

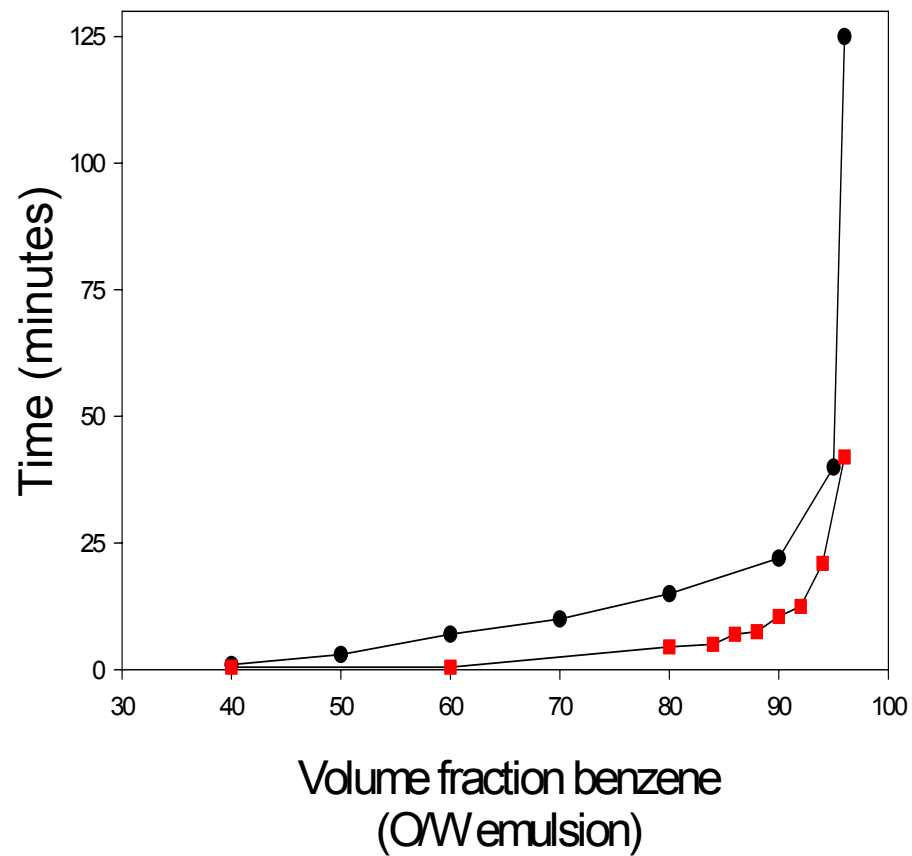
# Processing emulsions and suspensions

## Lecture 8

# Making emulsions

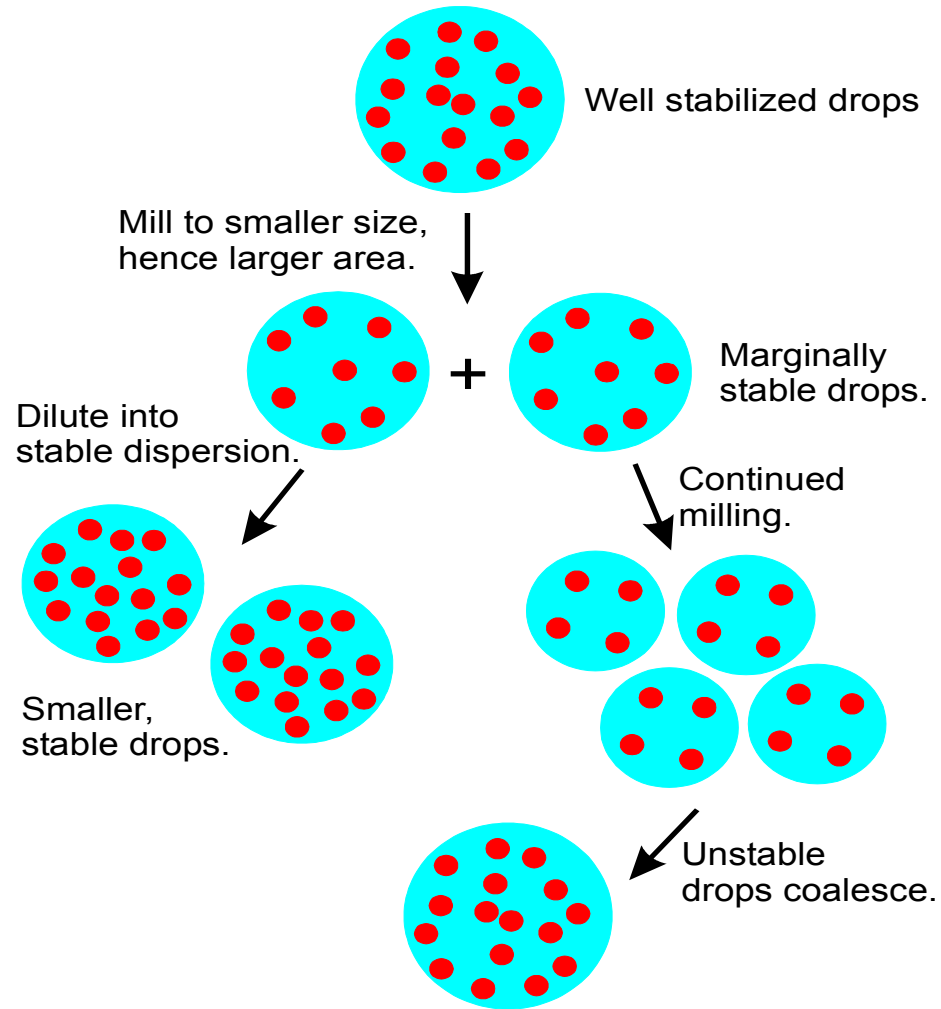
- Method of phase inversion
- PIT method
- Condensation methods - solubilize an internal phase in micelles
- Electric emulsification
- Intermittent milling

# Intermittent Milling

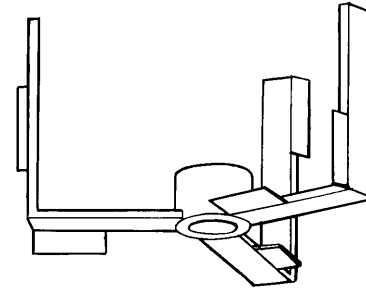
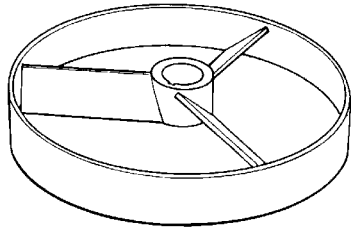


● Uninterrupted machine shaking  
■ Double shakes every 30 seconds

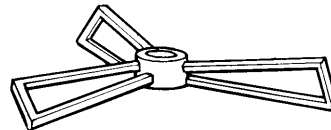
# Intermittent Milling



# High Speed Mixers

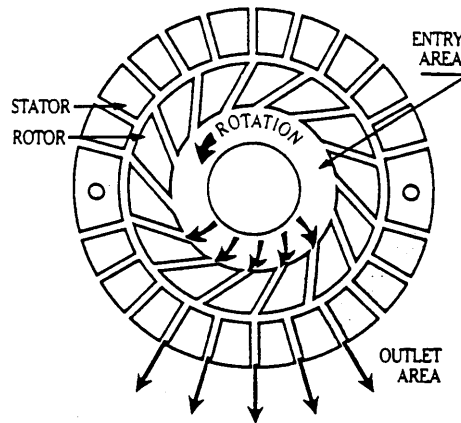


Typical speed are 3,000 to 4,000 RPM, the cavitation limit.



$$\begin{aligned} \text{Shear rate} &\approx \frac{3,000 \text{ RPM} \times 1 \text{ meter circumference}}{0.5 \text{ M from blade to wall}} \\ &= 100 \text{ sec}^{-1} \end{aligned}$$

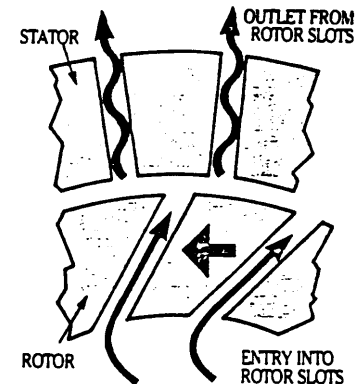
# Kady Mills



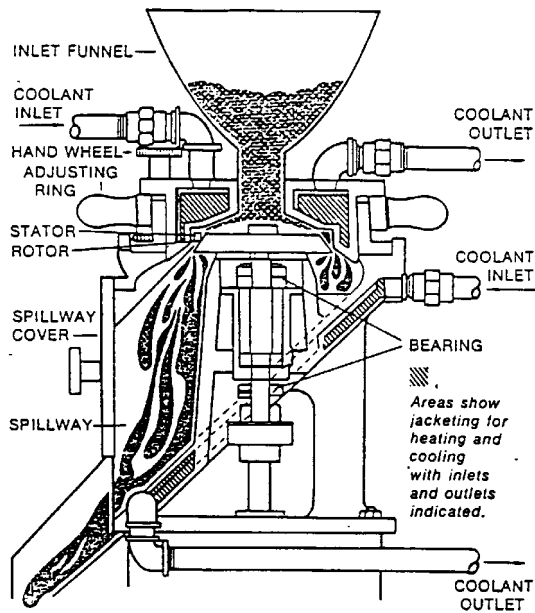
## Advantages:

High throughput,  
inexpensive, few moving  
parts.

**Disadvantages:** Not suitable for  
ultrafine particles, 1 poise  
maximum viscosity.



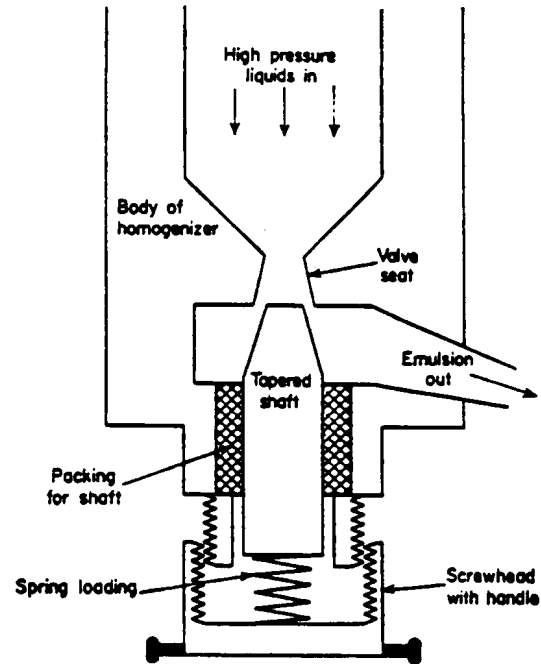
# Colloid Mill



Liquid, drawn by gravity, passes a spinning rotor adjusted to give a narrow gap between the rotor surface and the stationary walls.

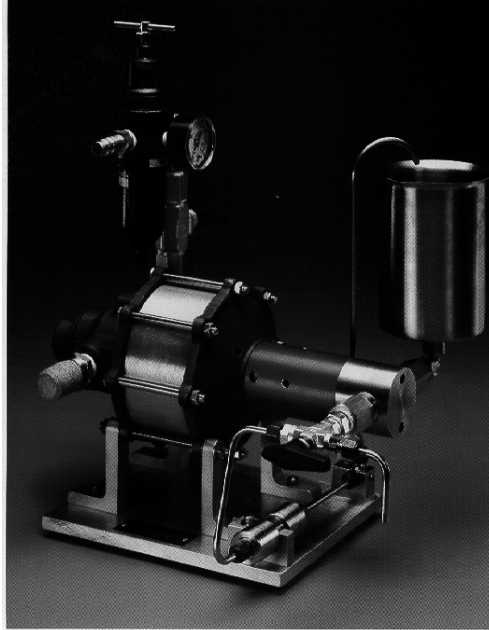
The spinning rotor pulls the liquid into long thin films which break into droplets as they emerge.

# Homogenizer



One type of single stage homogenizer.

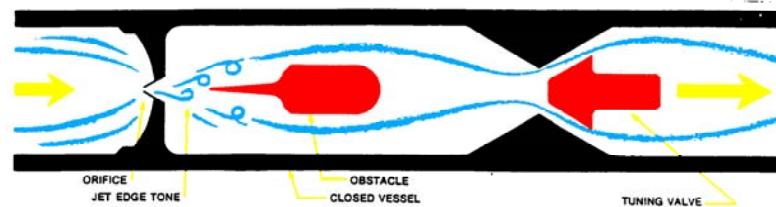
# Microfluidizer



A variation of a homogenizer in which fluid streams at high velocities are forced against each other in geometrically defined microchannels.

Requires only air pressure to operate.

# Sonolator



Converts the kinetic energy of high-velocity stream of liquid into high-intensity mixing action.

Runs at 200-2000 psi compared to 3000-5000 psi in the homogenizer.

System is “tuned” by adjusting the tuning valve to produce a maximum of acoustic energy!

The obstacle oscillates at high frequencies resulting in cavitation, turbulence, and shear.

# Ultrasonic Mills

Typically are in the shape of a blunt horn of various diameters.

An electrostrictive material (alternating voltage makes it expand and contract) is used to convert 60 Hz line current into 20 kHz ultrasonic vibrations.

The ultrasonic vibrations cause cavitation

Capable of brining particle sizes down to a few tenths of a micron.

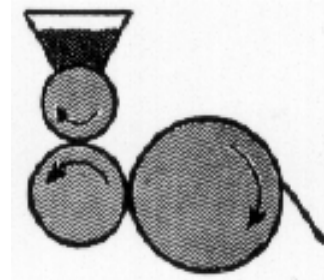
Steady-state size is a function of the additive and the horn-tip amplitude.

# Milling Equipment for Making Particle Dispersions

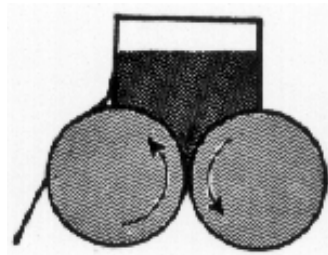
# Roll Mills



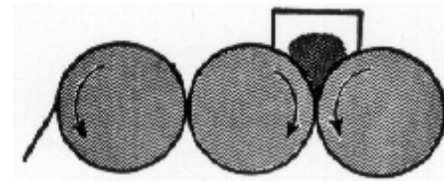
Dodge mill



Plymouth mill



Two-roll paste mill



Three-roll ink and paint mill

# Roll Mills

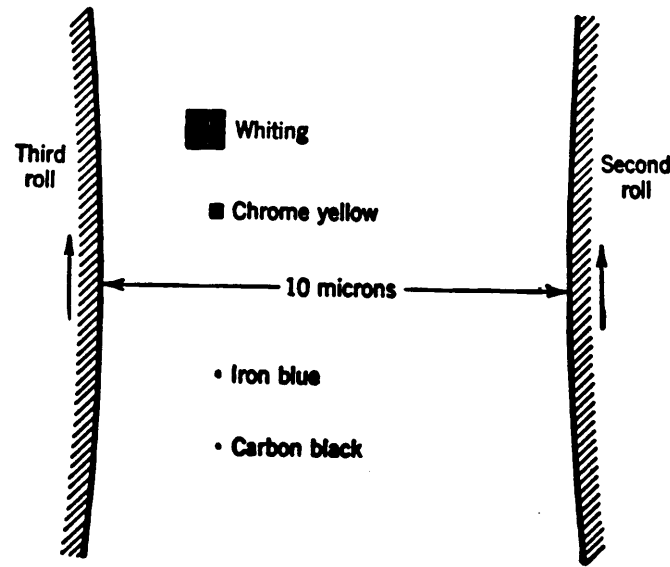
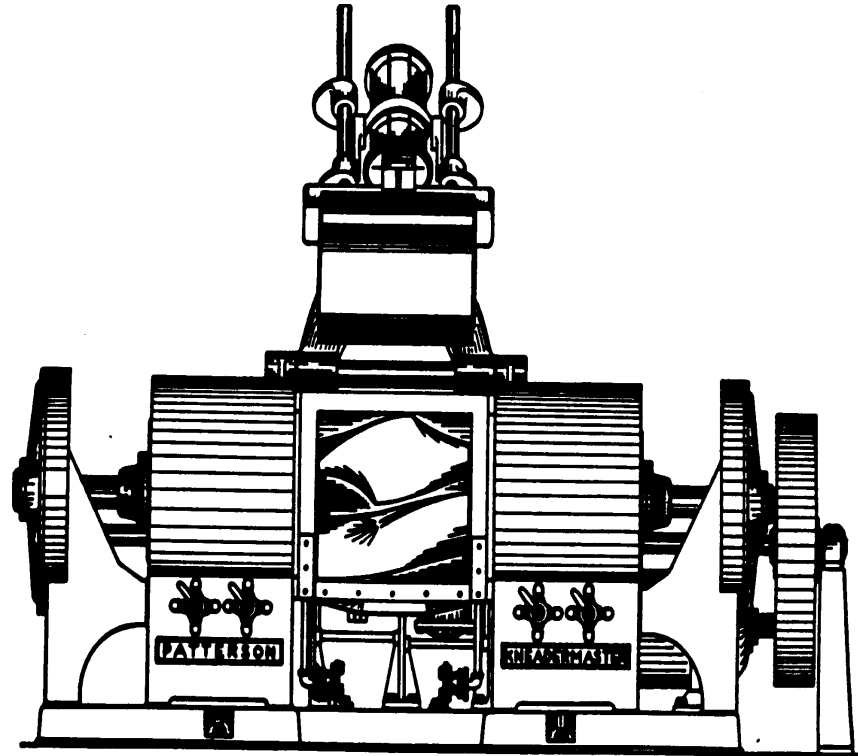


Diagram comparing clearance between rolls and size of primary pigment particles as approximated for three-roll mill during operation.

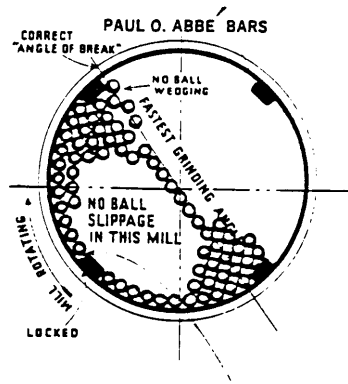
Large gaps mean low shear rates - milling is only possible at high viscosity.

# Mills for High Viscosities



# Ball and Roller Mills

**Ball Mill** – any mill in which steel or iron balls are used as the grinding medium. The cylinder is usually also made of steel.



Variables:

amount of grinding medium  
amount of material  
viscosity  
wet versus dry  
size of grinding medium  
composition of grinding medium

**Pebble Mill** – any mill in which flint pebbles or porcelain balls are used as the grinding medium, and the inside of the cylinder is lined with some non-metallic substance.

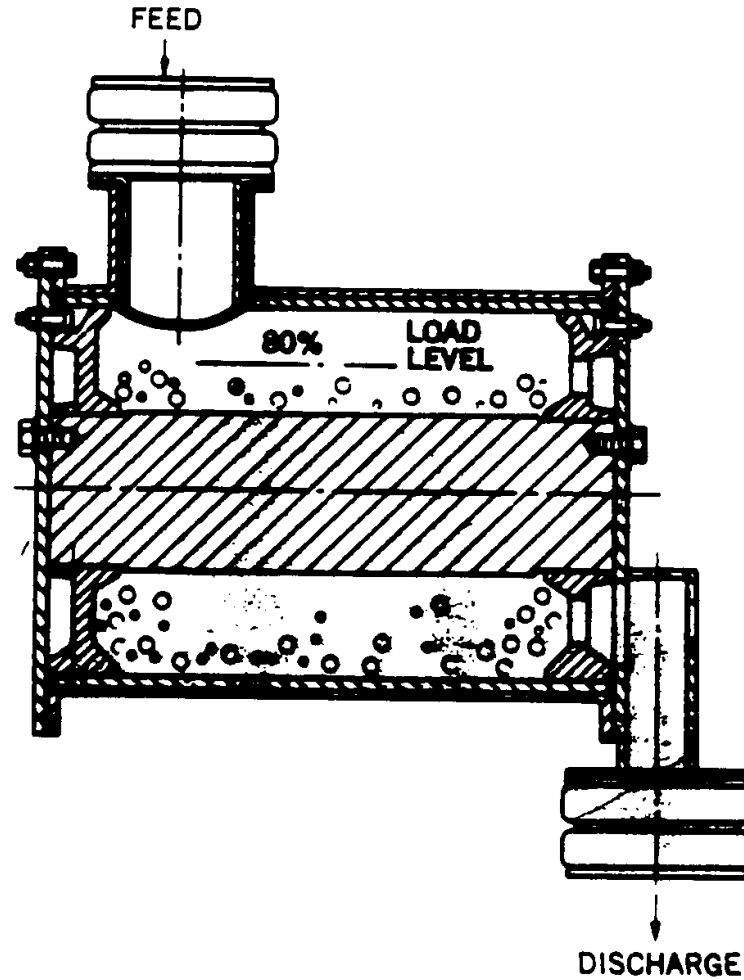
Advantages:

handles a wide variety of materials  
easy (safe) to use  
closed container

Disadvantages:

difficult to empty  
steady milling requires constant speed adjustment  
difficult to cool  
difficult to vent

# Vibrating Ball Mill



# Attritors

## Stirred Ball Mills

### Advantages:

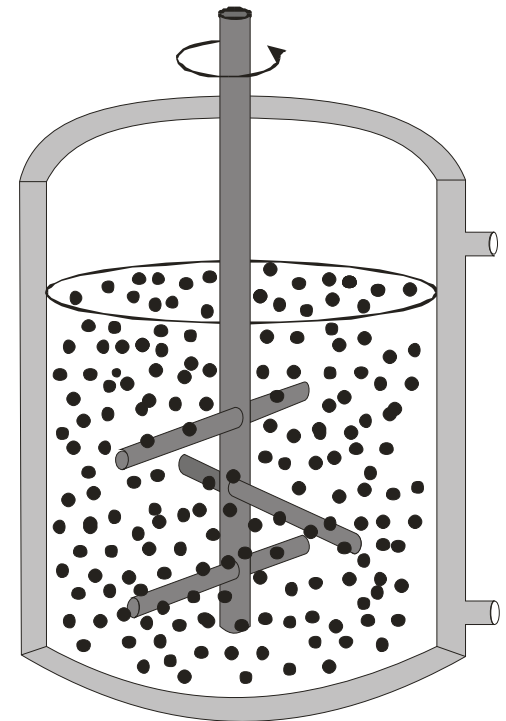
The milling action is controlled effectively by adjusting the rotation of the stirring blades.

Cooled with a water jacket

### Disadvantages:

Small particles deform rather than break.

Aggregation.  
Fine particles may coat the grinding medium.



# Sand Mills

Impeller disk attached to a shaft rotating at a selected speed in a container of standard grinding medium and the dispersion mixture.

Essentially highly efficient ball mills.

Typical grinding medium:

Ottawa sand 20-30 mesh

Advantages:

Very high quality of dispersion.

High through-put.

Disadvantages:

Difficult to clean

Requires good pre-mix.