노트 제목 2010-05-25

- Ch. 8 Introduction to modelling & simulation
- Ch. 9 Direct numerical simulation (DNS)
- Ch. 13 Large Eddy simulation (LES)
  - → I will use my note not following the textbook

Ch. 10 Turbulent-viscosity models.

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Ch. 12 "

→ I will use another book + my note.

Turbulence models & their application in hydraulics by W. Rodi

- CFD (computational fluid dynamics) is an important tool in design of fluid system.
- Rapid development of (super)computer capacity in 1990, CRAY C90 —— PC CPU chip nowadays.

⇒ turbulent-flow study

$$\frac{\partial u_i}{\partial t} + \frac{\partial}{\partial x_j} u_i u_j = -\frac{\partial p}{\partial x_i} + \frac{1}{Re} \nabla^2 u_i$$

Reynolds averaging : $u_i = \overline{u_i} + u_i'$

inst. mean flucts.

$$\rightarrow \overline{\frac{\partial}{\partial x_j} u_i u_j} = \frac{\partial}{\partial x_j}\overline{u_i u_j} = \frac{\partial}{\partial x_j}\bar{u}_i \bar{u}_j + \frac{\partial}{\partial x_j}\overline{u_i' u_j'}$$

↑ closure problem

$$\begin{cases} \dfrac{\partial \bar{u}_i}{\partial t} + \dfrac{\partial}{\partial x_j}\bar{u}_i \bar{u}_j + \dfrac{\partial}{\partial x_j}\overline{u_i' u_j'} = -\dfrac{\partial \bar{p}}{\partial x_i} + \dfrac{1}{Re}\nabla^2 \bar{u}_i \\ \dfrac{\partial \bar{u}_i}{\partial x_i} = 0 \end{cases}$$

↘ RANS (Reynolds-averaged N-S eqs).

Solve for $\bar{u}_i$ & $\bar{p}$.

$\overline{u_i' u_j'}$ should be modeled w/ $\bar{u}_i$ and their grads.
→ Ch. 10 ~ ch. 12

DNS, LES, RANS

◎ Direct numerical simulation (DNS)

↳ without using any turbulence model

- No turbulence model
  → unsteady, 3-dimensional Navier-Stokes eq.

$$\begin{cases} \dfrac{\partial u_i}{\partial x_i} = 0 \\ \dfrac{\partial u_i}{\partial t} + \dfrac{\partial}{\partial x_j} u_i u_j = -\dfrac{\partial p}{\partial x_i} + \dfrac{1}{Re} \nabla^2 u_i \end{cases} \qquad \underline{\underline{i = 1, 2, 3}}$$

→ 4 eqs, 4 unknowns (u_i & p)

unsteady 3-dimensional simulation

→ requires big CPU time & memory.

→ requires **efficient** numerical scheme!

10 min. ↓ 50 min.

1 month ↓ 5 months.

Steady N-S. → SIMPLE algorithm by Patankar

SIMPLER

SIMPLEST

SIMPLEX

⋮

↓

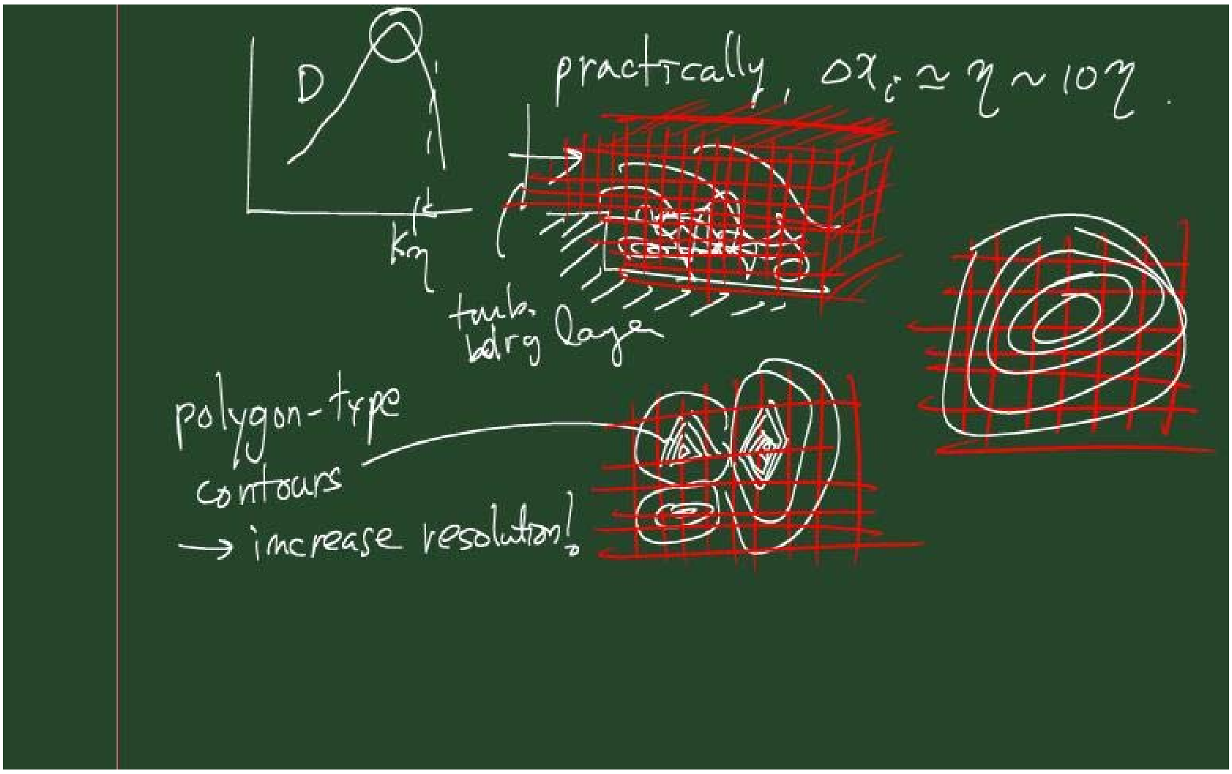
unsteady N-S → fractional step method by Kim & Moin (1985) JCP

- Resolution requirement.

  Mesh size $\Delta x_i < \eta$ (Kolmogorov length scale)

  to resolve smallest eddy motion

  → provide accurate dissipation.


D
k_η
practically, $\Delta x_i \simeq \eta \sim 10\eta$.
turb. bdry layer
polygon-type contours
→ increase resolution!