CROPPROCESSINGENGINEERING

Cleaning and Sorting

Comparative commercial value of a farm product is a function of its grade factor. *Grade* factors (that apply in various combinations to all products produced on the farm) could be classified on the basis of;

(i) ***Physical Characteristics:*** Considers M.C., unit size and weight, texture, colour (for reflectance), foreign matter and shape.

(ii) ***Chemical Characteristics:*** Considers analysis (composition), free fatty acid and index, odour and flavour.

(iii) ***Biological Characteristics:*** Considers; germination, type and amount of insect damage, type and amount of mould damage and bacteria count.

The general procedures that can be used to improve, maintain or change the quality of a product are;

(i) Control the storage conditions; i.e. Temperature, relative humidity and time,

(ii) Kill or inhibit destructive organism - by fumigation, refrigeration and heating,

(iii) Improve the physical characteristics i.e. changing or maintaining the M.C,removal of foreign or dissimilar material and sorting into various fractions.

Definitions:-

(i) ***Cleaning:*** removal of foreign or dissimilar material done by washing, screening, handpicking etc.

(ii) ***Sorting:*** Separation of cleaned product into various quality fractions that may be defined on basis of size, shape, density, texture and colour (physical characteristics).

(iii) ***Grading:*** Classification of material on the basis of commercial value and usage and is dependent upon more factors than recognised when physical sorting is considered i.e. physical, chemical and biological characteristics.

Note: Cleaning, sorting and partial or final grading of product is based upon the following material characteristics; size, shape, specific gravity and surface characteristics.

Types of Separators

(i) Pneumatic Separation

Consists of a set of screens and a fan for moving air through the grain which removes chaff, dirt and light weight seeds. Normally used with other cleaning procedures for separation that are not similar or on material that has been pre-cleaned or sized if a separation on density basis is desired.

(ii) Specific Gravity Separators

The separating device is based on two conditions;

- Ability of a grain to flow down an inclined plane and
- Lifting or floating *effect* produced by the upward motion of air i.e f (size, shape, weight and surface area). The prime unit is a triangular -shaped perforated table where air is fed from a fan from underneath and the table reciprocates moving materials towards the conveyance. The light particles are lifted and flow to the outlet fast.

(iii) Spiral Separation

Separate materials on the basis of shape. The unseparated material is divided and introduced into inner helixes at the top. The round elements in the mixture pick-up speed as they roll down the helices until their centrifugal force is sufficient to cause them to roll up and over the edge. They are caught in the outer helix and roll to the bottom and out the outside spout. The elements that are not round do not roll fast enough to be discharged over the edge. They are discharged through spouts connected to the inner spirals.

(iv) Centrifugal Separation

Use centrifugal force resulting from mixture rotation e.g. separation of cream from skim milk. Compare with (v).

(v) Cyclone Separator

Normally used in connection with pneumatic conveying of produce and wastes from processing.

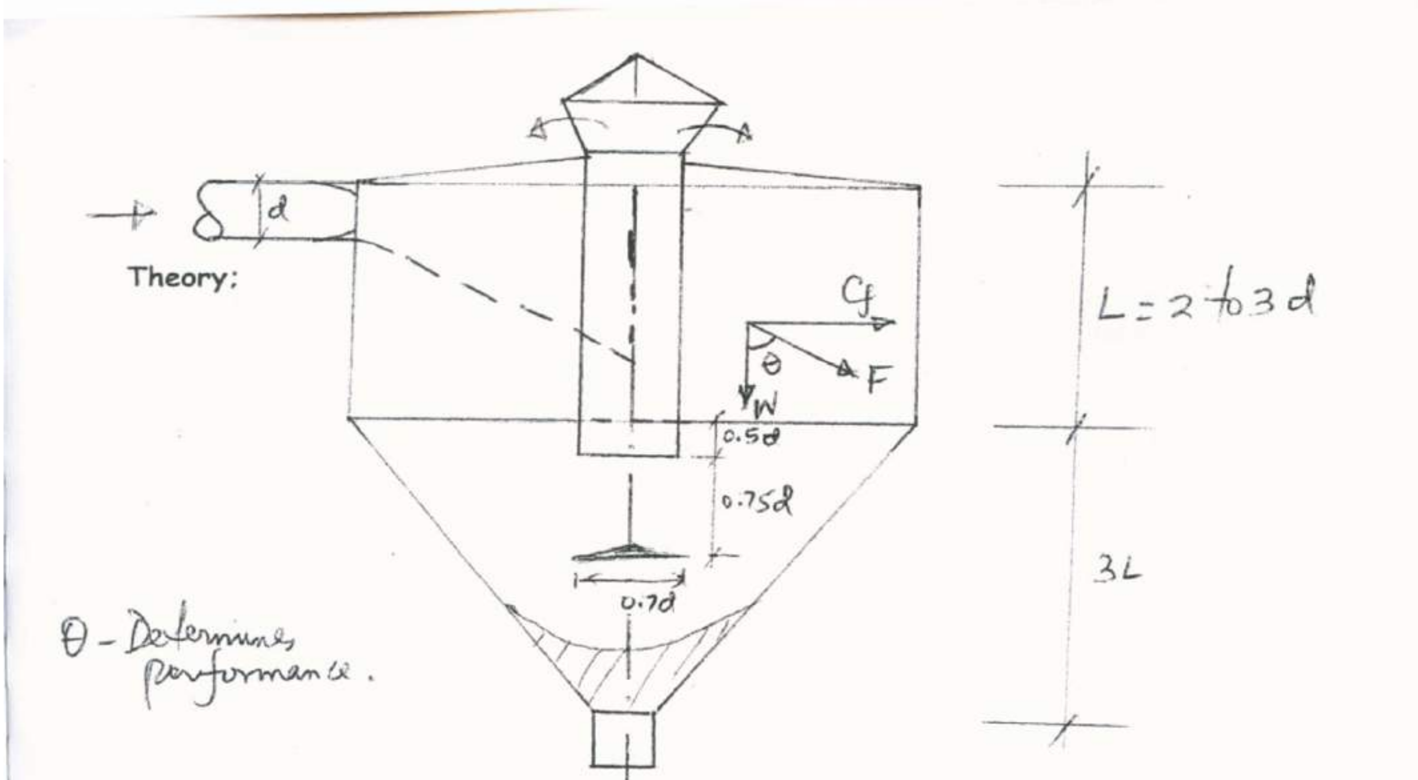

Fig. Schematic drawing of a cyclone separator.

Air and material enter tangentially at the top and descend with a circular motion. The material is separated during the downward descent and clean air ascends at the centre and is discharged. *A* particle entering the cyclone is acted upon by two forces C_f and W. The centrifugal *force:*

$$C_f = \frac{WV^2}{gR}$$

W = Particle weight
V = Linear or tangential velocity
g = Grantational acceleration
R = Radius of rotation

The separating force, $F^2 = W^2 + C_f^2$

$$= W^2 + \frac{W^2V^4}{g^2R^2}$$

$$F = W\sqrt{\left(1 + \frac{V^4}{g^2R^2}\right)}$$

and the performance factor,

$$S = \frac{C_f}{W} = \frac{V^2}{gR}$$

Note: the larger S is the more effective the separation.

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The entering particle is acted upon by the force F which causes it to move outward towards the wall during its downward helical travel. As it approaches the wall, the velocity (V) decreases due to wall friction and the particle settle into the cone. The rate of movement = f (shape, weight and size).

Size Reduction

Includes:

- Cutting (e.g fruits),
- Crushing,
- Grinding (e.g. limestone or fertilizer) and
- Milling (e.g flour).

Performance of a machine for reducing size of material is characterized by:

(i) Capacity
(ii) Power required per unit of material reduced
(iii) Size and shape of product before and after reduction and
(iv) Range in size and shape of the resultant product.

The reduced materials may be placed in three groups or classes based upon the size;

(i) **Dimension range:** Particles which can be accurately measured and easily seen with minimum measurements (1/8" or more) e.g chopped forage.

(ii) **Sieve range:** Particles with minimum range of 0.125 to 0.0029" e.g. ground feed and commercial fertilizers.

(iii) **Microscopic range:** Particles with minimum dimensions < 0.0029" e.g chemical powder, dust, cement etc.

Fineness Modules

Screening is done through Tyler Sieves and a shaking machine (Ro-Tap) is used. **Fineness Modules** indicates the uniformity of the grind in the resultant product. It is the sum of weight fractions retained above each sieve divided by 100. Numbers 3/8", 4, 8, 14, 28, 48 and 100 mesh sieves are used in the set.

Note: 3/8", 4 and 8 represents **coarse** material

14 and 28 represents **medium** material

48,100 and pan represents **fine** material

Example:- Determination of the fineness modules and uniformity index.

Mesh (Sieve No.)	% of Material Retained	Assigned No.	Product
3/8"	0.0	7	0
No. 4	5.7	6	34.2
8	23.2	5	116.0
14	35.1	4	140.4
28	18.4	3	55.2
48	9.3	2	18.6
100	5.8	1	5.8
Pan	2.5	0	0
Totals	100		370.2

(i) $$\text{Fineness modules} = \frac{\sum \text{product}}{\sum \% \text{ material retained}} = \frac{370.2}{100} = 3.702$$

Fineness modules is an indication of the uniformity of grind.

Note: The standard procedure specifies a 250g sample, oven dried to constant weight at 100°c and shaken in a Ro-Tap machine for five minutes.

Note: -If all the materials passed and were retained by No. 100, the modules would be 1 (most fine). - If all materials were retained by the No. 4 screen the modules would be 6.

(ii) Uniformity Index

Percentage of proportion of coarse, medium and fine in a given sample.

Coarse - 28.9

Medium - 53.5

Fine -17.6

Divide through by 10 and round off gives 3:5:2 which is important in knowing the level of grinding.

Energy Requirements in Size Reduction

Depends on the M.C. and fineness of size reduction required. The *energy* required to reduce a unit is proportional to a dimension of the reduced particle relative to a similar dimension of the original particle raised to some power n.

The energy required or necessary to reduce a specific mass of particle from one size to another is given by;

$$\Delta E \propto \Delta L/L^n$$

i.e. $E = -C\int_1^2 \frac{dl}{L^n}$ ....(i)

(a) Kicks Law assumes n = 1

$$\text{i.e } E = -C\int_1^2 \frac{dL}{L}$$

$$= -C[\ln L]_1^2$$

$$= -C \ln \frac{L2}{L1}$$

$$= C \ln \frac{L1}{L2}$$

$\Rightarrow$ $E = C \,\text{Ln} \frac{L1}{L2}$ i.e. Kick's Law ....(ii)

(b) Rittinger assumed that size reduction is a shearing procedure. Energy requirement is proportional to the new surfaces created (which in turn is proportional to the square of a common linear dimension i.e n = 2)

From;

$$E = -C\int_{1}^{2} \frac{dL}{L^n}$$

$$E = -C\int_{1}^{2} \frac{dL}{L^2}$$

$$E = -C\left[-1/_l\right]_{1}^{2}$$

$$= -C\left[\frac{-1}{L_2} + \frac{1}{L_1}\right]$$

$$= C\left[\frac{1}{L_2} - \frac{1}{L_1}\right]$$

Hence Rittenger's Law is; $E = = C\left[\frac{1}{L_2} - \frac{1}{L_1}\right]$ ------------------------ (iii)

The Equation (iii) is applicable in chemical and mechanical Engineering e.g. Coal and Limestone not in Agricultural materials. Equation (ii) is highly applicable to Agricultural products.

Example:

Supposing 4KW is required to reduce a material from 0.635 to 0.165cm, how much *energy* would be required if the reduction is to be 0.0833cm instead of 0.165cm. Use both Laws;

By Kick's Law;

$$E = C \ln \frac{L_1}{L_2}$$

$L_1 = 0.635cm$ and $L_2 = 0.165cm$

$$C = E/\ln \frac{L_1}{L_2}$$

$$= \frac{4}{\ln \frac{0.635}{0.165}}$$

$$= \frac{4}{\ln 3.8485}$$

$$= \frac{4}{1.3477}$$

$$= 2.968$$

$L_1 = 0.635cm$ and $L_2 = 0.0833cm$

$$E = 2.968 \ln \frac{0.635}{0.0833}$$

$$= 6.03KW$$

By Rittinger's Law;

$$E = C \left[\frac{1}{L_2} - \frac{1}{L_1}\right]$$

$$C = \frac{E}{\frac{1}{L_2} - \frac{1}{L_1}}$$

$$= \frac{4}{\frac{1}{0.165} - \frac{1}{0.635}}$$

$$= 0.892$$

Thus $L_1 = 0.635$ cm and $L_2 = 0.833$ cm

$$E = 0.892 \left[\frac{1}{0.0833} - \frac{1}{0.635} \right]$$

$$= 9.30 KW$$

NOTE

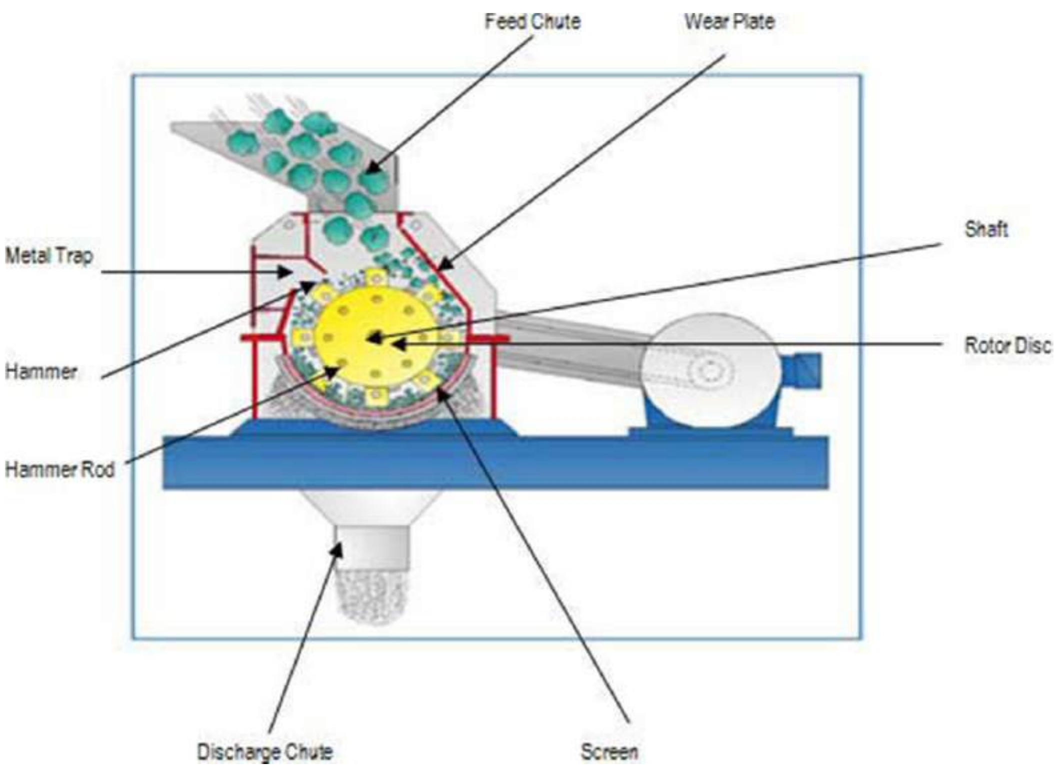
Kick Assumes n = 1

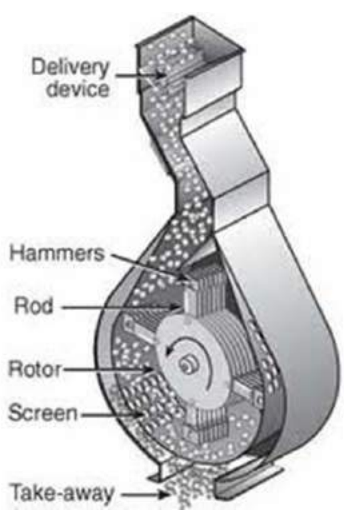
Rittinger assumes n = 2

Bond assumes that n = -3/2

REDUCING DEVICES

1. Hammer Mills





Consists of a rotating beater (Having hammers or beaters) and a heavy perforated screen. The material is 'beaten' until it is small enough to pass through the screen at the bottom after which it is removed by augers or fans or chain elevators. The reduction in size is by impact and the mills are common in feed, limestone and commercial fertilizers preparation.

Advantages

(i) Simple machine

(ii) Versatile in operation

(iii) Freedom from significant damage due to foreign objects

(iv) Freedom from damage when operating empty and

(v) The hammer wear does not materially reduce its efficiency.

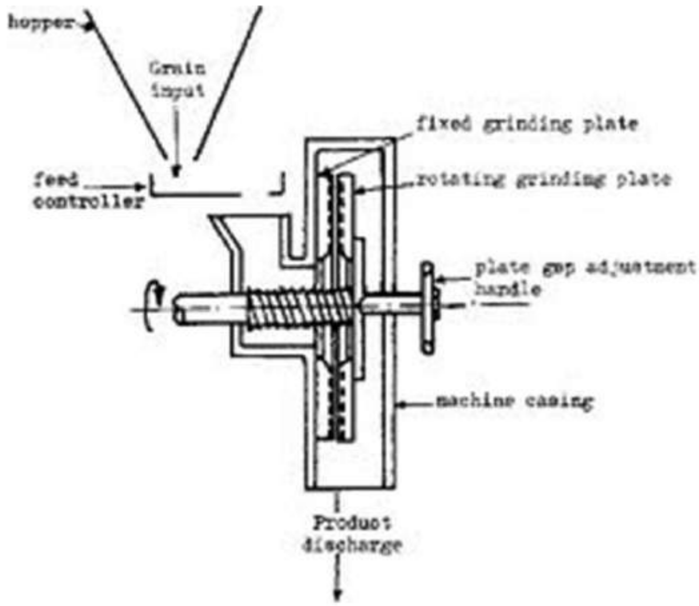
Limitations

(i) Inability to produce a uniform grind and

(ii) There is high power requirements

2. Attrition Mills (Burr or plate mill)

Consists of two roughened plates, one stationery and the other rotating. The material is fed between plates and is reduced by crushing and shear whereby the fineness of reduction is controlled by the type of plates and their spacing.



Advantages

(i) Has low initial cost

(ii) Products are relatively uniform and

(iii) The power requirements may be low

Limitations

(i) Foreign objects may cause breakage

(ii) If operated empty then there is excessive burr wear and

(iii) Worn out burrs yield poor results

Normally recommended for feed and food products;

3. CRUSHERS

Reduce the material by pressing or squeezing it until it breaks. Recommended for stones and lime but slightly used in agricultural materials.

Performance Characteristics of a size reducer operating ideally

(i) Should produce uniform products e.g. the attrition mills produces more uniform material than the hammer mills.

(ii) Should have minimum temperature rise during reduction

(iii) Should have minimum power requirements although difficult to determine since the type of material, fineness of grinding, moisture content, rate of feed, type and conditions of the mills affects the power requirements.