노트 제목 2010-03-25

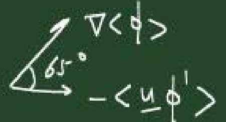
$\langle u_j \phi' \rangle = -\Gamma_T \nabla \langle \phi \rangle$

$-\rho \langle u_i u_j \rangle + \frac{2}{3} \rho k \delta_{ij} = 2 \rho \nu_T \langle S_{ij} \rangle$

- $\langle u_j \phi' \rangle$ is aligned with mean scalar gradient vector $\nabla \langle \phi \rangle$.

  $\rightarrow$ This is not true even in simple turb. flow.

  e.g. angle bet $\nabla \langle \phi \rangle$ and $-\langle \underline{u} \phi' \rangle$ is $65°$ in homo. turb. shear flow.



- $a_{ij} = -\rho \langle u_i u_j \rangle + \frac{2}{3} \rho k \delta_{ij} \sim \langle S_{ij} \rangle$

  proportional coeff. $\rightarrow$ scalar for 6 different componen-nts

  ν_T

  $\underline{b} = \begin{bmatrix} \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot \end{bmatrix} \underline{c}$ not true even in simple shear flow.

  $\underset{\sim}{b} = \alpha \underset{\sim}{c}$

- In 2D turb. boundary layer flow, important flow variables are $\langle u_1 u_2 \rangle$ and $\langle u_2 \phi' \rangle$.

  $\langle u_2 \phi' \rangle = -\Gamma_T \frac{\partial \langle \phi \rangle}{\partial x_2}$

  $\underbrace{\langle u_1 u_2 \rangle}_{\text{scalar}} = -\nu_T \underbrace{\frac{\partial \langle U_1 \rangle}{\partial x_2}}_{\text{scalar}}$ $\therefore$ scalar

  $\therefore$ not bad.

- If ν_T and Γ_T are properly modeled, the mean eqs can be solved.
- At high Re number and away from the wall,

  $$\frac{\nu_T}{\nu} \text{ and } \frac{\Gamma_T}{\Gamma} \sim Re \gg 1.$$

  ∴ molecular transport is negligible.
- $\sigma_T = \dfrac{\nu_T}{\Gamma_T}$: turbulent Prandtl number

  In most simple turb. flows, $\sigma_T \sim O(1)$. $Pr = 1$

✓ $\dfrac{\partial u}{\partial t} + \dfrac{\partial}{\partial x_j}(u_j u) = -\dfrac{1}{\rho}\dfrac{\partial p}{\partial x} + \nu \nabla^2 u$ if $\dfrac{\partial p}{\partial x} \doteq 0$ & $\nu = \Gamma$,

✓ $\dfrac{\partial \phi}{\partial t} + \dfrac{\partial}{\partial x_j}(u_j \phi) = \Gamma \nabla^2 \phi$ $\quad u \doteq \phi$ ∴ Similarity Let. u & ϕ

J Question

$$\frac{D\langle U\rangle}{Dt} = -\frac{1}{\rho}\frac{\partial\langle p\rangle}{\partial x} + \nu\nabla^2\langle U\rangle - \frac{\partial\langle u^2\rangle}{\partial x} - \frac{\partial\langle uv\rangle}{\partial y}$$

$\ll$

$\leftarrow \dfrac{\partial}{\partial x} \ll \dfrac{\partial}{\partial y}$

$u \sim v$

$$\frac{D\langle\phi\rangle}{Dt} = - \frac{\partial\langle u\phi'\rangle}{\partial x} - \frac{\partial\langle v\phi'\rangle}{\partial y}$$

$\langle U\rangle \gg \langle V\rangle$

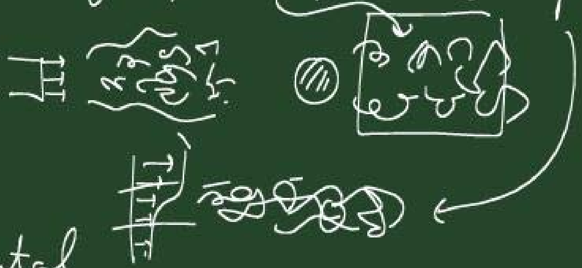
$\ll$

∴ $\langle uv\rangle$ & $\langle v\phi'\rangle$ are important.

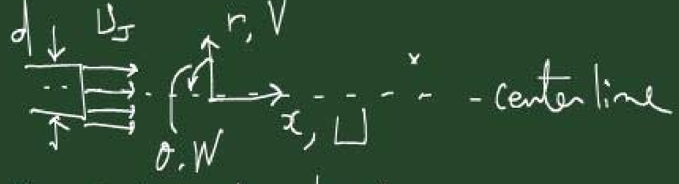
Ch 5. Free shear flows → jet, wake, mixing layer

"free" ?

→ remote from wall



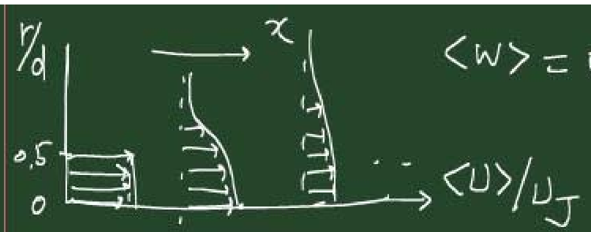
5.1 Round jet : experimental observations



statistically stationary, axisymmetric

U_J : jet-exit velocity

- $Re = U_J d/\nu$
- nozzle (jet) details.

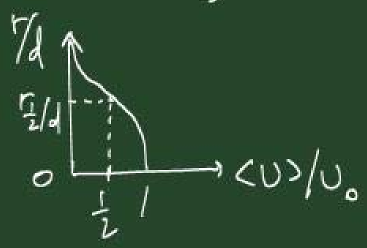


$\langle W \rangle = 0$, $\langle V \rangle \ll \langle U \rangle$

$U(x, r, \theta, t)$

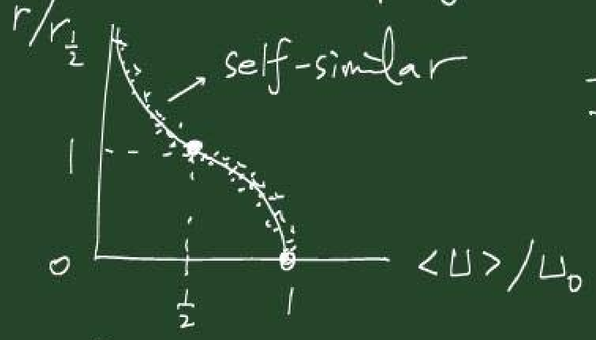
- Centerline velocity : $U_0(x) = \langle U(x, r=0, \theta=0, t) \rangle$

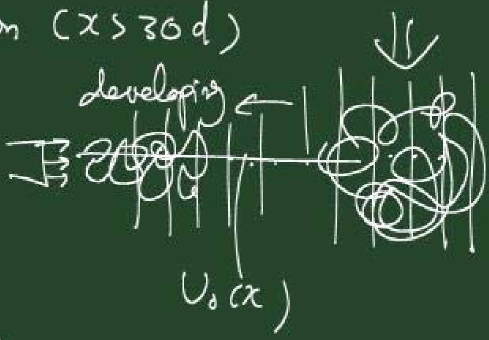
Jet half-width $r_{\frac{1}{2}}(x)$: $\langle U(x, r=r_{\frac{1}{2}}(x), \theta=0, t) \rangle = \frac{1}{2} U_0(x)$



As x increases,
jet decays (i.e. $U_0(x)$ decreases)
& jet spreads (i.e. $r_{\frac{1}{2}}(x)$ increases)

• Beyond the developing region ($x > 30d$)





self-similarity : important concept in turbulent flow

consider a quantity $Q(x, y)$

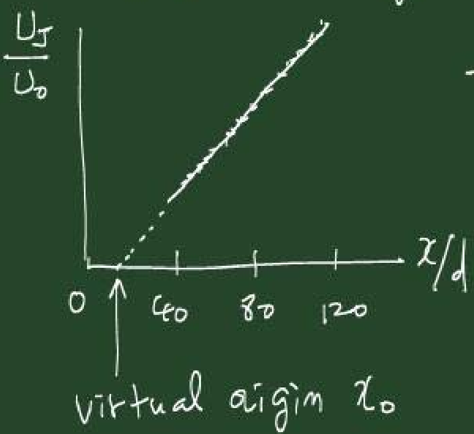
characteristic scales $Q_0(x)$ and $\delta(x)$

Define $\xi = y/\delta(x)$

$$\tilde{Q}(\xi, x) \equiv Q(x, y)/Q_0(x)$$

If $\hat{Q}(\xi, x) = \hat{Q}(\xi)$, $Q(x,y)$ is self-similar.

• Axial variation of scales



$$\rightarrow \frac{U_0(x)}{U_J} = \frac{B}{(x - x_0)/d}$$

B ← empirical constant