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DEPARTMENT OF FOOD TECHNOLOGY

23FTB201 - UNIT OPERATIONS IN FOOD PROCESS ENGINEERING

Unit – 2

An Introduction to Size Reduction

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INTRODUCTION

Size reduction in food processing is the process of breaking down large food materials into smaller, more manageable particles. This essential operation serves multiple purposes in the food industry, such as

- Improving texture and consistency
- Increasing surface area for better extraction or mixing
- Enhancing cooking and processing efficiency
- Facilitating transport, packaging, and storage

Common methods of size reduction include grinding, milling, chopping, and crushing. These techniques are employed using specialized equipment like grinders, mills, and crushers, depending on the food material and desired particle size.

Principle of Size Reduction

- **Mechanical Size Reduction**:
  - Involves the reduction of large particles to smaller sizes through mechanical forces.
  - The process typically uses mechanical equipment like crushers, grinders, mills, and sieves.
- **Energy Requirements**:
  - Size reduction requires energy to overcome the forces of particle cohesion (bonding forces) and resistance to compression or shear.
  - The energy consumed is generally proportional to the surface area created by the size reduction.
- **Particle Fracture Mechanisms**:
  - Size reduction can occur through **compression**, **shearing**, **impact**, or a combination of these forces.

Kick's law of size reduction

Kick’s law assumed that the energy required to reduce a material in size was directly proportional to the size reduction ratio dL/L. This implies that n is equal to -1.

- $K = K_K f_c$
- where K_K is called Kick's constant and f_c is called the crushing strength of the material, we have:
- $dE/dL = K_K f_c L^{-1}$
- which, on integration gives:
- $E = K_K f_c \log_e(L_1/L_2)$

Rittinger's law for Size reduction

Rittinger, on the other hand, assumed that the energy required for size reduction is directly proportional, not to the change in length dimensions, but to the change in surface area.

- $K = K_{Rfc}$ and so
- $dE/dL = K_R f_c L_2$

where K_R is called Rittinger's constant, and integrate the resulting form we obtain

- $E = K_R f_c(1/L_2 - 1/L_1)$

Bond's law of size reduction

Bond's law of size reduction states that the energy required to reduce a material's particle size is proportional to the square root of the material's surface-to-volume ratio.

Bond’s law has suggested an intermediate course, in which he postulates that n is -3/2 and this leads to

- $E = E_i (100/L_2)^{1/2}[1 - (1/q^{1/2})]$

These equations are dimensional equations and so if quoted values are to be used for the various constants, the dimensions must be expressed in appropriate units. In Bond's equation, if L is expressed in microns, this defines E_i and Bond calls this the Work Index.

Equipments used in crushing

Jaw Crusher

Principle:

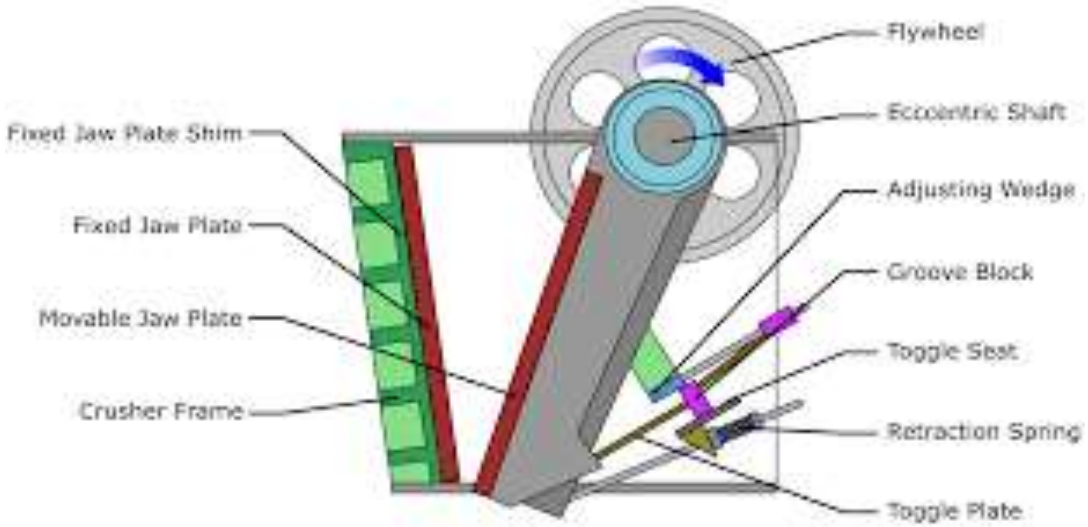
Crushing Action: Jaw crushers operate on the principle of compression. A moving jaw exerts force on the material, reducing its size when it is compressed between the stationary and moving jaws.

Working

- Material enters through the top of the jaw crusher.
- The moving jaw moves in a reciprocating motion, crushing the material against the stationary jaw.
- The crushed material exits through the bottom opening.

Application

- Used for primary crushing of soft to medium-hard foods like fruits (apples, tomatoes) and vegetables (carrots, potatoes).
- Juicing and sauces production, where size reduction aids in extraction.



Hammer Mill

Principle

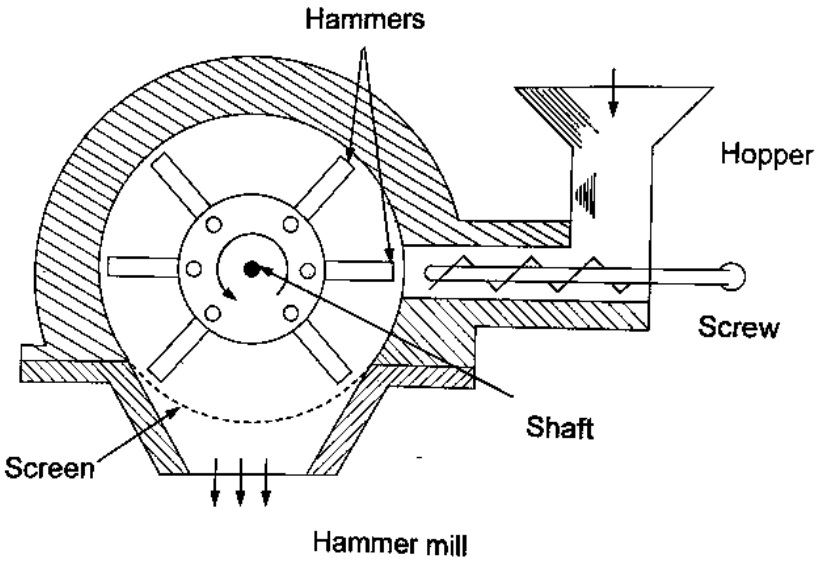
- Crushing Action: Hammer mills operate on the principle of impact. Material is fed into the mill, where it is struck by rotating hammers, breaking it into smaller particles.

Working

- Material is fed into a chamber containing hammers rotating at high speed.
- The hammers strike and crush the material into fine particles.
- The size of the particles is controlled by the mesh size of the screen in the chamber.

Application

- Grinding grains (wheat, corn) into flour.
- Crushing nuts and seeds into powder.
- Spice milling and drying processes for creating finer powders.



Roll Crusher

Principle

- Crushing Action: Roll crushers use compression and shearing forces. Two rotating cylinders (rolls) crush the material between them.

Working

- Material enters between two rolls rotating in opposite directions.
- As the rolls rotate, material is crushed between them.
- Adjustable spacing between the rolls allows control over the final particle size.

Application

- Crushing soft fruits (bananas, berries) for pulp.
- Crushing grains and seeds before milling.
- Sugar cane crushing for juice extraction.