CHEMICAL ENGINEERING
FACTS AT YOUR FINGERTIPS
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Sedimentation Centrifuging

Centrifugation is the method of choice in the chemical process industries (CPI) for separating solids from liquids. It relies on the G-forces generated by high-speed rotation to recover solids or liquids from slurries, as well as clarify liquids or classify solids.

Centrifuges can be categorized as either sedimentation or filtration units. Sedimentation centrifugation relies on a difference in density between the solid and liquid being separated. Filtering is performed with a rotating basket fitted with a filter medium, where the centrifugal force of rotation expels the liquid through the filter.

BASICS OF SEDIMENTATION CENTRIFUGING

The mechanics of sedimentation centrifuging make it ideal for two-phase systems with a high-density differential. As an incoming slurry spins in a sedimentation centrifuge, it forms an annulus adjacent to the bowl wall. The centrifugal force causes the denser material to move outwardly toward the wall of the centrifuge bowl, while the liquid overflows from the bowl or is picked up by a skimmer. Periodically, the solid must be removed from the centrifuge manually or with a cutter knife. Alternatively, it can be removed continuously with a screw conveyor. Sedimentation centrifugation allows material to be separated hundreds or thousands of times faster than simple sedimentation by gravity alone.

STOKES' LAW

According to Stokes' Law, the terminal velocity of a particle is determined by the centrifugal gravity ($\Omega^2 r$) created by the centrifuge with particle-balancing buoyancy and viscous drag taken into account. This terminal (settling) velocity is determined by the equation below:

$$V_s = \frac{1}{18\mu}\Omega^2 r(\rho_s - \rho_L)\,d^2$$

where

V_s = Settling velocity, m/s
μ = viscosity, kg/m·s
Ω = angular speed of rotation, rev/min
ρ_s = density of solid, kg/m^3
ρ_L = density of liquid, kg/m^3
d = particle diameter, m
r = centrifuge radius of curvature, m

Stokes' Law tells us that settling velocity can be maximized with a high centrifugal speed, large particle size, large density difference between solids and liquid, large separation radius and low liquid viscosity.

APPLICATIONS

Centrifuge selection is heavily dependent on characteristics of the incoming slurry, including particle size, solids concentration, liquid viscosity and density differential. Other factors that come into play are the need to remove solids periodically or continuously and the degree of purity required of the separated products. Table 1 summarizes the mechanics and suitable applications of common sedimentation centrifuges.

References

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TABLE 1. TYPES OF SEDIMENTATION CENTRIFUGES

Type	Mechanics		Best suited for
Tubular Bowl	• A vertical cylinder with the feed slurry introduced in the bottom of the bowl • The use of a distributor and baffle assembly accelerates the slurry to the speed of rotation	• The heavier phase becomes concentrated against the wall, while the lighter phase floats on top • The two phases are separated by a baffle • Liquid discharges over the top of the bowl, while solid buildup is removed manually	• Purification of lubricating and industrial oils • Food, biochemical and pharmaceutical applications • Solids should be less than 1% in volume of the slurry
Multi-chamber	• Constructed of a series of tubular sections arranged concentrically • The slurry feed enters in the smallest tube and continues through the outer tubes as they increase in size	• Larger solid particles settle in the small tubes, and particles of smaller sizes settle in subsequent tubes • Up to six chambers are typical with a maximum holding capacity of 0.064 m^3	• Clarifying fruit juices, wort and beer
Skimmer pipe / knife discharge	• Feed enters the hub end and is accelerated to speed before entering the separation pool • Solids settle on the bowl wall while liquid overflows the ring weir	• When a thick solid layer begins to form on the bowl wall, supernatent liquid is removed with a skimmer, and solids are knifed out with centrifugal filters	• Heavy-duty applications, such as coal dewatering
Disc	• Feed enters through the top axis of the bowl and is accelerated by a radial-vane assembly • The unit is constructed of a stack of typically 50 to 150 closely spaced conical discs arranged at an angle between 40 and 50 deg	• Solids settle under the disc and move downward to be released at the bottom of the bowl wall • Liquids travel up the conical channel, and their upward movement in the centrifuge is facilitated by holes across each disc	• Self-cleaning types: purification of beverages, mineral oils, and edible oils • Disc nozzle: corn wet milling (starch separation, gluten thickening), clay classification, acid crystal washing, lube oil dewaxing
Decanter	• Constructed of a solid external bowl and an internal screw conveyor mounted horizontally	• Solids are removed from the conical discharge end (the beach) • Bowl and conveyor rotate in the same direction, but at different speeds, creating a speed differential that controls the speed of solid removal	• Applications that require continuous removal of solids, where feed solids are high and volume reduction is important
Screen-bowl	• A solid bowl decanter with a cylindrical screen added to the conical end		• Improved cake dryness and highest product purity