Chemical Engineering Fluid Dynamics and Heat Transfer
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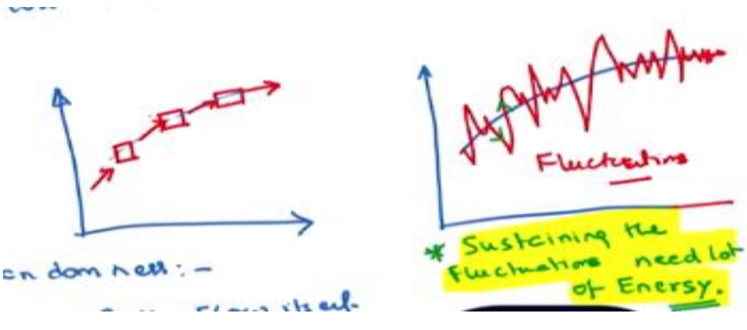
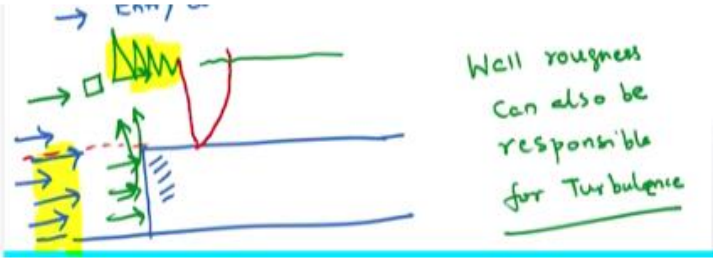
Lecture - 23
Turbulence - 01

So, welcome back. We are going to discuss the turbulence. We know from our basic understanding that if the Reynolds number is greater than 4000, then the flow nature will be turbulent. We will discuss turbulence in detail in the following lectures.

Turbulence → It's an irregular condition of flow, which can be described by laws of probability. Basically, there are fluctuations within the flow field. That means there will be fluctuation in the pressure and the velocity. So, typically if you consider the flow of a particle like Lagrangian concept within a laminar flow field, the stream line of the particle will be smooth and if the particle is in the turbulent flow field, the particle undergoes fluctuations. It means that at every instance of time, the particle will be moving randomly. This is the randomness that is associated with the turbulence. So, the genesis of the randomness probably lies in the entry condition or geometry of the flow itself. Wall roughness can also be responsible for turbulence. So, from the standpoint of the flow in order to sustain these fluctuations you need very high kinetic energy. That is why turbulence is possible only when the inertial effects are much stronger, that means Reynolds' number is very high.





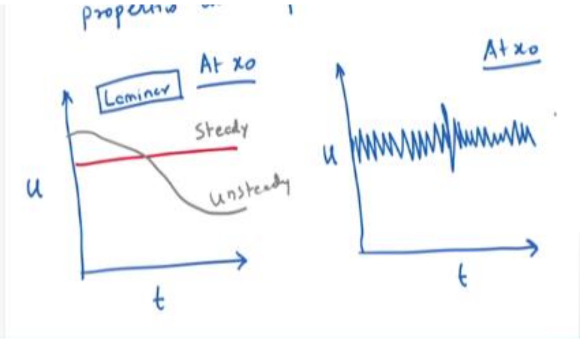
Important attributes of turbulence:

1.It is a random process and turbulent flow depends on both time and space

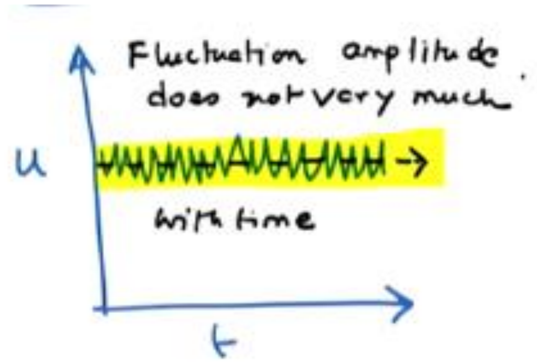
2.Turbulent flow in time and space depends on a very large number of degrees of freedom.

3.Turbulence is unpredictable in detail, but its statistical properties are reproducible.

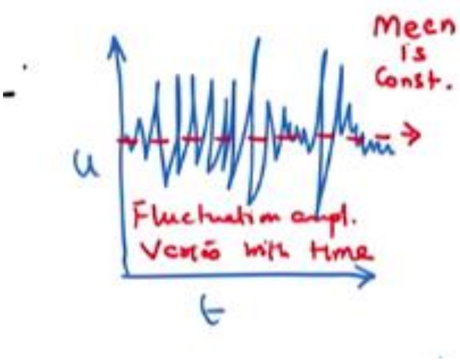
Consider a probe at location x_0 within the flow field, in the case of laminar flow field.



Let us discuss fluctuations at a a particular location.

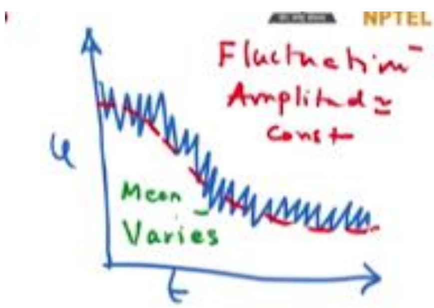


In this case, Mean velocity is nearly constant, fluctuation amplitude does not vary with time.

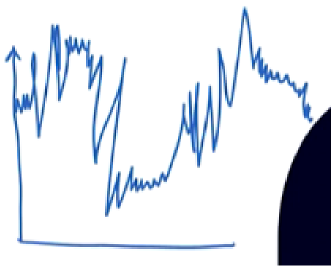


In this case, the mean velocity is nearly constant. But the fluctuation amplitude significantly varies with time.

In the third case,the fluctuation amplitude is nearly constant,but the mean varies.



In the last case,the both velocity of fluctuation and amplitude varies with time.



All these cases represent turbulent flow, and the four cases are different from each other by the variation of the mean and fluctuating component of velocity. So, we can distinguish or fully quantify a turbulence in terms of two velocities i.e., mean velocity and a fluctuation velocity. And this is known as the Reynolds decomposition of turbulence. Which is splitting up the flow into two parts,

Reynolds decomposition of turbulence:

$$u(y,t) = \bar{u}(y) + u'(\Gamma, t)$$

If we are considering 1D flow, if the flow to be turbulent flow, the local velocity or the instantaneous velocity split up into a time independent mean velocity which is basically a time average and a time and space dependent fluctuation component of the velocity. But u' is not only a function of x, y and z, what it means all possible spatial coordinates. So, this fluctuation irrespective of the nature of flow like this we are assuming to be a 1D flow, but when you are talking about turbulence the fluctuation can happen in all possible directions.

Correlation length: It is the length scale over which the nature of turbulence changes significantly. In the second case, the correlation length is finite.

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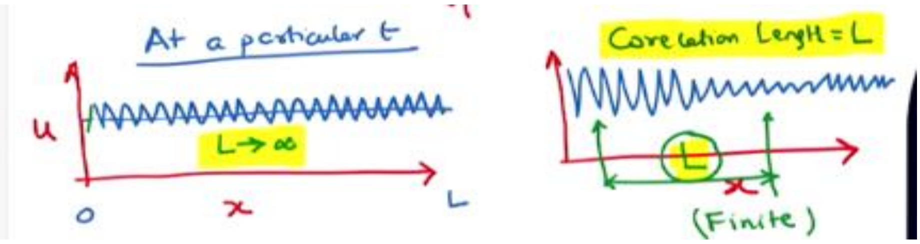

Another important parameter in turbulence:

Turbulent Reynolds number,$Re = \frac{u'L}{\gamma}$

$$u' \rightarrow fluctuating\ Component$$

$$L \rightarrow Correlation\ length$$

$$\gamma \rightarrow Kinematic\ viscosity$$

Thank you.