

# Estimación del MAC

Sergio Esteban

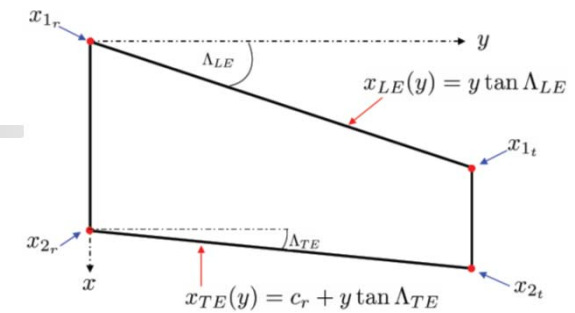


Figura 1.4: Geometría Detallada del Ala - parte 2.

$$\begin{aligned} \bar{c} &= \frac{2}{S} \int_0^{\frac{b}{2}} c^2 dy = \int_0^{\frac{b}{2}} (c_r + y (\tan \Lambda_{TE} - \tan \Lambda_{LE}))^2 dy \\ \bar{x} &= \frac{2}{C_{LS}} \int_0^{\frac{b}{2}} C_{l_a} c x dy = \frac{2}{S} \int_0^{\frac{b}{2}} (c_r + y (\tan \Lambda_{TE} - \tan \Lambda_{LE})) \cdot (nc_r + y \tan \Lambda_n) dy \\ \bar{y} &= \frac{2}{C_{LS}} \int_0^{\frac{b}{2}} C_{l_a} c y dy = \frac{2}{S} \int_0^{\frac{b}{2}} (c_r + y (\tan \Lambda_{TE} - \tan \Lambda_{LE})) y dy \\ \bar{z} &= \frac{2}{C_{LS}} \int_0^{\frac{b}{2}} C_{l_a} c z dy = \frac{2}{S} \int_0^{\frac{b}{2}} (c_r + y (\tan \Lambda_{TE} - \tan \Lambda_{LE})) y \tan \gamma dy \end{aligned} \quad (1.2)$$

- Para poder calcular las coordenadas geométricas del centro aerodinámico medio y la cuerda media, es necesario el definir las coordenadas locales en función de la envergadura del ala para poder ser integradas:

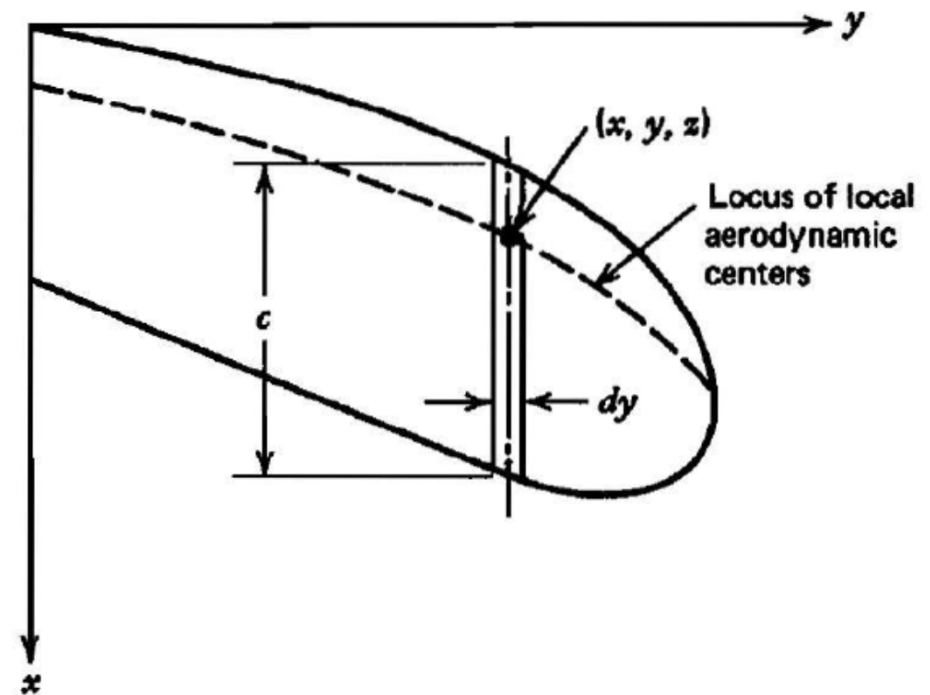


Figura 1.1: Geometría Estándar del Ala.

# Diferencia entre MGC y MAC - I

Apuntes Mecánica del Vuelo II: Prof. Francisco

- **Cuerda media geométrica (MGC):**

Cuerda de un ala rectangular equivalente, con la misma envergadura y superficie.

$$\bar{c}_{geo} = \frac{2}{S} \int_0^{b/2} c(y) dy, \quad \bar{c}_{geo} = \frac{S}{b}$$

- **Cuerda media aerodinámica (MAC):**

Es la longitud de referencia que hace que el coeficiente de momento de un ala sin flecha y sin torsión es igual al coeficiente de momento de su perfil.

$$C_{Mac} = \frac{1}{S c_{ref}} \int_{-b/2}^{b/2} c_{mac} \quad \bar{c}_{mac} \equiv \frac{2}{S} \int_0^{b/2} c(y)^2 dy$$

Ambas cuerdas se usan frecuentemente como longitud de referencia en el coeficiente de momento de cabeceo.

- En estabilidad y control de aviones, se suele usar  $\bar{c}_{mac}$  como longitud de referencia
- La ubicación del centro de gravedad en aviones se suele dar como un porcentaje de  $\bar{c}_{mac}$



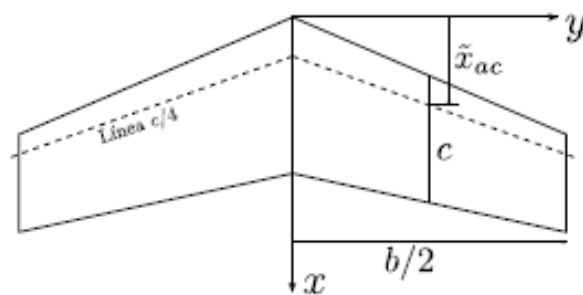
# Centro aerodinámico del Ala - I

## Centro aerodinámico:

- Punto respecto del cual, el coeficiente de momento de cabeceo de un ala no depende del ángulo de ataque.
- Es fundamental saber su ubicación, ya que de él dependen algunas derivadas de estabilidad de la aeronave.
  - Ubicación longitudinal
  - Ubicación transversal: centro aerodinámico de semialas (estabilizador vertical).

## Ubicación longitudinal

Despreciando los efectos de la resistencia en el momento aerodinámico, así como considerando ángulos de ataque y de diedro pequeños, se tiene:



$$C_{M_0} \simeq \frac{2}{S c_{ref}} \int_0^{b/2} C_{m_{ac}} c^2 dy + \frac{2}{S c_{ref}} \int_0^{b/2} C_l c \bar{x}_{ac} dy$$

$$= C_{M_{ac}} - \frac{\bar{x}_{ac}}{c_{ref}} C_L$$

Derivando respecto a  $\alpha$  y considerando  $C_{M_{ac}}$ ,  $C_{m_{ac}}$ ,  $\bar{x}_{ac}$  y  $\bar{x}_{ac}$  constantes:

$$\bar{x}_{ac} \simeq \frac{2}{S C_{L_\alpha}} \frac{\partial}{\partial \alpha} \int_0^{b/2} C_l c \bar{x}_{ac} dy = \frac{2}{S C_L} \int_0^{b/2} C_{l_{ad}}(y) c \bar{x}_{ac} dy$$

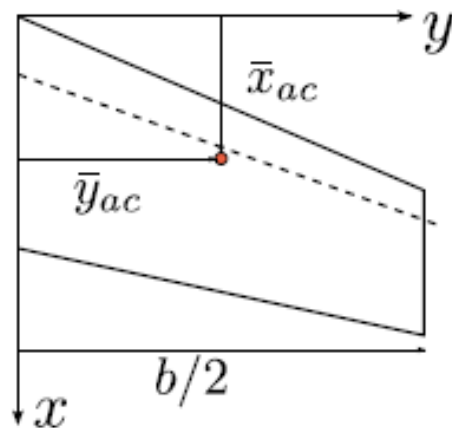
donde  $C_{l_{ad}}(y)$  es la distribución de sustentación adicional del ala.



# Centro Aerodinámico del Ala - II

## Ubicación transversal

- Problema trivial para un ala: **está en el plano de simetría del avión**
- Sí tiene interés en "alas asimétricas": **fuerzas en el estabilizador vertical**



Considerando el momento de balance en el encastre de un semiala

$$\begin{aligned} C_{\text{rollo}} &= \frac{1}{Sb} \int_0^{b/2} C_l c(y) y dy \\ &= C_{\text{rollac}} + \frac{\bar{y}_{ac} C_L}{b} \frac{1}{2} \end{aligned}$$

donde  $C_L$  es el coeficiente de sustentación del ala completa.

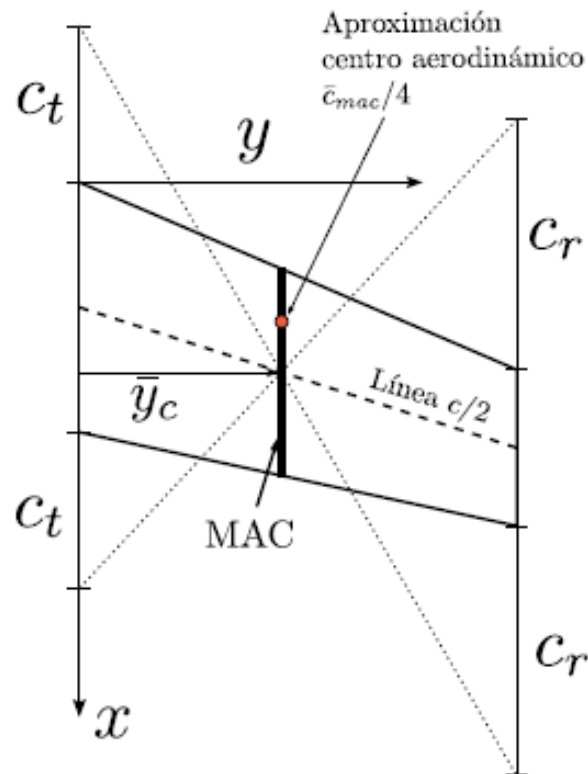
Derivando respecto a  $\alpha$  y considerando  $C_{\text{rollac}}$  y  $\bar{y}_{ac}$  constantes:

$$\bar{y}_{ac} \approx \frac{2}{SC_{L\alpha}} \frac{\partial}{\partial \alpha} \int_0^{b/2} C_l c(y) y dy = \frac{2}{SC_L} \int_0^{b/2} C_{l_{ad}}(y) c(y) y dy$$

# Centroide de un Ala

Definición:

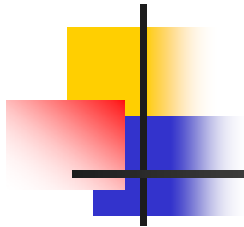
$$\bar{x}_c = \frac{2}{S} \int_0^{b/2} c(y) x_{ac}(y) dy, \quad \bar{y}_c = \frac{2}{S} \int_0^{b/2} c(y) y dy, \quad \bar{z}_c = \frac{2}{S} \int_0^{b/2} c(y) z_{ac}(y) dy$$



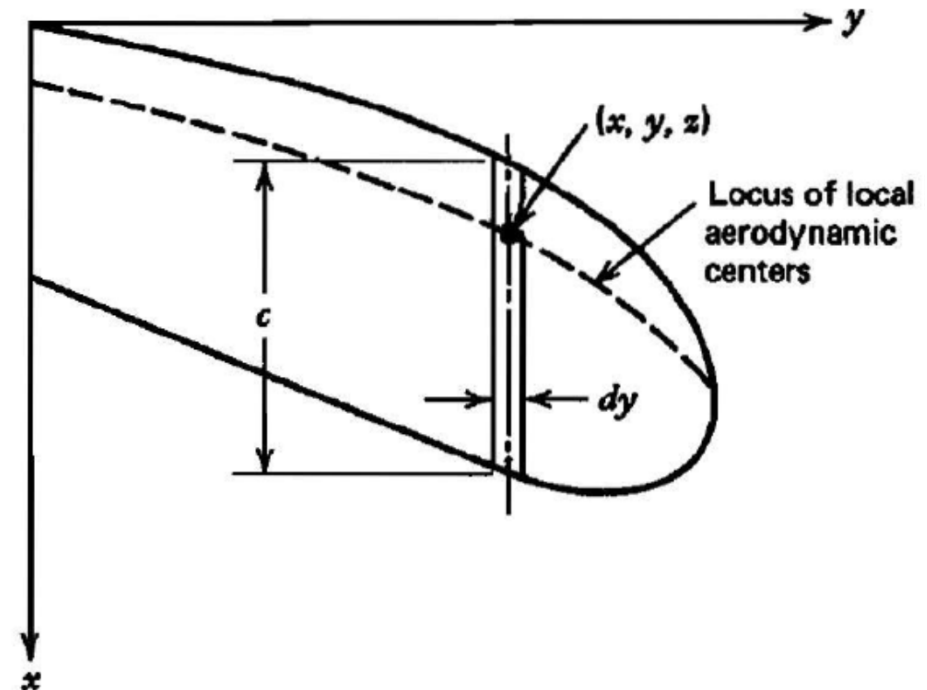
- En alas trapezoidales, la posición de  $\bar{c}_{mac}$  coincide con la cuerda centroidal.
- El centro aerodinámico no tiene por qué estar en  $\bar{c}_{mac}/4$
- El centroide está cerca del centro aerodinámico (se puede tomar como aproximación)
- Cuando la distribución de circulación adicional es constante (e. g. alas elípticas), la posición del centro aerodinámico coincide con el centroide.

La ubicación del centro de gravedad en aviones se suele dar como porcentajes de la MAC





$$\bar{c} = \frac{2}{S} \int_0^{\frac{b}{2}} c^2 dy$$
$$\bar{x} = \frac{2}{C_L S} \int_0^{\frac{b}{2}} C_{l_a} c x dy$$
$$\bar{y} = \frac{2}{C_L S} \int_0^{\frac{b}{2}} C_{l_a} c y dy = \eta_b \frac{b}{2}$$
$$\bar{z} = \frac{2}{C_L S} \int_0^{\frac{b}{2}} C_{l_a} c z dy$$



- $b$  - es la envergadura del ala.
- $C_L$  - es el coeficiente de sustentación total.
- $C_{l_a}$  - es el coeficiente de sustentación local adicional, el cual es proporcional a  $C_L$ .
- $z$  - coordenada vertical del centro aerodinámico local medido desde el plano  $xy$ .

Figura 1.1: Geometría Estándar del Ala.

- Diferente flecha en borde de ataque y borde de salida.
- Necesario definir geoméricamente los ángulos de flecha para ambos, borde de entrada y de salida.

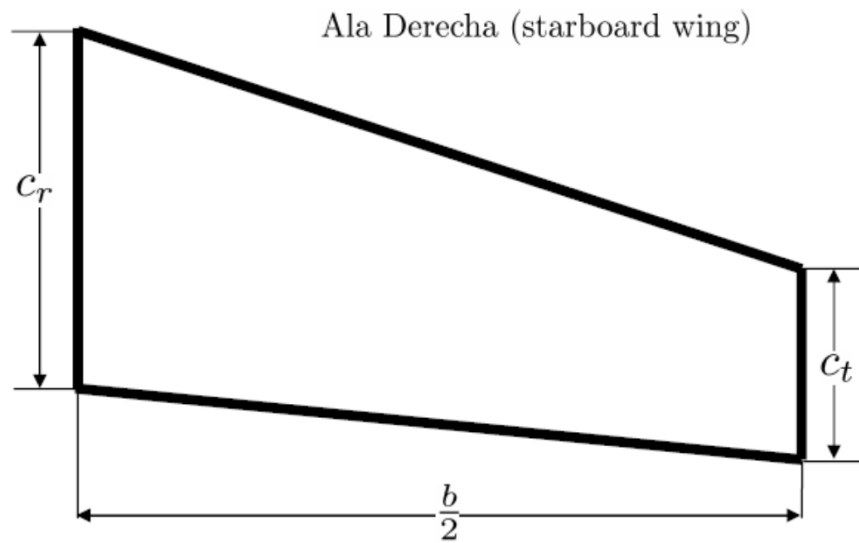
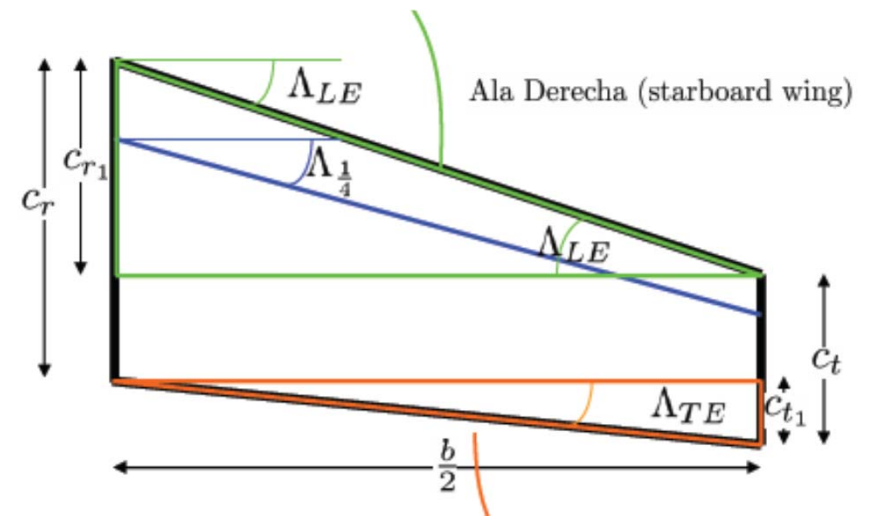
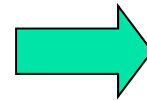


Figura 1.2: Geometría Inicial del Ala.





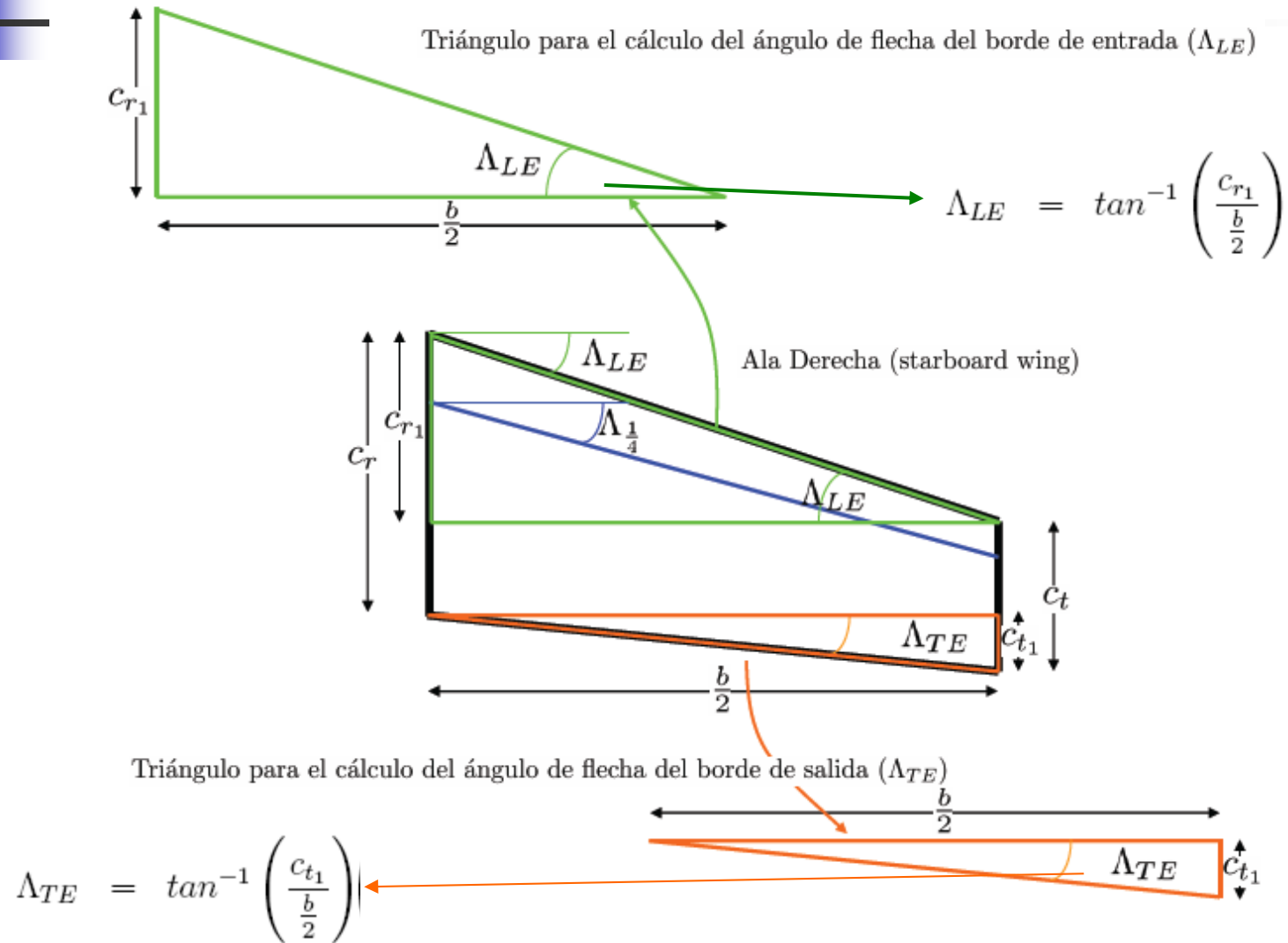
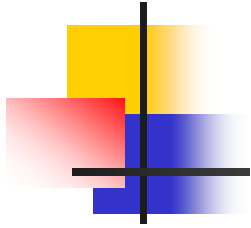


Figura 1.3: Geometría Detallada del Ala.

$$\Lambda_{LE} = \tan^{-1} \left( \frac{c_{r1}}{\frac{b}{2}} \right) \quad \Lambda_{TE} = \tan^{-1} \left( \frac{c_{t1}}{\frac{b}{2}} \right)$$

La semi-envergadura de la superficie sustentadora viene dada por diseño, mientras que la problemática viene al definir tanto  $c_{r1}$  como  $c_{t1}$ . El problema para definir los catetos opuestos de ambos triángulos tiene demasiadas incógnitas, por lo que se necesita que al menos definamos una variable de partida. Generalmente, la flecha del cuarto de cuerda ( $\Lambda_{\frac{1}{4}}$ ) suele ser la que se fija en el diseño inicial por motivos aerodinámicos, y una vez definida se puede definir los diferentes ángulos de flecha mediante análisis geométrico

$$c_{r1} = \frac{b}{2} \tan \Lambda_{\frac{1}{4}} + \frac{c_r - c_t}{4}$$

$$\Lambda_{LE} = \tan^{-1} \left( \frac{c_{r1}}{\frac{b}{2}} \right) = \tan^{-1} \left( \frac{\frac{b}{2} \tan \Lambda_{\frac{1}{4}} + \frac{c_r - c_t}{4}}{\frac{b}{2}} \right)$$

$$c_{t1} = \frac{b}{2} \tan \Lambda_{LE} + c_t - c_r$$

$$\Lambda_{TE} = \tan^{-1} \left( \frac{c_{t1}}{\frac{b}{2}} \right) = \tan^{-1} \left( \frac{\frac{b}{2} \tan \Lambda_{LE} + c_t - c_r}{\frac{b}{2}} \right)$$

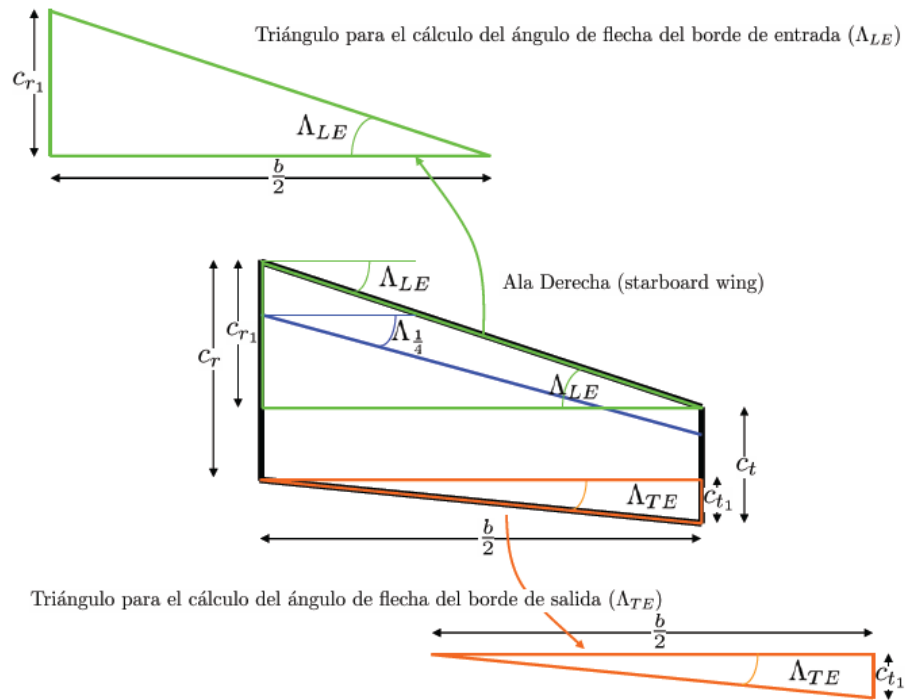


Figura 1.3: Geometría Detallada del Ala.

Una vez definidos geoméricamente los ángulo de la flecha para el borde de entrada y el borde de salida de la superficie sustentadora, pasamos a definir las líneas que definen el borde de entrada y el borde de salida del ala en función de la envergadura, con lo que definiremos la variación de la cuerda en función la envergadura. Para ello usamos la geometría definida en la figura 1.4, donde:

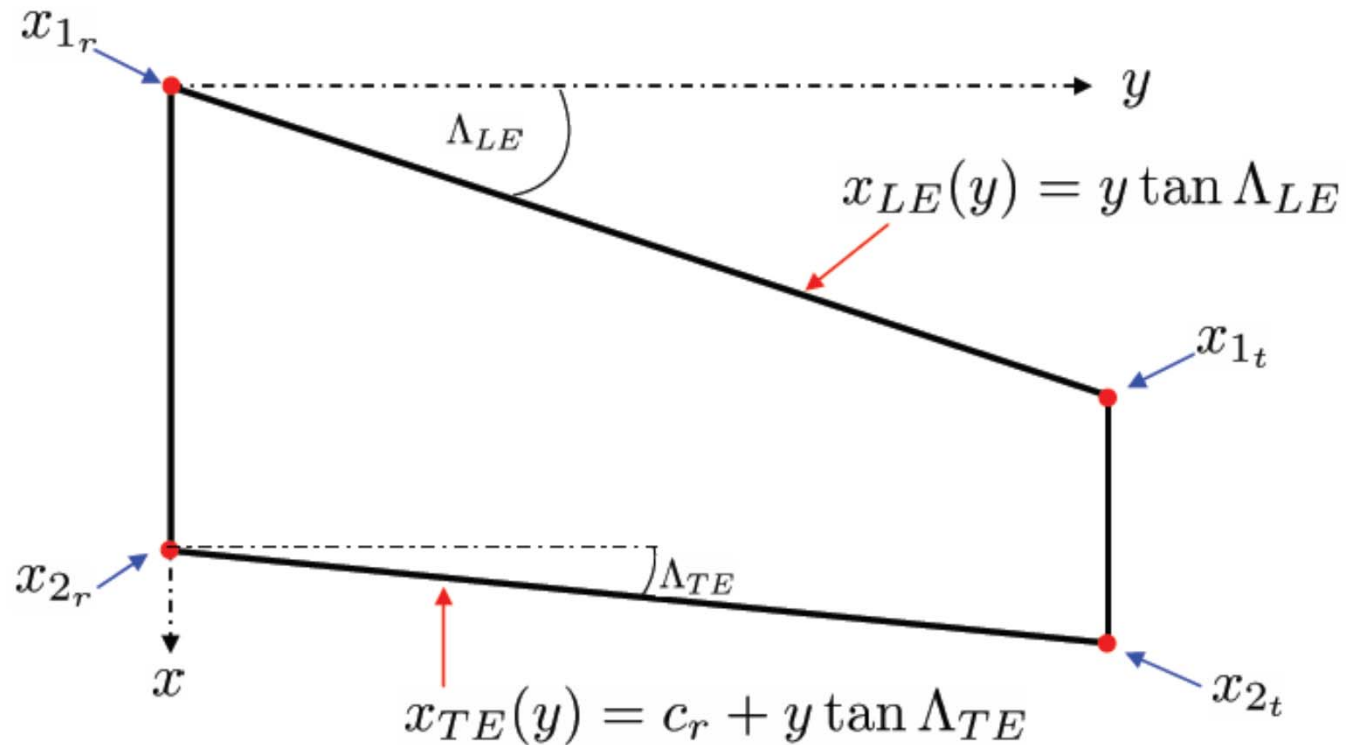
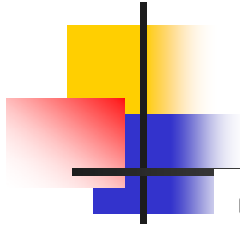


Figura 1.4: Geometría Detallada del Ala - parte 2.



- $x_{1_r}$  representa el punto más adelantado de la cuerda en raíz del ala, es decir el borde de entrada de la cuerda en raíz.
- $x_{2_r}$  representa el punto más retrasado de la cuerda en raíz del ala, es decir el borde de salida de la cuerda en raíz.
- $x_{1_t}$  representa el punto más adelantado de la cuerda en punta del ala, es decir el borde de entrada de la cuerda en punta.
- $x_{2_t}$  representa el punto más retrasado de la cuerda en punta del ala, es decir el borde de salida de la cuerda en punta.

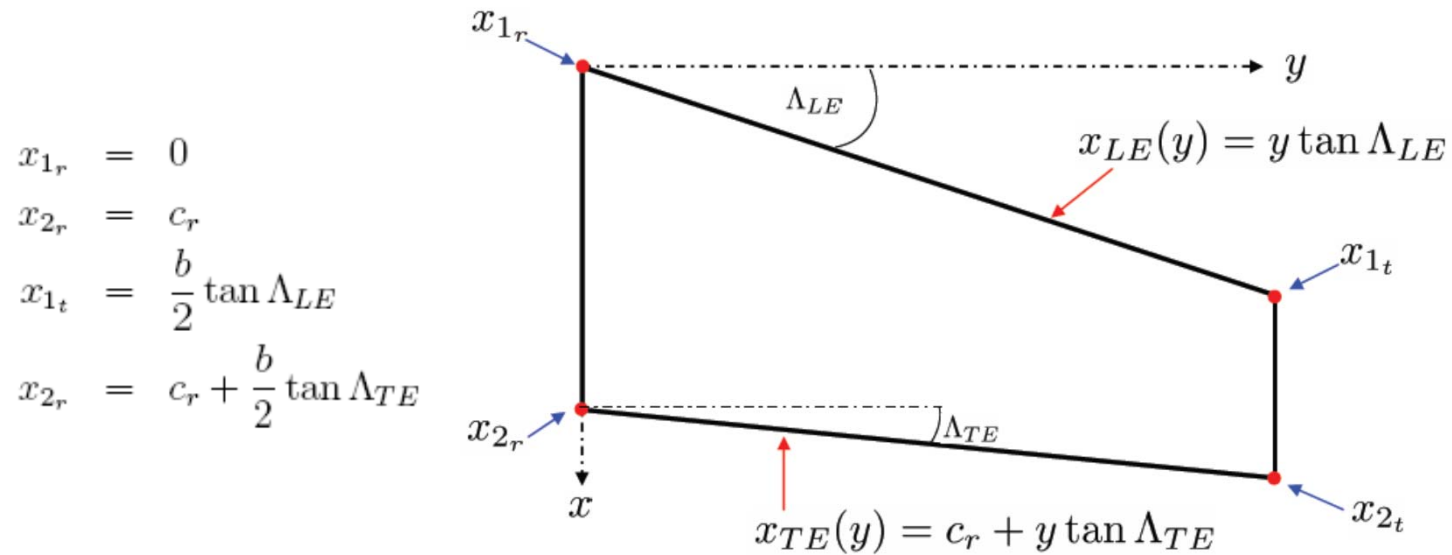


Figura 1.4: Geometría Detallada del Ala - parte 2.

De forma más genérica podemos definir la variación del borde de entrada y del borde de salida a medida que nos movemos por la envergadura del ala como:

$$\begin{aligned}x_{LE}(y) &= y \tan \Lambda_{LE} \\x_{TE}(y) &= c_r + y \tan \Lambda_{TE}\end{aligned}$$

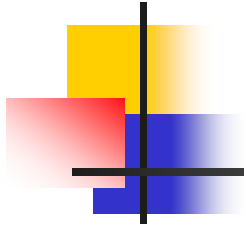
lo cual nos permitirá definir la ecuación que define el valor de la variación de la cuerda en función de la envergadura del ala tal que:

$$\begin{aligned}c(y) &= x_{TE}(y) - x_{LE}(y) = c_r + y (\tan \Lambda_{TE} - \tan \Lambda_{LE}) \\c(y) &= x_{TE}(y) - x_{LE}(y) = c_r + y (\tan \Lambda_{TE} - \tan \Lambda_{LE})\end{aligned}$$

$$C_{l_a} \rightarrow C_L$$

$$x(y) = n c_r + y \tan \Lambda_n, \text{ siendo } n = \frac{1}{4} \text{ para velocidades subsónicas}$$

$$\begin{aligned}\bar{c} &= \frac{2}{S} \int_0^{\frac{b}{2}} c^2 dy = \int_0^{\frac{b}{2}} (c_r + y (\tan \Lambda_{TE} - \tan \Lambda_{LE}))^2 dy \\ \bar{x} &= \frac{2}{C_{LS}} \int_0^{\frac{b}{2}} C_{l_a} c x dy = \frac{2}{S} \int_0^{\frac{b}{2}} (c_r + y (\tan \Lambda_{TE} - \tan \Lambda_{LE})) \cdot (n c_r + y \tan \Lambda_n) dy \\ \bar{y} &= \frac{2}{C_{LS}} \int_0^{\frac{b}{2}} C_{l_a} c y dy = \frac{2}{S} \int_0^{\frac{b}{2}} (c_r + y (\tan \Lambda_{TE} - \tan \Lambda_{LE})) y dy \\ \bar{z} &= \frac{2}{C_{LS}} \int_0^{\frac{b}{2}} C_{l_a} c z dy = \frac{2}{S} \int_0^{\frac{b}{2}} (c_r + y (\tan \Lambda_{TE} - \tan \Lambda_{LE})) y \tan \gamma dy\end{aligned} \tag{1.2}$$



$$\bar{c} = \frac{2}{S} \int_0^{\frac{b}{2}} c^2 dy$$

$$\bar{x} = \frac{2}{C_{LS}} \int_0^{\frac{b}{2}} C_{l_a} cx dy$$

$$\bar{y} = \frac{2}{C_{LS}} \int_0^{\frac{b}{2}} C_{l_a} cy dy = \eta_b \frac{b}{2}$$

$$\bar{z} = \frac{2}{C_{LS}} \int_0^{\frac{b}{2}} C_{l_a} cz dy$$

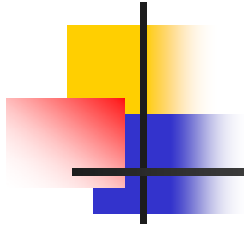


$$\bar{c} = \frac{2}{S} \int_0^{\frac{b}{2}} c^2 dy = \int_0^{\frac{b}{2}} (c_r + y (\tan \Lambda_{TE} - \tan \Lambda_{LE}))^2 dy$$

$$\bar{x} = \frac{2}{C_{LS}} \int_0^{\frac{b}{2}} C_{l_a} cx dy = \frac{2}{S} \int_0^{\frac{b}{2}} (c_r + y (\tan \Lambda_{TE} - \tan \Lambda_{LE})) \cdot (nc_r + y \tan \Lambda_n) dy$$

$$\bar{y} = \frac{2}{C_{LS}} \int_0^{\frac{b}{2}} C_{l_a} cy dy = \frac{2}{S} \int_0^{\frac{b}{2}} (c_r + y (\tan \Lambda_{TE} - \tan \Lambda_{LE})) y dy \quad (1.2)$$

$$\bar{z} = \frac{2}{C_{LS}} \int_0^{\frac{b}{2}} C_{l_a} cz dy = \frac{2}{S} \int_0^{\frac{b}{2}} (c_r + y (\tan \Lambda_{TE} - \tan \Lambda_{LE})) y \tan \gamma dy$$



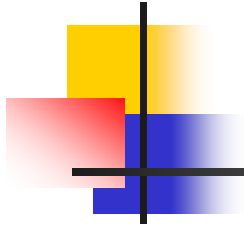
```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%  
% calculate the mean properties assuming the lift coefficient %  
% is a constant by the integration method using quad8 %  
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%  
cbar=quadl('mac',0,bo2);  
xbar=quadl('xac',0,bo2);  
ybar=quadl('yac',0,bo2);  
zbar=quadl('zac',0,bo2);
```

```
function line = xbar(y)  
global cr ct taper gamma bo2 span  
global lambdale lambdate lambdah lambdaq gamma csmall  
n=1/4.0;  
XLE= y*tan(lambdale);  
XTE = cr + y*tan(lambdate);  
c = (XTE - XLE);  
x= n*cr + y*tan(lambdaq);  
line = csmall.*c.*x;
```

```
function line = ybar(y)  
global cr ct taper gamma bo2 span  
global lambdale lambdate lambdah lambdaq gamma csmall  
XLE= y*tan(lambdale);  
XTE = cr + y*tan(lambdate);  
c = (XTE - XLE);  
line =csmall.*c.*y;
```

```
function line = zbar(y)  
global cr ct taper gamma bo2 span  
global lambdale lambdate lambdah lambdaq gamma csmall  
XLE= y*tan(lambdale);  
XTE = cr + y*tan(lambdate);  
c = (XTE - XLE);  
z = y*tan(gamma);  
line = csmall.*c.*z;
```

```
function line = mac(y)  
global cr ct taper gamma bo2 span  
global lambdale lambdate lambdah lambdaq gamma csmall  
XLE= y*tan(lambdale);  
XTE = cr + y*tan(lambdate);  
c = (XTE - XLE);  
line = (c.*c);
```



$$\bar{c} = \frac{2}{S} \int_0^{b/2} c^2 dy$$

where  $b$  = wing span

$$\bar{x} = \frac{2}{C_L S} \int_0^{b/2} C_{l_a} c x dy$$

$c$  = local chord

$C_L$  = total lift coefficient

$C_{l_a}$  = local additional lift coefficient, proportional to  $C_L$

$$\bar{y} = \frac{2}{C_L S} \int_0^{b/2} C_{l_a} c y dy = \eta_{cp} \frac{b}{2}$$

$C_{l_b}$  = local basic lift coefficient, independent of  $C_L$

$C_l = C_{l_b} + C_{l_a}$  = total local lift coefficient

$$\bar{z} = \frac{2}{C_L S} \int_0^{b/2} C_{l_a} c z dy$$

$m_{ac}$  = pitching moment, per unit span, about aerodynamic center (Fig. C.4)

$S$  = wing area

$y$  = spanwise coordinate of local aerodynamic center measured from axis of symmetry

$x$  = chordwise coordinate of local aerodynamic center measured aft of wing apex

$z$  = vertical coordinate of local aerodynamic center measured from  $xy$  plane

$\eta_{cp}$  = lateral position of the center of pressure of the additional load on the half-wing as a fraction of the semispan

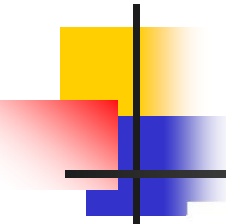




**Table C.1**

| <i>Planform</i>                                      | <i>Additional Loading Distribution</i>              | <i>M.A.C.</i><br>$\bar{c}$                                   | $\bar{y}$   |
|--|---|--|---|
| Constant taper and sweep (trapezoidal)               | Any   | $\frac{2c_r}{3} \frac{1 + \lambda + \lambda^2}{1 + \lambda}$ | $\eta_{cp} \cdot \frac{b}{2}$                           |
| Constant taper and sweep (trapezoidal)               | Proportional to wing chord (uniform $C_{l\alpha}$ ) | $\frac{2c_r}{3} \frac{1 + \lambda + \lambda^2}{1 + \lambda}$ | $\frac{b}{2} \cdot \frac{1 + 2\lambda}{3(1 + \lambda)}$ |
| Constant taper and sweep (trapezoidal)               | Elliptic  | $\frac{2c_r}{3} \frac{1 + \lambda + \lambda^2}{1 + \lambda}$ | $\frac{b}{2} \cdot \frac{4}{3\pi}$                      |
| Elliptic (with straight sweep of line of local a.c.) | Any   | $\frac{c_r}{3} \cdot \frac{8}{\pi}$                          | $\eta_{cp} \cdot \frac{b}{2}$                           |
| Elliptic (with straight sweep of line of local a.c.) | Elliptic (uniform $C_{l\alpha}$ )                   | $\frac{c_r}{3} \cdot \frac{8}{\pi}$                          | $\frac{b}{2} \cdot \frac{4}{3\pi}$                      |
| Any (with straight sweep of line of local a.c.)      | Elliptic  | $\frac{2}{S} \int_0^{b/2} c^2 dy$                            | $\frac{b}{2} \cdot \frac{4}{3\pi}$                      |





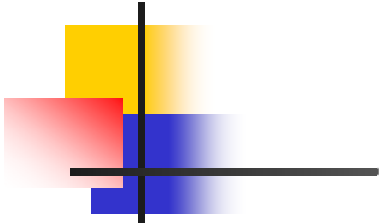
In the general case the additional loading distribution and the spanwise center-of-pressure position can be obtained by methods such as those of De Young and Harper (1948), Weissinger (1947), and Stanton-Jones (1950). For a trapezoidal wing with the local aerodynamic centers on the  $n$ th-chord line, the chordwise location of the mean aerodynamic center from the leading edge of the m.a. chord expressed as a fraction of the m.a. chord  $h_{nw}$  is given by

$$h_{nw} = n + \frac{3(1 + \lambda)^2}{8(1 + \lambda + \lambda^2)} \left[ \eta_{cp} - \frac{1 + 2\lambda}{3(1 + \lambda)} \right] A \tan \Lambda_n \quad (\text{C.2,1})$$

where  $A =$  aspect ratio,  $b^2/S$

$\lambda =$  taper ratio,  $c_t/c_r$

$c_t =$  wing-tip chord



### C.3 *m.a. Chord and m.a. Center for Swept and Tapered Wings (Subsonic)*

$$\begin{aligned}x &= \frac{b}{2} \cdot \frac{1}{3} \frac{1+2\lambda}{1+\lambda} \tan \Lambda_0 \\ &= \frac{1+2\lambda}{12} c_r A \tan \Lambda_0\end{aligned}$$

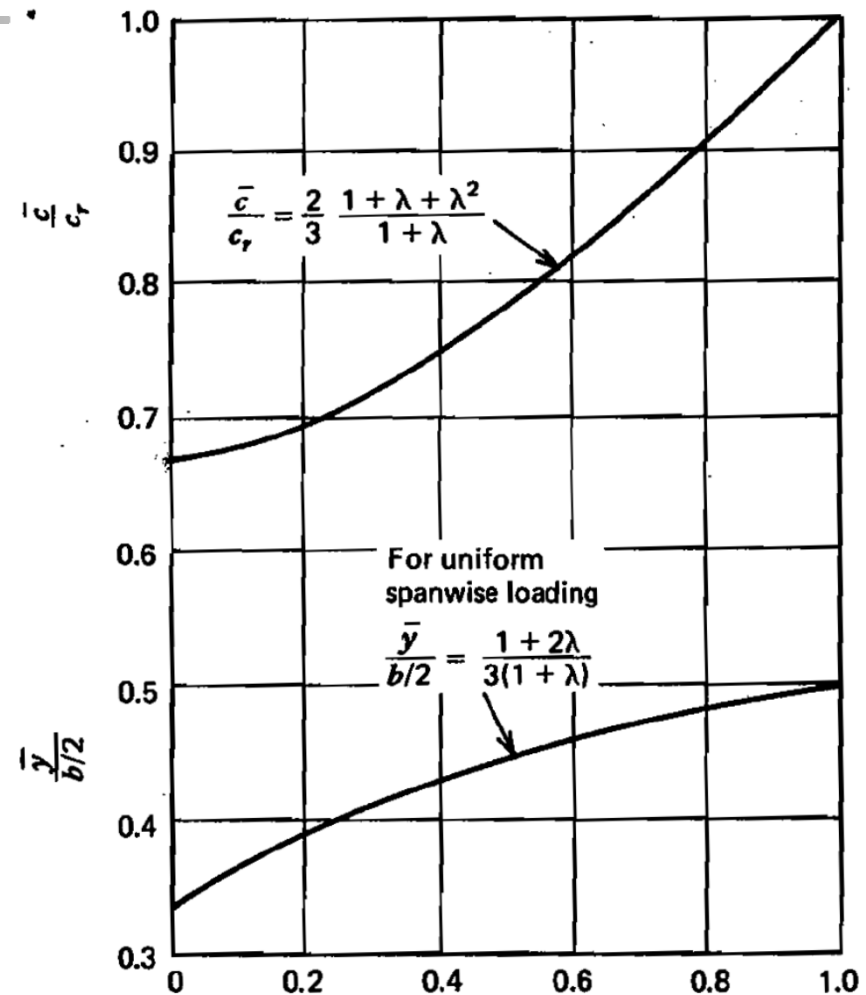
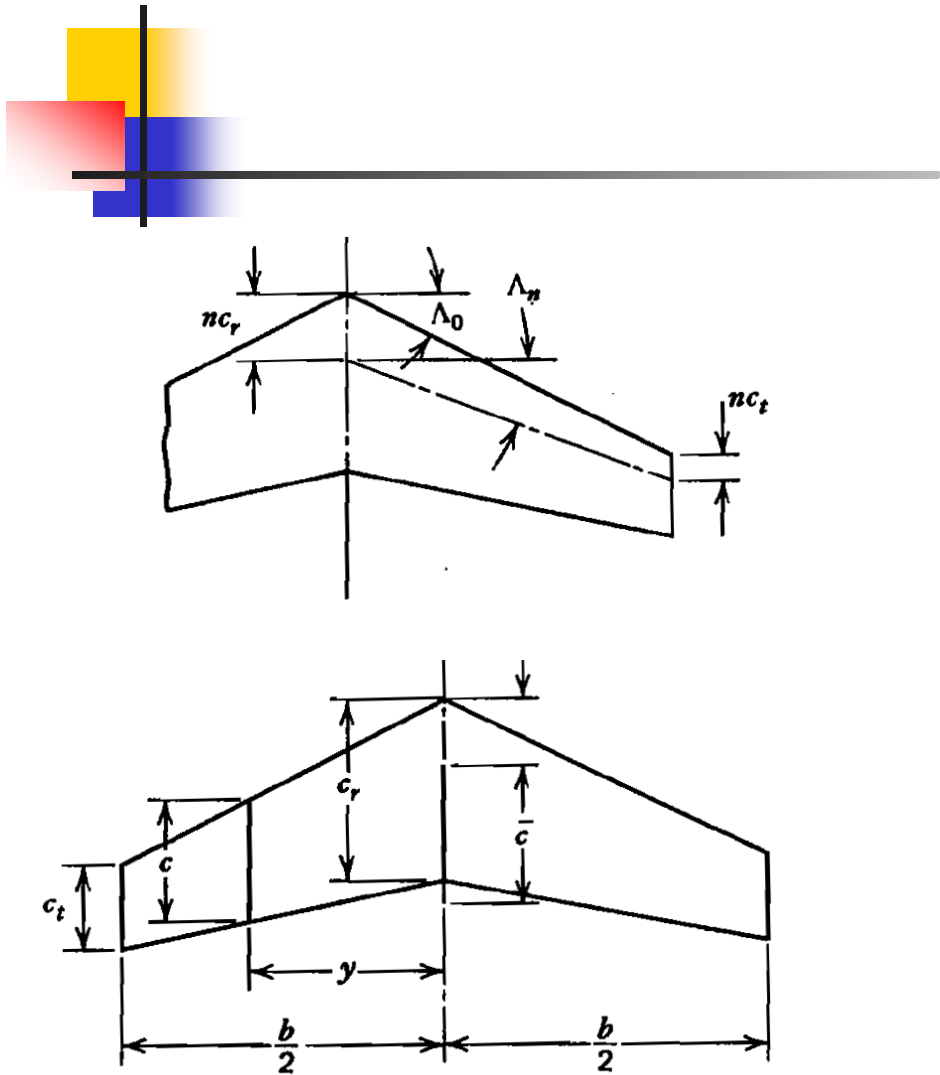
where  $\Lambda_0$  = sweepback of wing leading edge, degrees.

The sweepback of the leading edge is related to the sweep of the  $n$ th-chord line  $\Lambda_n$  by the relation

$$A \tan \Lambda_0 = A \tan \Lambda_n + 4n \frac{1-\lambda}{1+\lambda} \quad (\text{C.3,2})$$

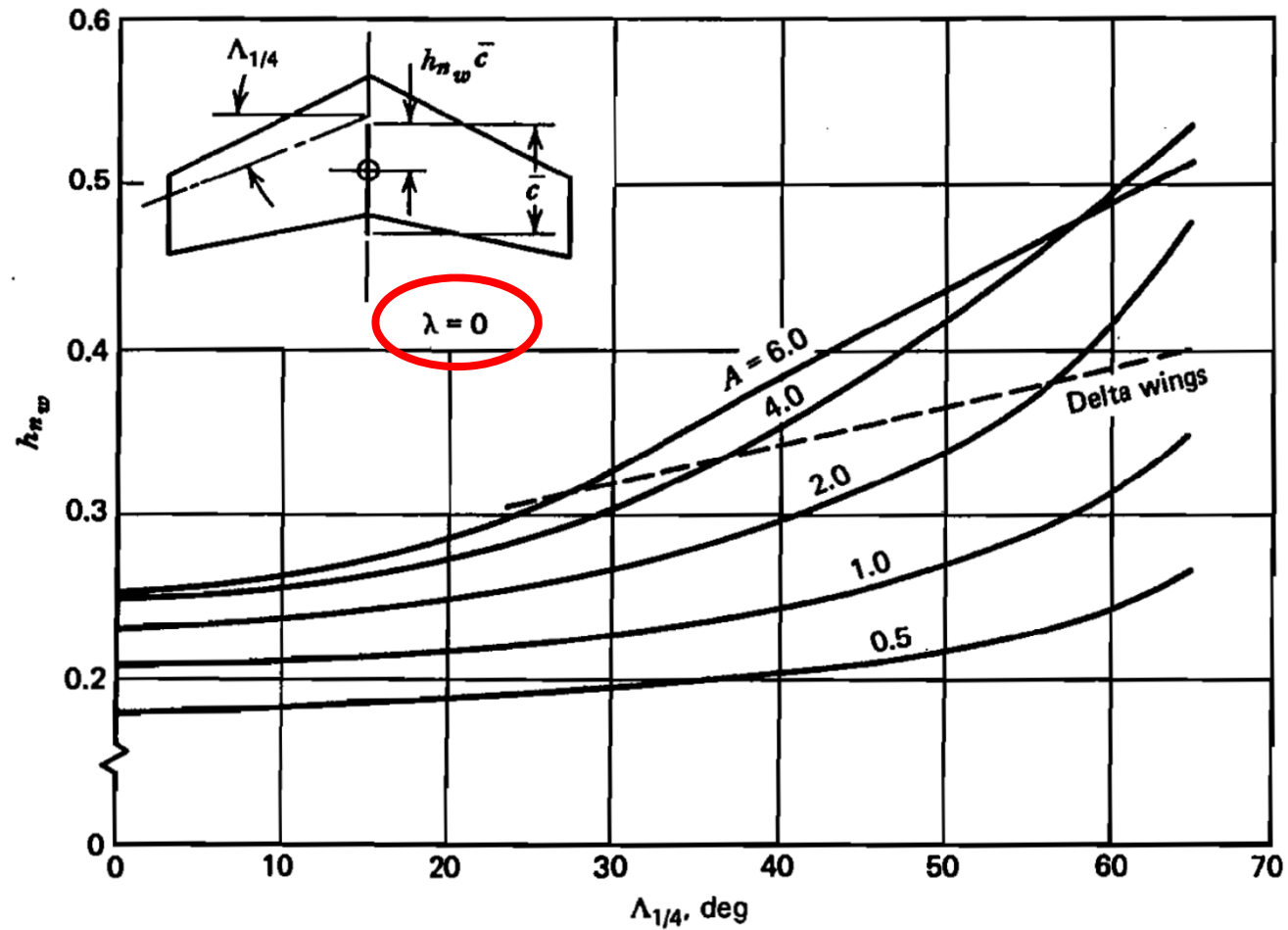
Using (C.3,2) and the expression for  $\bar{c}/c_r$ ,  $x$  can be obtained in terms of  $\bar{c}$  and  $\Lambda_n$  from

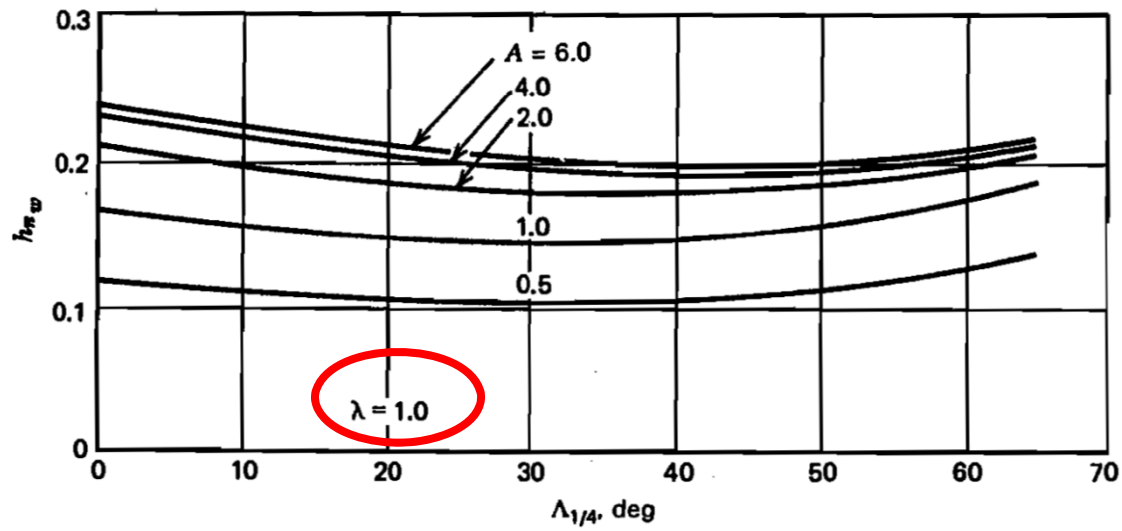
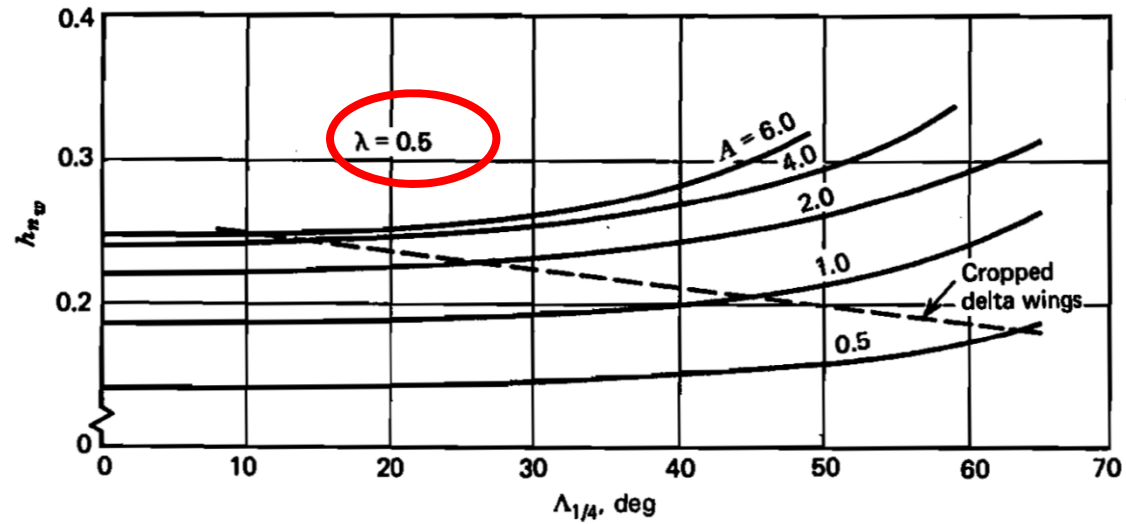
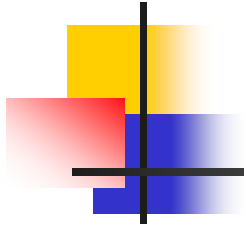
$$\frac{x}{\bar{c}} = \frac{(1+2\lambda)(1+\lambda)}{8(1+\lambda+\lambda^2)} \left[ A \tan \Lambda_n + 4n \frac{1-\lambda}{1+\lambda} \right] \quad (\text{C.3,3})$$

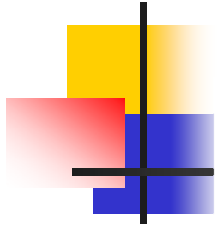


**Figure C.2** Mean aerodynamic chord for straight tapered wings; and spanwise position of mean aerodynamic center for uniform spanwise loading (i.e., constant  $C_{L\alpha}$ ). (From “Notes on the Mean Aerodynamic Chord and the Mean Aerodynamic Center of a Wing” by A. H. Yates, *J. Roy. Aero. Soc.*, June 1952.)

**Figure C.3** Chordwise position of the mean aerodynamic center of swept and tapered wings at low speeds expressed as a fraction of the mean aerodynamic chord. (From Royal Aeronautical Data Sheet Wings 08.01.01.)







## C.4 $C_{m_{ac_w}}$

The total load on each section of a wing has three parts as illustrated by Fig. C.4a. The resultant of the local additional lift  $l_a$ , is the lift  $L_a$  acting through the m.a. center (Fig. C.4b).

The resultant of the distribution of the local basic lift  $l_b$  is a pitching couple whenever the line of aerodynamic centers is not straight and perpendicular to  $x$ . This couple is given by

$$M_1 = 2 \int_0^{b/2} (x - \bar{x}) l_b dy = 2 \int_0^{b/2} x l_b dy$$

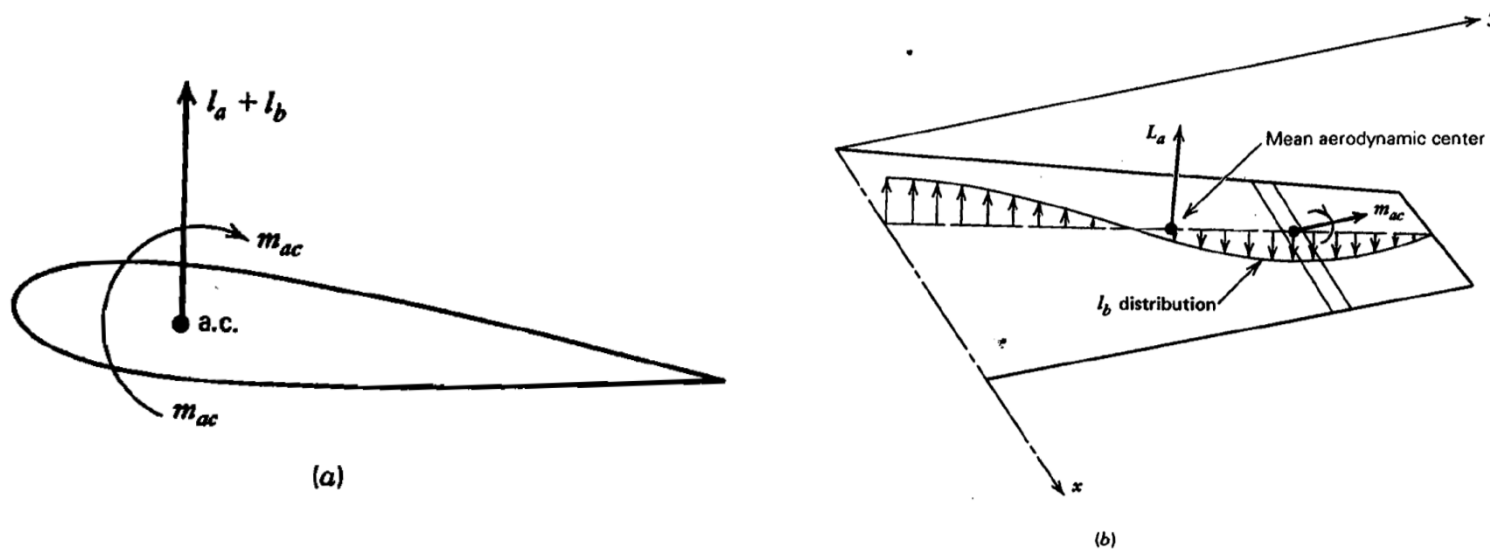


Figure C.4 (a) Section total load. (b) Wing loads.

$C_L$  = total lift coefficient

$C_{l_a}$  = local additional lift coefficient, proportional to  $C_L$

$C_{l_b}$  = local basic lift coefficient, independent of  $C_L$

$C_l = C_{l_b} + C_{l_a} =$  total local lift coefficient

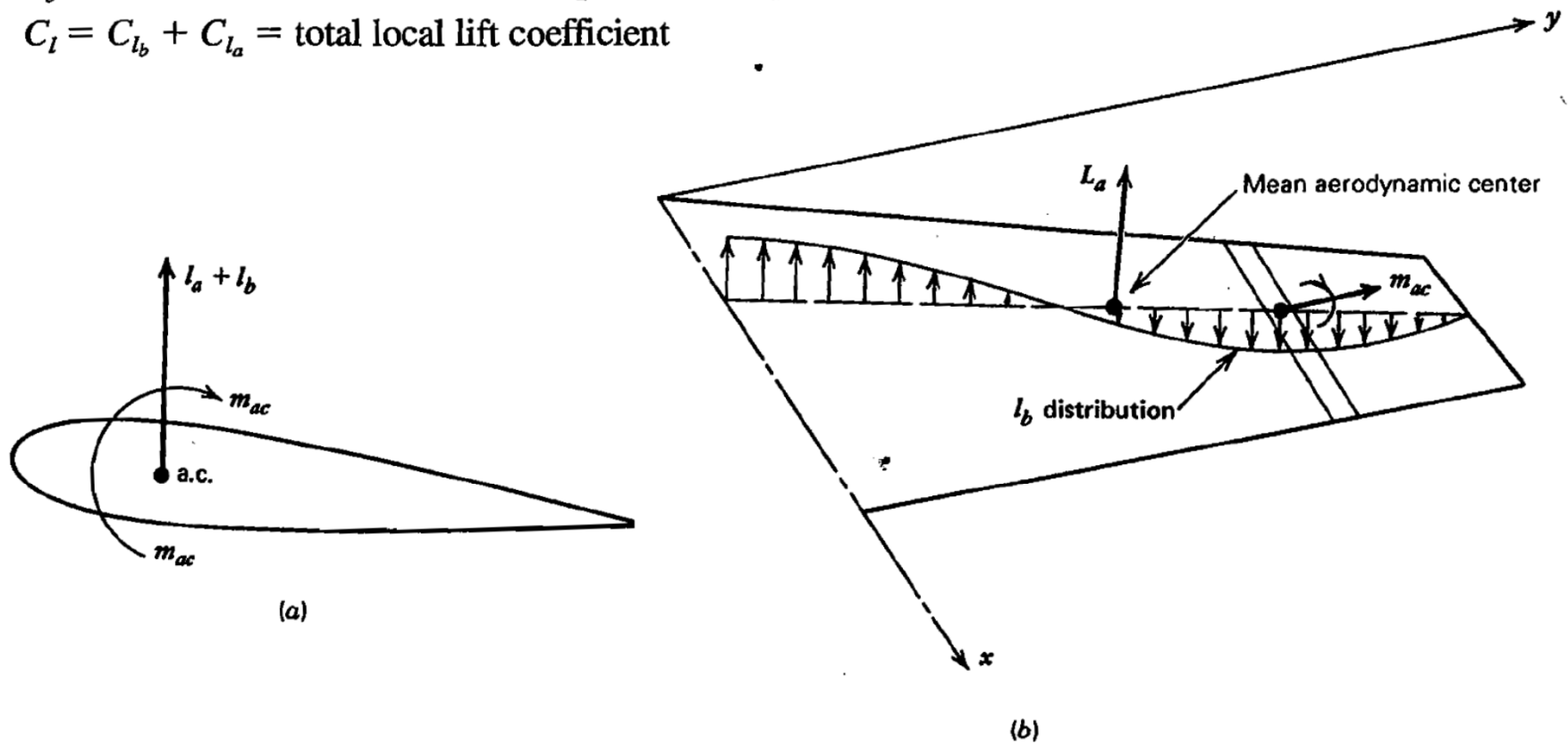
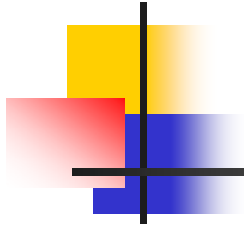


Figure C.4 (a) Section total load. (b) Wing loads.





The total pitching-moment coefficient about the m.a. center is then

$$C_{m_{ac_w}} = C_{m_1} + C_{m_2} = \text{const} \quad (\text{C.4,3})$$

If  $C_{m_{ac}}$  is constant across the span, and equals  $C_{m_2}$ , then (C.4,2) also becomes the defining equation for  $\bar{c}$ .

$$\begin{aligned} C_{m_1} &= \frac{4}{\rho V^2 S \bar{c}} \int_0^{b/2} x C_{l_b} \frac{1}{2} \rho V^2 c \, dy \\ &= \frac{2}{S \bar{c}} \int_0^{b/2} C_{l_b} x c \, dy \end{aligned}$$

$$C_{m_2} = \frac{2}{S \bar{c}} \int_0^{b/2} C_{m_{ac}} c^2 \, dy$$

# Software

- MAC Software
  - <http://www.softoxi.com/mean-aerodynamic-chord-video-trailer-screenshots.html>

Mean Aerodynamic Chord - Text Files : test.txt

File Language Help

Half wing dimensions (mm)

|                   | Panel 1 | Panel 2 | Panel 3 | Panel 4 | Panel 5 |         |
|-------------------|---------|---------|---------|---------|---------|---------|
| Major chord :     | 23      | 14      | 6       | 3       |         | Compute |
| Minor chord :     | 14      | 6       | 3       |         |         |         |
| Panel length :    | 55      | 24      | 12      |         |         | Clear   |
| Total Sweep +/- : | 12      | 5       | 3       |         |         |         |
| Center Position : | 30      | %       |         |         |         | Print   |

Weight : 44 g Wing load : 167.75 g/dm<sup>2</sup>

Results

|                |                      |                   |          |
|----------------|----------------------|-------------------|----------|
| Wing Span :    | 182.00 mm            | A.C. :            | 35.05 mm |
| Wing Area :    | 0.26 dm <sup>2</sup> | M.A.C. :          | 16.76 mm |
| Aspect Ratio : | 12.63                | M.A.C. Distance : | 11.11 mm |



# Bibliografía

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- B. Etkin and L. D. Reid “Dynamics of Flight: Stability and Control”
- Prof. F. Gavilán, “Apuntes Mecánica del Vuelo II”, Dpto. Ingeniería Aeroespacial Universidad de Sevilla