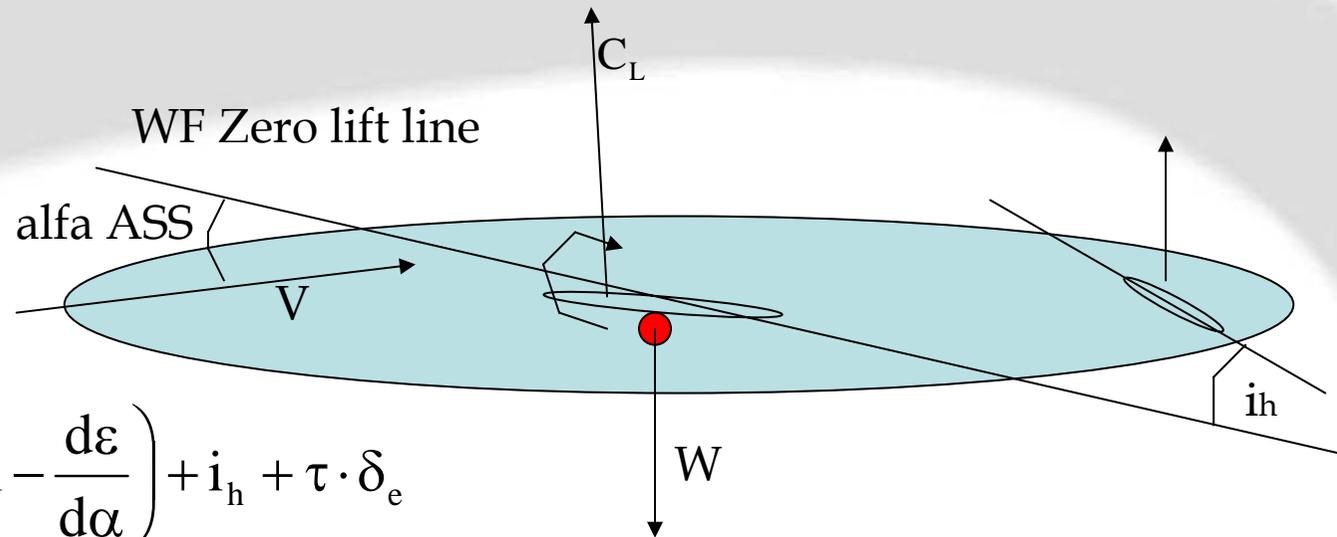
$$\alpha_h = \alpha \cdot \left(1 - \frac{d\varepsilon}{d\alpha} \right) + i_h + \tau \cdot \delta_e$$

$$C_L = C_{L_{\alpha_{wf}}} \cdot \alpha + C_{L_{\alpha_h}} \eta_h \frac{S_h}{S} \cdot \alpha \cdot \left(1 - \frac{d\varepsilon}{d\alpha} \right) + C_{L_{\alpha_h}} \eta_h \frac{S_h}{S} \cdot (i_h + \tau \cdot \delta_e)$$

$$C_{L_{\alpha}} = C_{L_{\alpha_{wf}}} + C_{L_{\alpha_h}} \cdot \eta_h \frac{S_h}{S} \left(1 - \frac{d\varepsilon}{d\alpha} \right)$$



MOMENTO:



$$\alpha_h = \alpha \cdot \left(1 - \frac{d\varepsilon}{d\alpha} \right) + i_h + \tau \cdot \delta_e$$

$$C_M = C_{M_{ac_wf}} + C_{L_{\alpha_{wf}}} \alpha (\bar{x}_{cg} - \bar{x}_{ac_wf}) - C_{L_{\alpha_h}} \eta_h \frac{S_h}{S} \alpha \left(1 - \frac{d\varepsilon}{d\alpha} \right) (\bar{x}_{ac_h} - \bar{x}_{cg})$$

$$- C_{L_{\alpha_h}} \eta_h \cdot \frac{S_h}{S} \cdot (i_h + \tau \cdot \delta_e) \cdot (\bar{x}_{ac_h} - \bar{x}_{cg})$$

$$C_{M_\alpha} = C_{L_{\alpha_{wf}}} (\bar{x}_{cg} - \bar{x}_{ac_wf}) - C_{L_{\alpha_h}} \eta_h \frac{S_h}{S} \left(1 - \frac{d\varepsilon}{d\alpha} \right) (\bar{x}_{ac_h} - \bar{x}_{cg})$$



PER ESSERCI EQUILIBRIO
(con $d\epsilon=0$)

$\Rightarrow i_h < 0$!!!

E tanto minore quanto minore è

$$C_{M_{ac_wf}}$$

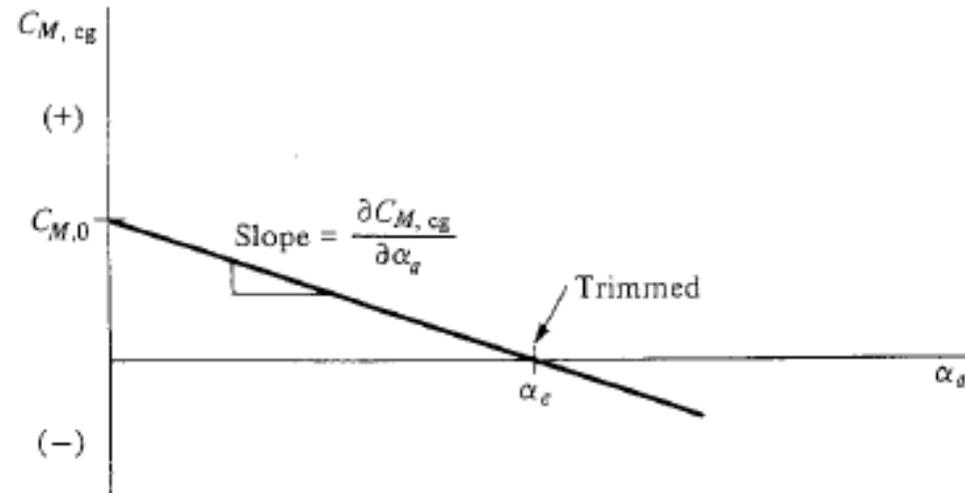
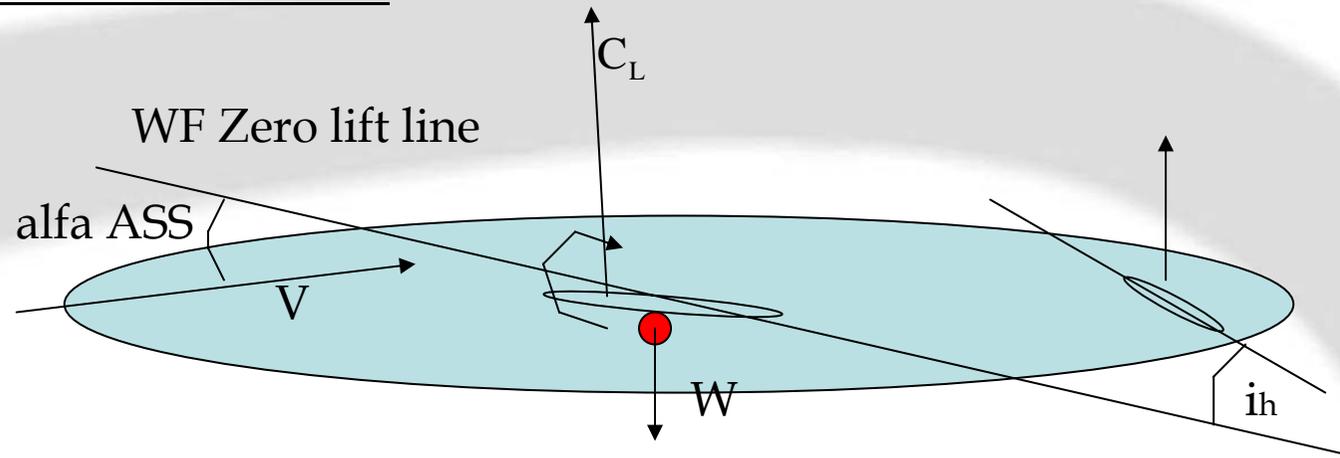


Figure 7.13 Moment coefficient curve with a negative slope.

$$C_M = C_{M_{ac_wf}} + C_{L_{\alpha_{wf}}} \alpha (\bar{X}_{cg} - \bar{X}_{ac_wf}) - C_{L_{\alpha_h}} \eta_h \frac{S_h}{S} \alpha \left(1 - \frac{d\epsilon}{d\alpha} \right) (\bar{X}_{ac_h} - \bar{X}_{cg}) - C_{L_{\alpha_h}} \eta_h \cdot \frac{S_h}{S} \cdot (i_h + \tau \cdot \delta_e) \cdot (\bar{X}_{ac_h} - \bar{X}_{cg})$$



MOMENTO con alfa assoluto:

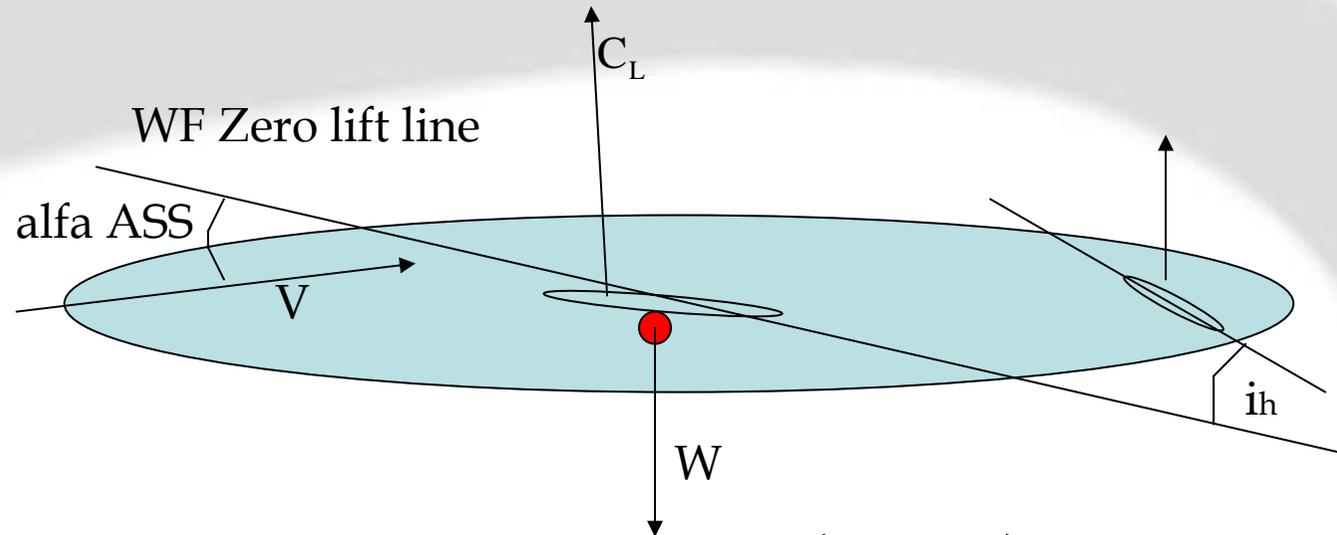


$$C_M = C_{M_{ac_wf}} + C_{L_{\alpha_{wf}}} \alpha (\bar{X}_{cg} - \bar{X}_{ac_wf}) - C_{L_{\alpha_h}} \eta_h \frac{S_h}{S} \alpha \left(1 - \frac{d\varepsilon}{d\alpha} \right) (\bar{X}_{ac_h} - \bar{X}_{cg}) - C_{L_{\alpha_h}} \eta_h \cdot \frac{S_h}{S} \cdot (i_h + \tau \cdot \delta_e) \cdot (\bar{X}_{ac_h} - \bar{X}_{cg})$$

$$C_M = C_{M_{ac_wf}} + C_{L_{\alpha_{wf}}} \left[(\bar{X}_{cg} - \bar{X}_{ac_wf}) - V_h \frac{C_{L_{\alpha_h}}}{C_{L_{\alpha_{wf}}}} \left(1 - \frac{d\varepsilon}{d\alpha} \right) \right] - C_{L_{\alpha_h}} \eta_h V_h (i_h + \tau \delta_e)$$



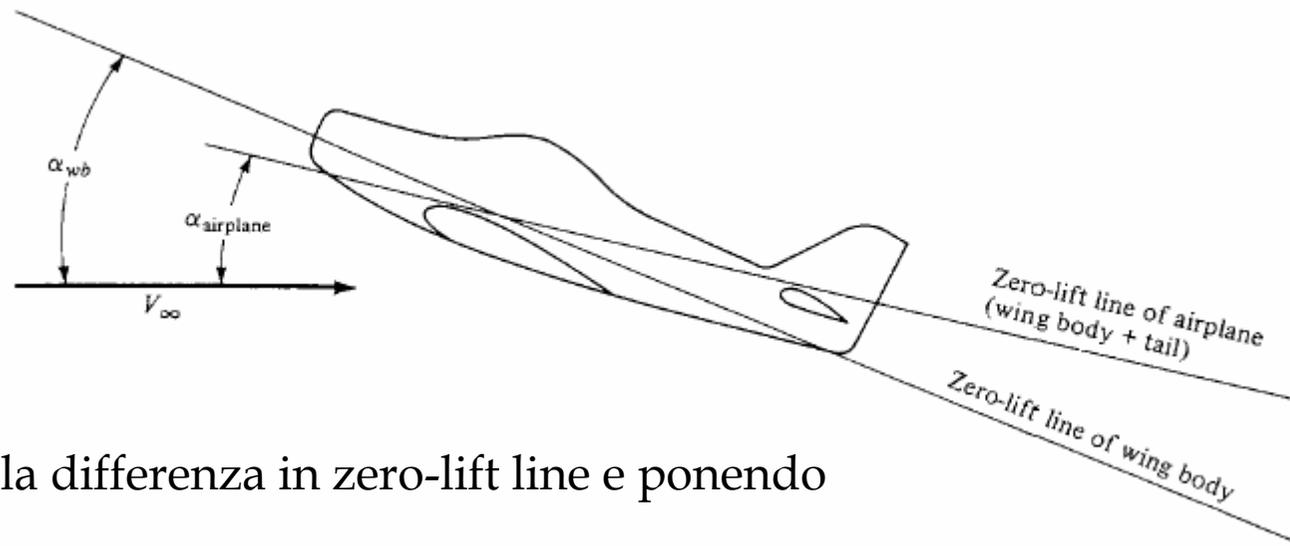
Con alfa pari all'angolo d'attacco assoluto le equazioni si semplificano:



$$C_{M_\alpha} = C_{L_{\alpha_{wf}}} (\bar{X}_{cg} - \bar{X}_{ac_wf}) - C_{L_{\alpha_h}} \eta_h \frac{S_h}{S} \left(1 - \frac{d\varepsilon}{d\alpha} \right) (\bar{X}_{ac_h} - \bar{X}_{cg})$$

$$C_{M_\alpha} = C_{L_{\alpha_{wf}}} (\bar{X}_{cg} - \bar{X}_{ac_wf}) - C_{L_{\alpha_h}} \eta_h \left(1 - \frac{d\varepsilon}{d\alpha} \right) \frac{S_h}{S} \frac{l_h}{c}$$

$$C_{M_\alpha} = C_{L_{\alpha_{wf}}} (\bar{X}_{cg} - \bar{X}_{ac_wf}) - C_{L_{\alpha_h}} V_h \eta_h \left(1 - \frac{d\varepsilon}{d\alpha} \right)$$



Trascurando la differenza in zero-lift line e ponendo

$$C_{L\alpha} = C_{L\alpha wf}$$

$$C_M = C_{M_{ac_wf}} + C_{L\alpha} \alpha \left[(\bar{x}_{cg} - \bar{x}_{ac_wf}) - V_h \frac{C_{L\alpha h}}{C_{L\alpha}} \left(1 - \frac{d\varepsilon}{d\alpha} \right) \right] - C_{L\alpha h} \eta_h V_h (i_h + \tau \delta_e)$$

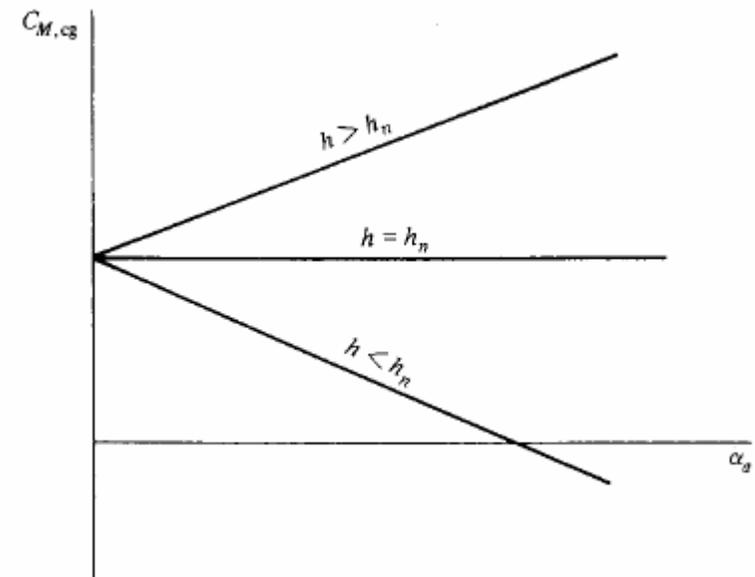


Stabilità statica

$$C_{M_{\alpha}} = C_{L_{\alpha}} \left[(\bar{X}_{cg} - \bar{X}_{ac_wf}) - V_h \frac{C_{L_{\alpha h}}}{C_{L_{\alpha}}} \left(1 - \frac{d\varepsilon}{d\alpha} \right) \right]$$

PUNTO NEUTRO

$$\bar{X}_N = \bar{X}_{ac_wf} + V_h \frac{C_{L_{\alpha h}}}{C_{L_{\alpha}}} \left(1 - \frac{d\varepsilon}{d\alpha} \right)$$



Stabilità statica

$$C_{M_{\alpha}} = C_{L_{\alpha}} \left[(\bar{X}_{cg} - \bar{X}_{ac_wf}) - V_h \frac{C_{L_{\alpha h}}}{C_{L_{\alpha}}} \left(1 - \frac{d\varepsilon}{d\alpha} \right) \right]$$

PUNTO NEUTRO

$$\bar{X}_N = \bar{X}_{ac_wf} + V_h \frac{C_{L_{\alpha h}}}{C_{L_{\alpha}}} \left(1 - \frac{d\varepsilon}{d\alpha} \right)$$

MSS

Margine di Stabilità Statica

$$MSS = \bar{X}_N - \bar{X}_{cg}$$

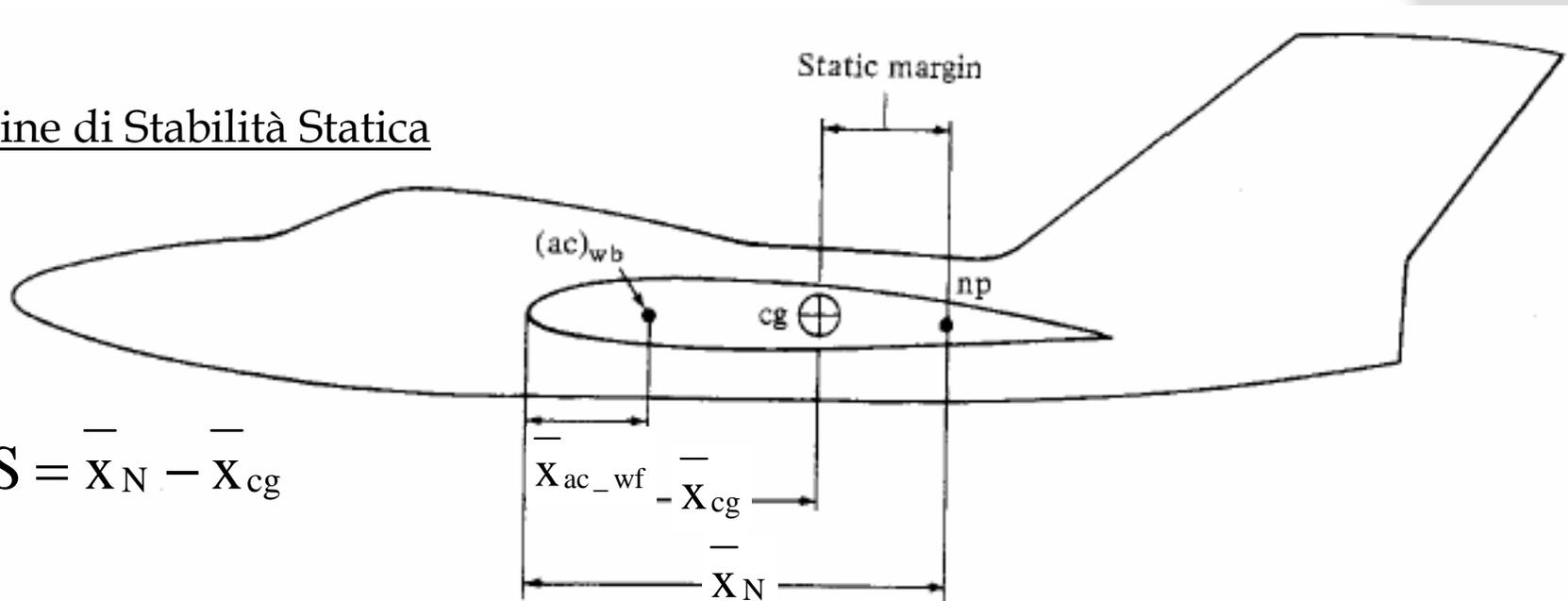


Figure 7.24 Illustration of the static margin.

Sostituendo al punto neutro la sua espressione: $\bar{X}_N = \bar{X}_{ac_wf} + V_h \frac{C_{L_{\alpha h}}}{C_{L_{\alpha}}} \left(1 - \frac{d\varepsilon}{d\alpha} \right)$

$$MSS = \bar{X}_N - \bar{X}_{cg}$$

$$MSS = \bar{X}_{ac_wf} + V_h \frac{C_{L_{\alpha h}}}{C_{L_{\alpha}}} \left(1 - \frac{d\varepsilon}{d\alpha} \right) - \bar{X}_{cg}$$

... E riguardando l'espressione del $C_{M_{\alpha}}$

$$C_{M_{\alpha}} = C_{L_{\alpha}} \left[(\bar{X}_{cg} - \bar{X}_{ac_wf}) - V_h \frac{C_{L_{\alpha h}}}{C_{L_{\alpha}}} \left(1 - \frac{d\varepsilon}{d\alpha} \right) \right]$$

$$C_{M_{\alpha}} = C_{L_{\alpha}} \cdot (-MSS)$$



$$C_{M_\alpha} = C_{L_\alpha} \cdot (-MSS)$$

Quindi anche :

$$C_{M_{CL}} = \frac{dC_M}{dC_L} = \frac{dC_M}{d\alpha} \cdot \frac{d\alpha}{dC_L} = \frac{C_{M_\alpha}}{C_{L_\alpha}} = -MSS$$

