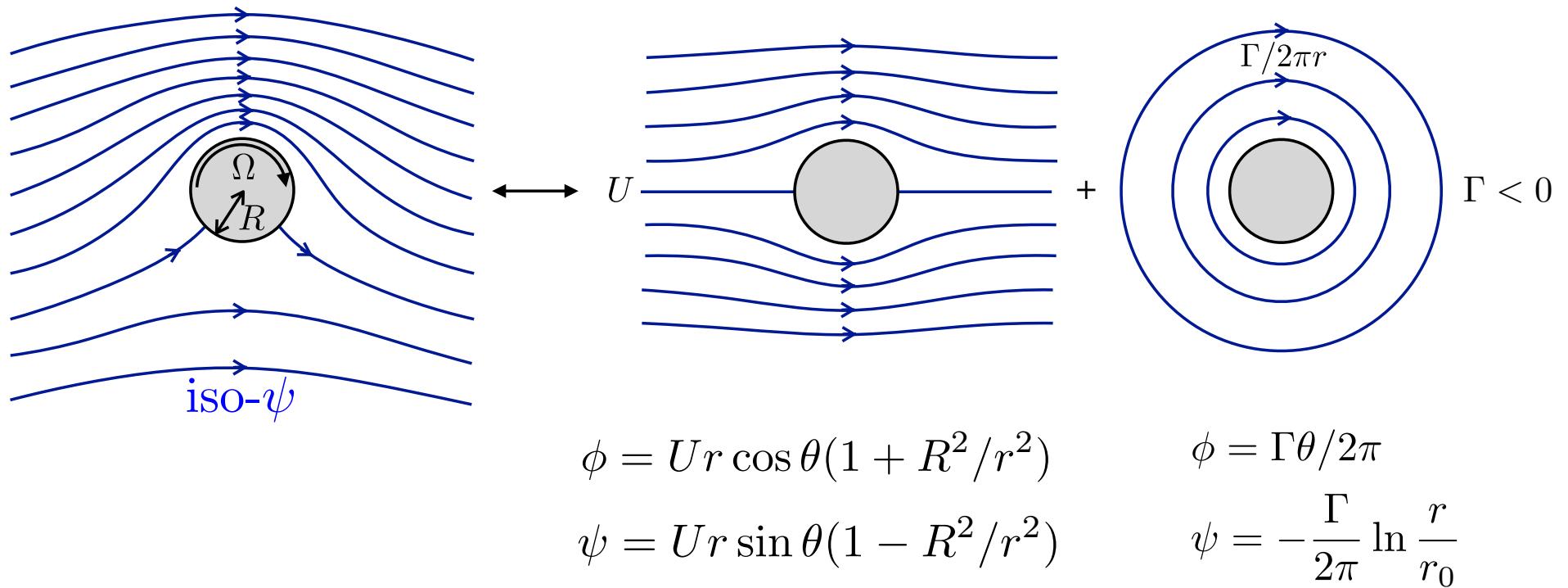
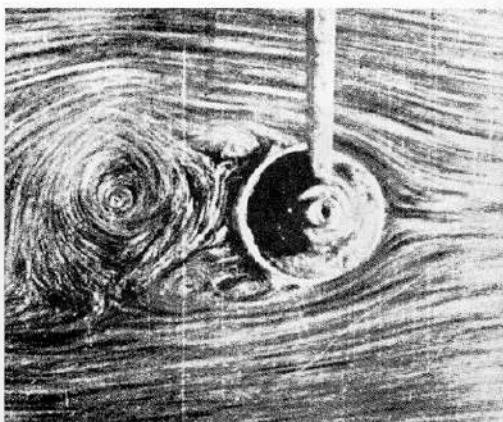


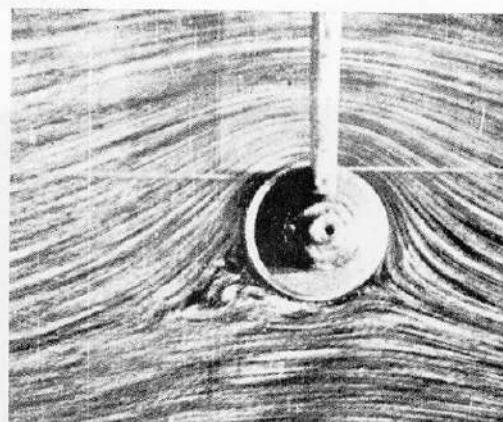
Trainée - Portance

Portance sur un cylindre tournant

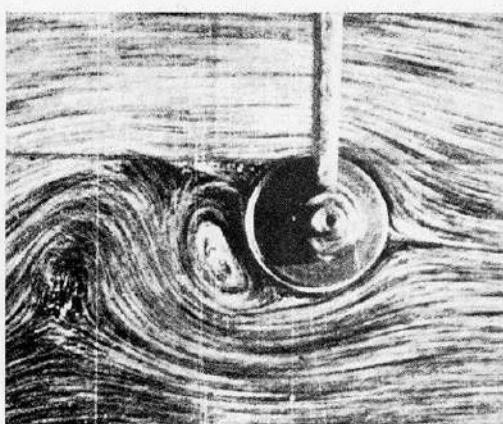




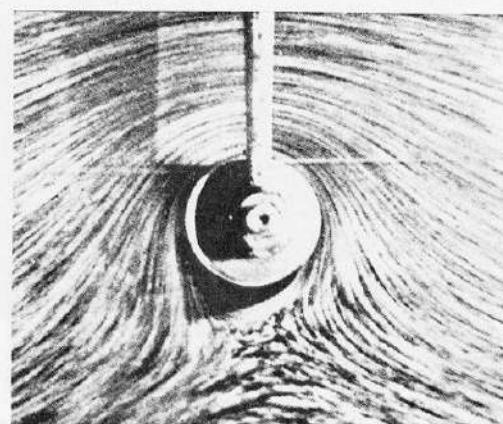
$a\Omega/U = 0$



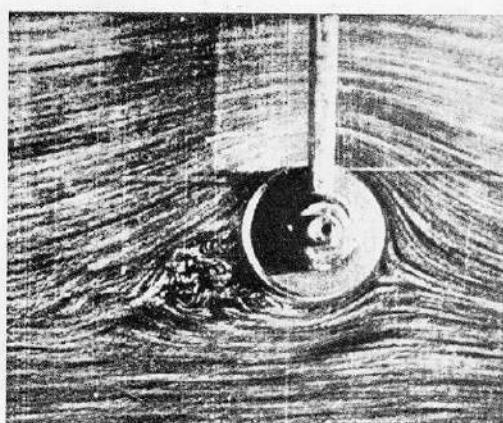
$a\Omega/U = 3$



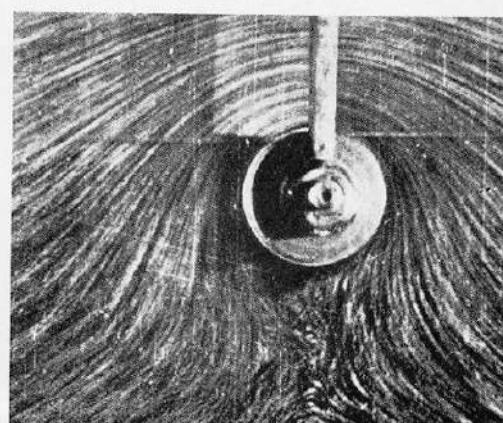
$a\Omega/U = 1$



$a\Omega/U = 4$



$a\Omega/U = 2$



$a\Omega/U = 6$

La pression sur le cylindre est donnée par l'équation de Bernoulli :

$$p + \frac{1}{2}\rho u^2(R) = p_\infty + \frac{1}{2}\rho U^2 \quad \left(\begin{array}{l} u_\theta(R) = -2U \sin \theta + \frac{\Gamma}{2\pi R} \\ u_r(R) = 0 \end{array} \right)$$

$$p = p_\infty + \frac{1}{2}\rho U^2(1 - 4 \sin^2 \theta - \gamma^2 + 4\gamma \sin \theta) \quad \text{avec} \quad \gamma = \frac{\Gamma}{2\pi R U}$$

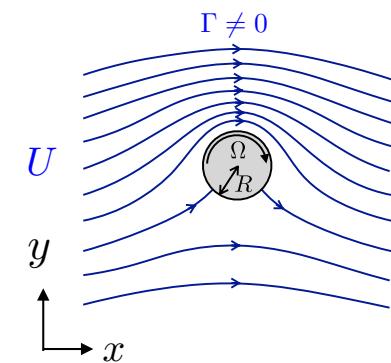
la circulation réduite

La trainée par unité de longueur de cylindre est donnée par :

$$F_t = F_x = - \int_0^{2\pi} p \cos \theta \ R d\theta$$

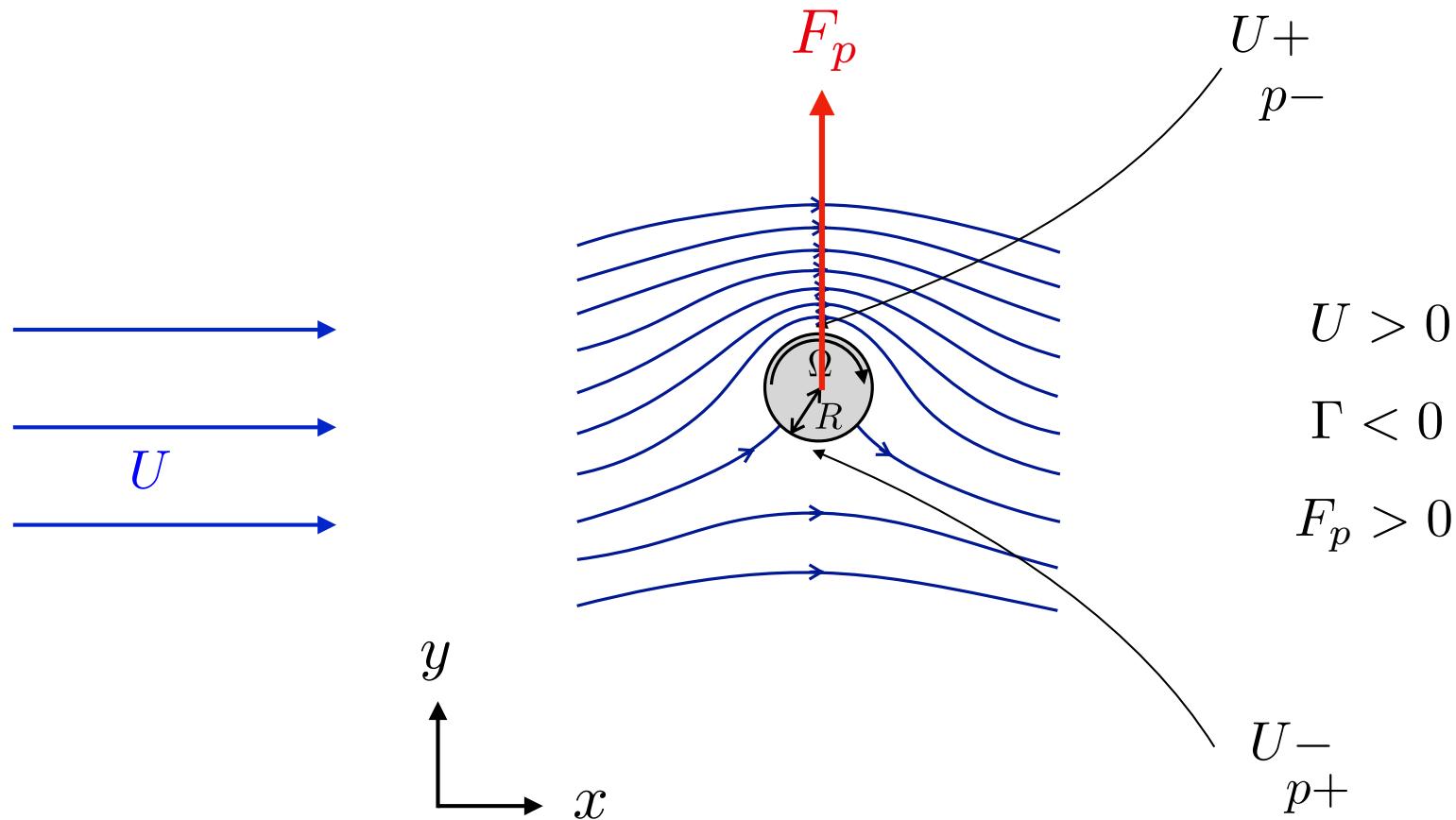
La portance par unité de longueur de cylindre est donnée par :

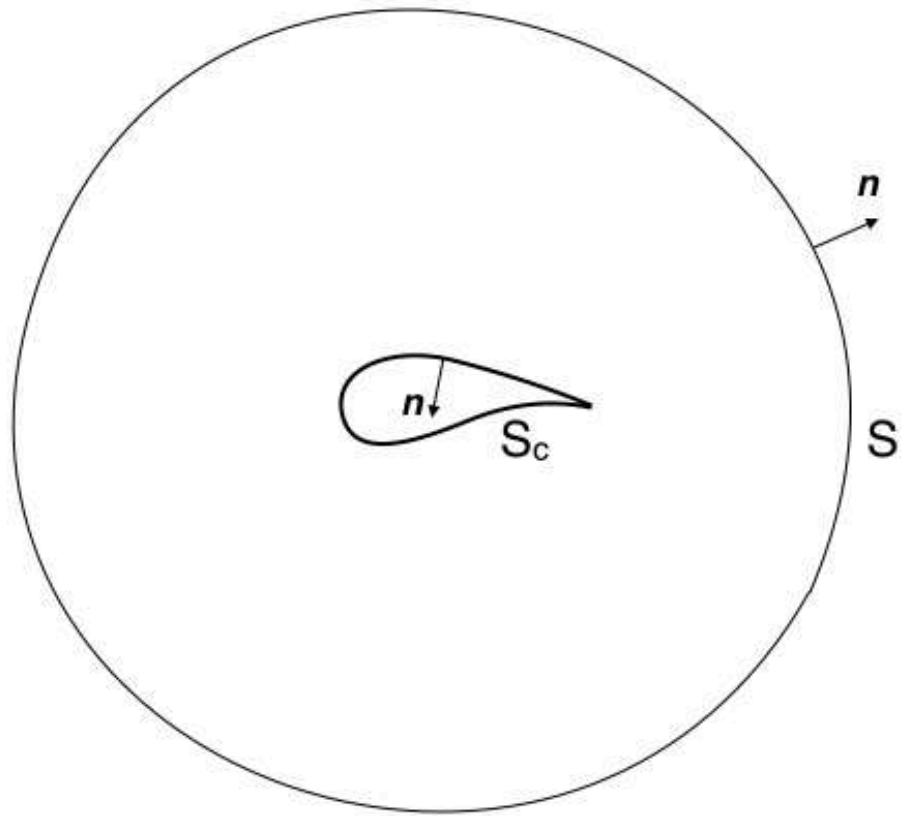
$$F_p = F_y = - \int_0^{2\pi} p \sin \theta \ R d\theta$$



$F_p = -\rho U \Gamma$ Formule générale de Joukovski qui lie la portance à la circulation

$$F_p = -\rho U \Gamma$$





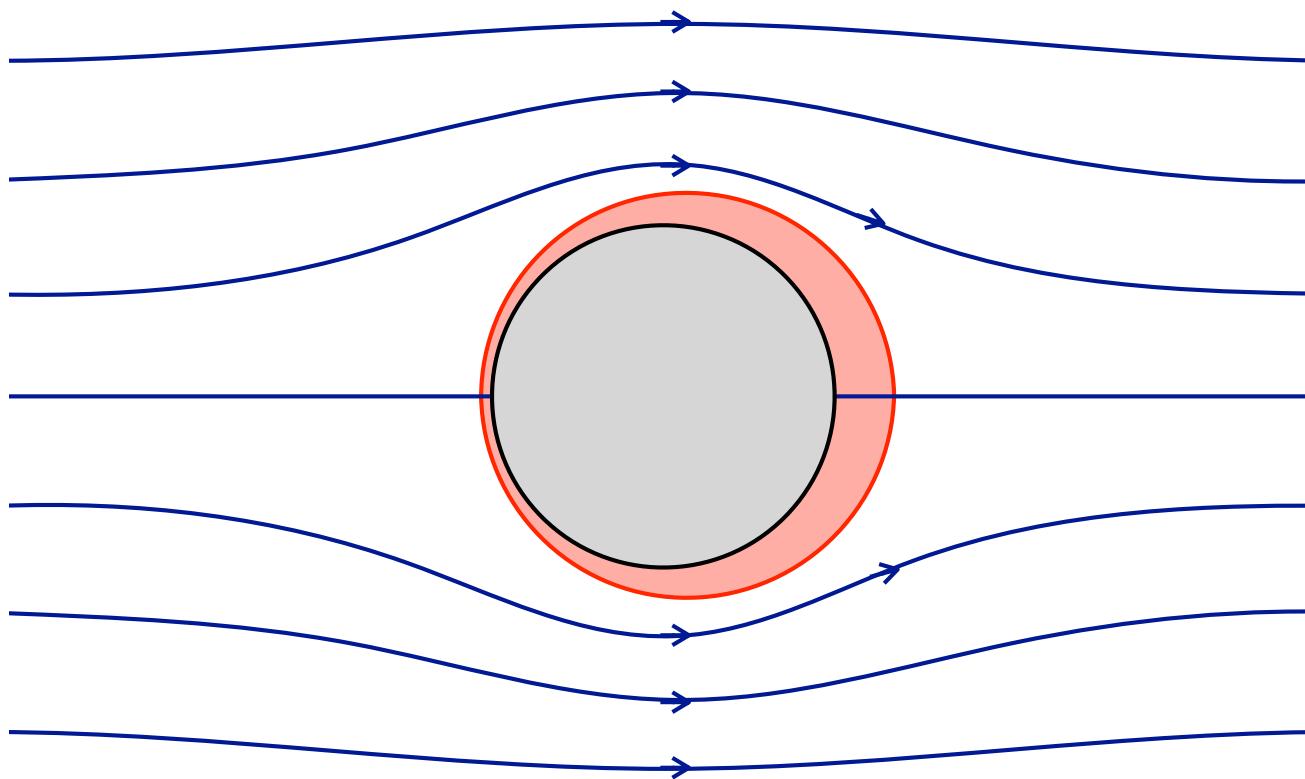
$$F = -\rho \mathbf{U} \wedge \int_S \mathbf{v} \wedge \mathbf{n} dS$$

2. Traînée de forme

2.1 Une couche limite à contre-sens

$$Re \gg 1$$

hypothèse: écoulement laminaire



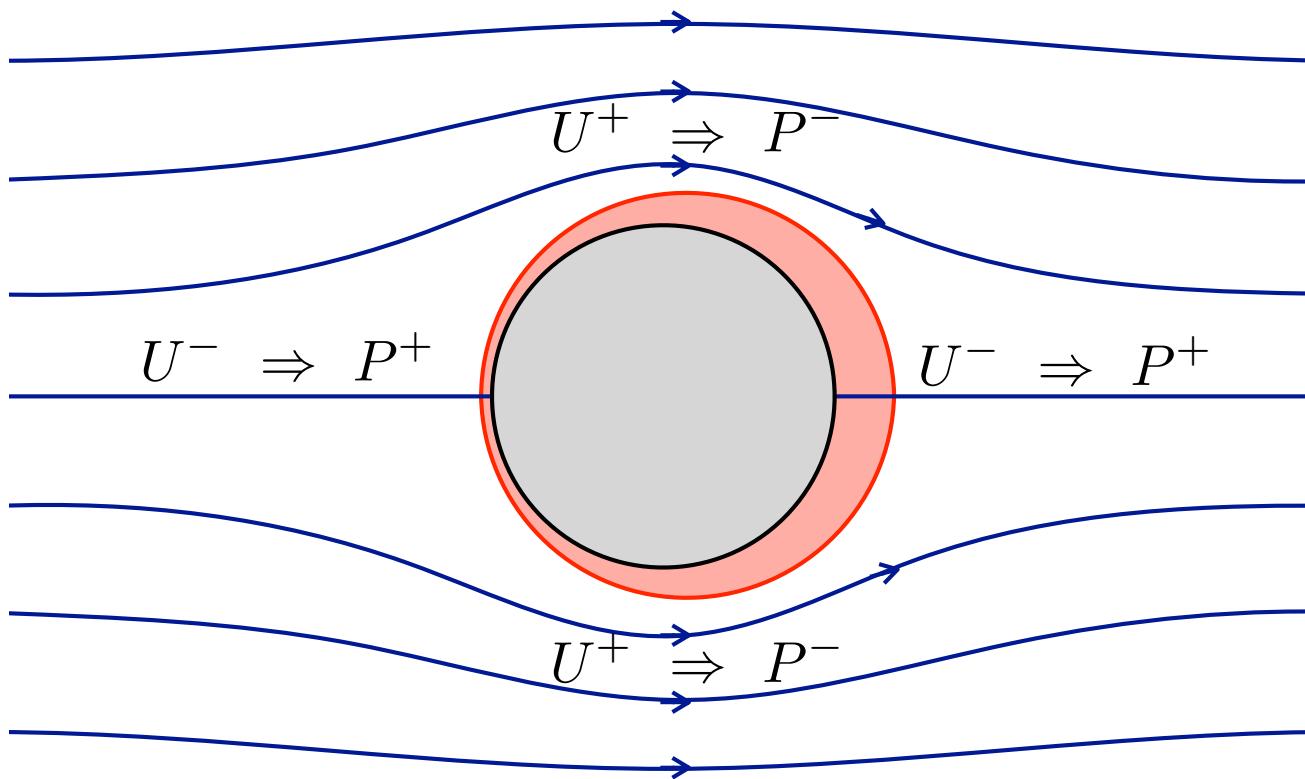
2. Traînée de forme

2.1 Une couche limite à contre-sens

$$Re \gg 1$$

hypothèse: écoulement laminaire

\Rightarrow hors couche limite: Bernoulli



2. Traînée de forme

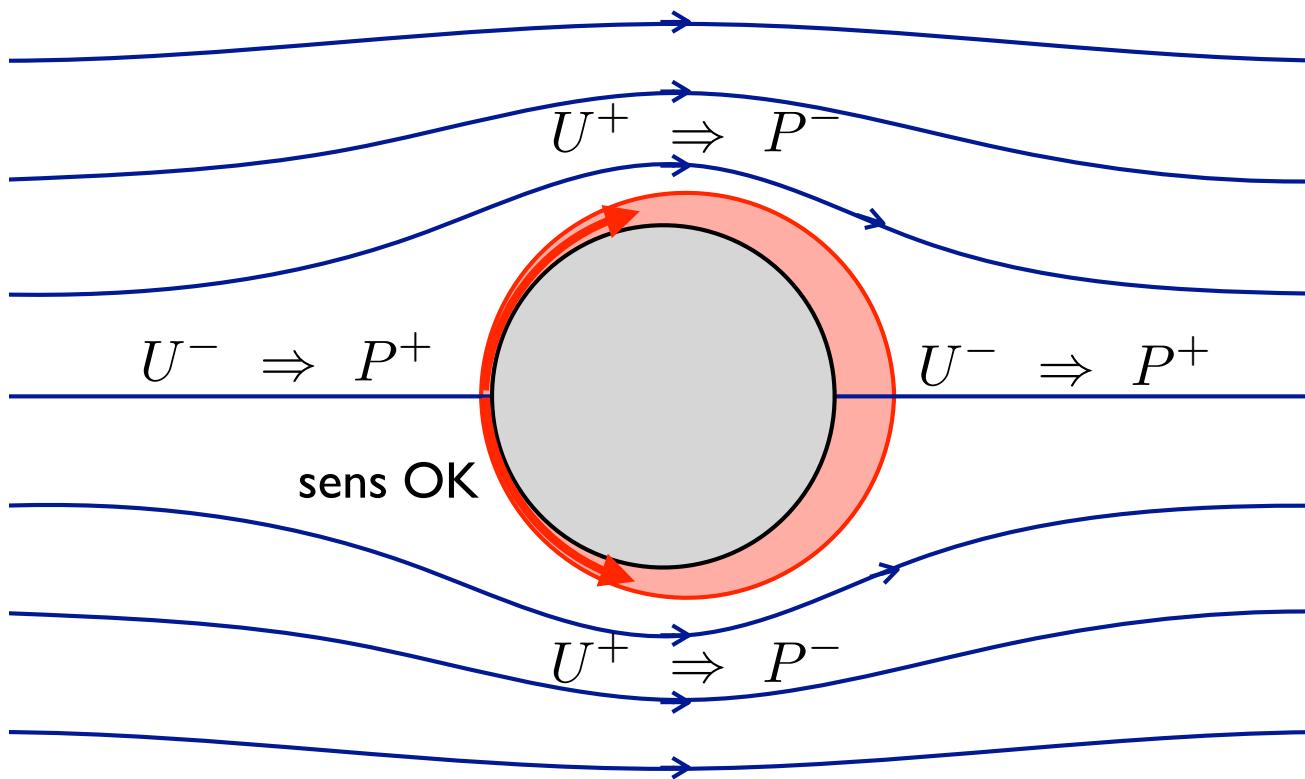
2.1 Une couche limite à contre-sens

$$Re \gg 1$$

hypothèse: écoulement laminaire

⇒ hors couche limite: Bernoulli

couche limite, écoulement visqueux: $P^+ \rightarrow P^-$



2. Traînée de forme

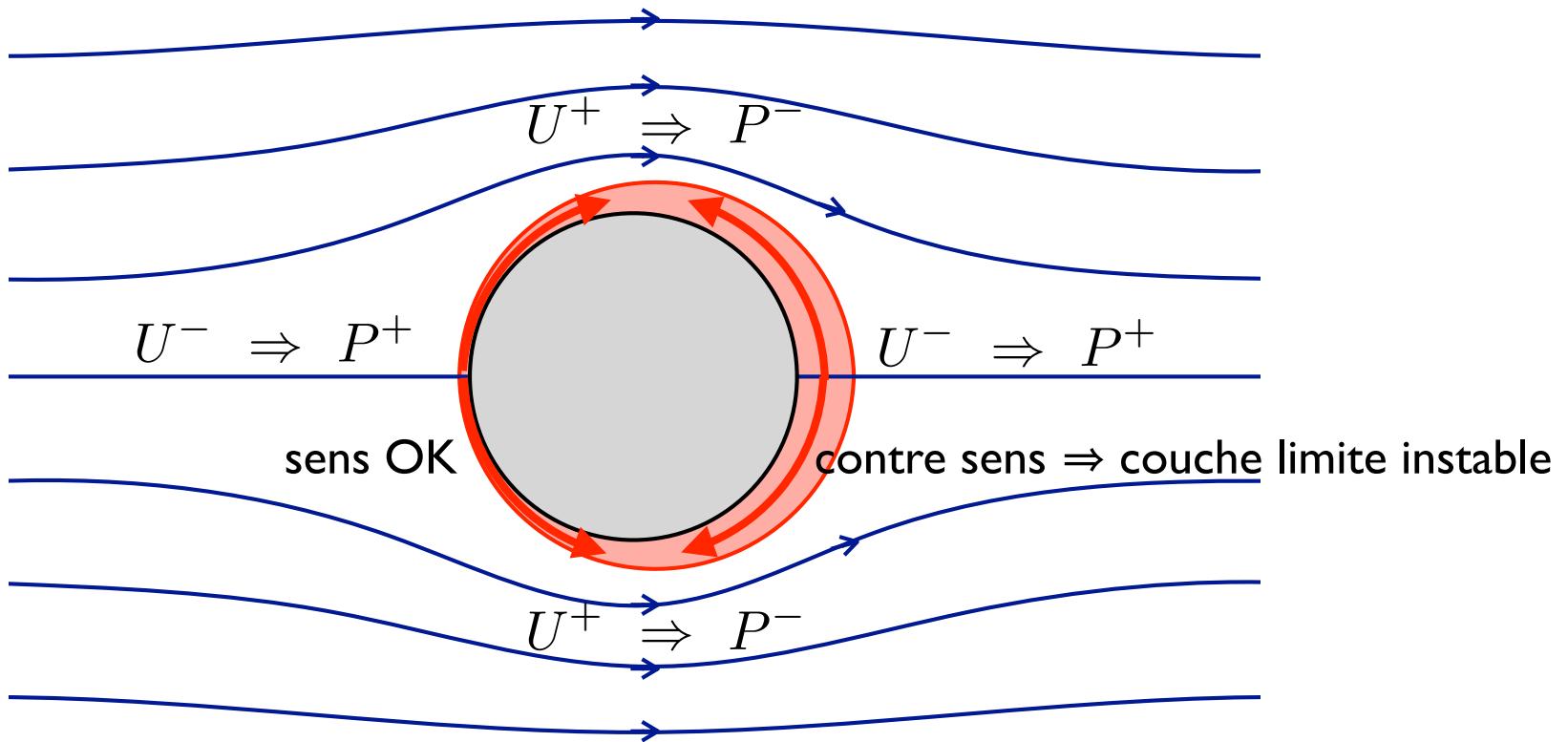
2.1 Une couche limite à contre-sens

$$Re \gg 1$$

hypothèse: écoulement laminaire

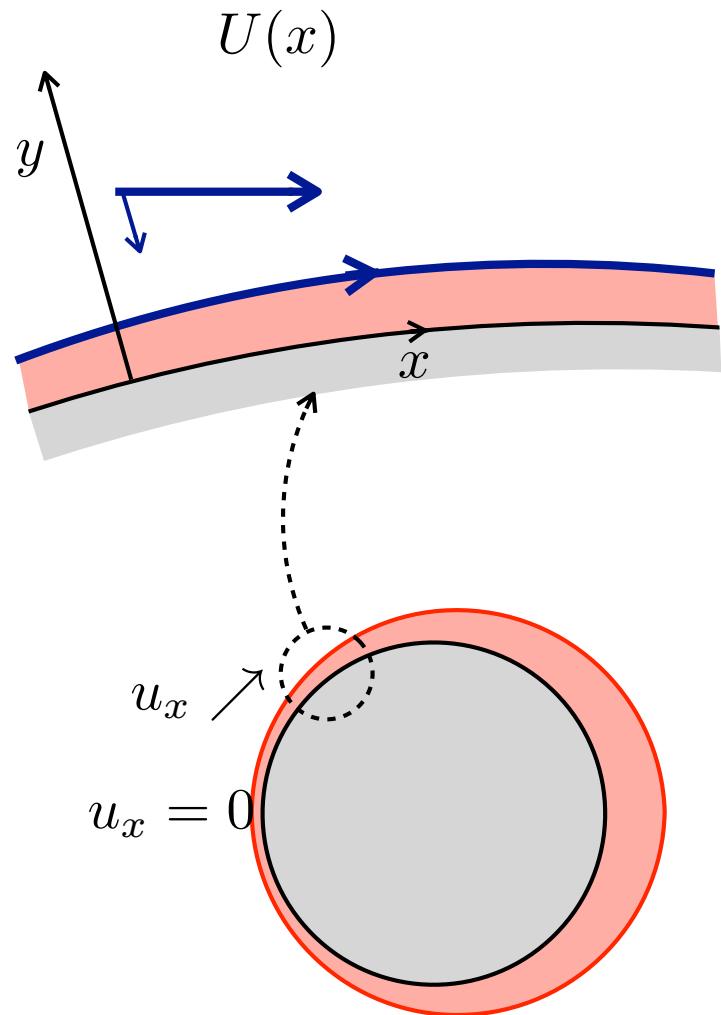
⇒ hors couche limite: Bernoulli

couche limite, écoulement visqueux: $P^+ \rightarrow P^-$



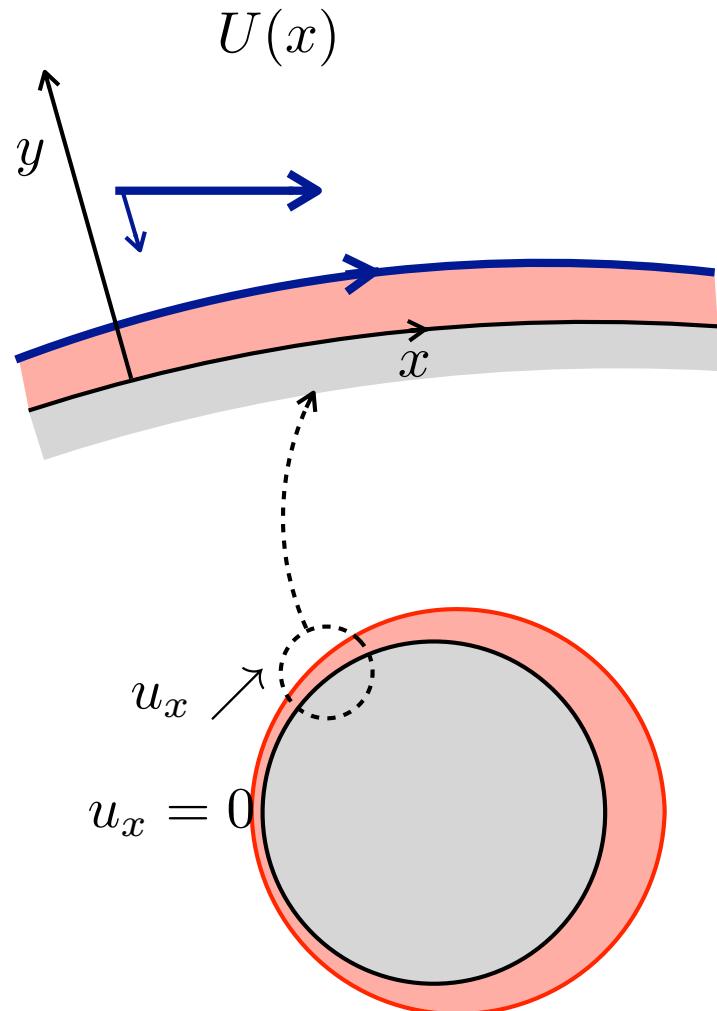
2. Traînée de forme

2.I Une couche limite à contre-sens



2. Traînée de forme

2.I Une couche limite à contre-sens



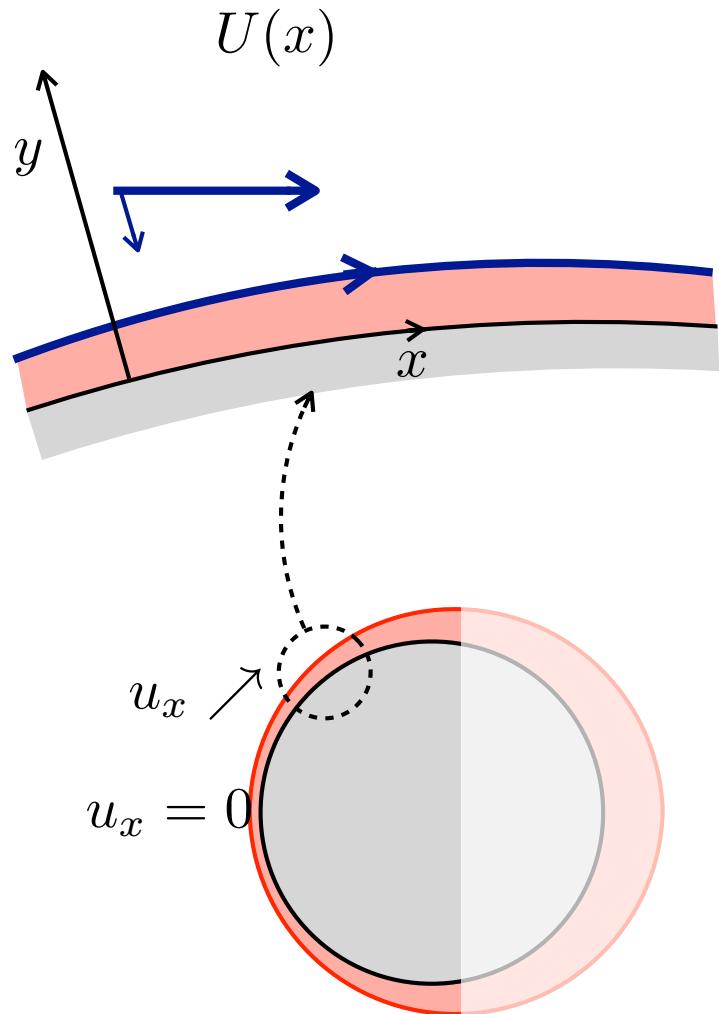
Incompressibilité

$$\nabla \cdot u = 0$$

$$\Rightarrow \partial u_y / \partial y = - \partial u_x / \partial x$$

2. Traînée de forme

2.1 Une couche limite à contre-sens



Incompressibilité

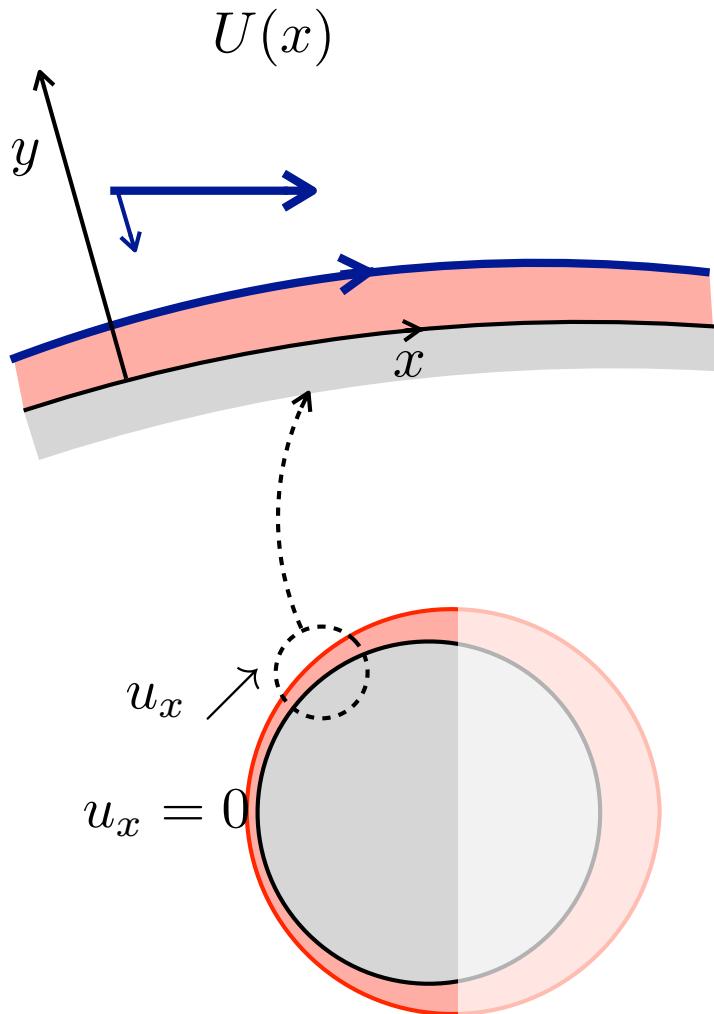
$$\nabla \cdot u = 0$$

$$\Rightarrow \partial u_y / \partial y = -\partial u_x / \partial x$$

$$u_x \nearrow \Rightarrow \partial u_x / \partial x > 0 \Rightarrow \partial u_y / \partial y < 0$$

2. Traînée de forme

2.1 Une couche limite à contre-sens



Incompressibilité

$$\nabla \cdot u = 0$$

$$\Rightarrow \partial u_y / \partial y = -\partial u_x / \partial x$$

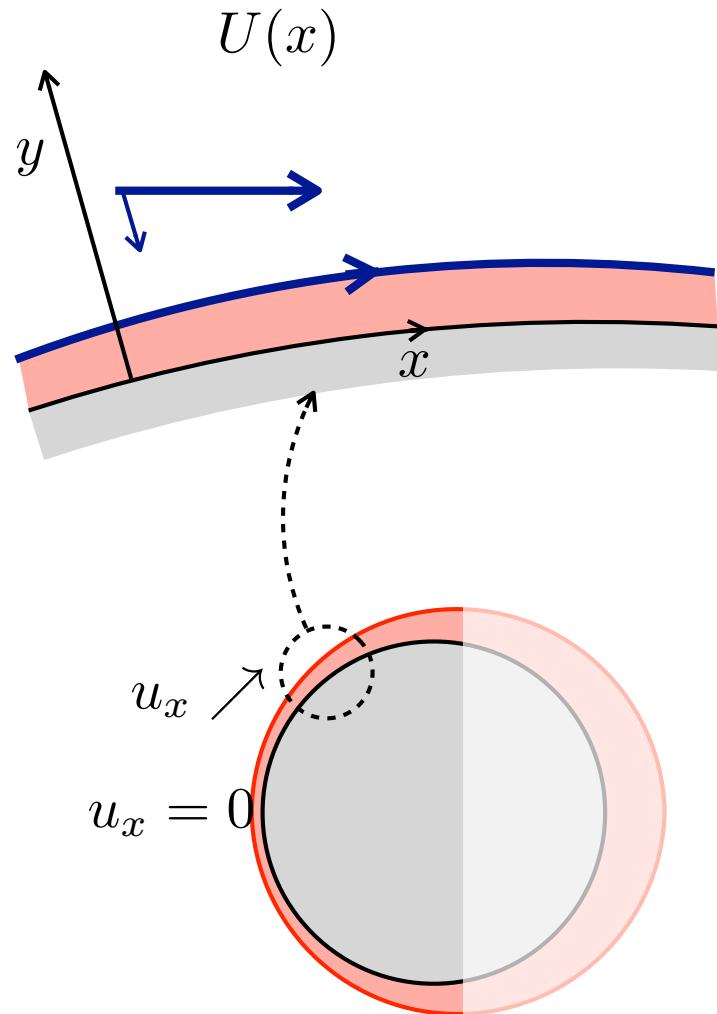
$$u_x \nearrow \Rightarrow \partial u_x / \partial x > 0 \Rightarrow \partial u_y / \partial y < 0$$

$$u_y(y = 0) = 0$$

$$u_y(y > 0) < 0$$

2. Traînée de forme

2.1 Une couche limite à contre-sens



Incompressibilité

$$\nabla \cdot u = 0$$

$$\Rightarrow \partial u_y / \partial y = -\partial u_x / \partial x$$

$$u_x \nearrow \Rightarrow \partial u_x / \partial x > 0 \Rightarrow \partial u_y / \partial y < 0$$

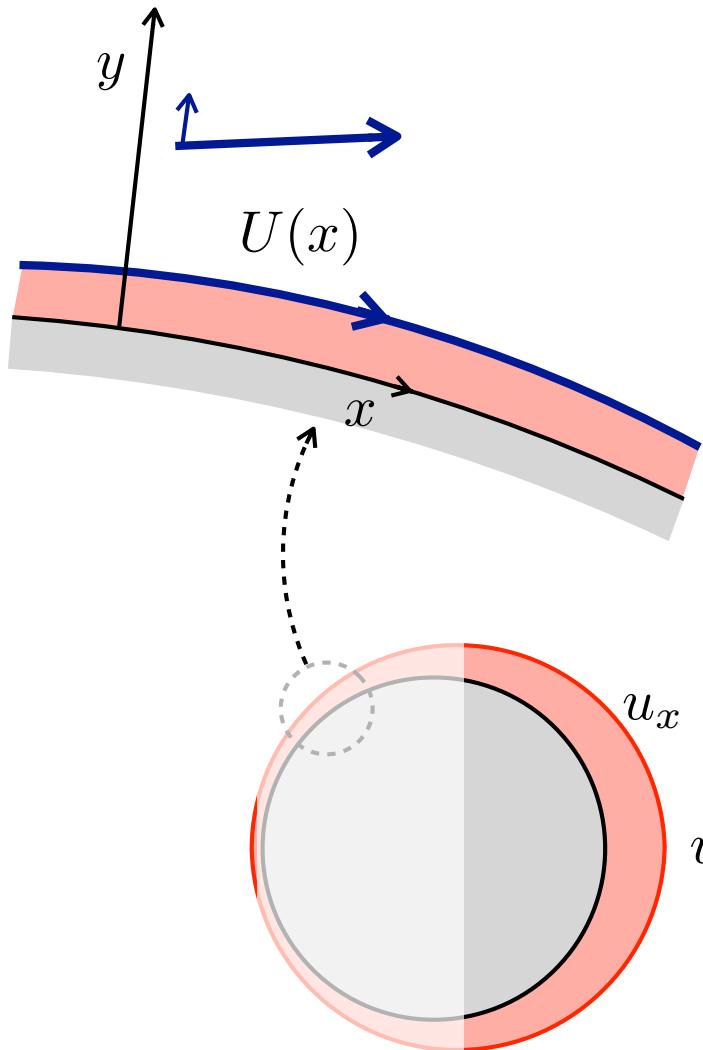
$$u_y(y = 0) = 0$$

$$u_y(y > 0) < 0$$

⇒ couche limite plaquée vers la paroi

2. Traînée de forme

2.1 Une couche limite à contre-sens



Incompressibilité

$$\nabla \cdot u = 0$$

$$\Rightarrow \partial u_y / \partial y = -\partial u_x / \partial x$$

$$u_x \searrow \Rightarrow \partial u_x / \partial x < 0 \Rightarrow \partial u_y / \partial y > 0$$

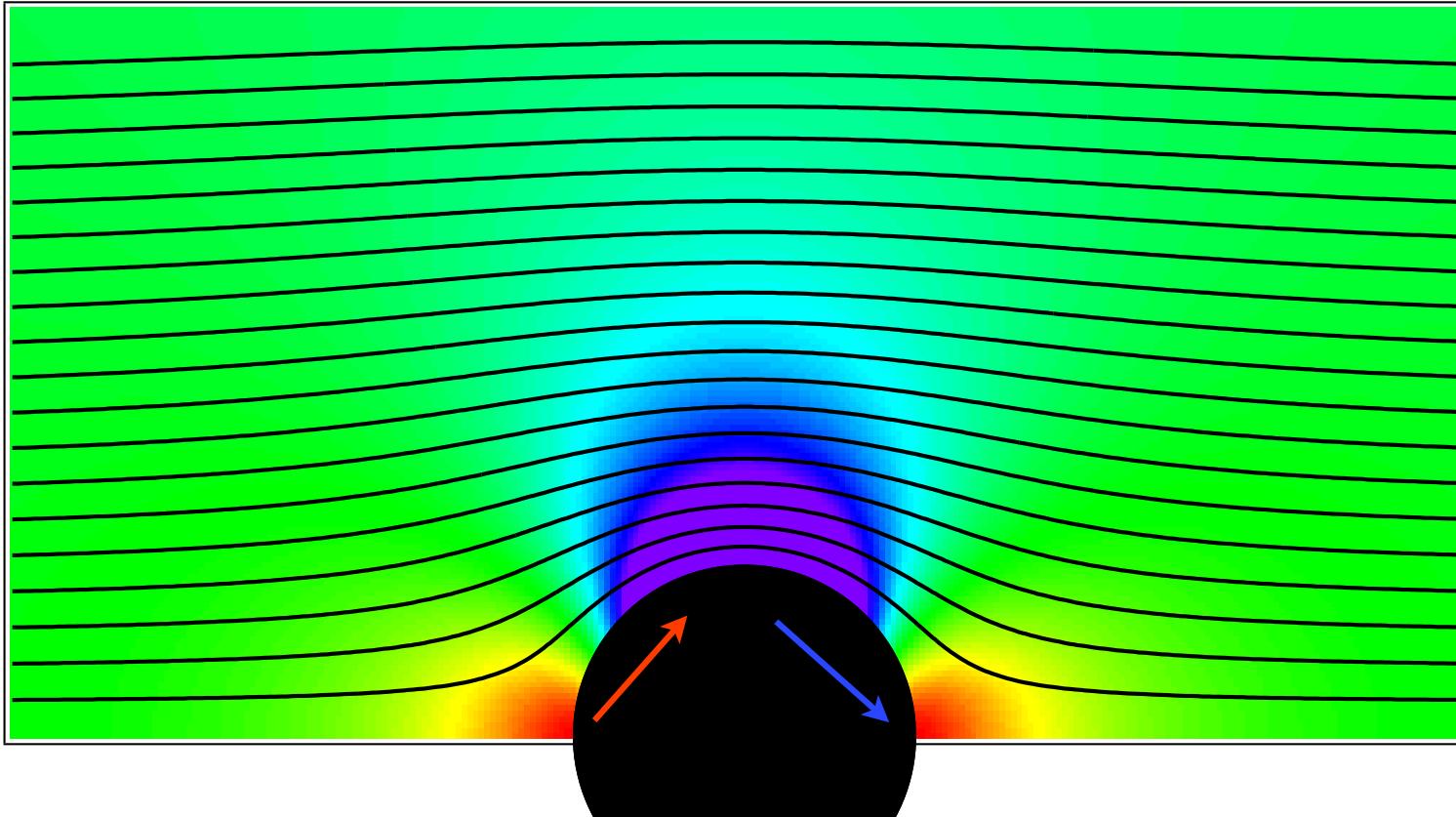
$$u_y(y = 0) = 0$$

$$u_x = 0 \qquad u_y(y > 0) > 0$$

\Rightarrow couche limite tend à s'épaissir

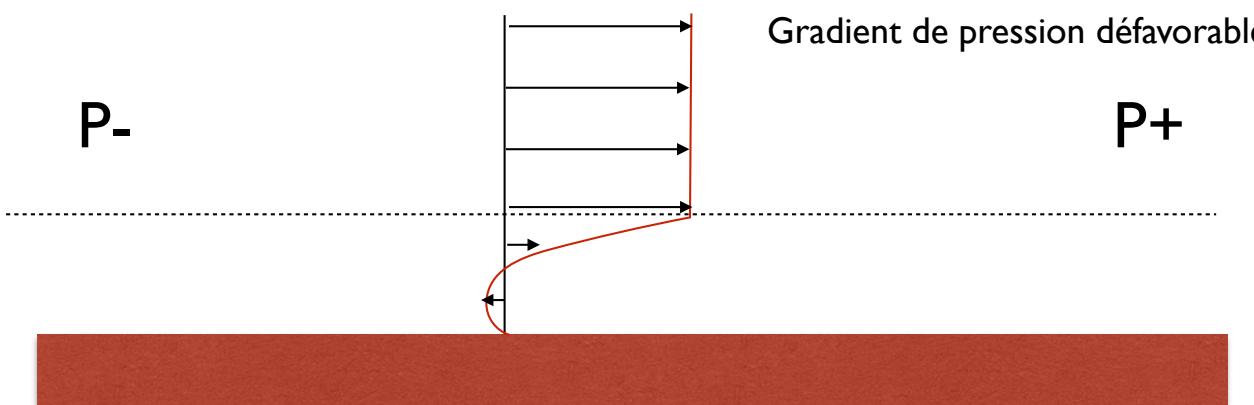
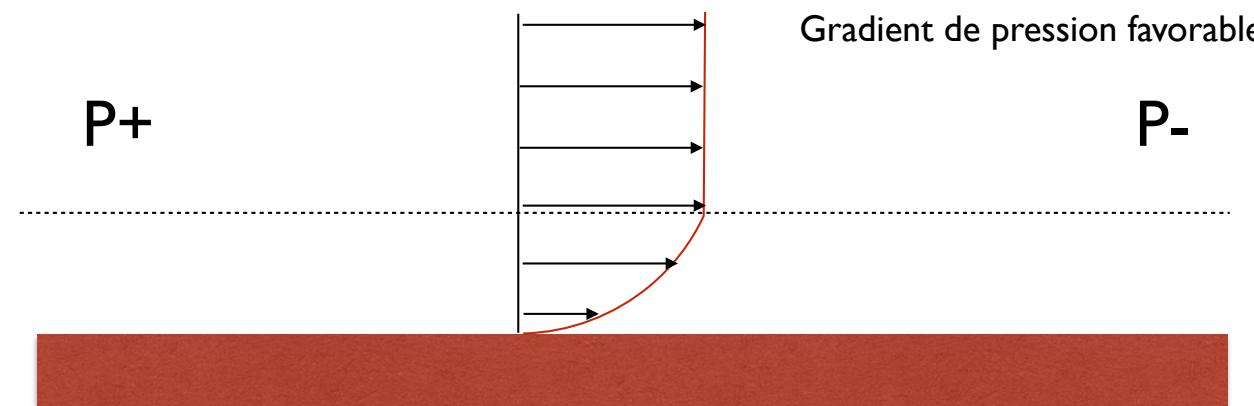
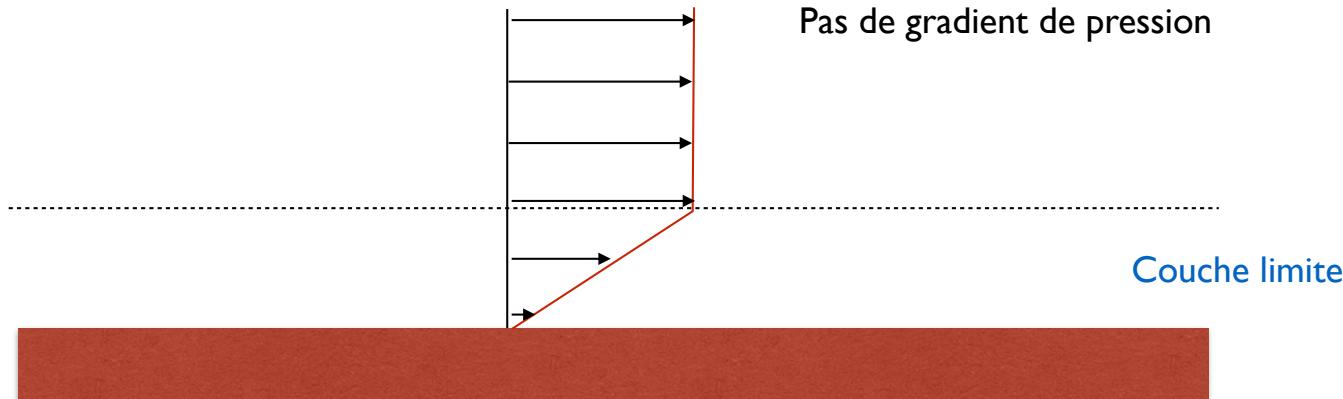
Ecoulement potentiel autour d'un cylindre

Lignes de courant et champ de pression

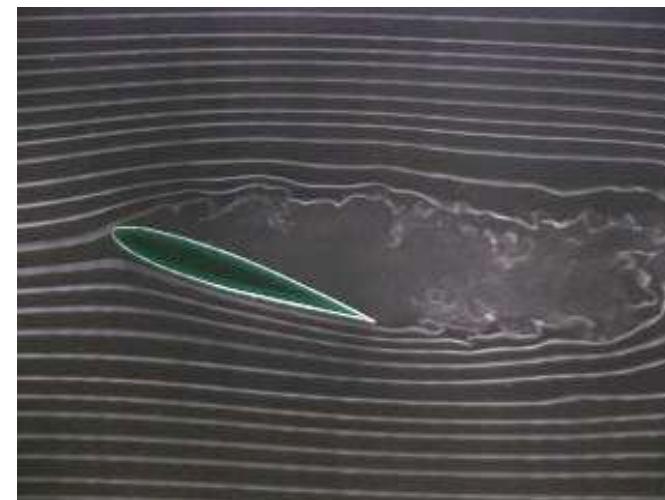
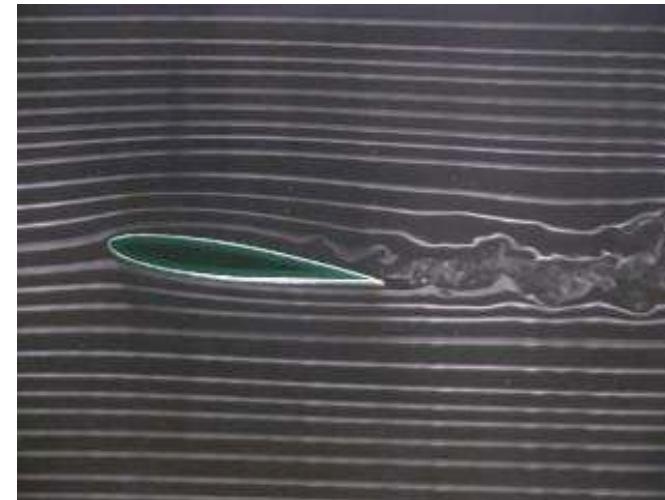
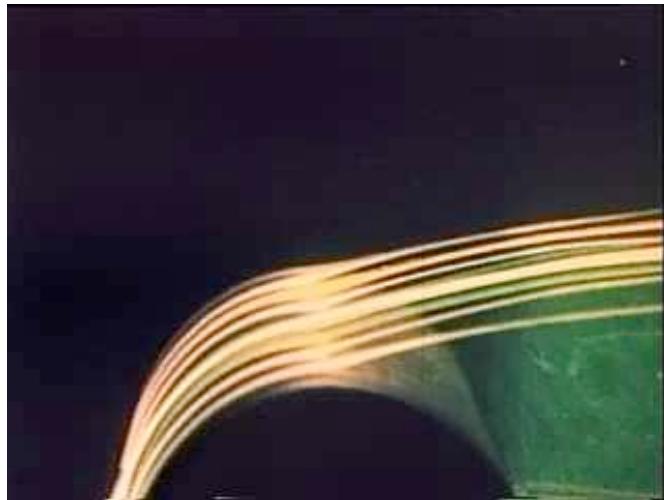


Grad. p
favorable

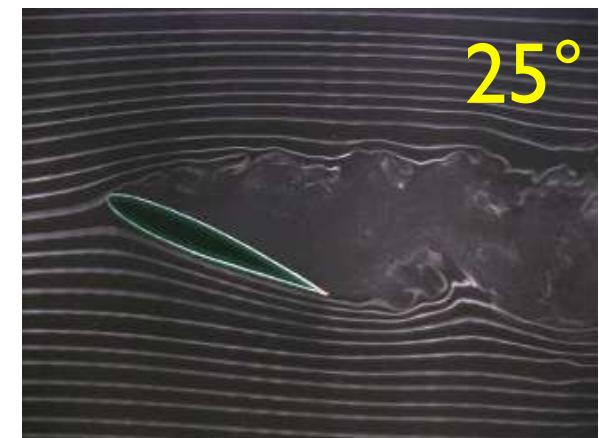
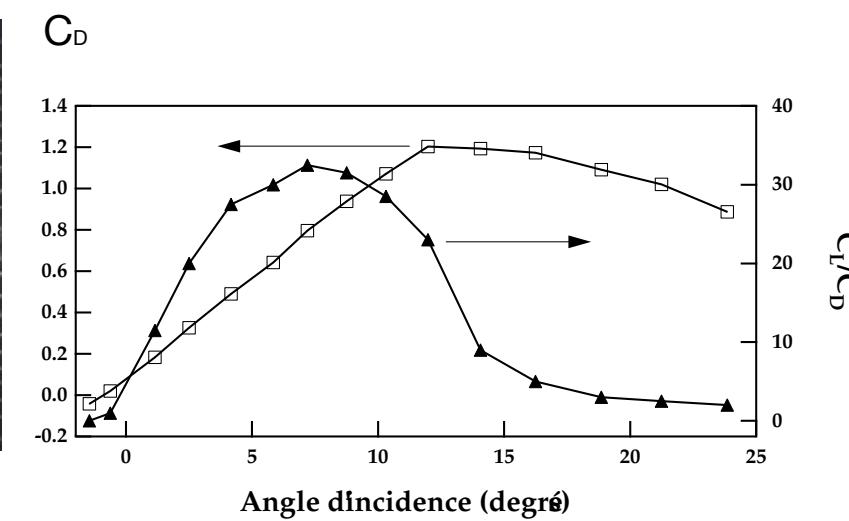
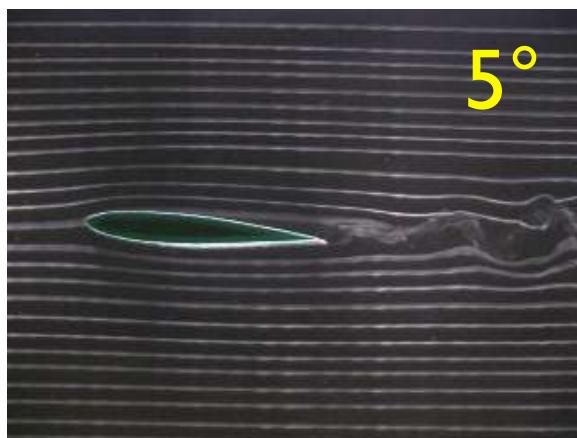
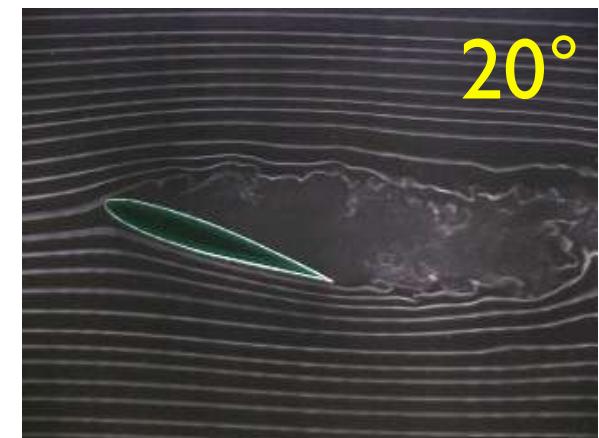
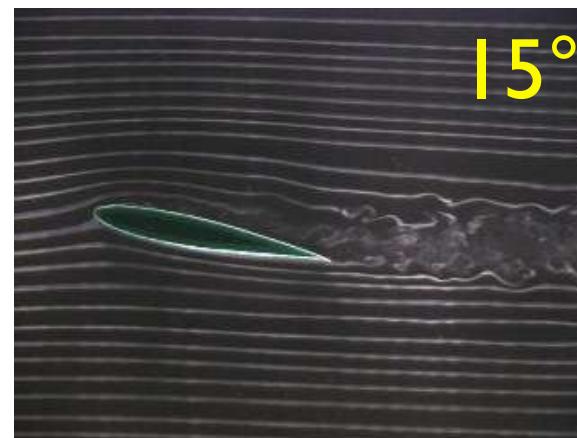
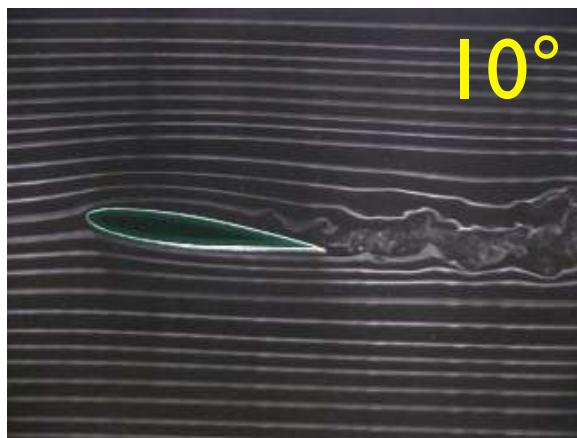
Grad. p
désfavorable



Décollement des couches limites et traînée de forme

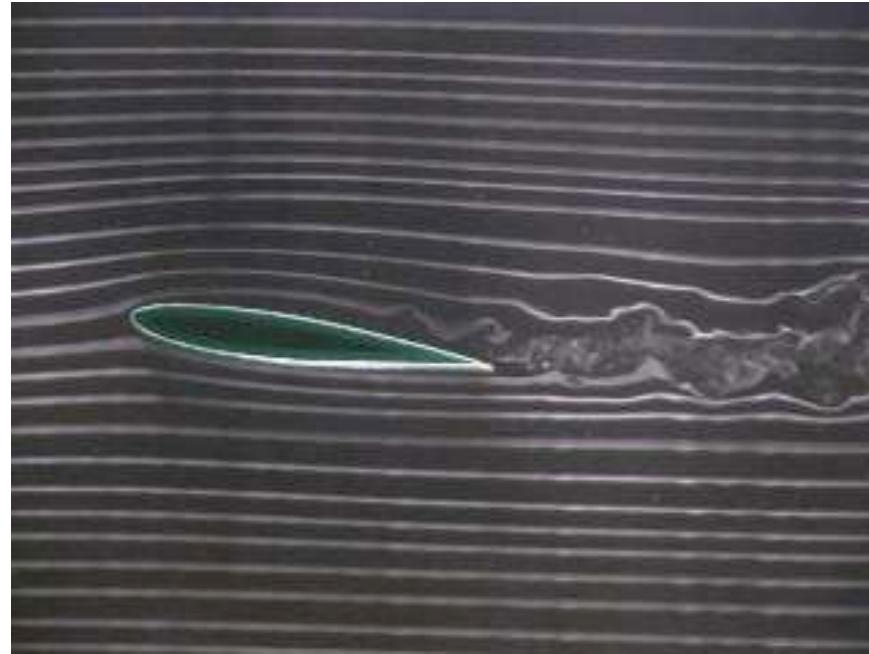


Décollement et portance

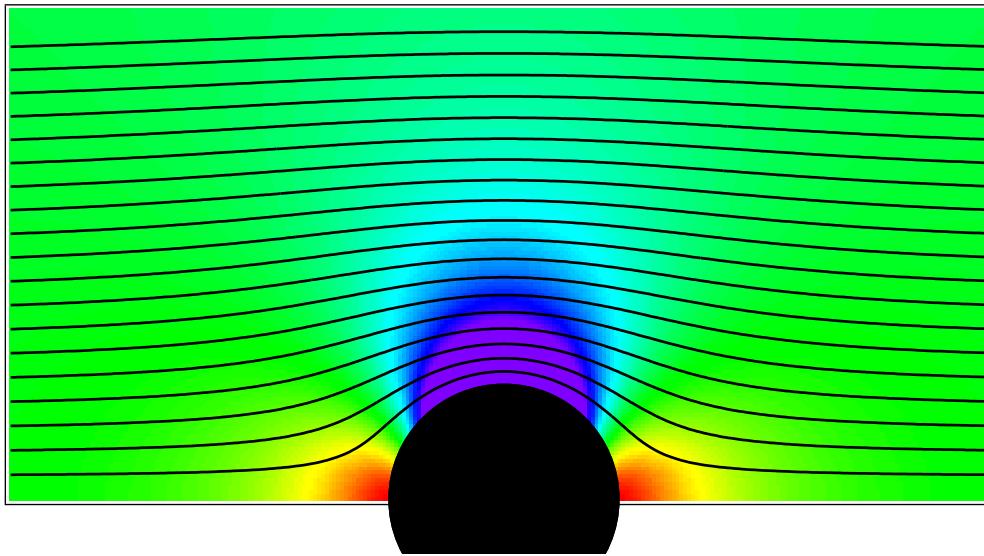




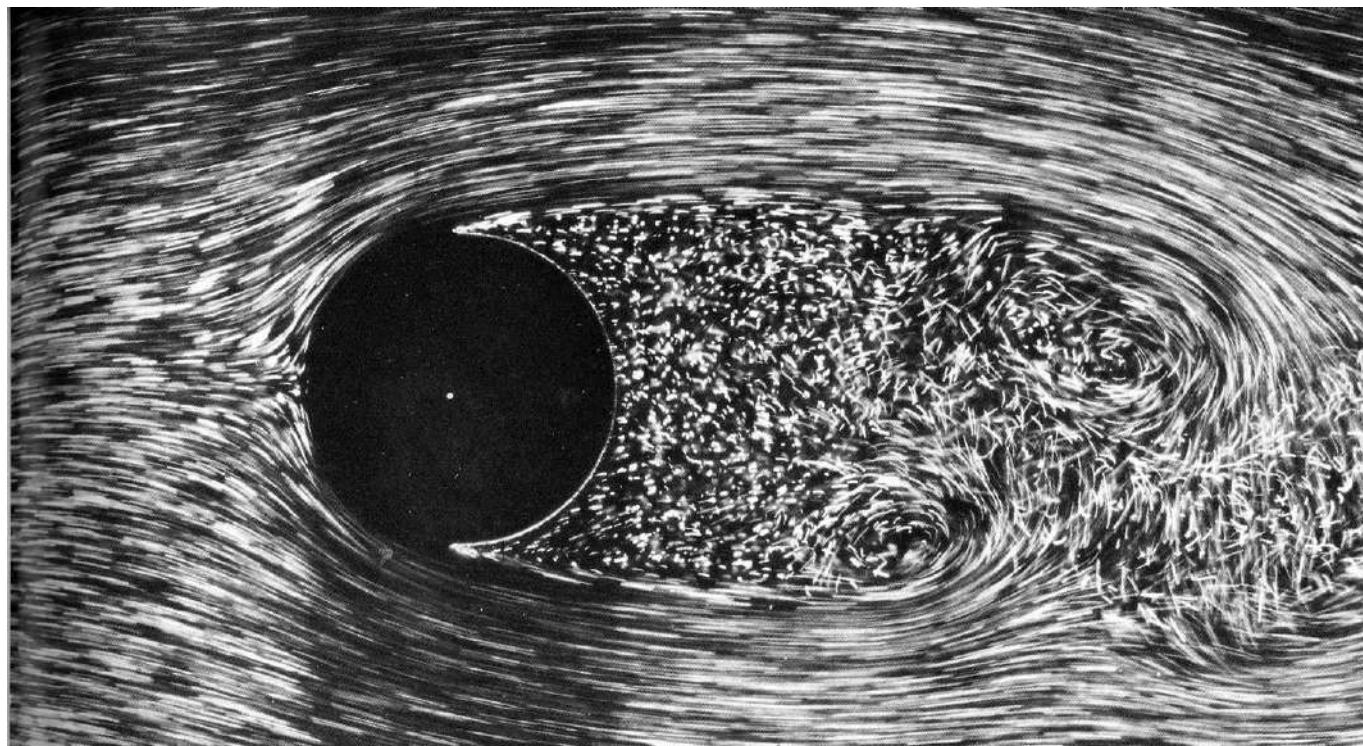
Incidence nulle



10° d'incidence



Ecoulement potentiel



Ecoulement réel

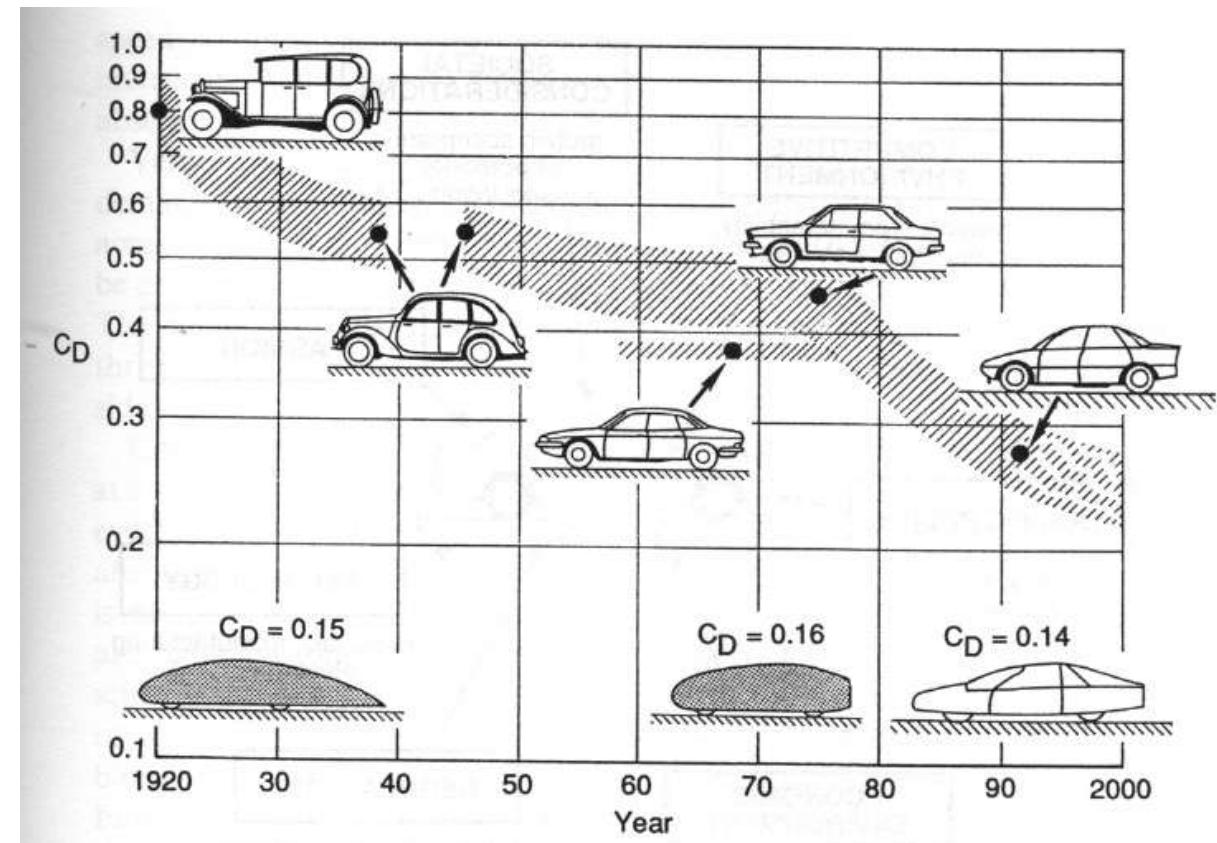
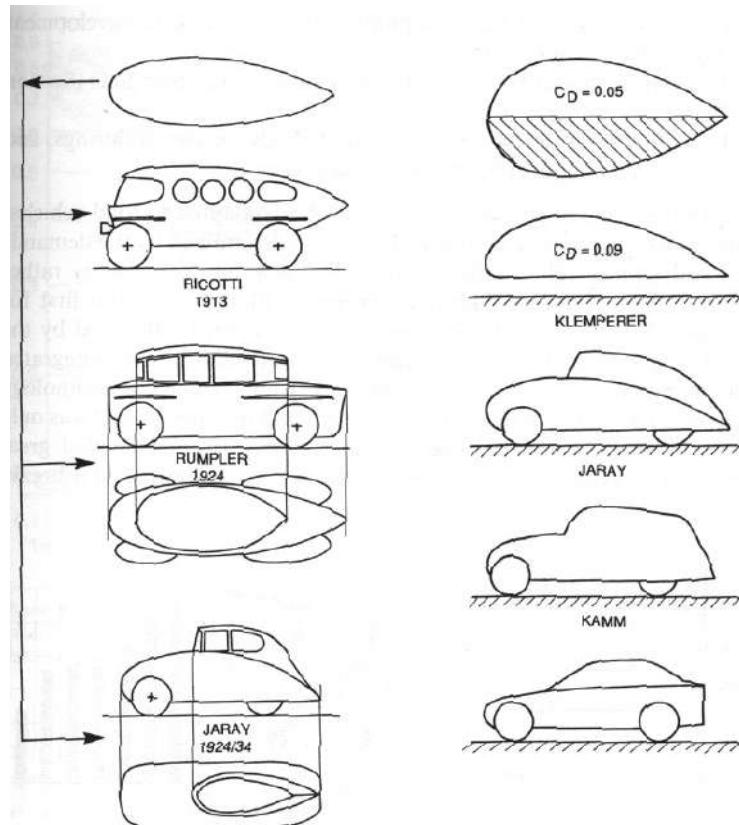
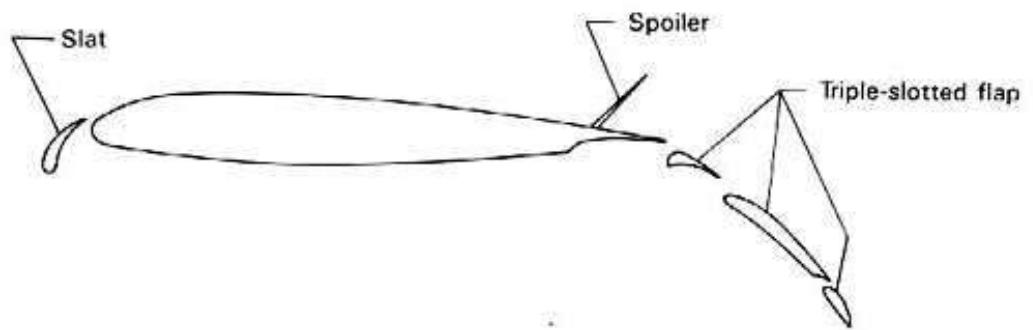
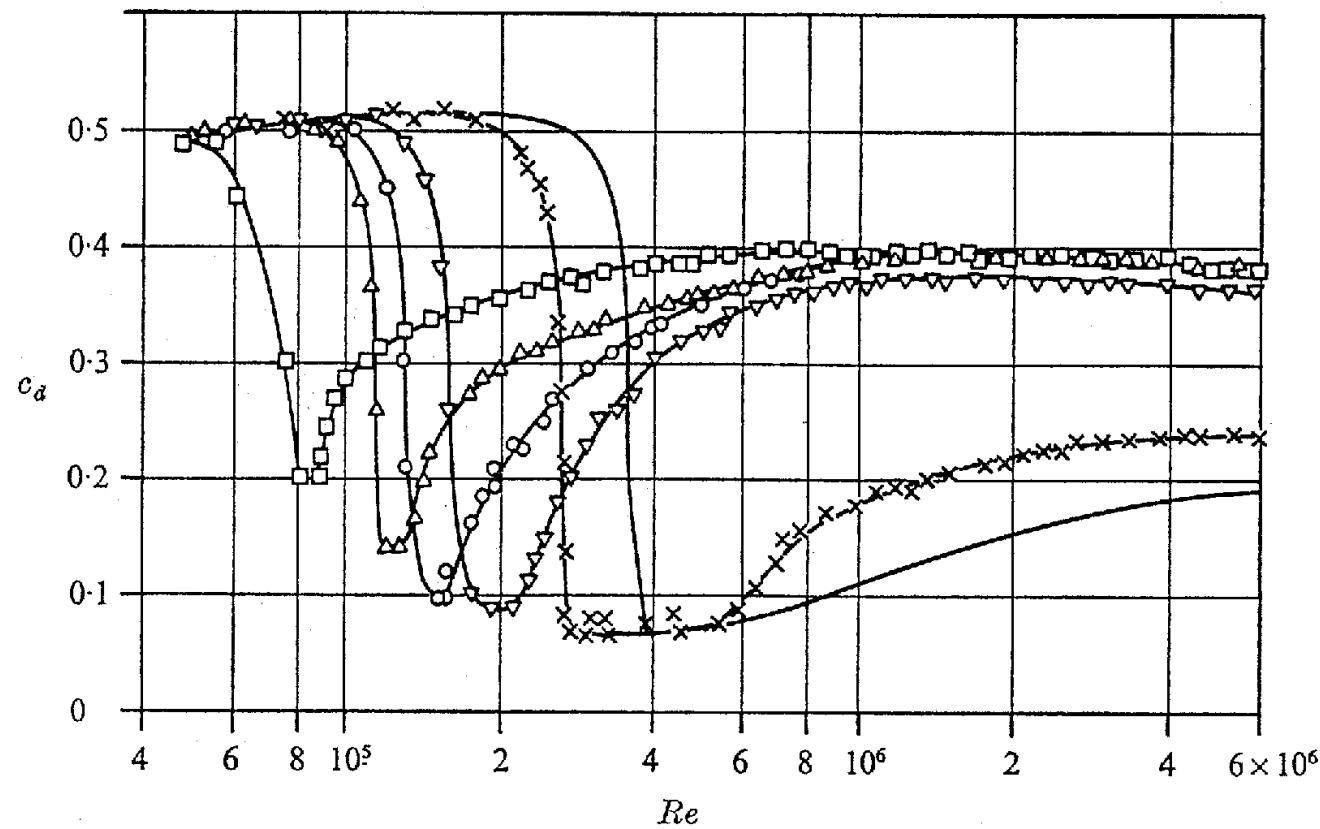


Figure 6 The drag history of cars. Using a logarithmic scale for drag emphasizes how difficult it is to achieve very low drag values. Research has been far ahead of what has been realized in production.

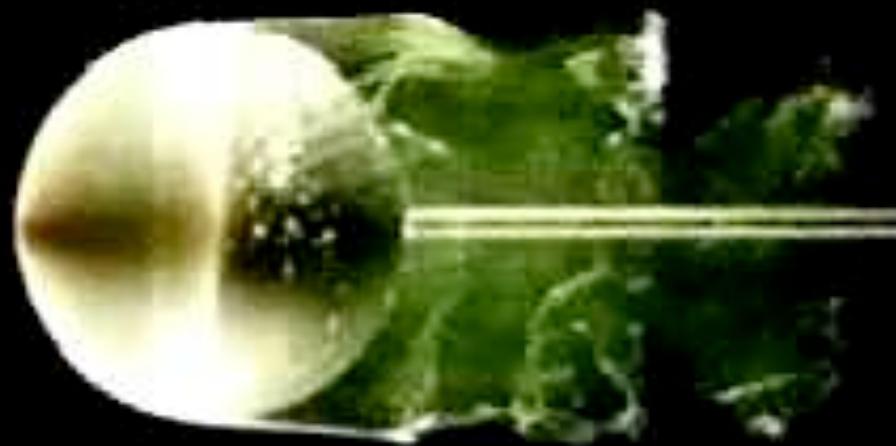


Contrôle du décollement



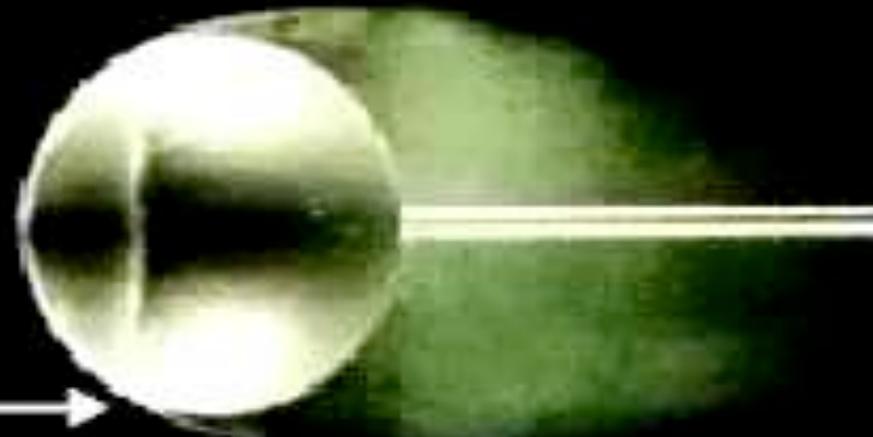


Laminar



Turbulent

Trip Wire →



I have not the smallest molecule of faith in aerial navigation other than ballooning or of expectation of good results from any of the trials we hear of.

Lord Kelvin

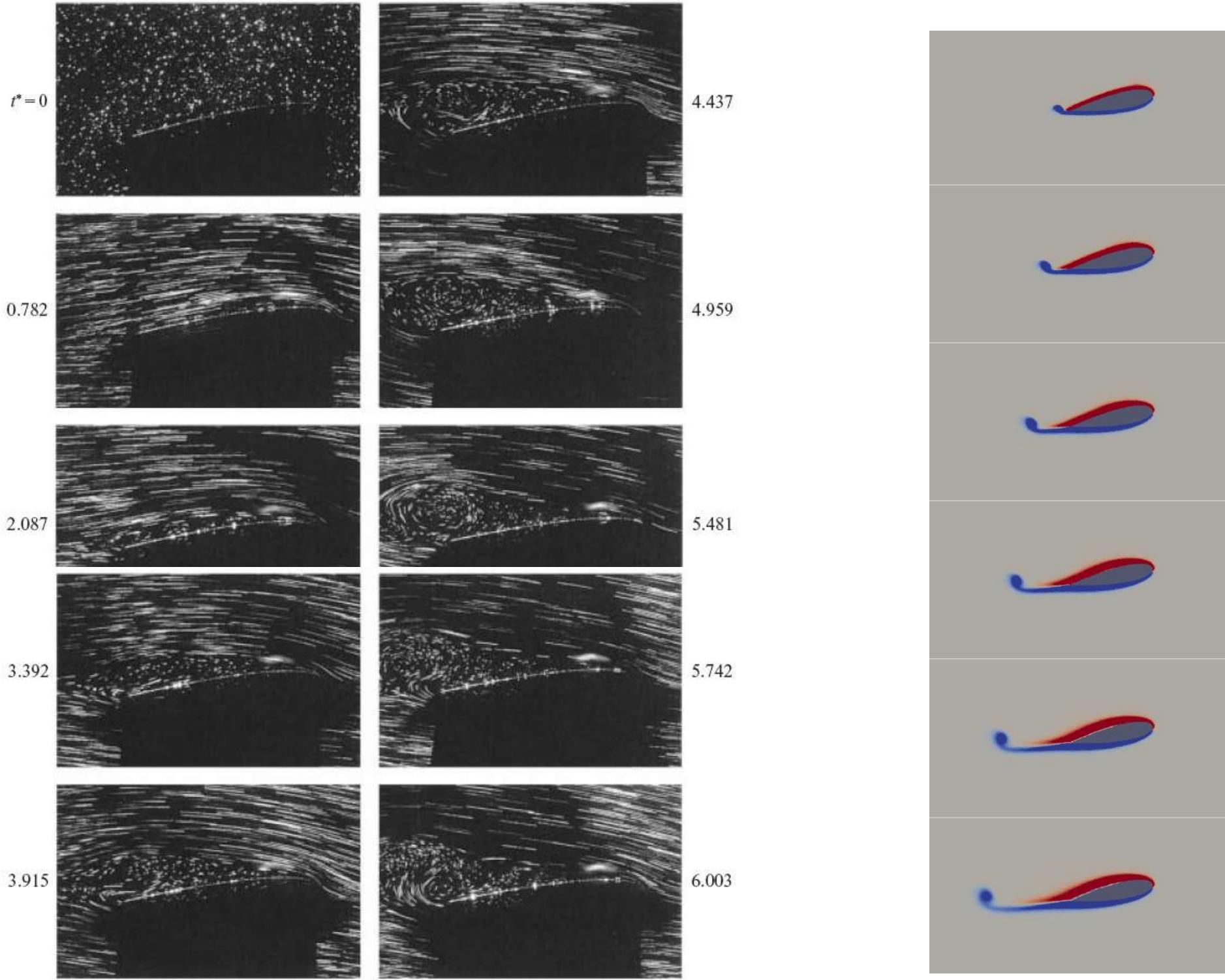


FIG. 5. Streak pictures at $Re_c = 1200$, $\alpha = 7^\circ$, trailing-edge vortex mode, exposure time: 0.5 s.

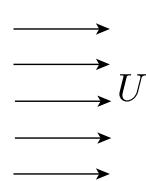
incidences modérées

$$\Gamma = \frac{1}{2} C_p U \ell$$

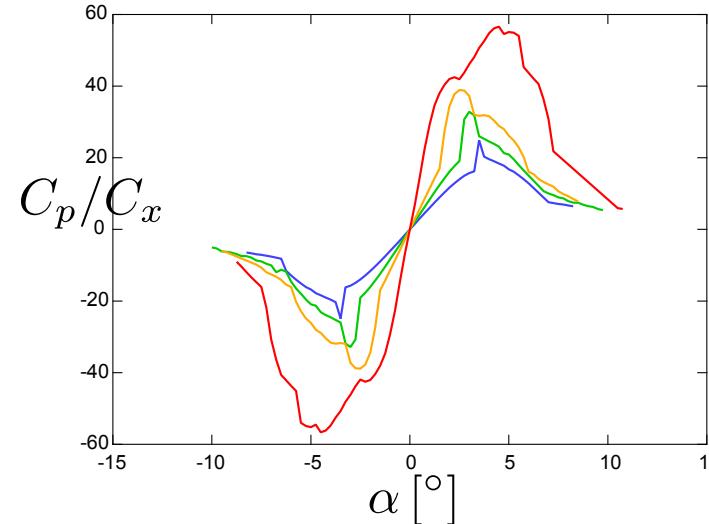
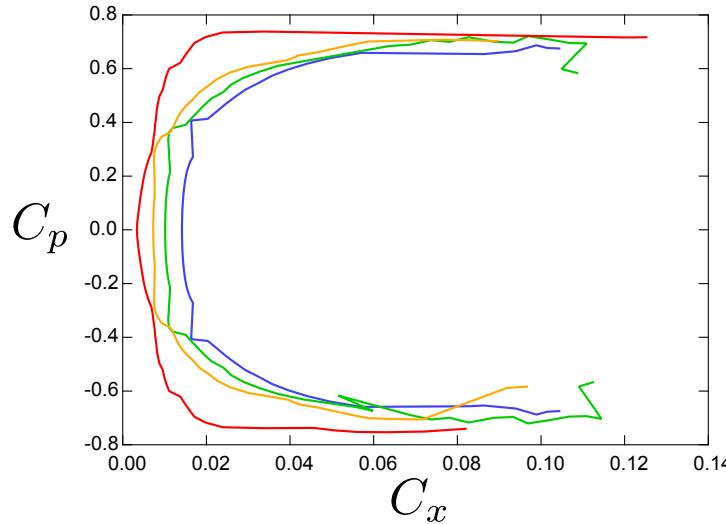
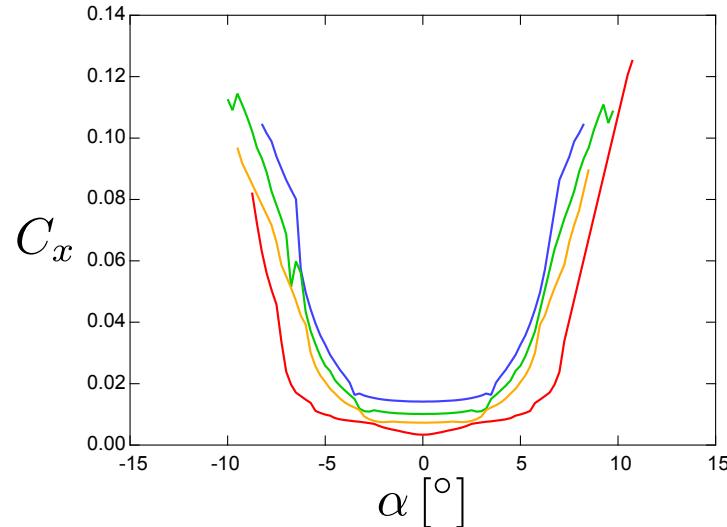
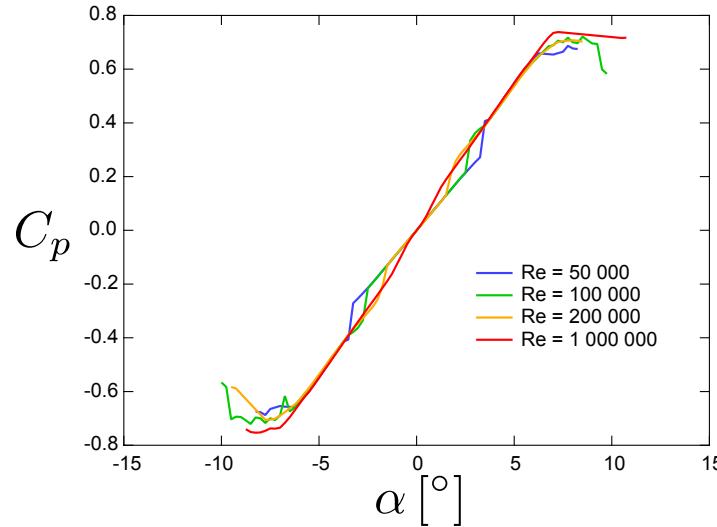
$$F_p = \boxed{C_p} \frac{1}{2} \rho U^2 \ell L$$

$$T = \boxed{C_x} \frac{1}{2} \rho U^2 \ell L$$

Polaires



Profil NACA 6, <http://airfoiltools.com>



Planeur

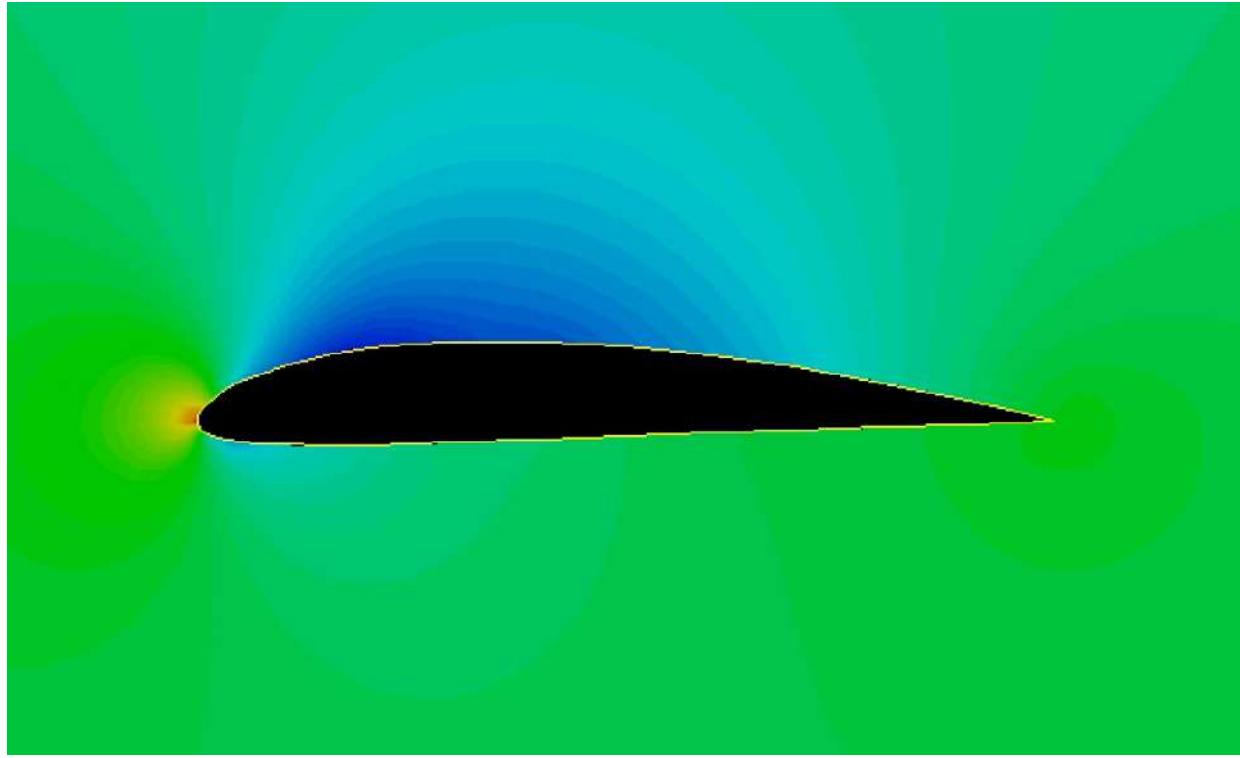


wired.com

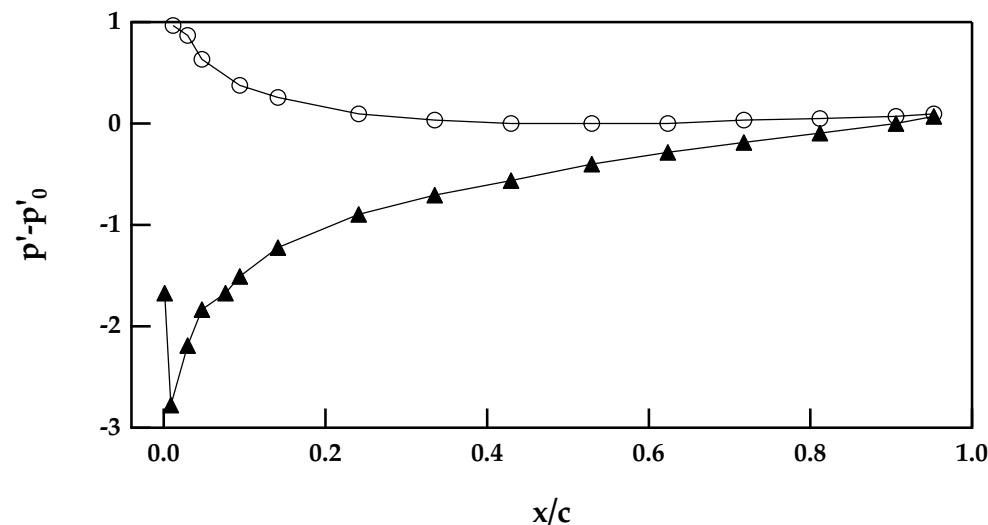
angle de chute le plus favorable ?

Comment faire voler une planche à voile



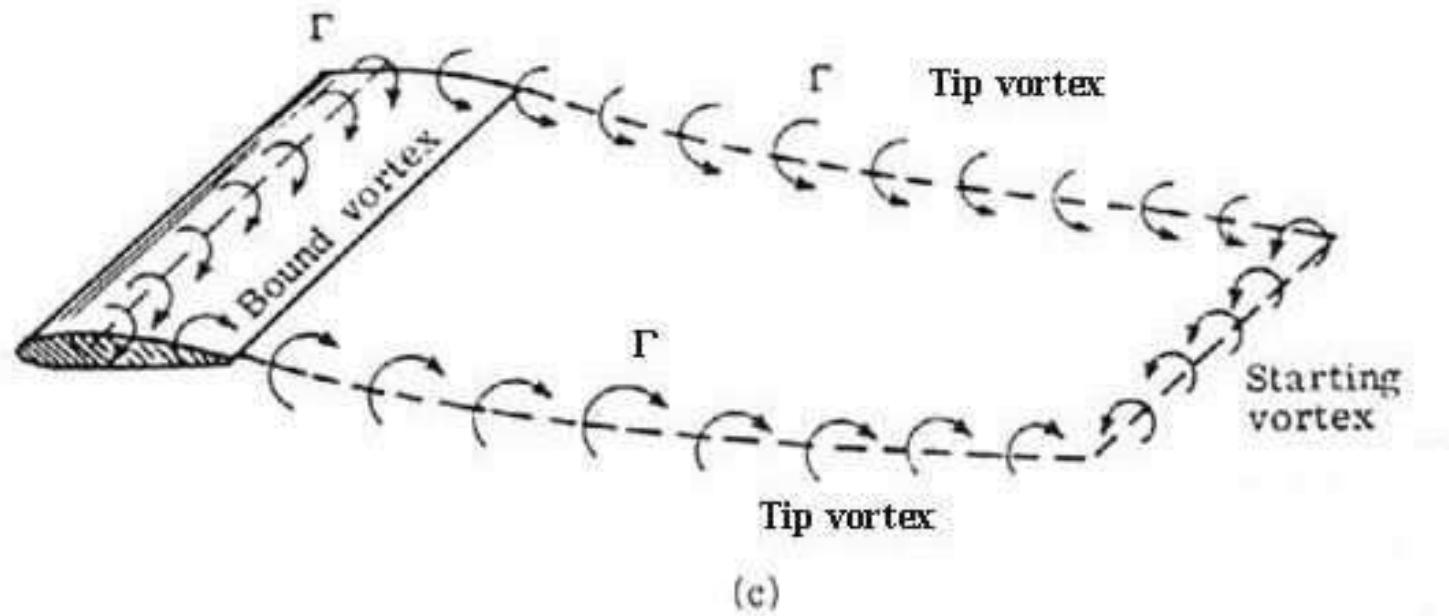


Champ de pression autour d'un profil d'aile

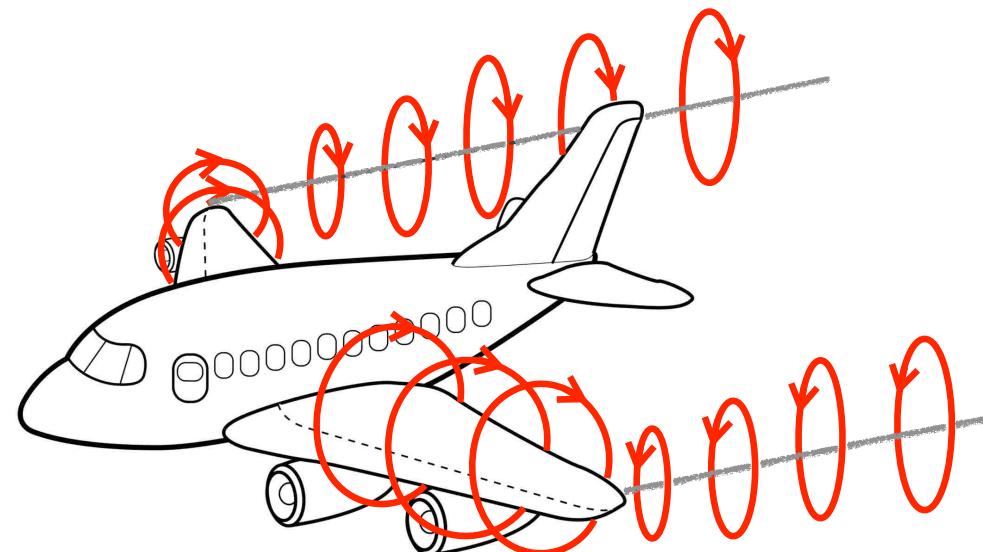


Tourbillons marginaux

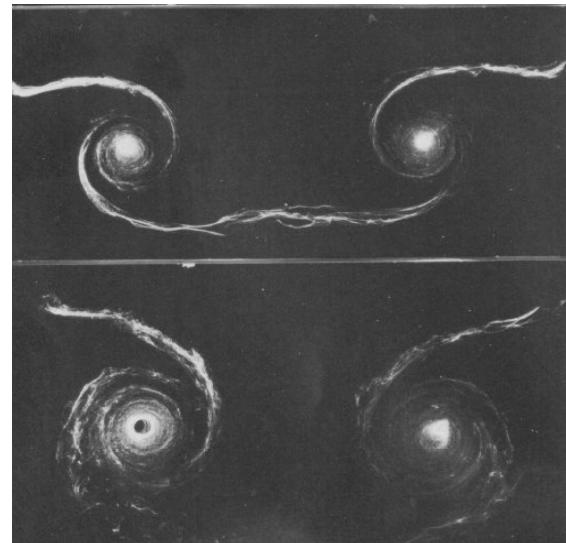
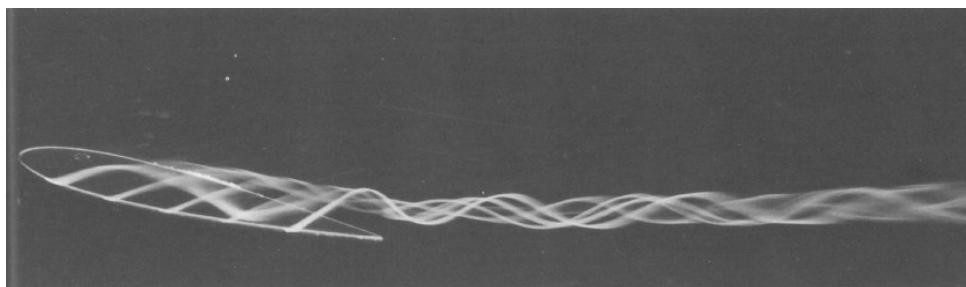




Tourbillons marginaux



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