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Department of Food Technology
Fluid Mechanics and Mechanical operation
Topic :Size Reductions

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Types of Size-Reduction Equipments

1. Crushers
   a) Jaw crusher
   b) Gyratory Crusher
   c) Crushing rolls
2. Grinders
3. Ultrafine grinders
   a) Fluid-energy mills
   b) Agitated mills
4. Cutting machines
   a) Knife cutters, dicers, slitters

2. Grinders
   a) Hammer mills
   b) Rolling mills
   c) Attrition mills
   d) Revolving mills
      i. Rod mills
      ii. Ball mills
      iii. Tube mills

Crushers: Large pieces into small lumps [150-250mm]

Grinders: product might pass a 40 to 200 mesh screen

Ultra fine grinders: feed size[< 6mm]; product [1-50 μm]

Cutters: definite size and shape [2-10mm length]

Factors to be considered for selecting equipment:

1) Properties of the feed to be handled such as hardness, crushing strength and etc.,
2) Nature of the product required
3) Quality of the material to be handled
4) Size of the material to be handled
5) Speed of the size reduction equipment

Crushers

- ✔ Slow-speed machines
- ✔ Coarse reduction of hard solids
- ✔ Mechanism: Compression

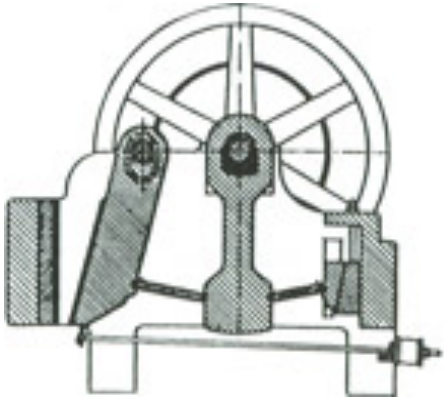
Types of Crushers:

a) Jaw crushers
b) Gyratory crushers
c) Rolling crushers

Jaw crushers

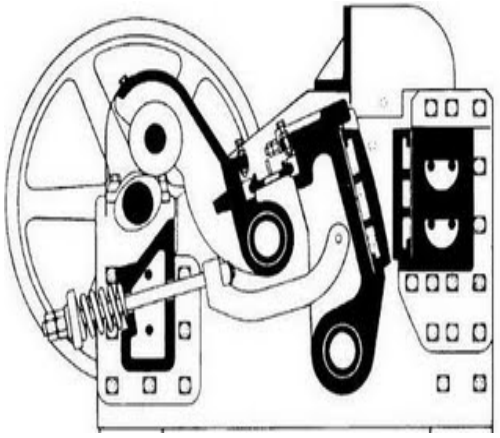
Blake Jaw Crusher

1. Movable jaw is pivoted at top
2. Maximum movement at bottom
3. No choke
4. High production rate
5. Low maintanance
6. Large reduction ratio is not possible
7. No uniform products
8. Comparitevely made in large sizes
9. Commonly used



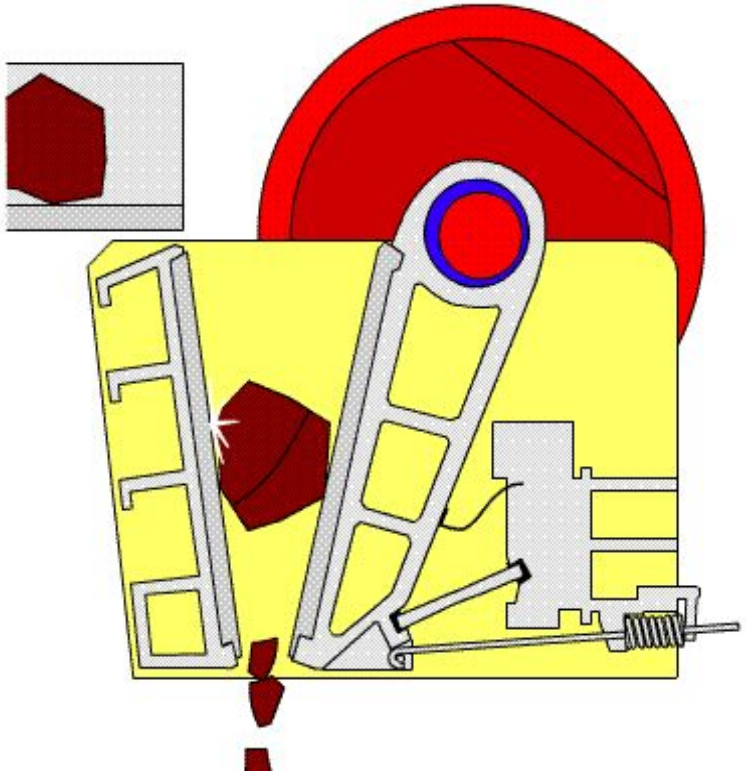
Dodge Jaw crusher

1. Movable jaw is pivoted at bottom
2. Maximum movement at top
3. Tendency to choke
4. Suitable for low production rate
5. High maintanance
6. Large reduction ratio is possible
7. Uniform products
8. Comparitevely made in smaller sizes and less widely used



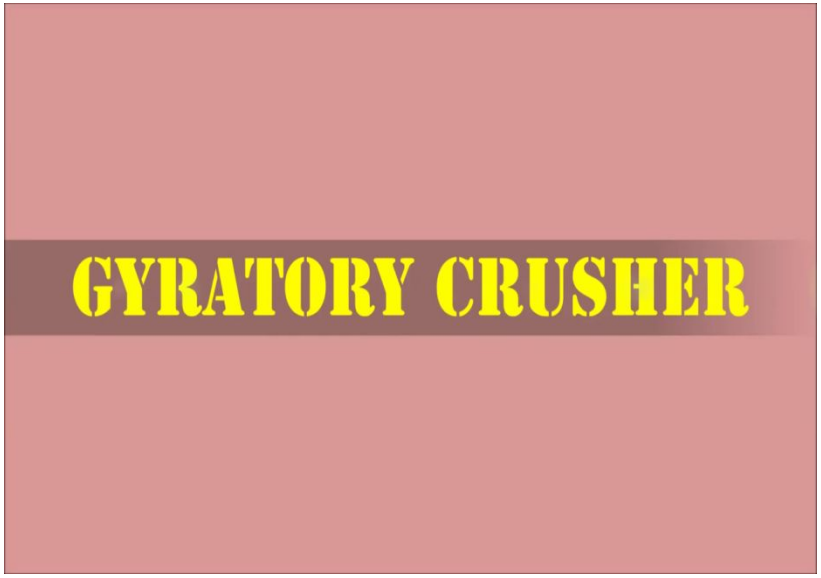
Blake Jaw Crusher

- ✔ Fixed and Movable Jaw
- ✔ Movable jaw is pivoted at top
- ✔ Jaws set to form a “ v ” open
- ✔ Movable jaw reciprocates in a horizontal plane and makes an angle of 20 to 30° with fixed jaw
- ✔ Jaws – manganese steel to withstand abrasion
- ✔ Maximum movement at bottom and little tendency to choke
- ✔ Jaws usually open and close 250 to 400 times per minute



Gyratory Crusher

- ✔ Funnel shaped case at top
- ✔ Conical crushing head is fixed at top and flexible bearing
- ✔ Lower end of shaft is driven by eccentric so as to trace a circle
- ✔ Crushing head moves towards and then away from the stationary wall
- ✔ Crushing action takes place around the cone
- ✔ Speed of the crushing head usually lied between 125 to 425 gyrations per minute
- ✔ Continuous, fluctuations in stresses are smaller
- ✔ Load on motor is nearly uniform
- ✔ Less power consumption and maintance
- ✔ Captial cost is high. So, suitable for large production

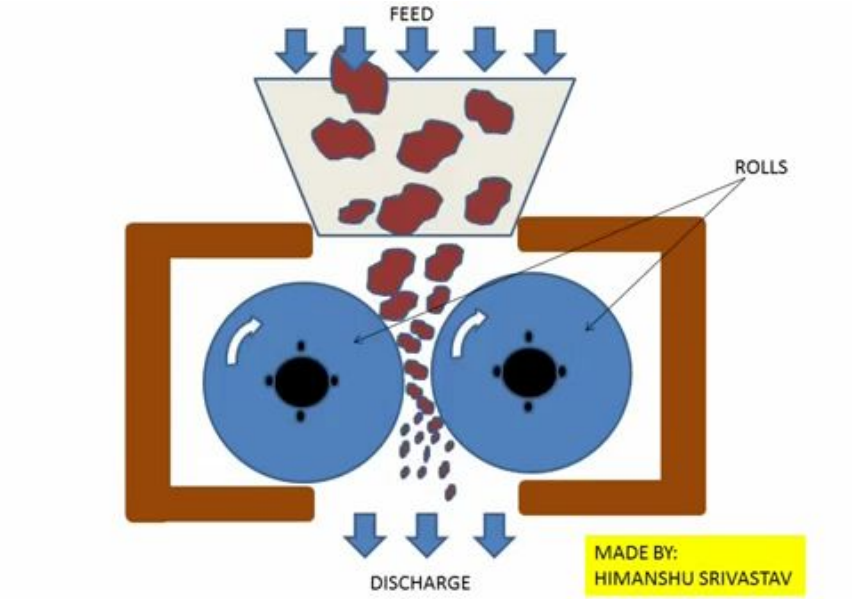


Comparision of Jaw & Gyratory crushers

Jaw Crusher	Gyratory crusher
1. Reciprocating action	1. Gyratory action
2. Discharge is discontinuous	2. Discharge is continuous
3. Primary crusher, takes a feed of larger size	3. Secondary crusher, takes a feed of smaller size
4. Load on motor is not uniform	4. Load on motor is nearly uniform
5. High maintanance	5. Low maintanance
6. High power consumption	6. Low power consumption
7. Low capital cost	7. High capital cost
8. Smaller capacity when used to produce a small size reduction	8. Larger capacity when used to produce a small size reduction

Crushing Rolls – Smooth Roll Crusher

- ✔ Two heavy metal rolls of the same diameter
- ✔ Rolls mounted on shafts, are rotated each other at the same speed
- ✔ One of the shafts moves in the fixed bearings and other moves in the movable bearings
- ✔ Clearance between the rolls can be adjusted according to the size of feed and size of product required
- ✔ Protected by spring loading against damage
- ✔ Speed of rolls varies from 50 to 300 rev/min
- ✔ Crushing rolls are secondary crushers accepting feed 12 to 75 mm in size
- ✔ Selection of rolls depends on size of the feed and product



Angle of nip: angle formed by the tangents to roll faces at a point of contact with a particle to be crushed

$$cos\alpha = \frac{r + d}{r + R}$$

R = radius of feed particle
r = radius of the roll
2d = gap between the rolls

Grinders – Hammer Mill

- ✔ Mechanism: Impact and attrition
- ✔ High speed rotor turning inside a cylindrical casing
- ✔ Rotor mounted in a shaft horizontally
- ✔ The swing hammers are pinned to a rotor disk
- ✔ Hammers are rectangular metal bars
- ✔ The particles are broken by the sets of swing hammers
- ✔ Product falls through a grate screen which forms the lower portion of the casing
- ✔ The shaft is rotated at high speed and centrifugal force causes the hammers to swing out radially
- ✔ Material is beaten by the hammers around inside the casing by impact

Grinders – Revolving Mill

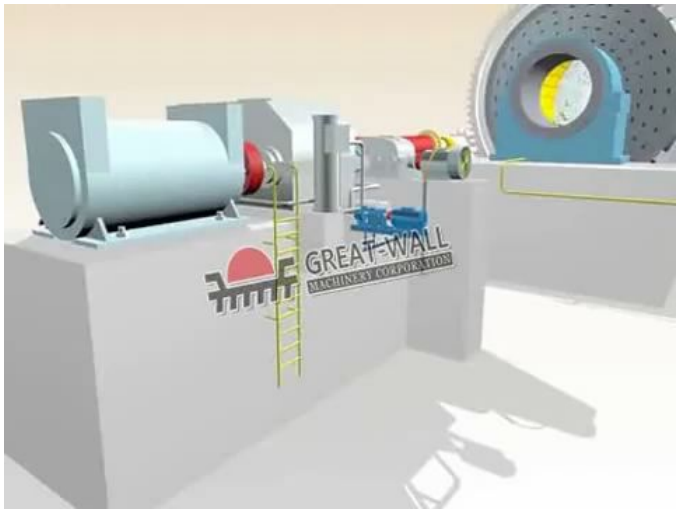
- ✔ Mechanism: Impact and attrition

Revolving mill / Tumbling mill:

- ✔ Cylindrical shell slowly rotaing on a horizontal axis and charged with a grinding medium to about half its volume.

Ball Mill:

- ✔ Hollow cylinder rotaing about its axis
- ✔ Legth of cylinder twice the diameter or more
- ✔ Grinding medium: steel balls
- ✔ The inner surface of the cylindrical shell is usually lined with an abrasion resistant material such as manganese steel or rubber
- ✔ The balls occupy 30 to 50% volume
- ✔ Ball diameter: 12mm to 125 mm
- ✔ Operation: Batch or continuous, wet or dry



Factors influencing the product size:

a) Feed rate
b) Properties of feed material
c) Weight of balls
d) Speed of rotation of the mill
e) Level of the material in the mill

Advantages of ball mill:

- ✔ Low capital cost and power consumption
- ✔ Suitable for batch and continuous
- ✔ Grinding medium is cheep
- ✔ Suitable for all materials
- ✔ Suitable for closed and open circuit

Cetrifuging: If the mill is operated at high speeds, the balls are carried right round in contact with the sides of the mill and the mill is said to be centrifuging.

Critical Speed: The minimum speed at which centrifuging occurs is called critical speed of the ball mill and under these conditions, centrifugal force will be exactly balanced by the weight of the ball. Little or no grinding takes place when the mill is centrifuging.

If the mill is to operate practically, the operating speed must be less than the critical speed.

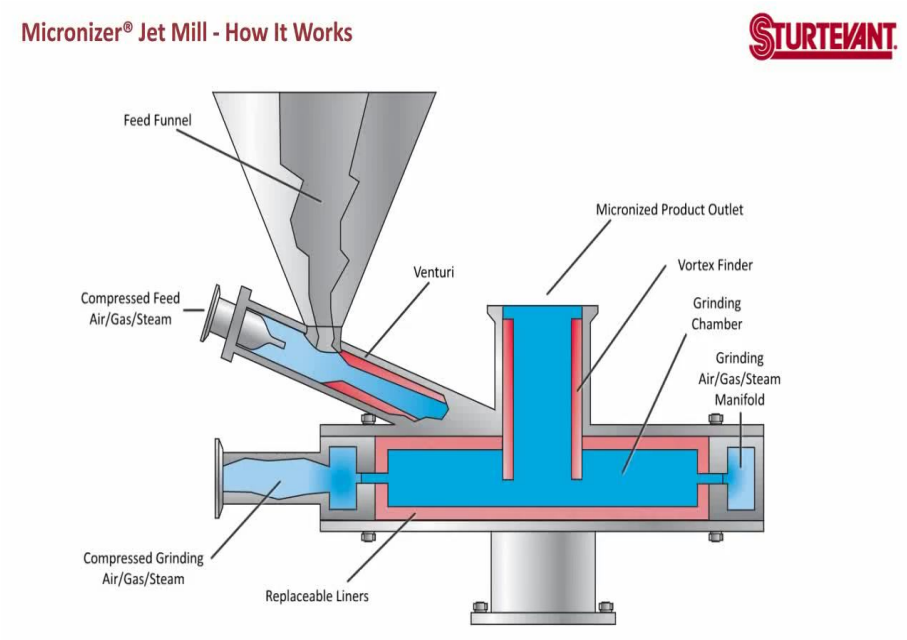
Generally, operating speed will be to 50% to 75% of the critical speed of the ball mill.

Comparision of Crushing & Grinding

	Crushing	Grinding
1.	Compression mechanism	Impact and attrition mechanism
2.	Large lumps to small lumps	Small lumps to powders
3.	Open circuit operation	Closed circuit operation
4.	Only for dry feed material	Both dry and wet material
5.	Reduction ratio: 6-8	High reduction ratio as 100
6.	Two types: primary and secondary crushers	Two types: grinders and ultrafine grinders
7.	Heavy duty and low speed machines	Light duty and high speed machines
8.	Energy consumption is high	Enegry consumption is low

Ultrafine Grinders-Fluid Energy Mill

1. Attrition mechanism-Attrition between the rapidly moving particles
2. A source of high pressure compressed fluids enters the chamber through nozzles in the periphery at high speed provides energy to the particles to achieve high velocity
3. No moving parts and no griding media
4. Feed supplied tangentially and its get accelerated, causing it to impact againg itself-breaking of particles
5. Larger size particles are held towards the outer periphery of the chamber by centrifugal force
6. Smaller one moves centrally



Size of feed particles – 150 microns
Size of products – 1-10 microns

Open and Closed Circuit Grinding

Open Circuit Grinding

1. If the material is passed only once through the machine and no attempt made to return the oversize material to it for further reduction
2. Favours for small reduction ratio and coarse reduction of particles
3. Advantages: simple in operation and minimum equipment requirements
4. Grinding mills are arranged in series or paralles without classification equipment

Closed Circuit Grinding

1. If the partially ground material from the machine is sent to a size separation unit, from where the undersize withdrawn as the product and the oversize material returned to the machine for reground
2. Favours for larger reduction ratios and fine reduction particles
3. Advantages: Higher capacity, lower power consumption, suitable for fine and ultrafine products, avoid coarse material in final product and eliminate overgrinding by removing fines early
4. One or more grinding mills with classification equipment

Unit-2 Separation of Solids

- ✔ Separation of solids: Screeing, magnetic separation and electrostatic separation
- ✔ Screeing: separation of solid particles according to size [using screen with known openings]
- ✔ Magentic separation: Separation of particles by means of magnetic field. Materials having different magnetic attractability are separated by passing them through a magnetic field.
- ✔ Electrostatic separation: separation of solid particles based on the differntial attraction or repulsion of charged particles under the influence of an electric field.
- ✔ Materials for screens: Metal bars, woven wire cloth, slik bolting cloth, perforated metal plates

Importance of screening operation

- ✔ Remove the fines from a feed material before a reduction equipment such as jaw crusher, ball mill or rod mill
- ✔ Prevent an incompletely crushed material (oversize) from entering into other unit operations
- ✔ Produce a commercial or process-grade material to meet specific particle size limits
- ✔ Remove the fines from a finished product prior to shipping

Classification of screens based on performance

- ✔ The objective of a screen is to accept a mixture of various sizes of grains and separate it into two fractions, namely an underflow and overflow.
- ✔ The underflow is the one that is passed through the screen
- ✔ The overflow is the one that is rejected/retained by/in the screen
- ✔ Classification: Ideal screen and Actual screen
- ✔ Ideal screen: An ideal screen is the one which sharply separates the feed mixture in such a way that the smallest particle in the overflow is just larger than the largest particle in the underflow
- ✔ The ideal separation based on Cut diameter (D_{pc}) which makes the point of separation between the undersize and oversize fraction is nearly equal to the mesh opening of the screen

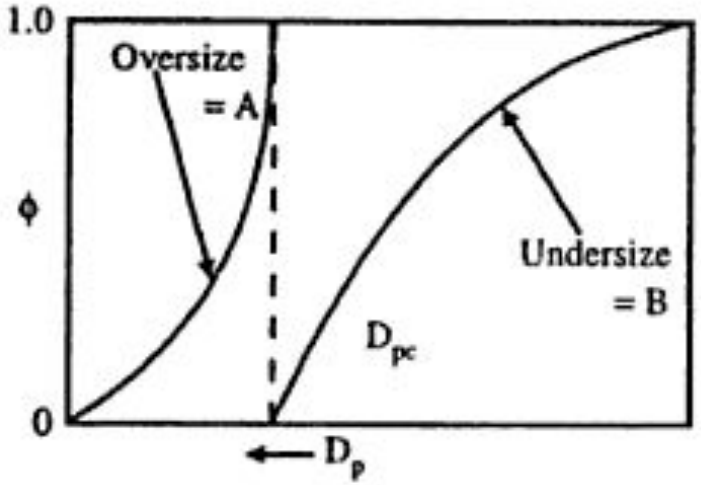
Comparison of Ideal and Actual screen

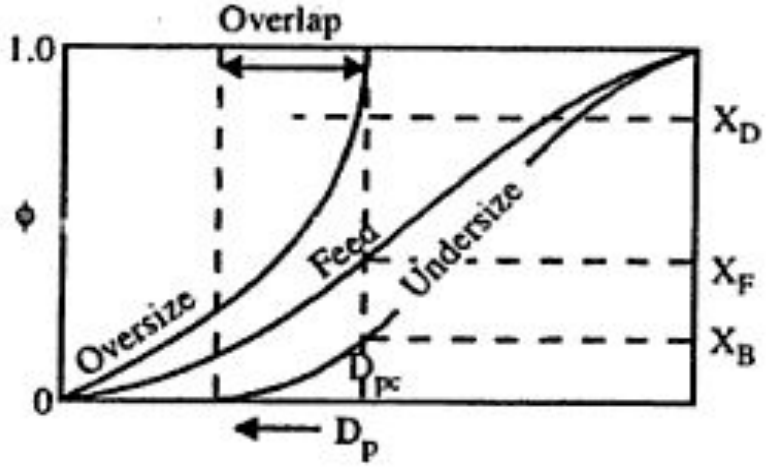
Ideal screen

1. Yields sharp separation
2. Efficiency of the screen is 100%
3. Such screen do not found in practice
4. The overflow will contain only particles larger than the cut diameter
5. Underflow will contain only particles smaller than the cut diameter

Actual Screen

1. Does not yield sharp separation
2. Efficiency of the screen is less than 100%
3. Such screen available in practice
4. The overflow may also contain particles small than the cut diameter
5. Underflow may also contain particles larger than the cut diameter





Types of standart screen series

- ✔ Tyler standard screen series
- ✔ BSS: British standard screen series
- ✔ IS:Indian standard screen series
- ✔ US: U.S. Sieve sereis
- ✔ ASTM: American standard teshing of mateiral screen series

- ✔ Mesh: In coarse screens, the term mesh refers to the distance between adjacent wires or rods
- ✔ In fine screens, the mesh is the number of openings per linear inch counting from the centre of any wire to a point exactly one inch distance
- ✔ The minimum clear space between the edges of the opening in the screening surface is termes as screen aperture or screen size opening

Types of screen analysis

- ✔ Differential analysis
- ✔ Cumulative analysis