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PHARMACEUTICAL ENGINEERING

UNIT 4

TOPIC :

- **Centrifugation :** Objectives, principle & applications of Centrifugation, principles, construction, working, uses, merits and demerits of Perforated basket centrifuge, Non-perforated basket centrifuge, semi continuous centrifuge & super centrifuge.

Centrifugation

- Centrifugation is a separation technique that uses centrifugal force to separate components of a mixture based on density, size, and shape.
- When a sample is spun at high speed in a centrifuge, the denser particles move outward toward the bottom, while the lighter components remain closer to the center (top).
- It is widely used in pharmaceutical, clinical, and industrial applications.

Objectives of Centrifugation

1. Separation of Components of a heterogeneous mixture.
2. Concentration of biological/chemical samples by removing excess liquid.
3. Isolation and purification of cells, proteins, or drug compounds.
4. Clarification of liquids by removing suspended impurities.
5. Preparation of samples for diagnostic and analytical purposes.

Principle of Centrifugation

- Centrifugation works on the principle of sedimentation enhanced by centrifugal force.
- The force pushes particles according to:
  - Density (heavier particles move faster outward).
  - Size & shape of particles.
  - Viscosity of the medium.
- Formula for centrifugal force:

  $F = m \cdot \omega^2 \cdot r$

  where,
  m = mass of particle,
  ω = angular velocity,
  r = radius from center of rotation.

Types of Centrifugation

1. Differential Centrifugation – separates particles based on size and density stepwise.
2. Density Gradient Centrifugation – uses a medium (e.g., sucrose gradient) to separate based on buoyant density.
3. Ultracentrifugation – very high-speed centrifugation for viruses, DNA, ribosomes.
4. Analytical Centrifugation – used for research and studying molecular weights.

Applications of Centrifugation

- Pharmaceutical Industry
  - Isolation of active pharmaceutical ingredients (APIs) from impurities.
  - Purification of enzymes, proteins, and vaccines.
- Medical/Clinical Use
  - Separation of blood components: plasma, serum, RBCs, WBCs, platelets.
  - Diagnostic studies (e.g., isolating cellular components).
- Food Industry
  - Separation of cream from milk.
  - Clarification of fruit juices, wines, and beverages.
- Industrial Use
  - Removal of impurities from oils and lubricants.
  - Wastewater treatment (sludge separation).

Advantages

- Fast and efficient separation.
- Can handle both small and large sample volumes.
- Useful for heat-sensitive materials (no heating required).
- Provides high purity separation.

Disadvantages

- Requires expensive equipment (ultracentrifuges).
- Generates heat, which may damage biological samples.
- Some methods require special media (e.g., density gradients).

Perforated Basket Centrifuge

Principle

- The perforated basket centrifuge works on the principle of centrifugal force, which is generated when the basket rotates at high speed.
- When a slurry (mixture of solid and liquid) is introduced, the centrifugal force pushes the liquid phase outward through a filter cloth and the perforated wall of the basket, while solid particles are retained inside the basket, forming a filter cake.

Construction

1. Basket
    - A cylindrical basket made of metal with perforated walls.
    - Provides the chamber for holding slurry during centrifugation.
2. Filter Cloth
    - A porous filter medium lining the inner surface of the basket.
    - Prevents fine solid particles from passing through perforations.
3. Drive System
    - Consists of a motor, spindle, and bearings that rotate the basket at high speeds to generate centrifugal force.
4. Housing/Casing
    - Outer cover enclosing the basket.
    - Collects and channels the separated liquid to the outlet.
5. Feeding Arrangement
    - An inlet system for introducing slurry into the rotating basket.

Working

1. The slurry is fed into the rotating perforated basket lined with filter cloth.
2. On rotation, centrifugal force drives the liquid through the filter cloth and perforations.
3. The liquid is collected in the housing and discharged through outlet pipes.
4. Solid particles remain inside the basket, forming a filter cake on the cloth surface.
5. After separation, the liquid is drained, and the solid cake is manually or mechanically removed.

Advantages

- Simple design and operation.
- Efficient solid-liquid separation even for fine particles.
- Versatile – can be used for pharmaceuticals, chemicals, dyes, and oils.
- Easy maintenance compared to other centrifuges.

Disadvantages

- Labour intensive – requires manual removal of filter cake.
- High energy consumption due to rapid rotation.
- Not suitable for continuous operation.
- May cause wear and tear due to mechanical stress.

Applications

- Pharmaceutical industry: Separation of drug suspensions, crystallized products, intermediates.
- Food industry: Clarification of edible oils and fats.
- Chemical industry: Separation of chemicals, pigments, and dyes.
- Biotechnology: Isolation of microbial biomass or precipitated proteins.

Non-Perforated Basket Centrifuge

Principle

- Operates on the principle of centrifugal force.
- When slurry is rotated at high speed in a solid (non-perforated) basket, the dense solid particles migrate outward to form a cake along the basket wall, while the liquid remains above the solid cake and is later decanted (poured out).
- Unlike the perforated basket centrifuge, the liquid does not pass through the wall during rotation, but instead separates by sedimentation within the rotating basket.

Construction

1. Basket (Solid Wall)
    - A cylindrical basket without perforations (non-porous walls).
    - Designed to hold slurry inside during centrifugation.
2. Drive System
    - Motor, shaft, and bearings to rotate the basket at high speed.
3. Housing
    - Encloses the basket and provides safety during operation.
4. Inlet/Feeding Arrangement
    - For introduction of slurry into the rotating basket.
5. Outlet/Decanting System
    - After centrifugation, liquid is removed by decantation or siphoning.

Working

1. Slurry is fed into the non-perforated basket.
2. On rotation, centrifugal force pushes solid particles outward towards the wall of the basket.
3. A solid cake forms at the wall, while the liquid remains as a separate layer above the solids.
4. The liquid phase is carefully removed by decantation, siphoning, or overflow.
5. The solid cake is then collected manually.

Advantages

- No filter medium required (since basket is non-porous).
- Useful for separating coarse particles and slurries where solids settle easily.
- Simple to design and maintain.
- Less wear and tear compared to perforated type.

Disadvantages

- Less efficient for fine particle separation (as liquid cannot pass through walls during rotation).
- Requires decantation step after centrifugation, making it slower.
- Not suitable for continuous operation.
- Labour intensive for cake removal.

Applications

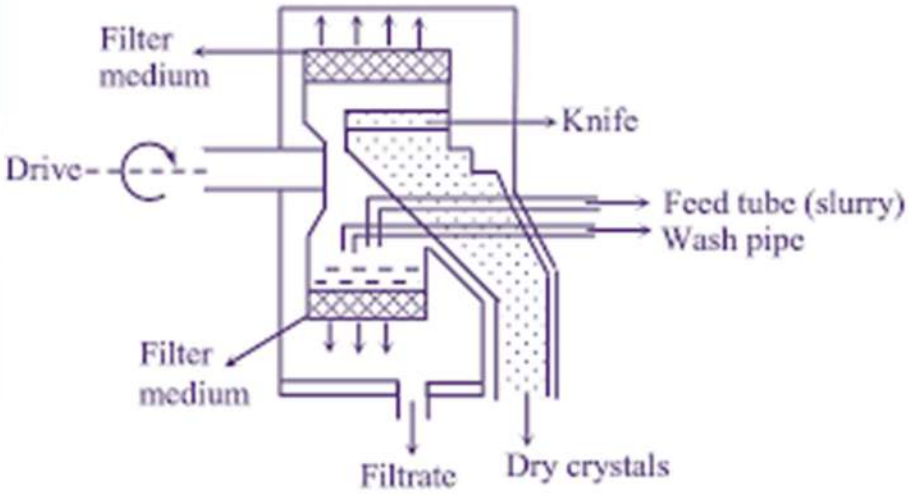
- Pharmaceutical industry: Used for separation of crystalline drugs where solids are coarse and heavy.
- Food industry: Separation of starch suspensions, sugar crystals.
- Chemical industry: Recovery of coarse chemical precipitates.
- Wastewater treatment: Removal of large suspended solids.

Semi-Continuous Centrifuge

Principle

- Based on the application of centrifugal force to separate solid and liquid phases from a slurry.
- Operates in a semi-continuous mode, meaning slurry feeding is continuous, but discharge of separated solids is intermittent (batch-wise).
- Liquid phase is continuously removed, while solids accumulate inside until discharged.

Construction



1. Centrifuge Bowl/Basket
    - May be perforated or solid, depending on the application.
    - Usually fitted with a filter medium (cloth or screen).
2. Feed System
    - Slurry is continuously fed into the rotating bowl via an inlet pipe.
3. Drive System
    - Motor and spindle arrangement for high-speed rotation.
4. Housing/Enclosure
    - Provides safety, prevents spillage, and collects clarified liquid.
5. Solid Discharge System
    - Solids are discharged intermittently either manually or automatically (by scrapers or plough mechanisms).

Working

1. Slurry is continuously introduced into the rotating centrifuge.
2. Due to centrifugal force, solids deposit on the wall of the basket, forming a cake.
3. The clarified liquid (filtrate) passes through the filter medium and is removed continuously.
4. Once enough solids have accumulated, the centrifuge is stopped or slowed, and solids are discharged.
5. Operation is then restarted for the next cycle.

Advantages

- Continuous liquid removal with intermittent solid discharge.
- Handles larger volumes compared to batch centrifuges.
- Provides better throughput than fully batch centrifuges.
- Can be automated to some extent (semi-automatic discharge).

Disadvantages

- Not truly continuous → solids must be discharged intermittently.
- Requires downtime for cake removal.
- More complex design compared to batch centrifuges.
- High energy consumption for large-scale operations.

Applications

- Pharmaceutical industry: Separation of bulk drug crystals, antibiotics, and fermentation products.
- Food industry: Clarification of fruit juices, separation of dairy products.
- Chemical industry: Recovery of pigments, dyes, and precipitates.
- Biotechnology: Recovery of microbial biomass from fermentation broth.

Super Centrifuge

Principle

- A super centrifuge works on the principle of very high centrifugal force to separate particles from liquids.
- Unlike normal centrifuges, it operates at extremely high speeds (up to 60,000 rpm), generating forces several thousand times greater than gravity (> 20,000 g).
- It separates particles mainly based on size, shape, and density differences, even when the difference is very small.

Construction

1. Rotor/Bowl
    - Narrow, tubular rotor designed to withstand ultra-high speeds.
    - Can be vertical or horizontal in design.
2. Drive Motor
    - High-speed motor (air-turbine or oil-driven) capable of achieving very high RPM.
3. Casing/Enclosure
    - Strong metallic housing with vacuum jacket or refrigeration system to reduce friction and heat.
4. Feed & Outlet System
    - Slurry or suspension is fed into the bowl.
    - Clarified liquid exits through an outlet, while solids deposit on the rotor wall.
5. Control Panel
    - For adjusting speed, time, and safety interlocks (essential due to very high forces).

Working

1. The suspension is introduced into the rapidly rotating rotor.
2. At ultra-high speeds, centrifugal force causes even the finest particles or macromolecules to sediment quickly.
3. Solids form a thin layer on the rotor wall, while the clarified liquid is removed.
4. After the run, the centrifuge is stopped and solid deposits are collected.

Advantages

- Extremely high separation efficiency (even for very fine particles, viruses, proteins).
- Provides rapid separation compared to normal centrifuges.
- Suitable for both analytical and preparative purposes.

Disadvantages

- Very expensive equipment.
- Requires skilled operation and maintenance.
- Limited capacity (usually handles small to medium volumes).
- Generates significant heat → requires refrigeration or vacuum system.

Applications

- Pharmaceutical industry: Purification of vaccines, separation of protein fractions, isolation of enzymes, and antibiotics.
- Biotechnology: Separation of viruses, DNA, ribosomes, and sub-cellular organelles.
- Medical/Clinical labs: Separation of plasma proteins, hormones, and diagnostic samples.
- Food industry: Clarification of fruit juices, milk whey proteins.