$W := 1200kgf$ $Xcg := 0.3 \cdot Cma$ $CD0 := 0.03$ $etot := 0.8$ $\rho := 1.225 \frac{kg}{m^3}$

ALA

$b := 10m$ $Cr := 1.6m$ $\lambda := 0.5$ $\varepsilon_r := 0deg$ $\varepsilon_t := -3deg$

$\alpha_{0L2dwt} := -2.5deg$ $\alpha_{0L2dwr} := -1.5deg$ $iw := 2deg$ $CL\alpha w_{2d} := 0.11deg^{-1}$

$Cm_{acw3D} := -0.08$ $Xacw := 0.25 \cdot Cma$ $ew := 0.9$

$\eta_i := 0.7$ $\eta_f := 1$ $\tau_{alett} := 0.40$ $\Gamma := 5deg$

FUSOLIERA

$Cm0_f := -0.05$ $Cm\alpha_f := 0.0035deg^{-1}$ $C_{N\beta f} := -0.0035deg^{-1}$

PIANO ORIZZONTALE

$CL\alpha h_{2d} := 0.11deg^{-1}$ $bh := 3.5m$ $Sh := 3m^2$ $ARh := \frac{bh^2}{Sh}$ $ARh = 4.083$

$eh := 0.9$

$\eta h := 1$ $\tau e := 0.40$ $ih := -2deg$ $Xach := 4m$ $Ch\alpha := -0.0080deg^{-1}$

$Ch\delta e := -0.013deg^{-1}$

PIANO VERTICALE

$Sv := 4.5m^2$ $lv := 5m$ $CL\alpha 3Dv := 0.0525deg^{-1}$ $CL\alpha 3Dv = 3.008$

$\tau_r := 0.50$ $d\sigma d\beta := 0.11$ $hv := 1.6m$ $\eta v := 1$

$V := 150 \frac{km}{hr}$

SOLUZIONE

$Cma := \frac{2 \cdot \left(\lambda^2 + \lambda + 1\right) \cdot Cr}{3(\lambda + 1)}$ $Cma = 1.244\,m$ $S := \frac{(Cr + \lambda \cdot Cr) \cdot b}{2}$ $S = 12\,m^2$

$AR := \frac{b^2}{S}$ $AR = 8.333$

$bc := Cr$ $Ct := \lambda \cdot Cr$ $ac := \frac{Ct - bc}{\frac{b}{2}}$ $C(y) := ac \cdot y + bc$

$b\varepsilon := \varepsilon_r$ $a\varepsilon := \frac{\varepsilon_t - b\varepsilon}{\frac{b}{2}}$ $\varepsilon(y) := a\varepsilon \cdot y + b\varepsilon$

$$ba := \alpha_{0L2dwr} \qquad aa := \frac{\alpha_{0L2dwt} - ba}{\frac{b}{2}} \qquad \alpha_{0L2d}(y) := aa \cdot y + ba$$

$$\alpha_{0L3Dw} := \frac{2}{S} \cdot \int_0^{\frac{b}{2}} \left(\alpha_{0L2d}(y) - \varepsilon(y)\right) \cdot C(y)\, dy \qquad \alpha_{0L3Dw} = -0.611 \cdot deg$$

$$CL\alpha w := \frac{CL\alpha w_{2d}}{1 + \frac{CL\alpha w_{2d}}{\pi\, AR \cdot ew}} \qquad CL\alpha w = 4.972 \cdot rad^{-1} \qquad CL\alpha w = 0.087 \cdot deg^{-1}$$

$$ARh := \frac{bh^2}{Sh} \qquad ARh = 4.083 \qquad CL\alpha h := \frac{CL\alpha h_{2d}}{1 + \frac{CL\alpha h_{2d}}{\pi \cdot ARh \cdot eh}} \qquad CL\alpha h = 0.071 \cdot deg^{-1}$$

$$Sh = 3\, m^2 \qquad CL\alpha h = 4.077 \cdot rad^{-1}$$

$$Xcg := 0.3 \cdot Cma \qquad Xacw := 0.25 \cdot Cma \qquad X_{acwb} := Xacw - \frac{Cm\alpha_f}{CL\alpha w} \cdot Cma$$

$$Xcg = 0.373\, m \qquad Xacw = 0.311\, m \qquad X_{acwb} = 0.261\, m$$

Xach è la distanza tra il fuoco dell'ala e quello del piano orizzontale
lh è la distanza tra cg e ac del piano orizzontale
Qui sotto sono tutte grandezze dimensionali

$$lh := Xach - (Xcg - Xacw) \qquad lh = 3.938\, m$$

Distanze adimensionali per equazione momento:

$$Xw\_ad := \frac{Xcg - X_{acwb}}{Cma} \qquad Xw\_ad = 0.09$$

$$Xh\_ad := \frac{lh}{Cma} \qquad Xh\_ad = 3.164$$

<u>Troviamo il risultato per comandi liberi</u> (domanda n. 2)

$$d\varepsilon d\alpha := \frac{2CL\alpha w}{\pi \cdot AR \cdot ew} \qquad d\varepsilon d\alpha = 0.422 \qquad CL0_w := CL\alpha w \cdot \left(iw - \alpha_{0L3Dw}\right) \qquad CL0_w = 0.227$$

$$\varepsilon 0 := \frac{2CL0_w}{\pi \cdot AR \cdot ew} \qquad \varepsilon 0 = 1.102 \cdot deg$$

$$Cm\alpha := CL\alpha w \cdot \frac{Xcg - X_{acwb}}{Cma} - CL\alpha h \cdot (1 - d\varepsilon d\alpha) \cdot \left(\frac{lh}{Cma} \cdot \frac{Sh}{S} \cdot \eta h\right) \qquad Cm\alpha = -0.025 \cdot deg^{-1}$$

$$Cm\alpha\_wb := CL\alpha w \cdot \frac{Xcg - X_{acwb}}{Cma} \qquad Cm\alpha\_wb = 7.839 \times 10^{-3} \cdot deg^{-1}$$

$$Cm\alpha\_t := -\left[CL\alpha h \cdot (1 - d\varepsilon d\alpha) \cdot \left(\frac{lh}{Cma} \cdot \frac{Sh}{S} \cdot \eta h\right)\right] \qquad Cm\alpha\_t = -0.033 \cdot deg^{-1}$$

$$F := 1 - \tau e \cdot \frac{Ch\alpha}{Ch\delta e} \qquad F = 0.754$$

$$Cm\alpha\_cl := CL\alpha w \cdot \frac{Xcg - X_{acwb}}{Cma} - CL\alpha h \cdot (1 - d\varepsilon d\alpha) \cdot F \cdot \left(\frac{lh}{Cma} \cdot \frac{Sh}{S} \cdot \eta h\right) \qquad Cm\alpha\_cl = -0.017 \cdot deg^{-}$$

$$Cm0 := Cm_{acw3D} + Cm0_f + CL0_w \cdot \frac{Xcg - X_{acwb}}{Cma} + CL\alpha h \cdot (\varepsilon 0) \cdot \frac{lh}{Cma} \cdot \frac{Sh}{S} \cdot \eta \qquad Cm0 = -0.047$$

$$Cmih := -CL\alpha h \cdot \left(\frac{lh}{Cma} \cdot \frac{Sh}{S} \cdot \eta h\right) \qquad Cmih = -0.056 \cdot deg^{-1}$$

$$Cm\delta e := -CL\alpha h \cdot \left(\frac{lh}{Cma} \cdot \frac{Sh}{S} \cdot \eta h \cdot \tau e\right) \qquad Cm\delta e = -0.023 \cdot deg^{-1}$$

$$\alpha t(\alpha) := \alpha - \varepsilon 0 - d\varepsilon d\alpha \cdot \alpha + ih \qquad \delta e(\alpha) := \frac{-Ch\alpha \cdot \alpha t(\alpha)}{Ch\delta e}$$

$$Cm(\alpha) := (Cm0 + Cm\alpha \cdot \alpha + Cmih \cdot ih + Cm\delta e \cdot \delta e(\alpha))$$

Qui sotto calcolo la risposta alla domanda n. 2, relativamente all'alfa di equilibrio a comandi liberi e alla corrispondente Velocità di equilibrio, che chiamo Veq.
(La variabile V (V=150 Km/h) è invece quella assegnata alla domanda 1 e relativa alla domanda a comandi bloccati)

$$\alpha := 0 \qquad \alpha eq := root(Cm(\alpha), \alpha) \qquad \alpha eq = 1.325 \cdot deg \qquad \alpha t(\alpha) = -3.102 \cdot deg$$

$$CLeq := CL0_w + CL\alpha w \cdot \alpha eq \qquad CLeq = 0.342 \qquad Veq := \sqrt{\frac{2}{\rho} \cdot \frac{W}{S} \cdot \frac{1}{CLeq}}$$

$$\delta e(\alpha eq) = 1.438 \cdot deg \qquad Veq = 68.464 \frac{m}{s} \qquad Veq = 246.471 \cdot \frac{km}{hr}$$

Calcolo PUNTO NEUTRO a comandi bloccati ed a comandi liberi con la formulazione esatta e approssimata

Punto neutro a comandi bloccati approssimato

$$XN := \frac{X_{acwb}}{Cma} + lh \cdot \frac{Sh}{S \cdot Cma} \cdot \frac{CL\alpha h}{CL\alpha w} \cdot (1 - d\varepsilon d\alpha) \qquad XN = 0.585$$

$$X_{N2} := \frac{Xcg}{Cma} - \frac{Cm\alpha}{CL\alpha w} \qquad X_{N2} = 0.585$$

Punto neutro a comandi bloccati esatto (formula con numeratore e denominatore)

$$denom := 1 + \frac{CL\alpha h}{CL\alpha w} \cdot \frac{Sh \cdot (1 - d\varepsilon d\alpha)}{S} \qquad denom = 1.118$$

X.ach2_ad è la distanza tra centro aer del PO e riferimento (bordo attacco CMA) adimensionalizzata rispetto alla CMA (vedi tratazione Roskam e file ppt MS_07

$$X_{ach2\_ad} := \frac{(Xach + 0.25Cma)}{Cma} \qquad X_{ach2\_ad} = 3.464$$

$$numer := \frac{X_{acwb}}{Cma} + \frac{Sh}{S} \cdot \frac{CL\alpha h}{CL\alpha w} \cdot (1 - d\varepsilon d\alpha) \cdot X_{ach2\_ad} \qquad numer = 0.62$$

$$XN\_exact := \frac{numer}{denom} \qquad XN\_exact = 0.554$$

Punto neutro a comandi bloccati esatto (dal Margine statico, conoscendo CM_alfa e CL_alfa)

Questo è il CL_alfa dell'intero velivolo

$$CL\alpha\_tot := CL\alpha w + CL\alpha h \cdot (1 - d\varepsilon d\alpha) \cdot \frac{Sh}{S} \cdot \eta h \qquad CL\alpha\_tot = 5.562$$

$$X_{N\_exact2} := \frac{Xcg}{Cma} - \frac{Cm\alpha}{CL\alpha\_tot} \qquad X_{N\_exact2} = 0.554$$

PUNTO NEUTRO a comandi liberi

$$F := 1 - \tau e \cdot \frac{Ch\alpha}{Ch\delta e} \qquad F = 0.754$$

Punto neutro com liberi approssimato

$$XN\_cl := \frac{X_{acwb}}{Cma} + F \cdot lh \cdot \frac{Sh}{S \cdot Cma} \cdot \frac{CL\alpha h}{CL\alpha w} \cdot (1 - d\varepsilon d\alpha) \qquad XN\_cl = 0.492$$

$$X_{N\_cl2} := \frac{Xcg}{Cma} - \frac{Cm\alpha\_cl}{CL\alpha w} \qquad X_{N\_cl2} = 0.492$$

p neutro com liberi esatto

$$CL\alpha\_tot\_cl := CL\alpha w + CL\alpha h \cdot (1 - d\varepsilon d\alpha) \cdot \frac{Sh}{S} \cdot \eta h \cdot F \qquad CL\alpha\_tot\_cl = 5.417$$

$$X_{N\_cl\_exact} := \frac{Xcg}{Cma} - \frac{Cm\alpha\_cl}{CL\alpha\_tot\_cl} \qquad X_{N\_cl\_exact} = 0.476$$

Punto neutro a comandi liberi esatto (formula con num e denomin)

$$denom\_cl := 1 + \frac{CL\alpha h}{CL\alpha w} \cdot \frac{Sh \cdot (1 - d\varepsilon d\alpha) \cdot F}{S} \qquad denom\_cl = 1.089$$

X.ach2_ad è la distanza tra centro aer del PO e riferimento (bordo attacco CMA) adimensionalizzata rispetto alla CMA (vedi tratazione Roskam e file ppt MS_07

$$X_{ach2\_ad} := \frac{(Xach + 0.25Cma)}{Cma} \qquad X_{ach2\_ad} = 3.464$$

$$numer\_cl := \frac{X_{acwb}}{Cma} + \frac{Sh}{S} \cdot \frac{CL\alpha h}{CL\alpha w} \cdot (1 - d\varepsilon d\alpha) \cdot X_{ach2\_ad} \cdot F \qquad numer\_cl = 0.519$$

$$XN\_exact\_cl := \frac{numer\_cl}{denom\_cl} \qquad XN\_exact\_cl = 0.476$$

calcolo potenza comandi liberi (domanda n. 2)

$$CD := CD0 + \frac{CLeq^2}{\pi\, AR \cdot etot} \qquad T := \frac{1}{2}\cdot\rho\cdot Veq^2\cdot S\cdot CD \qquad P := T\cdot V$$

$$P = 5.106 \times 10^4\, W$$

delta e comandi bloccati (domanda n. 1)

$$CL := \frac{W}{\frac{1}{2}\cdot\rho\cdot V^2\cdot S} \qquad CL = 0.922 \qquad \alpha := \frac{CL - CL0_w}{CL\alpha w} \qquad \alpha = 8.015\cdot deg$$

$$\delta e := \frac{-(Cm0 + Cm\alpha\cdot\alpha + Cmih\cdot ih)}{Cm\delta e} \qquad \delta e = -5.899\cdot deg$$

$$\alpha h := \alpha - \varepsilon 0 - d\varepsilon d\alpha\cdot\alpha + ih + \tau e\cdot\delta e \qquad \alpha h = -0.83\cdot deg$$

$$Lh := 0.5\cdot V^2\cdot\rho\cdot CL\alpha h\cdot\alpha h\cdot Sh \qquad \alpha h = -0.83\cdot deg \qquad Lh = -19.202\cdot kgf$$

$$CD := CD0 + \frac{CL^2}{\pi\, AR\cdot etot} \qquad T := \frac{1}{2}\cdot\rho\cdot V^2\cdot S\cdot CD \qquad P := T\cdot V \qquad P = 3.754 \times 10^4\, W$$

LATERO DIREZIONALE SOLUZIONE (domanda n. 3)

$$Vlat := 26\,\frac{km}{hr} \qquad \beta := atan\left(\frac{Vlat}{V}\right) \qquad \beta = 9.834\cdot deg$$

$$C_N := C_{N\beta}\cdot\beta + C_{N\delta r}\cdot\delta_r$$

$$C_{N\beta v} := CL\alpha 3Dv\cdot\frac{lv}{b}\cdot(1 - d\sigma d\beta)\cdot\eta v\cdot\frac{Sv}{S} \qquad C_{N\beta v} = 0.502\cdot rad^{-1} \qquad C_{N\beta} := C_{N\beta v} + C_{N\beta f}$$

$$C_{N\beta} = 0.301\cdot rad^{-1}$$

$$C_{N\delta r} := -CL\alpha 3Dv\cdot\frac{lv}{b}\cdot\eta v\cdot\frac{Sv}{S}\cdot\tau_r \qquad C_{N\delta r} = -0.282 \qquad \delta r := \frac{-C_{N\beta}\cdot\beta}{C_{N\delta r}} \qquad \delta r = 10.511\cdot deg$$

$$C_{roll} := C_{roll\beta}\cdot\beta + C_{roll\delta a}\cdot\delta a + C_{roll\delta r}\cdot\delta r$$

$$C_{roll\beta v} := -CL\alpha 3Dv\cdot\frac{hv}{b}\cdot(1 - d\sigma d\beta)\cdot\eta v\cdot\frac{Sv}{S} \qquad C_{roll\beta v} = -0.161\cdot rad^{-1}$$

$$C_{roll\beta\Gamma} := -2\cdot\frac{CL\alpha w\cdot\Gamma}{S\cdot b}\cdot\int_0^{\frac{b}{2}} C(y)\cdot y\,dy \qquad C_{roll\beta\Gamma} = -0.096\cdot rad^{-1}$$

$$C_{roll\beta} := C_{roll\beta v} + C_{roll\beta\Gamma}$$

$$C_{roll\delta a} := -2\cdot\frac{CL\alpha w_{2d}\cdot\tau_{alett}}{S\cdot b}\cdot\int_{\eta_i\cdot\frac{b}{2}}^{\eta_f\cdot\frac{b}{2}} C(y)\cdot y\,dy \qquad C_{roll\delta a} = -0.245$$

$$C_{roll\delta r} := CL\alpha 3Dv\cdot\frac{hv}{b}\cdot\eta v\cdot\frac{Sv}{S}\cdot\tau_r \qquad C_{roll\delta r} = 0.09\cdot rad^{-1}$$

$$\delta a := \frac{-C_{roll\delta r}\cdot\delta r - C_{roll\beta}\cdot\beta}{C_{roll\delta a}} \qquad \delta a = -6.458\cdot deg$$

$$X := \frac{Xach}{Cma} + 0.25 \qquad X = 3.464$$