FLUID MECHANICS FOR MECHANICAL ENGINEERING (ME 208F)

Section D:
Turbulent Flow - I

TURBULENT FLOW IN PIPES

- Most flows encountered in engineering practice are turbulent, and thus it is important to understand how turbulence affects wall shear stress.
- However, turbulent flow is a complex mechanism. The theory of turbulent flow remains largely undeveloped.
- Therefore, we must rely on experiments and the empirical or semi-empirical correlations developed for various situations.

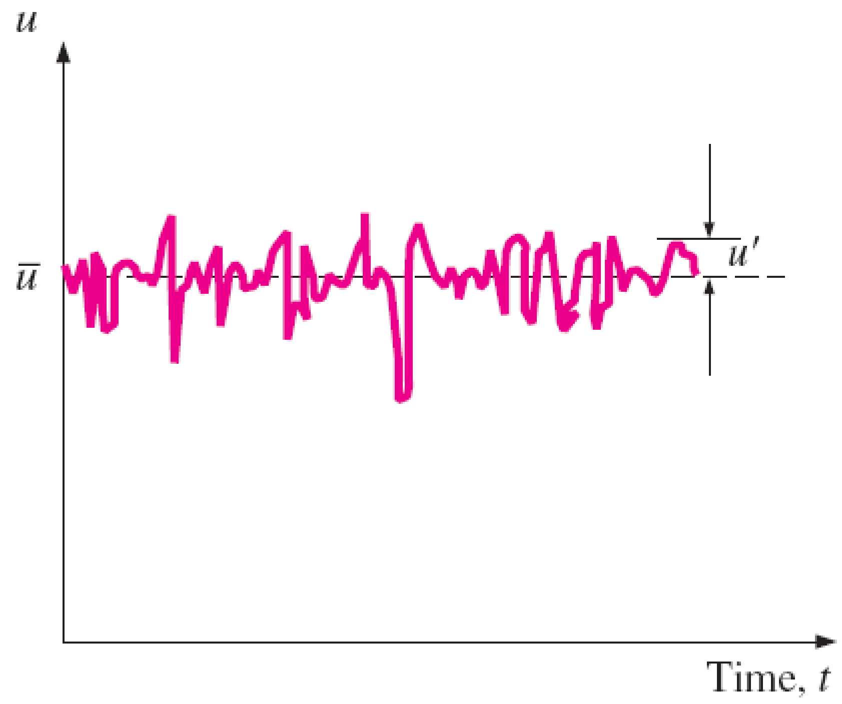
TURBULENT FLOW IN PIPES

- Turbulent flow is characterized by *random* and *rapid fluctuations* of swirling regions of fluid, called **eddies,** throughout the flow.
- These fluctuations provide an additional mechanism for momentum and energy transfer.
- In laminar flow, momentum and energy are transferred across streamlines by molecular diffusion.
- In turbulent flow, the swirling eddies transport mass, momentum, and energy to other regions of flow much more rapidly than molecular diffusion, such that associated with much higher values of friction, heat transfer, and mass transfer coefficients.

TURBULENT FLOW IN PIPES

- Even when the average flow is steady, the eddy motion in turbulent flow causes significant fluctuations in the values of velocity, temperature, pressure, and even density (in compressible flow).
- We observe that the instantaneous velocity can be expressed as the sum of an *average value* $\overline{u}$ and a *fluctuating component* u',

$$u = \overline{u} + u'$$



TURBULENT FLOW IN PIPES

- The average value of a property at some location is determined by averaging it over a time interval that is sufficiently large so that the time average levels off to a constant. $\Rightarrow$ $\overline{u'} = 0.$
- The magnitude of u' is usually just a few percent of $\overline{u}$, but the high frequencies of eddies (in the order of a thousand per second) makes them very effective for the transport of momentum, thermal energy, and mass.
- The shear stress in turbulent flow can not be analyzed in the same manner as did in laminar flow. Experiments show it is much larger due to turbulent fluctuation.

TURBULENT FLOW IN PIPES

- The turbulent shear stress consists of two parts: the *laminar component,* and the *turbulent component,*

$$\tau_{\text{total}} = \tau_{\text{lam}} + \tau_{\text{turb}}$$

- The velocity profile is approximately parabolic in laminar flow, it becomes flatter or “fuller” in turbulent flow.
- The fullness increases with the Reynolds number, and the velocity profile becomes more nearly uniform, however, that the flow speed at the wall of a stationary pipe is always zero (no-slip condition).