Corso Progetto Generale Velivoli

Equilibrio e Stabilità laterale
(effetto diedro e controllo a rollio)

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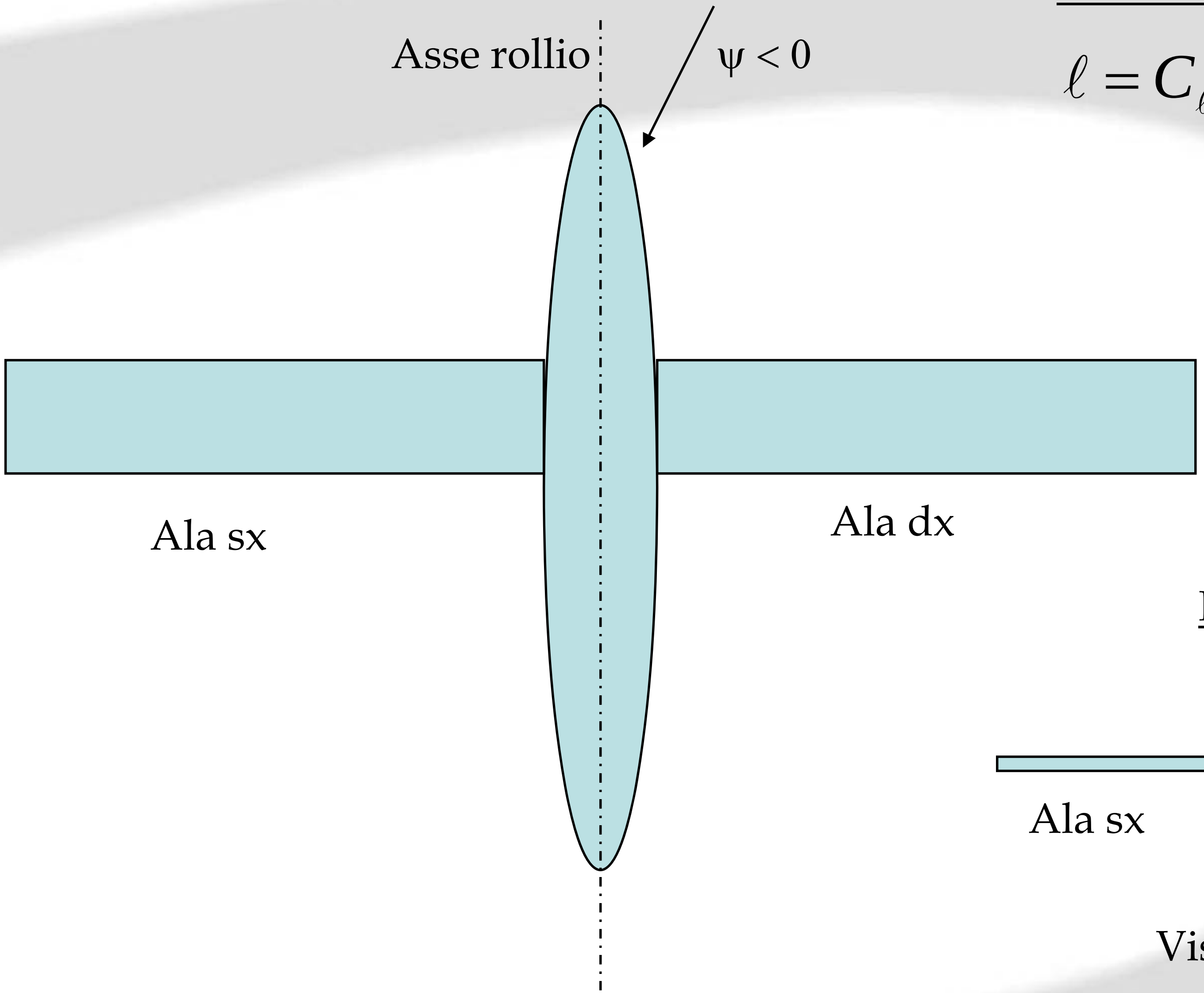
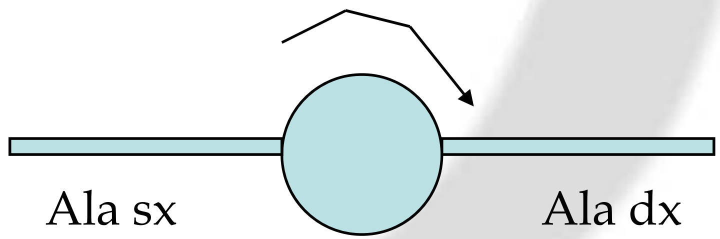
Convenzione segni ROLL



ROLLIO

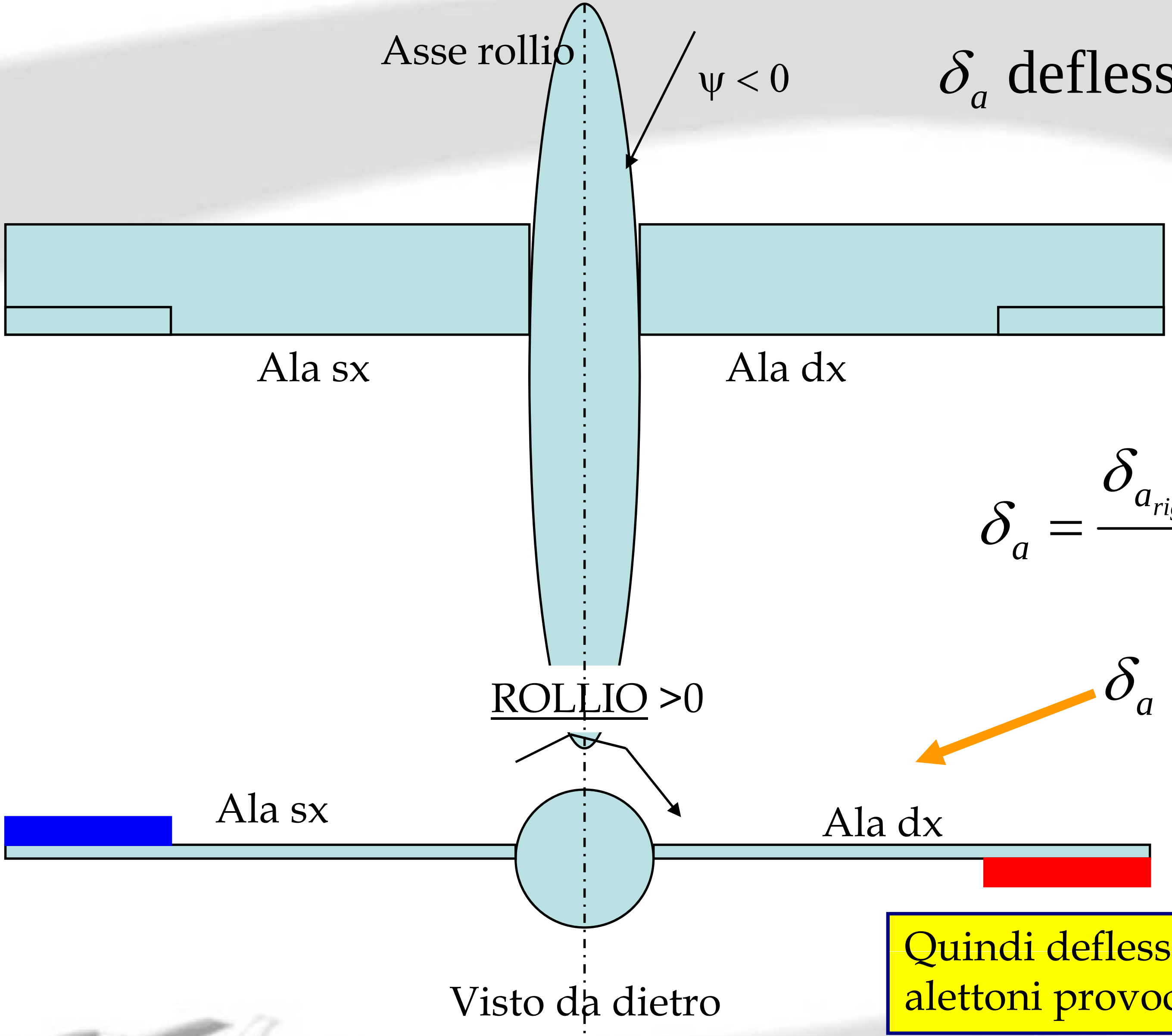
$$\ell = C_\ell \cdot q \cdot S \cdot b$$

ROLLIO >0



Visto da dietro

Convenzione segni ROLL



δ_a deflessione alettoni

$$\delta_a = \frac{\delta_{a_{right}} + \delta_{a_{left}}}{2}$$

δ_a POSITIVO

Quindi deflessione positiva degli alettoni provoca rollio negativo

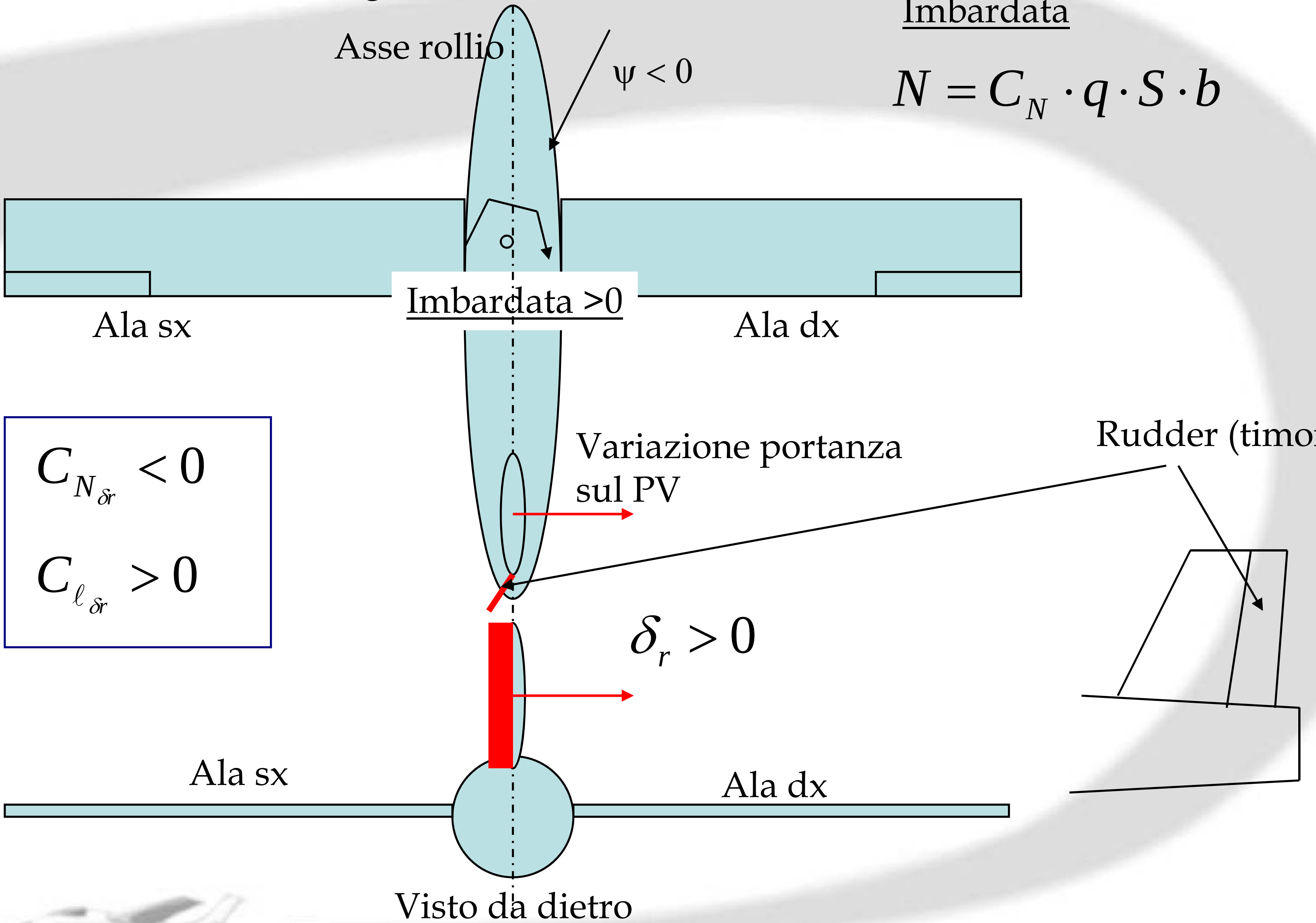
Convenzione segni Imbardata

Imbardata

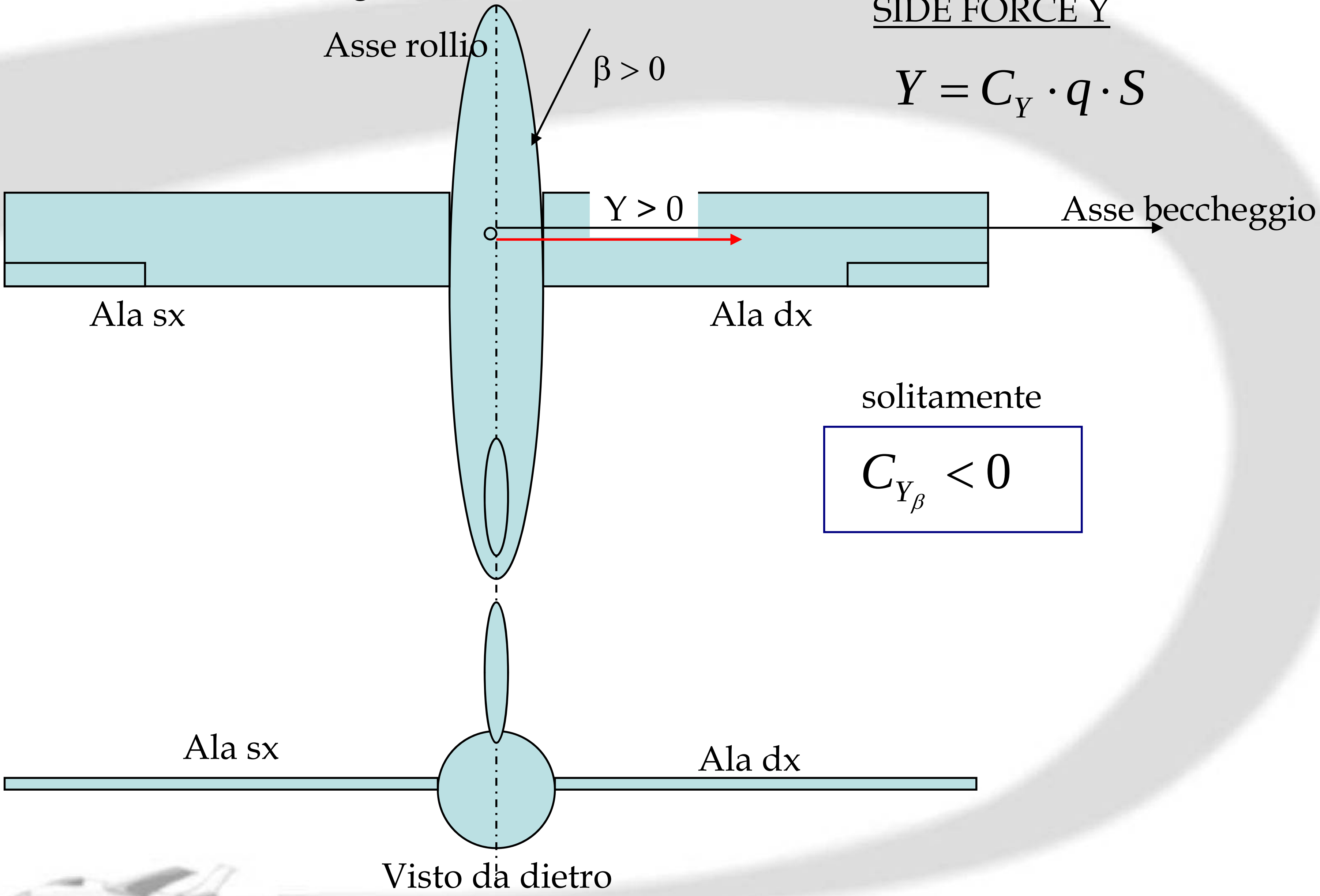
$$N = C_N \cdot q \cdot S \cdot b$$

$$C_{N_{\delta r}} < 0$$

$$C_{\ell_{\delta r}} > 0$$



Convenzione segno SIDE FORCE



SIDE FORCE Y

$$Y = C_Y \cdot q \cdot S$$

solitamente

$$\boxed{C_{Y_\beta} < 0}$$

Contributi

$$C_l = C_{l_0} + C_{l_\beta}\beta + C_{l_{\delta_a}}\delta_a + C_{l_{\delta_r}}\delta_r$$

C_{l_0} Piccolo , per velivoli simmetrici

$C_{l_\beta} = \partial C_l / \partial \beta$ EFFETTO DIEDRO, solitamente < 0

$C_{l_{\delta_a}} = \partial C_l / \partial \delta_a$ POT controllo alettone, solitamente < 0

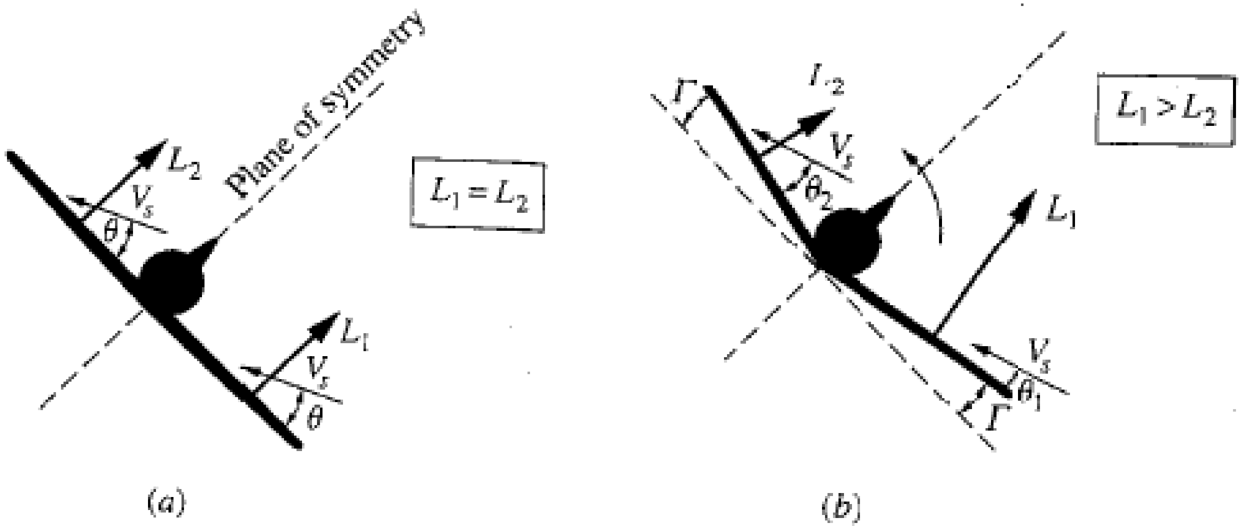
$C_{l_{\delta_r}} = \partial C_l / \partial \delta_r$ Effetto indiretto, solitamente > 0, ma variabile con l’assetto

Effetto DIEDRO

$$C_{l_\beta} = C_{l_{\beta_{wf}}} + C_{l_{\beta_h}} + C_{l_{\beta_v}}$$

- Contributo ala-fusoliera
- Contributo orizzontale (poco rilevante, solitamente)
- Contributo verticale (poco rilevante, solitamente)

Per avere stabilità laterale (in spirale) DEVE ESSERE NEGATIVA



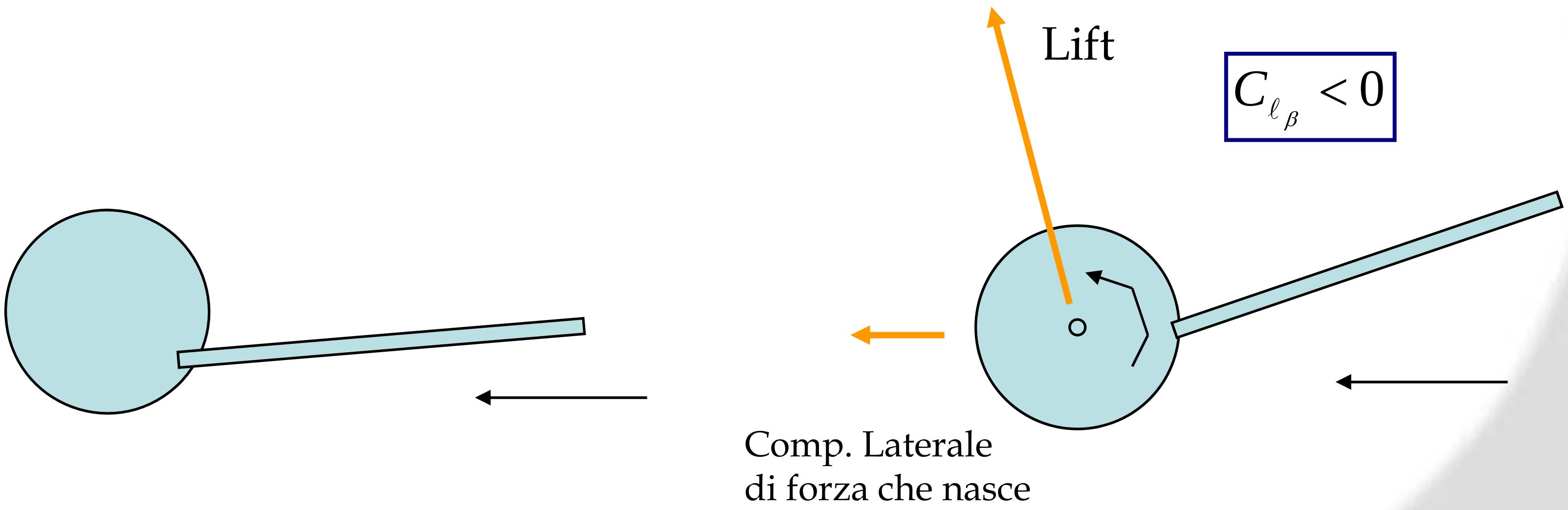
Scivolata d'ala

Effetto dell'angolo diedro alare per creare un C_{l_β} Negativo (cioè stabile)

Effetto DIEDRO

C_{l_β} Deve essere negativo per avere stabilità laterale.

Infatti se con vento che viene da dx il velivolo rolla a sx, produce una rotazione come in figura. In tal modo la portanza viene inclinata e nasce una forza laterale che tende ad annullare la componente V sin β.

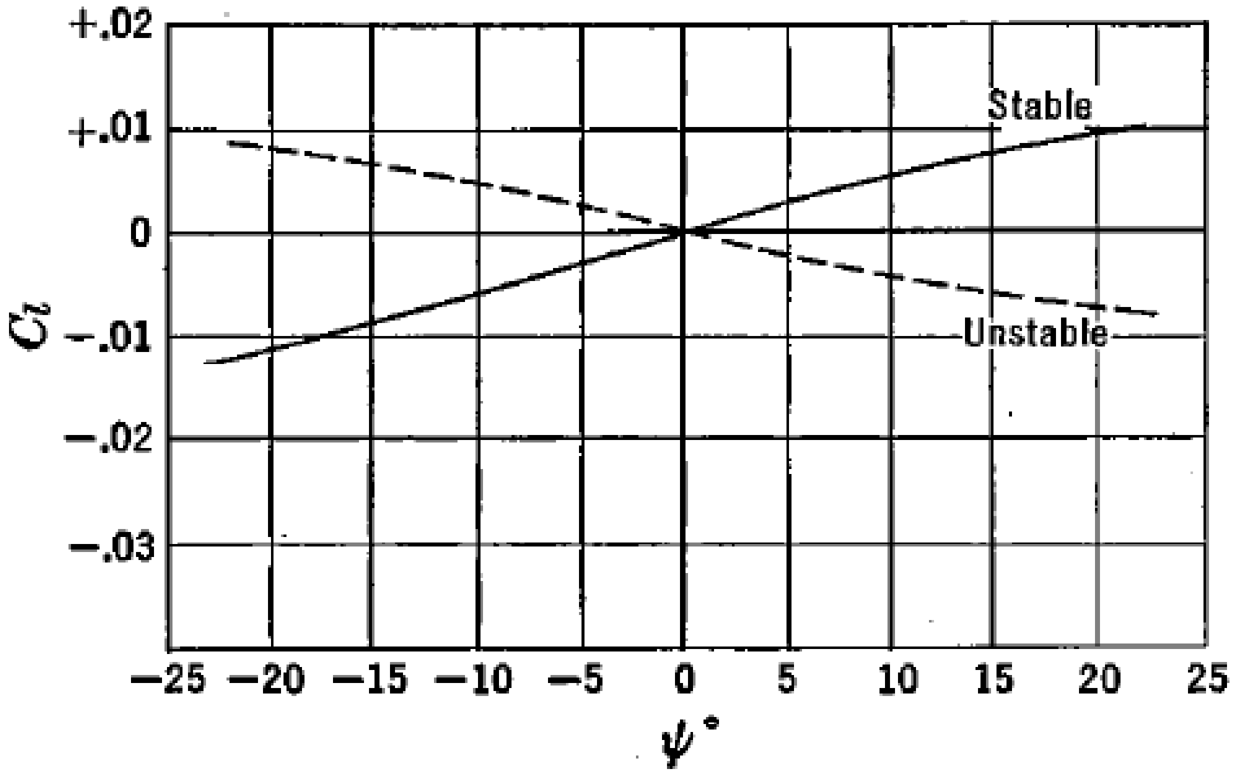


STABILITA' LATERALE

Effetto DIEDRO

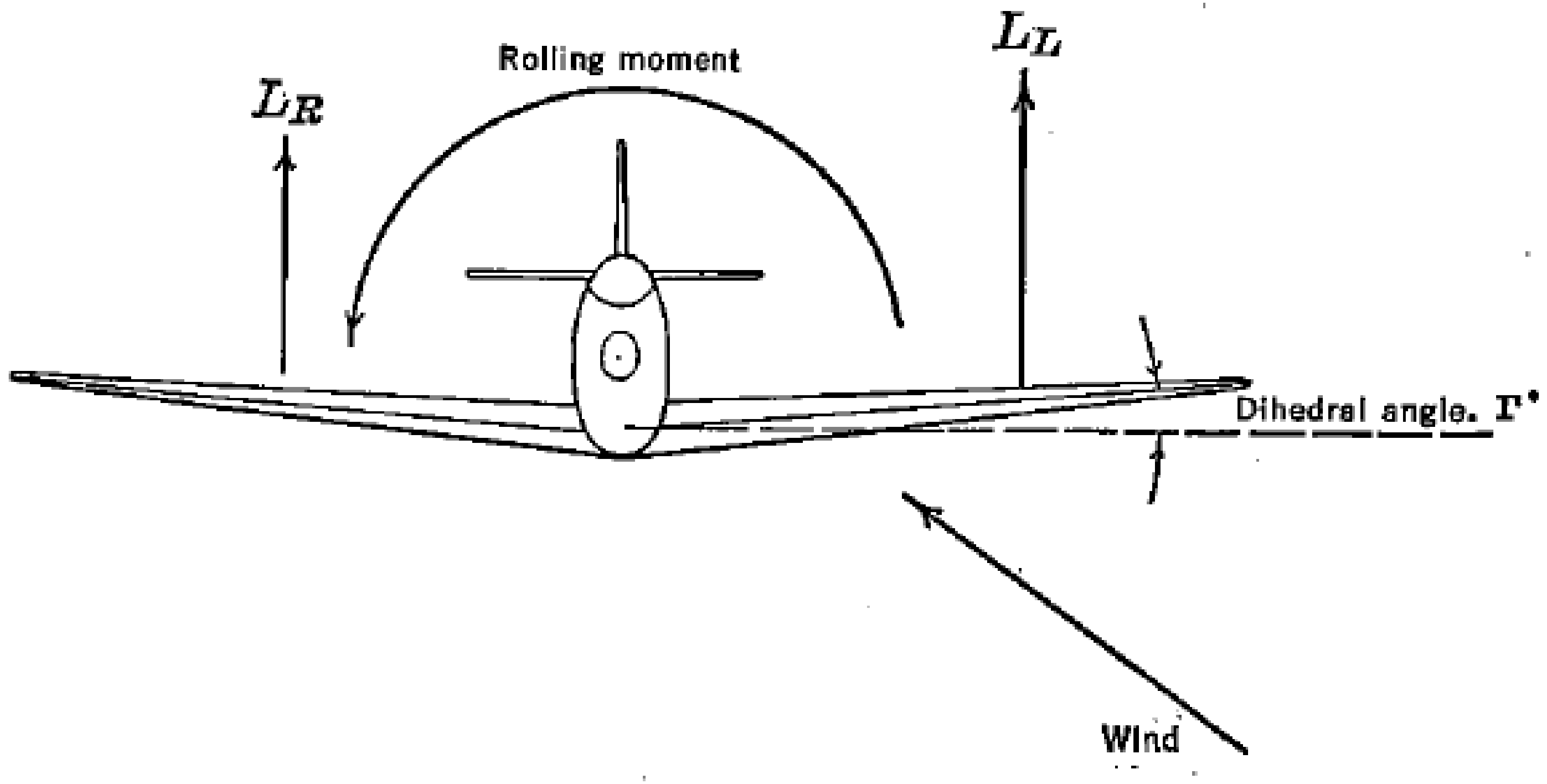
C_{l_β} Deve essere negativo per avere stabilità laterale.

Infatti se con vento che viene da dx il velivolo rolla a sx, produce una rotazione come in figura. In tal modo la portanza viene inclinata e nasce una forza laterale che tende ad annullare la componente V sin β.
In ψ è l'opposto.



Effetto DIEDRO

C_{l_β} Deve essere negativo per avere stabilità laterale.

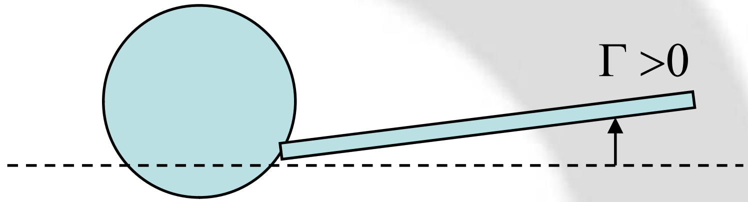


Effetto DIEDRO

$C_{l_{\beta_{wf}}}$

- Contributo ala-fusoliera

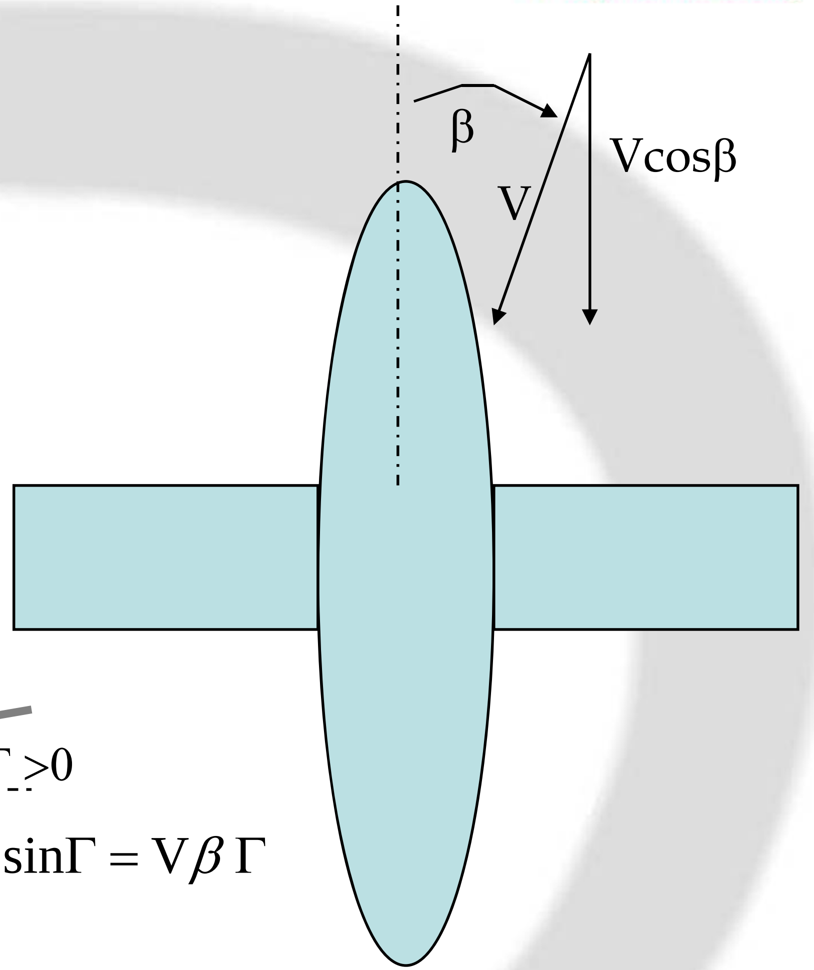
- A) ANGOLO DIEDRO Γ ALA
- B) Posizione relativa ala-fusoliera
- C) Angolo freccia dell'ala

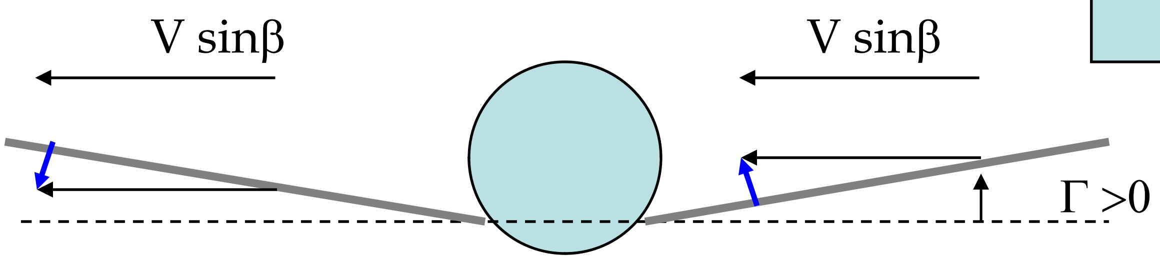


Effetto DIEDRO

$C_{l_{\beta_{wf}}}$ Contributo ala-fusoliera

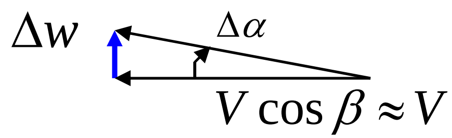
A) ANGOLO DIEDRO Γ ALA





$$\Delta w = -V\beta\,\Gamma$$

$$\Delta w > 0 \quad \Delta w = V\cdot\beta\cdot\sin\Gamma = V\beta\,\Gamma$$



$$\Delta\alpha > 0 \quad \Delta\alpha = \frac{V\beta\,\Gamma}{V} = \beta\,\Gamma$$

$$\boxed{C_{\ell_\beta}\Big|_{\Gamma} < 0}$$

Effetto DIEDRO

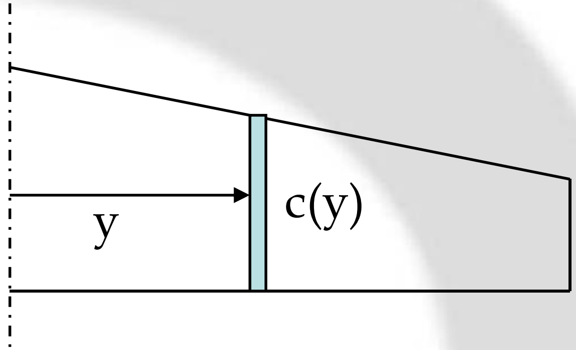
$C_{l_{\beta_{wf}}}$

Contributo ala-fusoliera

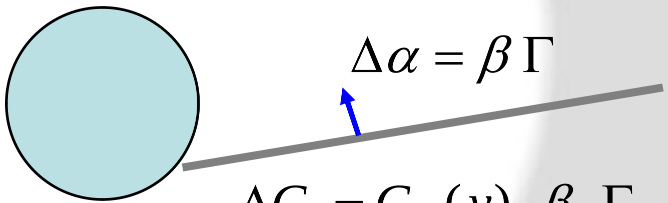
A) ANGOLO DIEDRO Γ ALA

$$\ell(y) = \left\lfloor C_{l_\alpha}(\Gamma\beta)\cdot q\cdot c(y)\cdot dy \right\rfloor\cdot y$$

Rollio dovuto alla striscia elem.



PORTO la pendenza della retta di portanza fuori dell'integrale e sostituisco il valore 2D con quello 3D dell'ala per tener conto di effetti tridimensionali. In effetti non è vero (come assunto nella presente trattazione con ala divisa in strisce) che ogni sezione lavora in modo indipendente dalle altre, perciò è opportuno mettere il valore 3D.



$$\Delta\alpha = \beta\,\Gamma$$

$$\Delta C_l = C_{l_\alpha}(y)\cdot\beta\cdot\Gamma$$

$$C_\ell(y) = \frac{\ell(y)}{qSb} = \frac{\left\lfloor C_{l_\alpha}(\Gamma\beta)\cdot c(y)\cdot dy \right\rfloor\cdot y}{Sb}$$

$$C_\ell\Big|_\Gamma = \frac{-2\Gamma\cdot\beta}{bS}C_{L_\alpha}\cdot\int_0^{b/2} c(y)\cdot y\cdot dy$$

Quindi =>

$$\boxed{C_{\ell_\beta}\Big|_\Gamma = \frac{-2\Gamma}{bS}C_{L_\alpha}\cdot\int_0^{b/2} c(y)\cdot y\cdot dy}$$

Effetto DIEDRO

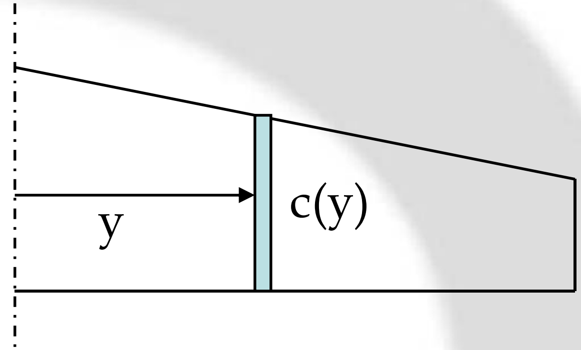
$C_{l_{\beta_{wf}}}$

Contributo ala-fusoliera

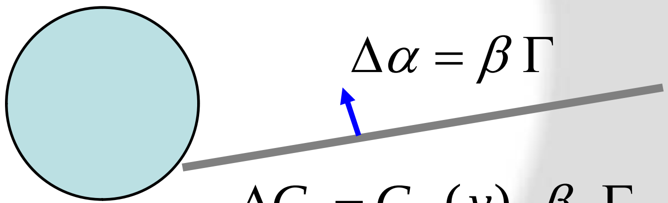
A) ANGOLO DIEDRO Γ ALA

$$C_\ell\Big|_\Gamma = \frac{-2\Gamma\cdot\beta}{bS} C_{L_\alpha}\cdot\int_0^{b/2} c(y)\cdot y\cdot dy$$

Rollio dovuto alla striscia elem.



Si può portare tutto il contenuto dell'integrale in termini adimensionali



$$\Delta\alpha = \beta\,\Gamma$$

$$\Delta C_l = C_{l_\alpha}(y)\cdot\beta\cdot\Gamma$$

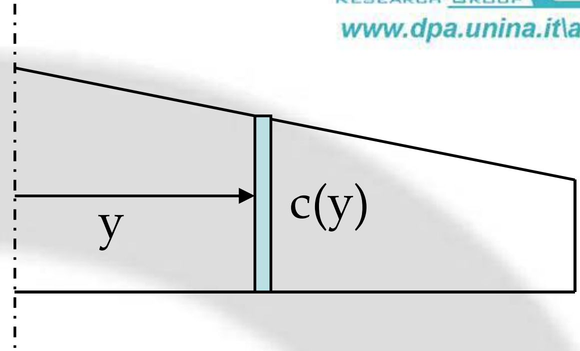
$$\Rightarrow\quad C_{\ell_\beta}\Big|_\Gamma = \frac{-2\Gamma}{bS}\frac{b^3}{8} C_{L_\alpha}\cdot\int_0^{b/2}\frac{c(y)}{b/2}\frac{y}{b/2}\frac{dy}{b/2}$$

$$\boxed{C_{\ell_\beta}\Big|_\Gamma = \frac{-\Gamma}{4} AR\cdot C_{L_\alpha}\cdot\int_0^1 \bar{c}\cdot\eta\cdot d\eta}$$

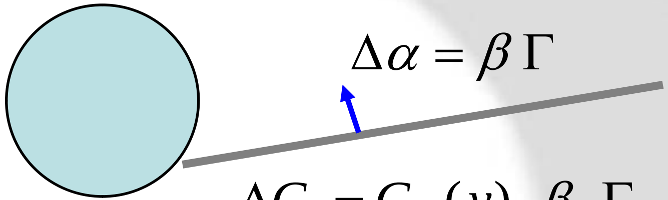
Effetto DIEDRO

$C_{l_{\beta_{wf}}}$ Contributo ala-fusoliera

A) ANGOLO DIEDRO Γ ALA



$$C_{\ell_\beta}\Big|_{\Gamma} = \frac{-\Gamma}{4} AR \cdot C_{L_\alpha} \cdot \int_0^1 \bar{c} \cdot \eta \cdot d\eta$$



$$\Delta\alpha = \beta\,\Gamma$$

$$\Delta C_l = C_{l_\alpha}(y) \cdot \beta \cdot \Gamma$$

- Dipende dall'angolo diedro
- Dipende dalla geometria dell'ala (dalla rastremazione λ)
- Non dipende dall'assetto (dal coeff. Portanza)

Sviluppando l'integrale, in caso di ala trapezoidale :

$$INT = \frac{8}{b^3} \int_0^{b/2} \left[c_r + \frac{c_t - c_r}{(b/2)} \cdot y \right] \cdot y \cdot dy = \frac{8}{b^3} \left[\frac{c_r}{2} y^2 + \frac{(c_t - c_r)}{3(b/2)} y^3 \right]_0^{b/2}$$

Effetto DIEDRO

$C_{l_{\beta_{wf}}}$

Contributo ala-fusoliera

A) ANGOLO DIEDRO Γ ALA

$$\boxed{C_{\ell_\beta}\Big|_\Gamma = \frac{-\Gamma}{4} AR\cdot C_{L_\alpha}\cdot\int_0^1 \bar{c}\cdot\eta\cdot d\eta}$$

$$INT = \frac{8}{b^3}\left[\frac{c_r}{2}y^2 + \frac{(c_t - c_r)}{3(b/2)}y^3\right]_0^{b/2} = \frac{8}{b^3}\left[\frac{c_r}{2}\frac{b^2}{4} + \frac{c_r}{3}\frac{(\lambda-1)}{(b/2)}\frac{b^3}{8}\right]$$

$$INT = \frac{8}{b^3}c_r b^2\left[\frac{1}{8} + \frac{(\lambda-1)}{12}\right] = \frac{1}{3}\frac{c_r}{b}\left[1+2\lambda\right]$$

Essendo $S = 2\frac{(c_r + c_t)}{2}\frac{b}{2} = c_r(1+\lambda)\frac{b}{2} \quad => c_r = \frac{2S}{b}\frac{1}{(1+\lambda)}$

Sostituendo: $INT = \frac{1}{3}\frac{c_r}{b}\left[1+2\lambda\right] = \frac{2}{b}\frac{S}{3b}\frac{(1+2\lambda)}{(1+\lambda)} = \frac{2}{3}\frac{1}{AR}\frac{(1+2\lambda)}{(1+\lambda)}$

Sostituendo la formula al posto dell'integrale:

$$\boxed{C_{\ell_\beta}\Big|_\Gamma = \frac{-\Gamma}{4} AR\cdot C_{L_\alpha}\frac{2}{3}\frac{1}{AR}\frac{(1+2\lambda)}{(1+\lambda)} = -\frac{\Gamma}{6}\cdot C_{L_\alpha}\frac{(1+2\lambda)}{(1+\lambda)}}$$

Dipende dalla geometria dell'ala (dalla rastremazione λ)

Effetto DIEDRO

$C_{l_{\beta_{wf}}}$

Contributo ala-fusoliera

A) ANGOLO DIEDRO Γ ALA

$$\left. C_{\ell_\beta} \right|_\Gamma = \frac{-\Gamma}{4} AR \cdot C_{L_\alpha} \cdot \int_0^1 \bar{c} \cdot \eta \cdot d\eta$$

$$\left. C_{\ell_\beta} \right|_\Gamma = -\frac{\Gamma}{6} \cdot C_{L_\alpha} \frac{(1+2\lambda)}{(1+\lambda)}$$

- Assumendo un valore medio di pendenza della retta di portanza pari a 0.080 (1/°)

- Per una rastremazione pari a 0.50

$$\left. C_{\ell_\beta} \right|_\Gamma = -\frac{\Gamma}{6} \cdot 0.08 \frac{2}{1.5} = -0.018 \cdot \Gamma \quad [1/°] \text{ con } \Gamma \text{ in rad}$$

=> $$\left. C_{\ell_\beta} \right|_\Gamma = -0.00030 \cdot \Gamma \quad [1/°] \text{ con } \Gamma \text{ in } [°]$$

Perkins dice =-0.0002 * Γ

Quindi l'ala fornisce mediamente un contributo (in 1/°) di 3 decimillesimi per ogni grado di diedro (viene leggermente più alto per ala rettangolare, sempre con AR circa 8-10)

Effetto DIEDRO

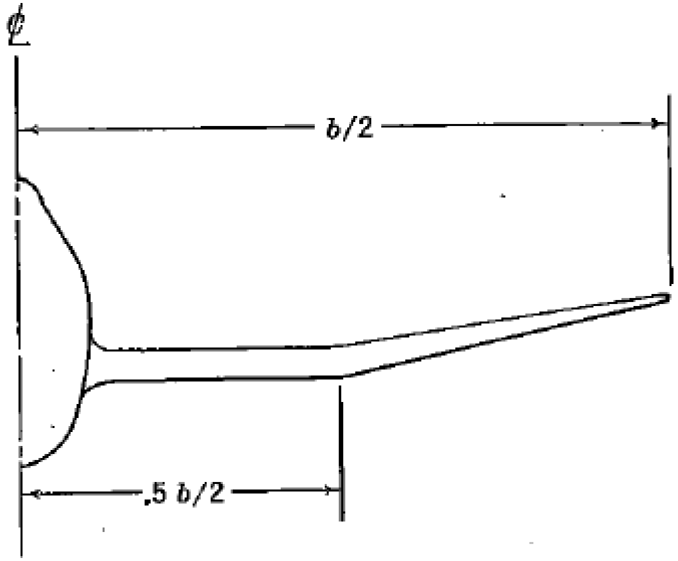
$C_{l_{\beta_{wf}}}$ Contributo ala-fusoliera

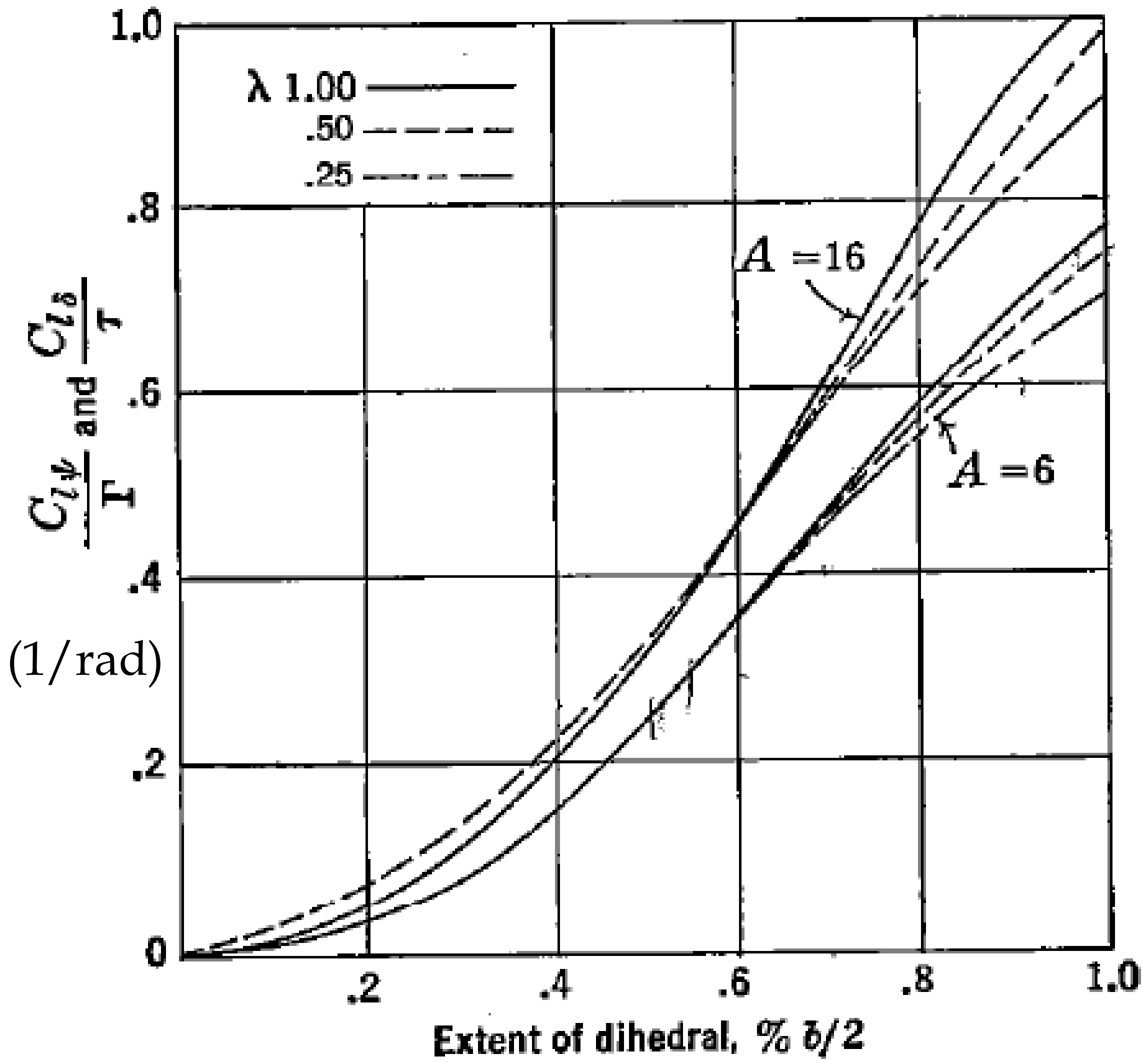
A) ANGOLO DIEDRO Γ ALA

$$\left. C_{\ell_\beta} \right|_{\Gamma} \approx -0.00020 \cdot \Gamma \quad [1/°]\ con\ \Gamma\ in\ [°]$$

$$\left. C_{\ell_\beta} \right|_{\Gamma} = \frac{-\Gamma}{4} AR \cdot C_{L_\alpha} \cdot \int_0^1 \bar{c} \cdot \eta \cdot d\eta$$

$$\left. C_{\ell_\beta} \right|_{\Gamma} = -\frac{\Gamma}{6} \cdot C_{L_\alpha} \frac{(1+2\lambda)}{(1+\lambda)}$$





Effetto DIEDRO

$C_{l_{\beta_{wf}}}$ Contributo ala-fusoliera

Abis) TIP SHAPE

$$\left. C_{\ell_\beta} \right|_{\Gamma} \approx -0.00020 \cdot \Gamma \quad [1/°] \text{ con } \Gamma \text{ in } [°]$$

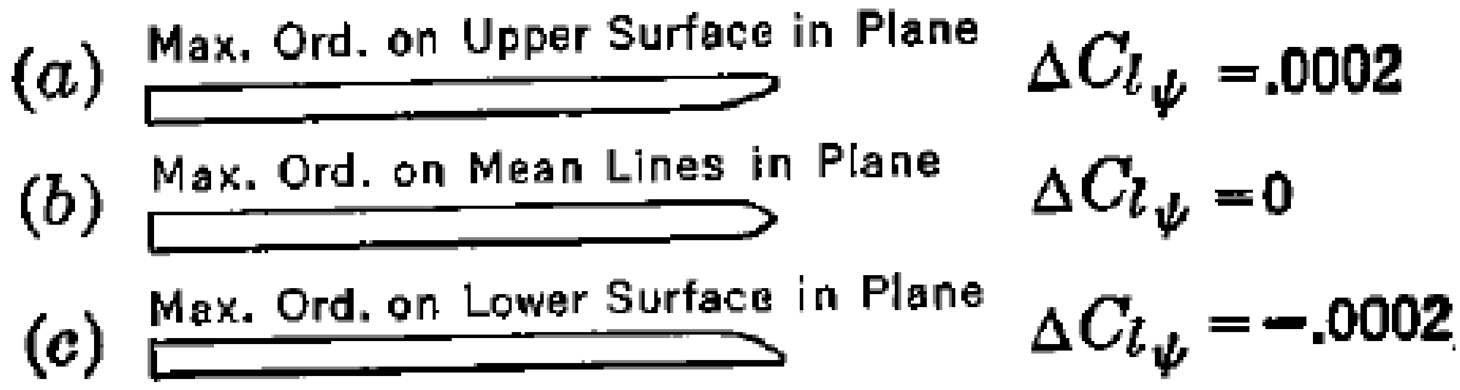


FIGURE 9–5. Effect of wing tip on C_{l_ψ}.

$$(C_{l_\psi})_{Wing} = \frac{C_{l_\psi}}{\Gamma}\Gamma + \Delta C_{l_\psi Tip\ shape}$$

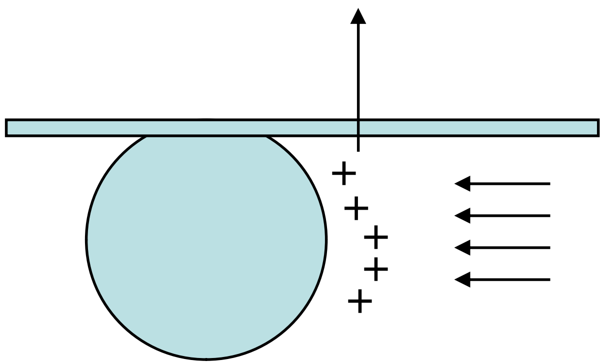
Effetto DIEDRO

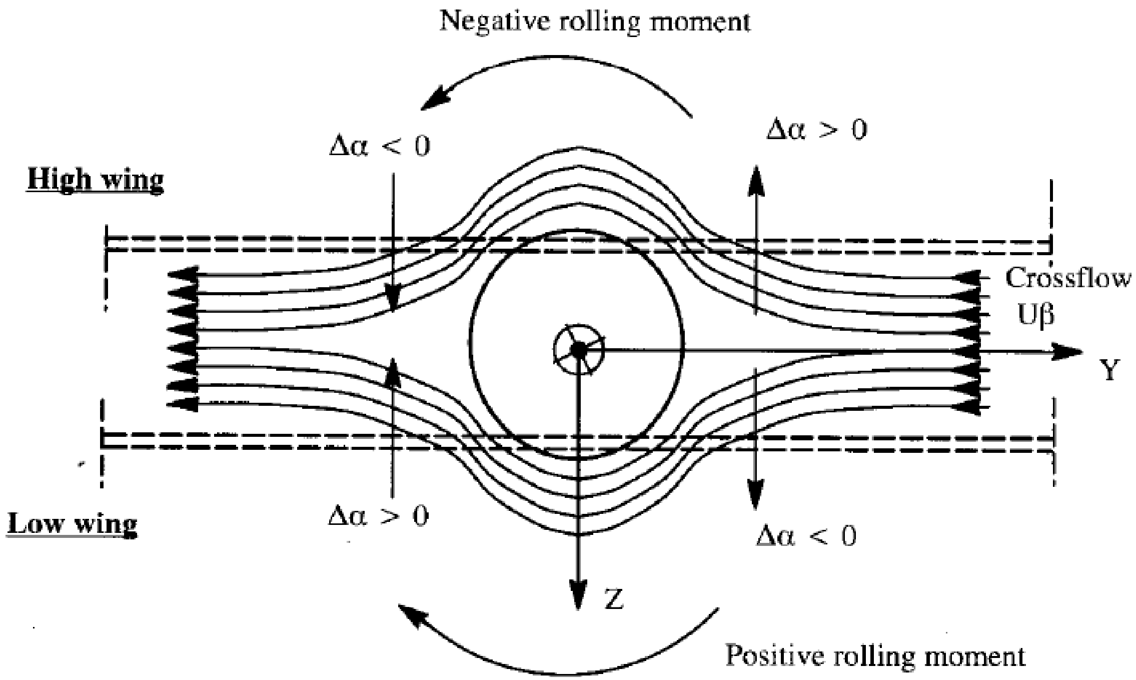
$C_{l_{\beta_{wf}}}$ Contributo ala-fusoliera
B) Posizione relativa ala-fus

ALA ALTA $\boxed{C_{\ell_\beta}\Big|_{PosWF} < 0}$

ALA BASSA $\boxed{C_{\ell_\beta}\Big|_{PosWF} > 0}$

2 Effetti :
- Variazione di angolo d'attacco in prossimità della radice dell'ala
- Sovrappressione sotto (ala alta) o sopra (ala bassa) nella zona sopravento
  Nel caso di ala alta la sovrappressione genera spinta sul ventre dell'ala alla radice





VALORI ORIENTATIVI (1/°)
HIGH WING = - 0.0006
MID WING = 0
LOW WING = + 0.0008

Effetto DIEDRO

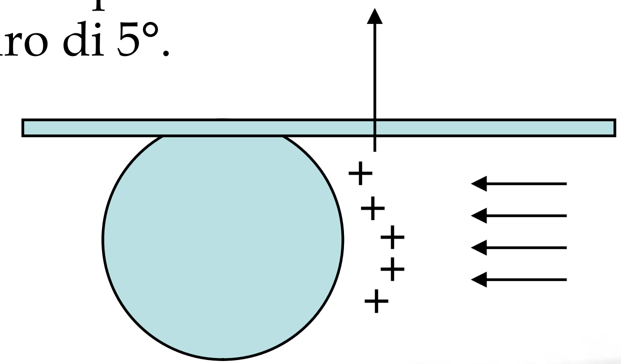
$C_{l_{\beta_{wf}}}$ Contributo ala-fusoliera
B) Posizione relativa ala-fus

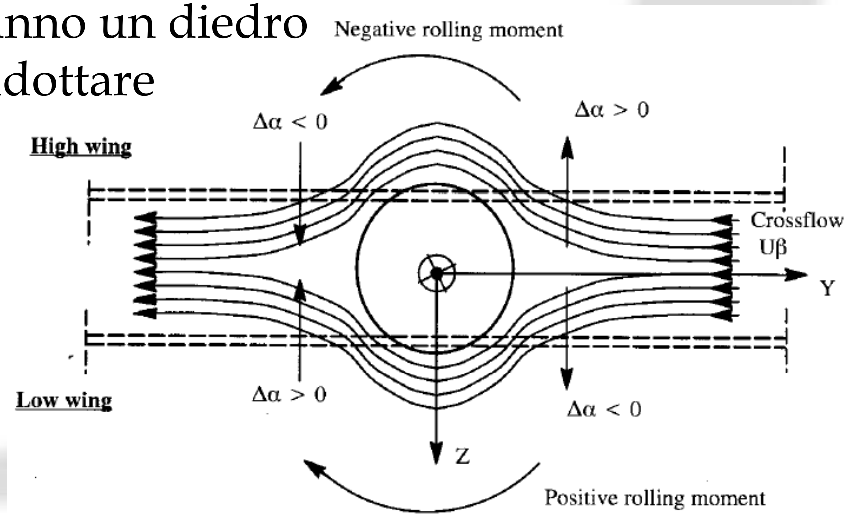
VALORI ORIENTATIVI (1/°)
HIGH WING = - 0.0006
MID WING = 0
LOW WING = + 0.0008

ALA ALTA $\boxed{C_{\ell_\beta}\Big|_{PosWF} < 0}$

ALA BASSA $\boxed{C_{\ell_\beta}\Big|_{PosWF} > 0}$

Dall'analisi precedente (-0.00030 circa per ogni grado di diedro)
Si vede quindi che orientativamente l'ala alta ha un contributo di posizione relativa "EQUIVALENTE" a circa 2° di angolo diedro, mentre per l'ala bassa è circa -2.5°.
Ecco perché solitamente i velivoli ad ala alta hanno un diedro
Pari a 1-2 ° mentre quelli ad ala bassa devono adottare
Un angolo diedro di 5°.





Effetto DIEDRO

$C_{l_{\beta_{wf}}}$ Contributo ala-fusoliera

C) Freccia

La componente di V parallela alla corda locale dell'ala sopravento (dx) è > di quella relativa all'ala sottovento (sx).

Ne consegue maggiore portanza sull'ala dx e quindi un momento di rollio che fa sollevare l'ala dx, cioè NEGATIVO !

- Ala Freccia positiva $\boxed{C_{\ell_\beta}\Big|_\Lambda < 0}$

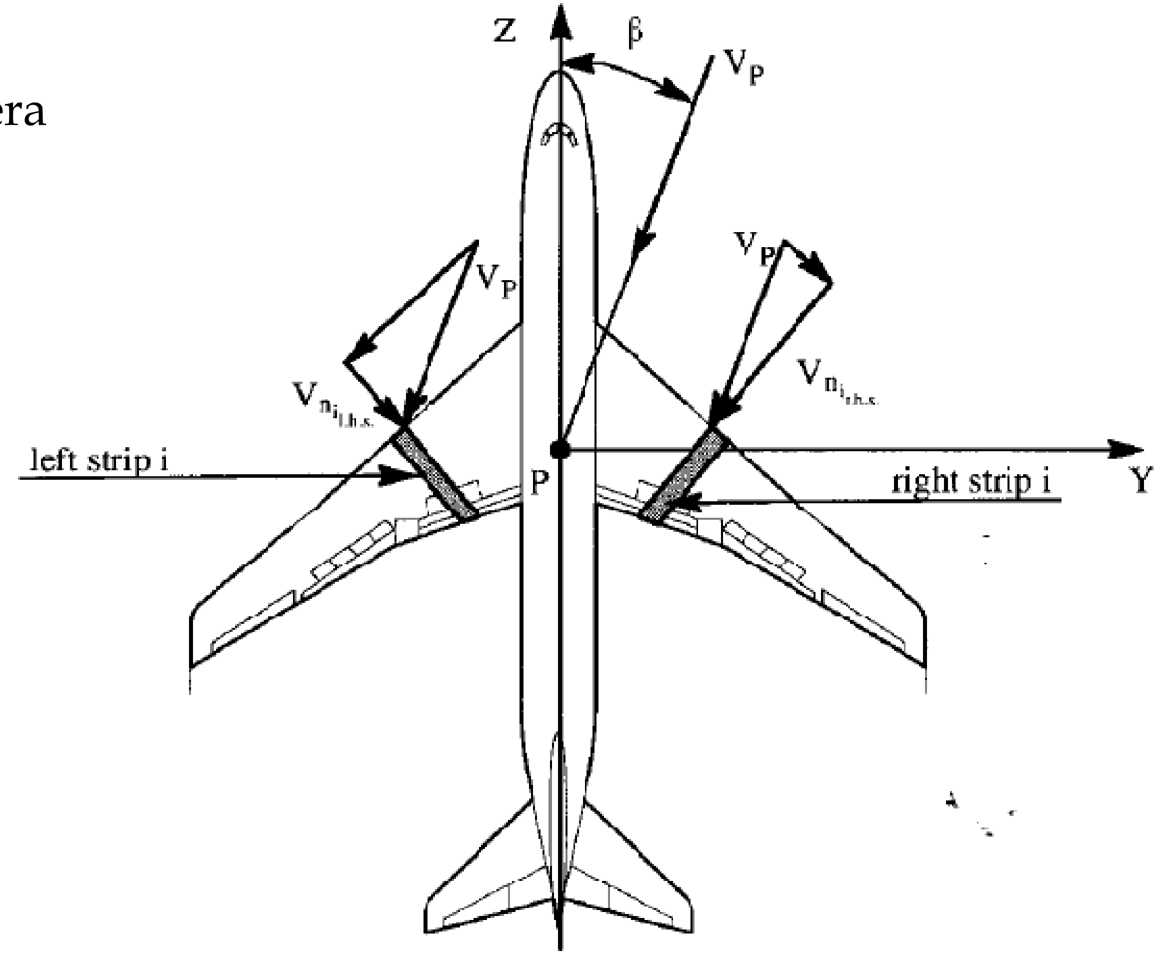


Figure 3.30 Differential Strip Velocities due to Sweep

NB: Tanto maggiore l'assetto (quindi il CL , maggiore l'effetto) !

Effetto DIEDRO

$C_{l_{\beta_{wf}}}$ Contributo ala-fusoliera

C) Freccia

Assumiamo il riferimento y come l'asse in figura e la coordinata s come quella riferita al l.e. dell'ala a freccia

$$y = s \cdot \cos\Lambda \qquad dy = ds \cdot \cos\Lambda$$

$$\Delta Lift(s) = C_{l\,n}(s) \cdot \frac{1}{2}\rho\left(V_{loc}(s)\right)^2 \cdot \left(c(s) \cdot ds\right)$$

Con $C_{l\,n}(s)$ coeff di portanza locale dovuto alla V normale alla corda

$$Ala\ \mathrm{dx} \qquad V_{\perp} = V\cos(\Lambda - \beta)$$

$$Ala\ \mathrm{sx} \qquad V_{\perp} = V\cos(\Lambda + \beta)$$

$$c = c(y) \cdot \cos\Lambda$$

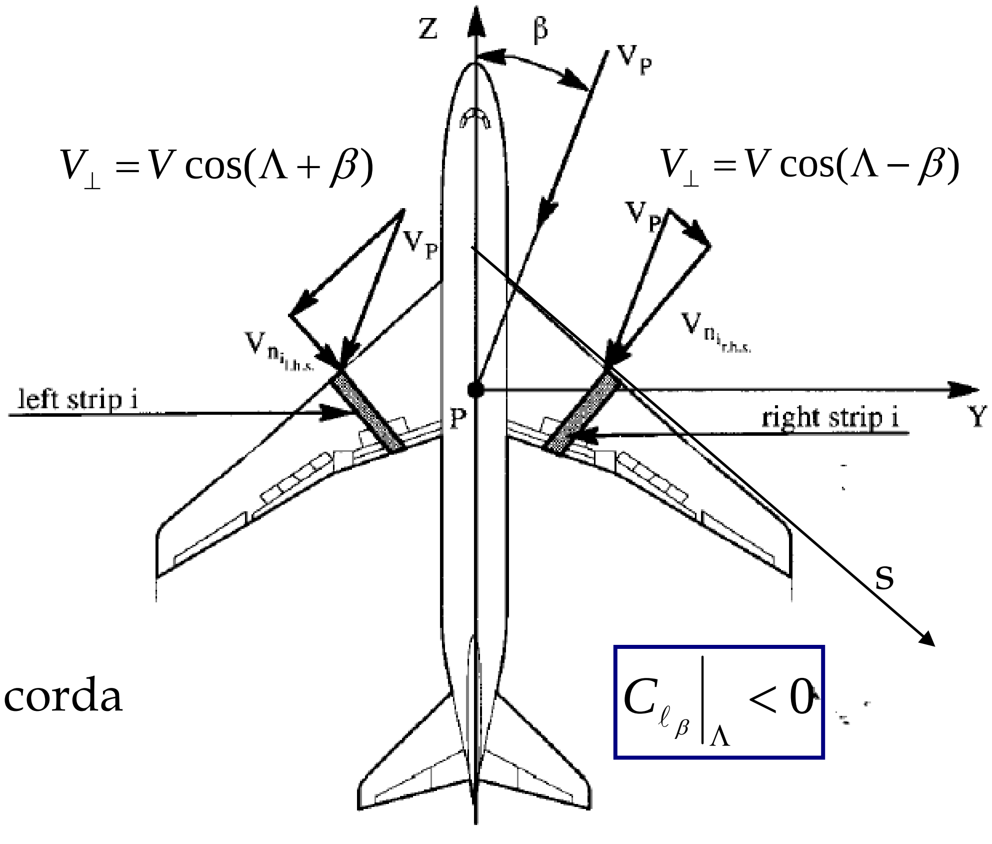


Figure 3.30 Differential Strip Velocities due to Sweep

$$\Delta Lift(y)_{right} = \left[C_{l\,n}(s) \cdot q \cdot \left(c(y) \cdot \cos\Lambda\right)\right] \cdot \cos^2(\Lambda - \beta) \cdot ds$$

$$\Delta Lift(y)_{left} = \left[C_{l\,n}(s) \cdot q \cdot \left(c(y) \cdot \cos\Lambda\right)\right] \cdot \cos^2(\Lambda + \beta) \cdot ds$$

Effetto DIEDRO

$C_{l_{\beta_{wf}}}$ Contributo ala-fusoliera

C) Freccia

$$\Delta Lift(y)_{right} = \left[C_{l\,n}(s)\cdot q\cdot\left(c(y)\cdot\cos\Lambda\right)\right]\cdot\cos^2(\Lambda-\beta)\cdot ds$$

$$\Delta Lift(y)_{left} = \left[C_{l\,n}(s)\cdot q\cdot\left(c(y)\cdot\cos\Lambda\right)\right]\cdot\cos^2(\Lambda+\beta)\cdot ds$$

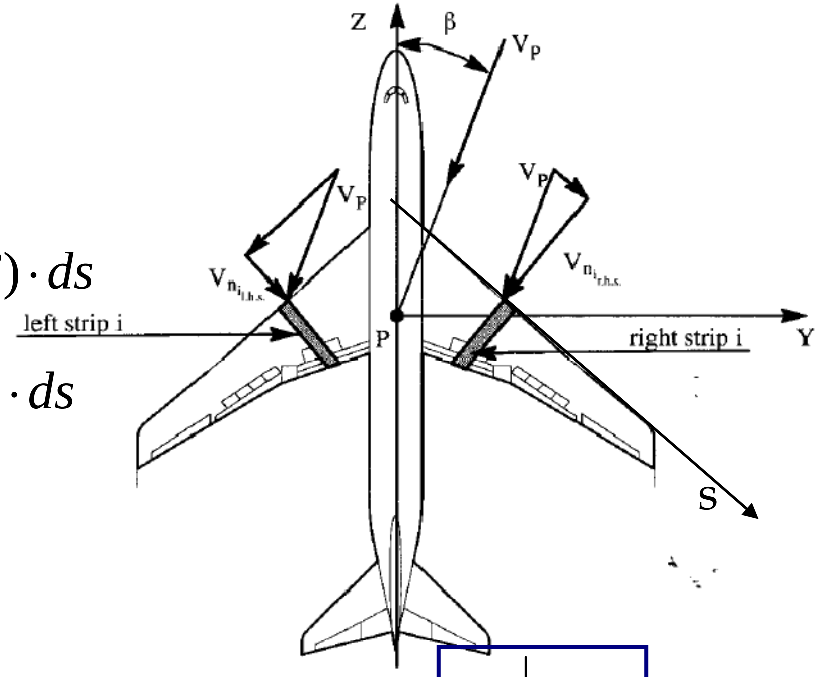


Figure 3.30 Differential Strip Velocities due to Sweep

$$\boxed{\left.C_{\ell_\beta}\right|_{\Lambda} < 0}$$

Rollio della striscia (dx – sx):

$$\Delta\ell(y) = -q\cdot c(y)\cdot C_{l\,n}\cdot y\cdot\left[\cos^2(\Lambda-\beta)-\cos^2(\Lambda+\beta)\right]\cdot\cos\Lambda\cdot ds$$

ma $\quad dy = ds\cdot\cos\Lambda \quad$ quindi

$$\Delta\ell(y) = -q\cdot c(y)\cdot C_{l\,n}\cdot y\cdot\left[\cos^2(\Lambda-\beta)-\cos^2(\Lambda+\beta)\right]\cdot dy$$

$$\boxed{\ell = -q\cdot C_{l\,n}\cdot\left[\cos^2(\Lambda-\beta)-\cos^2(\Lambda+\beta)\right]\cdot\int_0^{b/2} c(y)\cdot y\cdot dy}$$

Effetto DIEDRO

$C_{l_{\beta_{wf}}}$

Contributo ala-fusoliera

C) Freccia

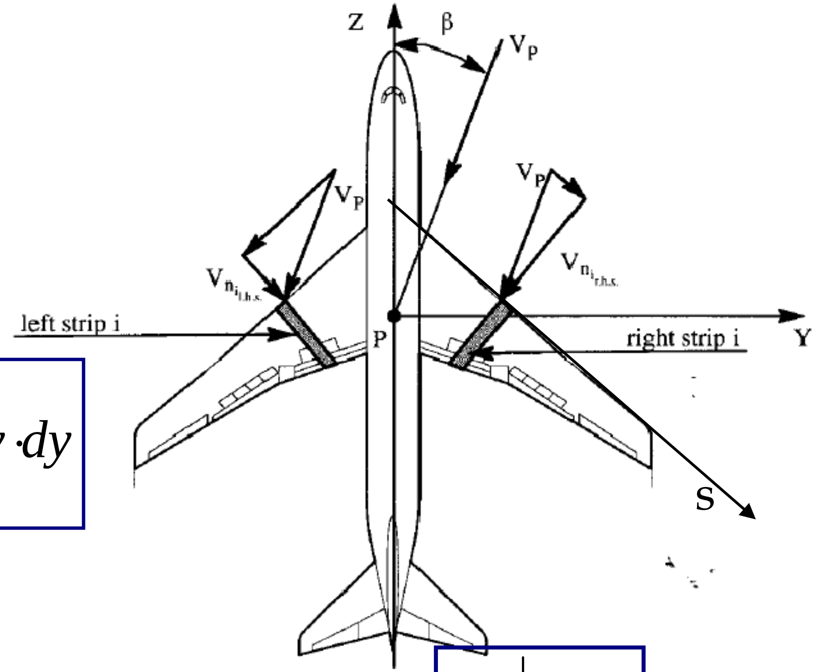


Figure 3.30 Differential Strip Velocities due to Sweep

$$\left. C_{\ell_\beta} \right|_{\Lambda} < 0$$

$$\ell = -q \cdot C_{l\,n} \cdot \left[\cos^2(\Lambda - \beta) - \cos^2(\Lambda + \beta)\right] \cdot \int_0^{b/2} c(y) \cdot y \cdot dy$$

La portanza dell'ala è:

$$L = 2 \cdot q \cdot \cos^2(\Lambda) \cdot C_{l\,n} \cdot \int_0^{b/2} c(y)\, dy$$

$$L = q \cdot S \cdot \cos^2(\Lambda) \cdot C_{l\,n} \quad \Rightarrow \quad C_L = C_{l\,n} \cdot \cos^2(\Lambda)$$

Quindi il coeff di mom di rollio dovuto alla freccia della'ala :

$$C_\ell = -\frac{C_L}{\cos^2\Lambda} \cdot \frac{1}{Sb} \cdot \left[\cos^2(\Lambda - \beta) - \cos^2(\Lambda + \beta)\right] \cdot \int_0^{b/2} c(y) \cdot y \cdot dy$$

Effetto DIEDRO

$C_{l_{\beta_{wf}}}$

Contributo ala-fusoliera

C) Freccia

$$\boxed{C_\ell = -\frac{C_L}{\cos^2\Lambda}\cdot\frac{1}{Sb}\cdot\left[\cos^2(\Lambda-\beta)-\cos^2(\Lambda+\beta)\right]\cdot\int_0^{b/2} c(y)\cdot y\, dy}$$

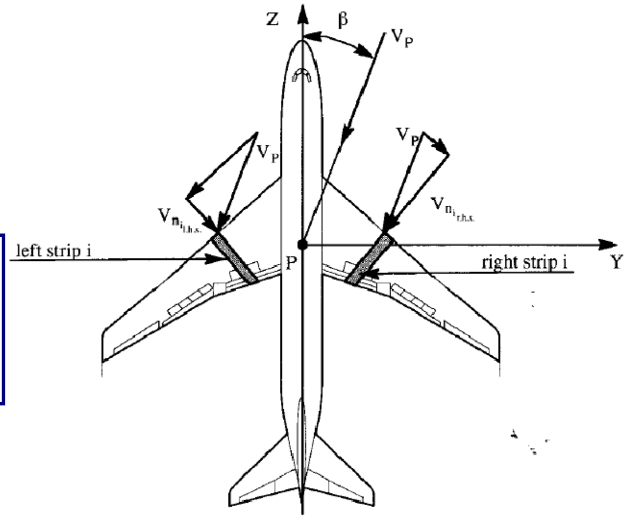


Figure 3.30 Differential Strip Velocities due to Sweep

Derivando rispetto a beta (per beta=0) :

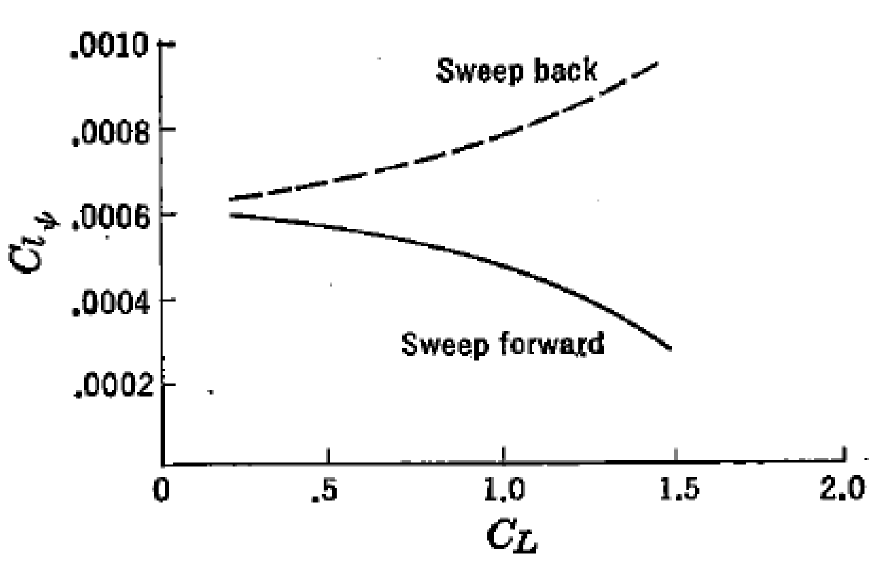
$$\boxed{C_{\ell_\beta}\Big|_{\Lambda} = -2\cdot C_L\cdot sen2\Lambda\cdot\frac{1}{Sb}\cdot\int_0^{b/2} c(y)\cdot y\, dy}$$

Si vede che dipende dall'assetto (dal coeff di portanza dell'ala) ed ovviamente dalla freccia. L'integrale dice che in un'ala rastremata l'effetto è leggermente minore che in un'ala rettangolare (come per il cl_beta dovuto al diedro).

Effetto DIEDRO

$C_{l_{\beta_{wf}}}$ Contributo ala-fusoliera
C) Freccia

$$C_{\ell_\beta}\Big|_{\Lambda} = -2 \cdot C_L \cdot sen2\Lambda \cdot \frac{1}{Sb} \cdot \int_0^{b/2} c(y) \cdot y \cdot dy$$



Oppure in termini adimensionali :

Nel caso di ala trapezia :

$$C_{\ell_\beta}\Big|_{\Lambda} = -\frac{(1+2\lambda)}{3\cdot(1+\lambda)} \cdot C_L \cdot \frac{1}{2} sen2\Lambda$$

Più in generale, includendo anche effetti 3D :

$$C_{\ell_\beta}\Big|_{\Lambda} = -f(AR,\lambda) \cdot C_L \cdot \frac{1}{2} sen2\Lambda$$

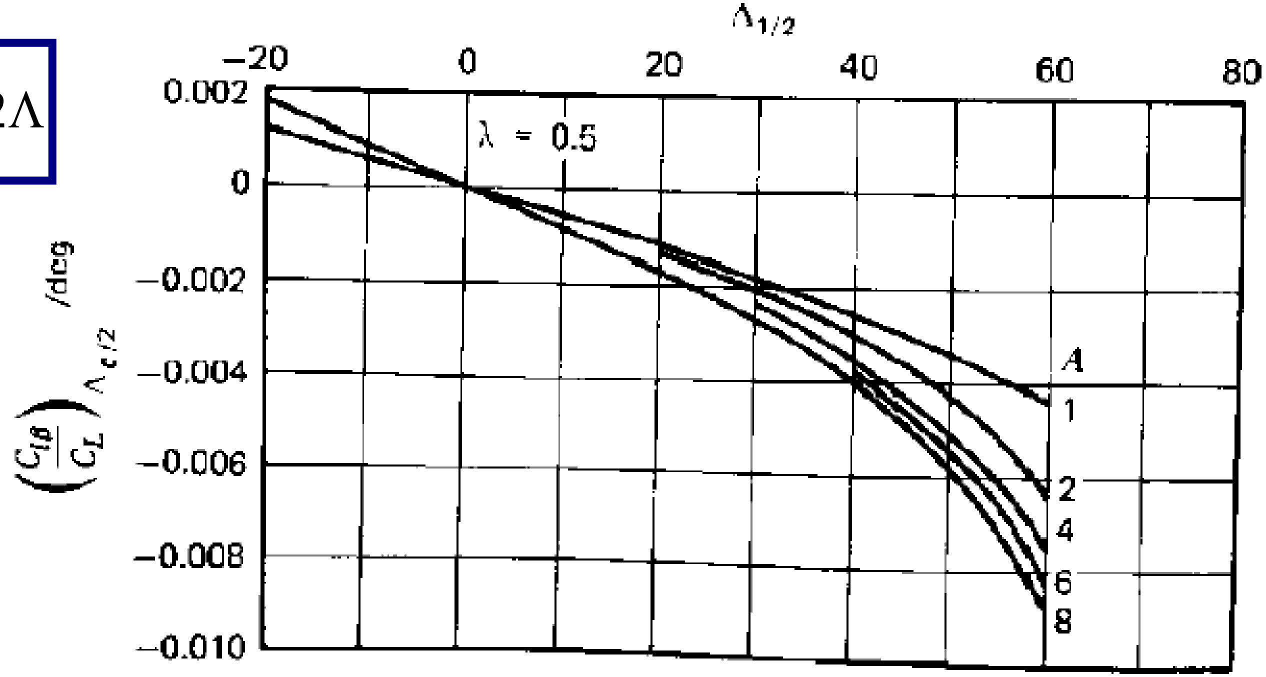
Effetto DIEDRO

$C_{l_{\beta_{wf}}}$ Contributo ala-fusoliera

C) Freccia

Attenzione, mettere con la formula il risultato è adimensionale, cioè (1/rad)

$$\boxed{C_{\ell_\beta}\Big|_\Lambda = -f(AR,\lambda)\cdot C_L \cdot \frac{1}{2} sen2\Lambda}$$



Es. : freccia 30°, rastr=0.50

$$C_{\ell_\beta}\Big|_\Lambda = -0.0025\cdot C_L \;\; [1/deg]$$

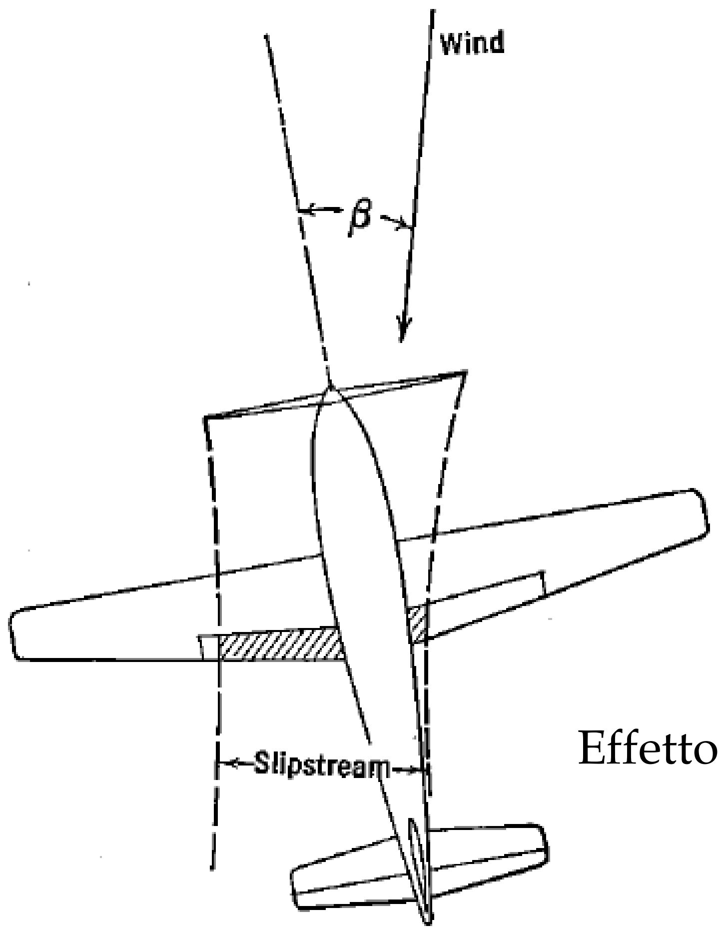
Che ad un assetto di crociera (CL=0.50) fornisce $C_{\ell_\beta}\Big|_\Lambda = -0.0012 \;\; [1/°]$

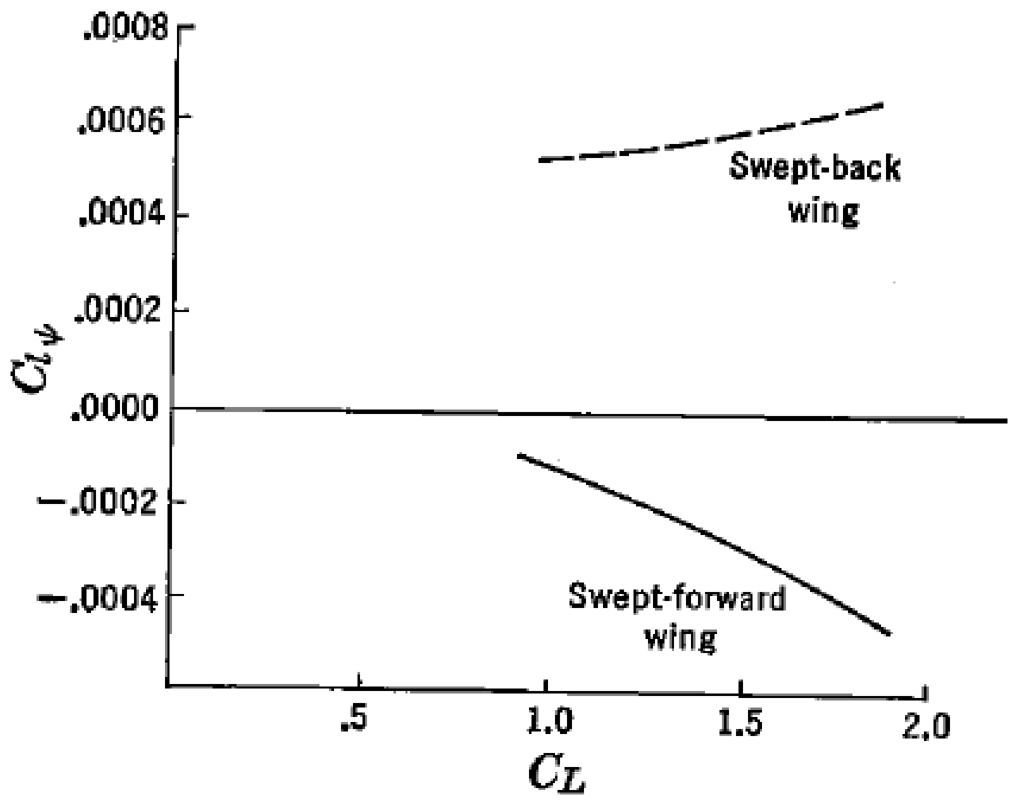
Equivalente all'effetto provocato all'incirca da 6° di angolo diedro dell'ala.

Effetto DIEDRO

$C_{l_{\beta_{wf}}}$

Contributo FLAP

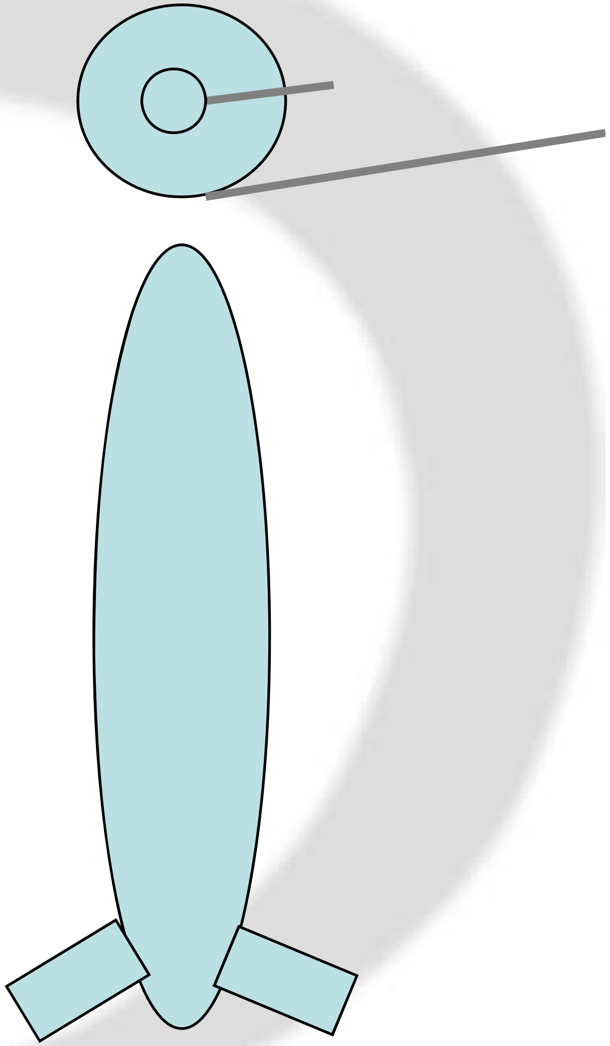




Effetto propulsore

Effetto DIEDRO

$C_{l_{\beta_h}}$ Contributo piano orizzontale



Si può trattare come l'ala (stessi effetti:
- Angolo diedro (del piano orizzontale)
- Posizione relativa piano fusoliera
- Freccia del PO

BISOGNA pero' successivamente adimensionalizzare

$$\Delta \ell_H = C_{\ell\beta_h} q S_H b_H \beta$$

$$\Delta C_{\ell\beta_H} = \frac{\Delta \ell_H}{q_\infty S b}$$

$$\boxed{C_{\ell\beta}\Big|_H = C_{\ell\beta_H}\,\eta_H\,\frac{S_H}{S}\,\frac{b_H}{b}}$$

Effetto DIEDRO

$C_{l_{\beta_v}}$ Contributo piano verticale

Esiste una deviazione della corrente dovuta all'ala ed alla Fusoliera. Si chiama side-wash e si indica con σ
In coda arriva un angolo pari a $(\beta-\sigma)$

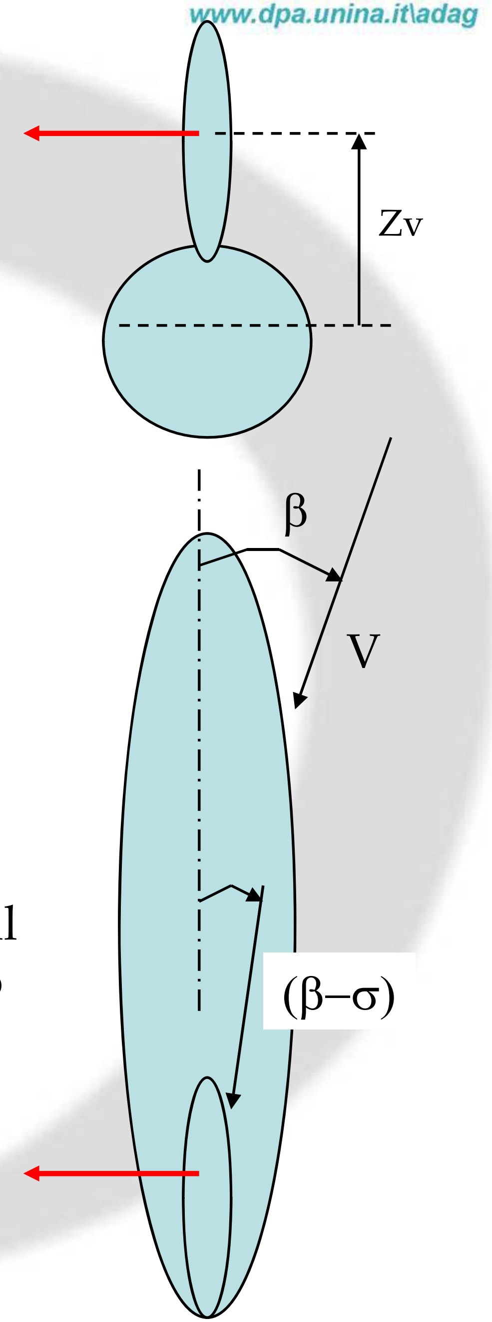
$$\beta_v = (\beta - \sigma) = \beta \cdot \left(1 - \frac{d\sigma}{d\beta}\right)$$

$$C_{L_v} = C_{L_{\alpha_v}} \cdot \beta_v = C_{L_{\alpha_v}} \cdot \beta \cdot \left(1 - \frac{d\sigma}{d\beta}\right)$$

$$\ell_v = -C_{L_v} \cdot q_v \cdot S_v \cdot z_v = -C_{L_{\alpha_v}} \cdot \beta \cdot \left(1 - \frac{d\sigma}{d\beta}\right) \cdot q_v \cdot S_v \cdot z_v$$

Mom roll negativo

$$\boxed{C_{\ell_\beta}\Big|_v = -C_{L_{\alpha_v}} \cdot \left(1 - \frac{d\sigma}{d\beta}\right) \cdot \eta_v \cdot \frac{S_v}{S}\frac{z_v}{b}}$$



Effetto DIEDRO

Velivoli militari

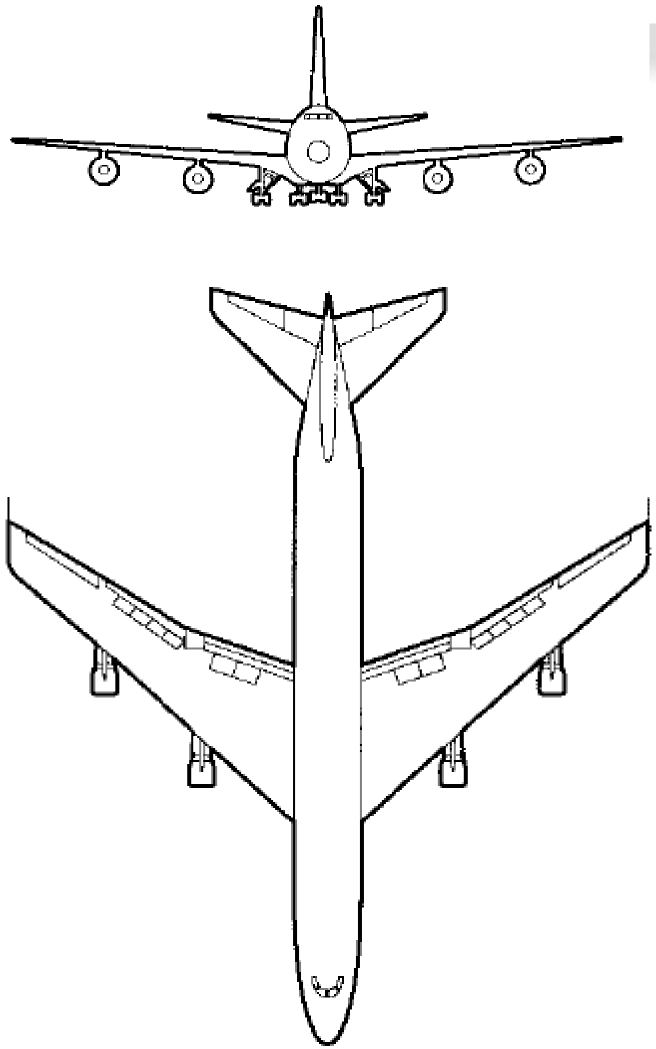
$$C_{l_\psi} = -\frac{C_{n_\psi}}{2}$$

In generale per velivoli civili deve essere dello stesso ordine di grandezza.

Se eccessivo non va bene.

-Tende ad ammazzare le manovre di rollio (per l'angolo di imbardata che si viene a verificare per l'imbardata avversa)
- Gravoso e fastidioso durante la piantata motore

Effetto DIEDRO e stab DIR

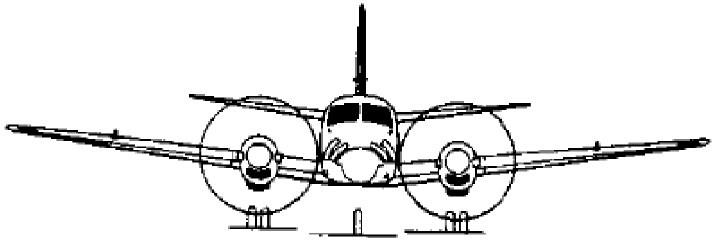


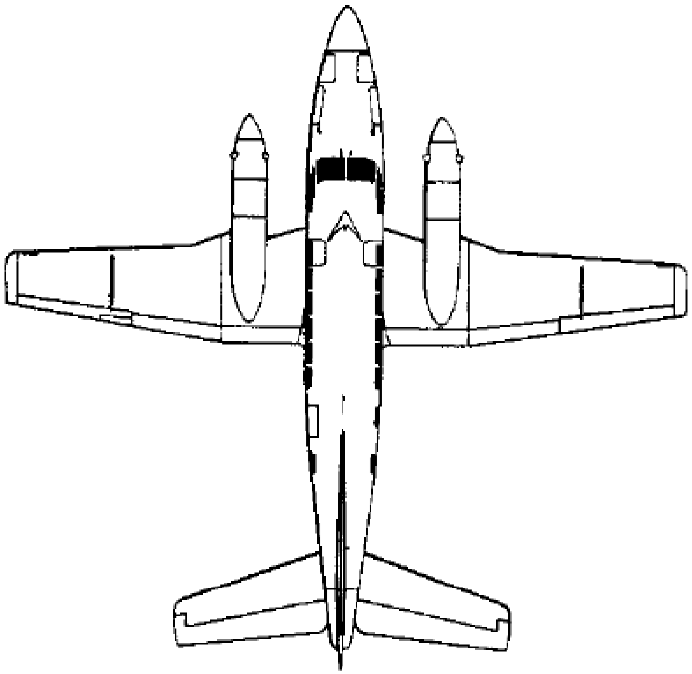
Flight Condition	Approach	Cruise (low)	Cruise (high)
C_{l_β}	–0.281	–0.160	–0.095
C_{l_p}	–0.502	–0.340	–0.320
C_{l_r}	0.195	0.130	0.200
C_{y_β}	–1.08	–0.90	–0.90
C_{y_p}	0	0	0
C_{y_r}	0	0	0
C_{n_β}	0.184	0.160	0.210

DER STAB in [1/rad]

Notare la forte riduzione dell'effetto diedro con la velocità (effetto freccia)

Effetto DIEDRO e stab DIR

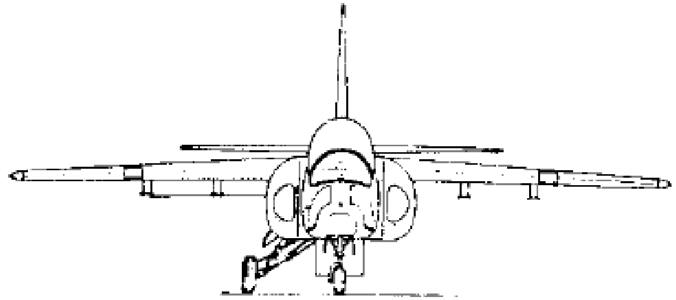


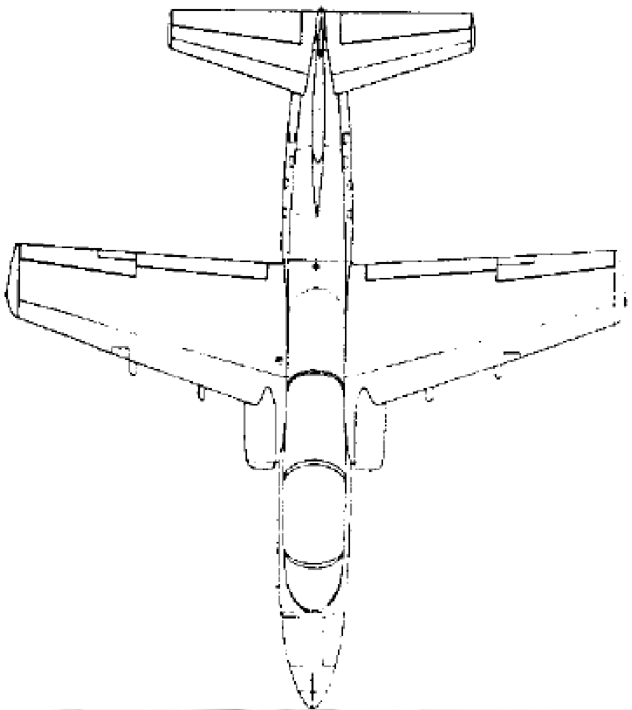


Flight Condition	Approach	Cruise (low)	Cruise (high)
C_{l_β}	–0.13	–0.13	–0.13
C_{l_p}	–0.50	–0.50	–0.50
C_{l_r}	0.06	0.14	0.14
C_{y_β}	–0.59	–0.59	–0.59
C_{y_p}	–0.21	–0.19	–0.19
C_{y_r}	0.39	0.39	0.39
C_{n_β}	0.120	0.080	0.080

DER STAB in [1/rad]

Effetto DIEDRO e stab DIR





Flight Condition	Approach	Cruise (low)	Cruise (high)
C_{l_β}	−0.140	−0.110	−0.110
C_{l_p}	−0.350	−0.390	−0.390
C_{l_r}	0.560	0.280	0.310
C_{y_β}	−0.94	−1.00	−1.00
C_{y_p}	−0.010	−0.140	−0.120
C_{y_r}	0.590	0.610	0.620
C_{n_β}	0.160	0.170	0.170

DER STAB in [1/rad]

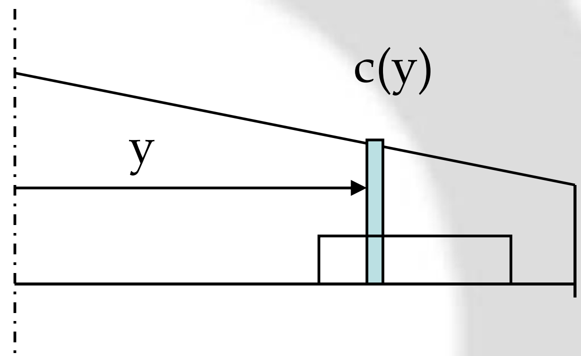
Nel caso di velivoli militari (molto manovrabili)
È meglio tenerlo basso, come si diceva :

$$C_{l_\psi} = -\frac{C_{n_\psi}}{2}$$

CONTROLLO LATERALE

$\boxed{C_{\ell_{\delta a}}}$ Coeff Momento Rollio dovuto alla deflessione alettoni

$$\Delta Lift(y) = C_{l_\alpha}(y)\cdot(\tau\cdot\delta_a)\cdot c(y)dy\cdot q_\infty$$

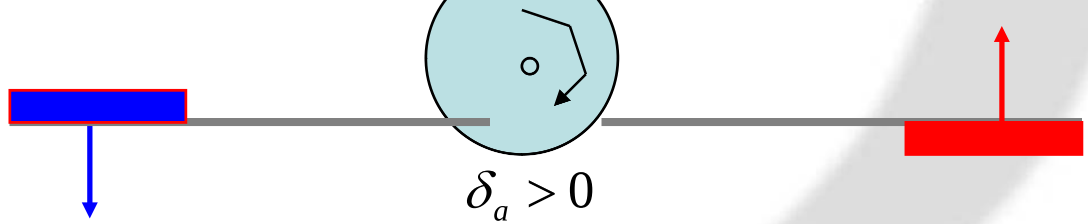


$\tau = \tau_a$ Dipendente dal rapporto locale corda alettone/corda ala

Supponendo che gli alettoni dx e sx siano deflessi in modo uguale:

$$\ell = -2\cdot q_\infty \int_{y_i}^{y_f} C_{l_\alpha}(y)\cdot(\tau\cdot\delta_a)\cdot c(y)\cdot y\cdot dy$$

$C_{\ell_{\delta a}} < 0$



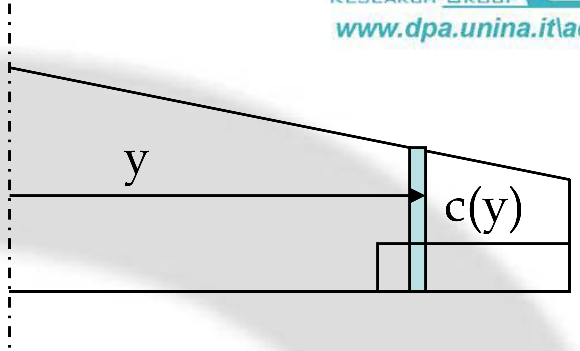
$\delta_a > 0$

Quindi:

$$C_\ell = \frac{-2\cdot C_{l_\alpha}\cdot\tau\cdot\delta_a}{S\cdot b}\int_{y_i}^{y_f} c(y)\cdot y\cdot dy$$

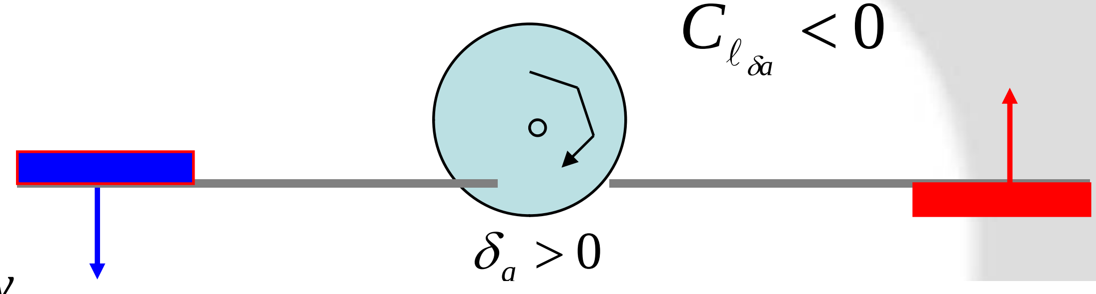
Ipotizzo pendenza della retta di portanza del profilo costante lungo l'apertura.
Potrei anche inserire il valore 3D per tener conto degli effetti tridimensionali.

CONTROLLO LATERALE



$\boxed{C_{\ell_{\delta a}}}$ Coeff Momento Rollio dovuto alla deflessione alettoni

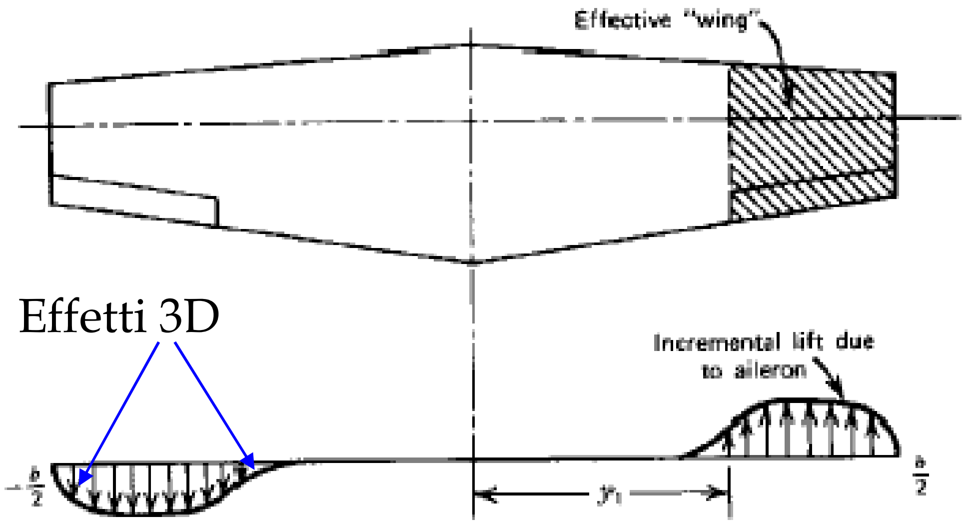
$$C_{\ell} = \frac{-2 \cdot C_{l_\alpha} \cdot \tau \cdot \delta_a}{S \cdot b} \int_{y_i}^{y_f} c(y) \cdot y \cdot dy$$



Se volessi tener conto degli effetti 3D

$$C_{\ell} = \frac{-2 \cdot C_{L_{\alpha\_w}} \cdot \tau \cdot \delta_a}{S \cdot b} \int_{y_i}^{y_f} c(y) \cdot y \cdot dy$$

In effetti, rispetto al caso del coeff. di mom rollio dovuto al diedro dove partecipa l'intera semi-apertura, qui è tutto confinato nella zona esterna.



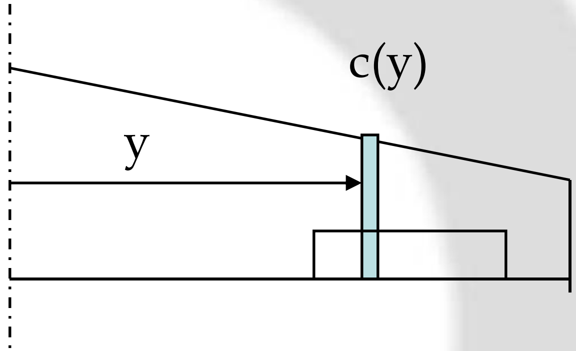
Quindi usare il valore 2D è forse + corretto

CONTROLLO LATERALE

$C_{\ell_{\delta a}}$ Coeff Momento Rollio dovuto alla deflessione alettoni

Qui si è usata la pendenza retta portanza 2D

$$C_\ell = \frac{-2 \cdot C_{l_\alpha} \cdot \tau \cdot \delta_a}{S \cdot b} \int_{y_i}^{y_f} c(y) \cdot y \cdot dy$$



$$C_{\ell_{\delta a}} = \frac{-2 \cdot C_{l_\alpha} \cdot \tau}{S \cdot b} \frac{b^3}{8} \int_{\eta_i}^{\eta_f} \bar{c} \cdot \eta \cdot d\eta = \frac{-Cl_{l_\alpha} \cdot \tau}{4} AR \int_{\eta_i}^{\eta_f} \bar{c} \cdot \eta \cdot d\eta$$

$$C_{\ell_{\delta a}} < 0$$

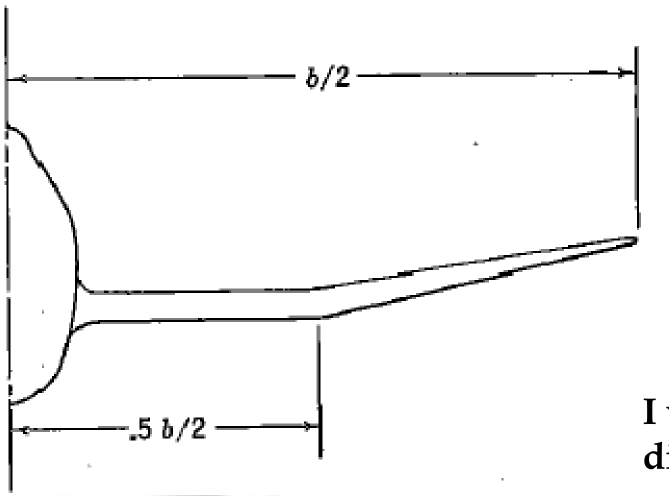
$$\boxed{C_{\ell_{\delta a}} = \frac{-2 \cdot C_{l_\alpha} \cdot \tau}{S \cdot b} \int_{y_i}^{y_f} c(y) \cdot y \cdot dy}$$

$$\boxed{C_{\ell_{\delta a}} = \frac{-C_{l_\alpha} \cdot \tau}{4} AR \int_{\eta_i}^{\eta_f} \bar{c} \cdot \eta \cdot d\eta}$$

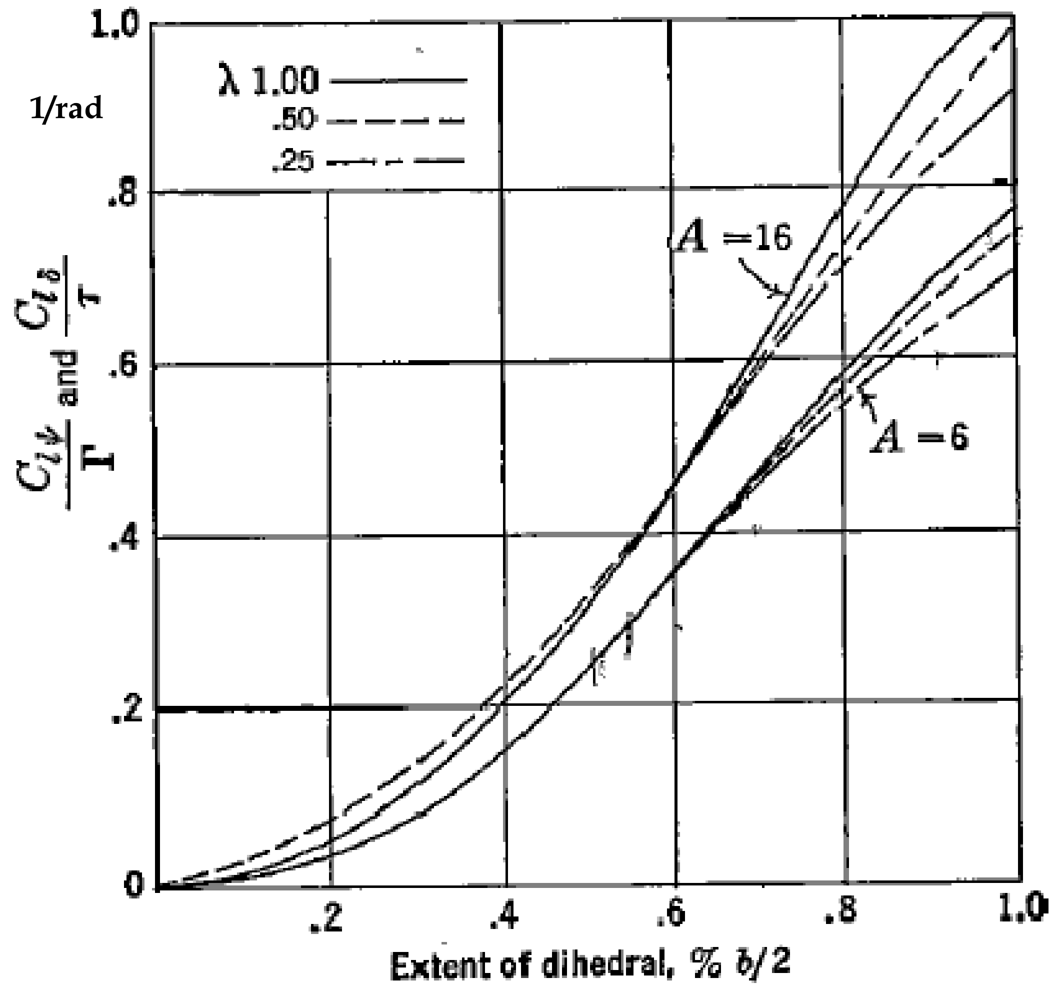
CONTROLLO LATERALE

$$C_{\ell_\beta}\Big|_\Gamma = \frac{-2\Gamma}{bS} C_{L_\alpha} \cdot \int_0^{b/2} c(y)\cdot y \cdot dy$$

$$C_{\ell_{\delta a}} = \frac{-2\cdot C_{l_\alpha}\cdot\tau}{S\cdot b}\int_{y_i}^{y_f} c(y)\cdot y\cdot dy$$



Cambiati di segno

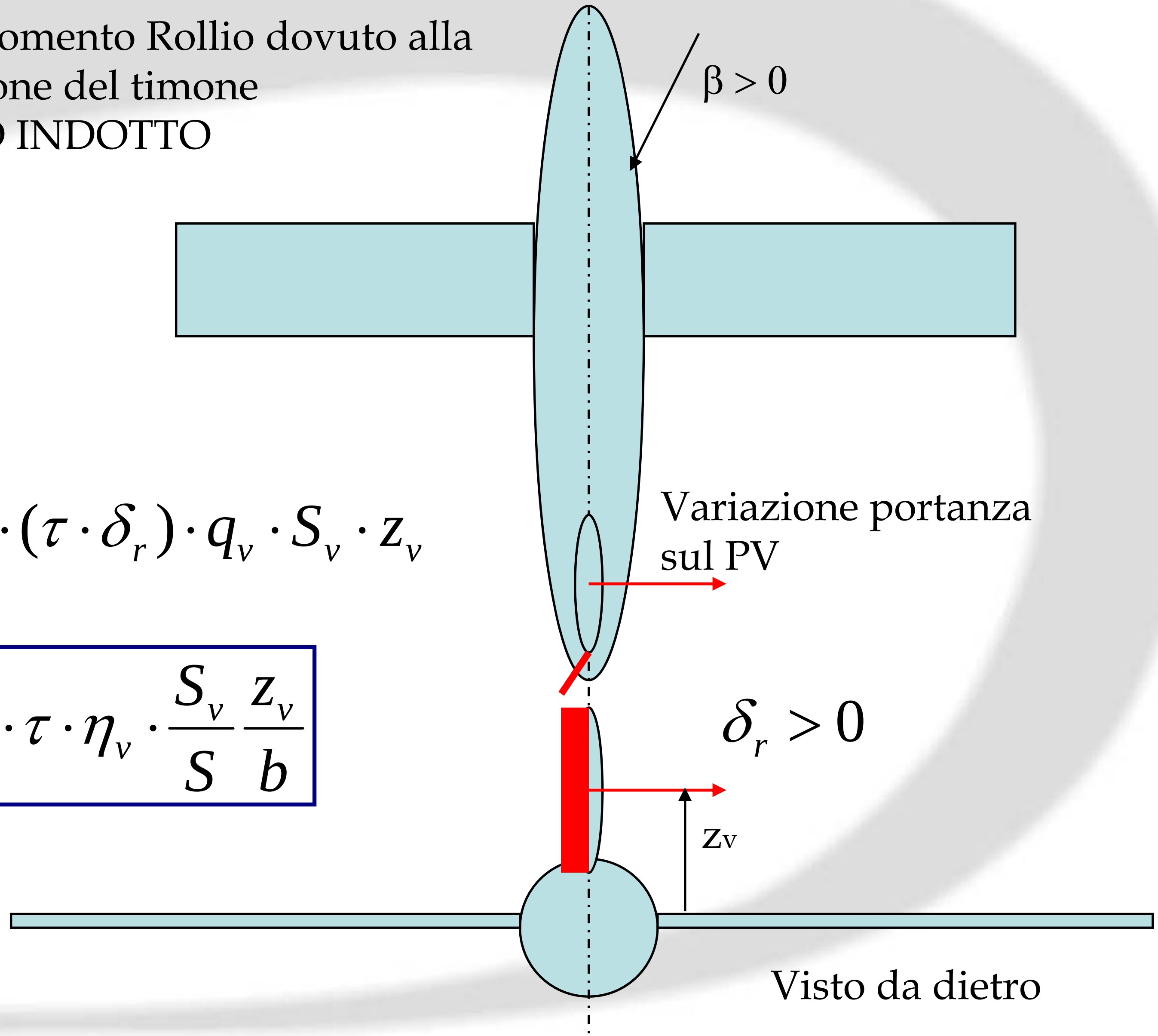


I valori del diagramma per la derivata rispetto al diedro andrebbero divisi per 57.3 ^2= 3283 per avere la derivata in (1/°) e per ° di diedro

ROLLIO INDOTTO dal Timone

$\boxed{C_{\ell_{\delta r}}}$ Coeff Momento Rollio dovuto alla deflessione del timone
ROLLIO INDOTTO

$$C_{\ell_{\delta r}} > 0$$



Mom rollio :

$$\ell = F_y \cdot z_v = C_{L_\alpha} \cdot (\tau \cdot \delta_r) \cdot q_v \cdot S_v \cdot z_v$$

$$\boxed{C_{\ell_{\delta r}} = C_{L_\alpha} \cdot \tau \cdot \eta_v \cdot \frac{S_v}{S} \frac{z_v}{b}}$$

ROLLIO INDOTTO dal Timone

$\boxed{C_{\ell_{\delta r}}}$ Coeff Momento Rollio dovuto alla deflessione del timone ROLLIO INDOTTO

$$\boxed{C_{\ell_{\delta r}} = C_{L_\alpha} \cdot \tau \cdot \eta_v \cdot \frac{S_v}{S}\frac{z_v}{b}}$$

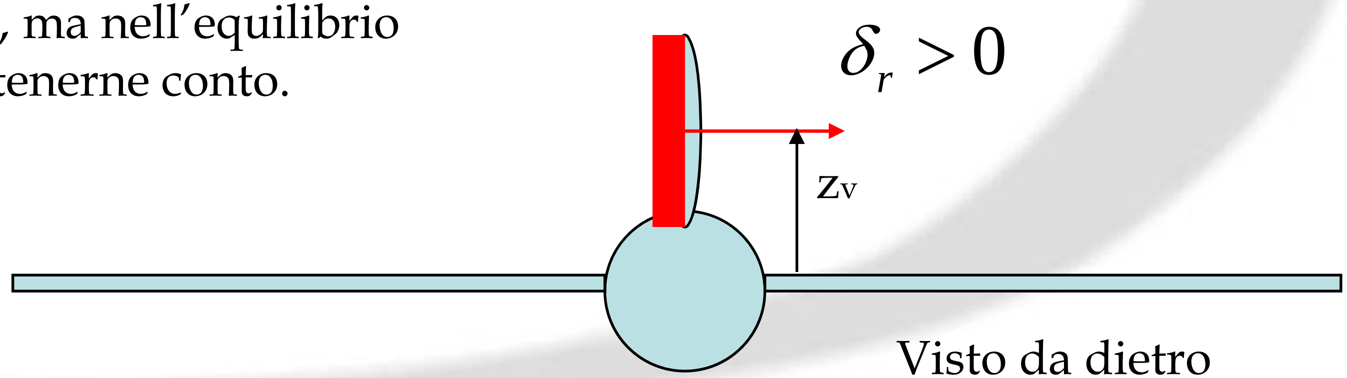
$$C_{\ell_{\delta r}} > 0$$

Dipende da z_v

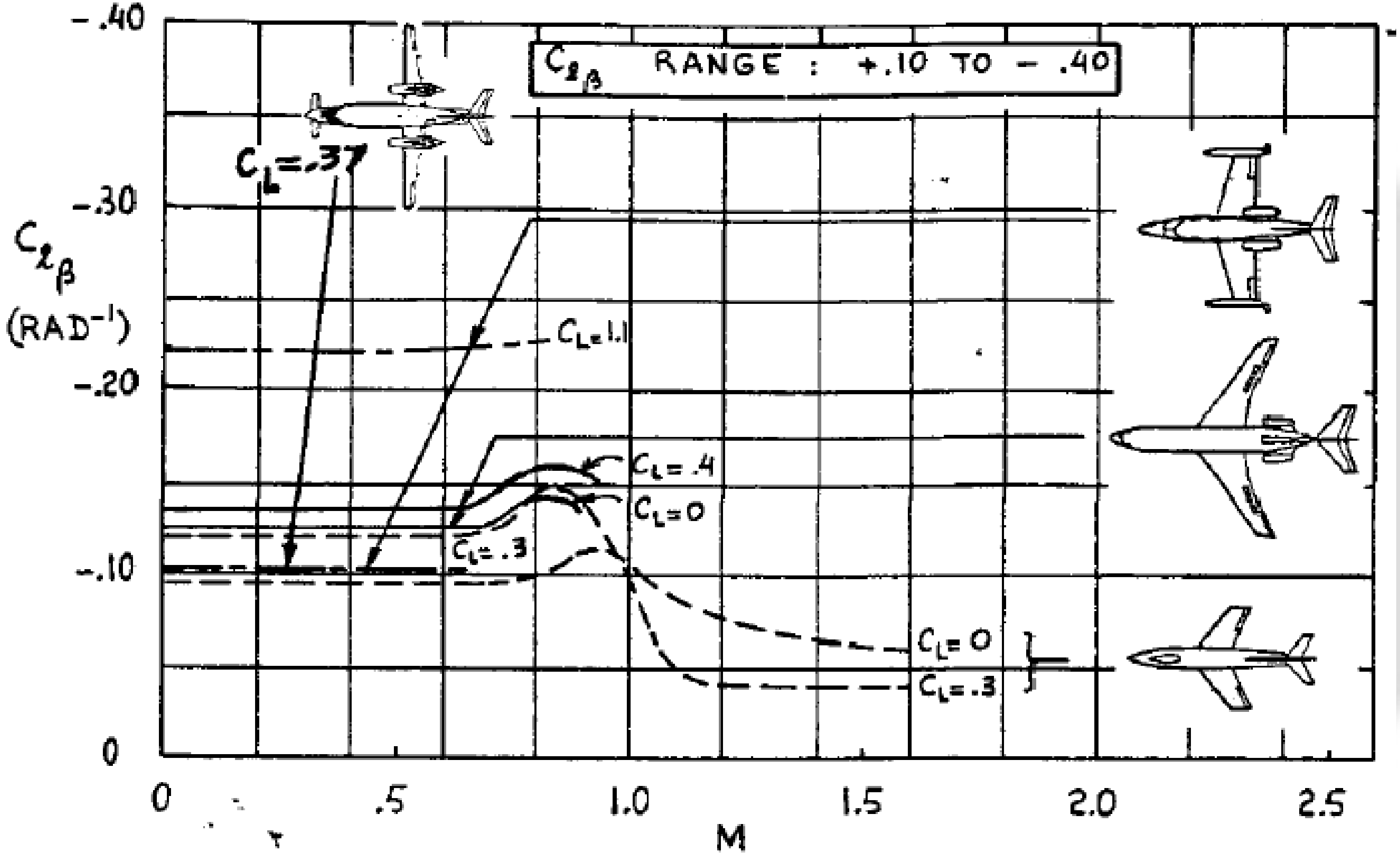
Ricordo che z_v è da intendersi rispetto agli assi stabilità (vento) e quindi dipende dall'assetto !!

Ad assetti elevati risulta tipicamente molto molto piccolo.

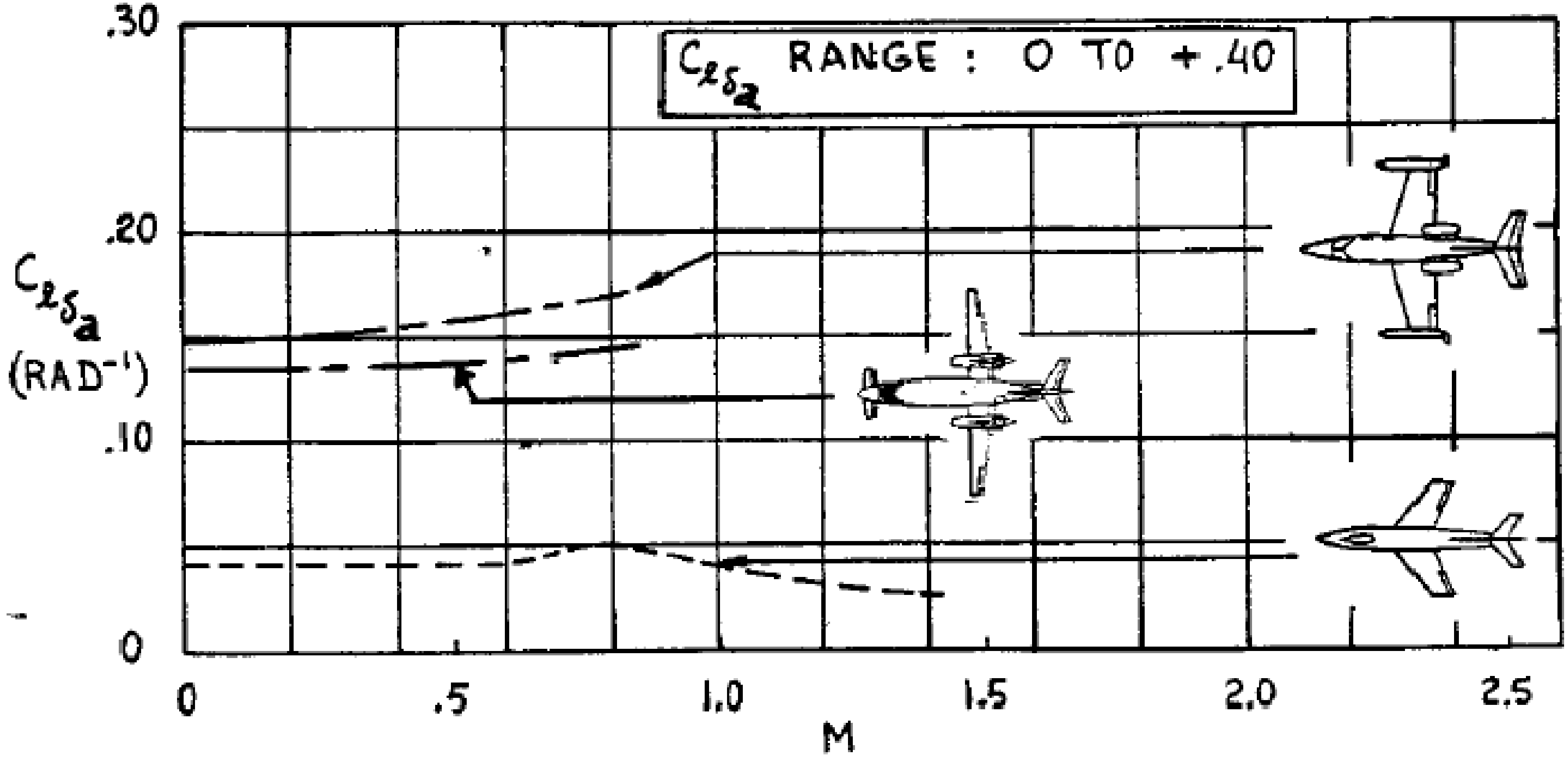
Tipicamente è piccolo, ma nell'equilibrio complessivo bisogna tenerne conto.

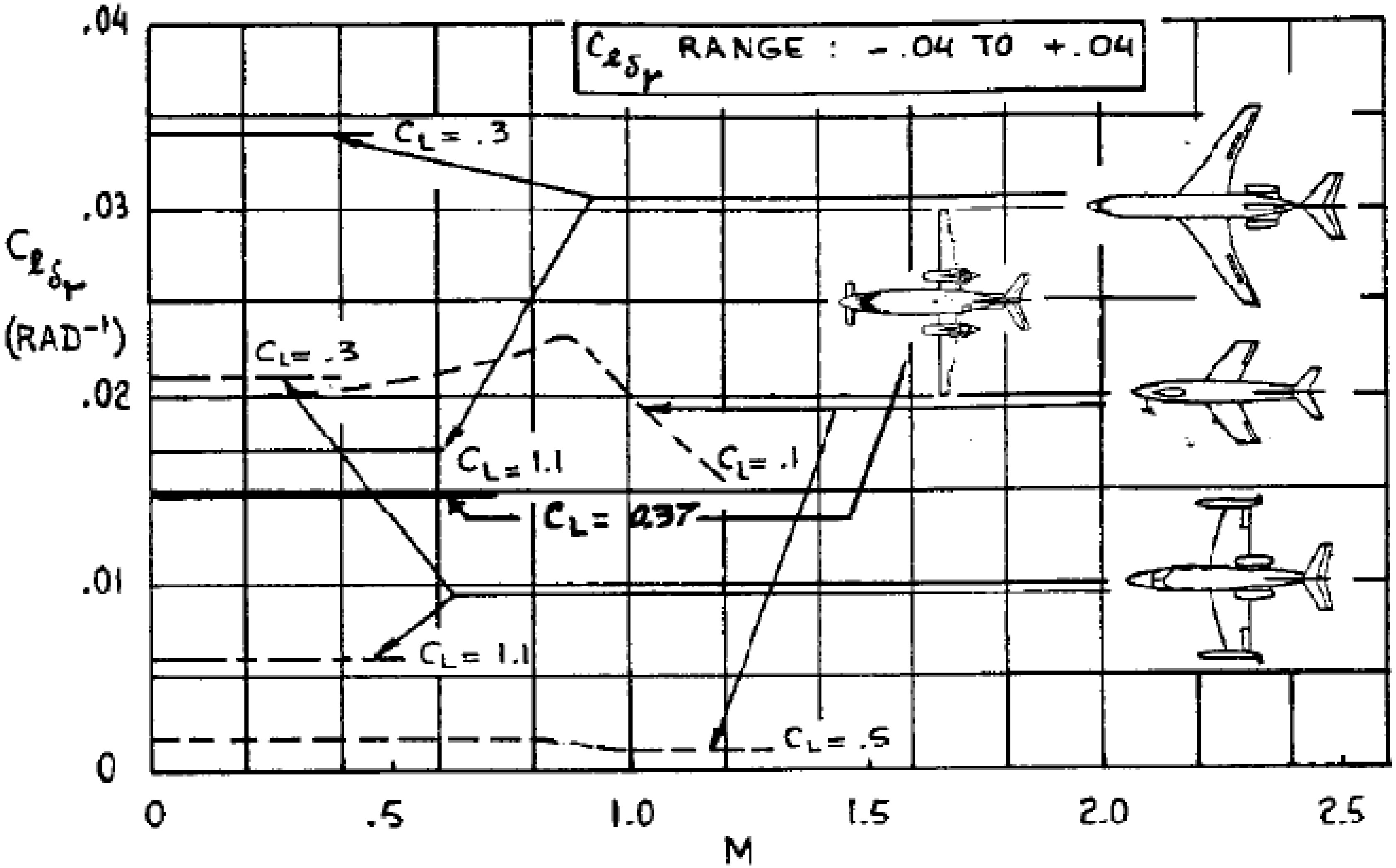


Visto da dietro

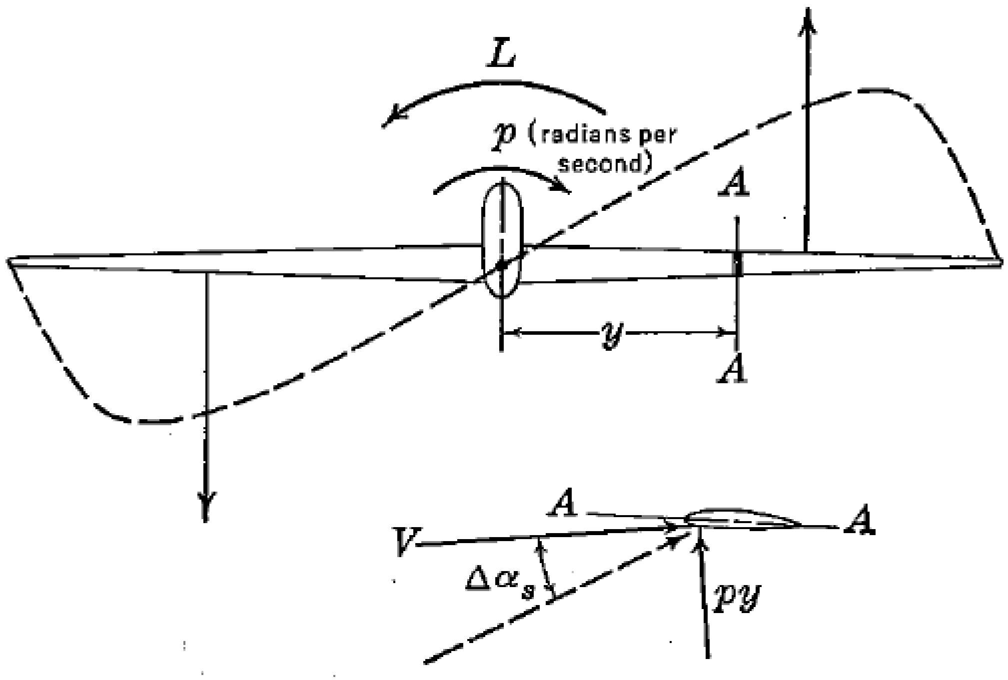

C_{l_β} RANGE : +.10 TO − .40
C_{l_β} (RAD^{-1})
−.40
−.30
−.20
−.10
0
C_L=.37
C_L=1.1
C_L=.4
C_L=0
C_L=.3
C_L= 0
C_L= .3
0
.5
1.0
1.5
2.0
2.5
M

NOTA: La seguente figura tratta da Roskam si basa su convenzione segno deflessione alettoni opposta. Quindi bisogna considerare il segno OPPOSTO

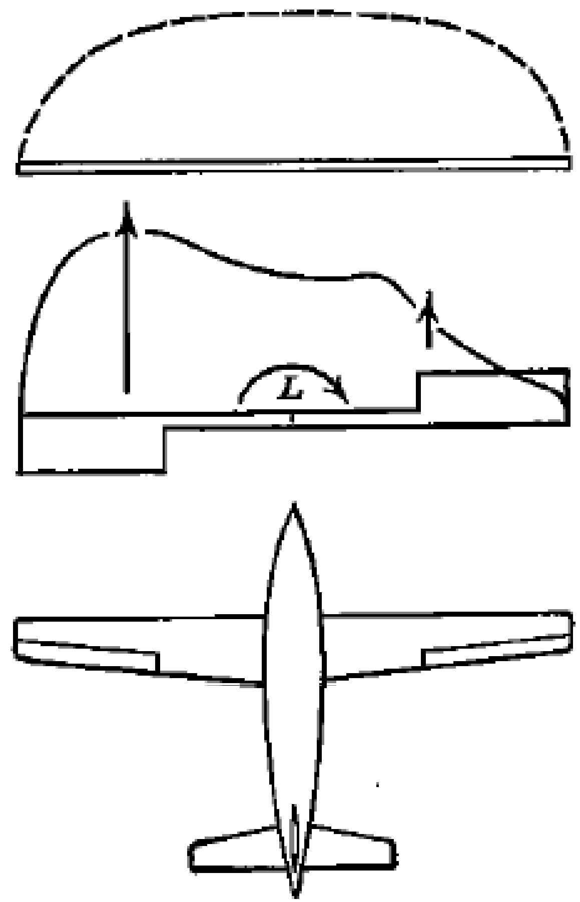



$C_{\ell_{\delta_r}}$ RANGE : -.04 TO +.04
$C_{\ell_{\delta_r}}$ (RAD^{-1})
.04
.03
.02
.01
0
C_L = .3
C_L = .3
C_L = 1.1
C_L = .1
C_L = .237
C_L = 1.1
C_L = .5
0
.5
1.0
1.5
2.0
2.5
M

CONTROLLO ROLLIO (Efficacia Alettoni)



Carico dovuto a p



Alettoni

CONTROLLO ROLLIO (Efficacia Alettoni)

$pb/2V$ The term $pb/2V$ is actually the helix angle made by the wing tip during a rolling maneuver. The lateral controls for modern airplanes are designed to give definite values of $pb/2V$ for full aileron deflection.

Cargo and bombardment types: $pb/2V = .07$

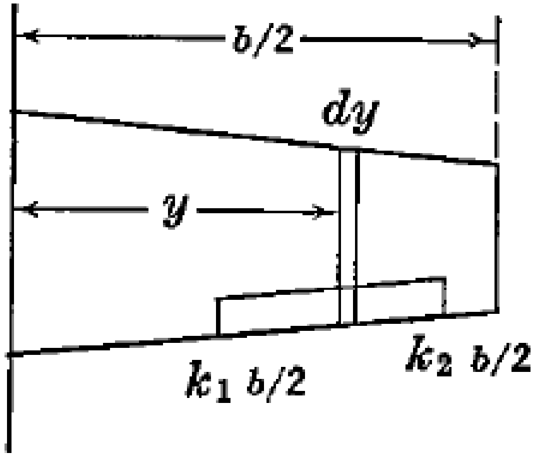
Fighter types: $pb/2V = .09$

$$I_x\dot{p} = \frac{\partial L}{\partial p}p + \frac{\partial L}{\partial \delta_a}\delta_a$$

$$0 = \frac{\partial L}{\partial p}p + \frac{\partial L}{\partial \delta_a}\delta_a$$

CONTROLLO ROLLIO (Efficacia Alettoni)

$$p = -\frac{\partial L/\partial \delta_a}{\partial L/\partial p}(\delta_a) \qquad p = -\frac{\partial C_l/\partial \delta_a}{\partial C_l/\partial p}\delta_a$$



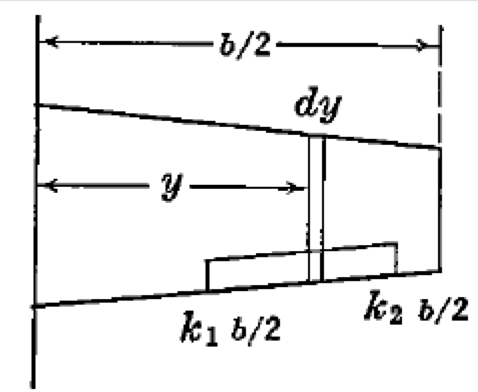
$$dC_l = \frac{c c_l y \, dy}{S_w b}$$

$$c_l = a_0 \tau \delta_a$$

$$C_l = \frac{2 a_w \tau \delta_a}{S_w b}\int_{k_1 b/2}^{k_2 b/2} c y \, dy$$

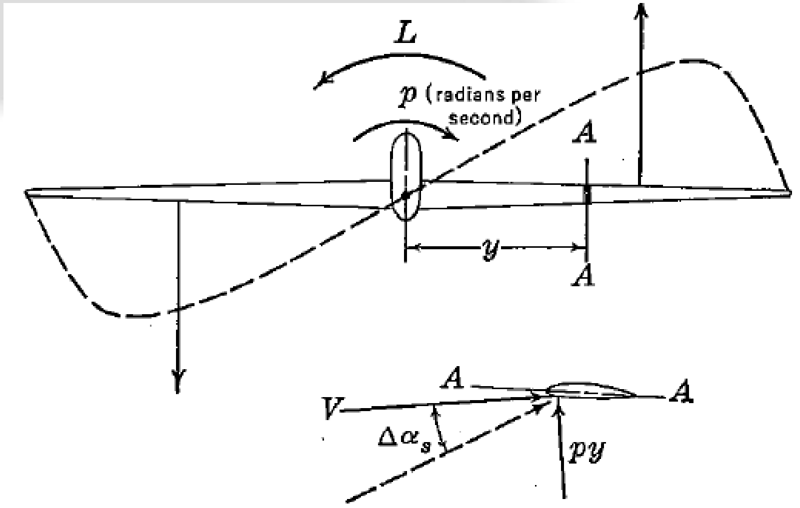
$$\frac{\partial C_l}{\partial \delta_a} = \frac{2 a_w \tau}{S_w b}\int_{k_1 b/2}^{k_2 b/2} c y \, dy$$

CONTROLLO ROLLIO (Efficacia Alettoni)



$$\Delta\alpha = \frac{py}{V}$$

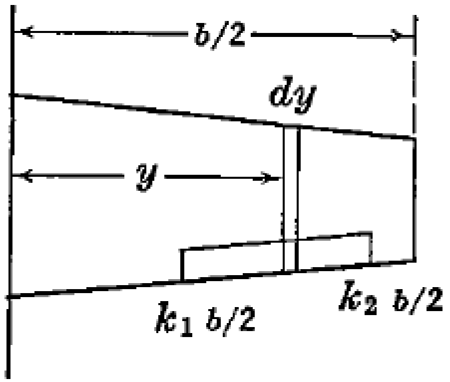
$$c_l = a_0 \frac{py}{V}$$



$$C_l = \frac{2a_w p}{VSb}\int_0^{b/2} cy^2\,dy$$

$$\frac{\partial C_l}{\partial p} = \frac{2a_w}{VSb}\int_0^{b/2} cy^2\,dy$$

CONTROLLO ROLLIO (Efficacia Alettoni)



$$= -\frac{\partial C_l/\partial \delta_a}{\partial C_l/\partial p}\,\delta_a$$

$$\frac{\partial C_l}{\partial \delta_a} = \frac{2a_w\tau}{S_w b}\int_{k_1 b/2}^{k_2 b/2} c y\, dy$$

$$\frac{\partial C_l}{\partial p} = \frac{2a_w}{VSb}\int_0^{b/2} c y^2\, dy$$

$$p = \tau V \frac{\int_{k_1 b/2}^{k_2 b/2} c y\, dy}{\int_0^{b/2} c y^2\, dy}\cdot\frac{\delta_a}{2}$$

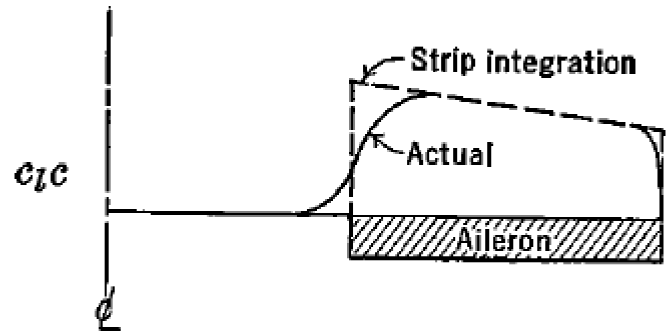
Ala rastremata

$$p = \frac{2\tau V \delta_a{}^{\circ}{}_{\mathrm{Total}}}{57.3b}\left[\frac{(k_2{}^3 - k_1{}^3)(1 - TR) + 3TR(k_2{}^2 - k_1{}^2)}{TR + 3}\right]$$

$$\frac{pb}{2V} = \frac{\tau \delta_a{}^{\circ}{}_{\mathrm{Total}}}{57.3}\left[\frac{(k_2{}^3 - k_1{}^3)(1 - TR) + 3TR(k_2{}^2 - k_1{}^2)}{TR + 3}\right]$$

CONTROLLO ROLLIO (Efficacia Alettoni)

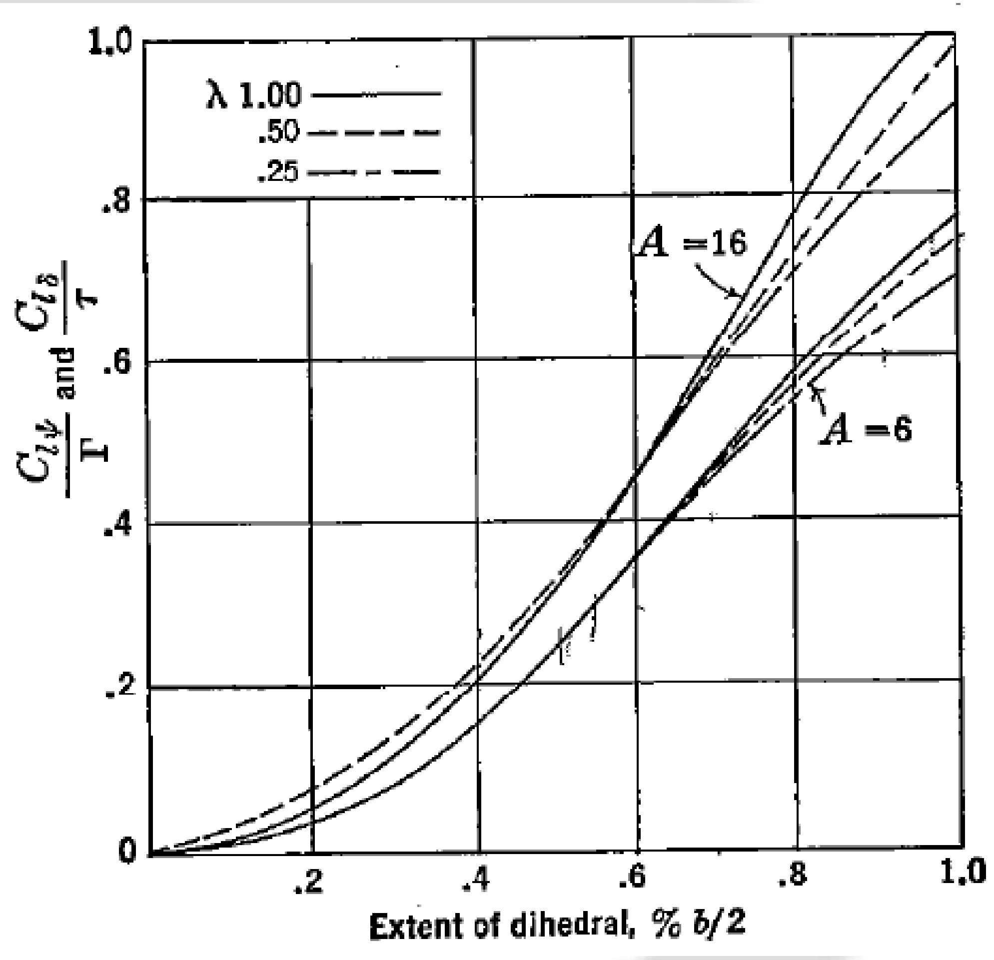
$$\frac{pb}{2V} = \frac{\tau \delta_a{}^{\circ}{}_{\text{Total}}}{57.3} \left[\frac{(k_2{}^3 - k_1{}^3)(1 - TR) + 3TR(k_2{}^2 - k_1{}^2)}{TR + 3} \right]$$



Fattore riduttivo pari a 0.90

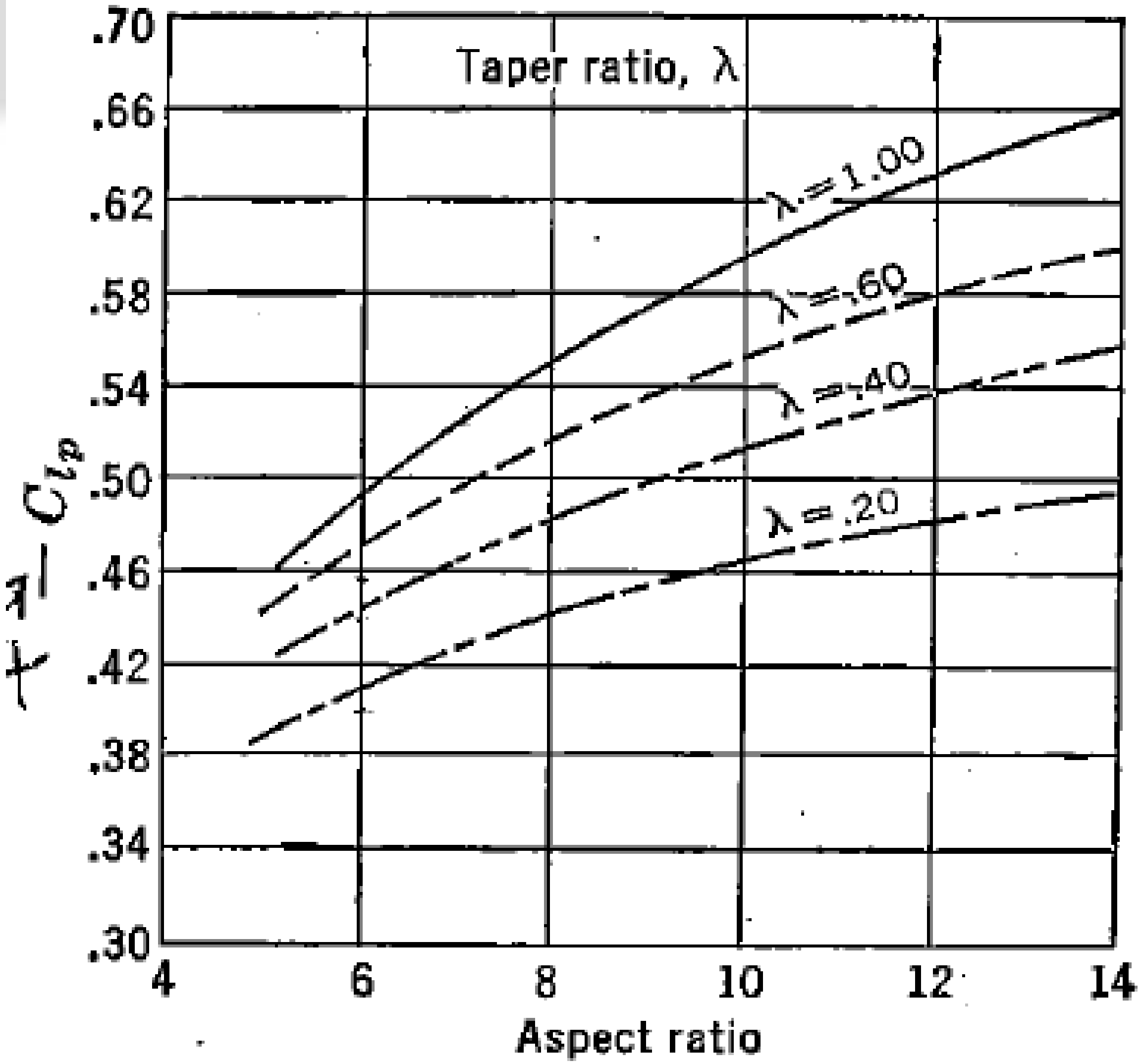
$$\frac{pb}{2V} = \frac{.9\tau \delta_a{}^{\circ}}{57.3} \left[\frac{(k_2{}^3 - k_1{}^3)(1 - TR) + 3TR(k_2{}^2 - k_1{}^2)}{TR + 3} \right]$$

CONTROLLO ROLLIO (Efficacia Alettoni)



CONTROLLO ROLLIO (Efficacia Alettoni)

$$C_{l_p} = \frac{dC_l}{d(pb/2V)}$$

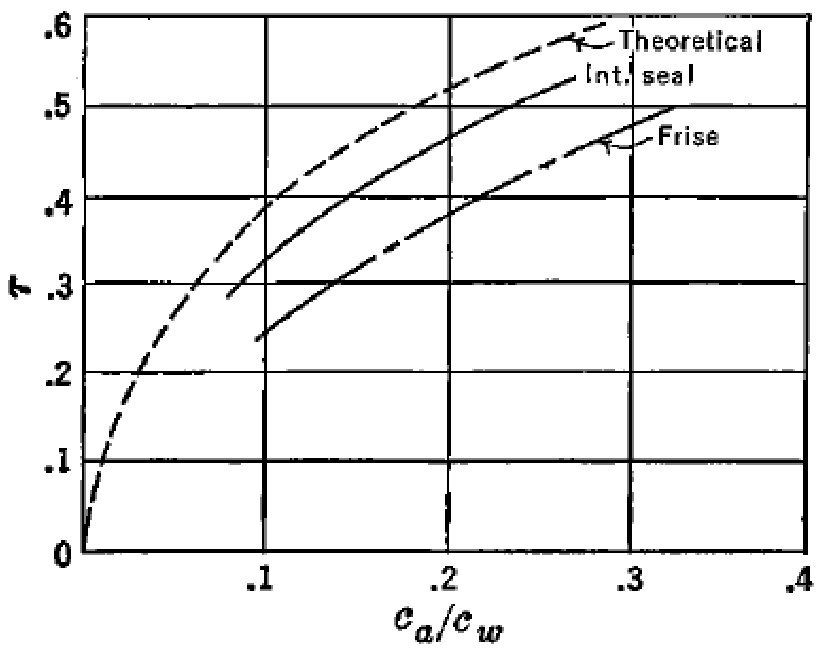


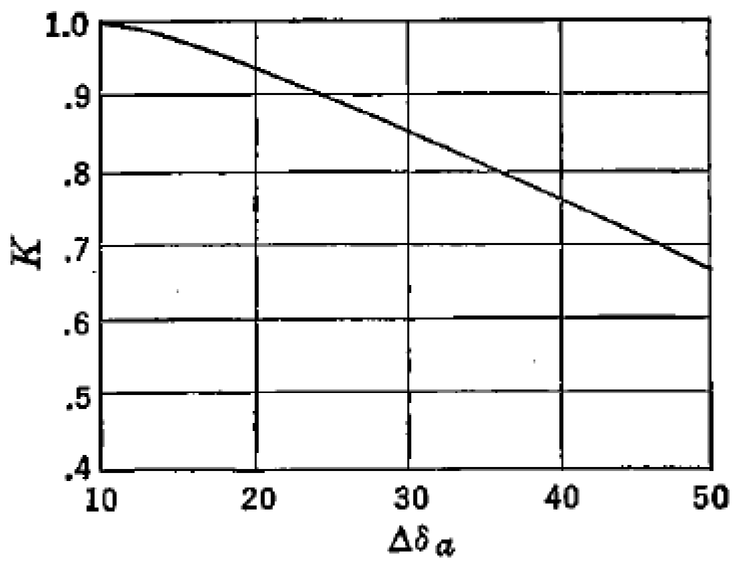
CONTROLLO ROLLIO (Efficacia Alettoni)

$$0 = C_{l_p}\left(\frac{pb}{2V}\right) - \frac{C_{l\delta}}{\tau}\cdot\frac{\tau\delta_a}{2}$$

$$\boxed{\frac{pb}{2V} = \frac{C_{l\delta}}{\tau}\,\frac{\tau\delta_a}{114.6C_{l_p}}}$$

$$\boxed{\frac{pb}{2V} = \frac{C_{l\delta}}{\tau}\,\frac{\tau\delta_a{}^{\circ}K}{114.6C_{l_p}}}$$





CONTROLLO ROLLIO (Efficacia Alettoni)

$$0 = C_{l_p}\left(\frac{pb}{2V}\right) - \frac{C_{l_\delta}}{\tau}\cdot\frac{\tau\delta_a}{2}$$

$$\boxed{\frac{pb}{2V} = \frac{C_{l_\delta}}{\tau}\,\frac{\tau\delta_a}{114.6C_{l_p}}}$$

$$\boxed{\frac{pb}{2V} = \frac{C_{l_\delta}}{\tau}\,\frac{\tau\delta_a{}^\circ K}{114.6C_{l_p}}}$$

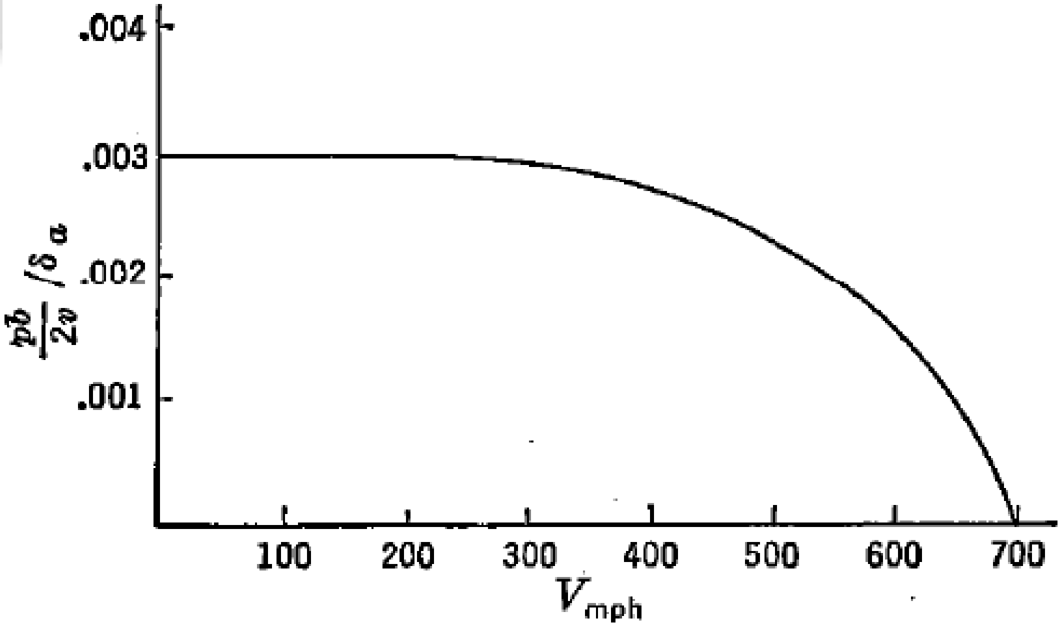
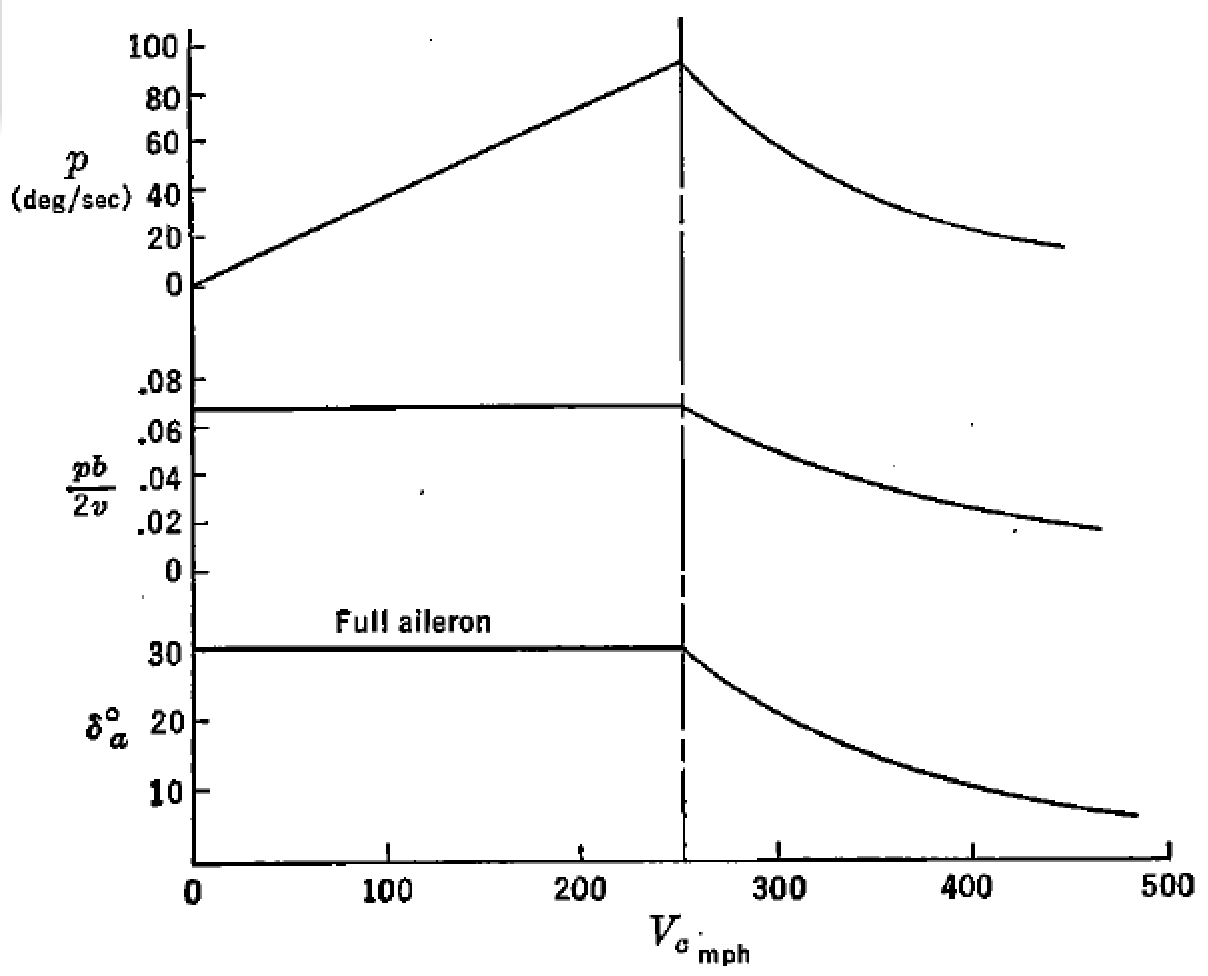


FIGURE 9–17. Fall-off of $pb/2V$ due to wing twist.

CONTROLLO ROLLIO (Efficacia Alettoni)

$$\frac{pb}{2V} = \frac{C_{l_\delta}}{\tau} \frac{\tau \delta_a {}^\circ K}{114.6 C_{l_p}}$$



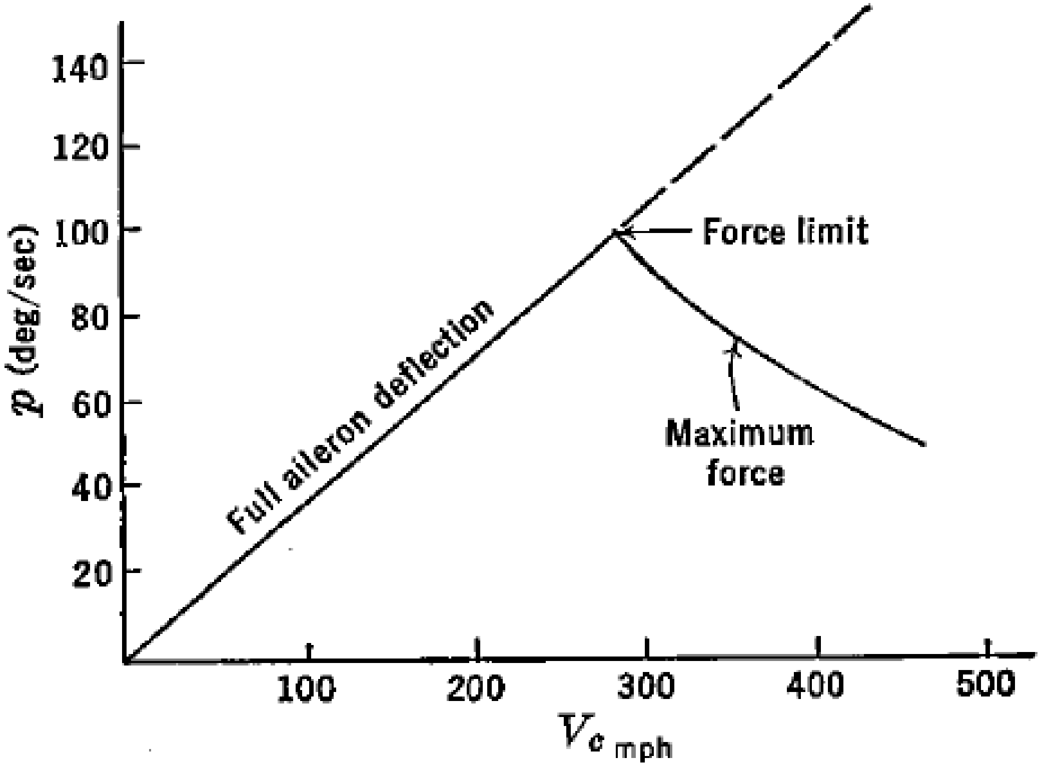
CONTROLLO ROLLIO (Efficacia Alettoni)

$$F_a = -qS_a c_a G K C_{h\delta} \delta_a$$

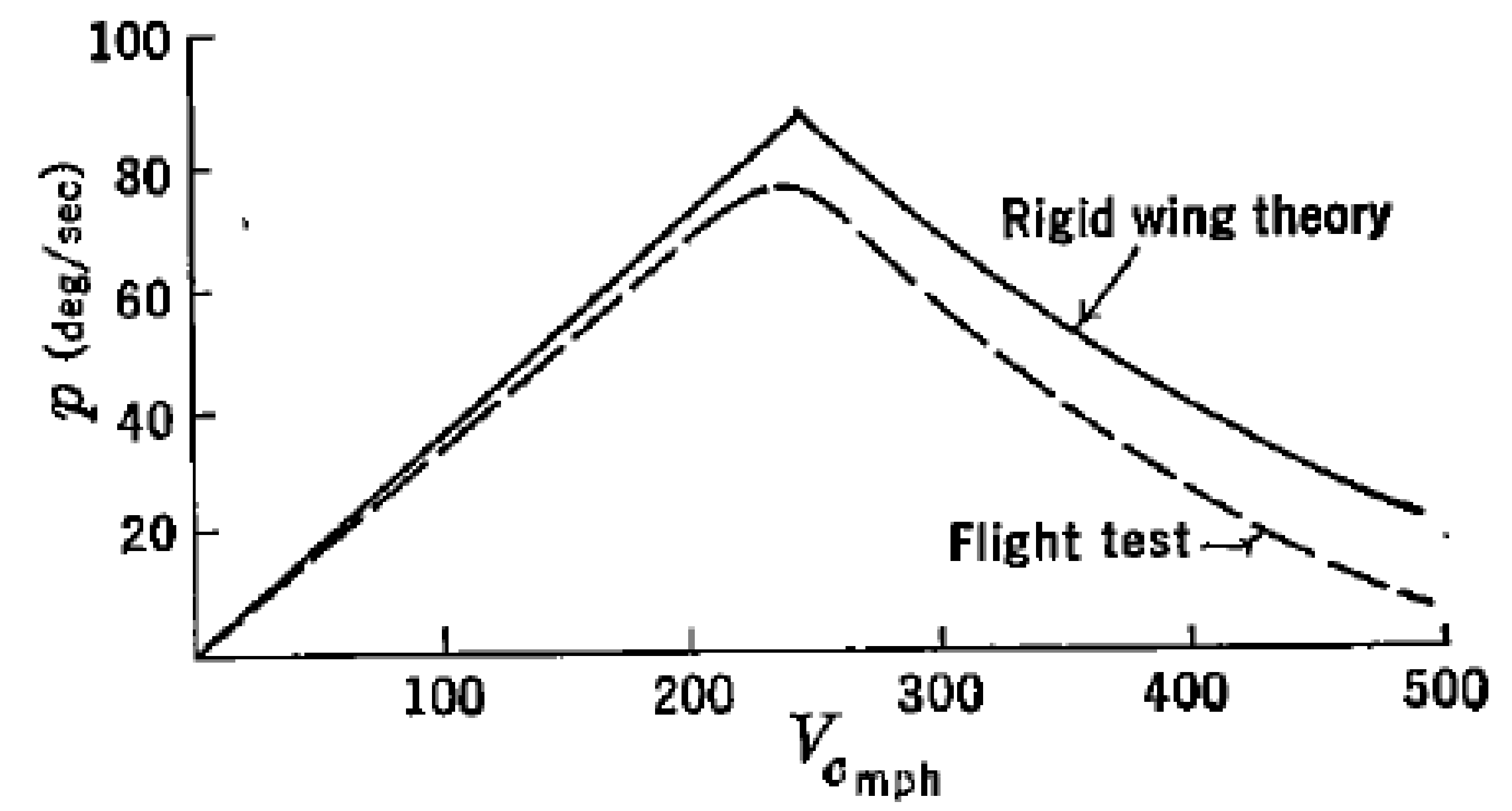
$$K$$

$$\left[1 - 2n \frac{C_{h\alpha}}{C_{h\delta}}\right]$$

$$p\rho V = K$$



CONTROLLO ROLLIO (Efficacia Alettoni)



CONTROLLO ROLLIO (Efficacia Alettoni)

Effetto stabilità direzionale

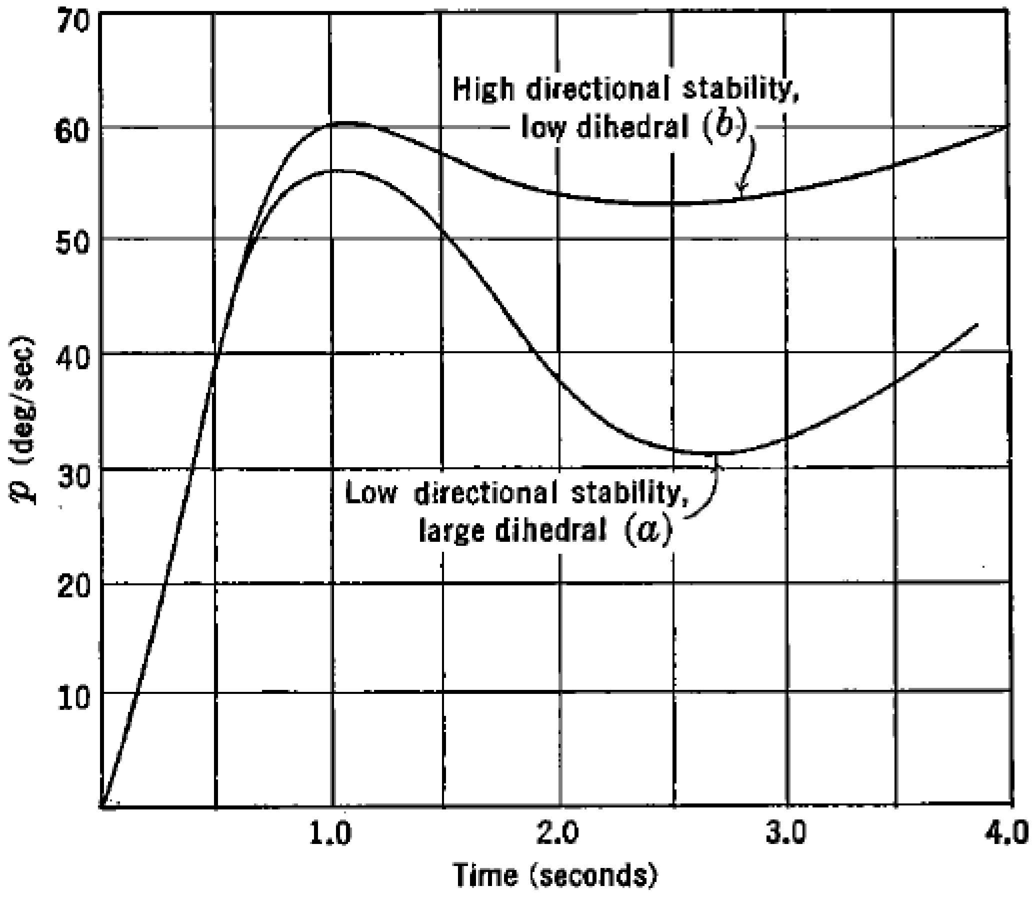
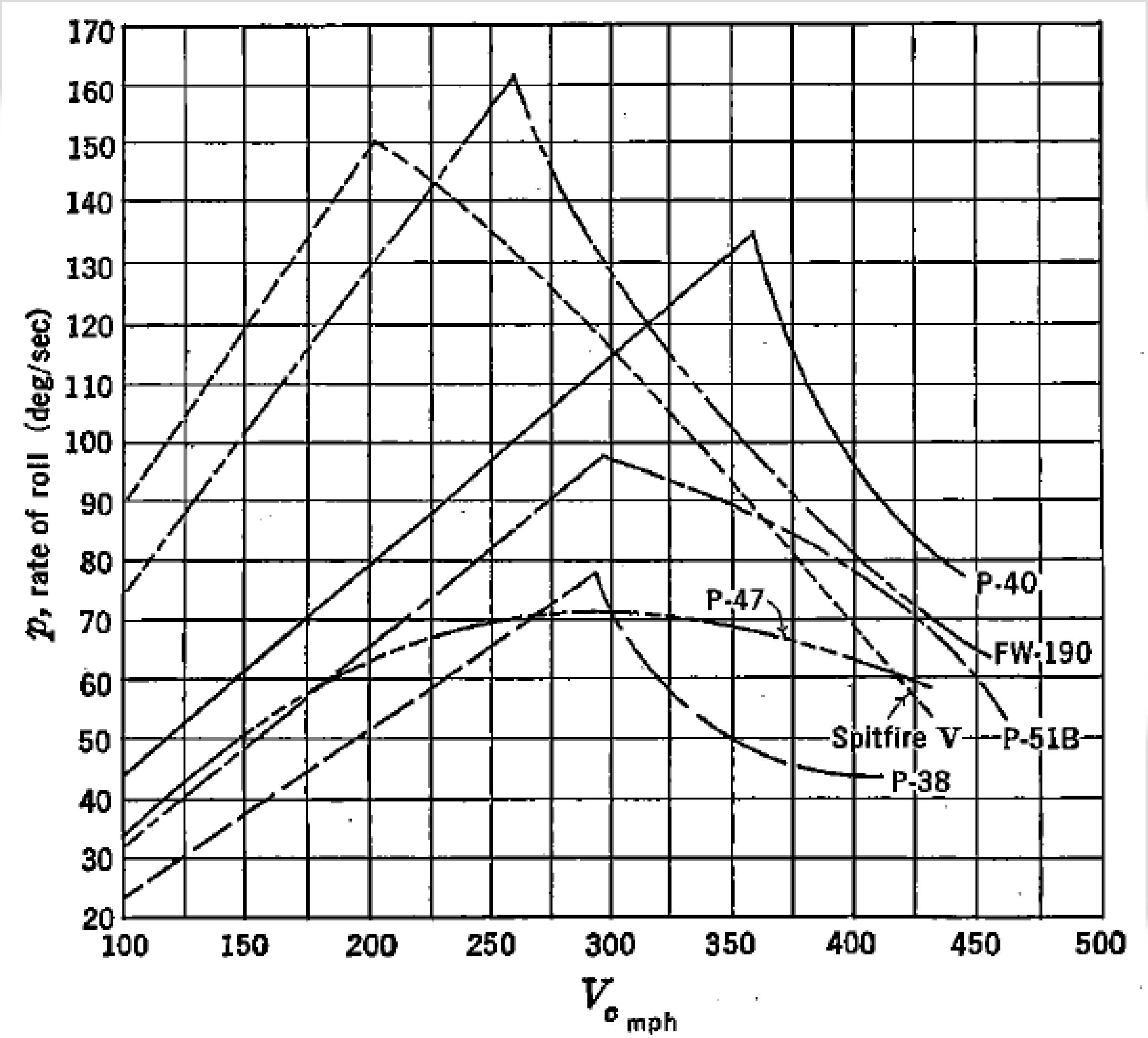


FIGURE 9–23. Typical rolling time histories.

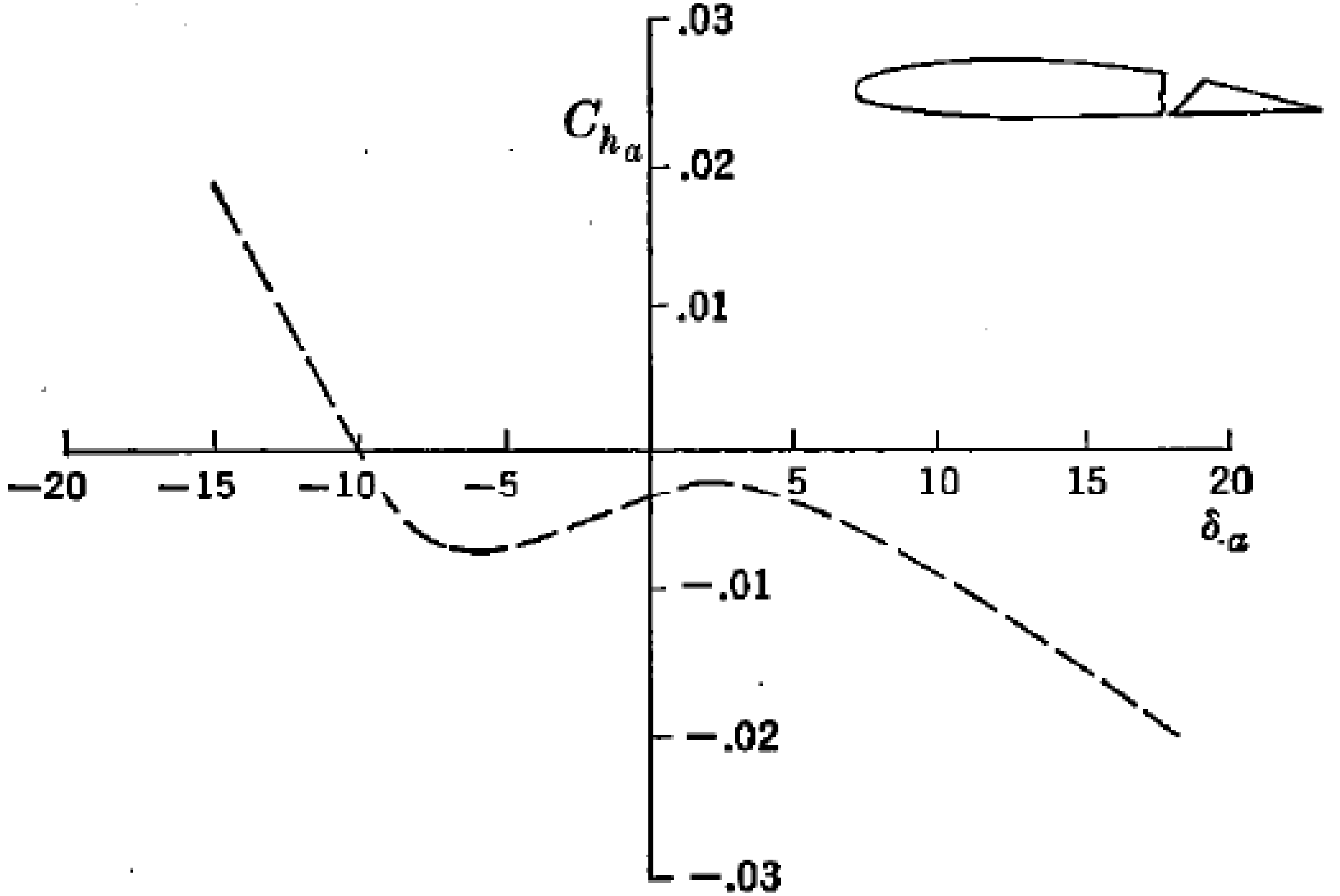
CONTROLLO ROLLIO (Efficacia Alettoni)

Vari velivoli



CONTROLLO ROLLIO (Efficacia Alettoni)

Bilanciamento aerodinamico alettoni
ALETTONI FRISE



CONTROLLO ROLLIO (Efficacia Alettoni)

Bilanciamento aerodinamico alettoni
ALETTONI Internal SEAL

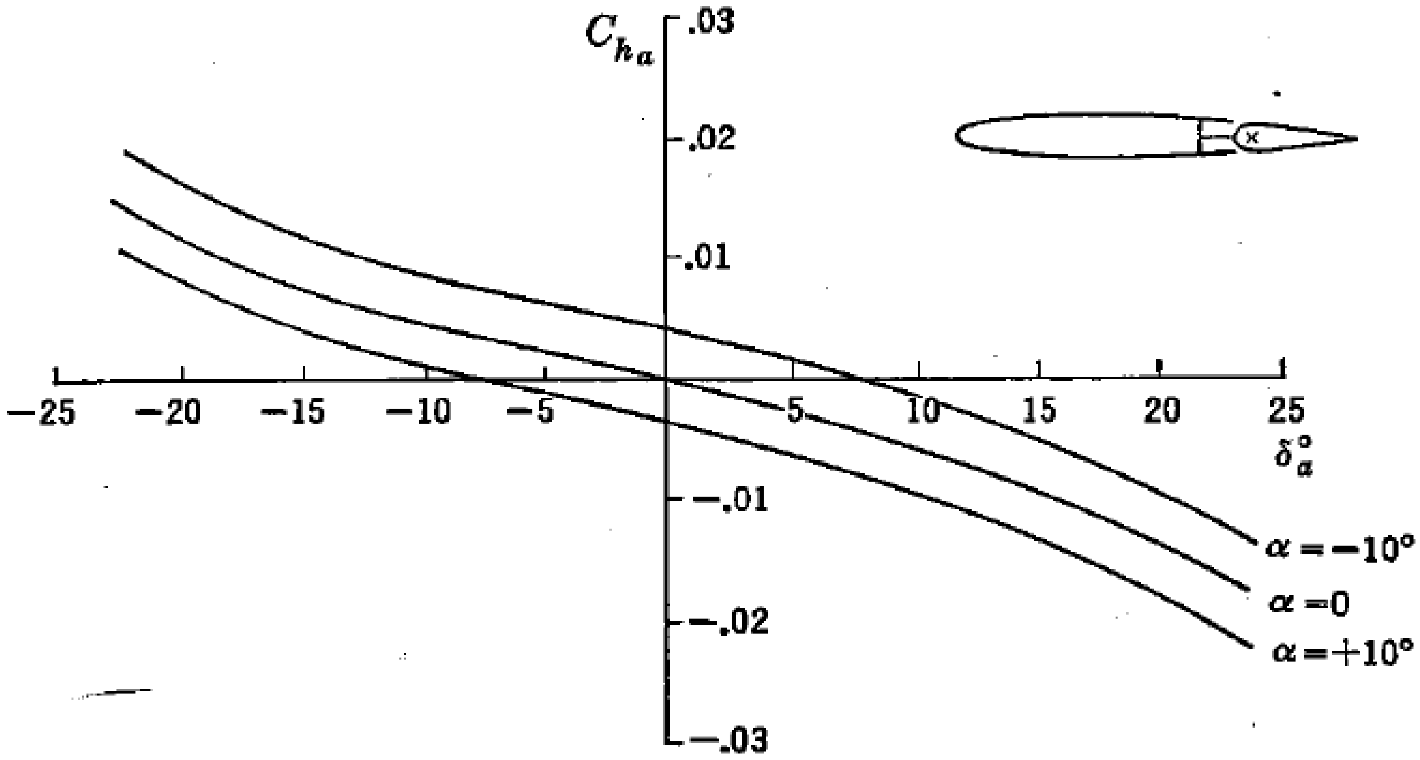


FIGURE 9–26. Typical internal seal aileron hinge moments.

CONTROLLO ROLLIO (Efficacia Alettoni)

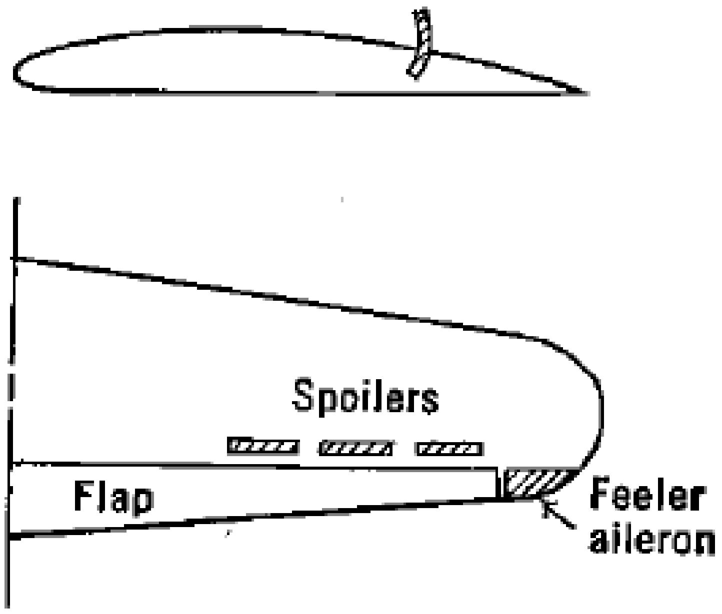


FIGURE 9–27. A spoiler-type aileron installation.