

## WEEK 6: COMPUTATIONAL FLUID DYNAMICS

### INTRODUCTION:

- **What is Computational Fluid Dynamics (CFD)?**
  - The Navier-Stokes equations can be discretized (numerically solved) by a discretization method to approximate the differential equations by a system of algebraic equations which can be solved on a computer. There are mainly three discretization techniques:
    - Finite Difference Method (FDM)
    - Finite Volume Method (FVM)
    - Finite Element Method (FEM)
  
- **Purpose of this course**
  - *To provide a background in the mathematical principles of governing equations used in CFD*
  - To provide a greater understanding of the mathematical simplifications and assumptions that can be used in CFD problems
  - *To achieve understanding of CFD results in comparison with the theoretical results and experimental data from engineering point of view*
  
- **What are the advantages of CFD?**
  - *Low cost*
  - *High speed*
  - *Complete and detailed information provided*
  - *Ability to simulate realistic physical flow conditions*

- **What are the disadvantages of CFD?**

- *Not enough physical models to compare*
- *Success relies on the validity of the mathematical model*
- *Numerical errors*
- *Round-off errors*
- *Truncation errors*
- *Unrealistic boundary conditions imposed*

- **Mathematical description of fluid flow problem**

CFD relies on the following three fundamental physical principles:

- *Conservation of mass*
  - *Conservation of momentum*
  - *Conservation of energy*
- Hence the fundamental governing equations of fluid dynamics are based on three physical principals which are:*

- *Continuity equation*
- *Momentum equation*
- *Energy equation*

*When the fundamental physical principals are applied to an infinitesimal fluid element, the governing partial differential equations of fluid dynamics are obtained.*

- **Non-conservative form vs conservative form**

- *Integral form, conservation form: Fixed control volume, fixed in space*
- *Integral form, non-conservative form: finite fixed control volume, mass moving with the flow*
- *Differential form, conservation form: Infinitely small fluid element, fixed in space*
- *Differential form, non-conservation form: Infinitely small fluid element of fixed mass moving with the fluid flow.*

- **Methods of prediction**

The fluid flow phenomena can be predicted through three different methods:

- *Experimental methods:*

- *These are actual measurements.*
- *The performance of a full-scale prototype system can be analyzed with the experimental measurements.*
- *However, cheaper small-scale performance tests are also available through experimental measurements*

- *Theoretical methods:*

- *A fluid flow phenomena can be mathematically modelled by a set of differential equations*
- *A closed form mathematical description of fluid flow can be achieved for some physical situations.*

- *Numerical methods:*

- *Numerical computation of complex flow phenomena is now possible through high speed computers*
- *A set of differential equations can be simultaneously solved to predict the flow fields*
- *Both accuracy and reliability are the issues in resolution of a numerical problem*
- *Results are compared with the experimental and/or theoretical results for a validation purpose*

**References:**

1. Aksel, M.H., 2016, "Notes on Fluids Mechanics", Vol. 1, METU Publications
2. Versteeg H.K., and W. Malalasekera V., 1995, "Computational Fluid Dynamics: The Finite Volume Method", Longman Scientific & Technical, ISBN 0-582-21884-5