Fluid Mechanics

Topic 5

Mixing tanks

Mixing

Why is mixing important?

Mixing is use extensively in the chemical process industry and also in civil engineering applications such as waste water treatment

We want to mix systems in order to improve homogeneity and uniformity thus reducing gradients with in the system

- **Concentration**. Disperse an additive homogeneously throughout a liquid. For example chlorine or ozone in order to sterilize water for use as drinking water. Also, to create uniform reaction kinetics by evenly dispersing reactants in a stirred tank reactor
- **Temperature**. To generate uniform reaction kinetics by evenly distributing heat throughout a system
- **Color**. Homogenize color additives in order to create a streak-free paint
- **Etc**…

Mixing processes

There are many types of mixing processes

- Liquid-liquid mixing
- Liquid solid mixing
- Liquid gas mixing
- Gas-gas mixing
- Solid-solid mixing

Since this is a fluid mechanics class, we're interested in mixing the involves a liquid phase

Types of mixing involving liquids and examples

- **Miscible liquid-liquid mixing**. Diluting a liquid sterilizing agent or fluoride into drinking water. Homogeneous catalysis, etc…
- **Immiscible liquid-liquid mixing**. Emulsions such as those used in emulsion polymerization or the in the production of cosmetics (hand lotion) or food (milk processing)
- **Solid liquid mixing**. Heterogeneous catalysis. Mixing of concrete
- **Gas-liquid mixing**. Stripping, removing volatiles from a liquid phase by contacting with gas phase. Absorber removes contaminants from a gas into a liquid phase. The mixing greatly improves mass transfer between phases

Mixing processes?

Stuart brings up a good point. Mixing is rather self explanatory

However, in engineering, we're interested in accomplishing tasks as **efficiently** and **effectively** as possible as we know that in industry this is directly related to **money**

Therefore, this class focuses on the design of mixing tanks in order to accomplish the mixing task in the best way possible

The mixing tank

We will talk about three fundamental pieces of equipment used in mixing tanks: the tank, the impeller, and the baffles. The first is the tank itself

The mixing tank is the vessel in which the mixing occurs

Design criteria that must be considered when choosing a mixing tank

- **Capacity**. How big does my tank need to be?
- **Single tank, series, or parallel**. Is mixing best achieved in a single tank or in multiple connected tanks?
- **Fluid movement**. How will fluid be pumped into/out of the tank
- **Tank material**. What material is best to construct the tank from? This includes system pressure, corrosiveness of fluid, heat of tank, etc…
- **Open or closed**. Will the tank be open to the atmosphere or will it be closed? Ease of maintenance, hazard of fluid, sensitivity of fluid to environmental factors, etc…

The mixing tank

Illustrations of various mixing tanks

- Various sizes
- Metal versus plastic
- Single mixers versus parallel or series
- Fluid inserted or removed from top or bottom
- Opened and closed models

Impellers (agitators)

The second piece of equipment we will consider is the mixing **impeller**

This is the rotating blade that **transfers momentum** to the liquid and causes the fluid to mix through **forced convection**

There are a huge number of impeller designs. We will look at four impeller designs in more detail

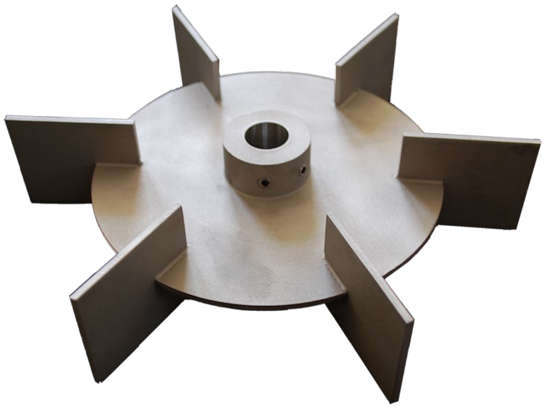
- Propellers
- Turbine impellers
- Paddle impellers
- Helical (or ribbon) impellers

Each of these impeller types has distinct flow characteristics and uses in the mixing field

Impellers (agitators)

Propeller

Turbine impeller



Paddle impeller

Why do we need so many different types of impellers?

Helical (ribbon) impeller

Impeller selection and fluid viscosity

The impeller is largely chosen based on fluid **viscosity**. Viscous fluids require slower **impeller speed** but impeller blades with greater **surface area**

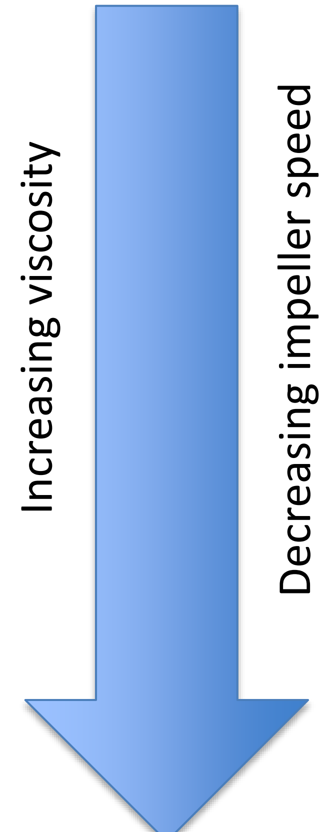
Propellers
400 - 2000rpm
For μ < 3000cp

Turbine impellers
100 - 200rpm
For μ < 100,000cp

Paddle impellers
50 - 150rpm
For 50,000 < μ < 500,000cp

Helical (ribbon) impellers
15 - 50rpm
For μ > 500,000cp

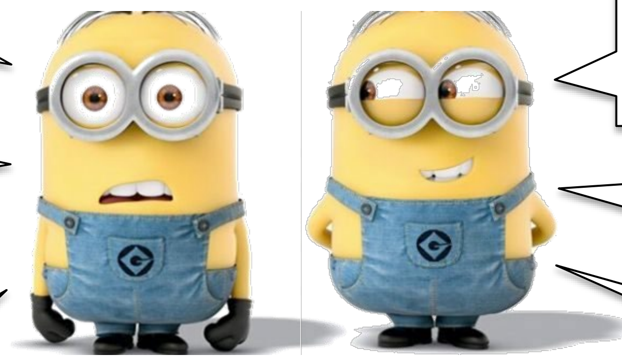
Turbulent mixing



Laminar mixing

Low viscosity mixing

Let us focus on **low viscosity mixing** using propellers or turbine impellers



We have our tank and our impeller, let's place the impeller in the center of the impeller in the tank and start mixing!

What?! Are you an idiot? If you use just a centered impeller in a low viscosity fluid, you're going to get horrible mixing

What do you mean? It will stir the fluid and homogenize it, right?

You are daft. Everyone knows that a centered impeller will cause swirling, not homogenization of the fluid!

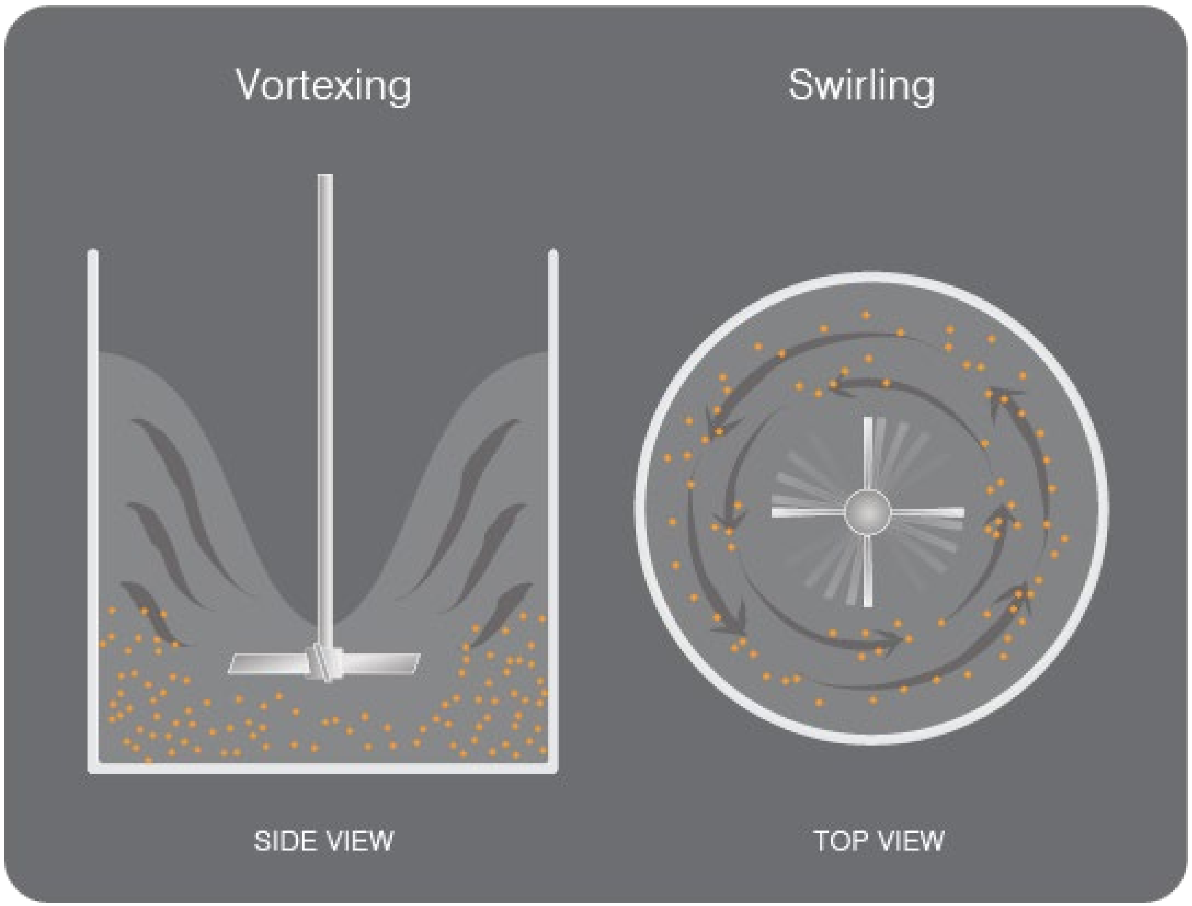
But swirling is okay, right?

Eventually swirling will get the job done but it will take ***forever***. Gah, I can't talk to you anymore, just watch this video

Video1, swirling during mixing: https://www.youtube.com/watch?v=4Kyy55EjyXQ

Swirling of fluid elements in low μ mixing

When swirling occurs, fluid elements just move around in circles instead of being mixed and homogenized with one another. This flow pattern leads to very poor mixing, meaning it takes a long time to achieve homogenization



When working with small volumes, a telltale sign of swirling is vortexing

However, large volumes may also be swirling and not exhibit vortexing

How to prevent swirling in low μ mixing

How do we prevent swirling from occurring in **low viscosity mixing** systems?

There are two main ways of preventing swirling. The first is **impeller offset**. The second, and more used method is to insert **baffles** into the mixing tank

Gah, just watch these videos!

Video 2, impeller offset: https://www.youtube.com/watch?v=DgdCFwwRMcg

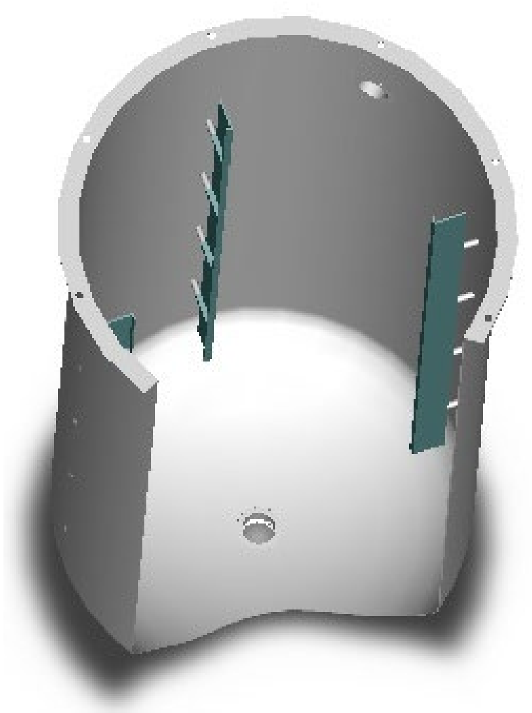
Video 3, use of baffles: https://www.youtube.com/watch?v=6E2-y96uYR4

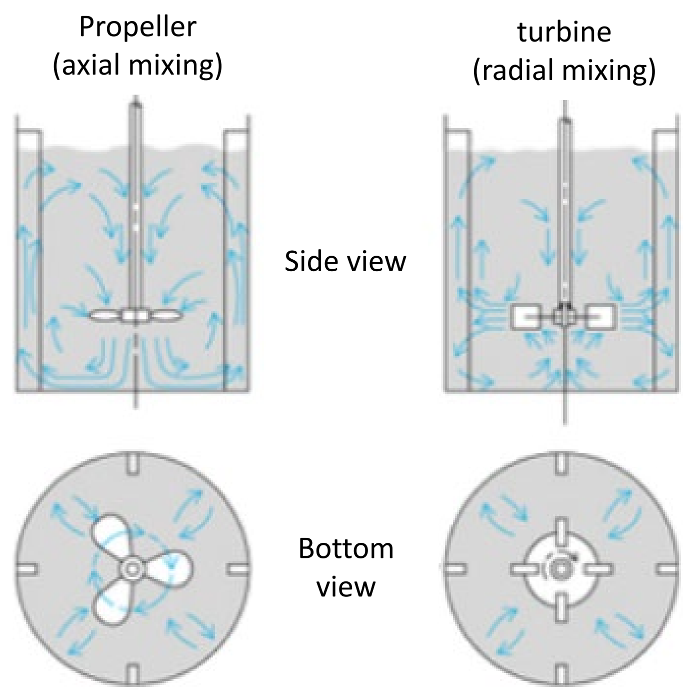
Video 4, use of baffles: https://www.youtube.com/watch?v=t7C-ErQVmvo

Baffles

Industrially, **baffles** are more often used than impeller offset to eliminate swirling and to enhance mixing. A tilted impeller is limited to small systems because of forces on the impeller shaft

Baffles are essentially small walls inside the mixing tank that block the swirling motion of the fluid

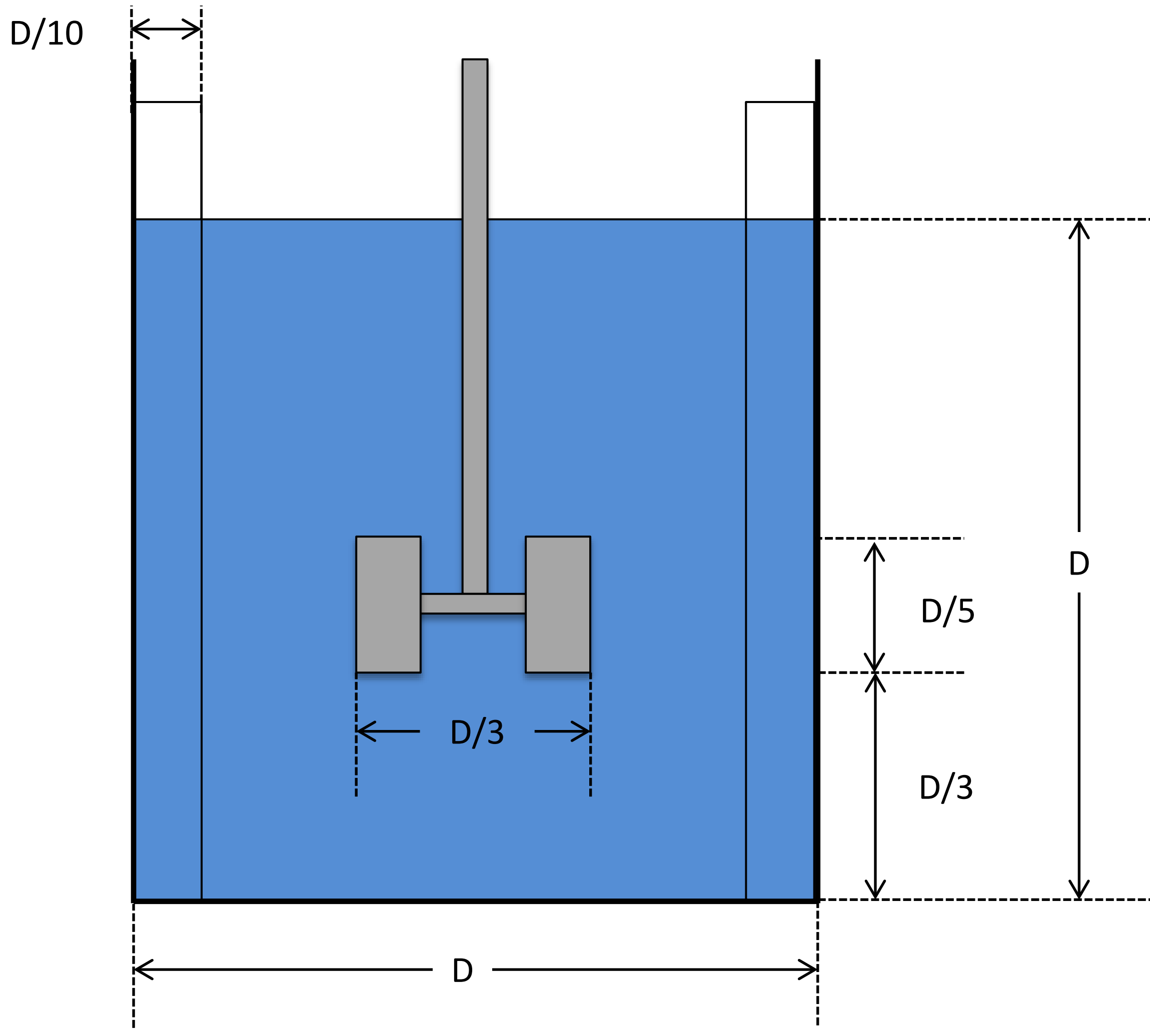




Baffles eliminate swirling and result in top to bottom fluid turn over for low viscosity fluids

Standard mixing tank for low μ fluids

Mixing tanks need to be designed specifically for an application. However, below is a schematic for the configuration of a standard mixing tank



Low μ vs high μ mixing strategies

Why do **impellers** with **larger surface area** need to be used to mix **high viscosity fluids**?

In low viscosity mixing the impellers have small surface area but move at high speed providing a lot of momentum to a few fluid elements. Mixing in this scenario is driven by the inertia of those fluid elements as they travel and disrupt the bulk of the fluid

If you tried to use a similar mixing technique for high viscosity fluids you may get mixing in the area immediately around the impeller, but the high viscosity of the fluid would result in the fluid motion being dampened very quickly. You would not achieve large scale mixing

Baffles are not needed for fluids with **viscosities above 5000cp** as little swirling occurs at higher viscosities

Low μ vs high μ mixing strategies

A better strategy for **high viscosity mixing** is to utilise **impellers with larger surface area** that span the entire mixing volume (helical/ribbon impellers)

This strategy does not require the inertia of the fluid elements to drive mixing. Instead all regions of the mixing tank are homogenized directly by the motion of the impeller

High viscosity mixing does not use baffles as swirling is not a problem. Furthermore, you want the helical impeller to travel close to the wall of the vessel, and the presence of baffles would not allow this

Here are three videos of high viscosity mixing

Video 5, large paddle impeller: https://www.youtube.com/watch?v=Q0rmmbtXsvk

Video 6, helical impeller motions: https://www.youtube.com/watch?v=BHgV05t3ITQ

Video 7, vertical helical mixer: https://www.youtube.com/watch?v=dua435wZdd4

Summary

There are two or three main components of a mixing system

- The tank
- The impeller
- Baffles (for low viscosity mixing)

The material, the size, and if tanks are in series or parallel depends on your unique mixing scenario

The size and shape of the impeller depends largely on the viscosity of the solution you're mixing

The use of baffles is helpful in low viscosity mixing to reduce swirling and to promote good mixing