Liquid Mixing

9.1 Introduction

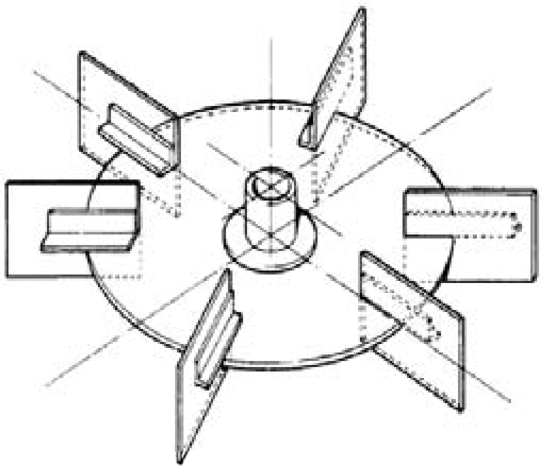
Mixing is one of the most common operations carried out in the chemical, processing. The term " **Mixing**" is applied to the processes used to reduce the degree of non-uniformity, or gradient of a property in the system such as concentrations, viscosity, temperature, and so on. Mixing is achieved by moving material from one region to another. It may be interest simply as a means of achieving a desired degree of homogeneity but it may also be used to promote heat and mass transfer, often where a system is undergoing a chemical reaction.

A rotating agitator generates high velocity streams of liquid, which in turn entrain stagnant or slower moving regions of liquid resulting in uniform mixing by momentum transfer. As viscosity of the liquid is increased, the mixing process becomes more difficult since frictional drag retards the high velocity streams and confines them to immediate vicinity of the rotating agitator.

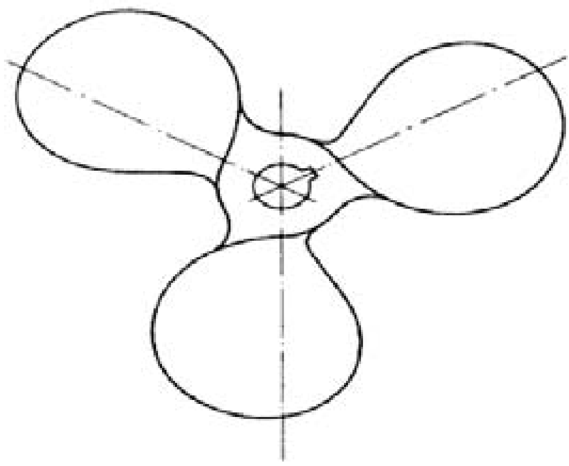
9.2 Types of Agitators

In general, agitators can be classified into the following two types: -

1- Agitators with a small blade area, which rotate at high speeds. These include **turbines** and **marine type propellers.**
2- Agitators with a large blade area, which rotate at low speeds. These include **anchors,** and **Paddles**, and **helical screws.**



Six-blade flat blade turbine



Marine Propeller

The second group is more effective than the first in the mixing of high viscosity-liquids.

For a liquid mixed in a tank with a rotating agitator, the shear rate is greatest in the intermediate vicinity of agitator. In fact the shear rate decreases exponentially with distance from the agitator. Thus the shear stresses and strains vary greatly throughout an agitated liquid in tank. Since the dynamic viscosity of a Newtonian liquid is independent

of shear rate at a given temperature, its viscosity will be the same at all points in the tank. In contrast the apparent viscosity of a non-Newtonian liquid varies throughout the tank. This in turn significantly influences the mixing process.

The mean share $\dot{\gamma}_m$ produced by an agitator in a mixing tank is proportional to the rotational speed of the agitator N

i.e. $\dot{\gamma}_m \propto N \quad = \dot{\gamma}_m = KN$

where, K is a dimensionless proportionality constant for a particular system.

It is desirable to produce a particular mixing result in the minimum time (t) and with the minimum input power per unit volume (P_A/V). Thus the efficiency function (*E*) can be defined as

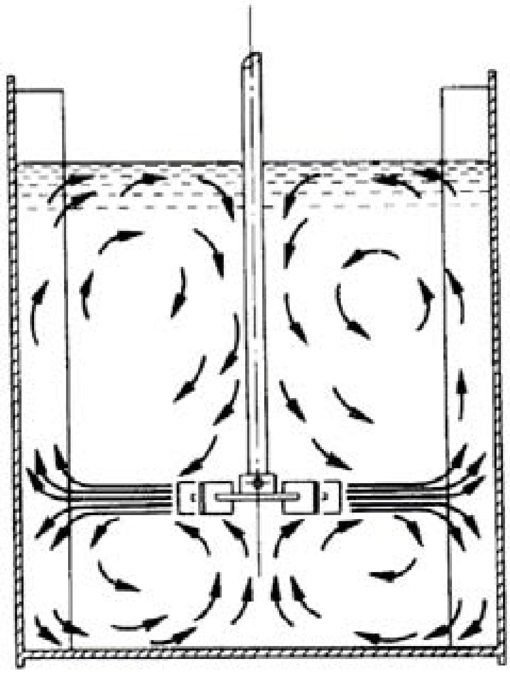
$$E = \left(\frac{1}{P_A/V}\right)\left(\frac{1}{t}\right)$$

9.2.1 Small Blade, High Speed Agitators

They are used to mix low to medium viscosity liquids. Two of most common types are 6-blade flat blade turbine and the marine type propeller.

Flat blade turbines used to mix liquids in baffled tanks produce radial flow patterns primarily perpendicular to the vessel wall. This type is suitable to mix liquids with dynamic viscosity up to 50 Pa.s.

Marine type Propellers used to mix liquids in baffled tanks produce axial flow patterns primarily parallel to the vessel wall. This type is suitable to mix liquids with dynamic viscosity up to 10 Pa.s.



Radial flow pattern produced by a flat blade turbine

Agitator Tip Speed (TS)

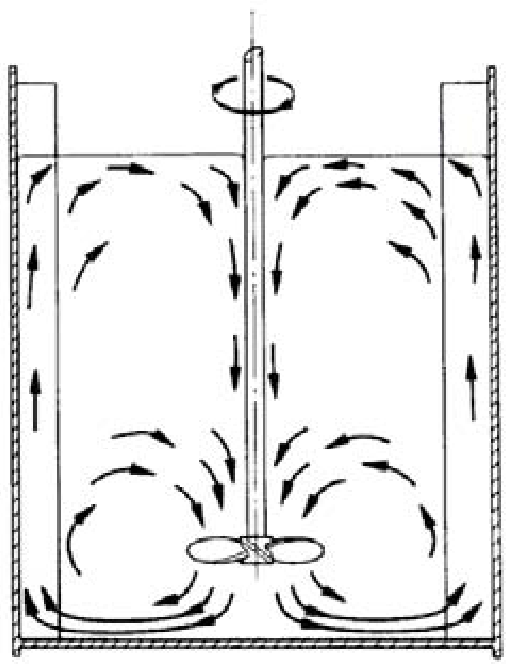
Is commonly used as a measure of the degree of the agitation in a liquid mixing system.

$TS = \pi D_A N$

Where, D_A: diameter of agitator.
N: rotational speed.

Tip speed ranges for turbine agitator are recommended as follows:

TS = 2.5 to 3.3 m/s for low agitation.
TS = 3.3 to 4.1 m/s for medium agitation.
TS = 4.1 to 5.6 m/s for high agitation.



Axial flow pattern produced by a marine