Fluid Flow Classifications

What Are Fluids? – Lesson 3

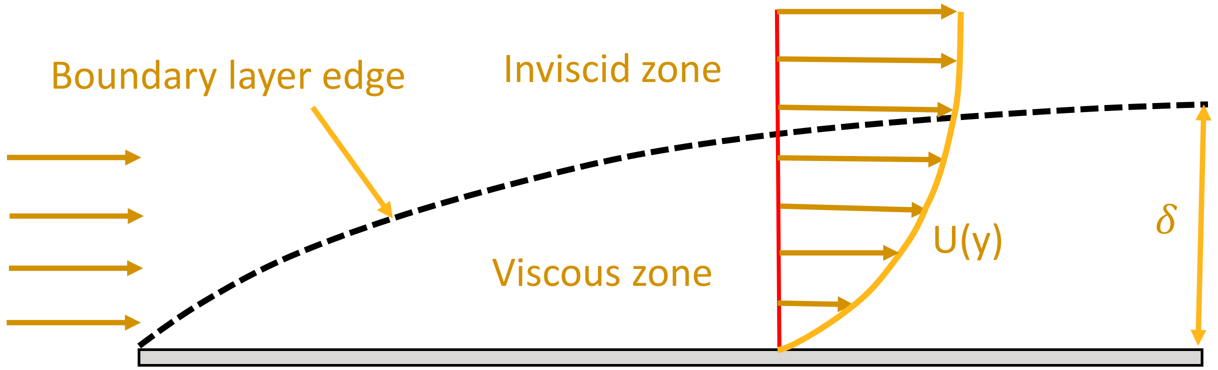
Ansys

Fluid Statics versus Fluid Dynamics

- Fluids can be at rest or in motion.
- Fluid statics is the study of fluids at rest (no motion).
  - Fluid statics is commonly referred to as hydrostatics.
- Fluid dynamics is the study of fluids in motion.
  - Fluid dynamics of liquids is called hydrodynamics.
  - Fluid dynamics of compressible gases is called gas dynamics.

Unsteady versus Steady Flow

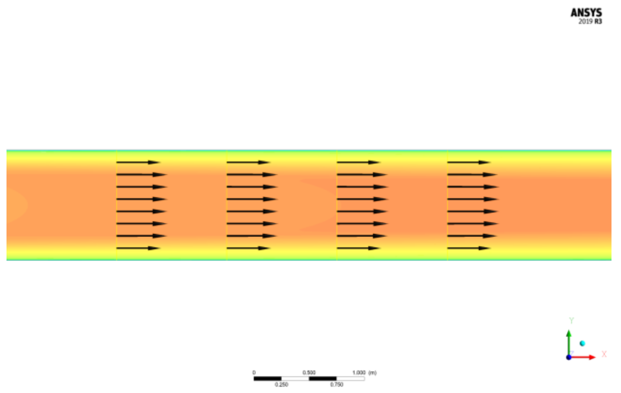
- Nearly all fluid motions observed in nature are inherently unsteady (time dependent).
  - Fluid unsteadiness exists at a range of scales from very tiny to macroscopic. The random, mixed motion we often observe is called turbulence.
- In many cases, we can ignore (or model) small-scale unsteadiness and consider the fluid motion as only a function of space. Fluid motion is time-independent: velocity, pressure, and temperature do not change with time at a given point. This is the steady-state assumption.
- For the purpose of modeling fluid motion, the steady-state assumption can be used to obtain useful and practical engineering solutions.
  - Effects of turbulence can be modeled so that the simplified steady-state solution yields accurate results for skin friction and heat transfer. We will discuss this topic in more detail later in this course.



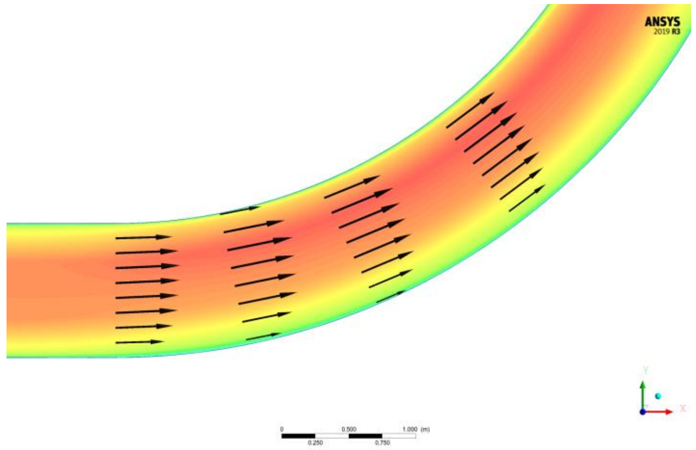
Steady-state boundary layer model for flow over a flat plate

Uniform versus Non-Uniform Flow

- Uniform Flow is a fluid flow in which characteristics and parameters remain unchanged with distance along the flow path.
  - A steady flow through a long straight pipe of a constant diameter is an example of uniform flow.
- Non-uniform Flow is a flow in which characteristics and parameters vary and are different at different locations along the flow path.
  - A steady flow through a pipe with bends or a pipe with a variable diameter exemplifies a non-uniform flow.



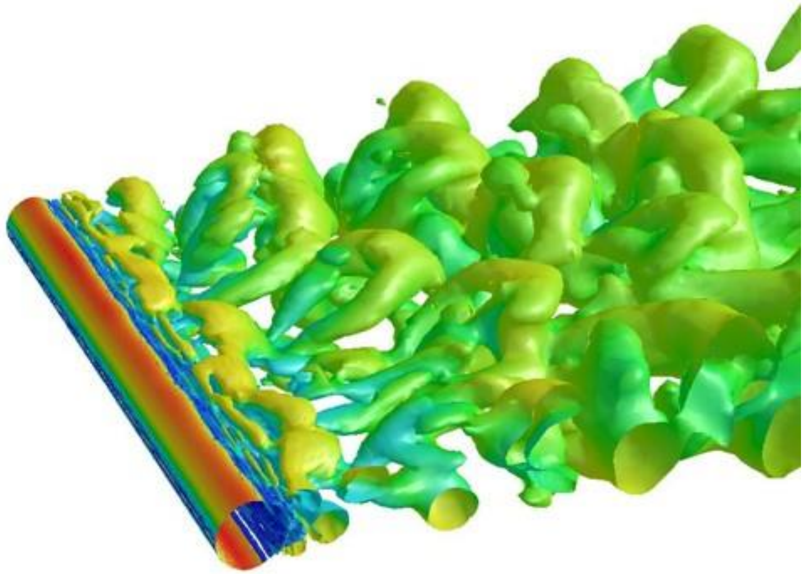
Uniform Flow



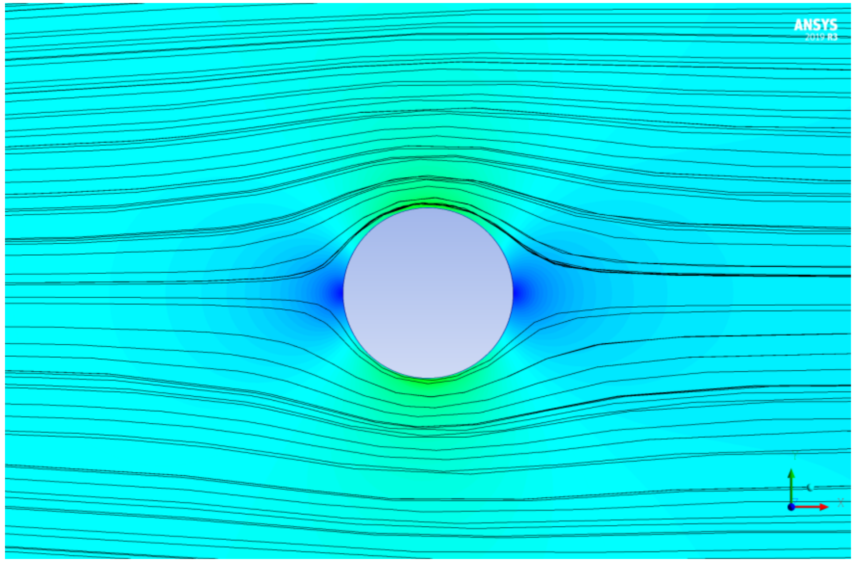
Non-uniform Flow

Rotational versus Irrotational Flow

- Rotation flow is a fluid flow in which fluid particles moving along the flow path also rotate about their respective axes.
- Irrotational flow is flow in which fluid particles moving along the flow path do not undergo rotation.



Rotational flow

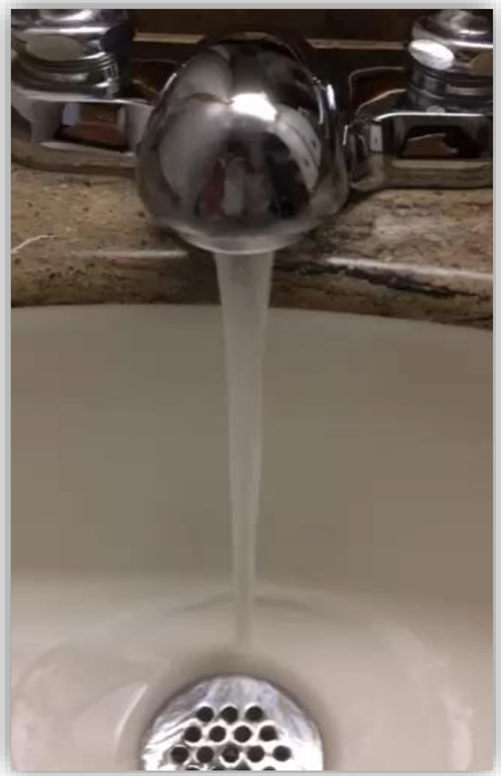


Irrotational flow

Laminar versus Turbulent Flow

- Laminar Flow
  - At low speeds, fluid particles move in a smooth, layered fashion (“lamina”).
  - The flow appears uniform with no substantial mixing of the fluid. This is laminar flow.
- Turbulent Flow
  - At higher speeds, fluid particles begin to exhibit random fluctuations and move in a chaotic, “tangled” fashion.
  - Flow appears non-uniform and significant mixing of fluid occurs. This is turbulent flow.
- Fluid flow can undergo a transition from laminar to turbulent flow such that both states of fluid motion are observed. Knowing where this transition occurs is a challenging question in fluid mechanics.

Laminar flow

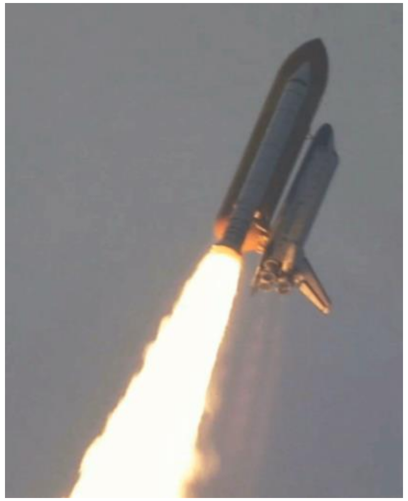


Turbulent flow

Incompressible versus Compressible Flow

- Incompressible Flow – In an incompressible flow, the volume of a given fluid parcel does not change (compress).
  - This implies that density is uniform throughout the fluid.
  - It is a reasonable assumption for all liquid flows and low-speed gas flows.
- Compressible Flow – In a compressible flow, the volume of a given fluid parcel can change (compress) with position.
  - This implies that density will vary throughout the fluid, usually in accordance with a thermodynamic equation of state.
  - Compressible flows are further classified according to speed of fluid relative to the speed of sound waves. This ratio is non-dimensional and is called the Mach number (Ma).
    - For Ma < 1, the flow is subsonic. Pressure waves in the flow can propagate in all directions.
    - For Ma > 1, the flow is supersonic. Pressure waves can compress to form shock waves, which propagate in the downstream direction only.

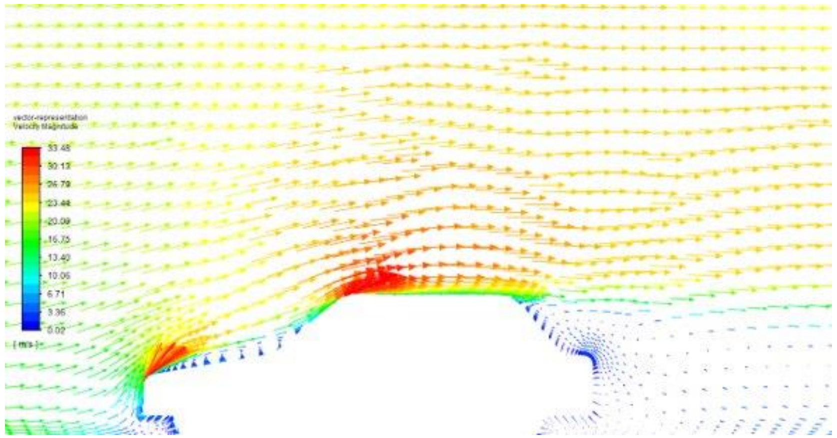
Incompressible flow



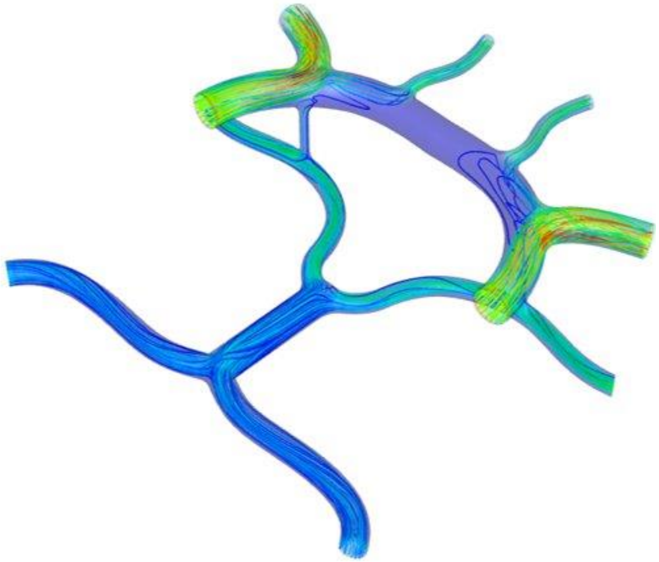
Compressible flow

Flow Configurations

- External Flow
  - An external flow is defined here as a flow over an object in an unconfined domain.
  - Viscous effects are typically important only in the vicinity of the object. Away from the object, the flow is essentially inviscid.
  - Examples: flow over aircraft, projectiles, ground vehicles.
- Internal Flow
  - An internal flow is defined as a flow which is confined by walls, partitions. and other boundaries.
  - Viscous effects in this case extend across the entire passage
  - Examples: flow in pipes, ducts, enclosures, nozzles.



External flow over a sedan



Internal flow through the Circle of Willis, a joining area of several arteries at the bottom side of the brain

Summary

- We have examined some characteristics of fluid motion, and how flows exhibit different behavior based on:
  - Steady-state versus unsteady
  - Uniform and non-uniform flows
  - Rotational and irrotational flows
  - Incompressible versus compressible flow
  - Laminar versus turbulent flow
  - Flow geometry and configuration (external versus internal flows)

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