Flow in Real Fluid

Fluid is a substance which is capable of flowing.

OR

Fluid is substance which deforms continuously under the influence of a shear or tangential force.

Types of Fluid:

- Ideal Fluid
- Real Fluid

Ideal Fluid	Real Fluid
Fluids which don't have viscosity and are incompressible are termed as ideal fluid such fluid do not offer shear resistance.	Fluids which do posses viscosity are termed as real fluids. These fluids always offer shear resistance.

Real Fluid further classified into two types:

1. **Newtonian fluid-** The fluids which obey Newton's law of viscosity are called as Newtonian fluids such fluids exhibit linear relationship between shear stress and rate of angular deformation. e.g. -water, air etc.
2. **Non-Newtonian Fluid**- Fluids which do not follow the linear relation between shear stress and rate of angular deformation are termed as Non-Newtonian fluids.

Types of Fluid Flow:

There are in general three types of fluid flow in pipes

- laminar
- turbulent
- transient

Laminar flow

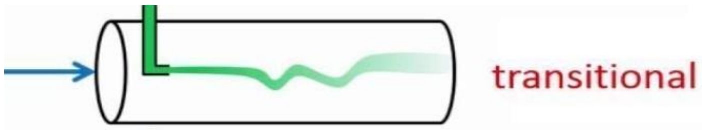
Laminar flow generally happens when dealing with small pipes and low flow velocities.

Turbulent flow

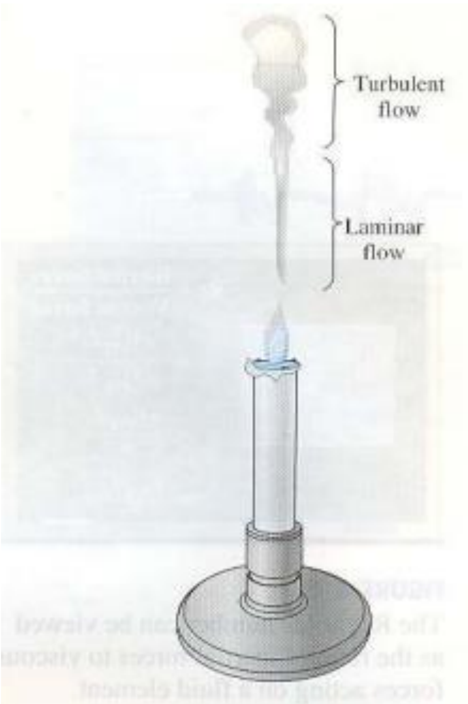
Turbulent flow happens in general at high flow rates and with larger pipes.

Transitional flow

Transitional flow is a mixture of laminar and turbulent flow, with turbulence in the center of the pipe, and laminar flow near the edges.



Turbulent or laminar flow is determined by the dimensionless **Reynolds Number**.



Reynolds Number:

Reynolds Number is a very important quantity for studying fluid flow patterns. It is a dimensionless parameter and widely used in fluid mechanics.

Reynolds Number of a flowing fluid is defined as the ratio of inertia force to the viscous force of that fluid.

The concept of Reynold’s number was introduced by George Stokes in 1851. However, the name “Reynolds Number” was given with the name of the British physicist Osborne Reynolds, who popularized its use in 1883.

Importance of Reynolds Number

Reynold’s Number (Re) is a convenient parameter that helps in predicting if a fluid flow condition will be laminar or turbulent. We know that Reynolds Number (Re)=inertia force/viscous force.

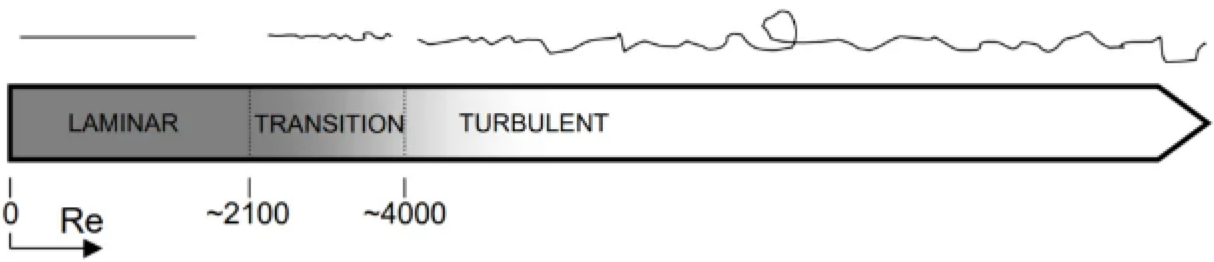
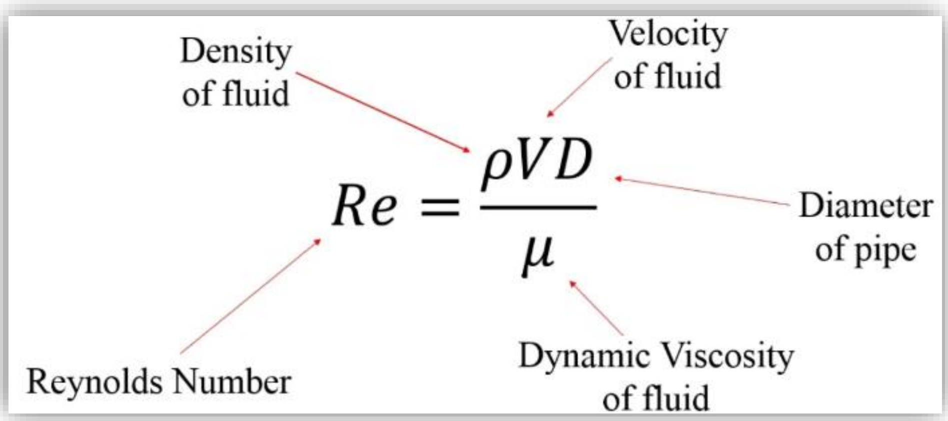


Fig. 1: Reynolds Number vs flow regimes

“2100<Reynolds Number (Re)<4000” indicates flow transition from laminar to turbulent and the flow consists of a mixed behavior. However, note that the value of Reynolds number (Re) at which turbulent flow begins is dependent on the geometry of the fluid flow, which is different for pipe flow and external flow.

Equation for Reynolds Number

Mathematically, The Equation for Reynolds number is represented as:



- the term μ/ρ is known as kinematic viscosity, ν

So, the Equation for Reynolds number can be written as:

$$\mathrm{Re} = \frac{V\,D}{\nu}$$

As the Reynolds Number is the ratio of two forces, there is no unit of Reynolds Number. So, Reynold's Number is dimensionless.

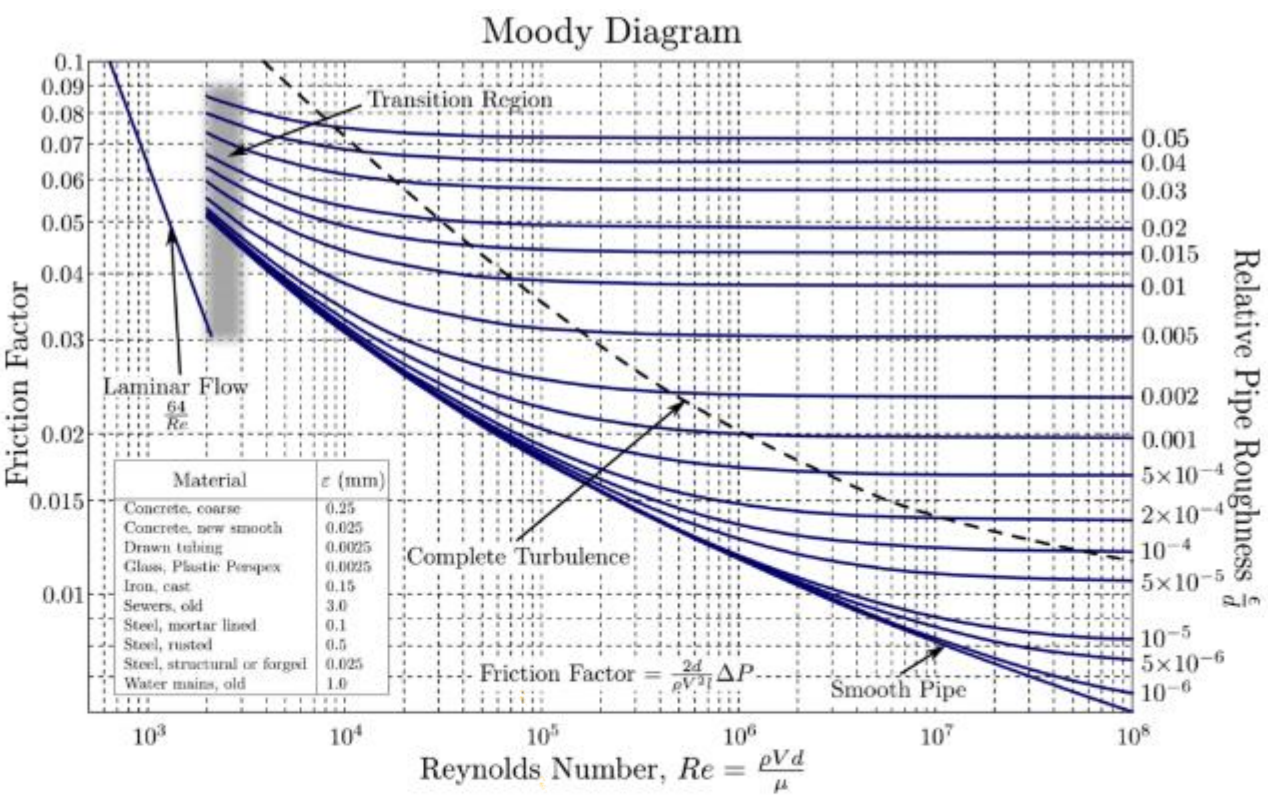
Applications of Reynold's Number

As Reynolds number is used for predicting laminar and turbulent flow, it is widely used as a design parameter for hydraulic and aerodynamic equipment.

For the design of piping systems, aircraft wings, pumping system, scaling of fluid dynamic problems, etc Reynolds number serves as an important design tool.

In the calculation of pressure drop and frictional losses, the Reynolds number plays an important role.

The following diagram, known as Moody chart provides a co-relation between friction factor, Reynold's Number, and Relative roughness and widely used in solving fluid flow problems.



Losses in Pipes

There are two types of losses in pipes:

- Major Losses
- Minor losses

"Major" losses occur due to friction within a pipe, and "minor" losses occur at a change of section, valve, bend or other interruption.

Major Losses (h_f) (Friction losses)

We're assuming that the entire pressure difference is due to friction in the pipe. So the observed hf can also be given by the Darcy equation:

$$h_f = f\,\frac{L}{D}\,\frac{V^2}{2g}$$

Where:
f is the friction factor
L is pipe length
D is pipe diameter

- For laminar flow:

  The friction factor (f) can be calculated based on Hagen-Poiseuille equation: $$f = \frac{64}{Re}$$

- For turbulent flow:

  The friction factor (f) can be calculated, depending on relative roughness (e/D or Ks/D), based on:

Smooth Pipes
- For $Re < 10^5$ $\longrightarrow$ $f = 0.316 / Re^{0.25}$ (Blasius equation)
- For $Re > 10^5$ $\longrightarrow$ $\dfrac{1}{\sqrt{f}} = 2\log\left(\dfrac{Re\sqrt{f}}{2.51}\right)$

Rough Pipes $\longrightarrow$ $\dfrac{1}{\sqrt{f}} = 2\log\left(\dfrac{3.7}{Ks/D}\right)$

Minor losses (h_L) (Local losses)

Some of the minor losses may be raised by:

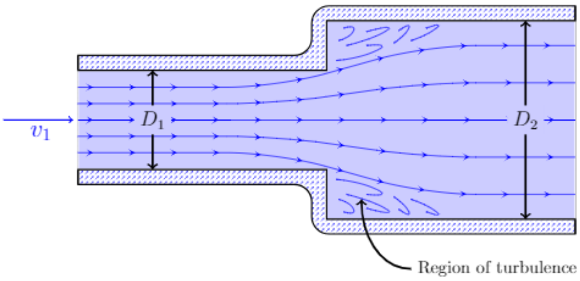
1. Sudden expansion or contraction
2. Valves, open or partially closed
3. Bends, elbows, tees, and other fittings
4. Pipe entrance or exit

The most common method used to determine these head losses

$$\boxed{h_L = K_L \frac{v^2}{2g}}$$

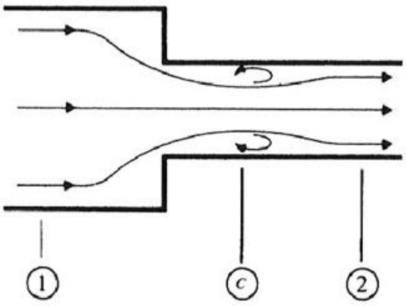
where K_L means **(local) loss coefficient**.

- Sudden expansion



$$h_L = \frac{(v_1 - v_2)^2}{2g}$$

- Sudden contraction



$$h_L = k_L \frac{v_2^2}{2g}$$

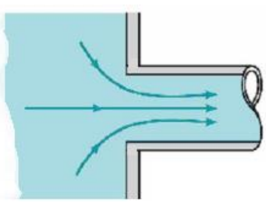
- Valves

$$h_L = k_v \frac{v^2}{2g}$$

- Elbows (Bend conduit)

$$h_L = k_e \frac{v^2}{2g}$$

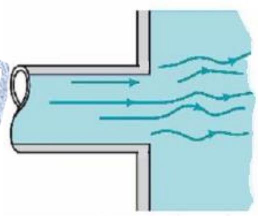
- Pipe entrance or exit



$$h_L = 0.5 \frac{v^2}{2g}$$

entrance of pipe

$$h_L = \frac{v^2}{2g}$$



exit of pipe

$$h_L = \sum k_L \frac{v^2}{2g}$$

Total losses = Friction loss + Local loss

$$H = h_f + h_L$$

Then the new form of Bernoulli's equation result is:

$$\frac{P_1}{\gamma} + \frac{{v_1}^2}{2g} + Z_1 = \frac{P_2}{\gamma} + \frac{{v_2}^2}{2g} + Z_2 + h_f + h_L$$

These losses are added to the second side of the Bernoulli Equation.