FLUID MECHANICS FOR MECHANICAL ENGINEERING (ME 208F)

Section C:
Viscous Flow - I

Flow Characteristics in Pipes

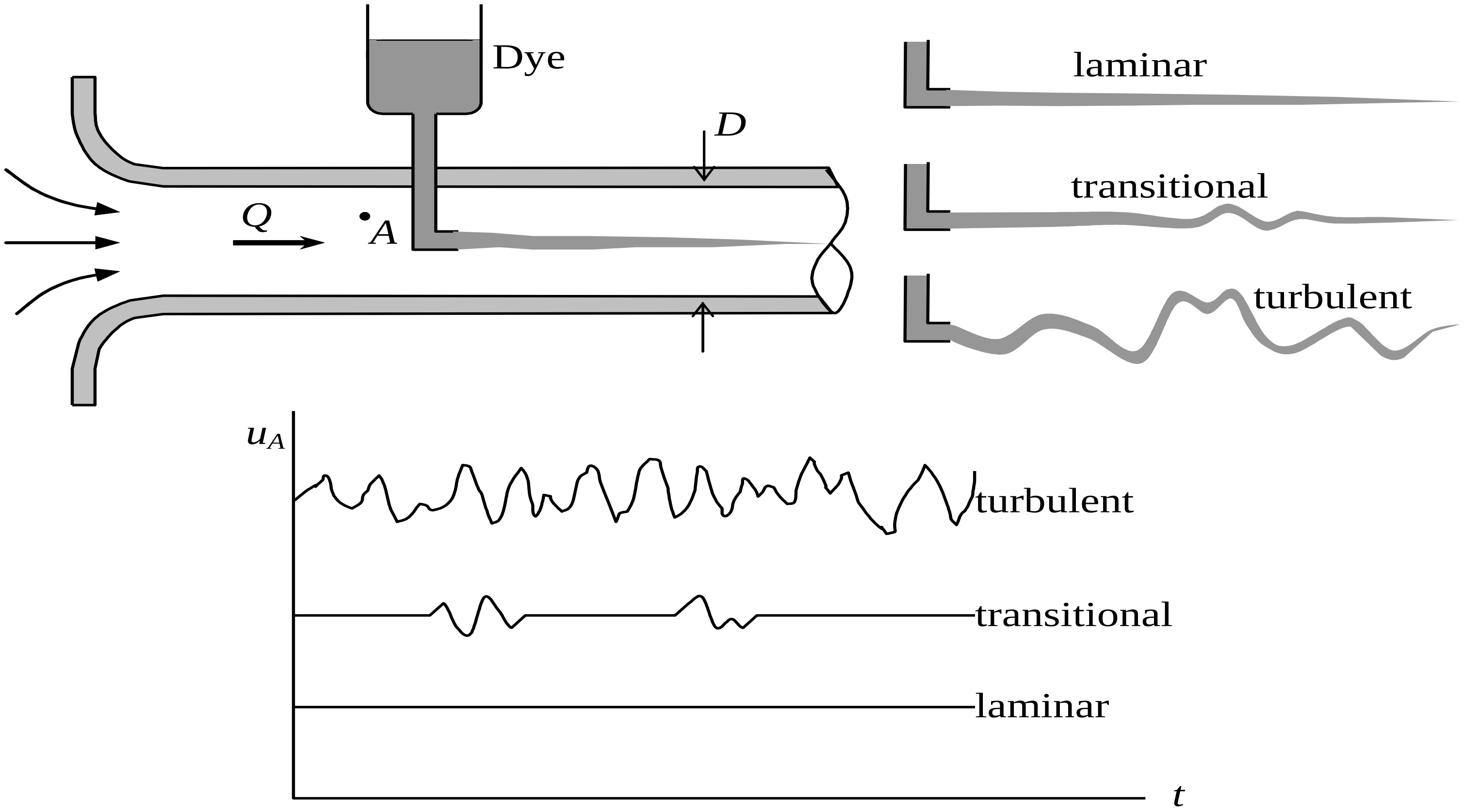
- This type of flow is also known as internal flow where the pipe is assumed to be completely filled with the fluid.
- The fluid motion is generated by pressure difference between two points and is constrained by the pipe walls. The direction of the flow is always from a point of high pressure to a point of low pressure.
- If the fluid does not completely fill the pipe, such as in a concrete sewer, the existence of any gas phase generates an almost constant pressure along the flow path.
- If the sewer is open to atmosphere, the flow is known as open-channel flow and is out of the scope of this chapter or in the whole course.

Flow Characteristics in Pipes

- Flow in pipes can be divided into two different regimes, i.e. laminar and turbulence.
- The experiment to differentiate between both regimes was introduced in 1883 by Osborne Reynolds (1842–1912), an English physicist who is famous in fluid experiments in early days.

Flow Characteristics in Pipes

- The Reynolds' experiment is depicted below -



Flow Characteristics in Pipes

- From the figure , the dye is used to mark the flow path of the fluid. In order to demonstrate the transition between laminar and turbulent regime, the - Q is varied.
- For a constant diameter pipe, the cross sectional area is also constant. Thus, by virtue of mass conservation, the velocity V is directly proportional to Q.
- For laminar regime, the flow velocity is kept small, thus the generated flow is very smooth which is shown as a straight tiny line formed by the dye.
- When the flow velocity is increased, the flow becomes slightly unstable such that it contains some temporary velocity fluctuation of fluid molecules and this mark the transition regime between both regimes. Then, the velocity can be increased further so that the fluid flow is completely unstable and the dye is totally mixed with the surrounding fluid. This phenomenon is known as turbulence.

Flow Characteristics in Pipes

This graph clearly shows a smooth velocity of laminar flow and a fluctuated velocity for turbulent flow.

Clearly, one of the main critical parameters that determines the flow regimes is the velocity.

This parameter, together with fluid properties, namely density ⍰ and dynamic viscosity μ, as well as pipe diameter D, forms the dimensionless Reynolds number, that is

$$\mathrm{Re} = \frac{\rho V D}{\mu}$$

From Reynolds' experiment, he suggested that $\mathrm{Re} < 2100$ for laminar flows and $\mathrm{Re} > 4000$ for turbulent flows. The range of Re between 2100 and 4000 represents transitional flows.