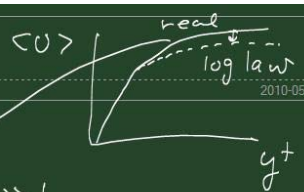
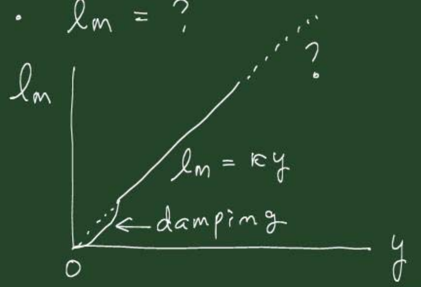
노트 제목 2010-05-19



- $l_m = ?$



In defect layer,

$$\left.\frac{\partial \langle U\rangle}{\partial y}\right|_{real} > \left.\frac{\partial \langle U\rangle}{\partial y}\right|_{log\ law}$$

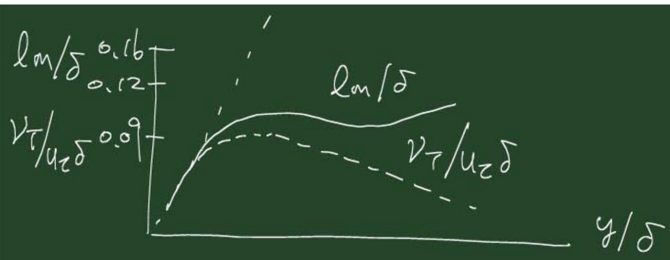
$$\tau < \tau_w \qquad\qquad \tau \simeq \tau_w$$

$\nu_T \left(= \tau \big/ \frac{\partial\langle U\rangle}{\partial y}\uparrow\right)$ is smaller than $u_\tau \kappa y$.

$$\nu_T = l_m^2 \frac{\partial\langle U\rangle}{\partial y} = (\kappa y)^2 \frac{u_\tau}{\kappa y} = u_\tau \kappa y$$

$\therefore$ $l_m < \kappa y$ in defect law

$\therefore$ $l_m = \min(\kappa y,\ 0.09\delta)$ Escudier (1966)



⊙ Overlap region reconsidered

log law $\quad \frac{\partial\langle U\rangle}{\partial y} \Big/ \frac{u_\tau}{y} \neq f\left(\frac{y}{\delta_\nu}\right)$

$= \text{const}$: universal indep. of Re.

But the Reynolds stresses depend on Re # in the overlap region

↓ alternative assump.

inner layer $u^+ = f_I(y^+)$ ~ may dep. on Re

outer layer $\dfrac{U_0 - \langle U \rangle}{u_0} = F_0(\eta)$, $\eta = y/\delta$

u_0 : velocity scale for outer layer
$\neq u_\tau$

in the overlap layer $(\delta_\nu \ll y \ll \delta)$
matching allows two ft. forms

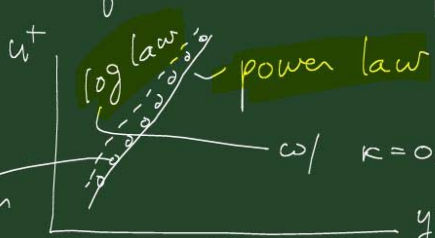
① log law, $u^+ = \frac{1}{\kappa} \ln y^+ + B$

② power law, $u^+ = C (y^+)^\alpha$

→ κ, B, C, α are allowed to depend on Re #.

if these are indep. on Re, laws are universal.

Fig 31



$\alpha = \dfrac{1.085}{\ln Re} + \dfrac{6.535}{(\ln Re)^2}$ ← $u_0 = U_0$

w/ $\kappa = 0.436$, $B = 6.13$ ← $u_0 = u_\tau$

data from Zagarola & Smits (1997)
$Re = 32 \times 10^3 \sim 30 \times 10^6$

the differences bet. the log law & power law are so small.

→ Controversy goes on.

◎ Reynolds-stress balances – skip

◎ Additional effects

- Mean press. gradient

Favorable press. grad. $\frac{dP_0}{dx} < 0$, $\frac{dU_0}{dx} > 0$

→ mean vel becomes steeper

$H = \delta^*/\theta$ decreases

c_f increases

Adverse press. grad. $\frac{dP_0}{dx} > 0$, $\frac{dU_0}{dx} < 0$

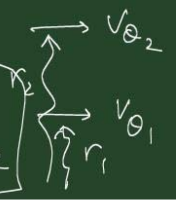
→ mean vel. becomes flattened

H increases

c_f decreases

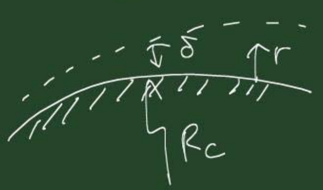
for strong $dP_0/dx > 0$, boundary layer separates.

- Surface curvature



$\boxed{\text{Rayleigh's circulation criterion: for } r_2 > r_1,\ (r v_\theta)^2|_2 > (r v_\theta)^2|_r \rightarrow \text{stable}}$

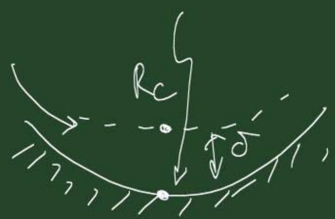
$\delta / R_c \simeq 0.01 \sim 0.1$



angular mtm increases with radius

→ stabilizing according to the Rayleigh's criterion.

→ reduction in $\langle u_i u_j \rangle$ & c_f compared to those in flat-plate bdry layer.

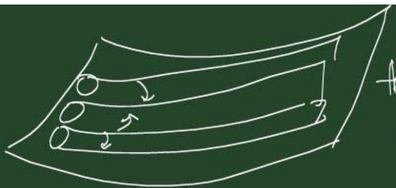


angular mtm decreases w/ radius.

→ destabilizing

→ longitudinal Taylor-Görtler vortices

→ $\langle u_i u_j \rangle$ and c_f increase.

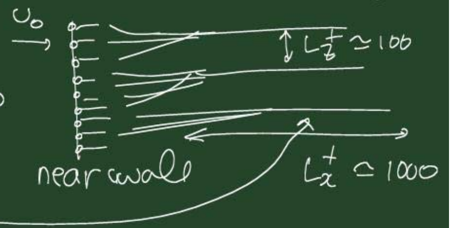


boundary layer

7.4 Turbulent structures

According to Kline & Robinson (1990) and Robinson (1991).

quasi - coherent structures in channel flow and boundary layer flow are



① low-speed streaks in $0 \le y^+ \le 10$

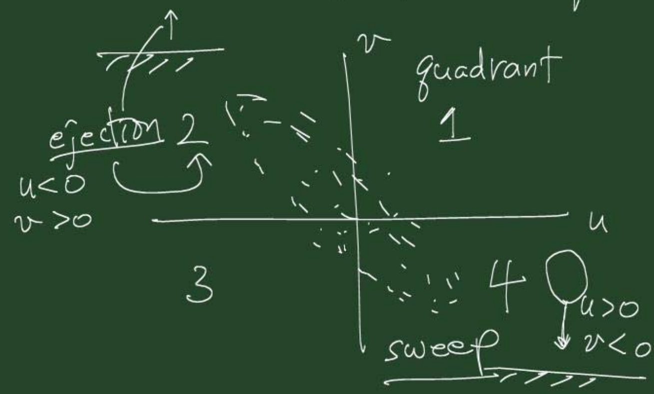
Kline et al. (1967)

② ejection of low-speed fluid from the wall

③ sweeps of high-speed fluid toward the wall

x-type probe : U & V

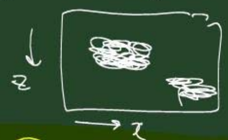
Quadrant analysis by Wallace et al. (1972)



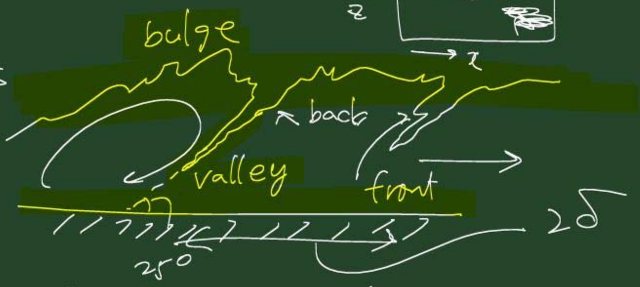
④ vortical structures

⑤ strong internal shear layers in $y^+ \le 80$

⑥ near-wall pockets

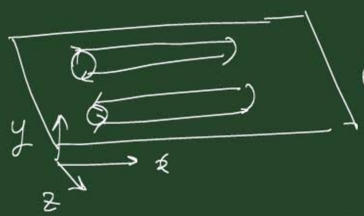


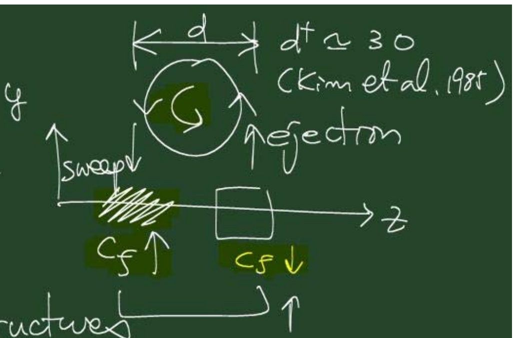
⑦ backs



⑧ large-scale motions in outer layer
(including bulges, superlayer, deep valleys of free-stream fluid.)

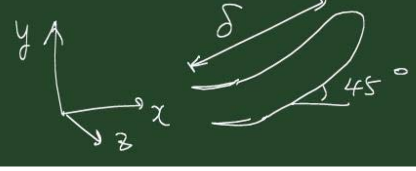
- streamwise vortices





→ are dominant vortical structures in the near-wall region ($y^+ < 100$)

- Horseshoe or hairpin vortices are dominant vortical structures in the outer layer.



- Large scale structures at $y \doteq 0.5\delta$
- Viscous superlayer at the edge of bdry layer.

* How to identify vortical structures?

Very important but difficult to define

numerical simulation $\longrightarrow$ $u_i(\underline{x}, t)$, $p(\underline{x}, t)$

- low pressure isosurface (Robinson) ~ associated w/ large-scale structures
- invariants of velocity-grad. tensor

  λ_2-method by Jeong & Hussain (1995)

  JFM, vol. 285, pp 69–

- proper orthogonal decomposition (POD)

  use two-pt. vel. corr.

  → indentify motions which contain most energy.

  Berkooz et al. (1993)