CHE454 LAB PROJECT

PARTICLE SIZE REDUCTION

TEAM MEMBERS:

ANUNAY MINJ (220183)
KAUSHALENDRA SINGH (220511)
RAUNAK JALAN (220875)
SUPRIYA SINHA (221107)
TAMANNA MEENA (221119)

OVERVIEW

What is the meaning of size reduction ?

Size refers to physical Dimension of an object.
Reduction refers to decrement or the process of decreasing the size.

SIZE REDUCTION

Size reduction (also called comminution) is the process of breaking down large solid materials into smaller particles to improve processing, handling, and efficiency. This is widely used in industries such as mining, pharmaceuticals, food processing, and construction.

Why is Size Reduction Important?

Increases Surface Area → Enhances reaction rates in chemical processes.

Improves Material Handling → Easier transportation & mixing.

Enhances Efficiency → Reduces processing time and improves machine performance.

Optimizes Particle Size Distribution → Ensures uniformity in end products.

Reduces Energy Consumption → Optimized crushing/grinding requires less power.

Advantages of size reduction

- Content uniformity
- Uniform flow
- Effective drying
- Increases surface area or viscosity
- Uniform mixing and drying
- Improve rate of absorption . Smaller the particles greater is absorption.
- Improve dissolution rate.

Disadvantages of size reduction

- Drug degradation
- Contamination

Motive Behind This Experiment

Experimental Determination of Feed & Product Size

We are experimentally determining the diameter of feed and crushed product.
This helps in analyzing size reduction effects and estimating the specific surface area change.

Analyze Specific Surface Area & Its Effect

Crushing increases specific surface area, improving reaction rates, mixing, and material processing efficiency.
A higher surface area allows for faster chemical reactions, better heat transfer, and uniform dispersion in various processes.

Estimate Power Consumption for Crushing

Power consumption increases as material is reduced in size due to higher energy demand for breaking particles.
We aim to calculate the energy required for manual crushing and compare it with machine-based processes.

Common Equipment Used for Size Reduction

Jaw Crushers – For coarse crushing of hard materials.

Ball Mills – Used for fine grinding after initial crushing.

Hammer Mills – Break down materials using repeated impact.

Roll Crushers – Compress and crush material between two rotating cylinders.

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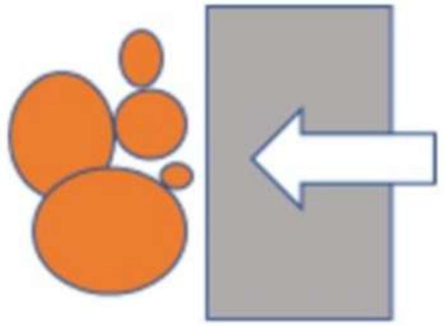
Size Reduction Methods

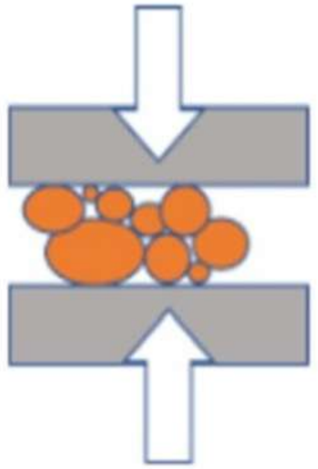
Impact

- Air Classifying Mill
- Universal Mill
- Pulverizer Mill



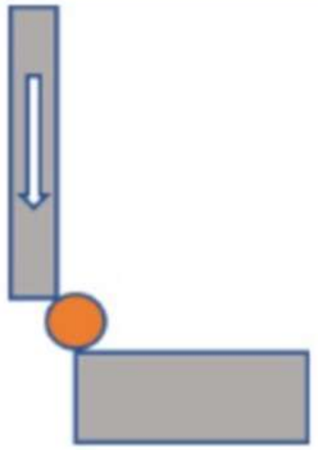
Compression

- Jaw Crusher



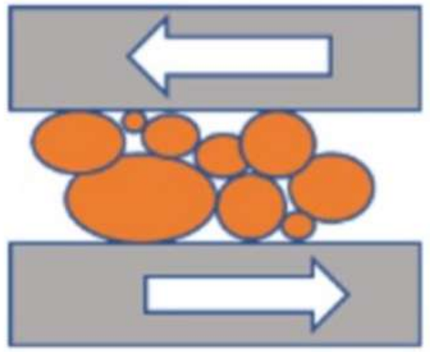
Shear

- Hammer Mill
- Pulverizer mill
- Chopper Mill



Attrition

- Ball mills
- Roller Mills



Challenges in Manual Crushing

Labor-Intensive: Requires significant human effort, leading to fatigue.

Inconsistency: Particle size may vary due to manual limitations.

Higher Energy Input: Manual effort per unit mass is much greater than machine crushing.

Time-Consuming: Takes significantly longer compared to automated processes.

Where Manual Labor is Preferred Over Machinery

Small-Scale Processing – For low material volumes, using machinery is inefficient (e.g., lab experiments).

Remote Areas – In places with limited electricity or infrastructure, manual labor is the only option (e.g., rural mining).

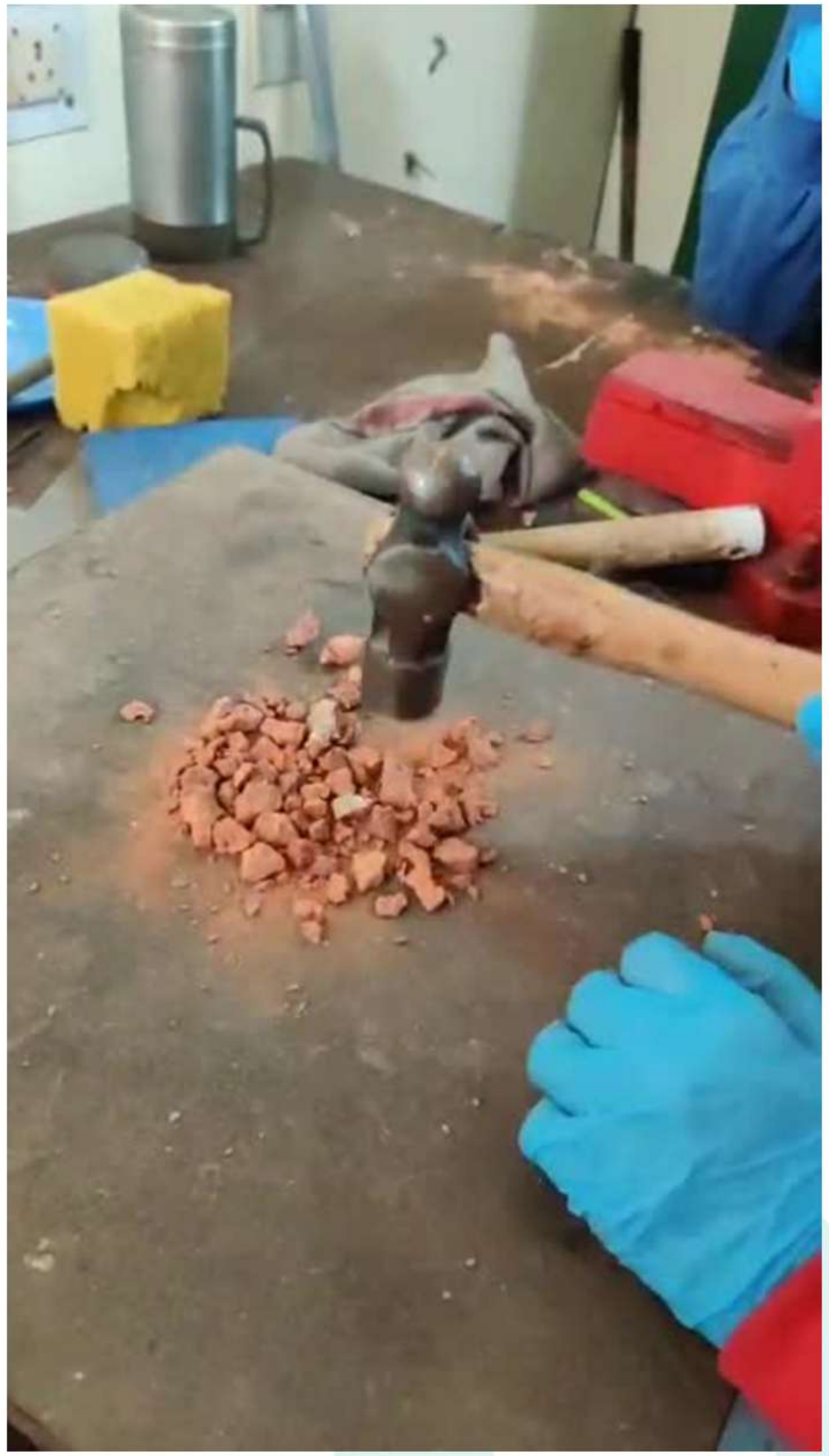
Delicate Materials – Some materials need careful handling to prevent damage (e.g., fragile minerals).

Cost Constraints – Machinery is expensive to buy, run, and maintain, making manual methods more viable in small businesses.

Precision & Flexibility – Manual crushing allows better control over particle size compared to fixed-output machines.

PROCEDURE:

In this experiment, we begin by selecting six different sizes of brick particles. Each sample is carefully weighed to determine its initial mass. Additionally, for each sample, the diameters of ten individual particles are measured using a vernier caliper to establish their average initial size. Next, we subject the samples to a controlled crushing process using a hammer, ensuring that the applied force remains consistent across all samples. This step is crucial in minimizing variations in the energy imparted to the particles. As a result of the crushing, some fine particles may scatter, leading to a slight loss in weight. Following the crushing process, we once again measure the diameters of the particles and record their new weights. This systematic approach helps in understanding the effect of controlled impact on particle size and weight reduction.







Assumptions

Sphericity Assumption:

We can not determine Sphericity here experimentally due to lack of information regarding the **actual** surface area of the particle. So, we have assumed sphericity to be **0.7** which is typical for feeds like bricks and rocks.

Nominal Diameter Calculation:

We need the exact volume of the particles to find the nominal diameter but it is hard to determine that experimentally. So, we assumed that the volume of each particle are proportional to the measured diameter of the feed bricks.

Measured Diameter = (Length + Breadth)/2

Density Assumption:

We have assumed the density of the bricks to be 2000kg/m3 or 2g/cm3.

Nominal Diameter Calculation

Based on the assumption that the **exact volume** of the particle is **proportional to the measured diameter,** we can **determine the contribution of each particle's** volume in the the respective total feed volume.

Volume Of Feed = Weight Of Feed/ Density

Get "Weights" For Each Particle In Volume Contribution

Determine The Particle Volume: W*V_Total

Determine The Nominal Diameter: Dp = (6V/π)^(1/3)

Nominal Diameter Sample Calculation (F1)

Measured Diameter	Diameter^3	Weights = D^3/Sum(D^3)	Particle Volume	Nominal Diameter
2	8	0.179928928	8.096801763	2.491262698
2.2	10.648	0.239485403	10.77684315	2.740388968
1.5	3.375	0.075907517	3.415838244	1.868447024
1.7	4.913	0.110498853	4.972448383	2.117573294
1.3	2.197	0.049412982	2.223584184	1.619320754
1.5	3.375	0.075907517	3.415838244	1.868447024
1.3	2.197	0.049412982	2.223584184	1.619320754
1.8	5.832	0.131168189	5.902568485	2.242136428
1.2	1.728	0.038864648	1.748909181	1.494757619
1.3	2.197	0.049412982	2.223584184	1.619320754
				1.968097532

Specific Surface Area Sample Calculation

dpi feed	dpi out
0.0197	0.0159

$$SSA\ Feed = \frac{6}{\delta_p \varphi} \times \Sigma \frac{xi}{Dpi} = \frac{6}{2000 \times 0.7} \times \frac{0.117}{0.0197} = 0.025594$$

$$SSA\ Product = \frac{6}{\delta_p \varphi} \times \Sigma \frac{xi}{Dpi} = \frac{6}{2000 \times 0.7} \times \frac{0.117}{0.0159} = 0.025594$$

Energy Required To Crush Calculation

Force Per Hammer Swing= 200 N

Hammer Swing Distance = 0.5m

Energy Transfer Efficiency = 30%

Number Of Strikes = 150 per sample

Time Taken = 1800 seconds

Feed Mass Processed = 765 grams

From these values, we get: Wi = 0.788

From which we get the value of E = 1.634 kWh/tonne

Results:

Average Nominal Diameter (Feed): 0.2293 m

Average Nominal Diameter (Product): 0.01327 m

Specific Surface Area (Feed): 0.18044 m2

Specific Surface Area (Product): 0.32915 m2

FORMULA:

SPHERICITY

$$\Phi = \frac{6V_p}{D_p S_p}$$

Where:

$V_p = Volume\ of\ particle$

$S_p = Surface\ area\ of\ partucle$

$Dp = Equivalent\ diameter\ of\ particle$

Specific surface area

$$SSA = \frac{6}{\delta_p \varphi} \times \Sigma \frac{xi}{Dpi}$$

Where,

δ= Density of the material

φ= Sphericity

Xi= mass fraction

Dpi= Nominal Diameter

SIZE REDUCTION THEORIES

The energy requirement for particle size reduction is a function of input and output of particle size, hardness, strengthand other properties of solids.

Various theories for energy requirement are:-

Rittinger's theory

Kick's theory

Bond's theory.

Rittinger's theory

According to this theory energy E required for size reduction of unit mass is directly proportional to the new surface area produced.

$E = K_R (S_n – S_i)$ .... (3)

Where

S_i = initial surface area
S_n = new specific surface area
K_R = Rittinger's constant.
E= amount of energy

Kick's Theory

- This theory states that the energy used in deforming a set of particles of equivalent shape is proportional to ratio of change in size.

$$E = K_k \ln \frac{d_i}{d_n} \qquad \ldots\ldots \qquad (5)$$

Where

K_k = Kick's constant

D_i = diameter of particle in the initial stage

D_n = diameter of the new particles.

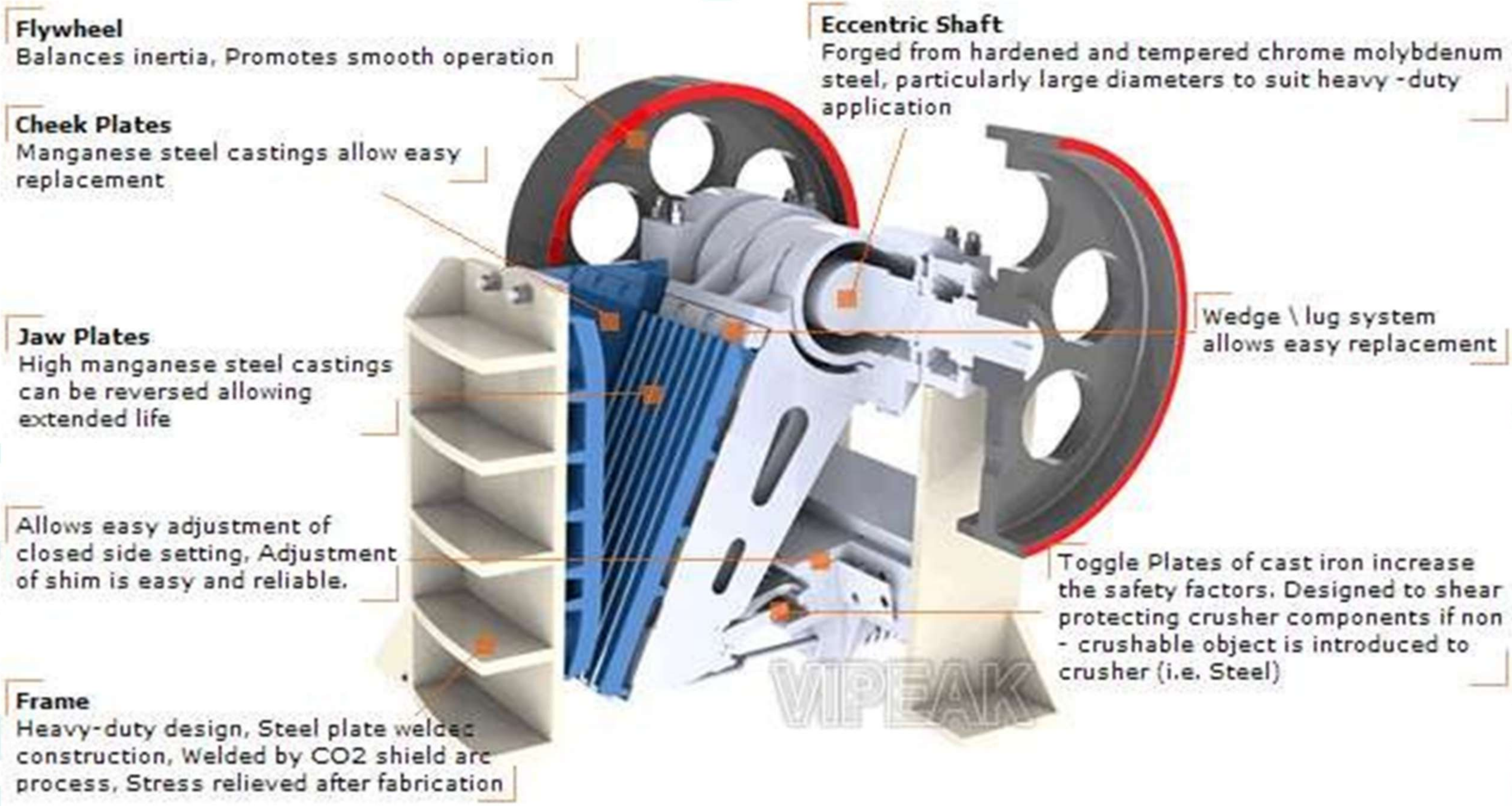
Bond's theory

This theory states that energy used in crack propagation is proportional to the new crack length produced.
It also states that deforming set of particles is proportional to change in dimensions.

$$E = 2K_B \left(\frac{1}{\sqrt{Dn}} - \frac{1}{\sqrt{Di}} \right) \quad \ldots \quad (4)$$

Where
K_B = Bond's work index.
Di = initial diameter
Dn = new diameter.

Size Reduction EQUIPMENTS jaw crusher



Observations & Learning: Insights & Improvements

1. Manual is Inefficient
2. High Energy Use
3. Inconsistent Results

Manual crushing is inherently inefficient, demanding high levels of physical effort while yielding inconsistent particle sizes. Its energy consumption far exceeds that of mechanized alternatives, making it less sustainable for large-scale operations.

Thank You