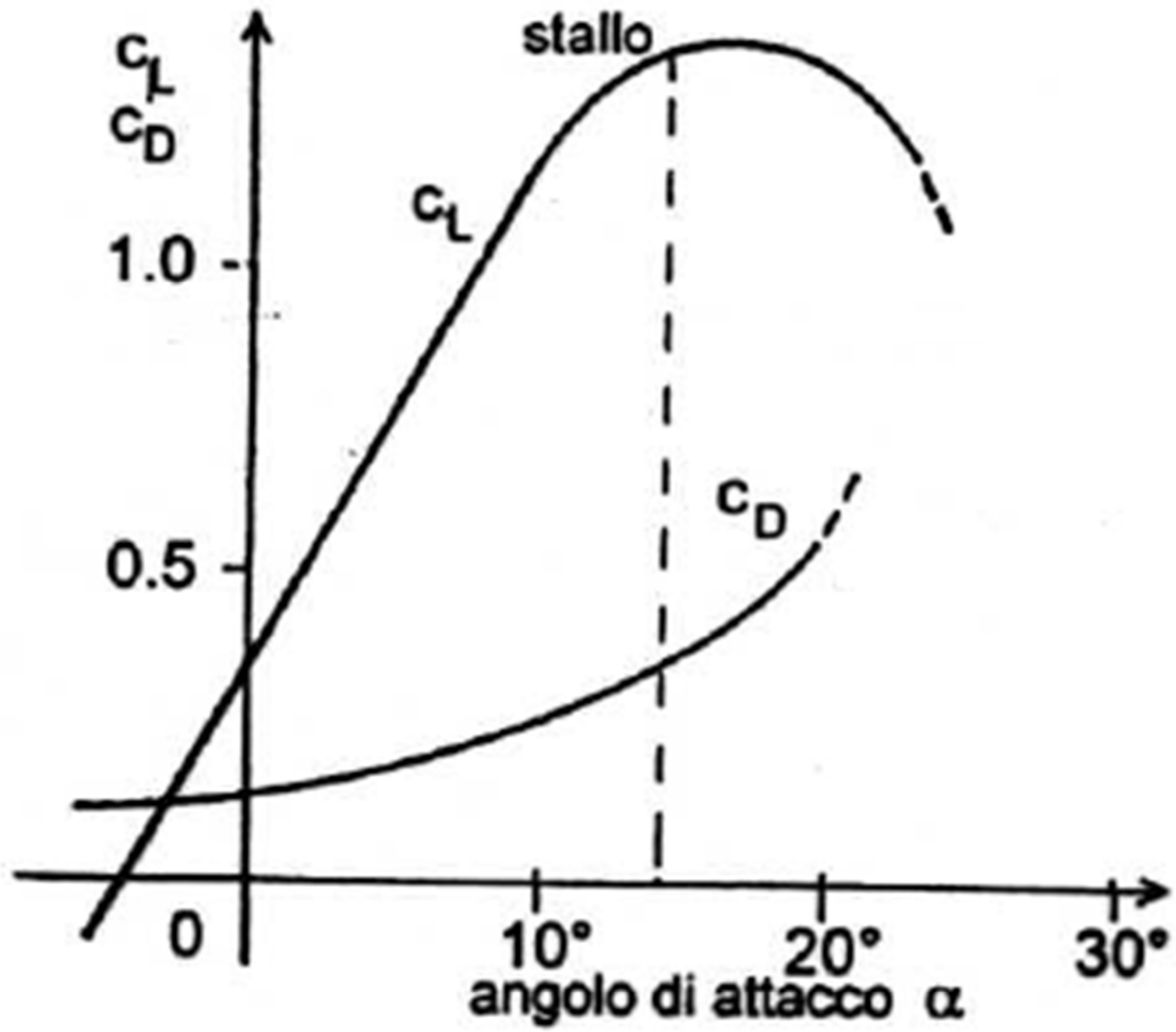
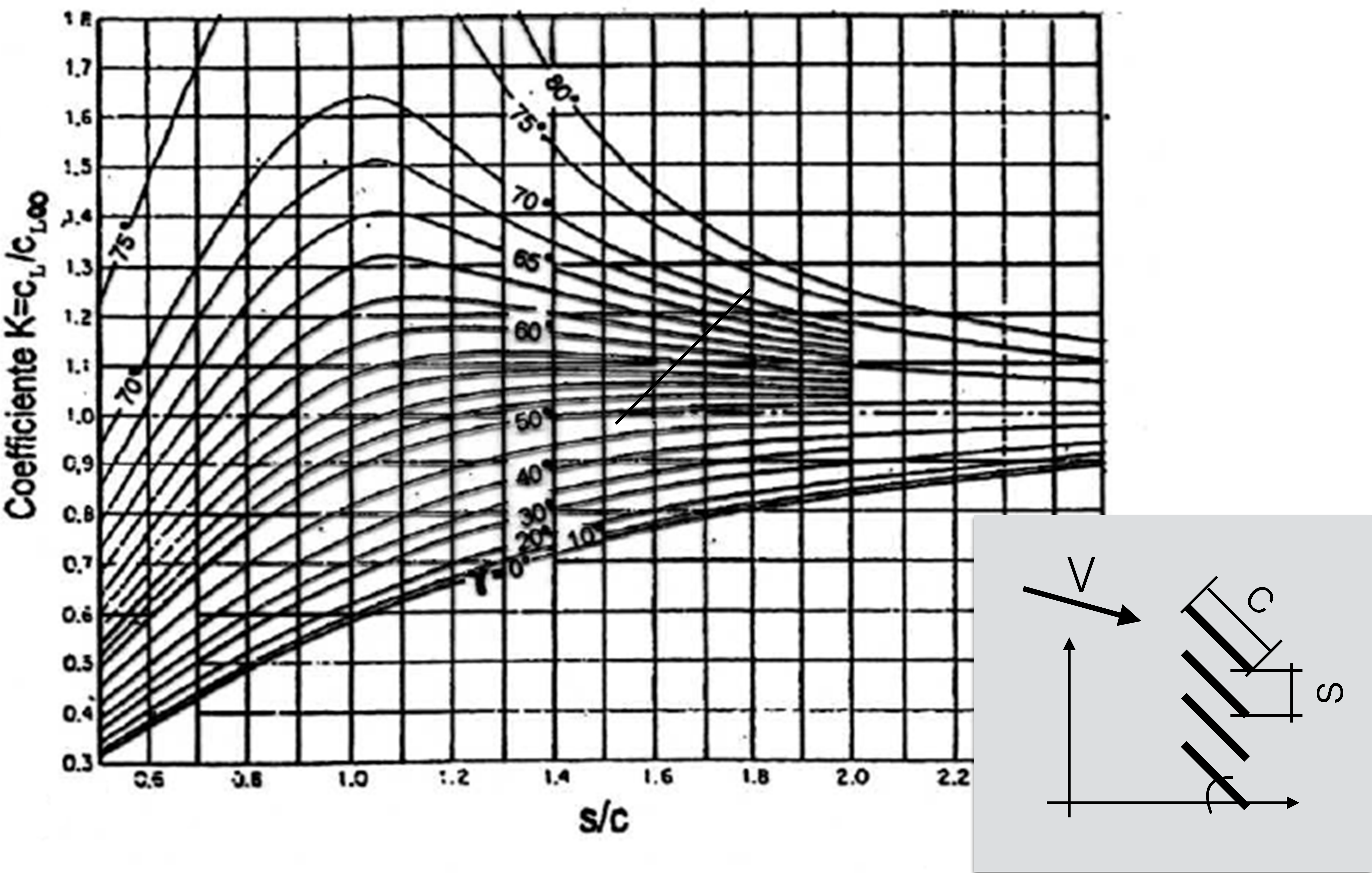
LEZIONE 11-12

Effetto schiera sulle prestazioni del profilo



Effetto schiera sulle prestazioni del profilo



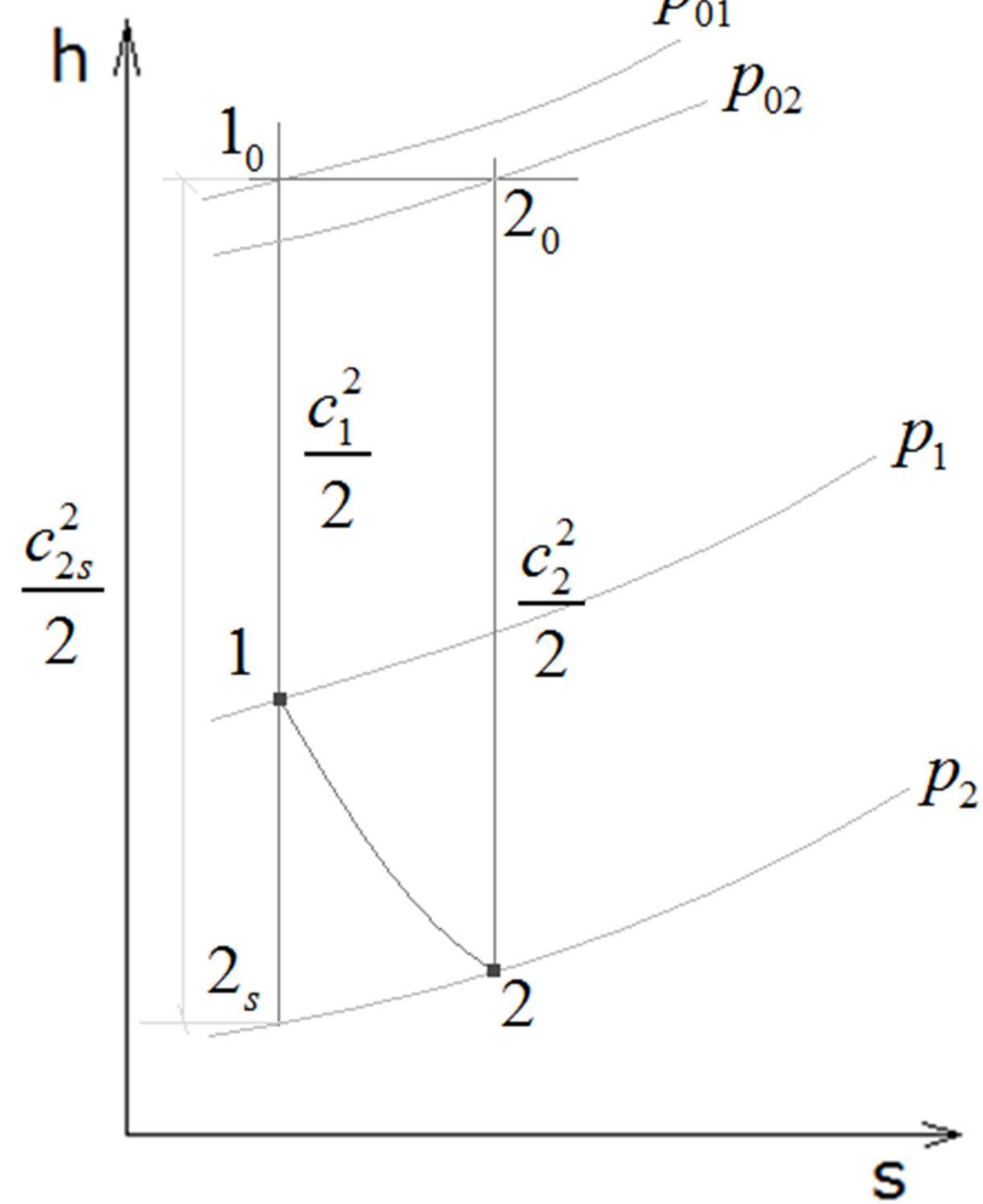
ugelli e diffusori

Distinguiamo due casi:

1) Nell’elemento abbiamo un incremento di velocità a spese di una riduzione di pressione. Questi saranno gli *ugelli*.
2) Nell’elemento l’energia cinetica diminuisce ed aumenta la pressione. Questi saranno i *diffusori*.

ugelli

$$\eta_{is} = \frac{h_1 - h_2}{h_1 - h_{2s}} = \frac{\dfrac{c_2^2}{2} - \dfrac{c_1^2}{2}}{\dfrac{c_{2s}^2}{2} - \dfrac{c_1^2}{2}} = \frac{c_2^2 - c_1^2}{c_{2s}^2 - c_1^2}$$



ugelli

(Ma<0,3)

$$p_{01} = p_1 + \frac{1}{2}\rho c_1^2 \quad \rightarrow \quad c_1^2 = \frac{2}{\rho}\left(p_{01} - p_1\right)$$

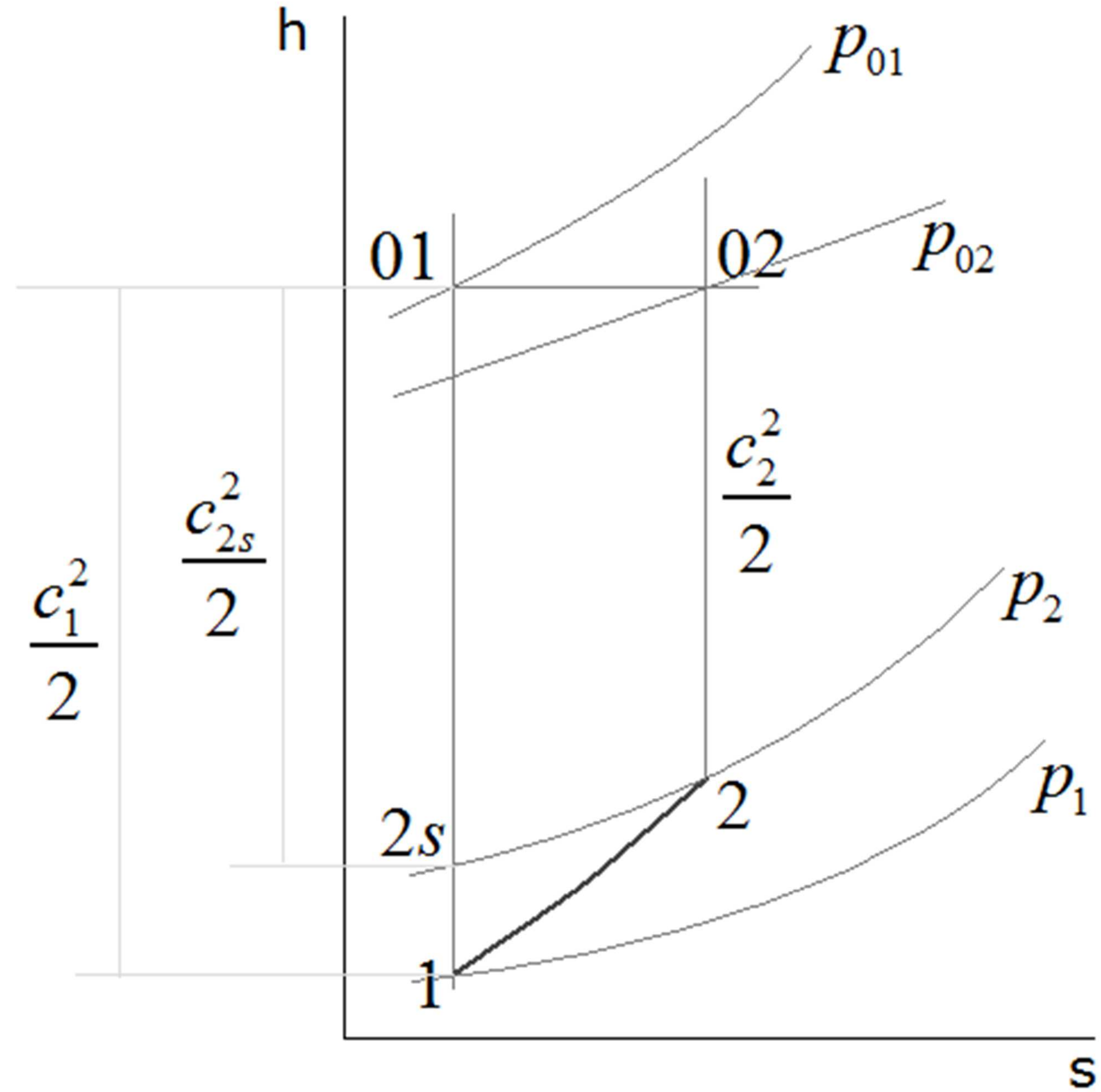
$$p_{01} = p_2 + \frac{1}{2}\rho c_{2s}^2 \quad \rightarrow \quad c_{2s}^2 = \frac{2}{\rho}\left(p_{01} - p_2\right)$$

$$p_{02} = p_2 + \frac{1}{2}\rho c_2^2 \quad \rightarrow \quad c_2^2 = \frac{2}{\rho}\left(p_{02} - p_2\right)$$

$$\eta_{is} = \frac{p_{02} - p_2 - \left(p_{01} - p_1\right)}{\cancel{p_{01}} - p_2 - \left(\cancel{p_{01}} - p_1\right)} = \frac{p_{02} - p_2 - \left(p_{01} - p_1\right)}{p_1 - p_2} = 1 - \frac{\Delta p_0}{p_1 - p_2}$$

Diffusori

$$\eta_{is} = \frac{h_{2s} - h_1}{h_2 - h_1} = \frac{c_1^2 - c_{2s}^2}{c_1^2 - c_2^2}$$



Diffusori

(Ma<0,3)

$$\eta_{is} = \frac{p_{01} - p_1 - \left(p_{01} - p_2\right)}{p_{01} - p_1 - \left(p_{02} - p_2\right)} = \frac{p_2 - p_1}{p_2 - p_1 + \left(p_{01} - p_{02}\right)} = \frac{1}{1 - \frac{\Delta p_0}{p_2 - p_1}}$$

coeff. recupero di pressione: $c_p = \frac{p_2 - p_1}{p_{01} - p_1}$

Diffusori

(Ma<0,3)

Legame tra c_p e η_{is}

$$\eta_{is} = \frac{p_2 - p_1}{p_2 - p_1 + \left(p_{01} - p_{02}\right)}$$

$$\frac{1}{\eta_{is}} = \frac{p_2 - p_1 + \left(p_{01} - p_{02}\right)}{p_2 - p_1} = \frac{p_{01} - p_1 - \left(p_{02} - p_2\right)}{p_2 - p_1} = \frac{1}{c_p} - \frac{p_{02} - p_2}{p_2 - p_1}$$

$$c_{pi} = \frac{p_2 - p_1 + \left(p_{01} - p_{02}\right)}{p_{01} - p_1}$$

Diffusori

(Ma<0,3)

$$p_2 = p_{02} - \frac{1}{2}\rho c_2^2$$

$$p_1 = p_{01} - \frac{1}{2}\rho c_1^2$$

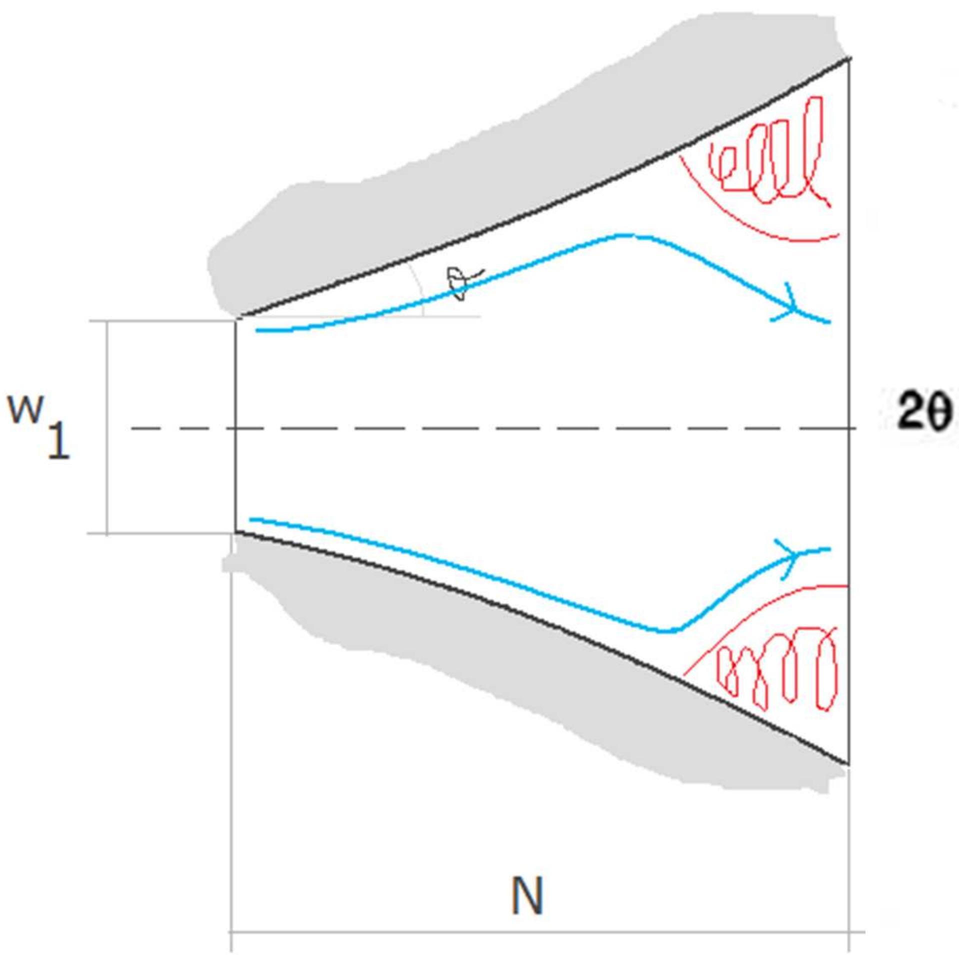
$$c_{pi} = \frac{c_1^2 - c_2^2}{c_1^2} = 1 - \left(\frac{c_2}{c_1}\right)^2 = 1 - \left(\frac{A_1}{A_2}\right)^2 = 1 - \frac{1}{A_R^2}$$

Diffusori

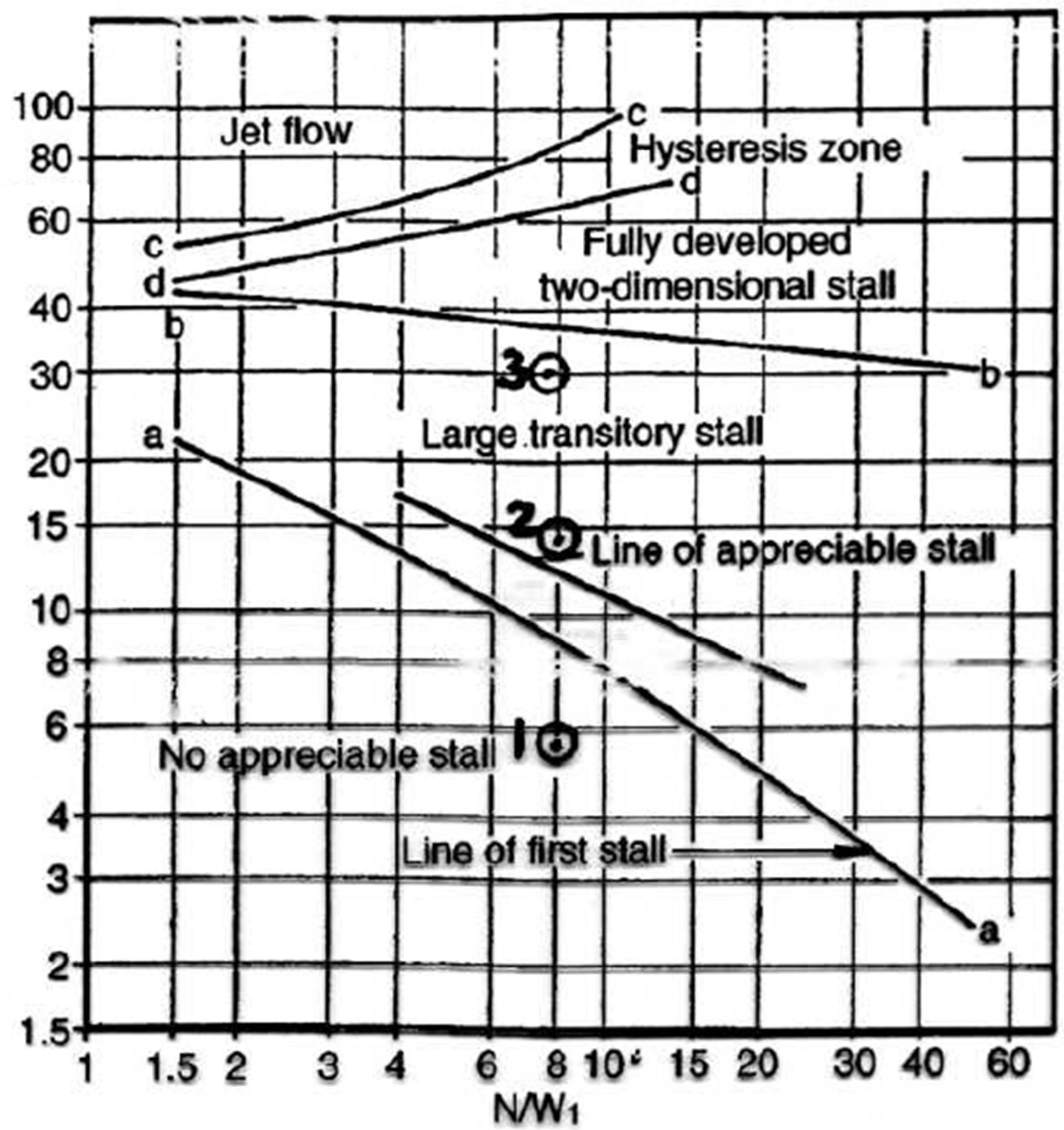
Legame tra c_p *,* η_{is} *e* c_{pi}

$$\frac{c_p}{c_{pi}} = \frac{p_2 - p_1}{p_{01} - p_1} \cdot \frac{p_{01} - p_1}{\left(p_2 - p_1\right) + \left(p_{01} - p_{02}\right)} = \eta_{is}$$

Diffusori



w1
2θ
N



Jet flow
Hysteresis zone
Fully developed
two-dimensional stall
Large transitory stall
Line of appreciable stall
No appreciable stall
Line of first stall
N/W1
100
80
60
40
30
20
15
10
8
6
4
3
2
1.5
1
1.5
2
3
4
6
8
15
20
30
40
60

Diffusori

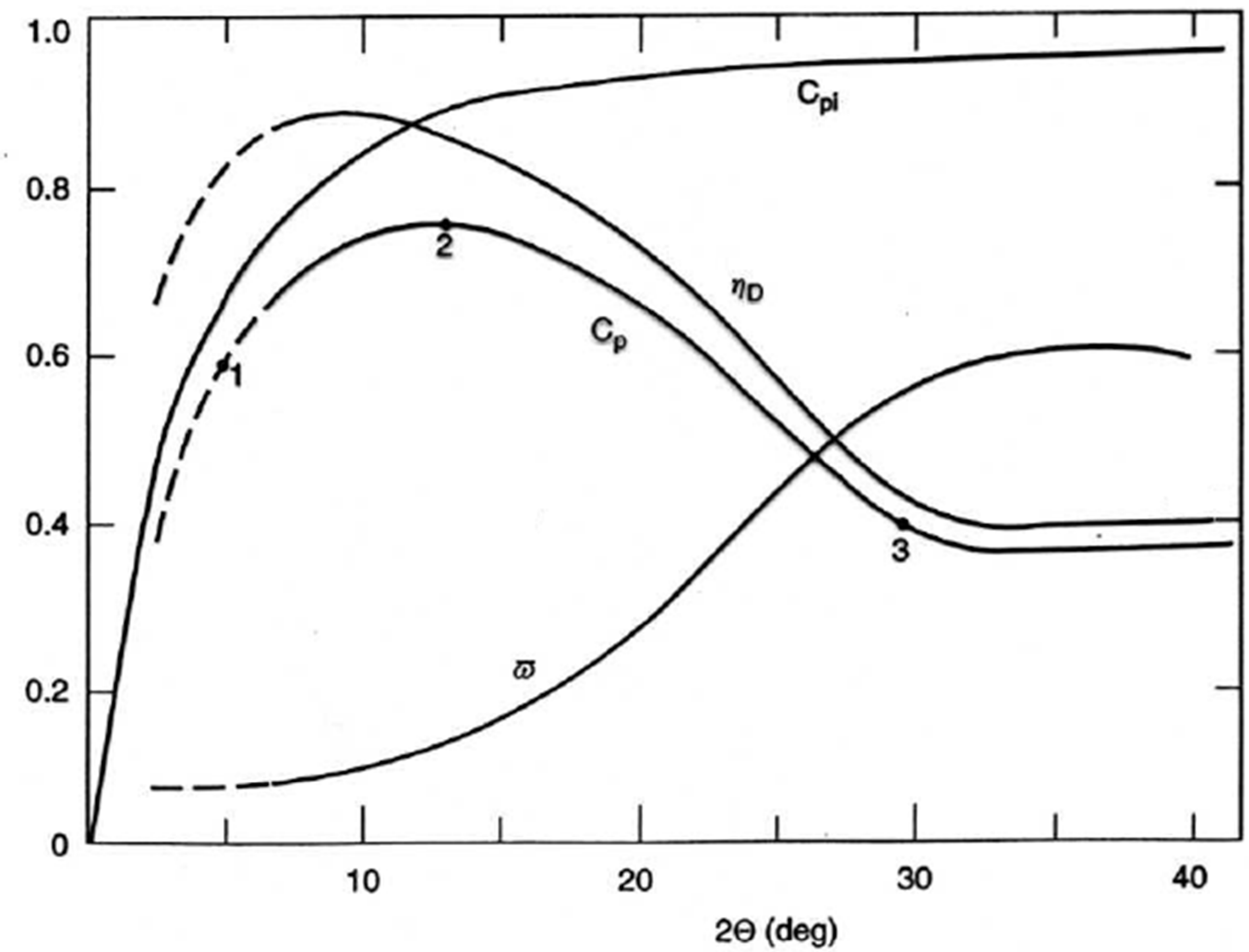


FIG. 2.16. Typical diffuser performance curves for a two-dimensional diffuser, with $L/W_1 = 8.0$ (adapted from Kline *et al.* 1959).

Schiere di espansione

Rendimento della schiera di pale (statoriche)

Le schiere di pale possono essere:

- Schiere di espansione (il flusso accelera e quindi abbiamo un ugello)
- Schiere di compressione (il flusso decellera e quindi abbiamo dei diffusori)

Schiere di espansione

$$\eta_{is} = 1 - \frac{\Delta p_0}{p_1 - p_2}$$ (ugello)

$$p_1 - p_2 = \frac{F_a}{s}$$

(per una schiera)

$$F_a = -F_t \tan \alpha_\infty + s \Delta p_0$$

$$\eta_{is} = \frac{1}{1 - \frac{\Delta p_0 s}{F_t \tan \alpha_\infty}}$$

Schiere di compressione

$$\eta_{is} = \frac{1}{1 + \dfrac{\Delta p_0}{p_2 - p_1}}$$ (diffusore)

$$p_2 - p_1 = -\frac{F_a}{s}$$

$$F_a = -F_t \tan \alpha_\infty + s \Delta p_0$$

(per una schiera)

$$\eta_{is} = 1 - \frac{\Delta p_0 s}{F_t \tan \alpha_\infty}$$

Schiere di compressione

$$F_t = c_F \frac{1}{2} \rho c V_\infty^2$$

$$V_\infty = \frac{V_a}{\cos \alpha_\infty}$$

$$\Delta p_0 = y \frac{1}{2} \rho V_2^2$$

$$V_2 = \frac{V_a}{\cos \alpha_2}$$

$$\Rightarrow \quad \frac{\Delta p_0 s}{F_t \tan \alpha_\infty} = \frac{y}{c_F \tan \alpha_\infty} \cdot \frac{\cos^2 \alpha_\infty}{\delta \cdot \cos^2 \alpha_2}$$

$$c_P = \left(\frac{s}{c}\right) y \left(\frac{V_2}{V_\infty}\right)^2 - c_F \tan \alpha_\infty$$

$$c_L = c_F \cos \alpha_\infty - c_P sen\alpha_\infty$$

$$c_D = c_F\, sen\alpha_\infty + c_P \cos \alpha_\infty$$

$$c_L = 2\left(\frac{s}{c}\right)\left(\tan \alpha_1 - \tan \alpha_2\right)\cos \alpha_\infty - c_D \tan \alpha_\infty$$

$$c_D = \left(\frac{s}{c}\right) y \frac{\cos^3 \alpha_\infty}{\cos \alpha_2}$$

$$\Rightarrow \quad \eta_{is} = 1 - \frac{2 c_D}{c_L sen\left(2\alpha_\infty\right)}$$

Schiere di compressione

$$\eta_{is} = 1 - \frac{2c_D}{c_L sen\left(2\alpha_\infty\right)}$$

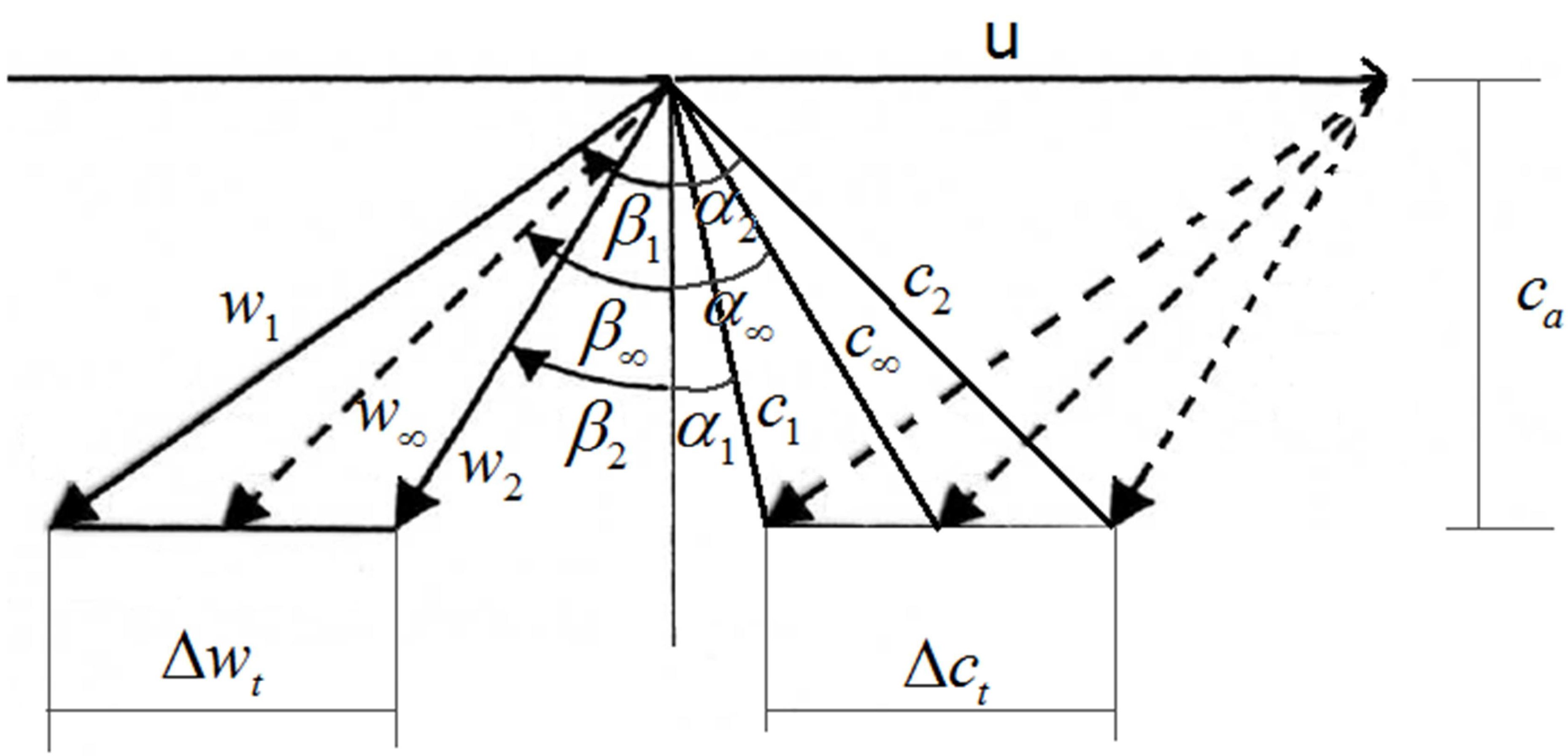
$$\frac{\partial \eta_{is}}{\partial \alpha_\infty} = 0$$

$$\frac{c_D}{c_L} = \cos t$$

$$\eta_{is,\max} = 1 - \frac{2c_D}{c_L}$$

$$\left|\alpha_\infty\right|_{ott} = 45°$$

Schiere in movimento (compressione)



$$\Delta c_t = c_{2t} - c_{1t} = w_{1t} - w_{2t} = \left|\Delta w_t\right|$$

$$F_t = s\rho c_a \left(w_{1t} - w_{2t}\right)$$

Schiere in movimento (compressione)

$$P = F_t \cdot u$$

$$\dot{m} = \rho s c_a$$

$$L_u = \frac{P}{\dot{m}} = \frac{F_t \cdot u}{\rho s c_a} = u\left(w_{t1} - w_{t2}\right)$$

$$F_t = c_F \frac{1}{2} \rho c w_\infty^2 = \frac{c_F \frac{1}{2} \rho c c_a^2}{\cos^2 \beta_\infty}$$

$$L_u = \frac{F_t \cdot u}{\rho s c_a} = \frac{c_F \delta}{2 \cos^2 \beta_\infty} \cdot c_a \cdot u$$

Schiere in movimento (compressione)

$$\lambda = \frac{L_u}{\omega^2 D^2} = \frac{L_u}{4u^2}$$

$$\varphi = \frac{Q}{\omega D^3} \propto \frac{c_a}{u}$$

$$\lambda = \frac{c_F \delta}{8\cos^2 \beta_\infty} \cdot \frac{c_a}{u} = \frac{c_F \delta}{8\cos^2 \beta_\infty} \cdot \varphi$$

Schiere in movimento

(compressione)

$$\eta_{is} = \frac{L_u - \dfrac{\Delta p_0}{\rho}}{L_u} = 1 - \frac{\dfrac{\Delta p_0}{\rho}}{L_u}$$

(espansione)

$$\eta_{is} = \frac{L_u}{L_u + \dfrac{\Delta p_0}{\rho}} = \frac{1}{1 + \dfrac{\dfrac{\Delta p_0}{\rho}}{L_u}}$$

$$\Delta p_0 = y \frac{1}{2} \rho w_2^2$$

$$L_u = \frac{c_F \delta}{2 \cos^2 \beta_\infty} \cdot c_a \cdot u$$

$$w_2 = \frac{c_a}{\cos \beta_2}$$

$$\varphi = \frac{c_a}{u}$$

Schiere in movimento

$$\eta_{is} = 1 - \frac{y}{c_F} \cdot \frac{\cos^2 \beta_\infty}{\delta \cos^2 \beta_2} \cdot \varphi$$ (compressione)

$$\eta_{is} = \frac{1}{1 + \frac{y}{c_F} \cdot \frac{\cos^2 \beta_\infty}{\delta \cos^2 \beta_2} \cdot \varphi}$$ (espansione)

rendimento di uno stadio

$$\Delta p_0 = \Delta p_{0,stat} + \Delta p_{0,rot}$$