MTE 449 Powder Metallurgy

Chapter 5

Powder Additives and Mixing

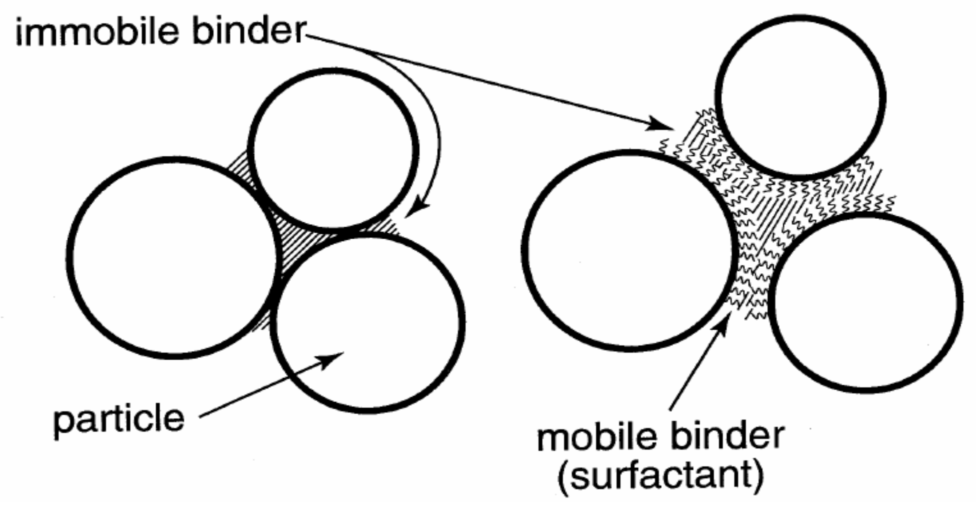
Nagy El-Kaddah

Powder Additives

- Additives are used to tailor powder characteristics
- Type and function of additives
  - Dispersants (ammonia polyacrylate) are used to increase packing density of the powder.
  - Agglomerating agents (polyethylene glycol) are used to reduce interparticle friction and provide rapid an homogeneous flow into a die cavity.
  - Binders (paraffin wax) are used to provide green strength to the powder.
  - Surfactants (stearic acid) are used to improve wetting characteristics of binders.
  - Plasticizers (glycerin) are used to lower the viscosity of powder-binder mixture
  - Thickeners (guar gum) are used to increase the viscosity of powder-binder mixture
  - Lubricants (zinc stearate) are used to reduce tool wear in compaction
- Some polymers serve many of these functions

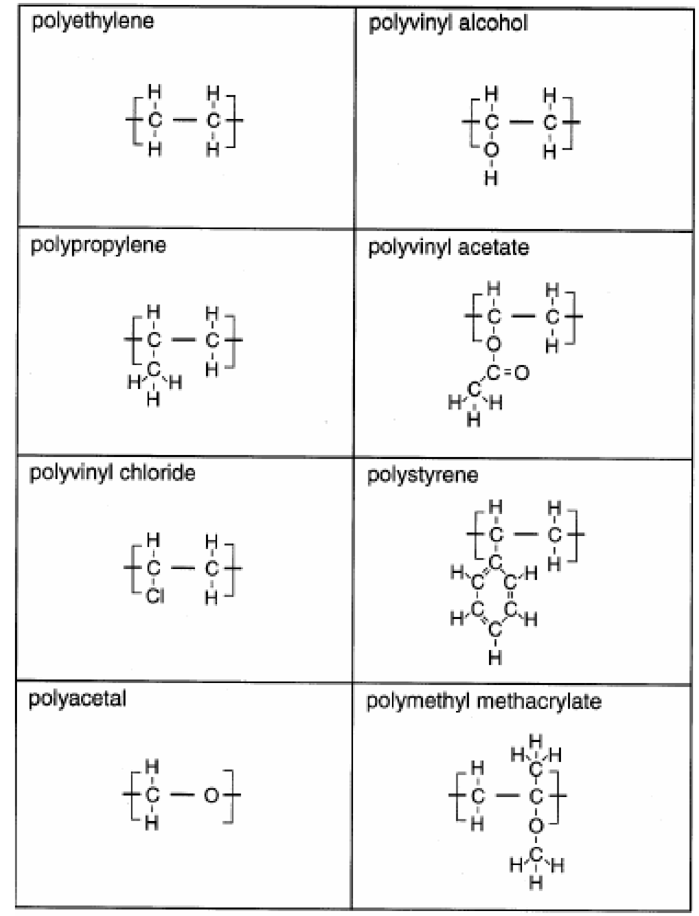
Powder Additives (cont.)

- Powder additives may be divided into two main groups
  1. Surface modifier
     - It involves changing surface characteristics by coating surface with thin layer of the additive to produce the desired function
     - It includes dispersants, and surfactants
  2. Bulk powder modifier
     - It deals with altering bulk properties of lose or packed powders by filling pores between particles
     - It is accomplished either coating or mixing and blending the particles with additives
     - It includes binders, agglomerating agents and lubricants



Lubricants and Binders

- They are low softening and melting points hydrocarbons
- Many are soluble in water
- Main hydrocarbons groups
  - paraffin wax
  - cellulose
  - polyacetal
  - polyethylene
  - polypropylene
  - stearates (wax + OH)
  - metallic stearates

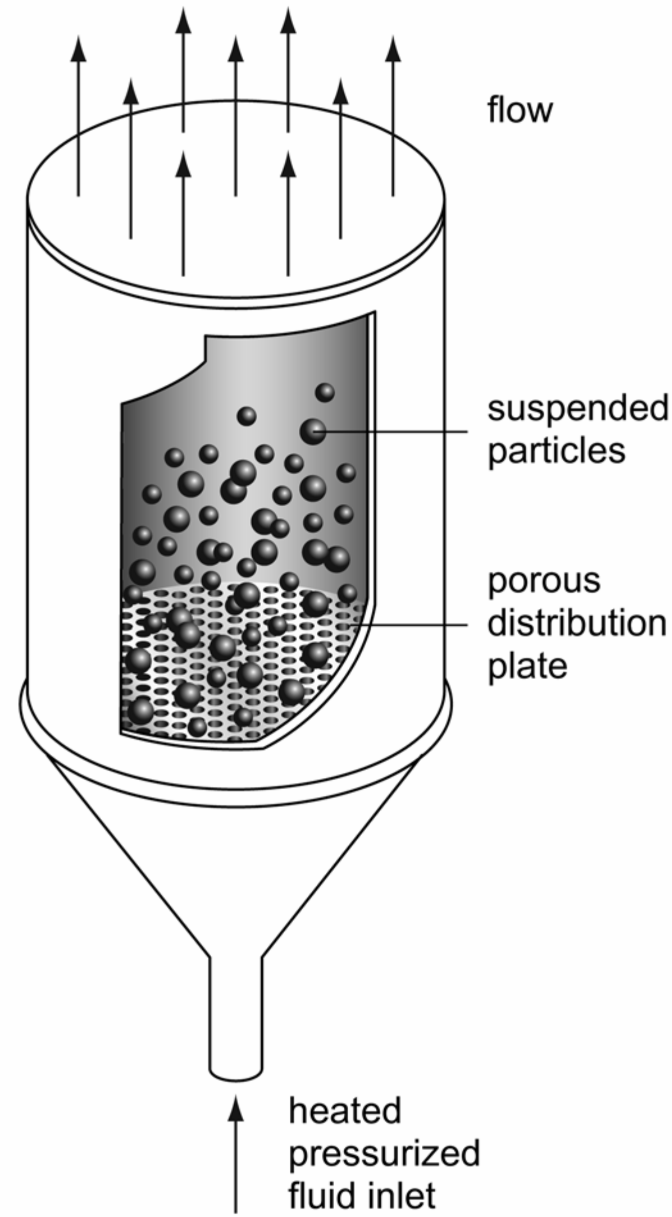


- Common lubricants
  - stearic acid -- 18 carbon chain, softens 45°C, 0.85 g/cm3
  - zinc stearate -- ZnO addition, softens 110°C, 1.09 g/cm3
  - lithium stearate -- Li2O addition, softens 200°C, 1.01 g/cm3
  - calcium stearate -- CaO addition, softens 115°C, 1.03 g/cm3
  - ethylene bis stearamid -- softens 129°C, 1.05 g/cm3

Particle Coating Processes

Fluidized bed

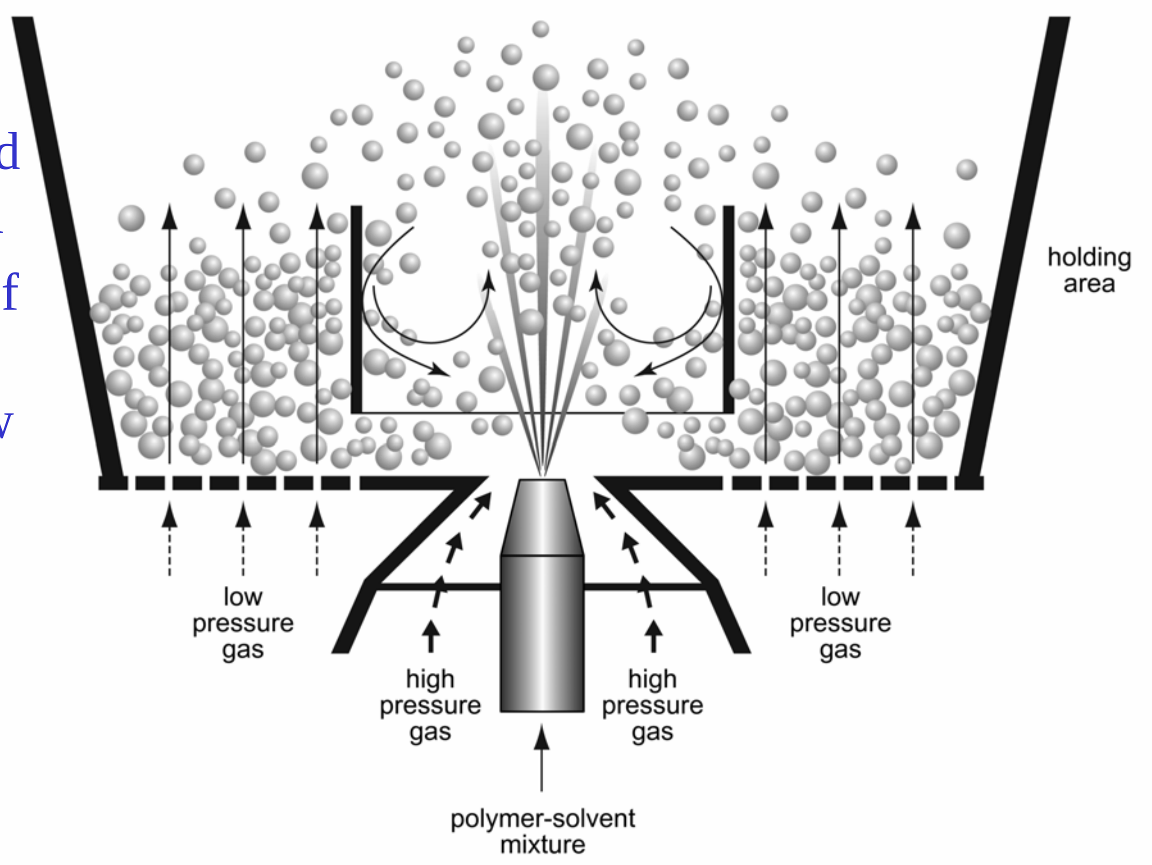
- The particles in the reactor are suspended and stirred by injecting high velocity gas through a porous plate at the base of the reactor
- The solvent-polymer is injected into the fluidization chamber together with the heated fluidization gas
- The polymer coat the particles and solvent vaporize and exit with fluidized gas.
- Agglomeration of coated particles is a result of collisions between the particles due to induced stirring of the particles by the flow in the bed
- To avoid elutriation of the particles with the exit gas, the superficial velocity of the gas in the bed must be less than terminal falling velocity of the particle
- This coating method is used with powders with narrow size distribution.



Particle Coating Processes (cont.)

Spouted bed

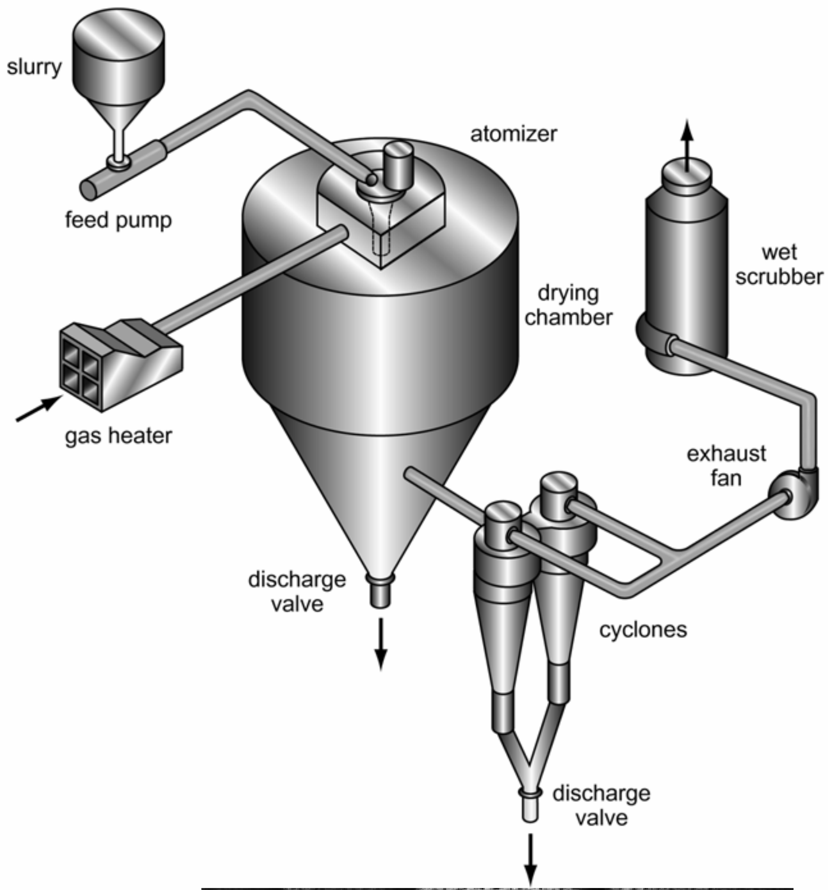
- The reactor is similar in concept and design to fluidized bed, but the injecting gas enters the center of the bed at higher velocity and the coating material enters the reactor at very high velocity using a separate nozzle.
- A baffle tube is used to provide recirculation of the particles from high to low velocity regions for enhanced collisions and agglomeration
- The inverted conical shape of the reactor walls is to reduce exit velocity to the gas below particle terminal velocity to avoid elutriation.
- This process can be used for powders with wide size distribution.

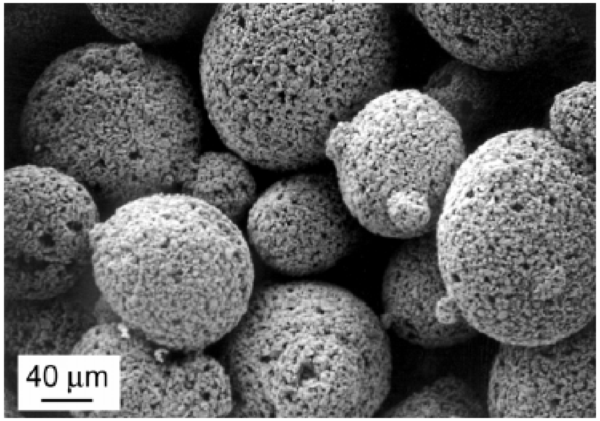


Particle Coating Processes (cont.)

Spray Drying

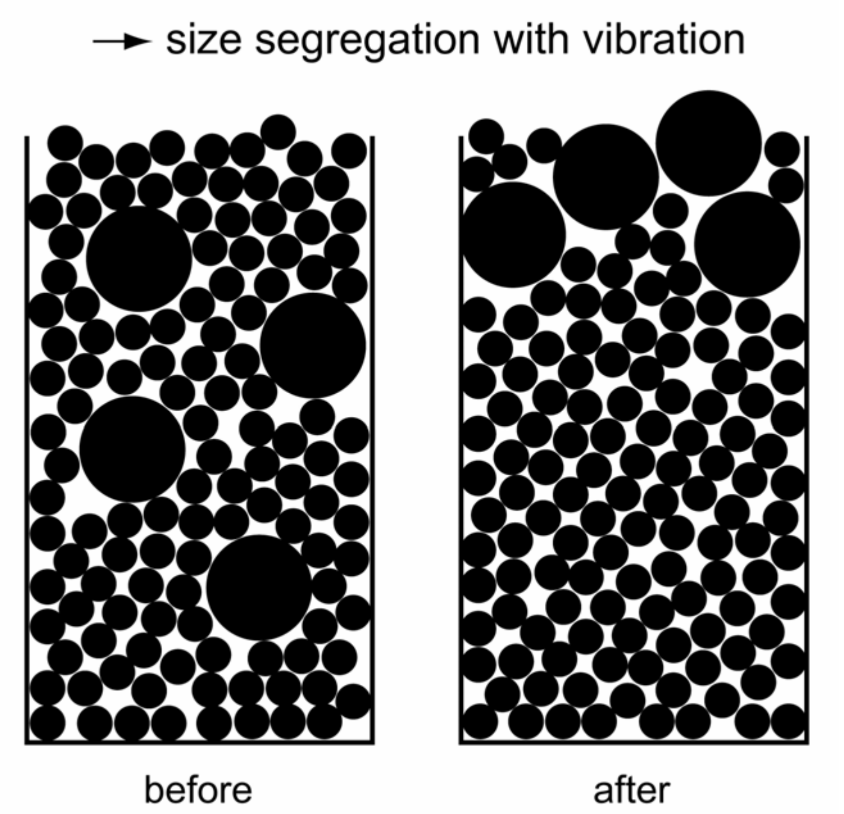
- It is used for coating and agglomerating fine hard ceramic, refractory metal and intermetallic particles.
- It is essentially a gas atomizer.
- The particles are mixed with solvent-polymer to form a slurry
- The slurry is atomized into small liquid droplets using a hot gas.
- During the free fall of the droplet, the solvent vaporize and the polymer hold the particles in the droplet together in the same shape of the atomized droplet
- This process produce porous spherical agglomerate of the powder.





Mixing and Blending

- Mixing and blending are important processing operations in powder preparation prior to compaction
- Mixing refers to the process of combining different materials such as nickel and iron, zirconia and alumina and wax and tungsten carbide
- Blending is the term used for homogenizing same material chemistry but with different material characteristics such as particle sizes from different sources and/or properties as a result of material segregation or sources
- Blending is essential in powder preparation because of inherent segregation of the particles during transportation.



Mixture Homogeneity

- Homogeneity is quantified using Homogeneity Index M

$$M = (So^2 - S^2)/(So^2 - Sr^2)$$

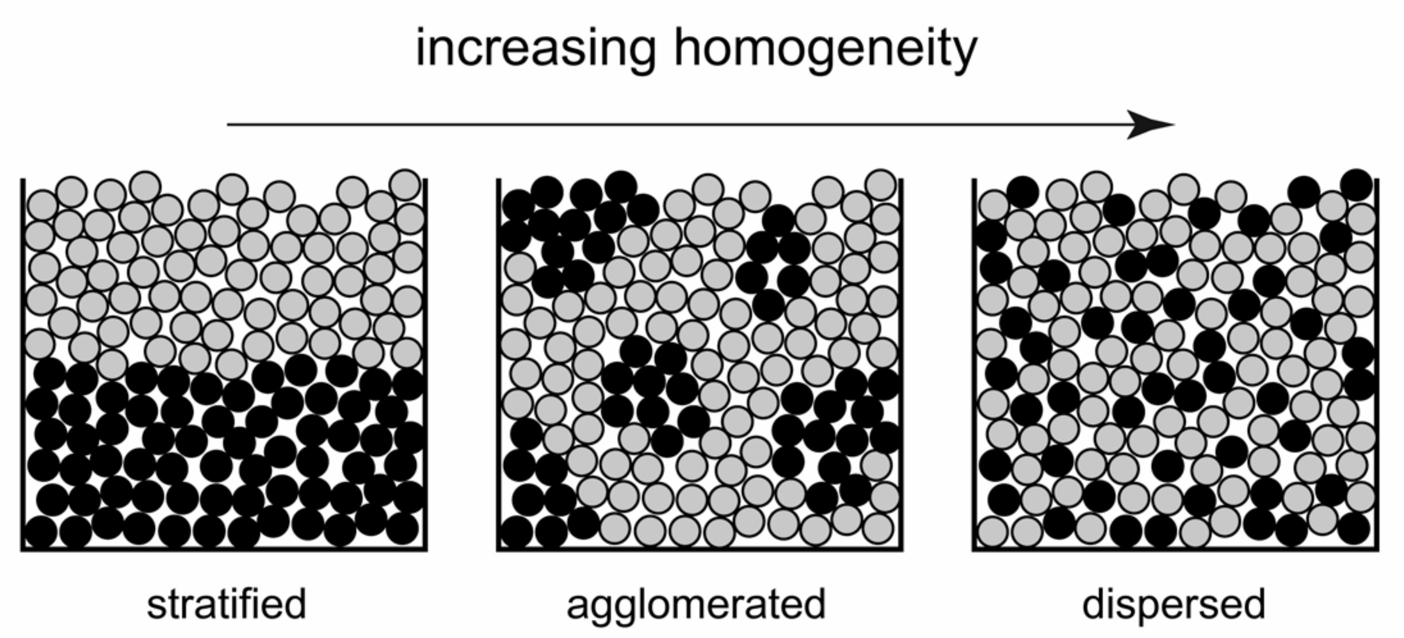
So^2 = initial variance of sample prior to mixing XP with (1-XP)

XP = concentration of major phase

S^2 = variance based on several samples

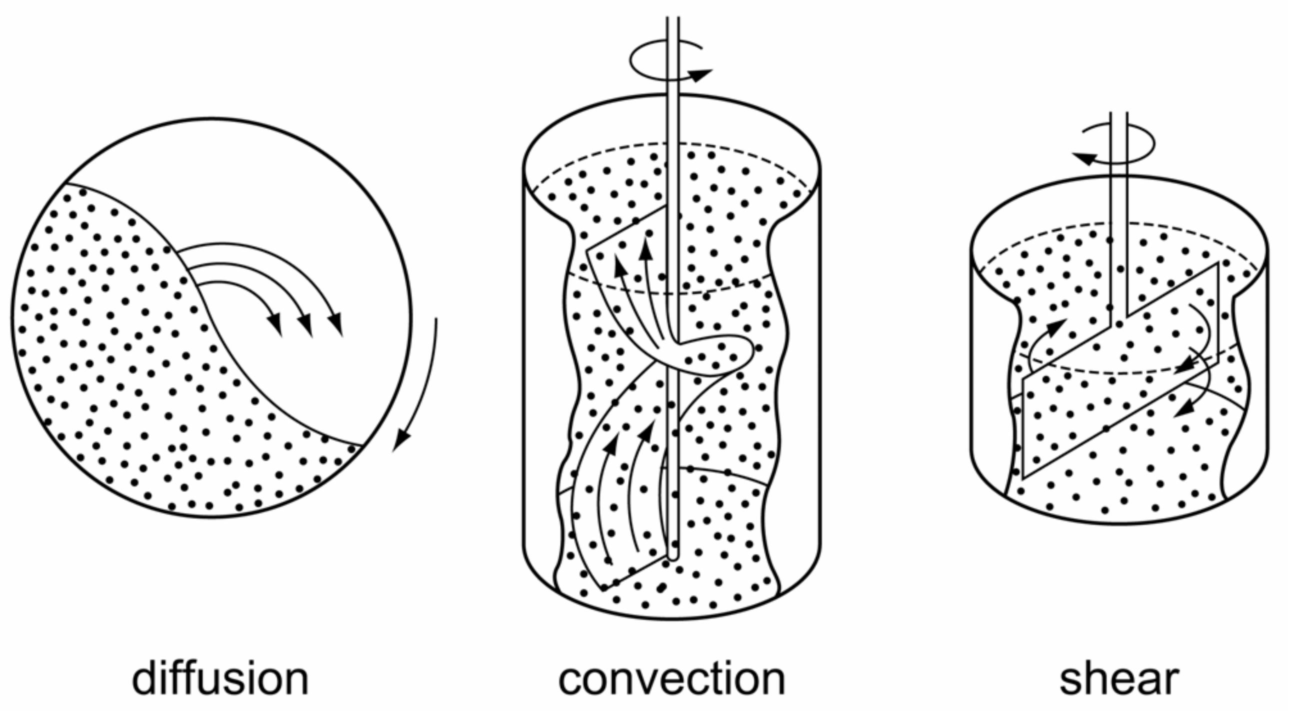
Sr^2 = perfectly mixed ideal = 0

- M varies from 0 to 1 with unity representing perfect mixing



Homogenization Mechanisms

- Homogenization of the powder is by stirring the powder
- Methods of agitating powder
  - Tumbling action of the powder in rotating drum (diffusion)
  - Axial recirculation of the powder using screw conveyer (convection)
  - Rotating the powder with paddles as in blade mixer (shear)



Mixing Kinetics

Starting with stratified mixture *M* is low

- fast early intermixing, *M* increases
- tumbling, falling, size separation demix
- asymptotic value when mixing rate = demixing rate

Mixing Time Equation

$$M = Mo + exp\ [K\ t + C]$$

t = time of mixing

Mo = initial mixture homogeneity

C and *K* are materials and processing dependent constants

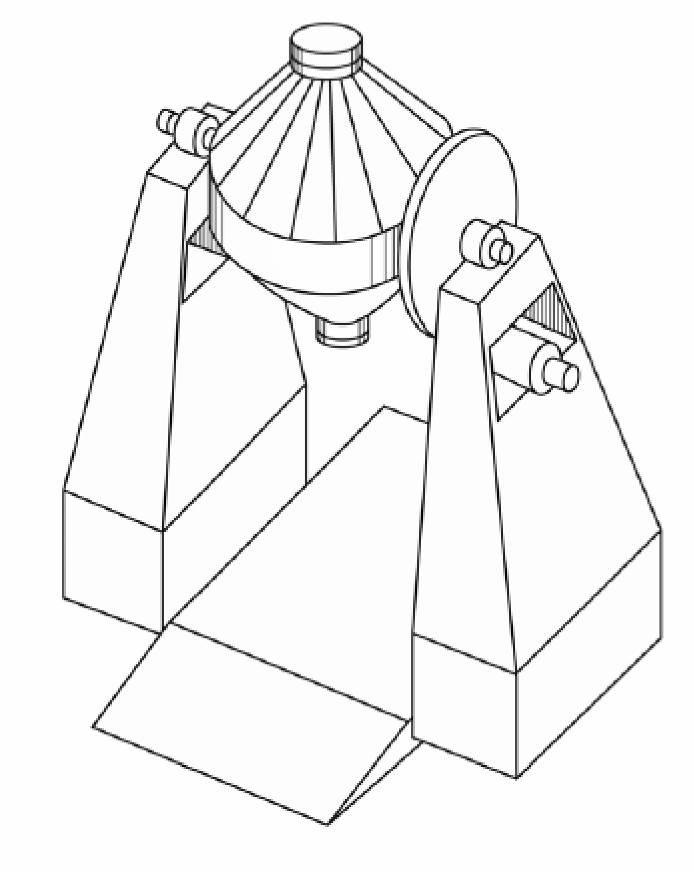
Dry Powder Mixers

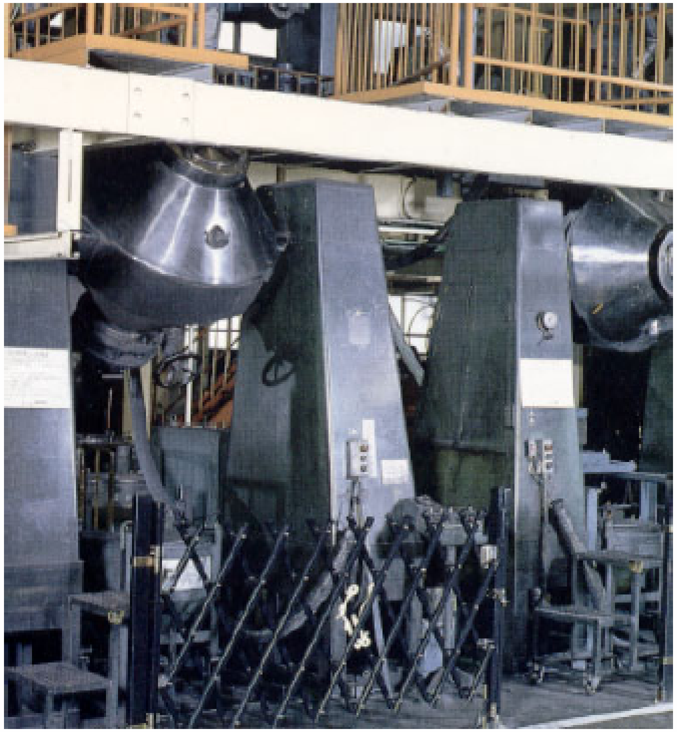
Double cone mixer

- Optimal Rotation Rate

$$N_o = 32 / d^{1/2}$$

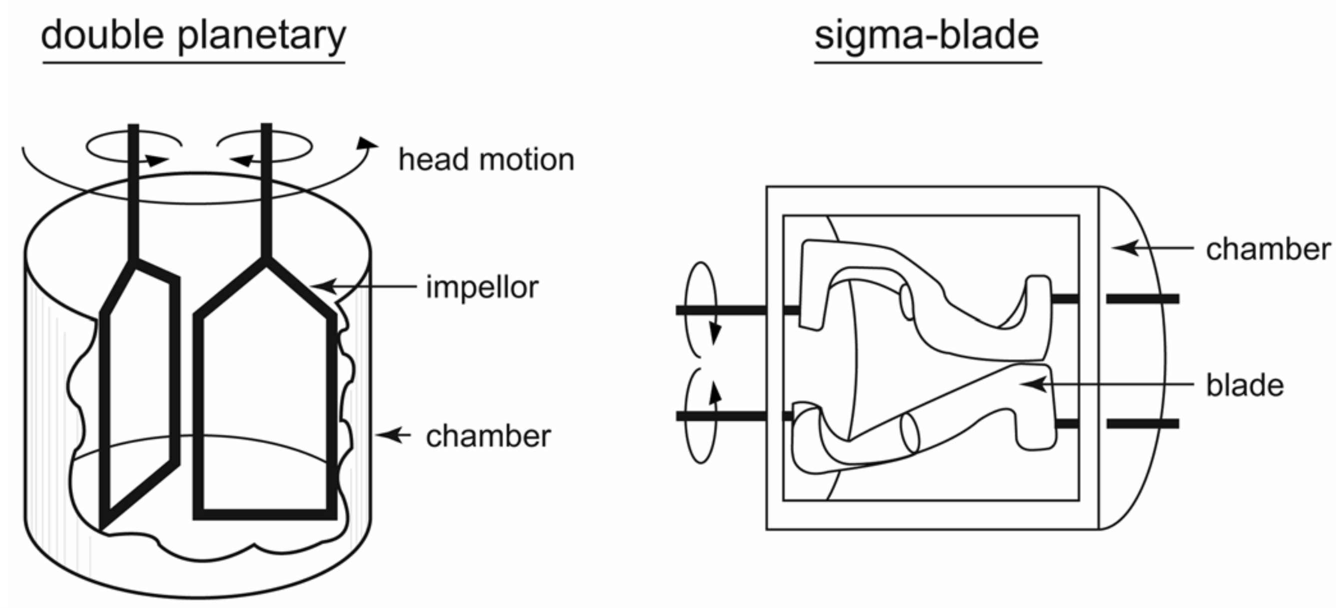
N_o in RPM (using d in m)





Wet Powder-Binder Mixers

Batch Mixers



Continuous Mixer