

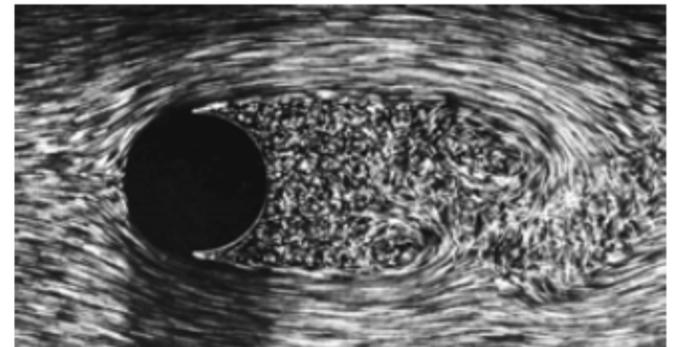
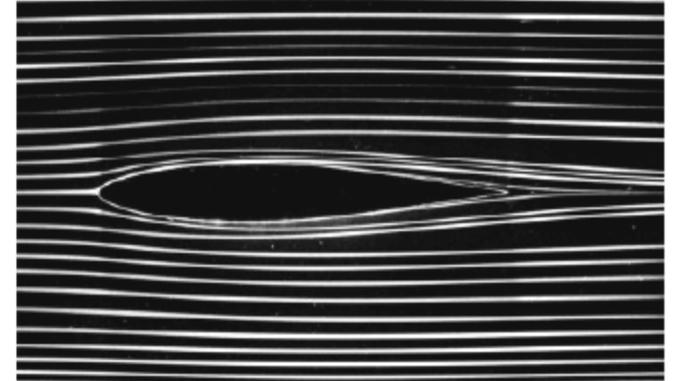
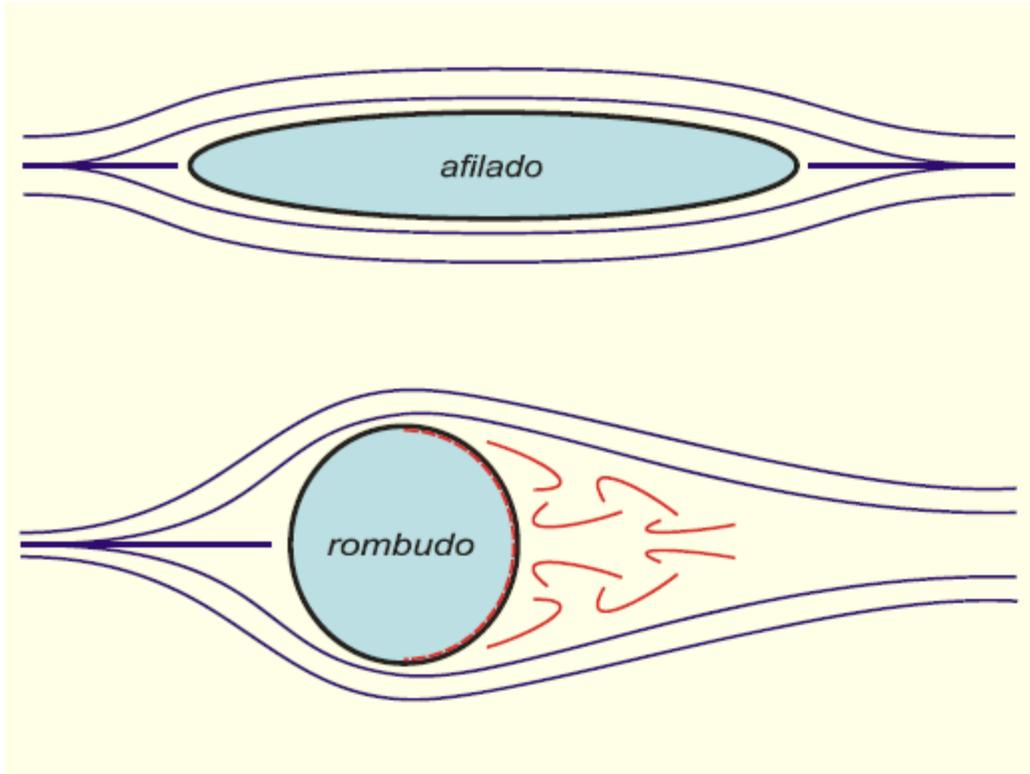
PNV5203 – Interação Fluido Estrutura I

Escoamento ao redor de corpos rombudos

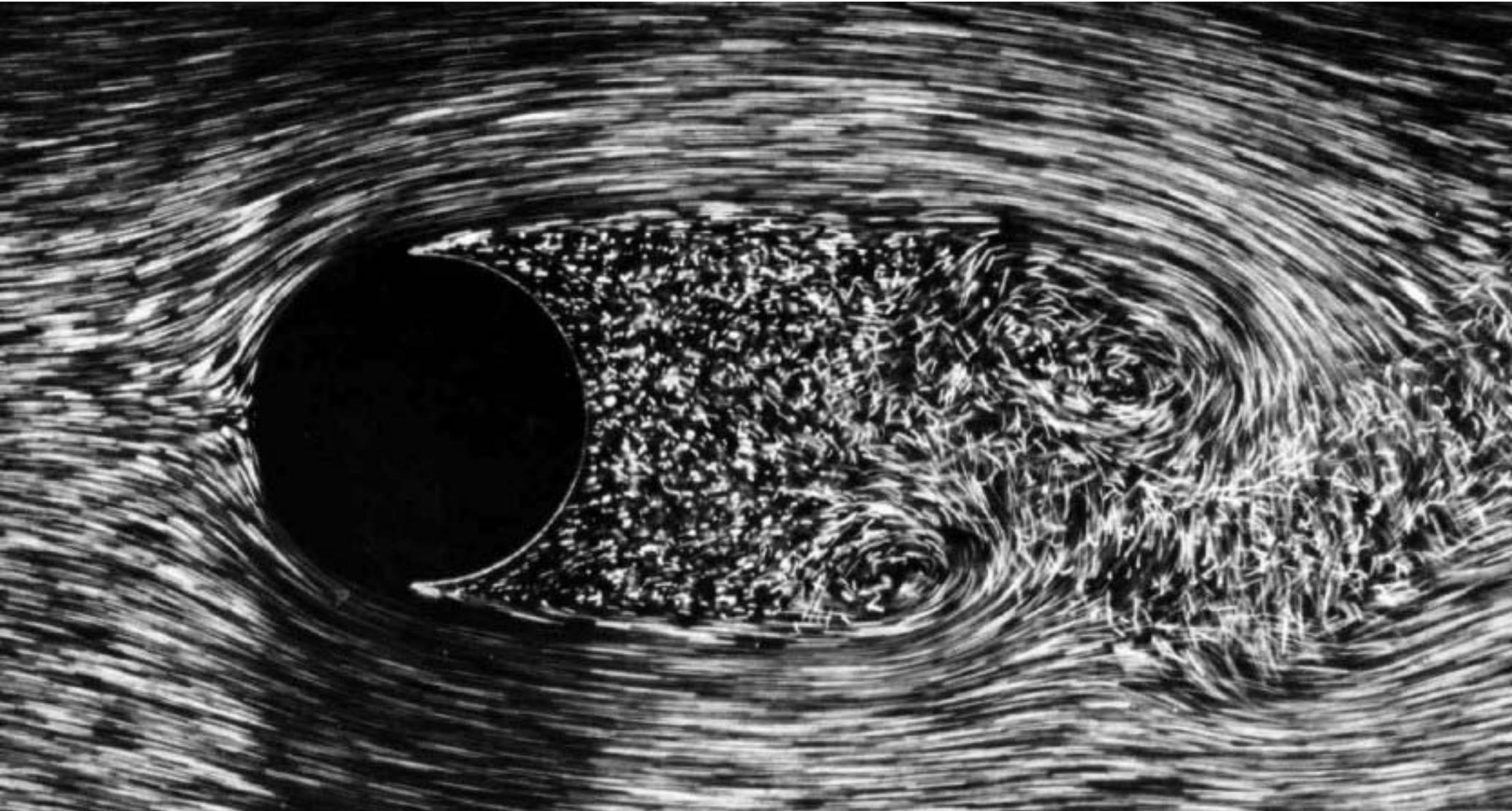


ESCOLA POLITÉCNICA DA UNIVERSIDADE DE SÃO PAULO
DEPARTAMENTO DE ENGENHARIA NAVAL E OCEÂNICA

Corpos rombudos



Separação



Rombudo ou afilado?

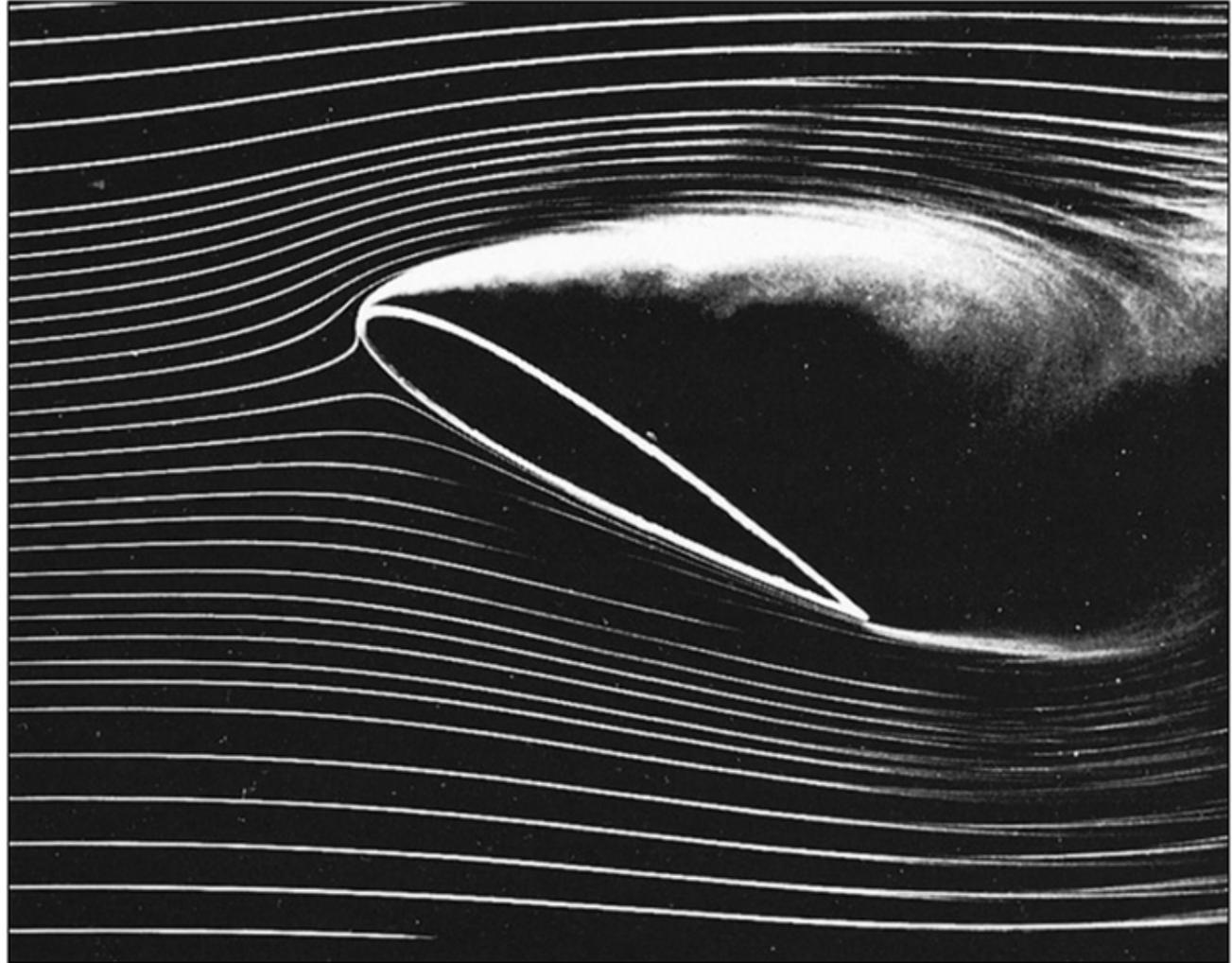
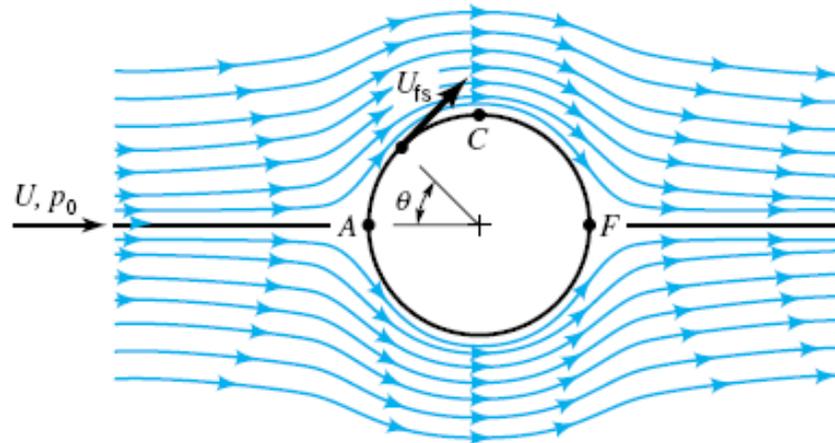
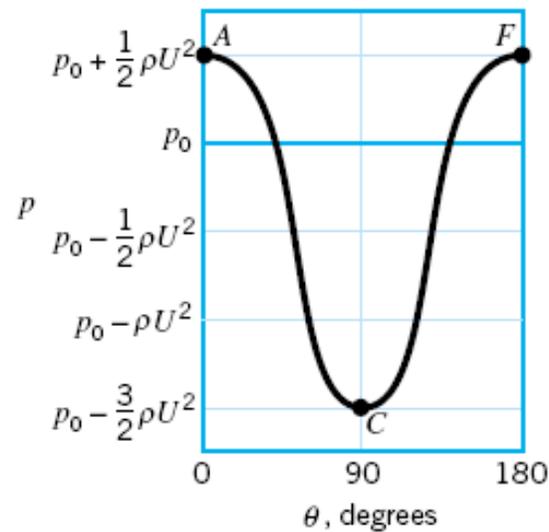


Fig. 7.24 At high angle of attack, smoke-flow visualization shows stalled flow on the upper surface of a lifting vane. [From Ref. 19, Illustrated Experiments in Fluid Mechanics (*The NCFMF Book of Film Notes*), National Committee for Fluid Mechanics Films, Education Development Center, Inc., copyright 1972.]

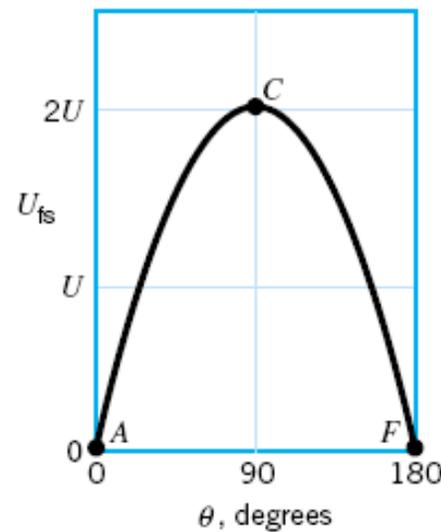
Escoamento ideal (invíscido)



(a)



(b)

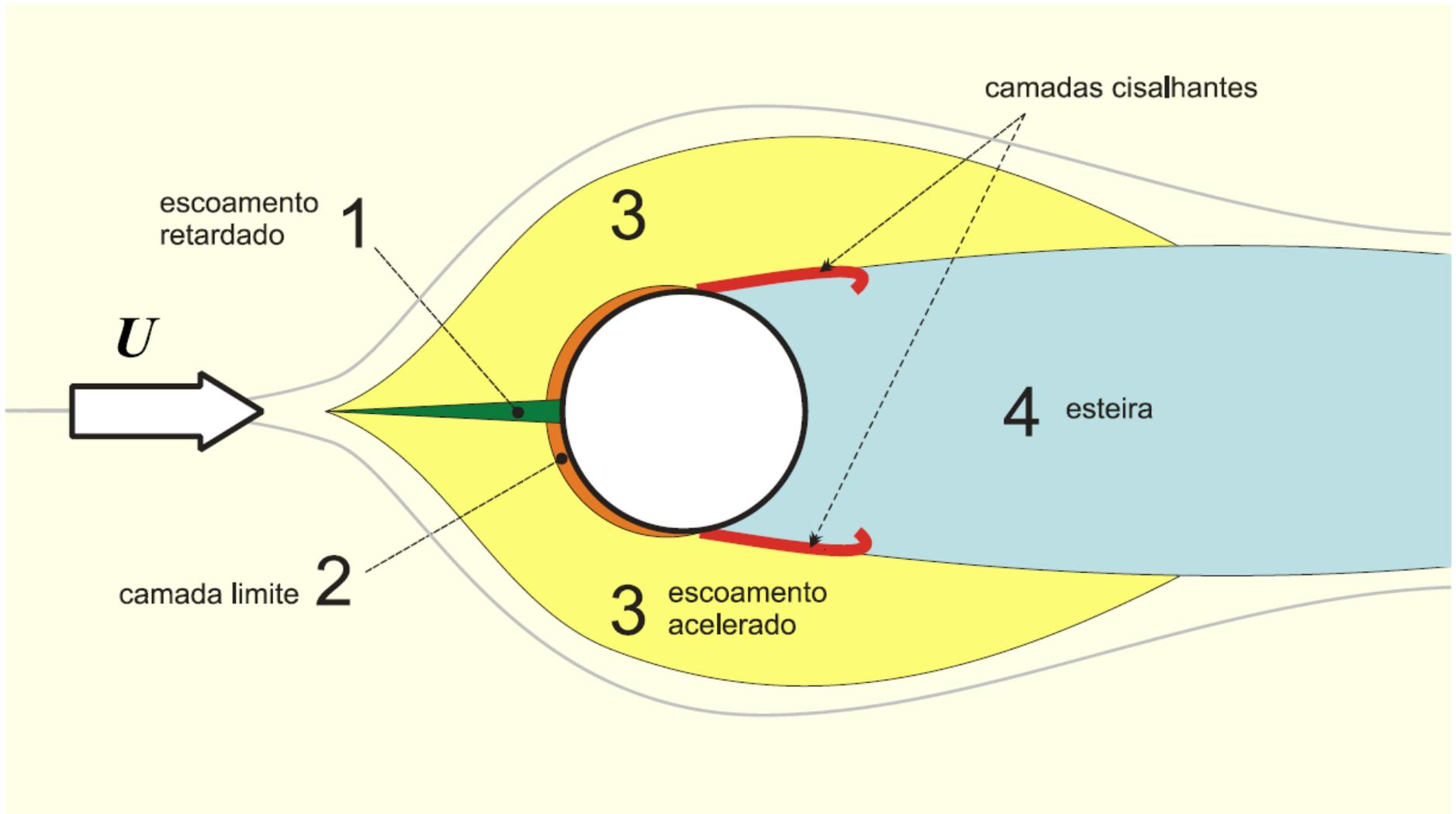


(c)

■ FIGURE 9.16

Inviscid flow past a circular cylinder: (a) streamlines for the flow if there were no viscous effects, (b) pressure distribution on the cylinder's surface, (c) free-stream velocity on the cylinder's surface.

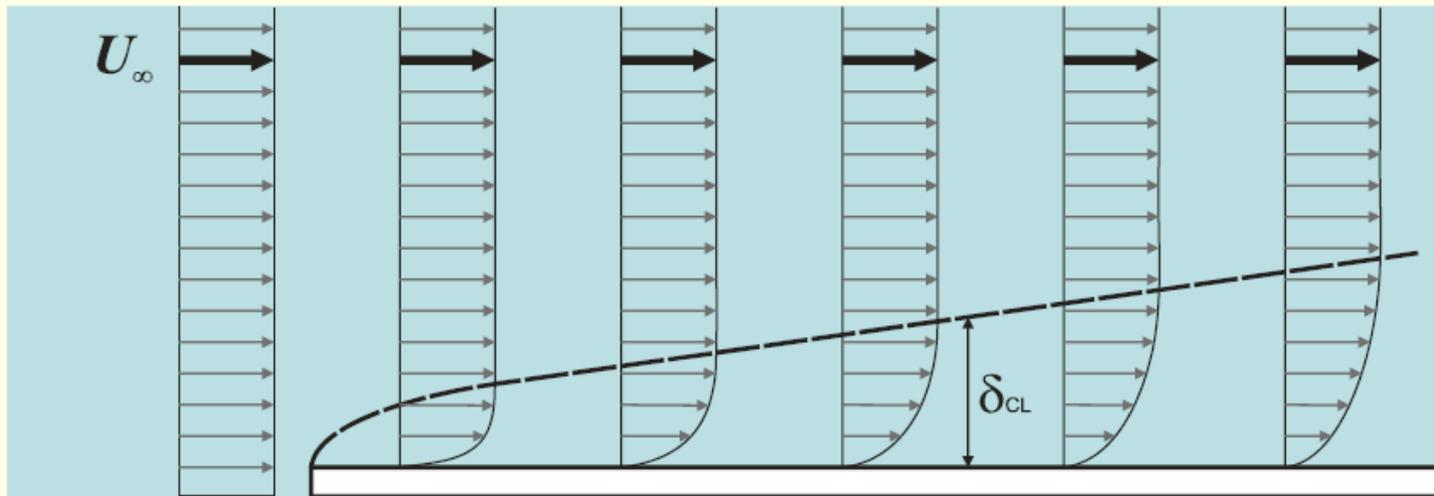
Regiões do escoamento



Número de Reynolds

$$\text{Re} = \frac{\rho U D}{\mu} = \frac{U}{\nu} D = \frac{\text{Forças inerciais}}{\text{Forças viscosas}}$$

Camada Limite (Prandtl, 1904)



Gradiente adverso de pressão

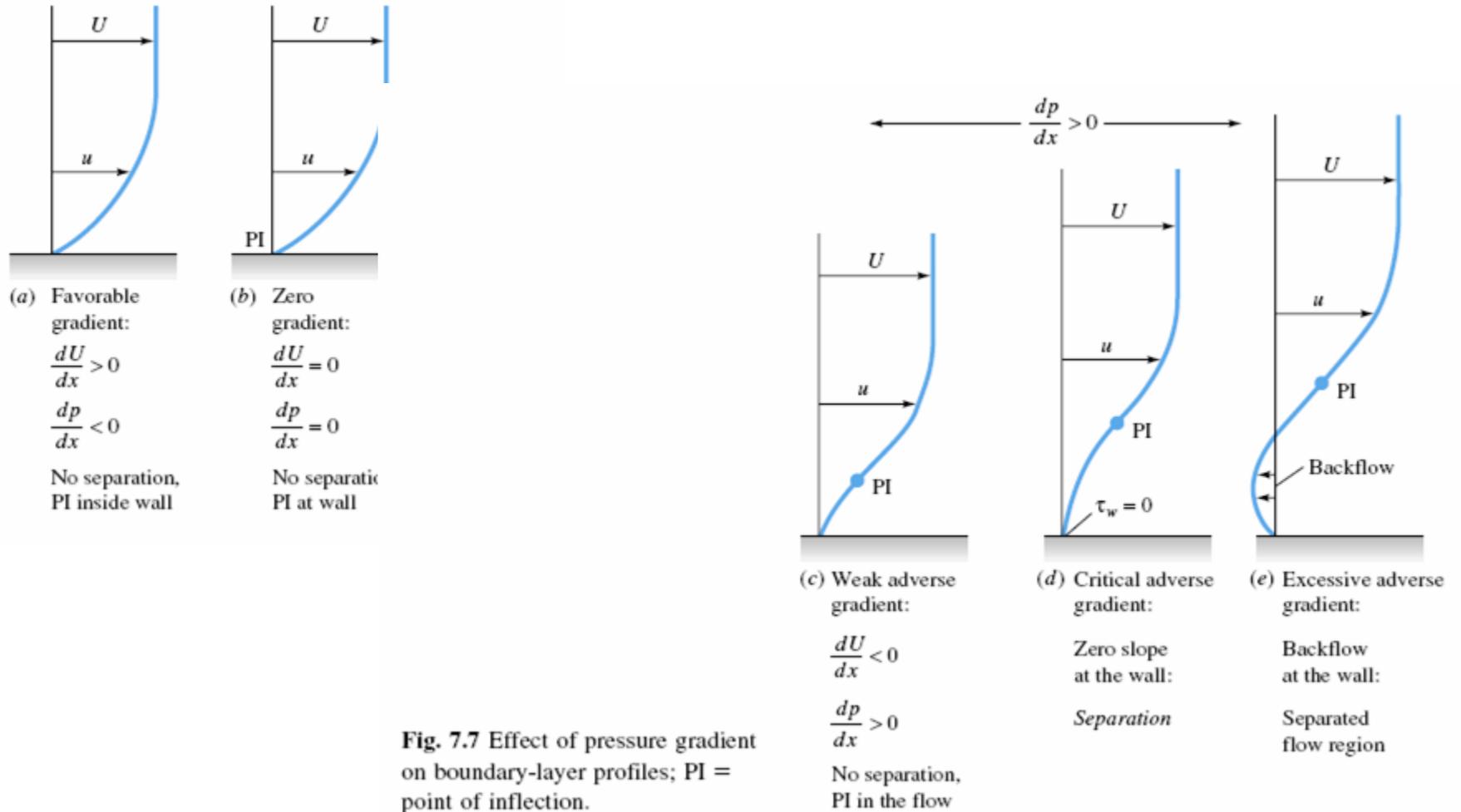
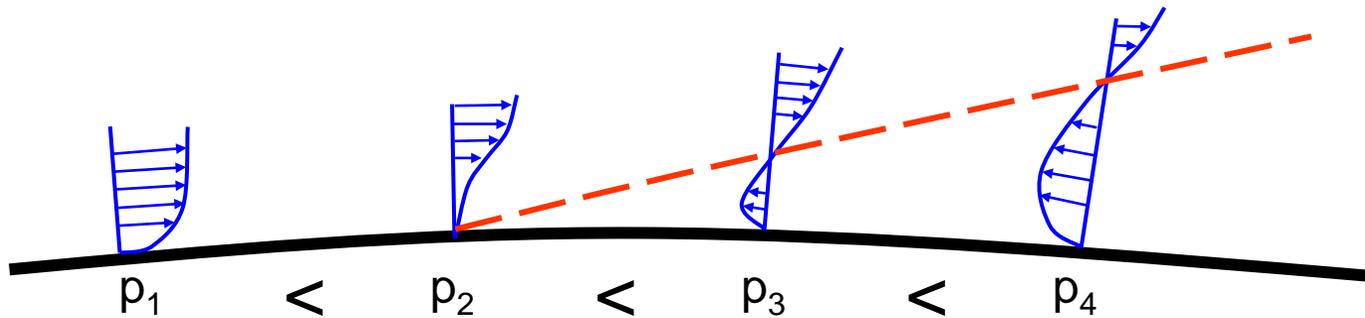
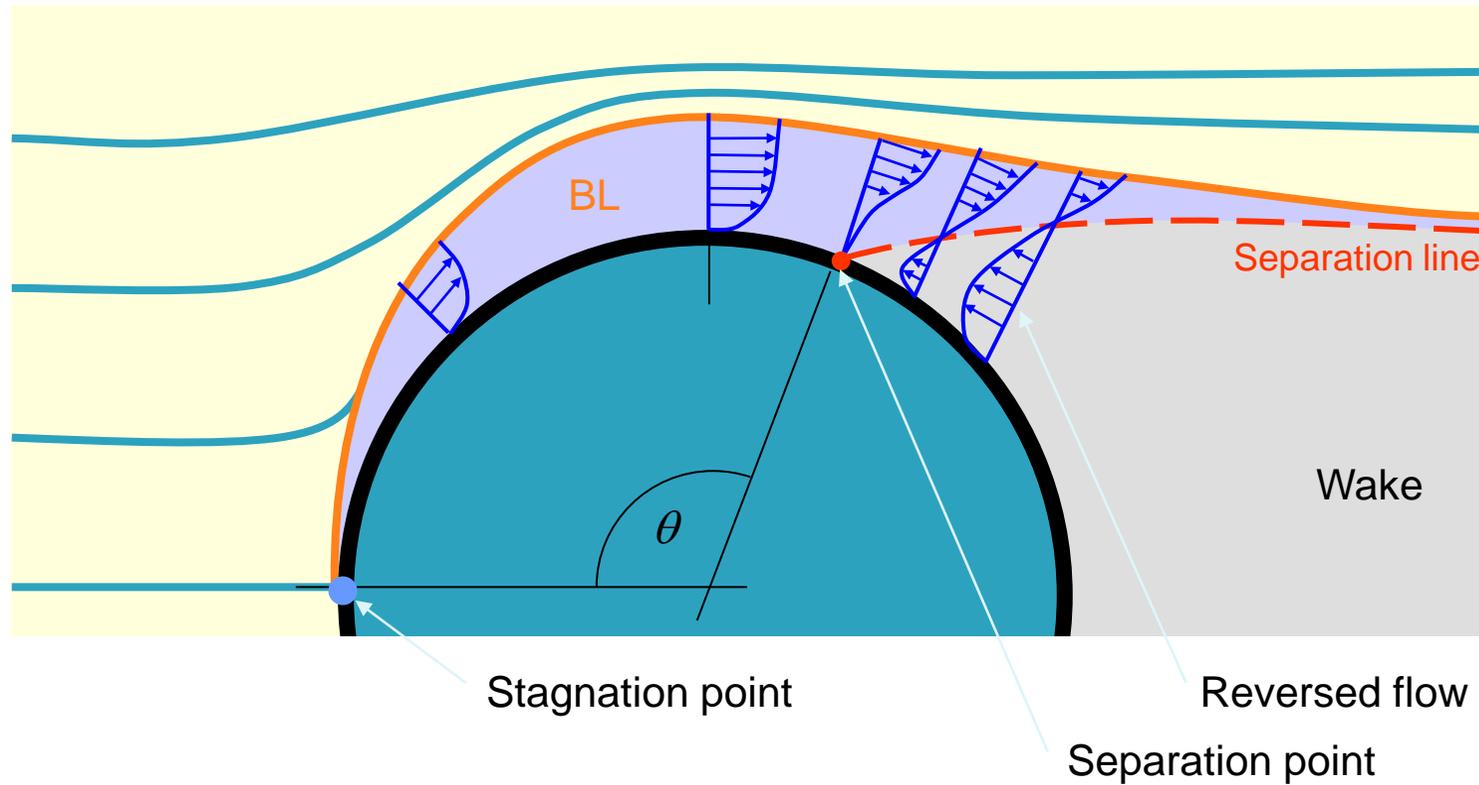
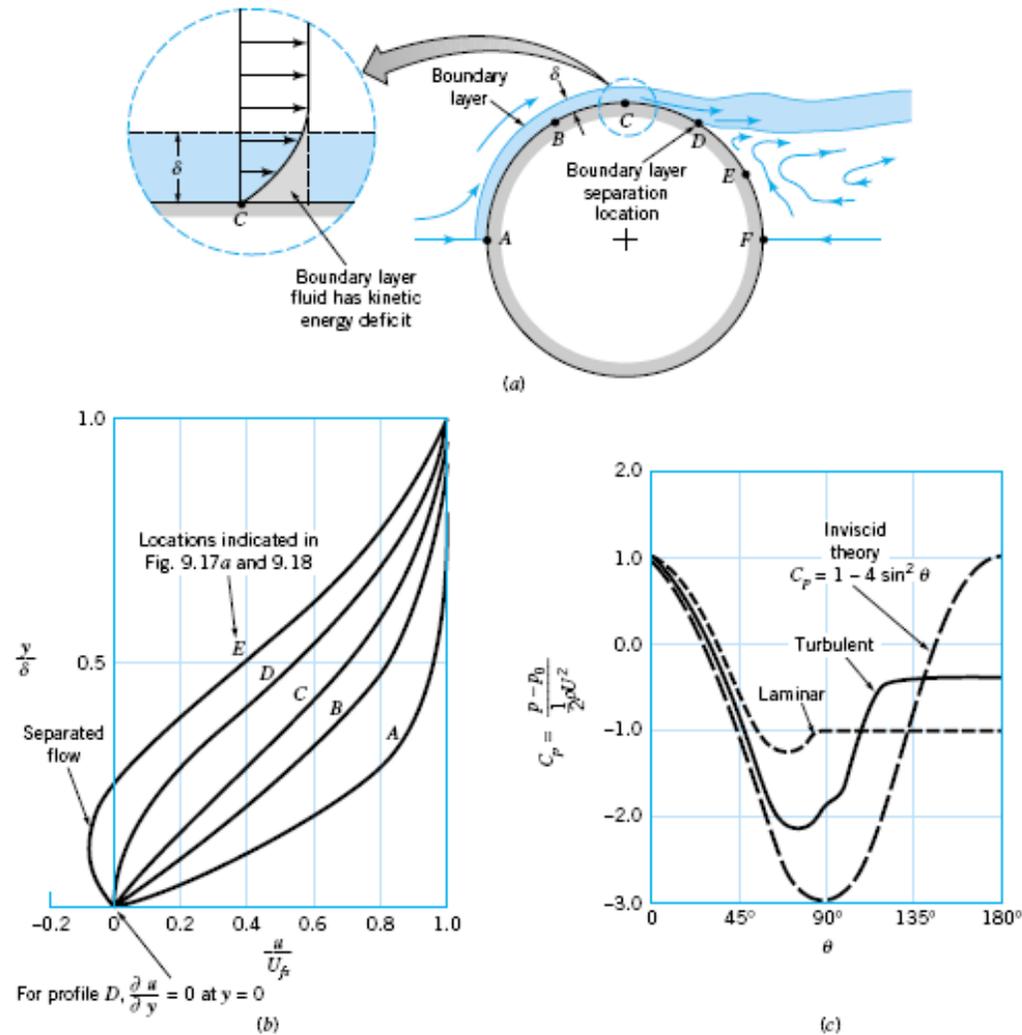


Fig. 7.7 Effect of pressure gradient on boundary-layer profiles; PI = point of inflection.

Separação do escoamento



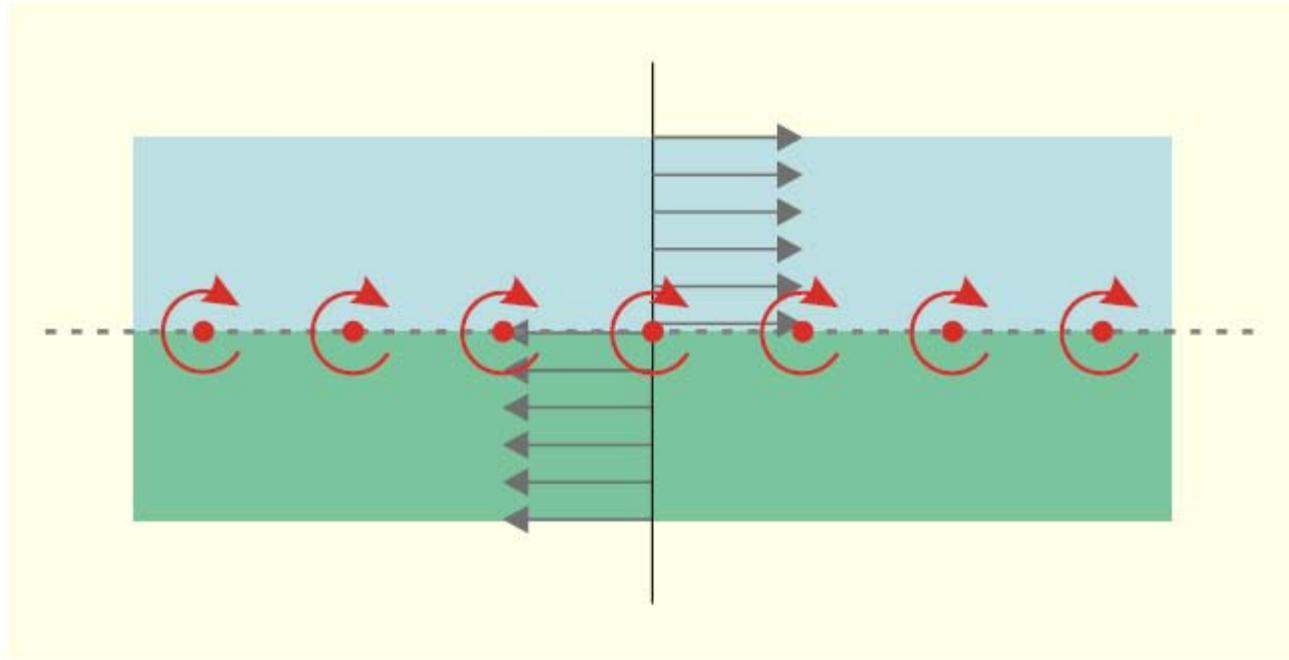
Camada Limite



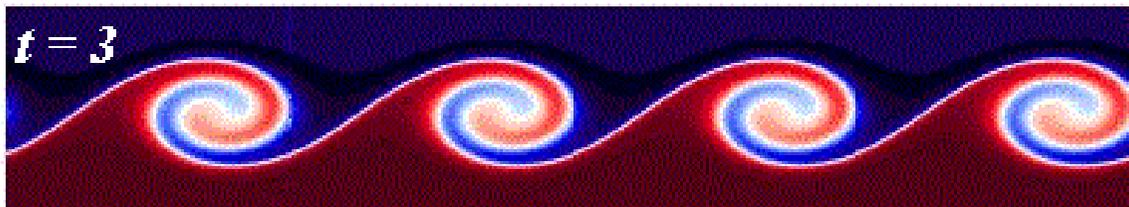
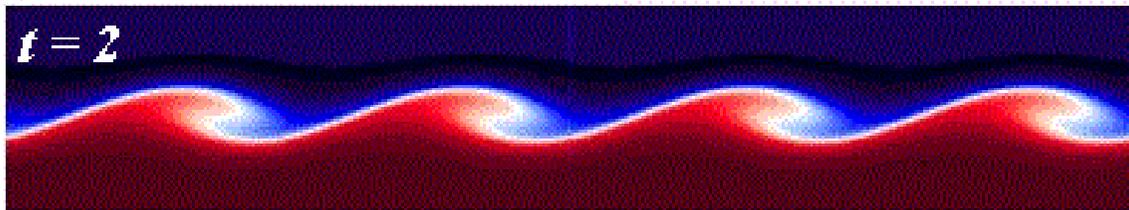
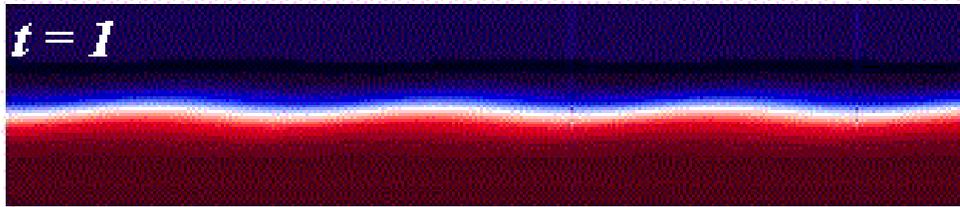
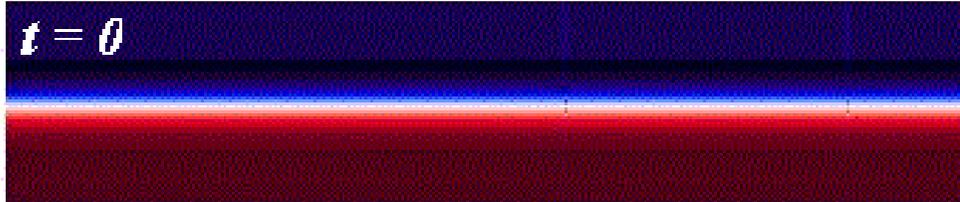
■ **FIGURE 9.17** Boundary layer characteristics on a circular cylinder: (a) boundary layer separation location, (b) typical boundary layer velocity profiles at various locations on the cylinder, (c) surface pressure distributions for inviscid flow and boundary layer flow.



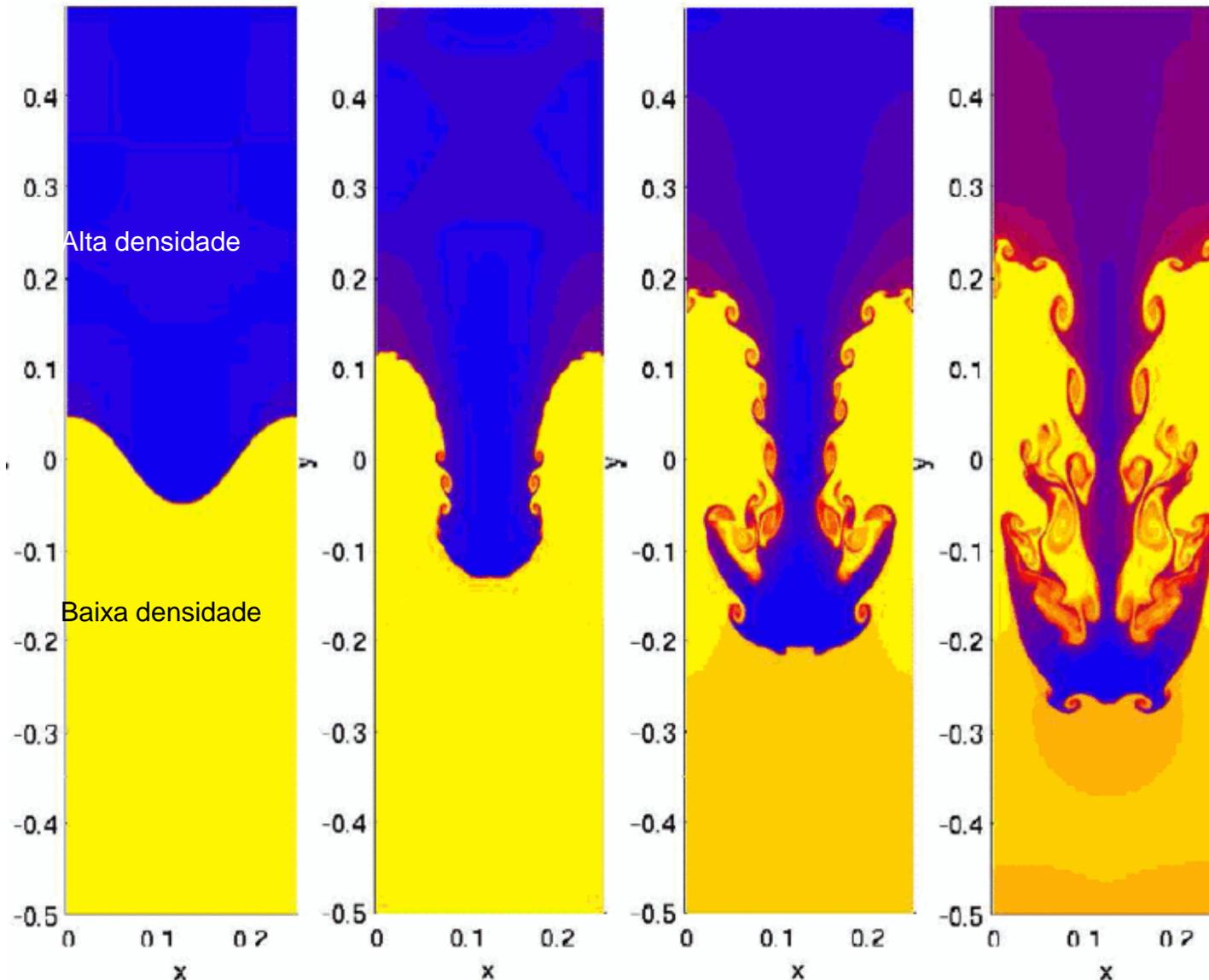
Vorticidade



Instabilidade de Kelvin–Helmholtz



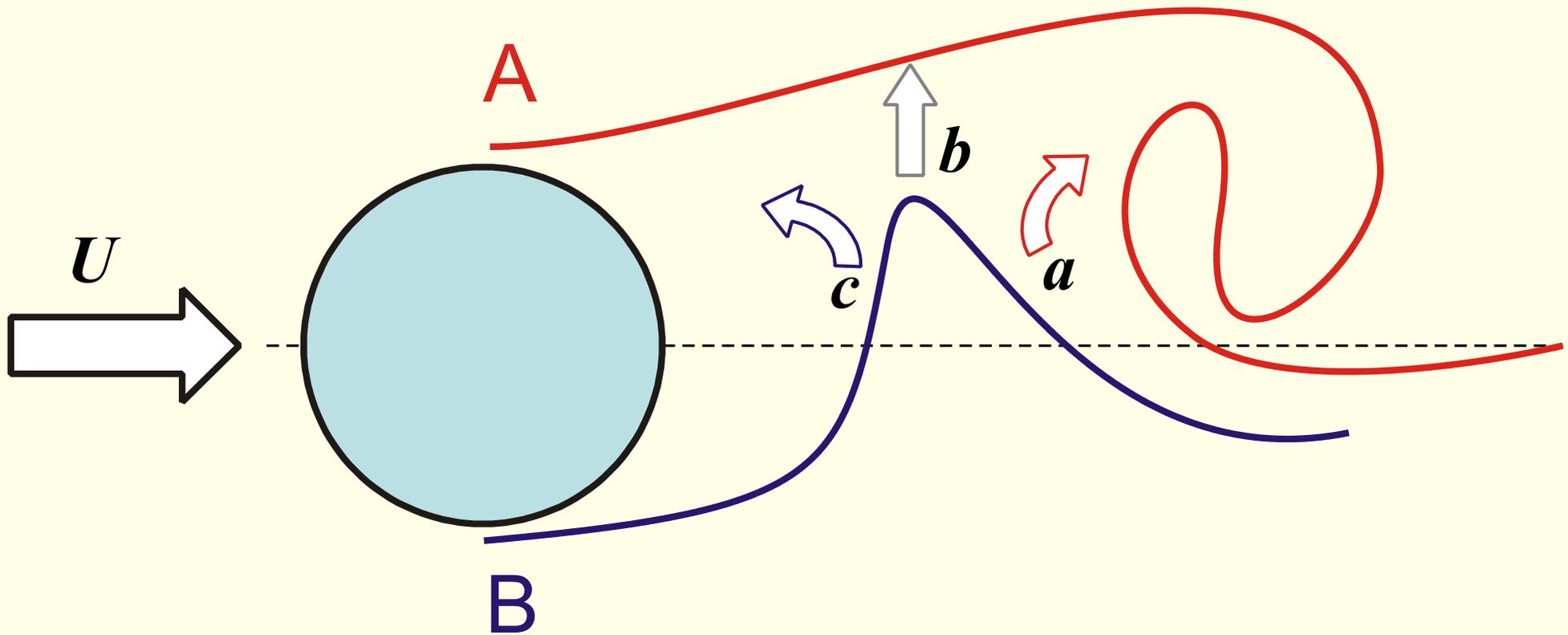
Instabilidade de Rayleigh–Taylor



Hydrodynamics simulation of a single "finger" of the Rayleigh–Taylor instability. Note the formation of Kelvin–Helmholtz instabilities, in the second and later snapshots shown (starting initially around the level $y = 0$), as well as the formation of a "mushroom cap" at a later stage in the third and fourth frame in the sequence.

Li, Shengtai and Hui Li. "Parallel AMR Code for Compressible MHD or HD Equations". Los Alamos National Laboratory.

Interação das camadas cisalhantes

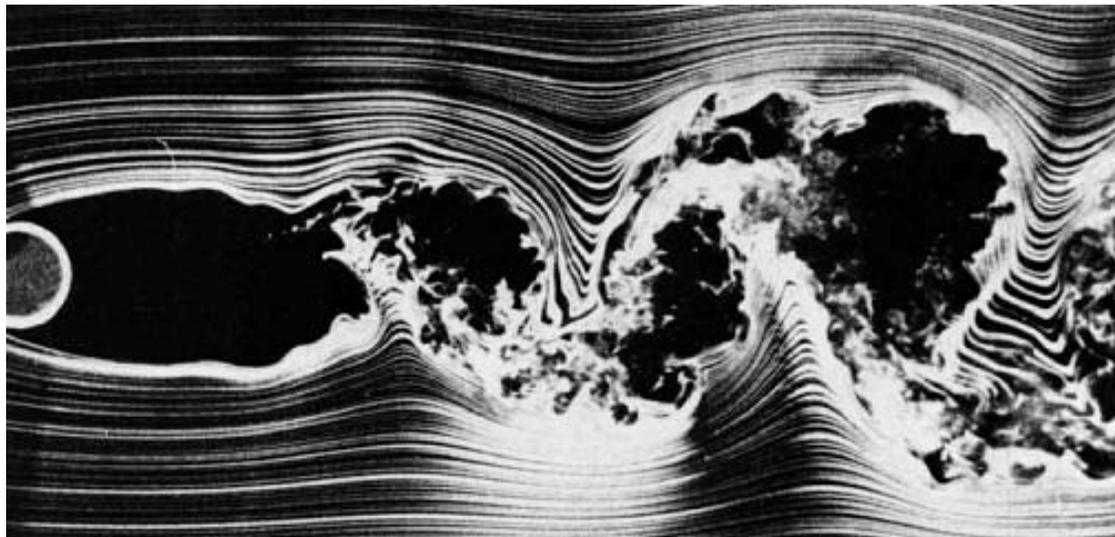


Esteira de vórtices

Laminar

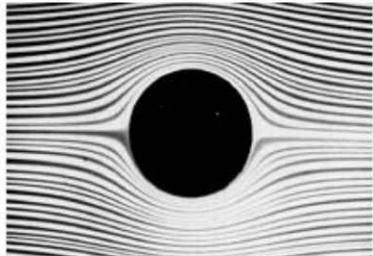


Turbulento

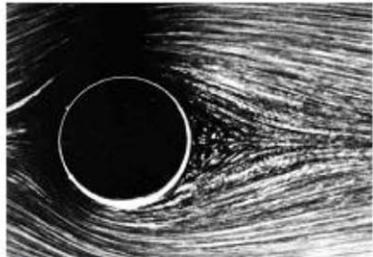


Formação da esteira

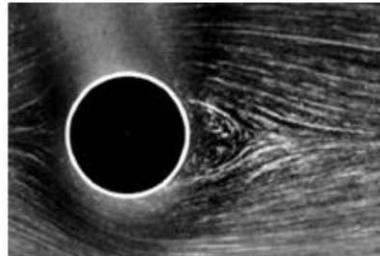
Forças inerciais desprezíveis
Forças viscosas dominam



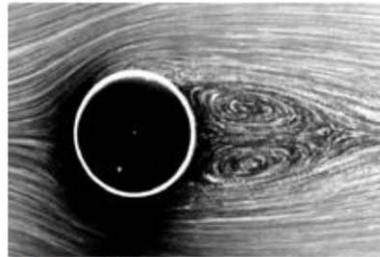
Sem separação (creeping flow)



Re = 9,6



Re = 13



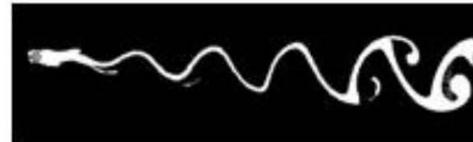
Re = 26



Re = 32



Re = 55



Re = 65



Re = 73

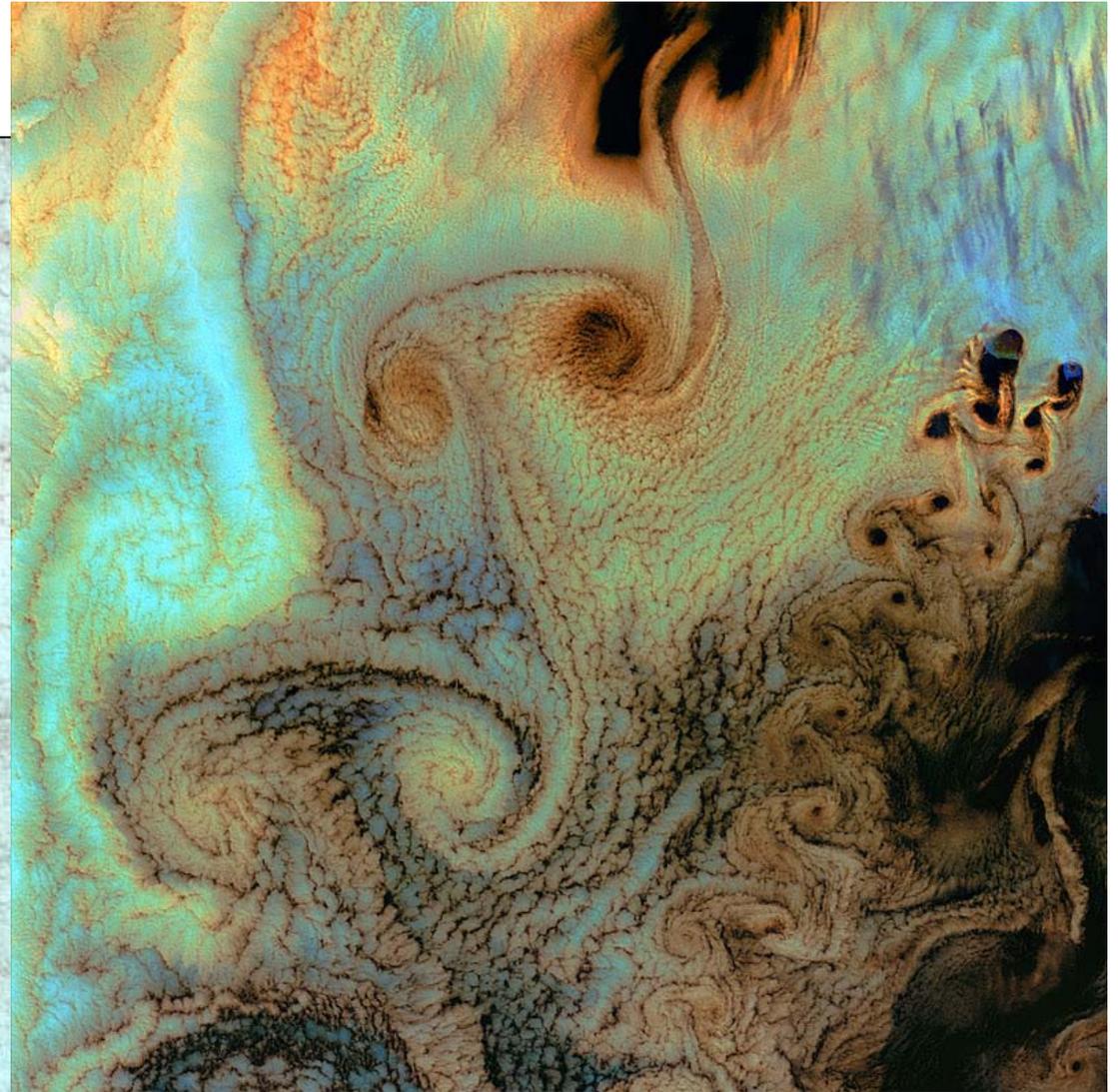
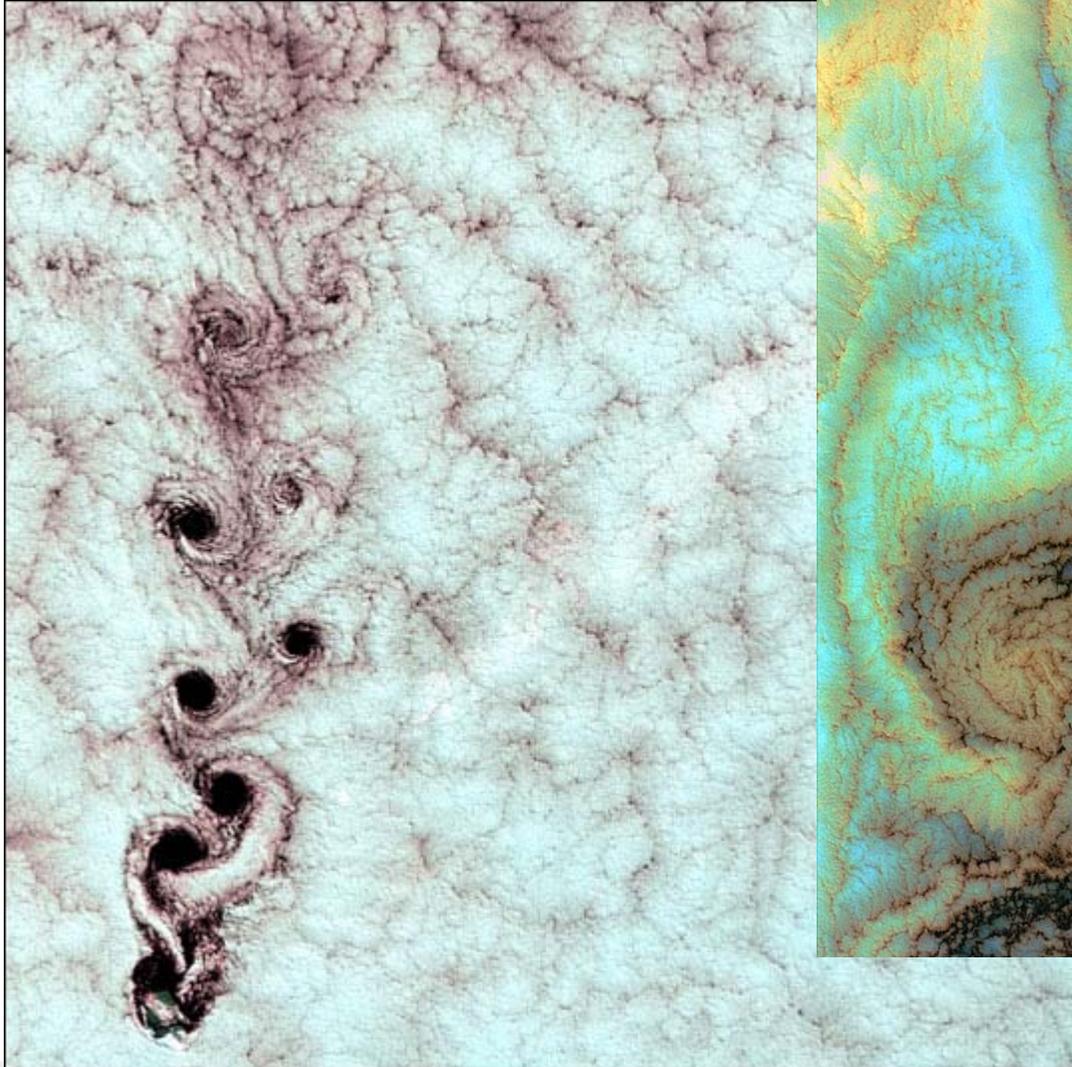


Re = 102



Re = 161

Esteira de vórtices



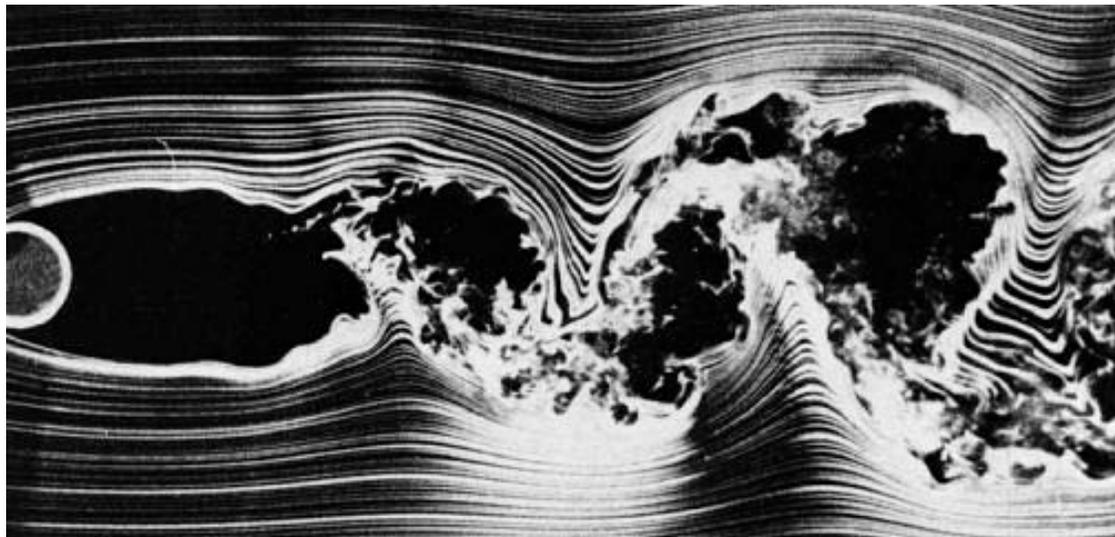
Aletian Islands. Credit: USGS

Esteira de vórtices

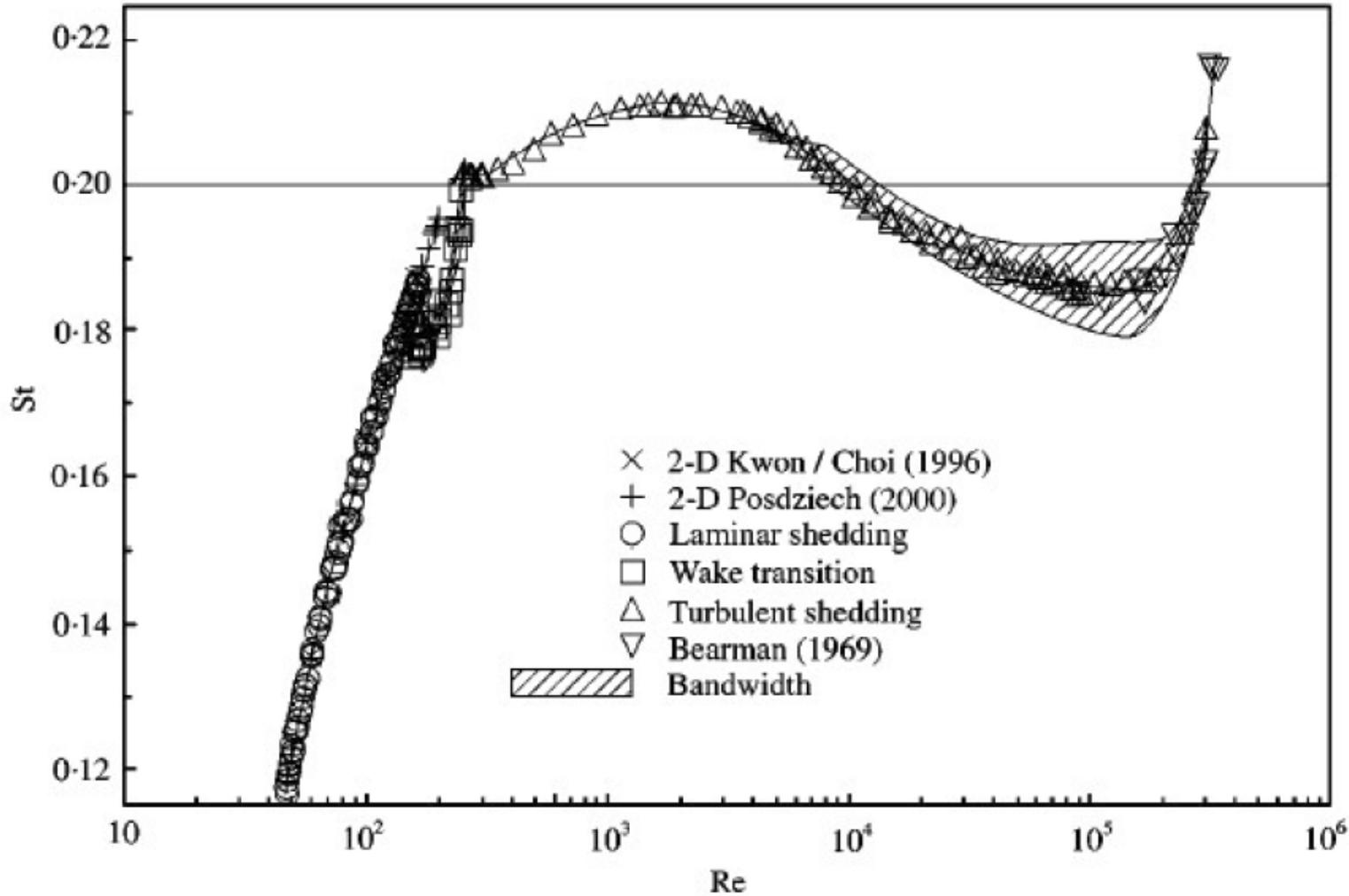
Laminar



Turbulento

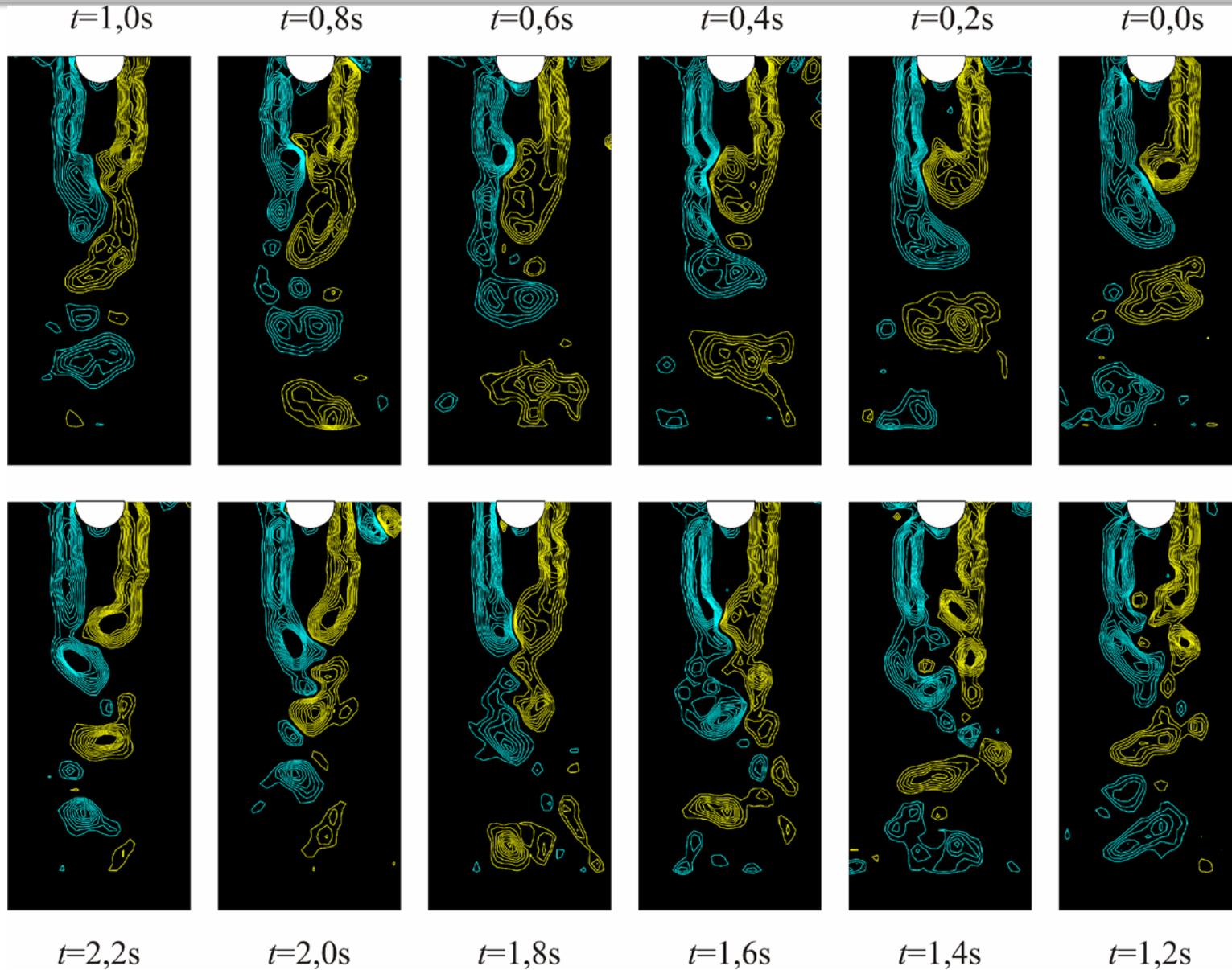


Número de Strouhal



$$St = \frac{f_s D}{U}$$

Emissão de vórtices



Comprimento de formação

Re=1000

Re=2050

Re=3010

Re=4010

Re=5000

Re=6050

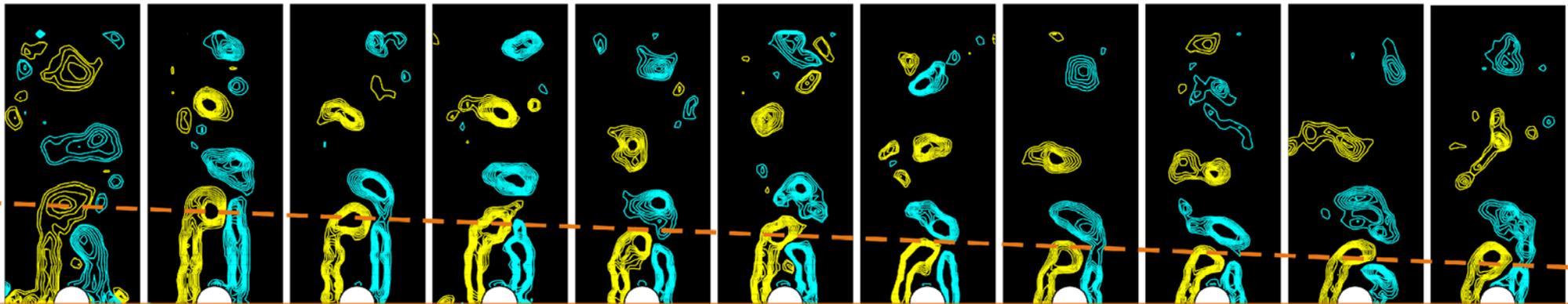
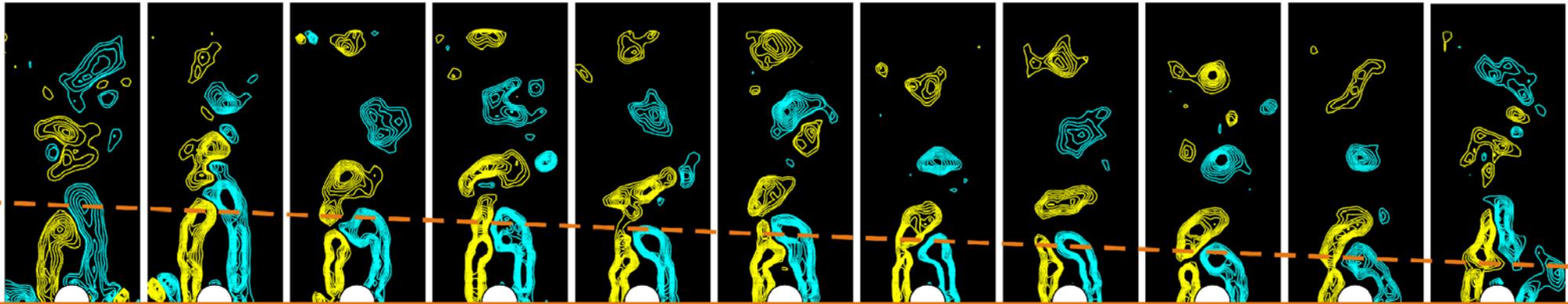
Re=7110

Re=8200

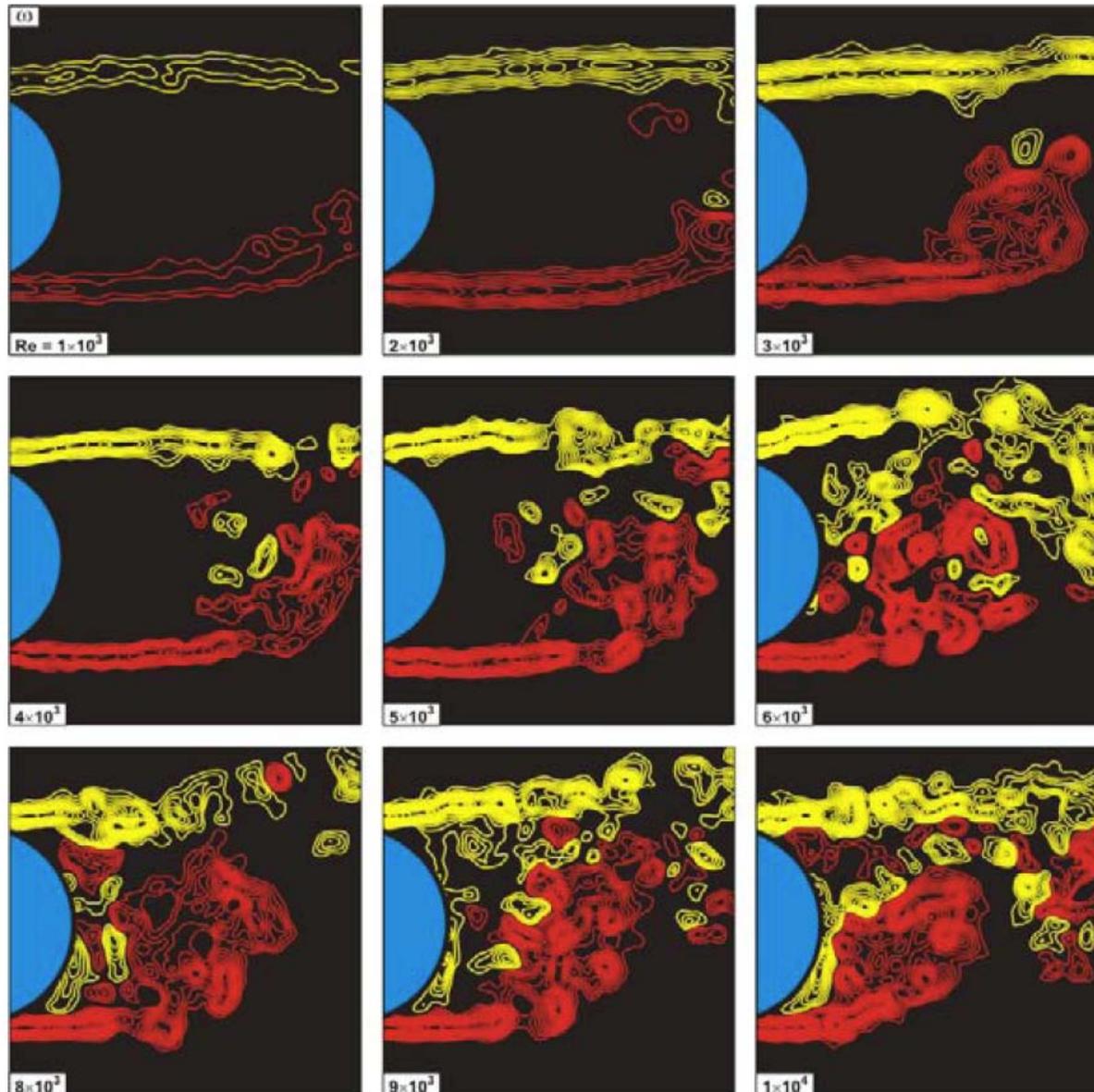
Re=9770

Re=10550

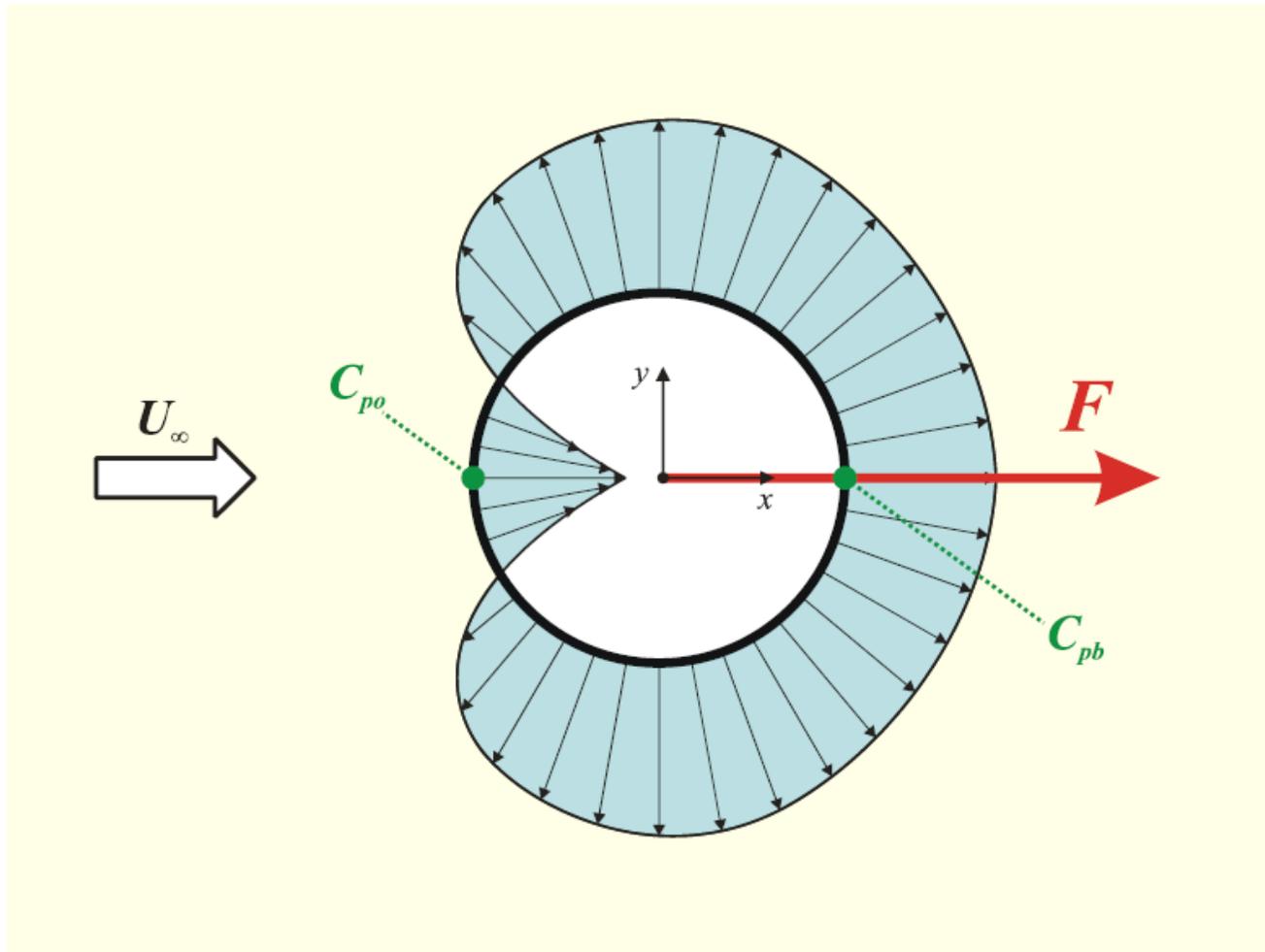
Re=13280



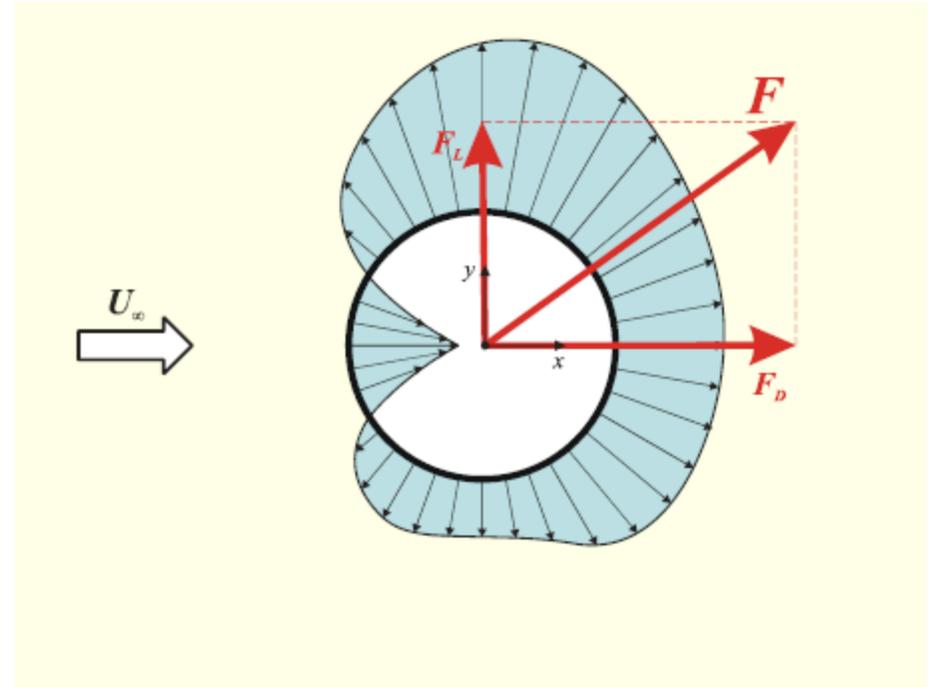
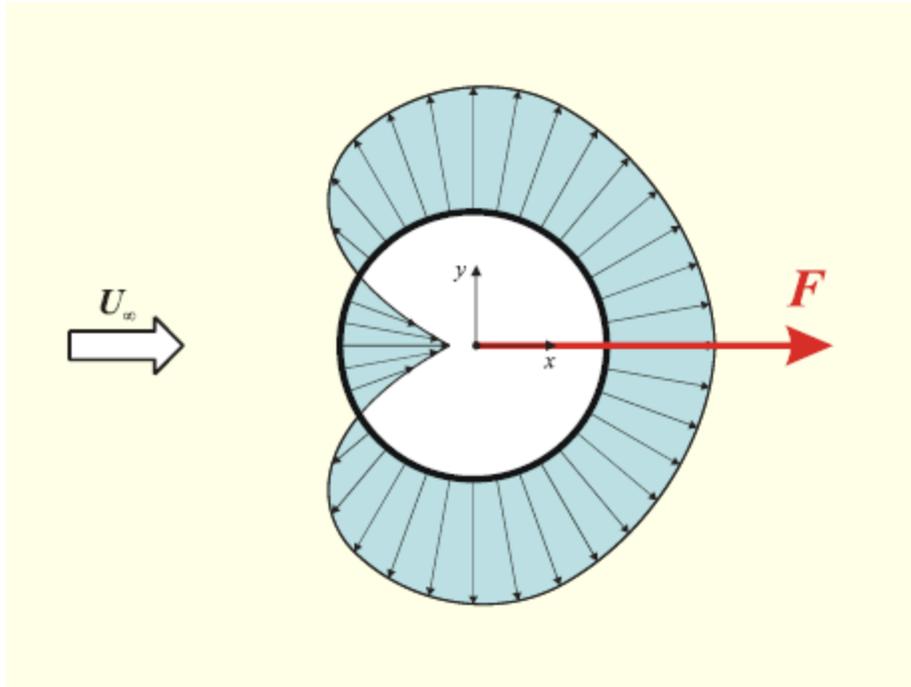
Comprimento de formação



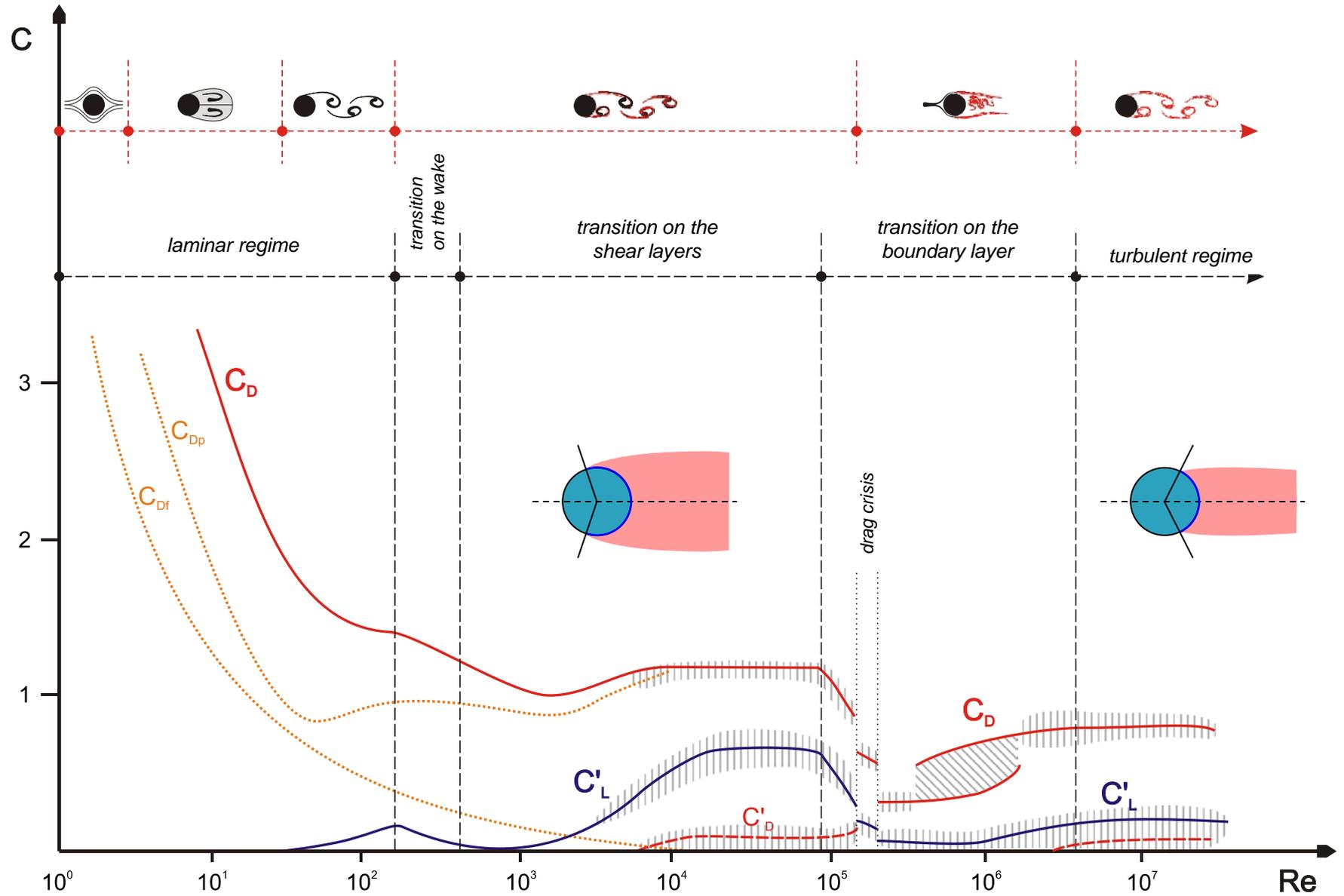
Campo de pressão



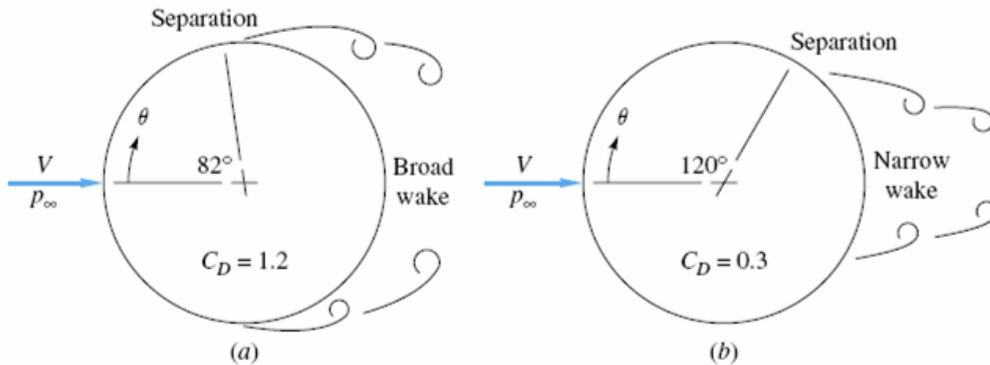
Campo de pressão



$C_D \times Re$: regimes laminar e turbulento



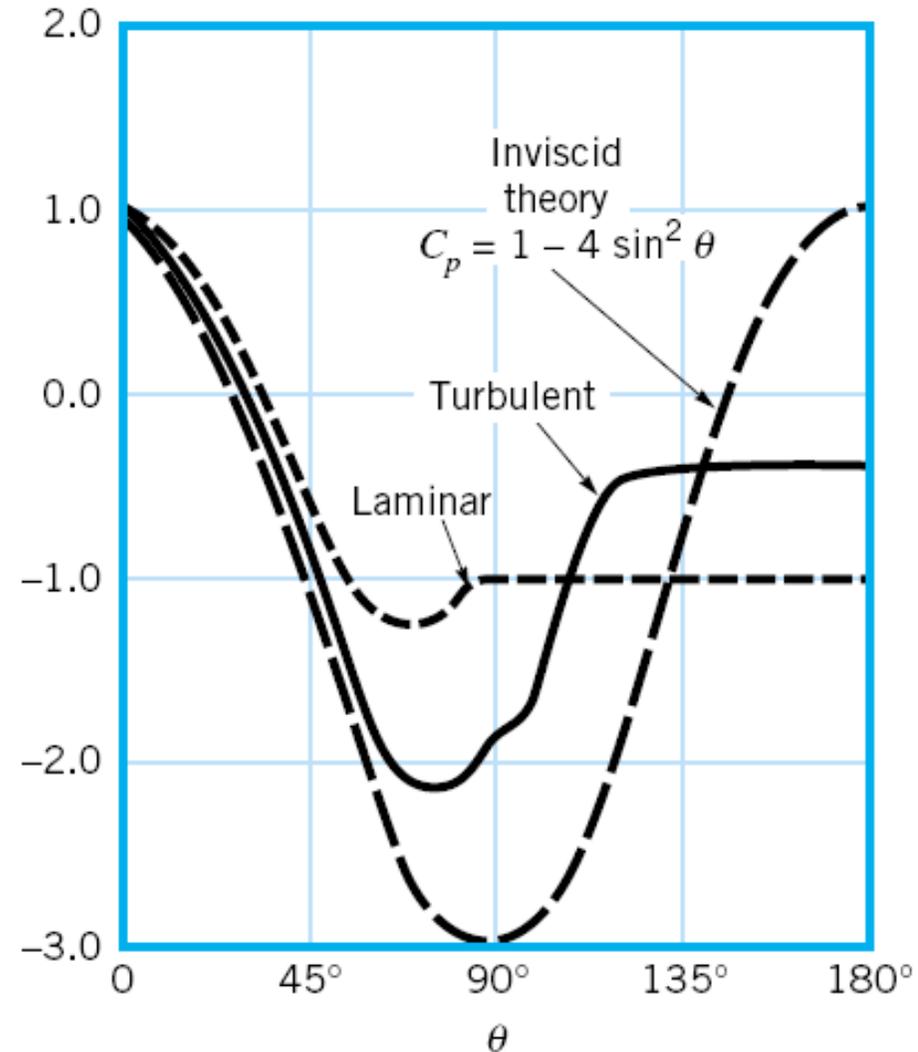
Coeficiente de pressão



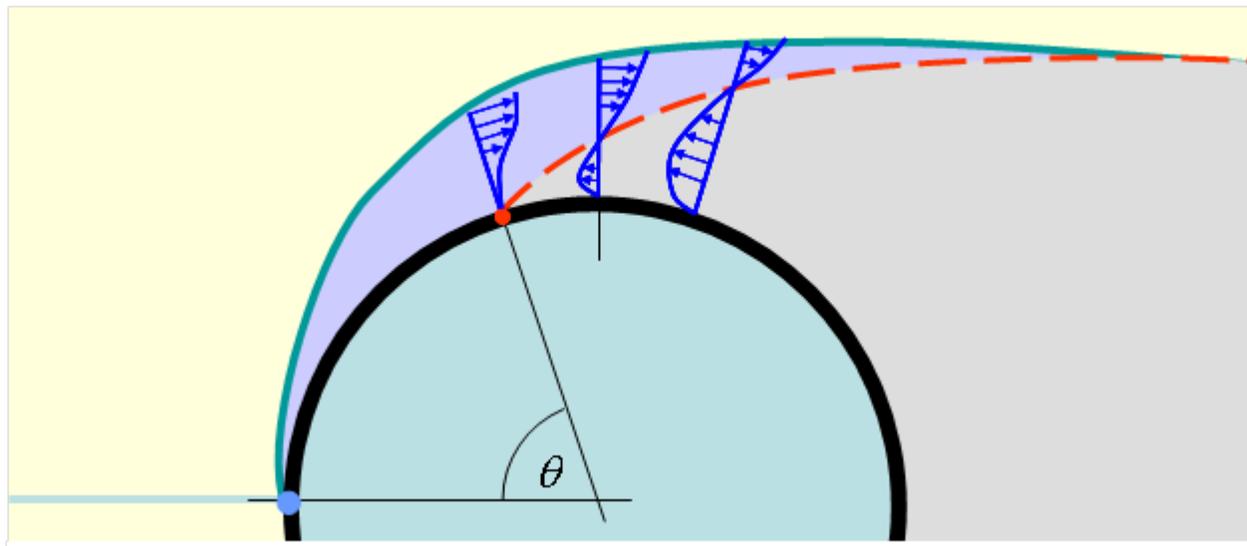
$$C_p = \frac{(p - p_\infty)}{\frac{1}{2} \rho U_\infty^2}$$

$$C_p = \frac{p - p_0}{\frac{1}{2} \rho U^2}$$

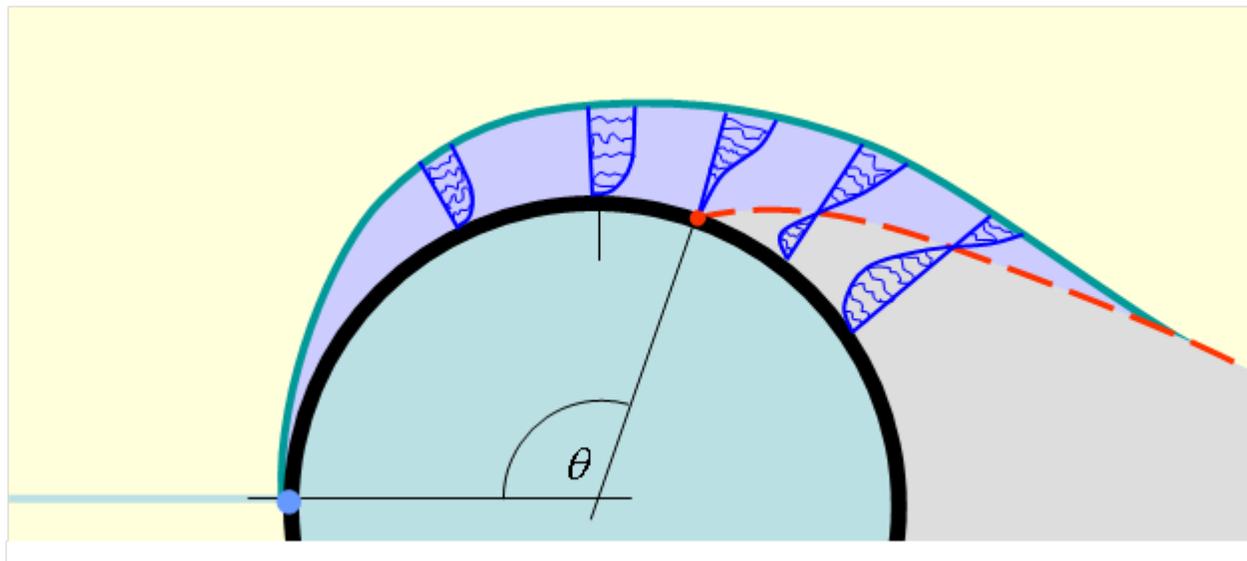
Fig. 7.13 Flow past a circular cylinder: (a) laminar separation; (b) turbulent separation; (c) theoretical and actual surface-pressure distributions.



Separação em regimes laminar e turbulento



Laminar
Boundary Layer



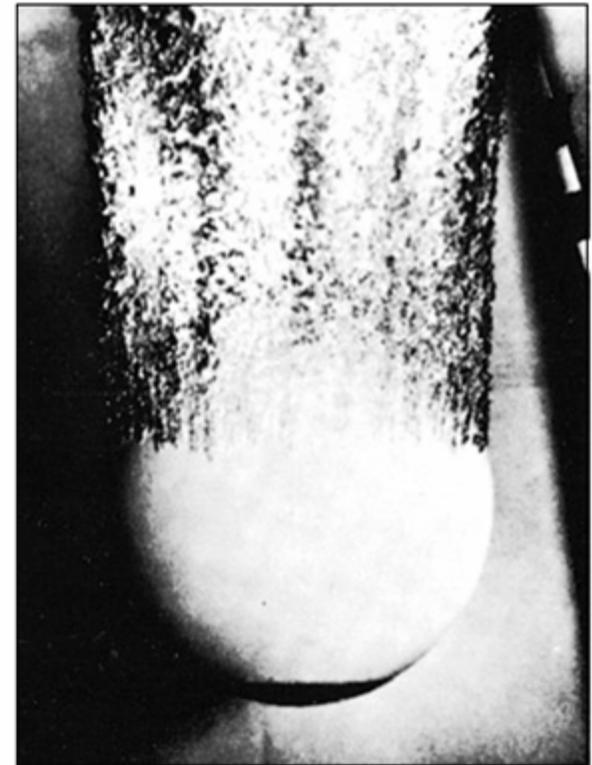
Turbulent
Boundary Layer

Separação em regimes laminar e turbulento

Fig. 7.14 Strong differences in laminar and turbulent separation on an 8.5-in bowling ball entering water at 25 ft/s: (a) smooth ball, laminar boundary layer; (b) same entry, turbulent flow induced by patch of nose-sand roughness. (U.S. Navy photograph, Ordnance Test Station, Pasadena Annex.)

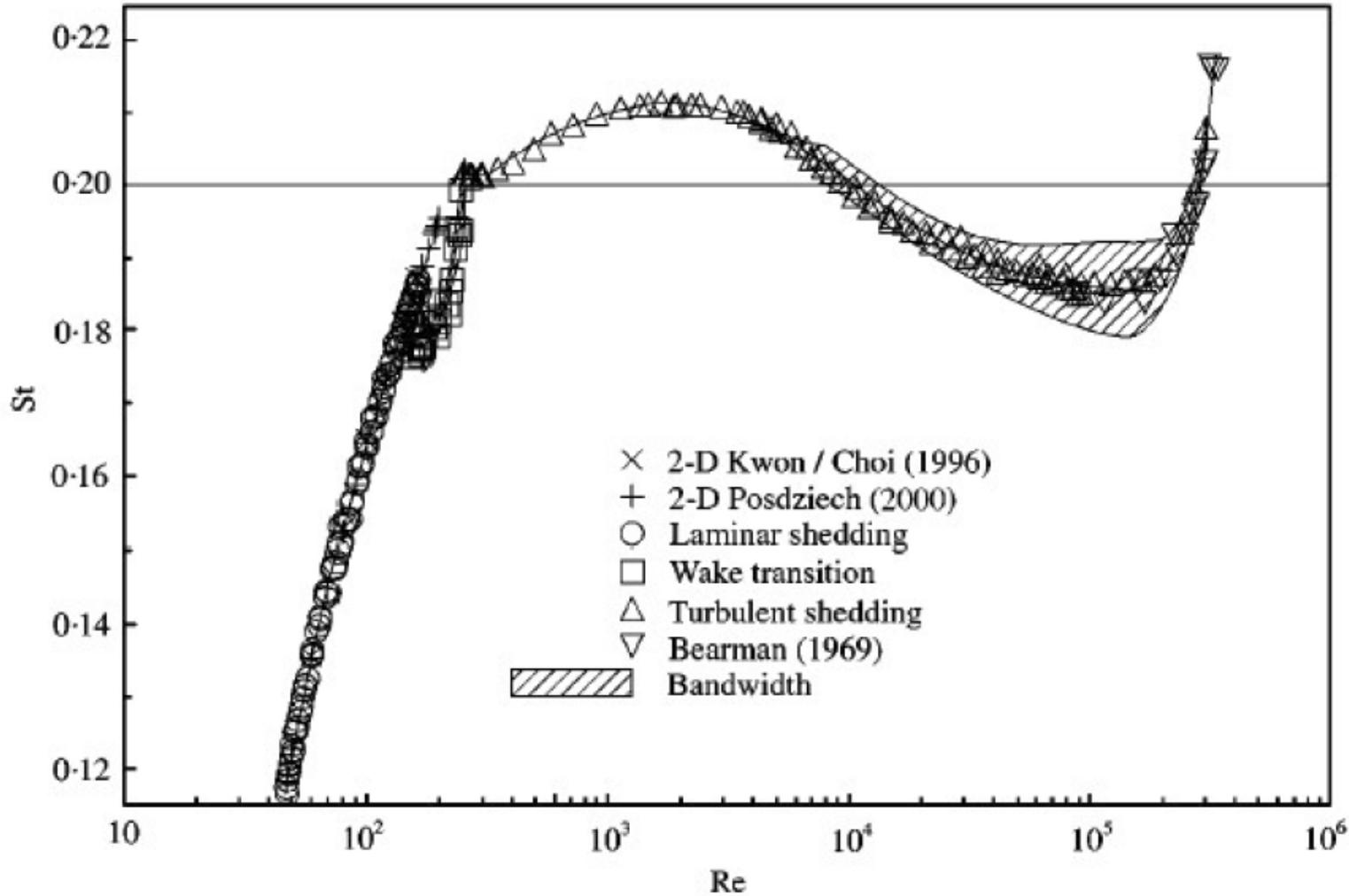


(a)



(b)

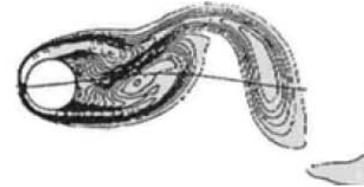
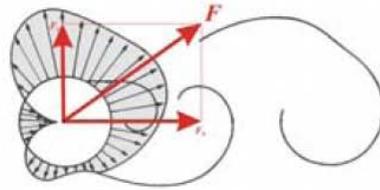
Número de Strouhal



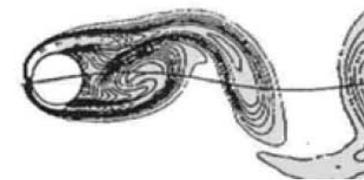
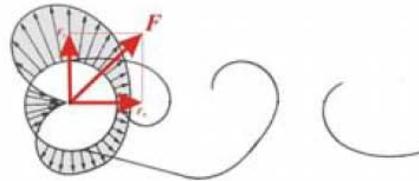
$$St = \frac{f_s D}{U}$$

Força cíclica

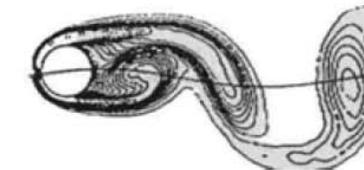
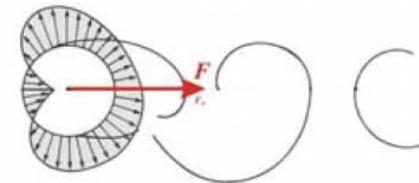
$$t = \frac{1}{12} T_s$$



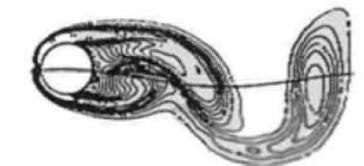
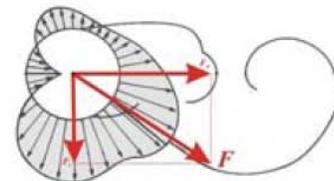
$$t = \frac{2}{12} T_s$$



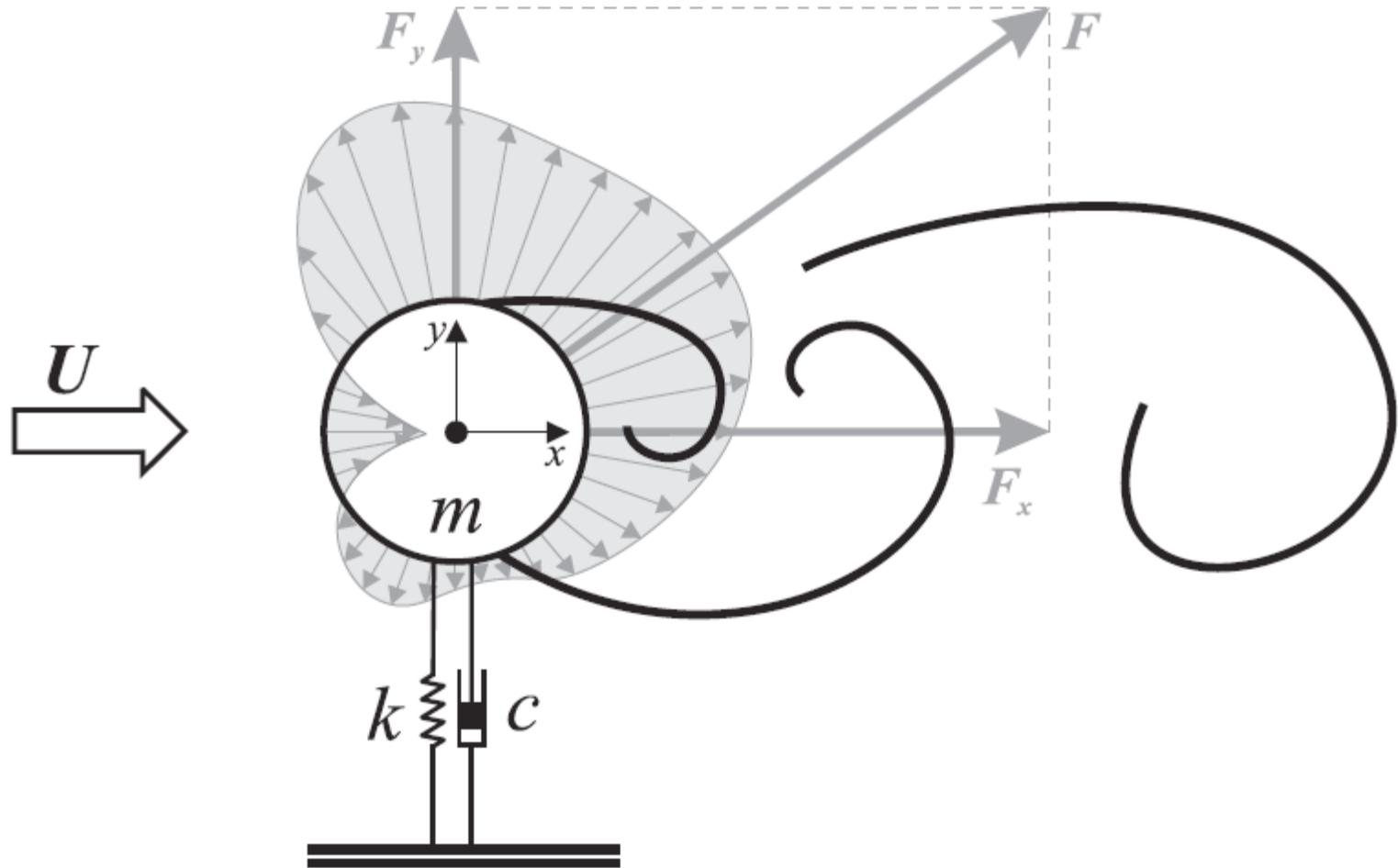
$$t = \frac{3}{12} T_s$$



$$t = \frac{4}{12} T_s$$



Interação Fluido Estrutura



Modos de emissão: cilindro em movimento

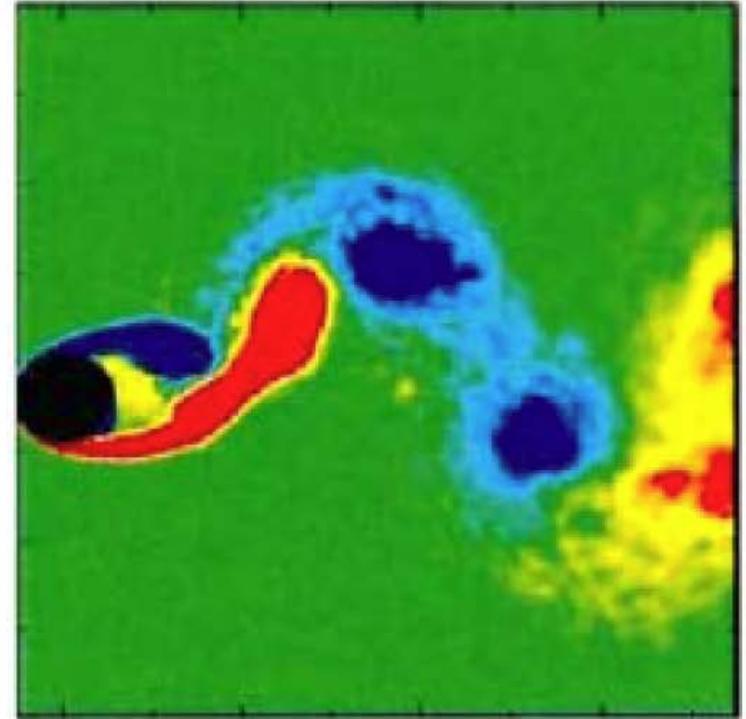
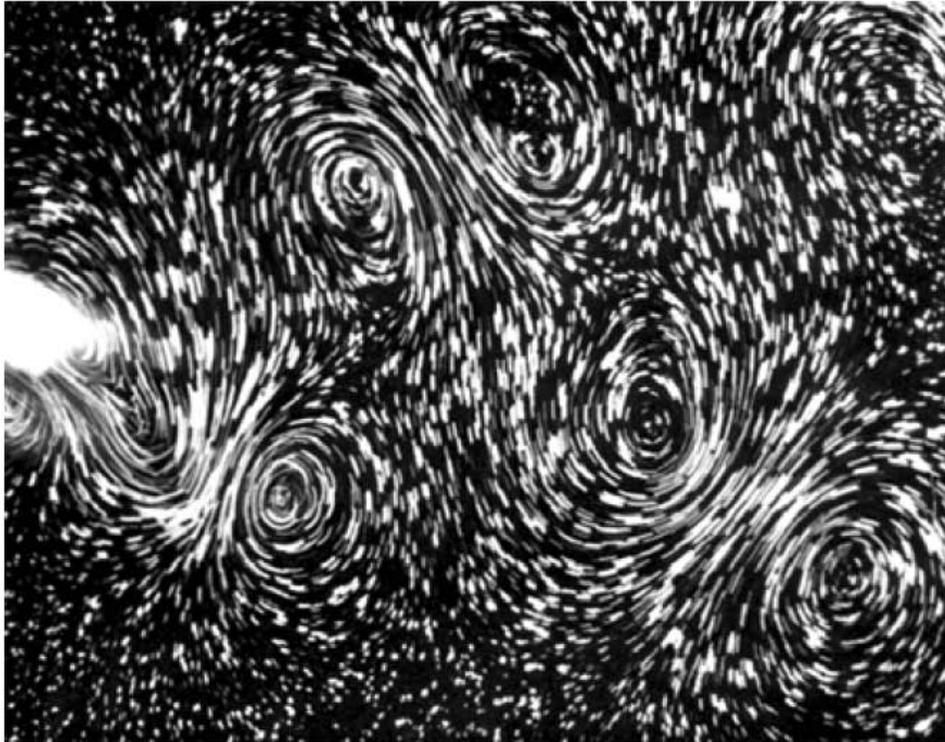


Figura 2.21: Modo de emissão 2P: (esquerda) visualização experimental de Williamson & Roshko (1988); e (direita) simulação numérica de Blackburn *et al.* (2000).

Modos de emissão: cilindro em movimento

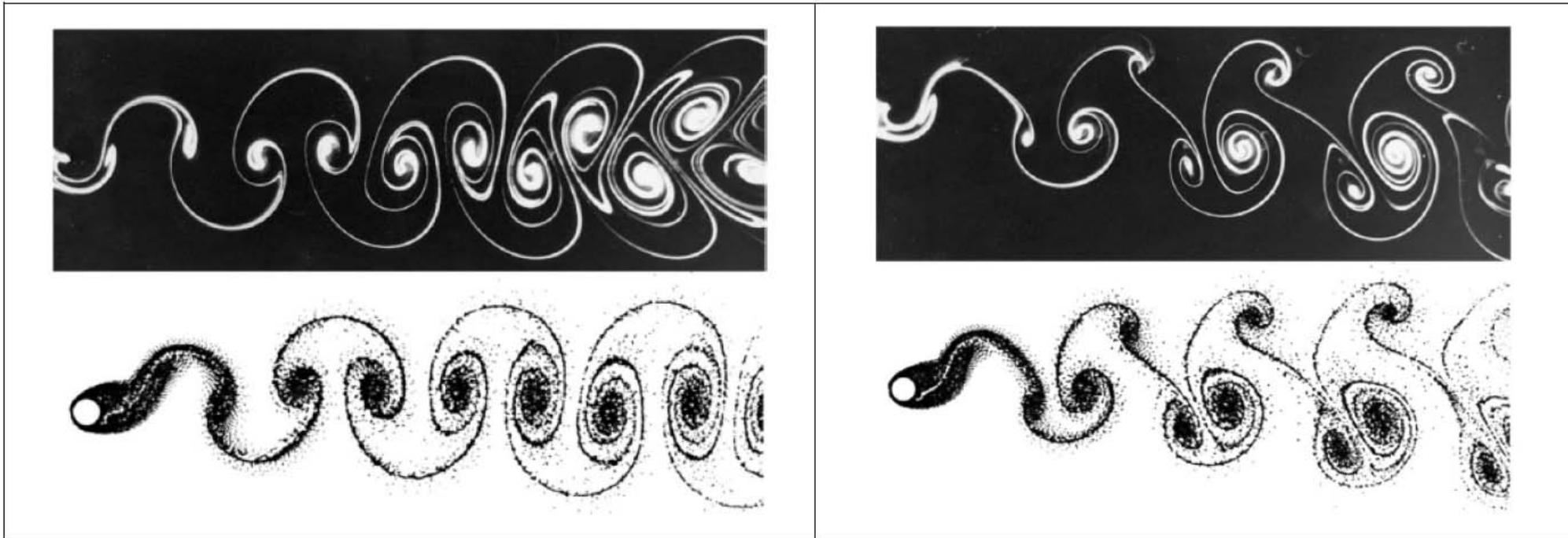


Figura 2.22: Modos de emissão: (esquerda) 2S; e (direita) P+S. Visualizações de Williamson & Govardhan (2004) e simulações numéricas de Meneghini & Bearman (1995).

Modos de emissão: cilindro em movimento

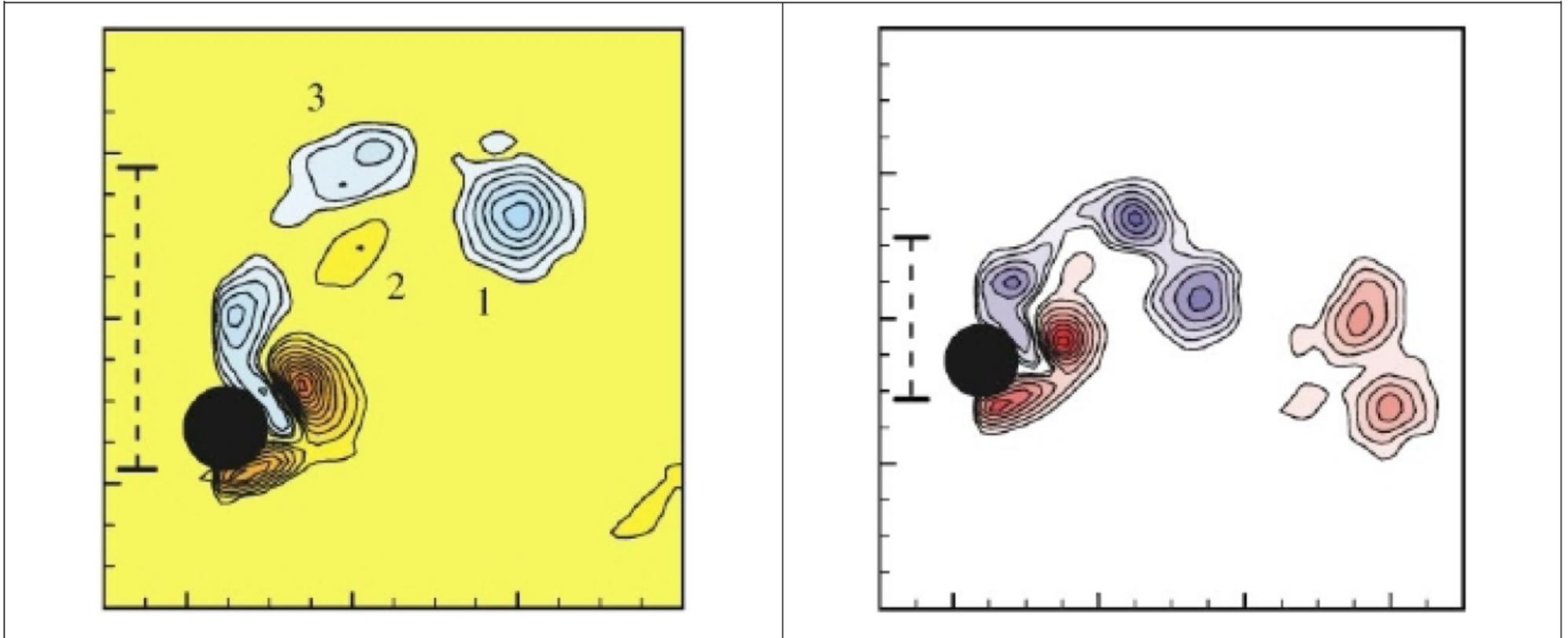
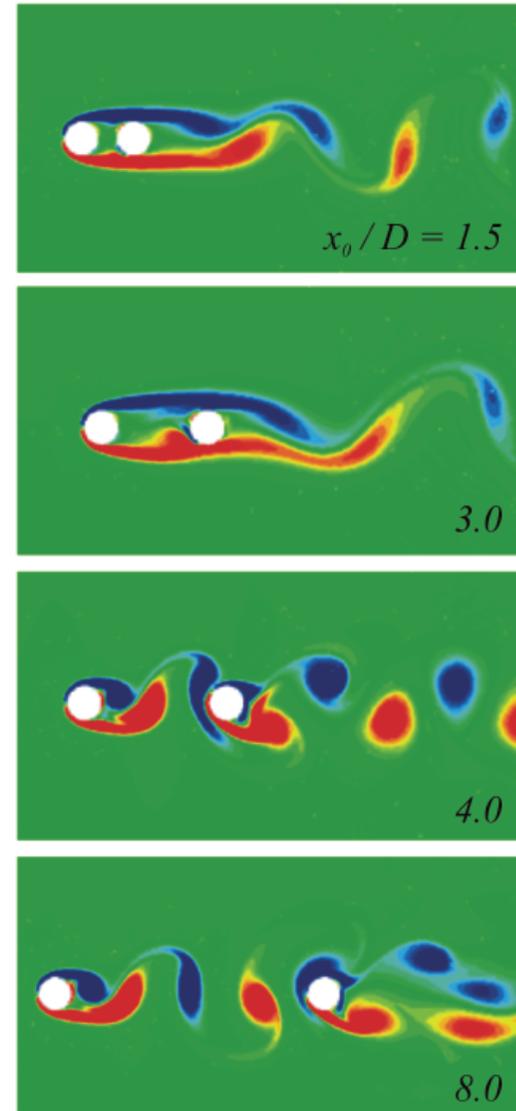
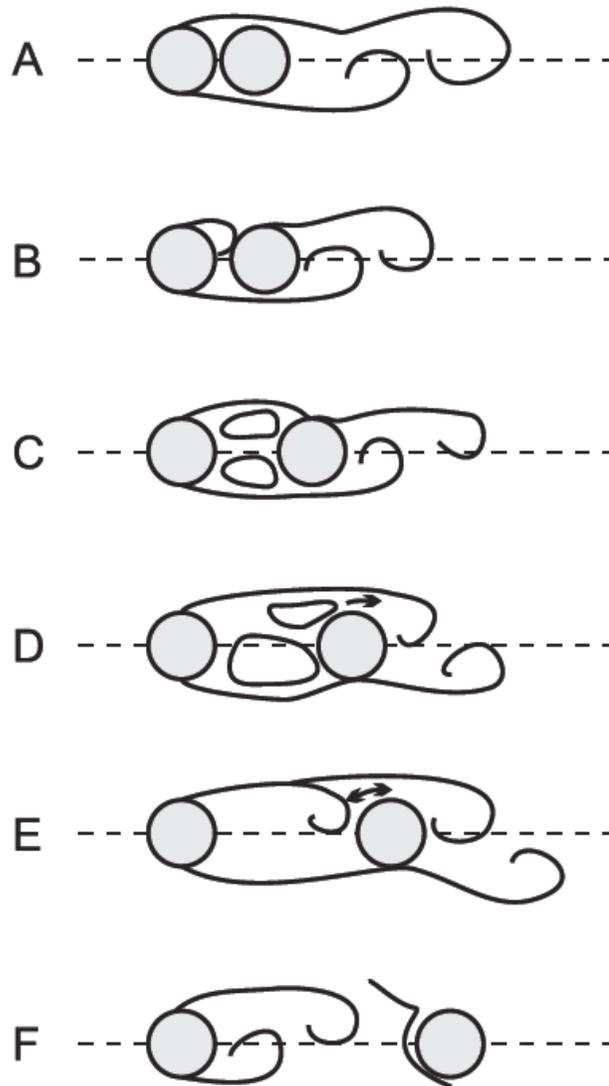
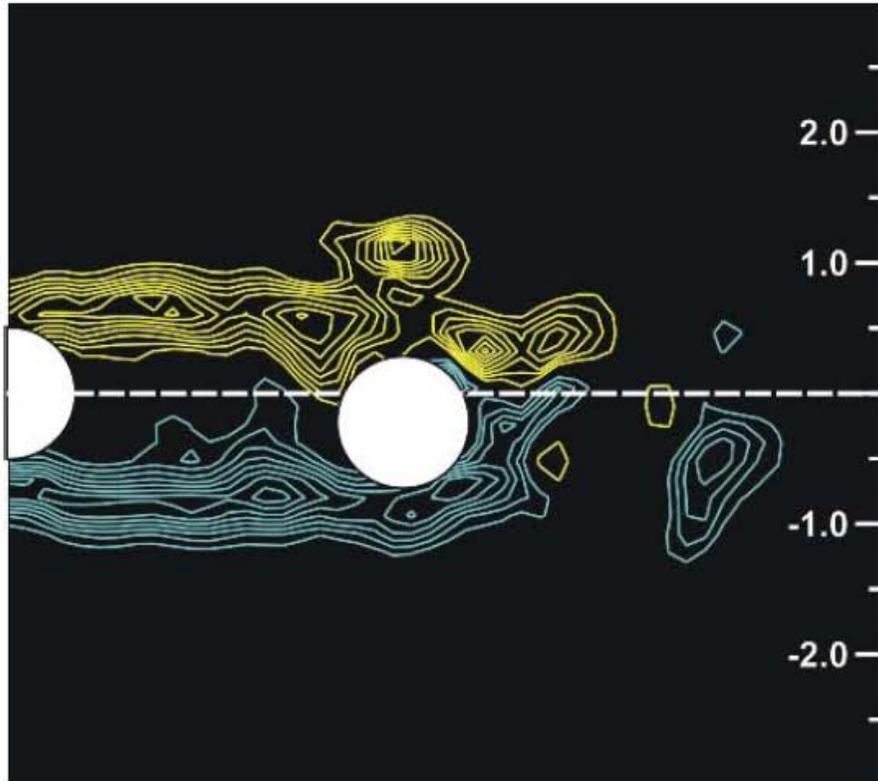


Figura 2.23: Modos de emissão: (esquerda) 2T; e (direita) 2C. Medições experimentais com PIV adaptadas de Williamson & Govardhan (2004).

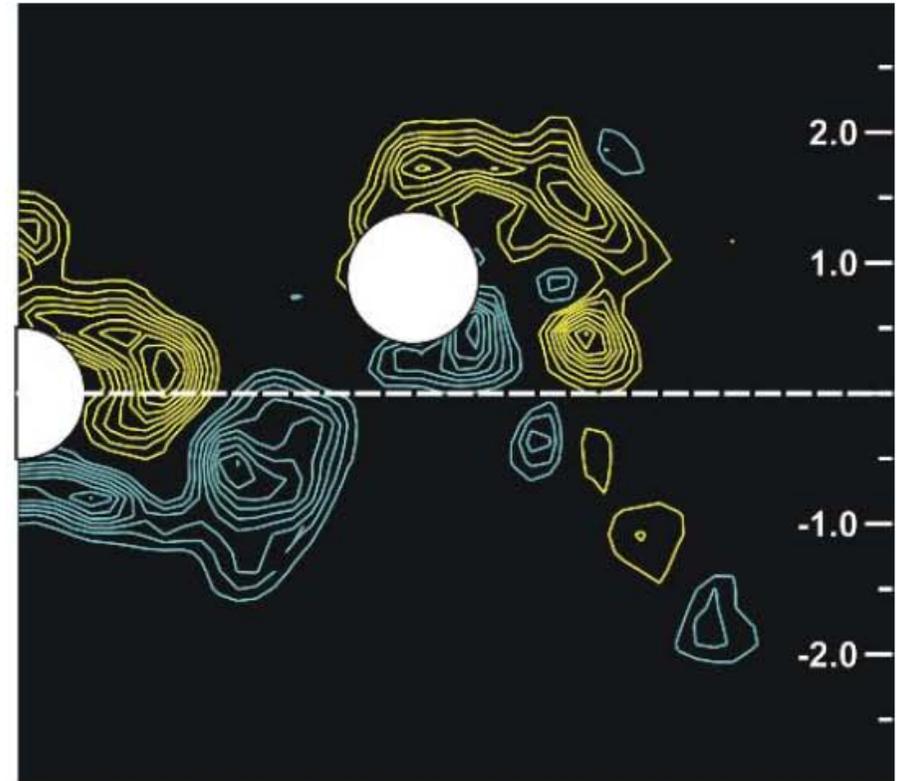
Efeitos de interferência



Efeitos de interferência



(a) $Re = 3200$, $\hat{y}/D = 0.2$.



(b) $Re = 7300$, $\hat{y}/D = 0.9$.

Interação Fluido Estrutura

