Introduction of the FLUID DYNAMICS

Takanori UCHI DA

Research Institute for Applied Mechanics (RIAM),
Kyushu University,
6-1 Kasuga-koen, Kasuga-city, Fukuoka 816-8580, JAPAN
What is Fluid? What is Flow?

◆ Let us first define
  What a **fluid**? and What is **flow**?

◆ A liquid, gas, air, and blood etc is all **fluid**.

◆ **Flow** is the continuous movement of a fluid from one place to another.
What is Laminar Flow?

What is Turbulent Flow?

- Smoke rising from cigarette
- Rapid
- Laminar flow
- Turbulent flow
- Transition
- Laminar flow
- Turbulent flow
What is Incompressible?

Incompressible: Neither compression nor the expansion are done, and the density (mass) does not change.

What is Viscous?

Viscosity: All the existing fluids (water and air etc) have the character of the viscosity.
What is Bluff Body Flow? ①

Alternate vortex street

Karman vortex street behind a cylinder placed in uniform flow. Re ~ 300 [Courtesy: Sadatoshi Taneda; from An Album of Fluid Motion by Van Dyke (1982)]
Credit: Jeff Schmaltz

Low-level winds rushing over the Cape Verde Islands off the coast of northwestern Africa created cloud vortex streets, as seen in this true-color Terra MODIS image from January 5, 2005. The vortex streets tend to create patterns of swirls and curves in a roughly symmetrical pattern, though as can be seen here, the lower vortex street is much more disorganized - to the point that the typical features are almost unrecognizable. Cloud vortices are also known as von Karman vortices.
COMPLEX Turbulent Flow

KEY WORDS: UNSTEADY, THREE-DIMENSIONAL

Man made structure
(such as vehicle, building etc)

God made structure
(such as terrain, topography etc)

Bluff Body Flow
Classification of FLUID DYNAMICS

★ **Computational Fluid Dynamics**
We try to clarify flow by using computer.

★ **Experimental Fluid Dynamics**
We try to clarify flow by using wind tunnel or towing tank.

★ **Theoretical Fluid Dynamics**
We try to clarify flow analytically.
Choice of the Numerical Method and Turbulence Model

Phase 1
Which numerical method is chosen?

- **FDM** (Finite Difference Method)
- **FVM** (Finite Volume Method)
- **FEM** (Finite Element Method)

Phase 2
Which turbulence model is chosen?

- **DNS** (Direct Numerical Simulation)
- **LES** (Large Eddy Simulation)
- **RANS** (Reynolds Averaged Navier-Stokes eq.)
Idea of FDM

① Governing equation
\[
\frac{d^2 T}{dx^2} = 0
\]

② Difference equation
\[
\frac{T_{i+1} - 2T_i + T_{i-1}}{\Delta x^2} = 0
\]

③ Simultaneous algebraic equations
\[
\begin{bmatrix}
1 & 0 & 0 & 0 & 0 & 0 \\
1 & -2 & 1 & 0 & 0 & 0 \\
0 & 1 & -2 & 1 & 0 & 0 \\
0 & 0 & 1 & -2 & 1 & 0 \\
0 & 0 & 0 & 1 & -2 & 1 \\
0 & 0 & 0 & 0 & 1 & 0
\end{bmatrix}
\begin{bmatrix}
T_1 \\
T_2 \\
T_3 \\
T_4 \\
T_5 \\
T_6
\end{bmatrix}
= \begin{bmatrix}
100 \\
0 \\
0 \\
0 \\
0 \\
0
\end{bmatrix}
\]

④ Solving a procession
- Direct method: Gauss elimination method
- Iteration method: Jacobi method, Gauss-Seidel method, SOR method etc

⑤ Obtaining solution
\[T_2=80^\circ C, \ T_3=60^\circ C, \ T_4=40^\circ C, \ T_5=20^\circ C\]
The RIAM-COMPACT is based on Large-Eddy Simulation (LES) Technique.

In LES, large-scale turbulent motion is computed explicitly, and only the effect of the small-scale motion has to be modeled.