ENE 503 – Computational Fluid Dynamics

WEEK 1: INTRODUCTION

<u>INTRODUCTION:</u>

- **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