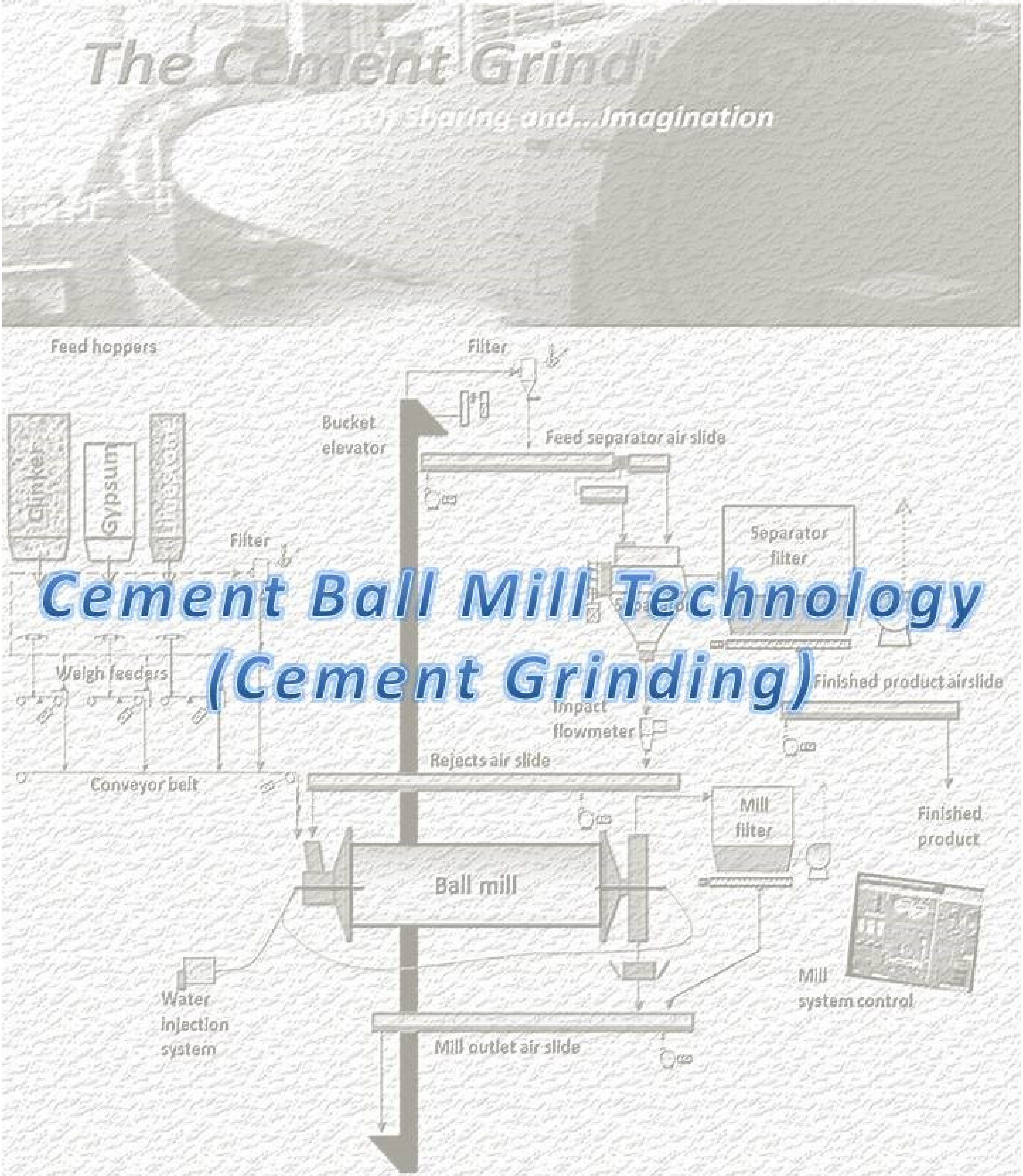

Cement Ball Mill Technology (Cement Grinding)

Marc Piccinin
Grinding Process Engineer
The Cement Grinding Office

Cement Ball Mill Technology

Introduction

My name is the Grinding Engineer.
I acquired my engineering degree somewhat by chance.
When you don't know if you are more literary or more scientific, this obviously complicates things when it comes to choosing your studies.
It was therefore without much enthusiasm that I began this cycle of 4 years.
And I finished it brilliantly since I was the 1st of my promotion.

Nevertheless, my first experiences in the industrial environment confirmed me in the idea that this was not really what I was looking for in life.
And then one day, I saw a job advertisement in a popular newspaper that interested me.
It was about grinding cement, with short but frequent trips.
I had no idea what cement was made at that time, but it piqued my curiosity and I promptly responded to this ad.
After several steps that I passed more or less well, I remained in the running with two other people for the position of Process Engineer, which I lost and then regained during a final interview.
So here I am, entering the world of grinding not only cement, but also mines.

The company I was working for now, although world famous for its grinding expertise, was not really organized for the training of its new employees.
Very few structured writings were available, but rather a set of heterogeneous texts and calculations that had to be digested in a short time.
The rest of the training was based on mill studies with correction by the most experienced engineers.
And very quickly, I had my first experience on site.
It was a month of January, near Amman, the largest cement plant in Jordan.
It was quite cold, and it had even snowed the day before.
I entered the mill through a DIN manhole.
It was impressive.
A ball mill with a diameter of 5,2 m!
The mill was emptied of its ball charge because the maintenance personnel had to remove the grids from the intermediate diaphragm.
The frame of the diaphragm had, indeed, structural defects, and I had to check this in detail.
It was the purpose of my visit, and I was sent, me the beginner, because no one was keen to do this job.
And that's how I gained experience, like that time when I was sent to solve a problem in an open-circuit mill in England, without success.

Then afterwards, I took charge of the whole Middle East.
I retain many epic memories of this period when I travelled to this region.
For example, I remember the visit to a large central discharge raw mill in Iran.
We were no less than 10 people in the drying chamber of the raw mill when someone activated the auxiliary motor.
Movement of panic, everyone wanted to leave by the door of the room at the same time.
Fortunately, this door was high and at ground level.
No one was injured except my colleague who injured his arm slightly.

A few years passed, I mastered my subject more and more and took pleasure.
One day, someone offered me to work for him.
It was an entrepreneur wanting to invest in a grinding plant.
It is true that at the time, the region where he wanted to set up his factory was very poorly served and the local authorities had just laid the first stone of an area of activity planned for industrial use.
My new job was simply Operations Manager.
When I started, various equipments were already installed such as silos for clinker and gypsum, cement silo and conveyor belts.
The ball mill was missing producing Portland cement type CEM I 32.5 with 95% cement and 5% gypsum.
The clinker was to come mainly from a cement plant located 120 km away.

Cement Ball Mill Technology

There, this clinker was produced in a Lepol-type kiln.
This meant, in my eyes, that the grain size would be very stable over time with a majority of grains between 9 and 10 mm.
It was also recognized that the grindability and hardness of the clinker of the Lepol system were very favorable for a mill in open circuit.
Based on these data, I calculated the size of the mill needed to produce 50 t/h of cement at 3200 Blaine with 3% residue on 90µm and 80% passing on 40µm.
The Bond formula that I generally used gave me an energy requirement of 35,83 kWh/t.
This specific energy multiplied by the production (35,83 x 50) gave a necessary absorbed power of 1800kW.
As the project envisaged an open circuit system, I was looking for a mill with an L/D ratio equal to 3,5.
The second-hand mill finally selected had a diameter of 3,5m for a total length of 11,375m and an installed power of 2000kW.
The L/D ratio was slightly lower than the optimal value, but since the cement fineness target was not so high, I wasn't worried.
The cement mill was equipped with a lifting lining in chamber 1, a simple intermediate diaphragm and a non-classifying lining in chamber 2.
The next step was to fill the right ball charge in order to ensure a good cement quality.
And finally, I chose a bag filter and its fan to provide the ventilation of the mill.

The first weeks of operation of the new grinding station passed without major problems.
However, the production was only around 46 t/h.
Some adjustments were then decided to achieve the planned objective.
First, the degree of filling in the two compartments was increased.
Then, and after resistance tests, it was decided to produce at a slightly lower fineness.
Production stabilized at 49 t/h.
A few months passed and the throughput of the installation began to decrease to 44 t/h.
After a visit inside the mill and an axial test, it appeared that pollution of uncrushed particles in the second chamber had drastically reduced the mill efficiency.
We were certain that the situation could only get worse.
The cement factory which supplied the clinker confirmed that the mineralogical properties had been modified after some work carried out around the kiln.
It was therefore decided to organize a meeting with some suppliers to find the best solution to improve the performance of the installation.
After a precise calculation of the return on investment, the solution of replacing all the internal equipment of the mill was taken.
Following this investment, production reached 50,5 t/h at the right fineness.

After a few years of operation without major problems, I compared the performance of our grinding unit with that of cement plants in the region and found that open-circuit cement production had gradually become obsolete.
A new investment was therefore necessary, i.e. to close the circuit with one of these new dynamic separators, also called turboseparators.
Also modifying the ball charge of the mill and increasing the ventilation, the new throughput of the installation reached 57 t/h, an improvement of 14%.
In addition, the quality of the finished product was better.

One day, considering the market demand, the company offered new products to its customers, two types of OPC cement type I 42,5 and 52,5.
However, I was disappointed by the performance of the installation, and the 1st generation separator was suspected of being responsible for this significant energy consumption.
Indeed, during the production of the finest cement at 4900 Blaine, the data from the impact flowmeter in the control room showed a huge circulation factor, between six and eight.
Since there was a new type of separator on the market, also called high efficiency separator, we replaced ours.
With a gain of 10% on the coarsest cement and gains of 15 and 20% on the finer cements.
The return on investment was quick, 15 months!

Cement Ball Mill Technology

The industrial zone developed a few years earlier had been so successful that it led to a new shortage of building materials.
Among other things, the demand for cement therefore increased exponentially to meet the needs for residential housing.
The owner of our crushing station asked me for a last effort to keep up with demand.
Pushed against the wall, I offered him the radical solution of semi-integral pre-grinding.
Expensive solution but with the certainty of ensuring a significant increase in production.
An installation with a roller press in a closed circuit on a high-efficiency separator was approved by my boss.
The construction work did not prevent the mill from producing cement, except for a three-week shutdown to change it to mono chamber.
The result of this final operation exceeded expectations.
If the total absorbed power of the installation had increased by 28%, the output for the three types of cement increased by 76% on average.
My mission was fulfilled.

This is the story of the Grinding Engineer.
This story is inspired by a mixture of real facts and fiction.

If I told it, it is because with the industrial revolution and development in the vast majority of countries in the world, the cement industry has become a major consumer of energy.
Global cement production was around 4,1 billion tonnes in 2016.
Considering an average consumption of 110 kWh to produce 1 ton of cement, the electricity consumption is approximately 451 billion kWh!
The part of grinding represents 65% of total consumption (23% for grinding raw material and 42% for grinding clinker).
The world park of mills is divided into four types, ball mills, vertical mills, roller presses and horizontal mills.
The grinding efficiency of these machines is very low and most of the energy provided by the absorbed power is lost in heat, vibration, frictional wear or noise.
The ball mill is the least efficient of all, but is still the most widely used equipment in the world, despite the emergence of more efficient devices like the vertical mill.
And it is also commonly accepted that there is still great potential for possible improvements in ball mills.

The story of the Grinding Engineer may be an ordinary story, but to make it come true you have to read what follows.
Happy reading in the world of grinding!

Chapter 1

Comminution

1. Introduction

- Particle size reduction, or comminution is an important step in many technological operations.
- In the cement industry, the grinding of the clinker and raw material is the process which requires the highest percentage of energy.
- Consequently, the high costs of energy drives us to optimize the processes in the plant, and among them the milling process.
- Various methods to study the grinding process and to know the energy required have been developed (like the work index).
- All these methods are coming from the comminution laws.

2. Definition of the comminution

- Fragmentation or comminution is the action of splitting or decrease the size of a given material.
This refers to the reduction of a body or several bodies in fragments of dimension previously established, or to the reduction of a solid set, already fragmented into smaller volume elements.
- Fragmentation objectives are mainly the following:
* Generation of a certain particle size or particle size distributions
Examples: cement, colours, pigments, filler materials, plastics, paper, cosmetics, food
* Increase of surface area to enable respectively enhance physical and chemical reactions
Examples: dissolution and melting of solids, extraction from the solid phase, hardening of binders, transportation and combustion of solids, heterogeneous reaction
* Decomposition of heterogenic solids for successive separation
Examples: ore milling, flotation, waste treatment
- The result of the comminution is measured by the reduction ratio:

$$R_r = \frac{F_{80}}{P_{80}}$$

Where:
Rr is the reduction ratio
F80 is the percentage of passing of the feed
P80 is the percentage of passing of the product
- Classification by the hardness of the feed material:

Hard comminution	Medium comminution	Soft comminution
Basalt	Limestone	Lignite
Hard ore	Coal	Rock salt
Pebble	Gypsum	Chalk
Quartzite	Potash	Plastic
Slag		Corn
Clinker		Spicery

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Chapter 2

Laws of Comminution

- Particle size reduction, or comminution is an important step in many technological operations.
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- Consequently, the high costs of energy drives us to optimize the processes in the plant, and among them the milling process.
- Various methods to study the grinding process and to know the energy required have been developed (like the work index).
- All these methods are coming from the comminution laws.
- There are three laws of comminution.

1. First law - RITTINGER (1867):

- According to this law, the area of the new surface produced by crushing or grinding is directly proportional to the useful work consumed, is to say that the fragmentation work is proportional to the sum of new surfaces produced. -
- Mathematically, it is expressed by the following relation:

$$\mathbf{W = K\left(\frac{1}{d} - \frac{1}{D}\right) = K(S_f - S_i)}$$

Where:
W is the energy consumed,
d is the dimension of the particles of the product,
D is the dimension of the particles of the feed,
Si is the initial area,
Sf is the final area,
and K is a coefficient

- K coefficient depends on the shape of the particle, the type of material, the number of defects and the efficiency of the forces applied for the comminution work.
- This law only applies to the fragmentation of fine particles (< 100µ).

2. Second law - KICK (1885):

- This law says that the energy required is directly proportional to the volume reduction between particles before and after the fragmentation operation (crushing), i.e. proportional to the variation of volume of the particles.
- Mathematically, it is expressed by the following relation:

$$\mathbf{W = K.\log\left(\frac{D_{80}}{d_{80}}\right)}$$

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Chapter 3

Types of Tube Mills

1. Introduction

- This presentation intends to describe the different types of tube mills encountered in the industry.
- We will not talk about old mills mot more used like conical mills.
- Different types of classification are possible.
- For example, we can perform a first classification of different types of mills by type of grinding media used:
* Rod mills
* Ball mills
* SAG mills
* AG mills
* Pebbles mills
- One can classify also according the mills working in discontinuous mode (laboratory) or continuous mode (cement industry, mining, pigments, food...etc).
- In this presentation, we have first to split in two processes:
* Wet Process
* Dry Process

2. Tube mills in wet process

- Wet process is the process where grinding is performed with material forming a pulp with addition of water (minimum 30%).
- Mills presented in this chapter:
* Rod mills
* AG mills
* SAG mills
* Pebbles mills
* Ball mills

2.1 Rod mills:

- Rod mills are usually used as the first grinding stage after crushing in the mining industry. Since the growth of the AG, SAG mill circuits (with much higher capacities), rod mill technology is almost fallen into disuse.
- Their use is then generally limited to specialized cases such as:
* A very coarse product size is required
* Overgrinding is to be minimized
* The ore is very hard
NB: Note that rod mills can be utilized in dry process to grind coke or iron ore.
- Different discharge arrangements are possible:
* Trunnion discharge
* End peripheral discharge
* Centre peripheral discharge

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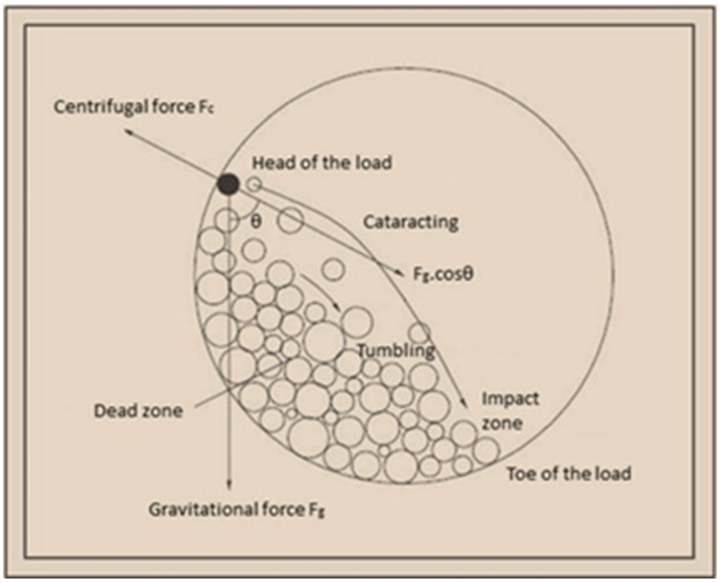
Chapter 4

Speed of rotation

- The speed of rotation is often expressed as a percentage of the critical speed.
- We will see here below how to calculate the mill's critical speed.
- In two words, the critical speed is defined as the rotational speed where centrifugal forces equal gravitational forces at the mill shell's wall.
- At this point, balls will not fall away from the mill's shell.

1. Calculation:

- General sketch:



- The grinding ball is subjected to two forces
* Centrifugal force: Fc
* Gravitational force: Fg
- The centrifugal force is given by the following formula:

$$F_c = m\omega^2 \frac{D_i}{2}$$

Where:
m is the mass of the ball,
ω is the angular speed and
Di is the mill's internal diameter
- The gravitational force is given by the following formula:

$$F_g = mg$$

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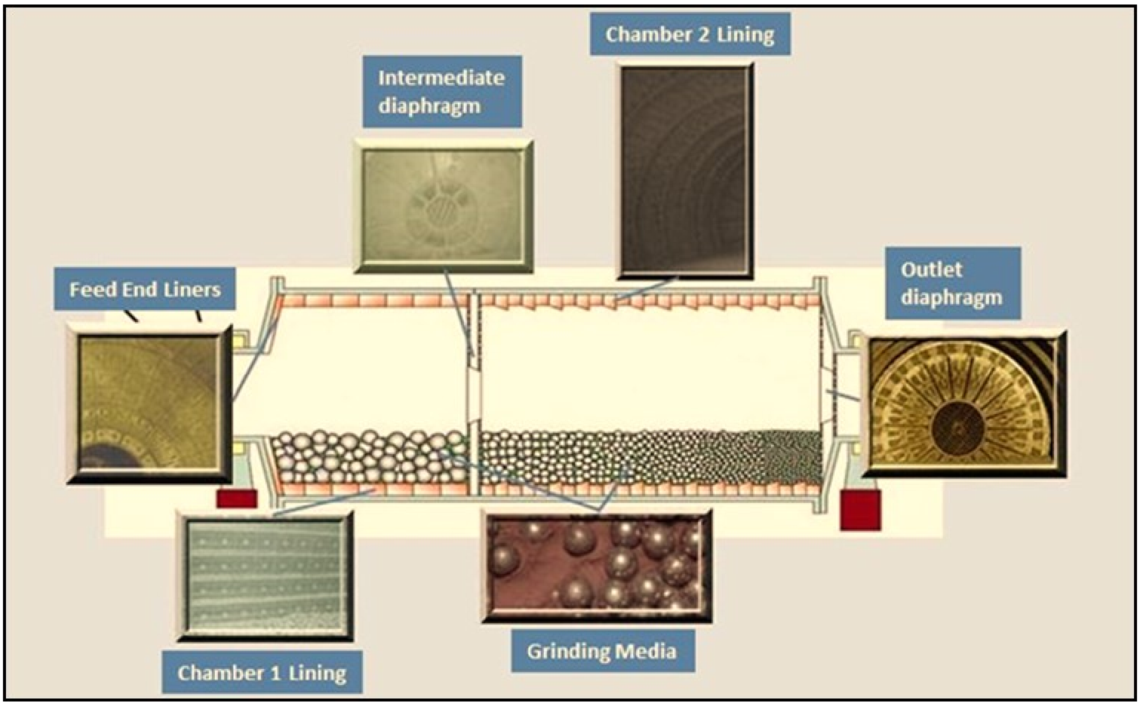
Chapter 5

Internal equipment of ball mills

1. Introduction

- The internals of a ball mill can be divided in 4 categories:
• Head liners
• Shell linings
• Diaphragms
• Grinding media
- These internals are designed and made in order to:
• To protect the mill shell
• To have the best life expectancy
• To minimize the operating costs
• To improve the specific energy consumption of the mill
• To allow a higher production
- Each category will be detailed in the chapters hereafter.
- Sketch of the mill's internals:



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Chapter 6

Grinding media

1. Introduction

- Grinding media is a very important factor of the mills internals, not only on a mill's efficiency point of view but also on a wear point of view.
- Generally, the ball charge consists of grinding balls of several sizes and of different material qualities.
- For coarse grinding compartment, balls between 100 and 60 mm are used.
- For finishing compartment, balls between 60 and 15 mm are normally used.
- The composition of the ball charge depends on various factors, such as:

• Mill diameter
• Mill length
• Ratio L/D
• Mill speed
• Types of linings
• Mill circuit
• Type of separator
• Grindability of the fresh feed
• Granulometry of the fresh feed
• Hardness of the fresh feed
• Product fineness

- Concerning the ball quality, it depends of:

• Impact forces in the first chamber
• Friction forces between the balls and the liners
• Abrasiveness of materials
• Corrosion especially in wet process

2. Composition of the ball charges

- This will be detailed in Chapter 25.

3. Ball charges quality

- Three types of balls exist on the market:

• Forged balls
• Cast Iron balls
• High Chromium Cast Iron balls

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Chapter 7

Cement 2 chamber ball mill general specifications

1. Introduction

- Two-chamber mills are the most widely used in the cement industry.
- They probably constitute more than 95% of the world's ball mill park.
- This chapter will therefore define how to equip a 2-chamber mill.
- To this end, good expertise is essential.
- What we need to know to study a cement mill…!
• Theory
• Practical things
• Tips
• Tools
• Grinding software

2. General remarks

- Cement mills can have:
• 1 chamber
• 2 chambers
• 3 chambers
• And more
- Cement mills can be in:
• Open circuit
• Closed circuit
- In this chapter, we will develop cement mills with 2 chambers in closed circuit.

3. Classical circuit

- A cement mill classical circuit looks like the following:

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Chapter 8

Cement ball mill sizing method explanation

1. Introduction

- The Bond method is used to size a cement ball mill.
- Efficiency correction factors are applied with the Bond equation.
- The method is valid both for clinker grinding and for raw materials grinding.
- This method only gives a rough and initial idea for sizing a cement ball mill.
- To go ahead, a deeper study is necessary with ball mills suppliers or a specialized engineering office.
- Two calculators have been developed for sizing mono chamber mills and two compartment mills.

2. Bond equation and correction factors

2.1. Bond formula:

- The well-known Bond formula used is the following:

$$E = 10 \times W_i \times C \times \left(\frac{1}{\sqrt{P_{80}}} - \frac{1}{\sqrt{F_{80}}} \right)$$

With:
E = specific energy in kWh/t
Wi = work index in kWh/t
C = correction factor
P80 = sieve which has 80% of passing in the product
F80 = sieve which has 80% of passing in the feed
- Efficiency correction factors are giving by the following equation:

$$C = C_1 \times C_2 \times C_3 \times C_4 \times C_5 \times C_6$$

With:
C1 is a correction for dry grinding,
C2 is a correction for open circuit
C3 is a correction for mill diameter,
C4 is a correction for feed size,
C5 is a correction for product fineness.
C6 is a correction for high-efficiency separators.

2.2. Correction factors:

2.2.1. C1 definition:

$$C_1 = 1{,}3 \text{ if dry circuit and 1 if wet circuit}$$

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Chapter 9

Dimensions of the mill according to the production

1. The general sheet

- The sheet below gives the production in t/h of a cement mill in function of:
• The cement fineness target in Blaine
• The general dimensions of the mill
- The following hypotheses are used:
• Mill in closed circuit
• Separator of the third generation
• Mill Length/Diameter ratio around 3,2
• Mill speed of rotation around 73% of the critical speed
• Filling degree of both chambers around 31%
- Specific powers used are:
• 3000 Blaine: 28 kWh/t
• 3500 Blaine: 35,8 kWh/t
• 4000 Blaine: 44,4 kWh/t
• 4500 Blaine: 53,6 kWh/t
- The length of chamber 1 is defined for the coarsest cements, here 3000 up to 3500 Blaine.

Mill			Chamber 1			Chamber 2			Mill		Capacity according fineness			
Diameter	Total length	Speed	Length	Balls	Power	Length	Balls	Power	Total balls	Total power	3000 Blaine	3500 Blaine	4000 Blaine	4500 Blaine
m	m	rpm	m	t	kW	m	t	kW	t	kW	t/h	t/h	t/h	t/h
2,4	7,95	20,5	2,5	14	151	4,75	28	296	42	446	16	12	10	8
2,6	8,7	19,7	2,75	19	203	5,25	36	401	55	604	22	17	14	11
2,8	9,2	19,0	2,75	22	244	5,75	46	526	68	770	27	21	17	14
3	9,7	18,3	3	27	316	6	56	654	83	970	35	27	22	18
3,2	10,45	17,7	3,25	34	403	6,5	69	833	103	1237	44	35	28	23
3,4	10,95	17,2	3,5	41	506	6,75	81	1008	123	1513	54	42	34	28
3,6	11,7	16,7	3,75	49	616	7	94	1189	144	1805	64	50	41	34
3,8	12,45	16,3	3,75	55	706	7,75	117	1507	172	2213	79	62	50	41
4	12,95	15,9	4	66	856	8	134	1769	200	2625	94	73	59	49
4,2	13,45	15,5	4,25	76	1013	8,25	152	2032	228	3045	109	85	69	57
4,4	14,2	15,1	4,5	89	1205	8,75	177	2421	266	3626	130	101	82	68
4,6	14,7	14,8	4,75	103	1421	9	200	2783	303	4204	150	117	95	78
4,8	15,45	14,5	4,75	112	1568	9,75	235	3326	347	4894	175	137	110	91
5	16	14,2	5	128	1828	10	263	3778	391	5605	200	156	126	105
5,2	16,75	13,9	5,25	146	2111	10,5	299	4363	445	6474	231	181	146	121
5,4	17,25	13,7	5,5	166	2430	10,75	331	4907	496	7337	262	205	165	137
5,6	17,75	13,4	5,75	187	2780	11	365	5496	551	8277	296	231	187	155
5,8	18,5	13,2	5,75	200	3020	11,75	418	6378	618	9398	336	262	212	175

2. Some graphics from the general sheet

- Speed of rotation in rpm and total length in m in function of the mill diameter in m

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Chapter 10

Ball Mill Inspection

1. Introduction

- This document is intended to help the staff of the cement plants.
- On a process point of view, a mill inspection is only representative if the grinding mill circuit is in a steady working condition with a representative cement product.
- If this condition is fulfilled, the whole installation must be stopped in crash-stop
- It means all the equipments must be stopped at the same moment, especially weigh feeders, fresh material, belt conveyor and separator rejects devices if closed circuit.
- If one of the hereabove mentioned points is not respected, the first chamber will probably have a lot of undesired material.
- Before to work around the ball mill, all the safety procedures must be done and checked by the staff concerned by the visit of the mill.
- It is also better to leave a small ventilation in order to cool both mill's chambers more quickly and thus reduce production stoppages.
- Flap of the fan must be opened around 10-15%.
- It is better to enter first into the first compartment in order to follow the flowpath of the material from the beginning of the grinding process.
- Generally, people enter by the manholes foreseen for both compartments
- From time to time, when the mill diameter is larger, it is possible to enter by the inlet trunnion in the first chamber and by the central screen of the intermediate diaphragm in the second chamber.
- This method saves time, because you no longer have to remove the two doors (manholes) from the shell.
- It will only be necessary to remove the central grid of the intermediate diaphragm.
- It is important to limit the number of people visiting the mill for safety reasons.
- This procedure was performed for a 2 compartments mill.
- For other configurations of mills, a simple adjustment is necessary.
- For outside staff, it is also necessary to check the kind of internals and the length of the chambers.

2. Essential accessories

- In order to carry out the right visit, some accessories are required.
- A list of items below.
- The light:
• A torch is the minimum required but not sufficient the most of the time:

• As some people can take measurements, pictures or write, it is better to install a worksite light in order to illuminate the whole compartment

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Chapter 11

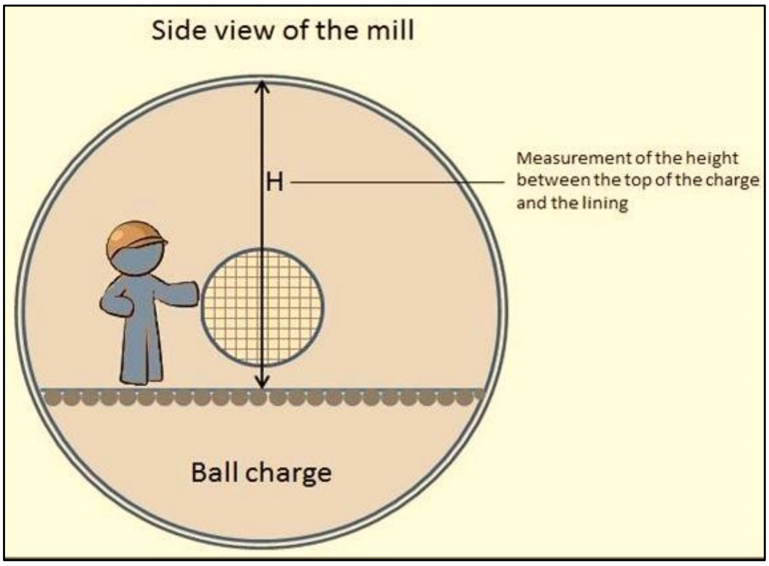
Measurement of the degree of filling of the mill

1. Introduction

- The volume load is also called the filling degree and is always expressed in %.
- The measurement of the mill's volume load is a basic operation of the maintenance department.
- There are three typical ways to realize this measurement:
1. The measurement of the height between the top of the charge and the lining.
2. Count the number of visible lining plates on the diameter.
3. The measurement of the central screen (or inlet trunnion) and the distance between the top of the central screen and the top of the charge.
- The three methods are developed below.

2. Measurement of H

- One measures H because the calculation is made with the H/D ratio.
- D being the internal diameter of the mill and is supposed to be known.
- The measurement is easy to do except for large diameters (higher than 3,5m) because H is higher than 2,2m.



- In this case, many people adopt a handmade template that allows a very reliable measure.
- On the side of the lining, the exact point where to put the meter is the average height of the plate, as shown in the sketch below

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Chapter 12

Ball mill axial test procedure

1. Introduction

- In order to have a good idea of the ball mill's efficiency (linings, ball charge, diaphragms, ventilation), we have to do a granulometric analysis inside the mill.
- This analysis includes three steps:
• The sampling campaign inside the mill
• The sieving of the samples in the laboratory
• The results analysis with the curve and its interpretation

For this presentation, we consider a classical 2 chambers mill as example.

2. The Sampling Campaign

- The sampling campaign after a crash-stop is also known as "axial test".

2.1. First chamber:

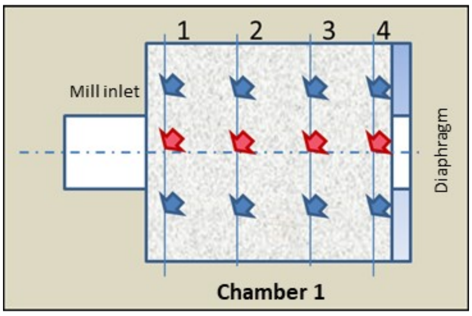
- As described in the mill inspection procedure in a previous chapter, we need the following:

4 solid bags

A scoop or something similar to take the material

Procedure:

- Take 4 samples (inlet, 2 intermediate samples, at the intermediate diaphragm) of ± 3kg each.
- Ideally for each sample, take materiel in three points as shown on the drawing here below.



- If for some reason it is not possible to take the samples at 3 points, the samples must be taken in the axis of the mill (red arrows in the figure above).
- If there is a lack of material at this point, take as close as possible.
- Dig a little by removing the balls at the sampling points and take the sample with the scoop.

... The rest in the full book

Chapter 13

Sieving analysis in two steps

1. Introduction

- This presentation will introduce the sieving analysis in two steps for the following types of samples:
• Fresh feed samples: clinker, gypsum, limestone, pozzolana...
• Mill axial test samples
- For other types of samples like circuit samples, fly ash or cement samples, big sieves are generally not used.
- The sieving of coarse samples is often performed in two steps:
• A first step for the biggest dimensions
• A second step for the smallest dimensions
- We suggest the following sieves:

Example of sieves	
Big sieves	Small sieves
50mm	1,18mm
25mm	0,5mm
12,5mm	212µ
9,5mm	90µ
4,75mm	63µ
2,36mm	45µ
	32µ

- Of course, similar sieves can be used.

2. Preparation of the sample for the first step

- Mill axial samples are usually between 3 and 5 kg each.
- The whole sample is passing through the big sieves without difficulty and waste of time.
- Fresh feed samples are bigger, with a weight comprised between 20 to 50 kg each.
- If the laboratory only wants to use a part of the sample, it is always possible to use a splitter in order to get a representative sample.
- Picture of a sample splitter:

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Chapter 14

Sampling campaign in the circuit of a cement mill

1. Introduction

- Periodic sampling campaigns in a ball mill grinding circuit are essential in order:
• To follow the installation in terms of fineness and mass balances
• To find existing problems and solve them
• To improve the performance of the installation.
• To reach the desired cement quality
- Schedule a sampling campaign every 3 months.

2. Before the sampling campaign

- The grinding circuit must be in steady condition at least 2-3 hours before the beginning of the sampling campaign.
- The time to reach stability varies from one mill to another.
- All the production data must be taken just before the beginning of the sampling campaign.
These data vary from an installation to another but basically, we need at least:
• Type of cement produced
• Production (t/h)
• Composition
• Fineness target and production target (residue and Blaine)
• Last fineness data (residue and Blaine)
• Separator tails flow rate (t/h) if existing
• Cement temperature at mill outlet
• Water injection quantity if existing
• Grinding aid quantity if existing
• Absorbed power of the ball mill and other main equipments (for the mill, take the absorbed power directly in the electrical room, it is more reliable)
• Other data like fans dampers position, pressure at mill outlet, separator speed...etc

3. Equipment and tools required

- What we need to carry out a sampling campaign in good conditions.
- Big bags for the fresh feed samples (clinker, gypsum, limestone...), for example 50kg cement bags is a good option.

... The rest in the full book

Chapter 15

Cement ball mills power formulas

1. Introduction

- This paper intends to describe different methods to calculate the power of a ball mill.
- Seven methods will be presented here:
• Bond formula
• Hogg and Fuerstenau formula
• Torque Factor (FLS) formula
• Slegten formula
• 911 Metallurgist website formula
• Beeck formula
• Holderbank formula
• Other formulas

- Generally, the absorbed power of a ball mill depends of the following basic data:
• Diameter
• Length
• Filling degree
• Speed of rotation
• Type of process
• Type of mill
• Type of linings
• Components

- Let's review the different formulas:

2. Bond Formula

- The Bond power formula is the following:

$$P_b = 4,879 \times D^{0,3} \times (3,2 - 3 \times J) \times V_{cr} \times \left(1 - \frac{0,1}{2^{9-10\times V_{cr}}}\right)$$

Where:
Pb is the power by ton of balls at the shaft in kW/ton,
D is the internal mill diameter in m,
J is the volume load (filling degree) in % and
Vcr is the percentage of the critical speed.

- If the mill is in dry process with grate discharge, the formula must be multiplied by 1,08.
- Like it is the case in the cement industry, we have:

$$P_b = 4,879 \times D^{0,3} \times (3,2 - 3 \times J) \times V_{cr} \times \left(1 - \frac{0,1}{2^{9-10\times V_{cr}}}\right) \times 1,08$$

... The rest in the full book

Chapter 16

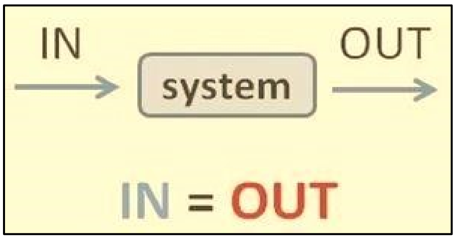
Ball mill heat balance

1. Introduction

- It is well known that the biggest part of the energy introduced in a ball mill is converted into heat.
- Only around 5% of this energy is used to grind the material at the required fineness.
- As a consequence, this heat can induce very high temperatures inside the cement mill.
- These temperatures can affect the grinding process if they reach a certain limit.
- Therefore, it is important to make the heat balance of the installation in order to solve possible problems.

2. Principle

- For all heat balances, there must be an equilibrium between what goes in and what goes out of the system.
- Of course, it is also the case for the cement mill heat balance.
- This principle is illustrated below:



3. The three basic parameters

- Regardless to the characteristics and production data of the installation that we have to know, the heat balance turns principally around 3 values:

3.1. Temperature of the product at mill outlet:

- It is generally accepted that beyond 105-110 degrees centigrade, adverse reactions to the grinding process can take place.
- This can also affect the quality of the cement.
- These reactions are:
• Trouble of gypsum dehydration which may cause cement "false set".
• Particles agglomeration due to electrostatic charges which causes coating phenomenon on balls and linings.
- The exact temperature which must not be exceeded varies from case to another.
- It depends of the kind of circuit, the material properties, the ambient temperature, the required fineness, the separator efficiency, the ball charge...etc.
- We consider that 105°C is a good reference.

3.2. Ventilation of the mill:

- The ventilation has 3 objectives:
• To insure the cooling of the mill and the material
• To dedust the mill
• To remove the fine particles from the mill

... The rest in the full book

Chapter 17

Mill ventilation

1. Introduction

- The ventilation of the cement ball mill has 3 objectives:
• To insure the cooling of the mill and the material
• To dedust the mill
• To remove the fine particles from the mill

2. Cooling of the mill

- A good cooling of the mill and the material inside the mill is necessary to maintain a proper working temperature.
- The temperature of reference is the one of the material at the mill outlet.
- For the cement mills, one cannot exceed a temperature of 105-110°C according the type of circuit.
- Higher temperatures can induce the dehydration of gypsum.
- This dehydration must be avoided to create cement false set problems.
- For the limestone, a temperature lower of 100°C should be better.
- Another consequence of higher temperatures is that we will probably observe a coating on the lining and the balls.
- Last but not least, the fluidity of the cement decreases drastically in case of too high temperature.

3. Problem of coating

- The coating is an agglomeration of material on the lining and/or grinding media.
- It is due to the superficial cohesion forces and the forces generated by the static electricity.
- This phenomena is happening with cement but also with limestone.
- As limestone has the particular propriety to produce a big amount of very fine particles (less than 2 microns) when grounded, the problem of coating can become crucial.
- Coating is an agent of efficiency loss which can be very important (up to 30%) because:
- Coating is disturbing the segregation of the ball charge in case of classifying lining.
- Coating is also reducing the attrition's efficiency of the small balls which are not more in contact with the material.

4. Dedusting of the mill

- This function seems to be evident if we want to avoid the accumulation of dust in the whole system.

5. Ventilation usual values

- When we want to define the necessary ventilation in a grinding installation, it is calculated in terms of air velocity in the free section of the mill, i.e.:

ventilation <=> air speed in m/sec

- The reference values which are generally admitted are divided in two cases and are the following:

... The rest in the full book

Chapter 18

Mill ventilation measurement

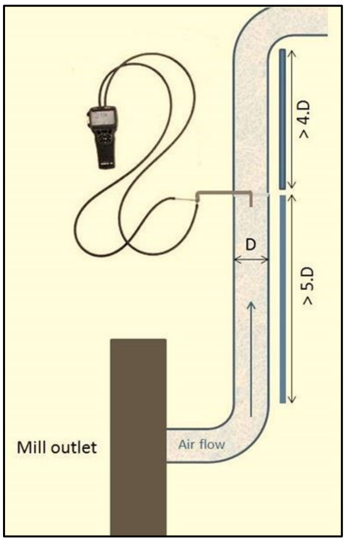
1. Introduction

- The ventilation of a ball mill is extremely important for the reasons described in the previous chapter.
- The measurement of the air flow is therefore necessary to carry out an optimal adjustment, to check the actual operation and the conformity of the flow rates of the installation and finally to identify installation errors or leaks.
- The measurement of the flow (Q) consists in fact of a measurement of the air speed (V) which is then multiplied by the passage section (S):

Q = S x V

2. Determine the measurement point(s) in the circuit

- The next step to ensure that the ventilation is the right one is the checking on site.
- The flow measurement points depend of the configuration of the grinding circuit.
- Generally, the best points are in a place where there are no elbows or other connections.
- Finally, where the flow of air is the least disturbed.
- In fixing the measuring point, the following recommendations should be observed:
• The shape and size of the pipeline must be constant
• The length of the duct segment before the measuring point must be higher than 5D (D = duct diameter)
• The length of the duct segment after the measuring point must be higher than 4D
- See the figure below:



- In practice, it is rare to find optimal conditions.
- But keep in mind that the closer we get to it, the more reliable the result will be.
- Usually the measurements are made in the vertical duct at the outlet of the mill and in the duct downstream of the fan.
- Other points of the circuit can also be measured if necessary, such as the ventilation at the level of the separator (useful for 3rd generation separators).

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Chapter 19

False air in grinding circuits

1. Introduction

- Unwanted false air in cement plants can be a big problem and has to be taken seriously.
- In fact, false air brings the following inconveniences:
• Drop in production of installations
• Increase of the power consumption
• Drop of temperature for drying raw material
• Higher wear of fans
• Difficulty to transport material
- It is therefore important to know the points where false air can appear and to know the percentage of false air in order to take appropriate measures.
- For that, some measurements are necessary on site.
- False air is mostly present in the following areas of a cement plant:
• Raw mill grinding area
• Kiln area
• Cement mill grinding area
- For grinding circuits, potential false air entry points are:
• Mill outlet
• Feeding points
• Holes in ducts
• Maintenance opening doors
• Flaps, expansion joints
• Connections
• Filters
- In the chapters here below, we will develop false air problem in:
• Raw and coal grinding areas with ball mills
• Cement mill circuits

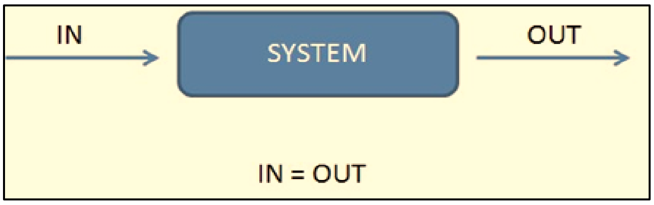
... The rest in the full book

Chapter 20

Material balance of grinding circuits

1. Introduction

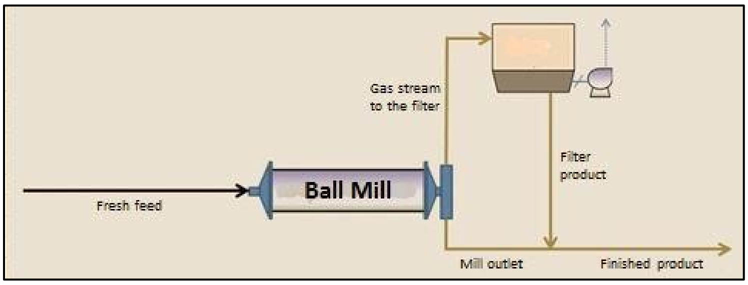
- Like the heat balance of a grinding plant, the mass balance responds to a very simple rule: anything that comes in the circuit will go out of the circuit.
- This is illustrated by the small picture below:



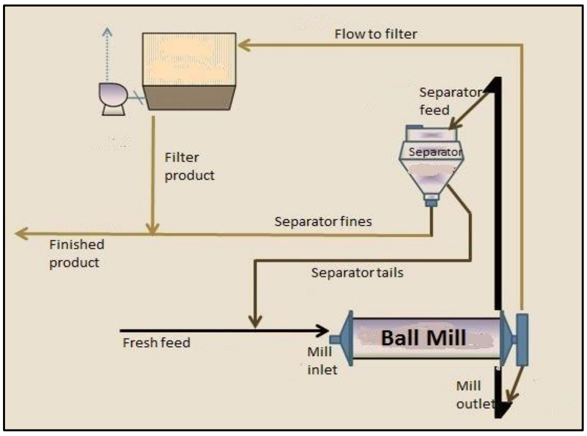
- This short presentation introduces the mass balance calculators that were developed for 7 different grinding circuits.
- The seven circuits are the following:

2. The 7 grinding circuits

- Open circuit:



- Closed circuit (separator of the first generation, product of the filter in the finished product):



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Chapter 21

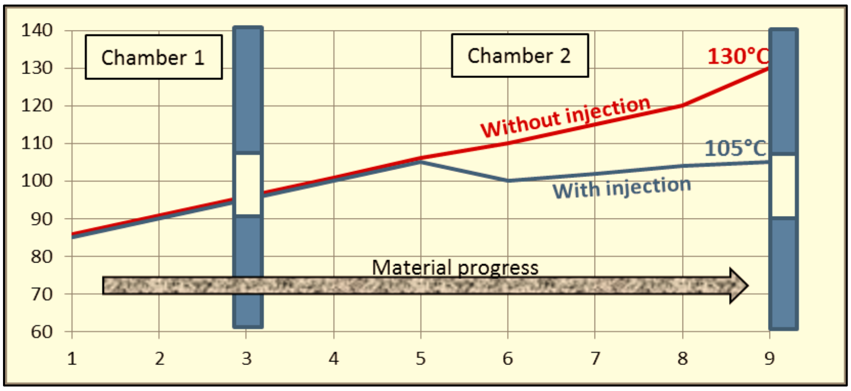
Water injection

1. Introduction

- Tube mills are generating a lot of heat.
- Gradually, as the material advances in the mill, the temperature increases.
- Everyone knows that the temperature does not exceed a certain level generally evaluated to 105-110°C.
- Beyond this limit, one can encounter the following problems:
• Fall of the fluidity of the material
• Production of superfine particles
• Coating on the balls and linings
• Blockage of the slots of the outlet diaphragm
• Dehydration of gypsum
• Flash and false set of the cement
• Cement storage problem in silos
• Block formation in silos
- All these problems have the following consequences:
• A drastic drop of the efficiency of the grinding plant
• A decrease in production
• Additional costs of maintenance
- To avoid these problems, the mill is ventilated.
- Sometimes, however, ventilation is not sufficient and it is then necessary to use other means:

Water injection

- Below, an illustration of the temperature increase phenomenon and the effect generated by the injection of water:



2. Where to inject water?

- Normally, water is injected into the second chamber of the cement mill, where the temperature is higher.
- If the clinker temperature exceeds 100 °C, it is advisable to inject a certain quantity in chamber 1.
- In this case, it is generally agreed that one third of the total amount is injected in chamber 1 and two thirds in chamber 2.

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Chapitre 22

Material amount inside the mill

1. Introduction

- It is always interesting to know the amount of material inside a ball mill and the time the material remains in the mill.
- Concerning this amount of material, there are two ways to see the things:
• I.e. the amount of material in the mill after a crash-stop
• Or to know this quantity at a time t when the mill is in operation
- Now, concerning the residence time, also called the retention time, the best thing is to do a test.
- Mill retention time (MRT) will be developed in another page.

2. Quantity of material inside the ball mill

2.1. Quantity when the mill is stopped:

- The mill must be stopped in crash-stop!
- It is recommended to go inside the mill and verify the filling degree and the material level for all compartments.
- We have to calculate the voids between balls to know this quantity of material.
- When balls are of the same diameter, voids always correspond to 47,6% of the total volume.
- See the demonstration on the table below:

Ball Diameter		Ball Volume	Ball Number by Side	Cubic Volume = Total Volume	Ball Number	Total Volume of the Balls	Percentage of Balls on Total Volume	**Percentage of voids**
mm		mm3		m3		m3		
90		381703,51	30	19,683	27000	10,3059947	52,4	**47,6**
80		268082,57	30	13,824	27000	7,23822947	52,4	**47,6**
70		179594,38	30	9,261	27000	4,84904826	52,4	**47,6**
60		113097,34	30	5,832	27000	3,05362806	52,4	**47,6**
50		65449,85	30	3,375	27000	1,76714587	52,4	**47,6**
40		33510,32	30	1,728	27000	0,90477868	52,4	**47,6**
30		14137,17	30	0,729	27000	0,38170351	52,4	**47,6**
25		8181,23	30	0,421875	27000	0,22089323	52,4	**47,6**
20		4188,79	30	0,216	27000	0,11309734	52,4	**47,6**
17		2572,44	30	0,132651	27000	0,0694559	52,4	**47,6**
15		1767,15	30	0,091125	27000	0,04771294	52,4	**47,6**

- When there different diameters, the percentage of the voids is lower.
- It is calculated with the following formula:

$$\%\mathbf{Voids} = 1 - \frac{\rho_{\mathbf{bulk}}}{\mathbf{SG}}$$

Where:
ρbulk is the bulk density of the balls
SG is the specific gravity of the ball

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Chapter 23

Mill Retention time

1. Introduction

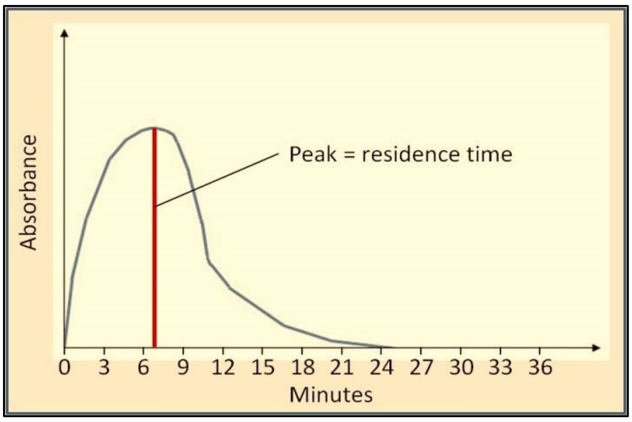
- It is always interesting to know the time the material remains in the mill.
- It is called mill residence time (MRT).
- The MRT represents the average time required for the bulk material (cement or other) to pass through the mill.
- Now, to know it, the best thing is to do a test.
- Concerning the amount of material inside the mill, it can be calculated with the result of the MRT.

2. Residence time inside the mill:

- The best way to know the residence time of the material inside the mill is to realize a test with a tracer
- The tracer used is called fluorescein and is a dark orange/red powder.

2.1. Procedure of the test:

- Here is basically the procedure for the retention time test.
- Mark the clinker with fluorescein placed in a solution of water and bring everything into a solid plastic bag..
- The amount of fluorescein is roughly 15 g per 20 tons of fresh material + tails from the separator.
- The tracer mixed with a little hot water is introduced into the bag containing 5 kg of clinker.
- To take clinker with a certain percentage of fines.
- Before starting the test, make sure that the grinding installation is operating in steady conditions.
- The bag containing the tagged clinker is introduced to the inlet of the mill.
- The stopwatch is then initiated.
- A sample is taken every minute at the mill discharge (30 seconds for short mills having an L/D <3).
- The test duration depends of course on the installation and its operating conditions but can vary from a few minutes to over 20 minutes.
- Samples are then stirred, allowed to stand for at least 30 seconds, and filtered.
- The liquid is then analysed in a spectrophotometer.
- Finally, a graph is plotted, the absorbance versus time, and the peak of minutes is used as retention time.
- Example of graph:



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Chapter 24

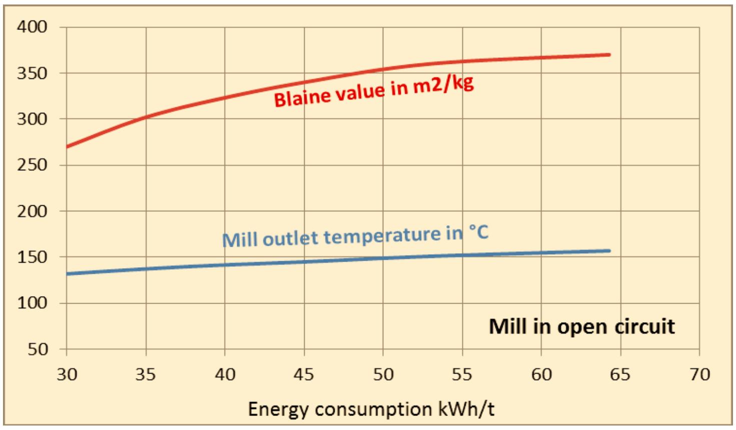
Grinding aids

1. Introduction

- Everybody knows that the efficiency of a ball mill is very low.
- Generally, this efficiency is in the range of 3 to 5%.
- The great majority of the energy produced is converted into heat.
- In the first part of the past century, practically all the cement mills were operating in open circuit.
- Due to demand, among other things, for greater strengths cements, manufacturers must produce products with higher fineness.
- They began to meet temperature problems (too high) in the mills with the following consequences:
• Agglomeration of particles on the linings and balls
• Efficiency loss and drastic increase of the specific power (kWh/t)
• Difficulty for producing a high Blaine cement
- A practical example is the old cement plants in England.
- These plants were provided with Vickers mills in open circuit.
- Vickers mills had a diameter of 2,55m and a length of approximately 12m.
- They were very long (L/D = 4,7).
- The rotational speed was approaching 77% of the critical speed.
- They were configured in 3, 4 and even 5 compartments.
- It was not unusual to get temperatures above 130-140 ° C at the mill outlet.
- Some installations even were producing cement at 4000 Blaine for a consumption of 70-80 kWh/t!
- We made a heat balance of a similar cement mill with different Blaine fineness, without water injection and with correct ventilation.
- Results are below:

Specific power (kWh/t)	Cement fineness Blaine (cm2/gr)	Temperature at mill outlet (°C)
30	2700	132
35	3000	137
39	3200	141
45	3400	145
53	3600	151
64	3700	157

- And the graph:



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Chapter 25

Composition of the grinding media

1. Introduction

- This page intends to introduce the ball charge composition calculator.
- Indeed, the ball charge is of great importance for the performance of the mill.
- But first, it is important to emphasize that the composition of a ball charge of a cement mill depends on many parameters and a composition miscalculated can significantly affect the performance of the installation.
- It is also better to do a complete audit before to modify a ball charge.
- A full explanation of a sampling campaign inside the mill is available in a later chapter.
- It is also advisable to let the experienced people calculate a grinding charge.

2. Cement mill with 2 compartments

2.1. First compartment:

- The first compartment (or first chamber) is also known as coarse chamber or crushing chamber.
- It is equipped with lifting lining in order to increase the ascending trajectory of the balls.
- The diameter of the balls is mostly from 90mm to 60mm with some exception (100mm for harder materials).
- Balls smaller than 60mm have a limited efficiency and must be avoid.
- Balls are working by impact.

2.1.1. Factors influencing the composition of the charge:

- The granulometry of the fresh feed:
• This is probably the most important factor
• Important remark: we take into consideration the fresh feed at mill inlet
- The hardness of the clinker:
• Do not confuse with the grindability of the clinker
• On this subject, see the explanation in the chapters devoted to grindability and hardness (42 and 43)
• A good and easy test to know the clinker hardness is the well-known Slegten hardness test
- The kind of lining, because the lining is generally made with a lifting effect but we can define three types of situation:
• Weak lifting effect
• Normal lifting effect
• Aggressive lifting effect
- The specific power consumption of the chamber, the value is normally comprised between 8 and 12 kWh/t.
- Other less important factors:
• The percentage of slag in the feed
• The percentage of additives (like limestone) in the feed
• The percentage of moisture in the total feed
• The type of clinker (grey or white)

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Chapter 26

Ball top size

1. Introduction

- This small presentation for introducing the calculation of the top size grinding media used in a tumbling mill. Three formulas are described here:
• The Bond formula
• The Rowland (Allis-Chalmers) formula
• The Azzaroni formula
- Everybody knows these formulas and uses them frequently.
- We do not want to argue about the reliability of these formulas, each having its own opinion on the subject.
- We therefore limit ourselves to describe them.

2. The Fred.C.Bond formula

- The formula is the following:

$$D_b(\text{Bond}) = 25{,}4.\sqrt{\frac{P_f.\frac{W_i}{1{,}102311}}{C.V_{cr}}.\sqrt{\frac{S_{gs}}{\sqrt{\frac{D}{0{,}3048}}}}}$$

Where:
Db = the top size of the grinding media in mm
Pf = size in µ of the 80% passing in the fresh feed
C = 200 for ball mills
Wi = Work index in kWh/t
Vcr = percentage of the critical speed (if 75% => 75)
Sgs = specific gravity of feed in t/m3
D = internal diameter of mill in m

- One can have the choice between balls and cylpebs
- Depending on the diameter determined by the calculation, the commercial size proposed must be chosen in line with the result.

3. The Rowland (Allis-Chalmers) formula

- The formula is the following:

$$D_b(\text{Rowland}) = 25{,}4.\sqrt{\frac{P_f}{330}}.\left(\frac{S_{gs}.\frac{W_i}{1{,}10229}}{V_{cr}.\sqrt{3{,}281 \times D}}\right)^{0{,}33333}$$

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Chapter 27

Sampling of the grinding media

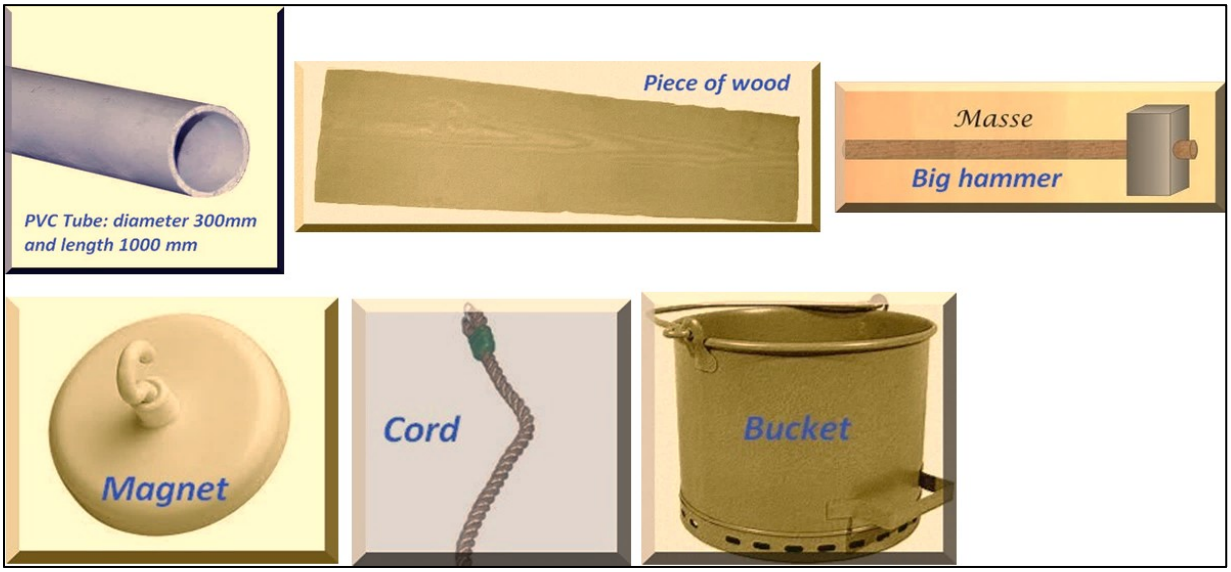
1. Introduction

- It is always interesting to know the ball charge gradation inside a ball mill.
- Reasons are:
• To see the difference with the theorical ball charge given by the supplier or somebody else
• To adjust the future make-up
• To get a good idea of the wear of the balls
• To decide if it is time to change completely the ball charge
• To check if the classification is good in second chamber
- Experienced engineers have a good feeling only having a look during the mill's visit but results of a complete sampling is better in order to convince other people.
- The problem number one is the difficulty of the job.
- In fact, it is very hard and long work.

2. Method used in the mining industry:

- Let us recall the method often used in wet process:

2.1. Tools needed:



- A tube in PVC with a diameter of 300mm and a length of 1000mm (this tube must be resistant, a thickness of 8-10mm is necessary)
- A piece of wood is necessary between the tube and the hammer due to the impact
- A big hammer to knock the tube into the ball charge
- A magnet to remove the balls from the ball charge
- A cord for lifting the magnet and the balls
- A solid bucket to carry the balls in the laboratory

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Chapter 28

Marked Ball Test

1. Introduction

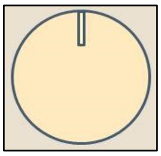
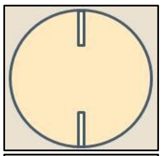
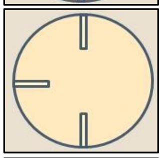
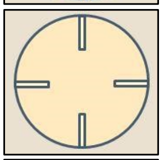
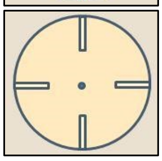
- Marked ball tests, abbreviation MBT, are performed both in cement and mining area.
- It is obviously admitted that they have much more importance in the field of mines where the wear is drastically higher.
- Economic interest is more critical, whether for the mining people or the supplier of balls.
- However, these tests are also very useful in the cement field.
- It is important to note that some producers (cement and mining) make reservations about the merits of these tests.

2. Goals of the MBT

- A supplier wants to prove that his product is better.
- A cement producer wants to compare various suppliers for inclusion in the vendor list, for example.
- A supplier of grinding media and a mining/cement producer agree to realize a deep study in order to obtain the best ball quality.

3. Marked balls

- It is widely accepted that 200 balls are necessary and sufficient to do the test (200 balls for one quality of alloy).
- A hole is drilled in each ball.
- The hole has the following dimensions: diameter 5mm and 15mm deep.
- Example of marked ball:

Quality 1		Single hole drilled from surface to center
Quality 2		Two holes drilled in line 180°
Quality 3		Two holes drilled in line 180° and 3rd hole at 90° in the same plane
Quality 4		Four holes drilled at 90° in the same plane
Quality 5		Four holes drilled at 90° in the same plane and 5th hole to center in a perpendicular plane

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Chapter 29

Cyclones

1. Introduction

- In cement manufacturing industries, large-sized cyclone separators are used as main process equipment in significant numbers for handling high volumetric flow rates of dust-laden gases.
- The best example being the preheating units of rotary kilns.
- The cyclone is a simple mechanical device commonly used in the grinding circuits to remove relatively large particles from gas streams.
- Cyclones are often used as precleaners to remove more than 80% of the particles greater than 20µm in diameter.
- Smaller particles that escape the cyclones can then be collected by more efficient control equipment like bag filters and electro precipitators.
- Cyclones are relatively inexpensive since they have no moving parts and they are easy to operate.
- The most common type of cyclone is known as reverse flow cyclone separator.

2. Advantages of cyclones

- Low capital cost.
- Ability to operate at high temperatures and pressures.
- Low maintenance requirements because no moving parts.
- Constant pressure drop.
- Can separate both solid and liquid particles, sometimes both simultaneously.

3. Disadvantages of cyclones

- Low efficiency especially for very small particles.
- High operating costs in case of high pressure drop.
- Subject to erosion or clogging if abrasive solids are processed.

4. Principle of operation

- The spiral pattern of gas flow is developed by the manner in which the gas is introduced.
- It enters along the side of the cyclone body wall and turns a number of times to spiral down (external vortex) to the bottom.
- Particles in the gas are subjected to centrifugal forces which move them radially outwards, against the inward flow of gas and towards the inside surface of the cyclone.
- When the gas reaches the bottom of the cyclone, it reverses direction and flows up the center of the tube, also in a spiral fashion.
- This spiral fashion is also called inner vortex and fine particles are carried with the air and leave the cyclone through the immersion tube.
- Solids at the wall are pushed downwards by the outer vortex and are going out by the solids exit.
- Gravity has been shown to have little effect on the cyclone's operation.

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Chapter 30

Static separators

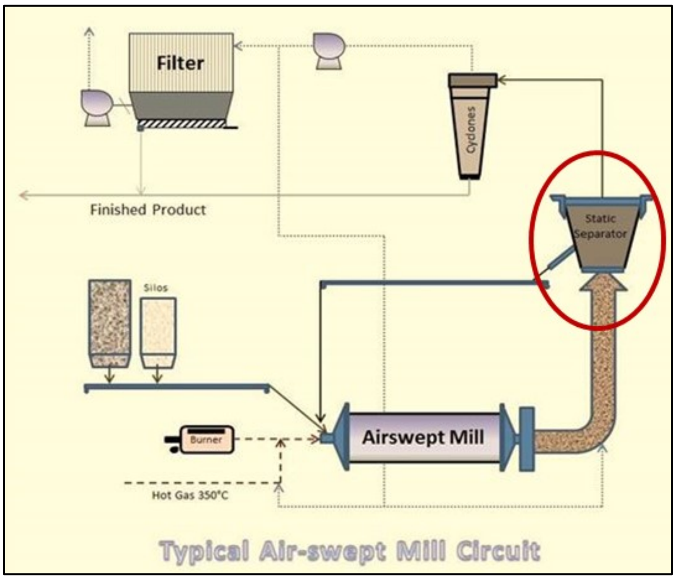
1. Introduction

- Separators are widely used in the cement industry and more particularly in grinding circuits.
- But what are separators?
- Basically, separators separate fine particles from coarse particles.
- Fine particles are usually collected as a finished product while coarse particles are sent back for further grinding.
- The trick is to ensure that the coarse particle stream does not contain fine particles, and on the other hand, the fine particle stream does not contain coarse particles.
- An efficient separator should prevent over-grinding and consequent waste of energy.
- There are mainly two kinds of separators, static separators and dynamic separators.
- The big difference is that static separators have no moving parts and can only be adjusted with mechanical modifications.
- This chapter is devoted to classical static separators and V separators which are another type of static.

2. Static separators

2.1. Introduction:

- The static separator is, like the cyclone, a simple mechanical device commonly used in grinding circuits to eliminate relatively coarse particles found in the gas streams.
- Static separators are relatively inexpensive because they have no moving parts and are easy to use.
- They are used in particular in the circuits of raw and coal mills.
- Here is a circuit with an air swept mill used for coal grinding:



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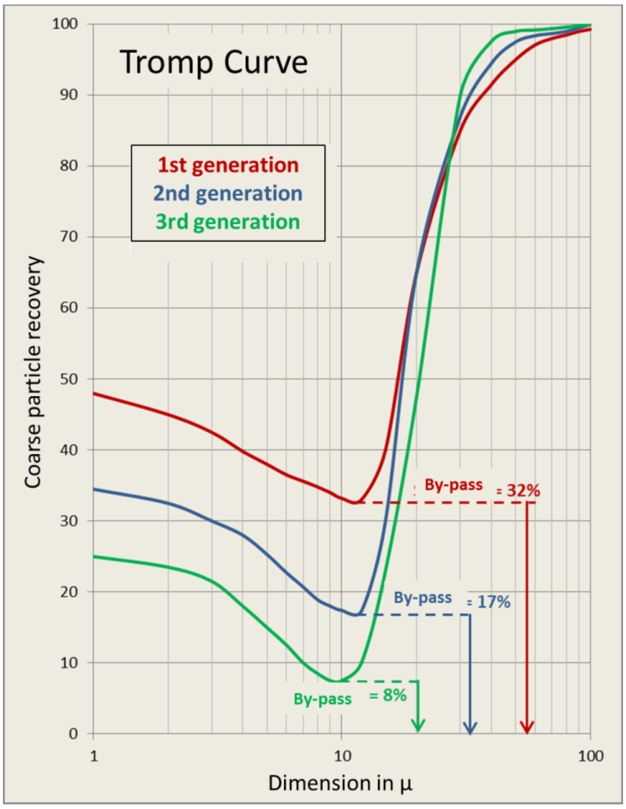
Chapter 31

Introduction to dynamic separators

- After having introduced the cyclones and the static separators, we are going to talk about the dynamic separators, which constitute the vast majority in the cement grinding circuits.
- Dynamic separators are classified into three generations, although a world famous supplier has recently developed a separator which they classify as fourth generation.
- In the first generation separators, the air flow is generated by a fan inside the separator body.
- In the second generation, the airflow is generated by an external fan and there are cyclones.
- And finally, the third generation has a rotating cage which replaces the counter-pallets of the 1st and 2nd generation.
- Comparison of the main characteristics:

Category	1st generation	2nd generation	3rd generation	4th generation
Name	Turbo separators	Separators with cyclones	Cage separators	Integrated cyclone
Second name	Conventional	-	High-efficiency	High-efficiency
Design	Compact	Voluminous	Compact or voluminous	Compact
Varieties	None	None	Many	None
Efficiency	40-60%	60-80%	80-90%	No data available
By-pass	20-70%	10-40%	0-30%	
Imperfection	0,35-0,75	0,2-0,5	0,15-0,4	
Blaine of tails	1100-2000	800-1200	550-1200	

- Trump Curves Comparison:



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Chapter 32

First generation separators

1. Introduction

- There are also called:
• Turbo separators.
• Classic or conventional separators.
- The material to be classified is dispersed in the area where the separation is created by a distribution plate.
- The air flow required for the separation is produced by a fan located inside the separator itself.
- The separator material feed is carried out mechanically by means of suitable continuous conveyors.
- Separators can have one or two motors, gear reducers and shaft:
• One for the main fan .
• One for the distribution plate and the conterblades.

- Here a non-exhaustive list of conventional separators:
• Heyd (Ch.Pfeiffer)
• Sturtevant Whirwind Air Classifier
• Turbopol (Polysius)
• Schmidt
• Raymond
• Escher Wyss
• CV (F.L.Smidth)
• Hischmann
- These separators are used for both raw material and cement.

2. Advantages of 1st generation dynamic separators

- Possibility of mechanical adjustments.
- Possibility of very large flow rates.
- Flexibility to produce products of different qualities.
- Low volume required.
- Limited investment.

3. Disadvantages of 1st generation dynamic separators

- Bad efficiency especially with high circulating loads due to:
• Poor distribution of the material in the cross section.
• Poor dispersion of the material in the separating air.
• Large quantities of fine material are recirculated in the air, increasing the amount of fines coming with the tails.
- No (or little) possibility of cooling or drying the material.

4. Principle of operation

- The main fan produces a stream of air circulating within the separator.
- The fan blades pull air from inside the inner cone and push it into the outer cone.
- The material is generally fed on the top of the separator.

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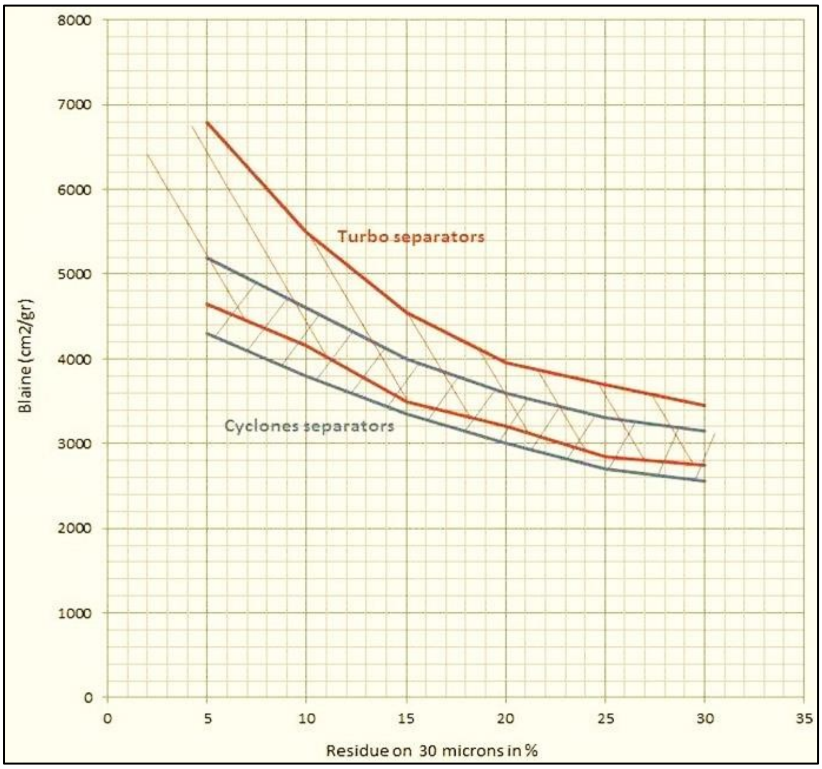
Chapter 33

Second generation separators

1. Introduction

- Also called: Cyclones separators.
- As the 1st generation, the material to be classified is dispersed in the area where the separation is created by a distribution plate.
- The air flow required for the separation is produced by an external fan.
- The separator material feed is carried out mechanically by means of suitable continuous conveyors.
- Fines are conveyed in external cyclones.
- Fresh air entry and air exit to filter.
- The fan that moves the air is a more efficient design and has a considerably reduced dust loading.
- These separators have better separation efficiency due to the external fan and the cyclones.
- Comparison between cyclones and conventional separators:
- The diagram here below shows the specific surface (Blaine) produced in order to achieve a certain percentage of residue on 30µm (From Duda Cement Data Book).
- For example, to get 20% residue on 30µm, a turbo separator needs to produce cement at 3200-3900 Blaine and a separator with cyclones 3000-3600 Blaine.



- Here a non-exhaustive list of cyclones separators:
• Wedag ZUB (KHD Humboldt Wedag)
• Cyclopol (ThyssenKrupp Industrial Solutions)
• SKET (ZAB Co.)
• FCB cyclones
• Other copies from former Eastern Europe

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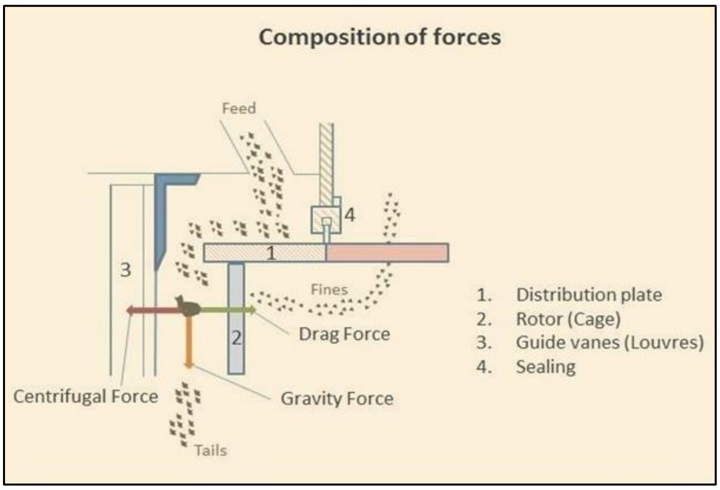
Chapter 34

Third generation separators

1. Introduction

- Also called:
• Cage separators
• High Efficiency Separators
- These separators were developed by several major manufacturers in the early eighties.
- But the first was the O-Sepa separator, which was developed in the late 1970s by the innovation office of the Japanese company Onoda Cement Co.
- As the second generation, the air flow required for the separation is produced by an external fan.
- The separator material feed is carried out mechanically by means of suitable continuous conveyors, as air slides.
- Fines are conveyed by air in external cyclones or directly to a bag filter.
- The main separating device is a cylindrical rotor.
- The rotor is like a cage composed of blades closely spaced.
- The rotor is operated by a variable speed drive.
- The rotor speed determines swirl in the classifying zone and therefore the cut of the separator.
- The composition of forces acting in the separating zone is showed in the figure below:



- Here a non-exhaustive list of High Efficiency separators:
• O'Sepa (FLSmidth)
• Sepol (ThyssenKrupp Industrial Solutions)
• Sepal (FLSmidth)
• SD (Sturtevant)
• Sepmaster (KHD Humboldt Wedag)
• QDK and TGS (Christian Pfeiffer Maschinenfabrik GmbH)
• TSV (Fives FCB)
• O&K (Orenstein & Koppel AG)
• PRESEP VTP (PSP Engineering a.s.)
• CTC SERIES (CEMTEC)
• Cemag Cross Flow (CMP AG)
• ICS and ICV (Intercem Engineering GmbH)
• XP4 (Magotteaux)
• Copies from China

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Chapter 35

Cement cooling in the separator

1. Introduction

- Cement leaving the ball mill typically has a temperature above 100°C.
- And for that reason, cement often needs to be cooled to avoid some problems ahead in the production line.
- A problem that the cement manufacturer can meet is the formation of lumps in silos due to the release of water from the gypsum (dehydration).
- Another reason for cooling the cement is the bagging procedure and to handle bags at lower temperature.
- The device generally used is the cement cooler which has a cylindrical body and tubes inside with a recirculation of water.
- Cement passes through the labyrinth of tubes (from the bottom to the top) and is cooled.
- The cement cooler can decrease the cement temperature up to 60°C and has a specific consumption of 1-1,3 kWh/t of cement.
- Before investing in a cooler, it is essential to control if the separator is not able to perform this cooling function.

2. Separator as cooler

- Separators can have good cooling capability or not depending on their characteristics:

2.1. Static separators and cyclones:

- Static separators used in series with the air are not able to cool.
- It is the same for cyclones.

2.2. First generation separators (turbos):

- All these separators are designed with an internal air circulation.
- The main fan is inside.

In these conditions, the cooling effect is negligible.

- In some cases, a secondary fresh air circuit has been added to the existing separator, but the cooling capacity is limited.

2.3. Second generation separators (cyclones):

- These separators have an external fan but the majority of the air is recirculated.
- A secondary fresh air circuit is always installed but has not been sized to efficiently cool the cement.
- This generation of separator due to their configuration with cyclones allow a better cooling than the 1st generation.

2.4. Third generation separators (rotor):

- This type of separator is well suited for cooling because big air quantities are passing through it.
- In fact, separators circuits vary from one to another but there is always the possibility to adjust the air temperature at separator inlet.
- A certain quantity of air can be recirculated, the adjustment is often realized with the fresh air flap.
- At the start of the mill, it is better to recirculate the air to the separator in order to help the mill (with the rejects) to reach its normal working temperature.
- After that, more fresh air is allowed in order to cool the cement.

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Chapter 36

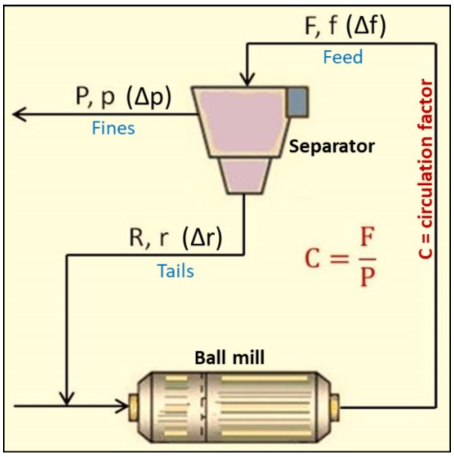
Tromp curve

1. Introduction

- In order o determine the performances of a separator, one uses generally the Tromp curve so called separation curve or selectivity curve.
- Of this Tromp curve are generated various parameters allowing to compare the separator with other generations of separators.
- We shall see in detail the Tromp curve further in the presentation.
- Another tool of analysis is the efficiency of the separator.
- Contrary to the Tromp curve which is based on the recovery in the rejects, the efficiency is based on the recovery in the fines of the separator.
- To establish a Tromp curve, a sampling campaign in good conditions must be organized.
- The sampling campaign has been described in chapter 14.

2. Background of the theory

- Here is the basic diagram to introduce the Tromp curve:



- Referring to the diagram above, we have:

• F = throughput of the separator feed in tons/hour
• R = throughput of the separator rejects in tons/hour
• P = throughput of the separator fines in tons/hour

- As well as:

• f = passing at a certain sieve of the separator feed in %
•r = passing at a certain sieve of the separator rejects in %
• p = passing at a certain sieve of the separator fines in %

- These percentages of passing are generally cumulated and are expressed in %.
- In some cases, there can also be specified in mass unit (as grams or kg)

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Chapter 37

Lagrange correction of analysis results

1. Introduction

- Taking samples in a grinding circuit is very useful for several reasons:
• To know the fineness in different points of the circuit
• To establish a mass balance of the complete circuit
• To study the behaviour of the separator
- Finally, the periodic samples taken in a ball mill circuit are essential to help in resolving existing problems or to improve plant performance.
- One knows that the grinding circuit must be in steady state at least 2-3 hours before the beginning of the sampling campaign in order to collect representative samples.
- Despite these dispositions, unforeseen events can still occur during the sampling campaign:
• Sudden change of fresh material particle size
• Flaps malfunctioning
• Lack of material at the sampling point
• Pumping phenomenon in an air slide
• Human errors
- In addition, some grinding circuits have not been designed with well-defined points of sampling and it is often necessary to proceed without much visibility.
- The consequence of these unexpected is that the analysis results can be completely altered.
- It is therefore difficult to analyse the actual situation.
- For example, the calculation of the Tromp curve of the separator gives a poor correlation (<0,98).
- In this case, there are methods for reconstituting the samples.
- The method used in our calculator is called "Lagrange correction method".
- Of course, the method has its limit and if the correlation is below 0,96, it is best to organize a new sampling campaign.

2. Explanation of the method

- Samples of the separator:
• Feed
• Fines
• Rejects

- Baseline:
• Cumulative passing on each sieve of the feed in %
• Cumulative passing on each sieve of the fines in %
• Cumulative passing on each sieve of the rejects in %

- First calculation:
• Partial passing between each interval of the feed in %: f_p
• Partial passing between each interval of the fines in %: p_p
• Partial passing between each interval of the rejects in %: r_p

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Chapter 38

Interpretation of the Tromp curve

1. Introduction

- In order to determine the performances of a separator, one uses generally the Tromp curve so called separation curve or selectivity curve.
- It is probably the best tool to evaluate the separator efficiency.
- Of course, the study is carried out after taking samples around the separator and analysing the samples by laser diffraction.
- Let's recall that from the Tromp curve, we define the imperfection factor.
- This factor is calculated from the following formula:

$$I = \frac{D75 - D25}{2.D50}$$

With:
I = Imperfection factor
D75 = the dimension in µm having 75% probability to go into the rejects of the separator
D25 = the dimension in µm having a 25% probability to go into the rejects of the separator
D50 = the dimension in µm having a 50% probability to go into the rejects of the separator (•)
(•) D50 is also the cut size of the separator

- The higher is the imperfection and the less efficient is the separator.
- If It is very low, the separator is very good.
- The ideal separator would therefore have an imperfection factor equal to 0, but this is not possible.
- The imperfection is in the range of 0,1 to more than 1 for the very bad separators ...
- So, we have to determine D75, D50 and D25 and this is where things can get complicated.
- There are several reasons for that:
• The results of the laser analysis do not give a good correlation
• The separator by-pass is very high and we have no value for D25 (and maybe D50)
• We have no value for D75.
- In all these cases, we have to extrapolate.
- For example, we can work with trend curves in the Excel calculator.
- This is what we will see in the next chapter.

2. Examples of trend curves

- There are 6 types of trend curves in the Excel calculator:
• Exponential
• Linear
• Logarithmic
• Polynomial
• Power
• Moving average

... The rest in the full book

Chapter 39

European standard for cements (EN 197-1)

1. Introduction

- All the following documents have been consulted to write this presentation:
• EN-197-1_en.pdf
• Mortar-cementitious.pdf
• Specifying-constituent-materials-for-concrete-to-bs-en-206_1.pdf
• fiche_conseil_nouvelle_norme_NF_EN_1971_2012.pdf
• CT-G56.pdf
• normes_160904_cle0f133d.pdf
• Leccion4.TiposCEMENTOS.pdf
• INSTRUC_RECEP_CEMENTOS_consolidada.pdf
• Cimento Portland e Adicoes.pdf
• 8_I CEMENTI COMUNI E LA NORMA UNI-EN 197-1_1.pdf
- These documents are easily downloadable copying the titles above.

- EN 197-1 is the first standard adopted in the framework defined by the European Construction Products Directive, which sets the rules for placing construction products on the market.
- This European Standard for Common Cements is a unique text, a common basis for all members of the European Union.
- European countries called this EN 197-1 standard with their national designation.
- Few examples here below:

Swiss	SN EN 197-1:2011
France	NF EN 197-1 : 2012
Belgium	NBN EN 197-1
UK	BS EN 197–1
Italy	UNI EN 197-1
Germany	DIN EN 197-1
Spain	UNE-EN 197-1:2011
Portugal	NP EN 197-1:2012

- The European standard EN 197-1 describes common cements, as well as their composition, specifications and conformity criteria.

2. Cement types and composition

- The standard divided the cements into five types:

CEM I	Portland cement
CEM II	Composite Portland cement
CEM III	Blastfurnace cement
CEM IV	Pozzolanic cement
CEM V	Composite cement

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Chapter 40

Cement components

1. Introduction

- This presentation describes the influence of different components of the cement in the grinding process.
- We therefore do not discuss in depth the manufacture, chemistry and mineralogy of the cement and its derivatives.
- There are an impressive number of publications, studies and other papers that explain in extensively these subjects, and generally very well written by experts.
- At the end of the presentation, a summary table gives the advantages and disadvantages of the various components that may be encountered for obtaining cement, and from a grinding technology point of view.
- The components that will be discussed are:
• Clinker
• Gypsum
• Limestone
• Limestone filler
• Pozzolana
• Slag
• Fly ash
- The consequences for grinding circuits that will be covered are:
• Specific consumption
• 2 chambers or single chamber mill
• 1st chamber length
• 1st chamber lining type
• Ball charge of first chamber
• Material level
• 2nd chamber lining type
• Ball charge of second chamber
• Drying
• Temperature
• Ventilation
• Separator behaviour
• Feed localization
• Fineness of finished product
• Final product particle size distribution
- Here is a table summarizing the different cement components:

Cement components - summary	
Main components	
Clinker	Portland cement Alumina cement White cement
Set regulator	Gypsum Hemihydrate Anhydrite Limestone
Additives	
Hydraulic materials	Blast furnace slag Other slag

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Chapter 41

Parameter formulas for cement manufacturing

1. Introduction

- This short presentation to introduce the typical cement parameters used in the cement industry.
- In practice, the proportion of the main constituents of the clinker is calculated in the form of ratios, modules or chemical indices.
- These modules are the result of studies of many scientists on the Portland clinker formation and reaction mechanisms.
- These modules are also known as quality control formulas.

2. List of formulas

2.1. Hydraulic module (HM):

- Also known as Michaelis Hydraulic Module.
- The formula is:

$$\text{Hydraulic module (HM)} = \frac{C_aO}{S_iO_2 + Al_2O_3 + Fe_2O_3}$$

- HM is generally comprised between 1,7 and 2,3.

2.2. Silica Ratio (SR):

- Also known as Kühl's silicic modulus.
- The formula is:

$$\text{Silica Ratio (SR)} = \frac{S_iO_2}{Al_2O_3 + Fe_2O_3}$$

- A high value corresponds to a high level of silica.
- A low value is detrimental to the proper functioning of the kiln.
- SR is generally comprised between 1,5 and 5.

2.3. Alumina-Iron Ratio (A/F):

- Also known as Kühl's aluminoferric modulus.
- The formula is:

$$\text{Alumina-Iron Ratio } \left(\frac{A}{F} \text{ or AR}\right) = \frac{Al_2O_3}{Fe_2O_3}$$

- AR is generally comprised between 1,5 and 2,5.

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Chapter 42

Grindability and grindability tests

1. Introduction

- This article is intended to present the main grindability and hardness tests used in the industry.
- It is obvious that these tests are widely used in the cement industry for several reasons:
- Sizing/dimensioning of new installations and improvement of existing installations.
- A great number of grindability and hardness tests have been developed by Grinding Engineers, Research offices of Universities, cement producers or cement plants suppliers.
- This paper will develop some of these tests.
- But before, it is necessary to explain the difference between grindability and hardness because both are often mixed up.

2. Grindability definition

- Dictionaries on the Web have the following definition: "Relative ease with which a material can be ground".
- Another definition can be: "Grindability is the measure of specific energy consumption required to reduce a certain mass of material from a given fresh and initial size up to a defined product size".
- Whatever the definition, one thing is certain, the grindability of a material is dependent of a lot of factors.
- For example, clinker grindability depends on its chemical composition and the conditions of burning and cooling.
- Everybody knows that alite (C_3S) cracks much more easily than belite (C_2S).
- Then a clinker with high lime saturation will have a better grindability.

3. Grindability tests

- Three well-known tests are developed below:
• Bond test
• Hardgrove test
• Zeisel test

3.1. Bond grindability test:

- The test developed by Fred C. Bond in 1952/1961 is widely used worldwide.

3.1.1. Machinery required:

- Mill diameter 305 mm (12") and length 305 mm (12") with rounded corners and a smooth internal lining.
- Speed of rotation: 70 rpm.
- Ball charge:
• 43 balls of 36,83 mm
• 67 balls of 29,72 mm
• 10 balls of 25,4 mm
• 71 balls of 19,05 mm
• 94 balls of 15,94 mm
• Total: 20,125 kg of balls
- Balance and sieves are obviously required.

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Chapter 43

Hardness and hardness tests

1. Definition of hardness

- The usual definition seen on the web is: "Hardness is the property of a material which enables it to resist plastic deformation, usually by penetration".
- Here is another definition: "It is the resistance of a material to deformation, indentation, or penetration by such means as abrasion, drilling, impact, scraping, or wear".
- Anyway, the concept of hardness is different from that of grindability.
- A material can be very hard and have good grindability.
- On the contrary, a material can be very soft and have poor grindability.
- The following tests are presented in this chapter:
• Mohs scale for the hardness of minerals
• Intensive penetration hardness testing
• JK drop weight test
• Slegten hardness test

2. Mohs scale for the hardness of minerals

- This scale was created in 1812 by the German geologist and mineralogist Friedrich Mohs.
- The Mohs scale is used to determine the relative hardness of minerals from ten well-defined minerals of varying hardness.
- This scale (nonlinear) is graduated from 1 to 10.
- 1 is the lowest hardness and 10 is the highest hardness.
- The principle of this scale is based on the fact that a mineral can scratch another if its own hardness is higher.
- Mohs hardness scale:

Mineral	Hardness
Talc	1
Gypsum	2
Calcite	3
Fluorite	4
Apatite	5
Feldspar	6
Quartz	7
Topaz	8
Corundum	9
Diamond	10

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Chapter 44

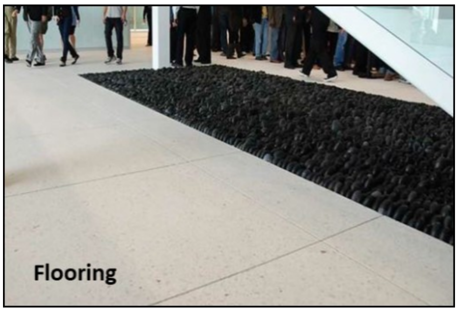
White cement

1. Introduction

- White cement is a variety of Portland cement that is made from carefully selected raw materials so that they contain virtually no iron, manganese or chromium, or other materials that give it colour.
- White cement is seen as a luxury product.
- It is used primarily for aesthetical reasons due to its whiteness.
- White cement:

- Applications can be:
• Architectural fixtures
• Terrazzo
• Sculptures
• Exterior cladding
• Concrete elements

- Some pictures of application:


Flooring


Sculpture

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Chapter 45

Particle Size Distribution Representation

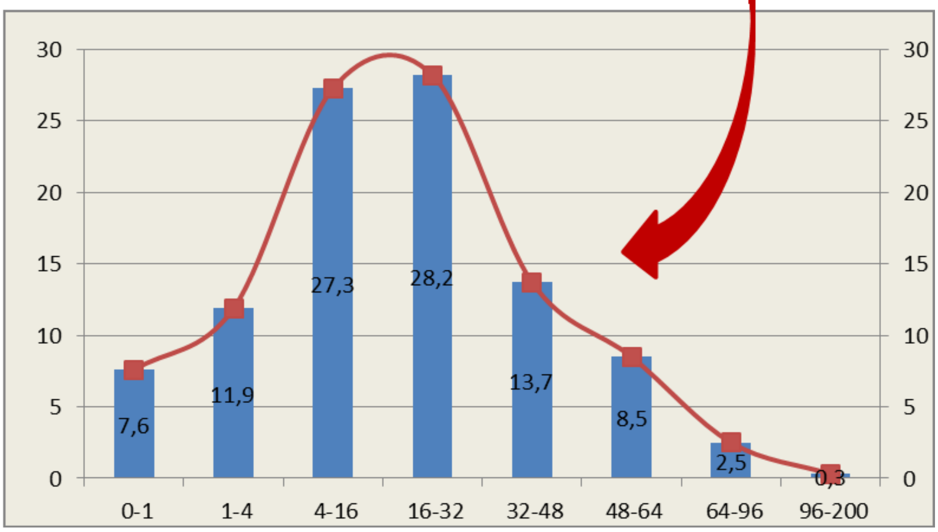
1. Introduction

- Analysis of samples of material in the cement industry, either by dry or wet sieving, or by laser diffraction are very extensive.
- The results arrived at the office of the Process Engineer will be subject to interpretation.
- One can plot a graph for the partial results, i.e. partial percentages of passing (or residue) vs the dimension of the particle.
- Or one can plot a graph for the cumulated passing (or residues) in order to analyse the particle size distribution of the sample and its quality.

2. Partial results

- Graphics with histograms or curves are often plotted.
- X-axis is the range (interval) between two sieves.
- Y-axis is the partial passing in % or the partial residue in %.
- See example below:

Sieve in µ	Passing cumulated in %	Range	Passing partial in %
1	7,6	0-1	7,6
4	19,5	1-4	11,9
16	46,8	4-16	27,3
32	75	16-32	28,2
48	88,7	32-48	13,7
64	97,2	48-64	8,5
96	99,7	64-96	2,5
200	100	96-200	0,3



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Chapter 46

Blaine Specific Surface Area

1. Introduction

- Cement fineness is expressed either in terms of Particle Size Distribution (PSD) with residues (or passing) on reference sieves or by its specific surface area in Blaine.
- In this presentation, we will develop the Blaine method which is the most widely used in the world of cement.
- As we know, cement contains grains (particles) of very different sizes and shapes.
- The diameter can vary between less than 1 µ up to approximately 100 µ.
- Of these particles, it is the smallest ones that offer the largest area in relation to the volume.
- It is therefore these small particles which, during the concrete mixing, present the greatest number of contacts with water and participate most actively to the phenomena of setting and hardening.
- It can also be said that the total surface area of the cement particles is inversely proportional to their diameter.
- If the following two conditions are met:
• All particles have the same diameter
• All particles are spherical
- We have the following table:

Particles characteristics								
Diameter			Surface	Volume	Density	Weight	Number	Blaine
mm	cm	microns	cm2	cm3	g/cm3	g	for 1 g	cm2/g
0,1	0,01	100	0,000314159	5,23599E-07	3,15	0,000001649336	606305	190
0,01	0,001	10	3,14159E-06	5,23599E-10	3,15	0,000000001649	606304545	1905
0,005	0,0005	5	7,85398E-07	6,54498E-11	3,15	0,000000000206	4850436361	3810
0,001	0,0001	1	3,14159E-08	5,23599E-13	3,15	0,000000000002	606304545112	19048

- The following table gives the diameter for usual Blaine values (always with the 2 hypotheses above):

Blaine	Diameter
cm2/g	microns
3000	6,3
3500	5,4
4000	4,8
4500	4,2
5000	3,8

- As we have seen in the previous tables, the Blaine is a measure of surface area by weight.
- The most commonly used unit is cm2/g.

2. Usual Blaine values inside the cement ball mill

- We will now review the Blaine values normally encountered in a cement grinding circuit.

2.1. Mill in open circuit:

- Cement fineness: 3000 Blaine.
- The sheet below gives a good idea of the Blaine value in the finished compartment.
- Blaine analysis of the first compartment is generally not realized due to the too coarse product.

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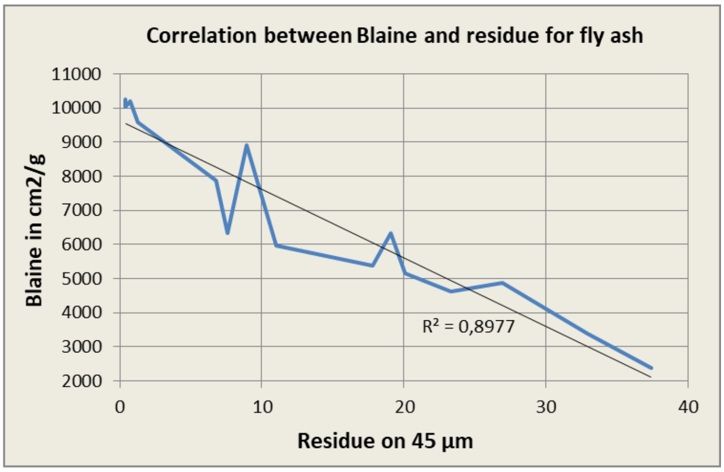
Chapter 47

Correspondence between Blaine and residues

1. Introduction

- This short presentation will detail the relationship between Blaine fineness and the residue on a sieve of a given Portland cement.
- Other materials such as raw meal or fly ash will be mentioned as examples.
- To the question to know if there is a direct relationship between Blaine and residue, the answer is YES.
- When the Blaine increases, the residue on a given sieve decreases.
- On the contrary, if the Blaine decreases, the residue on a given screen increases.
- And there are the exceptions that prove the rule.
- Here is an example of good relationship between Blaine and the residue for fly ash:

Residue on 45µ	Blaine in cm2/g
0,4	10260
0,4	10040
0,7	10190
1,3	9590
6,8	7880
7,6	6320
8,9	8910
11	5970
17,8	5380
19,1	6320
20,1	5150
23,3	4620
26,9	4880
32,9	3380
37,4	2370



- On voit que la corrélation (R^2) est pratiquement égale à 0,9.
- Ce qui est exceptionnel pour ce genre d'essais.

2. Blaine

- A little reminder about Blaine fineness.
- The fineness of cement is measured as specific surface area.
- This is called the Blaine specific surface.
- The specific surface area is expressed by the total of the surface area in square centimeters of all the cement particles being in one cement gram.
- The units used are generally: cm2/g and also m2/kg

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Chapter 48

Mill output variation formulas

1. Introduction

- Various formulas have been developed to predict the new output of a cement or raw mill when the Blaine fineness or the residue of reference is increased or decreased.
- These formulas can be considered relatively reliable for reasonable changes of fineness target.
- On the contrary, if the new Blaine fineness or the new residue of reference is very different, laboratory tests are required to have an answer which is close to the reality.
- Here below, some formulas used in the cement industry to predict the mill's output vs Blaine or residue.
- This list is not exhaustive.

2. Production vs Blaine

2.1. First formula:

$$P_2 = \frac{P_1}{e^{\frac{(B_2 - B_1) \times 0,49}{1000}}}$$

2.2. Second formula:

- This is the first formula in another form.

$$P_2 = \frac{P_1}{10^{\left(\frac{B_2 - B_1}{1000}\right) \times 0,213}}$$

2.3. Third formula:

$$P_2 = P_1 \times \left(\frac{B_1}{B_2}\right)^{1,3}$$

- This formula is well accepted between 2700 and 3200 Blaine.

2.4. Fourth formula:

$$P_2 = P_1 \times \left(\frac{B_1}{B_2}\right)^{1,6}$$

- This formula is well accepted for Blaine figures higher than 3200cm2/g.

- An important note for the third and fourth formulas, they are also used to define the new production of a classic separator or a high efficiency separator:
• Exponent 1,3 for high efficiency separator
• Exponent 1,6 for conventional separator

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Chapter 49

Grinding of limestone

1. Limestone

- Here are a few reminders.
- What is limestone?
- Calcium carbonate - $CaCO_3$
- Limestone can be:
• Rich: 90-100 of $CaCO_3$
• Poor
- Other elements: SiO_2 (quartz), Al_2O_3, Fe_2O_3…
- Importance of the content of SiO_2 (free silica) for:
• Wear rate - choice of alloy (balls and linings)
• Hardness - ball charge gradation

2. Different applications of the limestone powder

- The main applications to grind limestone are:
• For chemical industry, cosmetics, pharmaceutical industry, agriculture…
=> Fine grinding (less than 1% residue on 90m)
• For cement industry (to produce clinker)
=> Coarse grinding (10-20% residue on 90m)

3. Different types of grinding

- The 2 types of grinding are:
• Wet process
• Dry process

3.1. Wet process:

- The advantages are:
• Lower specific energy
• Simplicity of installation
- In Open circuit:
• The finished product is the mill discharge product
• To adopt mill L/D = 3.5-4 in order to have a longer retention time of the material inside the mill
- In Closed circuit:
• With hydro cyclones

3.1. Dry process:

- Generally adopted all over the world.
- At this point, we only will develop dry process circuits.

… The rest in the full book

Chapter 50

Coal grinding technology

1. Introduction

- Noble fuels are coal, fuel oil and natural gas.
- Due to the increase of the oil prices in the last decades, coal usage as primary fuel source in the cement industry has grown in large proportions.
- For safety reasons, coarse coal is always supplied on site.
- Then, a grinding/drying plant is necessary to convert the coal into valuable fuel.
- Before choosing and sizing the coal grinding circuit, we have to take into consideration the following factors:
• Coal quality
• Hot air sources for coal drying
• Number of fuel consumption points
• Type of kiln and available space, especially when installing a new plant to an existing kiln
• Industrial safety systems
- Concerning the machinery and the system, a choice must be made between:
• Ball mill and Vertical Roller mill
• Direct and indirect firing system
• Operation of the system in inert or non-inert condition
• Bag filter or electrostatic precipitator for dust removal purposes
- These points will be analysed in the following chapters.

2. Types of coals

2.1. Introduction:

- Coal is a readily combustible rock containing more than 50 percent by weight of carbonaceous material formed from compaction and indurations of variously altered plants and similar to those in peat.
- See the classification of coal after.

2.2. Classification of coal:

- Coal can be classified in four categories:
• Peat
• Lignite
• Bituminous
• Anthracite

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Chapter 51

Drying capacities

1. Introduction

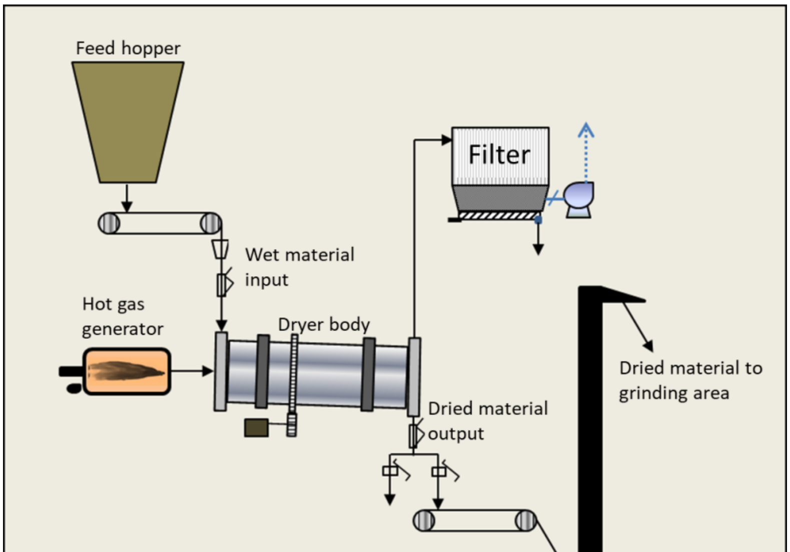
- Drying is an important operation in cement plants.
- The raw material coming from the quarry often contains a certain percentage of moisture which should be eliminated in order to avoid handling problems and the generation of vapours which can clog auxiliary equipment.
- All this without mentioning problems to grind such material in dry process.
- Moisture problems also exist for cement mills, but rarely, in the case of a component like limestone or pozzolana.
- It is generally accepted that from 0,5% moisture, every 1% increase will cause a mill's efficiency drop of 10%.

2. Kinds of drying methods

There are two types of drying methods:
* In equipment specially designed for this use
* Or directly into the mill
- In the latter case, the system will then be called drying/grinding.

2.1. External devices:

- The most famous are rotary dryers.
- Rotary dryers are used for drying wet materials or powders.
- Coal is a typical material for this application.
- The rotary dryer consists of a rotating drum with lifting blades which lift the material as the drum rotates.
- Then, the material falls in the stream of hot air flowing through the drum.
- The speed of the drum is normally between 2 and 6 rpm and its inclination 3 to 6 degrees.
- Some rotary dryers have the entrance of the hot gases to the material discharge.
- Schematic of a rotary dryer:



Typical flow sheet of a rotary dryer

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Chapter 52

Pre-grinding systems

1. Introduction

- Pre-grinding systems have emerged in the 80s.
- The first machines installed have been roller presses.
- Soon, these systems have known a great success despite initial problems of wear of the rollers.
- Five years after its appearance, there were already no less than 300 of these presses worldwide.
- The success of the roller press is due among other things:
• Relatively low investment costs (for simplified flowsheet)
• Significant energy savings that can be achieved with this technology
- We know that the energy efficiency of the ball mill is desperately low, between 3 and 5%.
- Even in the optimal utilization, an increase of production will always be limited.
- Pre-grinding systems thus provide a more than satisfactory solution when necessary to increase radically the production of existing grinding installations.
- In this study, two types of machines will be analysed:
• The roller press
• The vertical shaft impactor
- Basically, the gains made with these two machines are:

Machine	Acronym	Main suppliers	Production increase in %	Energy savings in %
			t/h	kWh/t
Vertical shaft impactor	VSI	Barmac	15-30	5-20
		Canica		
		MagImpact		
Roller press	HPGR	Polysius	20-100	10-40
		KHD		
		FLSmidth		

2. Vertical shaft impactor

2.1. Introduction:

- The vertical shaft impactor was first developed for quarries.
- This is indeed a very efficient machine to give a good size and a suitable shape to aggregates used in civil construction.
- Moreover, since the crusher is very compact, mobile system solutions (truck) can be proposed.
- Later, the vertical shaft impactor has proved to be a promising alternative to roller presses which were always facing serious problems of premature wear and breakage of the rollers.
- But clinker is a very abrasive material and the internal parts of the crusher (ejectors) have also experienced premature wear problems.
- In addition, and contrary to the roller press, the increase in production is still limited.
- Finally, the use of this cement solution has always stayed sporadic.

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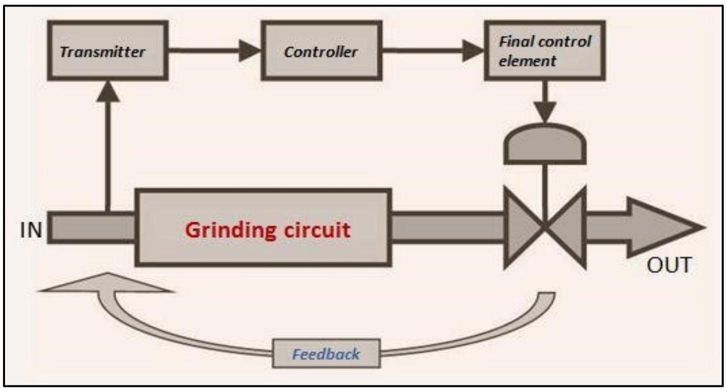
Chapter 53

Mills controls systems

1. Introduction

- In the past, when the cement mills were in open circuit, the conduct of the installation was almost always operated manually, without any control system.
- In open circuit, the task of the operator in the control room was reduced to a minimum, i.e. increase or decrease the mill output according to the fineness of the finished product.
- In reality, it's a little more complicated than that, but there was no imperative need to develop control tools as it is the case today.
- In effect, grinding plants in closed circuit have become more and more complex with the addition of high-efficiency separators and pre-grinding systems.
- The measured values are numerous and the conduct in control room has become tedious.
- It is not uncommon for operators decrease the output of their mill to avoid a big problem.
- It is a human attitude!
- Therefore more and more sophisticated control systems have been developed to enable:
• To achieve complex or sensitive operations that can not be entrusted to humans
• To replace the operator for repetitive tasks
• To increase the precision of the system
• To improve the stability of the grinding circuit
• To ensure the quality of the finished product
• To achieve and maintain optimum capacity of the installation
- And ultimately, increase the production of the mill and reduce its specific consumption.
- A diagram among many others of control system:



- The advantages of automation of a grinding circuit are the following:
• Security: Keeping the output within a range that ensures the security of the system
• Stability: Keep the output at a constant value, despite the disturbances that can affect the process
• Optimization: Keep the output to a higher value than the output without automation
• Quality: Optimize the output precisely up to the desired value to ensure the quality of the final product
• Repetitiveness: Enable to perform repetitive tasks at regular intervals
• Reproducibility: Perform a sequence of operations without requiring human intervention

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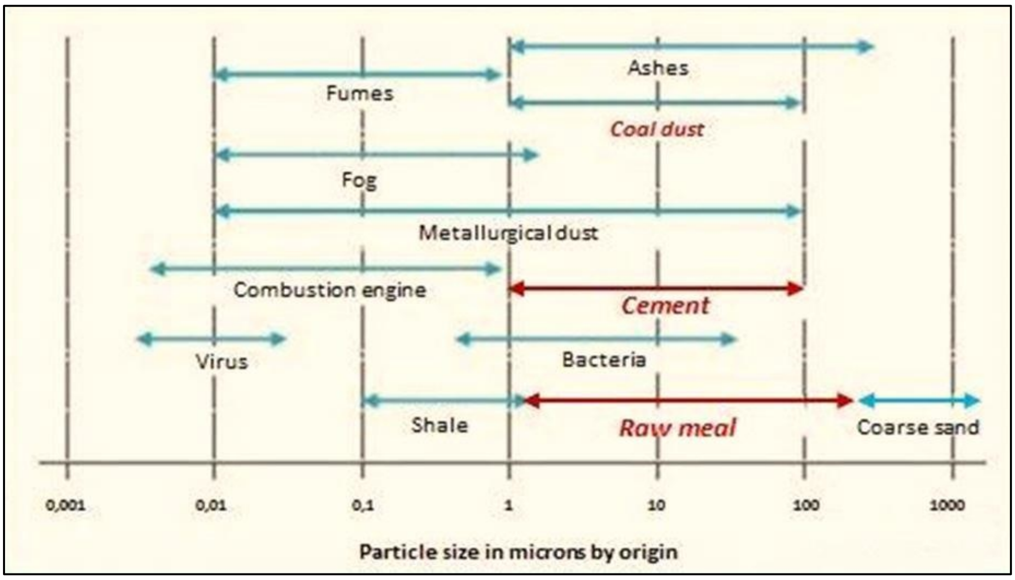
Chapter 54

Filters in grinding circuits

1. Introduction

- We will not repeat the importance of filtration in industrial environments and particularly in cement plants.
- Filtration, which is also known as dedusting system, pursues several objectives in the cement grinding plants:
• To keep equipment clean to prevent mechanical problems (clogging, blocking ...) and process complications
• To collect materials that are either added to the finished product or return to the grinding circuit
• To send to the atmosphere a clean air that meets government standards of each country
- The table below gives an idea of the size of the particles to recover depending on the type of application:



- There are many types of filtration:
• Filtration by gravity: sedimentation chamber
• Mechanical Filtration: gravity, inertia, centrifugal forces (cyclone)
• Wet filtration (scrubber): capture of particles in a liquid phase
• Fibrous media filtration (baghouses)
• Electrostatic Filtration: electric field (electrofilter)

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Chapter 55

Fans in cement grinding

1. Introduction

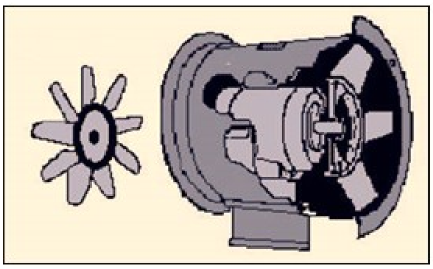
- Fans are widely used in industrial applications like the cement industry such as ventilation, material handling, boilers, refrigeration, dust collection, cooling applications and others.
- Fans are very common in the area of cement grinding.
- They are used for the following purposes:
• Allowing drying capacities for raw mills
• Carrying raw meal from air-swept mills
• Dedusting systems for auxiliaries with the presence of filters
• Dedusting cement mills with the support of a filter
• Dedusting and carrying cement from the separator to a filter
• Allowing the right quantity of air recirculating in a 3rd generation separator circuit
- The above list is not exhaustive.
- In the chapters below, we will discuss more deeply about these fans.
- But before that, we must define what is a fan.

2. Definition

- Fans are rotating machines capable of moving a given mass of air, which communicate a certain pressure, enough to bear the pressure drop that will occur in the circulation through the ducts.
- Fans fall under the general classification of turbomachinery like pumps.
- Fans are similar in many respects to pumps.
- Both are turbomachines that transfer energy to a flowing fluid.
- It is easy to distinguish between fans and pumps: pumps handle liquids, fans handle gasses and mainly air.
- Fans are composed of:
• Rotating element
• Support
• Motor
- The rotating element is the main part of the fan and can be a propeller or an impeller.

3. Classification of fans

- The fans are rotating machines able to provide a continuous flow of air for aerodynamic action.
- There are essentially two different types of fans.
• Axial fans:



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Chapter 56

Inclined vibrating screens

1. Introduction

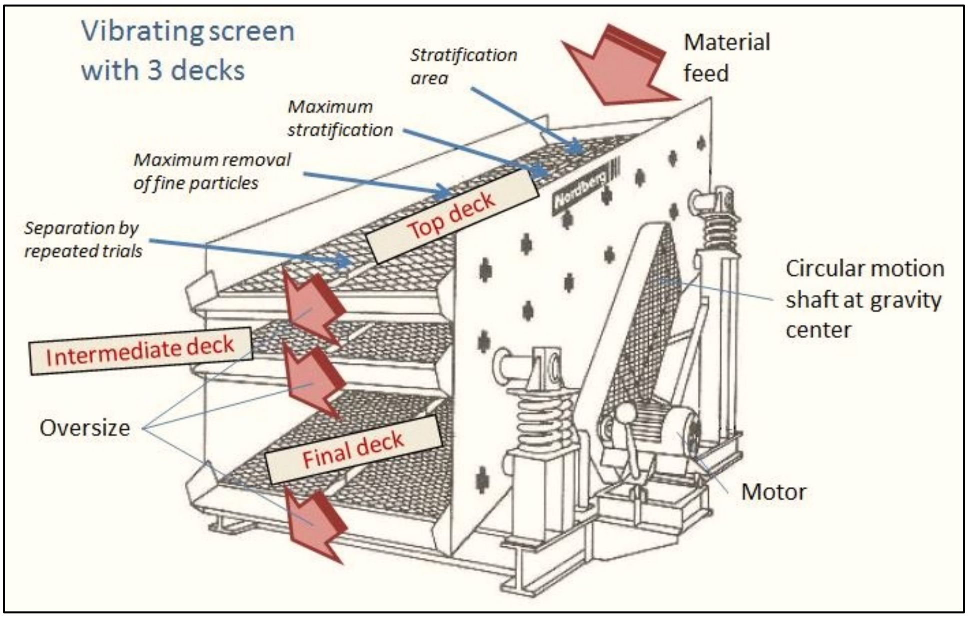
- Screening or sieving is defined as the mechanical method that performs a division of particles through a sieve.
- There are many types of methods and devices that can perform this operation.
- In this presentation, we will limit ourselves to talk about a single type: the inclined vibrating screen.
-The vibrating screen is widely used in the mining area, in quarries but also in the cement industry.
- It is found very often in the primary, secondary and tertiary crushing circuits.
- More recently, the vibrating screen was proposed in the pre-crushing circuit to increase the production of raw mills and cement mills.
- This document is dedicated to this kind of equipment.

2. General data

- The inclination of the screen varies from 15° to 25° (typically 20°).
- The typical shaft speed of rotation is from 650 to 1100 rpm (vibration frequency).
- Typical stroke (circular motion diameter) is between 3,2mm (1/8") and 16mm (5/8").
- G force is in the range of 3,5 G to 4,5 G.
- Travel rate is between 1200 m/h (75 fpm) and 2400 m/h (125 fpm).
- The screen efficiency is between 80% et 95%.

3. Operating principle

- The principle of operation is illustrated in the figure below:



- The material is fed through the upper part of the screen.
- The feed must be optimized in order to spread over the entire width.
- The illustration below shows a bad feed, since a good part of the sieve is empty.

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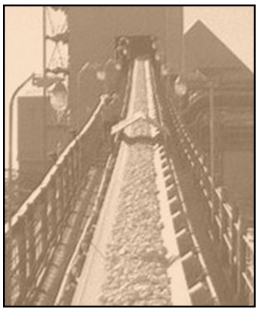
Chapter 57

Belt conveyors

1. Introduction

- Belt conveyors are the most common devices mainly for horizontal transport.
- They consist of an endless belt that passes over a series of rollers which serve either to support or guide for the conveyed material.
- One distinguishes different types of belts:
• Cloth and rubber belts
• Natural and synthetic fibers belts
• Steel belts
• Metallic mesh belts
- At the bottom, the belt is still flat, while at the top, it is either flat or concave.
- The flat configuration is achieved by horizontal rollers while the concave disposition when this is the case, is realized with appropriate inclined rollers.
- The feeding of the conveyor belt is carried out through appropriate hoppers at one end of the upper part of the belt.
- The discharge is for its part arranged at the other end, usually the side of the drive pulley.
- With this type of conveyor, one can easily transport hundreds of tons of material per hour (if not thousands) over kilometers away, especially for the material coming from the quarry.
- Only the big dump trucks can compete with a belt conveyor.
- Generally, the bands are horizontal, but one can also provide inclined if necessary.
- In this case, the angle of inclination should be less than the coefficient of friction between the material and the belt to prevent slippage of the material on the belt.
- The width of the band is often between 0,3 and 2,4 m.
- The belt speed can vary from 0,25 to 3 m/s according to belt width and the type of material.
- Here are some views of belt conveyors:



- In the case of a cement mill grinding installation, the feed of the mill (or of the pre-grinding system) is very often carried out by a conveyor belt, either horizontal or inclined.

2. Belt conveyor advantages

- A wide range of materials can be treated when they cause problems in other modes of transport.
- The belt conveyor can be used for an abrasive material, wet, dry, sticky or dirty.
- Higher capacity can be processed at significantly lower cost per tonne-kilometer.
- Conveyor belts with a capacity of 11,000 t / h and more can be installed to match with higher capacity mining machinery.

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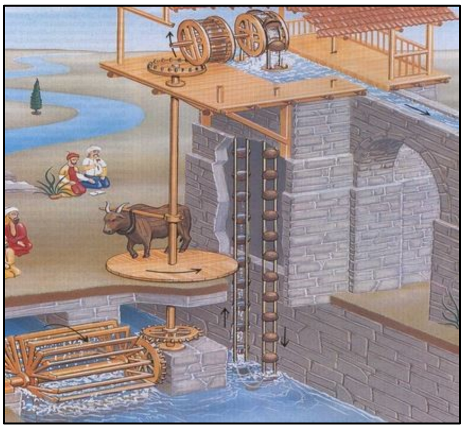
Chapter 58

Bucket elevators

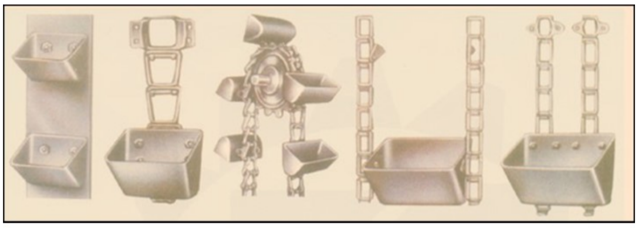
1. Introduction

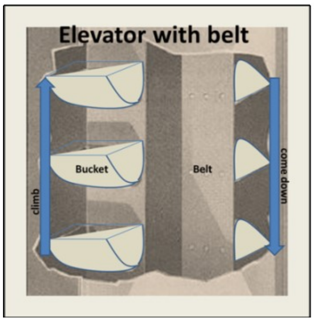
- Bucket elevators are devices specially adapted for vertical transport of materials of all types (granular and powdered).
- They are widely used in the cement industry, particularly for:
• Conveying of material from the outlet of a pre-grinding system to the input of a separator when the system exists
• Conveying of cement from mill outlet to the separator
• Transportation of finished cement to the entrance of the storage silo
- The bucket elevator can raise the material of a few meters to more than 150 meters and its capacity can reach over a thousand tons an hour.
- It is undoubtedly the vertical handling device the less expensive in energy and the most efficient with a relatively limited maintenance.
- Bucket elevators have been developed a long time ago.
- Here is a picture of a bucket elevator in the antiquity:

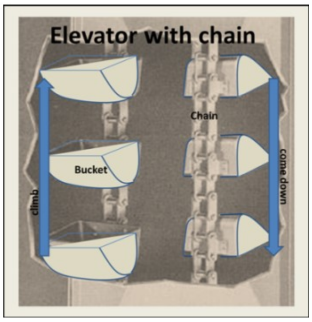


2. Types of bucket elevators

- The buckets are fixed either on chains or on a belt (see illustrations below).







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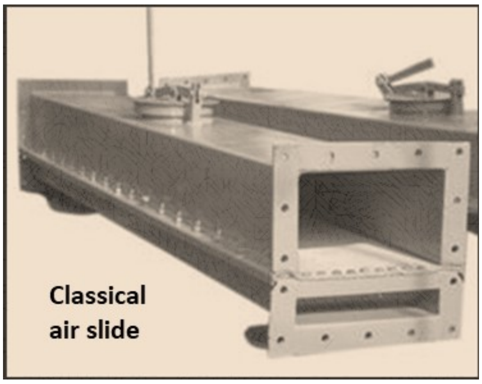
Chapter 59

Air slides

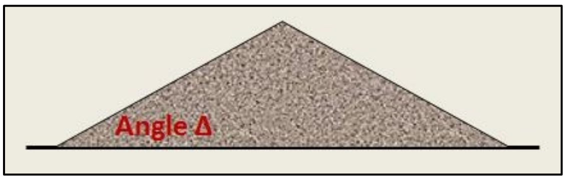
1. Introduction

- The air slides are a transport system well adapted to the powdered materials.
They are found in all sectors of a cement plant and particularly in a grinding installation, especially around the separator.
It is a reliable means of transportation, relatively economical and has a substantial development potential.
Here below a picture of an air slide:



2. System History

- The fluidized air transport system is a solution to the problems encountered with gravity transport systems.
- Indeed, when we wanted to move the material from a point A to a point B, we faced the angle of repose of the material.
- The angle of repose is the angle obtained when the material is in permanent equilibrium.
- That is to say, when the material naturally takes a constant slope from the horizontal plane.
- This is known as natural side slope, often noted Δ angle.
- See the figure here below:



- Materials angle of repose:

Material	Angle of repose
Portland cement	30°-44°
Aerated	10°-20°
Clinker	25°
Fly ash	42°
Anthracite < 3mm	20°
Limestone < 3mm	33°

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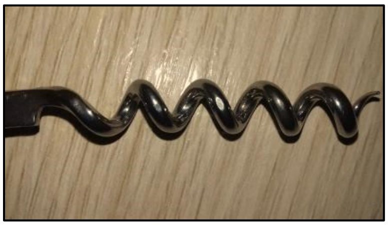
Chapter 60

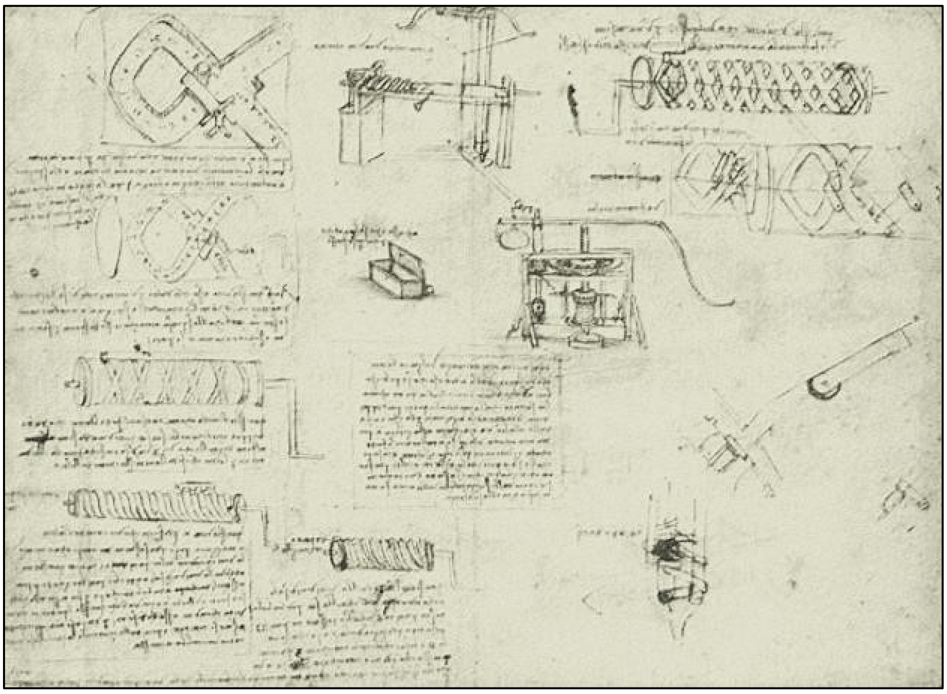
Screw conveyors

1. Introduction

- Also known as endless screw, the Archimedes screw is a material transport system particularly suitable for treating dust at low angular velocity and with high flow rates.
- The endless screw is one of the oldest types of industrial conveyors and can simply be illustrated by a… corkscrew!



- Here below, an old parchment showing the age of the system:



- It consists of a helicoid while turning on its own axis exerts an axial pressure component on the material contained in the U conveying tube.
- The advantages of the endless screw conveyor are:
• Possibility of high flows
• Ability to accept products at high temperatures
• Also adapted for inclined and vertical transport
• Loading and unloading at any point of the screw
- In a cement grinding plant, one often finds this type of conveyor at the discharge of bag filters and ESP filters.

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Chapter 61

Solutions to increase the efficiency of a grinding circuit

1. Introduction

- Everybody knows that the cement industry is a huge consumer of energy.
- The global cement production was about 3,6 billion tonnes in 2012.
- If we take an average of 110 kWh to produce 1 ton of cement, it means a consumption of electricity of about 400 billion of kWh.
- Considering that grinding departments are responsible for 65% of the total consumption (23% Raw meal and 42% Cement), it is then necessary to optimize these installations!
- The world's fleet is divided into four types of grinding machines:
• Tube Mills
• Roller Presses
• Vertical Roller Mills
• Horizontal Roller Mills
- You can see on the following table the estimated grinding efficiency for each type:

Type of Grinding Machine	Grinding Efficiency
Tube Mill	**5%**
Roller Press	15%
Vertical Roller Mill	10%
Horizontal Roller Mill	15%

- The grinding efficiency of these machines is very poor and the greater part of the energy supplied by the absorbed power of the devices is lost into heat, vibration, friction wear or sound noise.
- The tube mill is the less efficient but is still the most common equipment in the world despite the emergence of more efficient devices like the vertical roller mill.
- And it is also commonly accepted that there is still a huge potential for possible improvements regarding ball mills.
- We will now review all the solutions to improve a ball mill circuit.
- Here is the list:
• Increase the filling degree
• Right lifting lining in chamber 1
• Flow control intermediate diaphragm
• Classifying lining in second chamber
• Right ball charge gradation
• From open to closed circuit
• High Efficiency separator
• Pre-crushing system
• Pre-grinding system
• Automated control
• Predictive maintenance
• Grinding aids

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Chapter 62

Grinding plant sizing

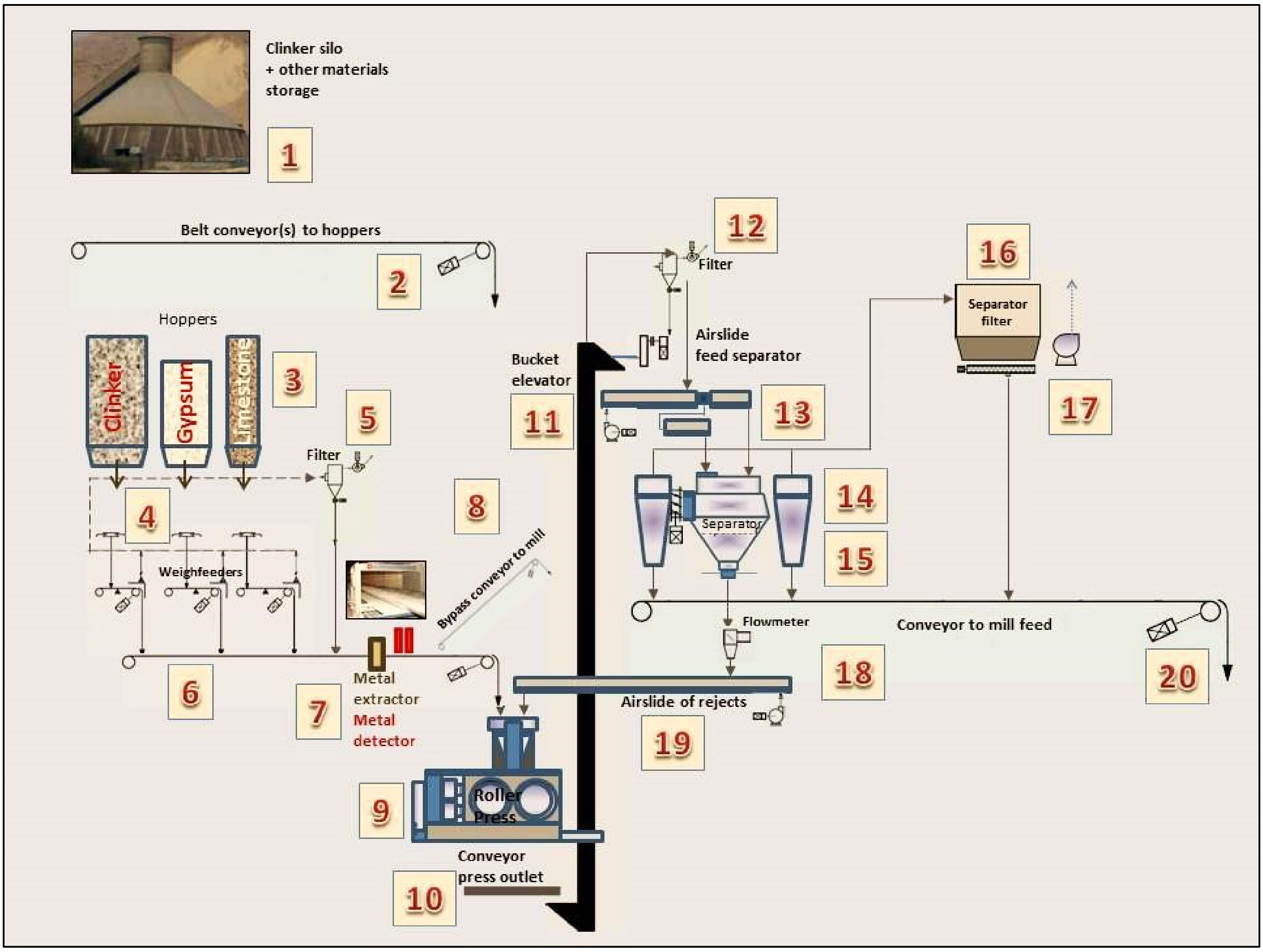
1. Introduction

- This presentation introduces some calculators giving elements of sizing and only a first and rough idea of the dimensions of a cement grinding circuit.
- The goal is not to replace an engineering office or any other equipment supplier but to give an initial idea of the size of the mill and its auxiliaries.

2. Non-exhaustive list of equipments to be sized

2.1. Flowsheet of the installation:

- This is a circuit equipped with a semi-finished pre-grinding system.
- The flowsheet is divided into 2 parts.
- Flowsheet of the pre-grinding system:



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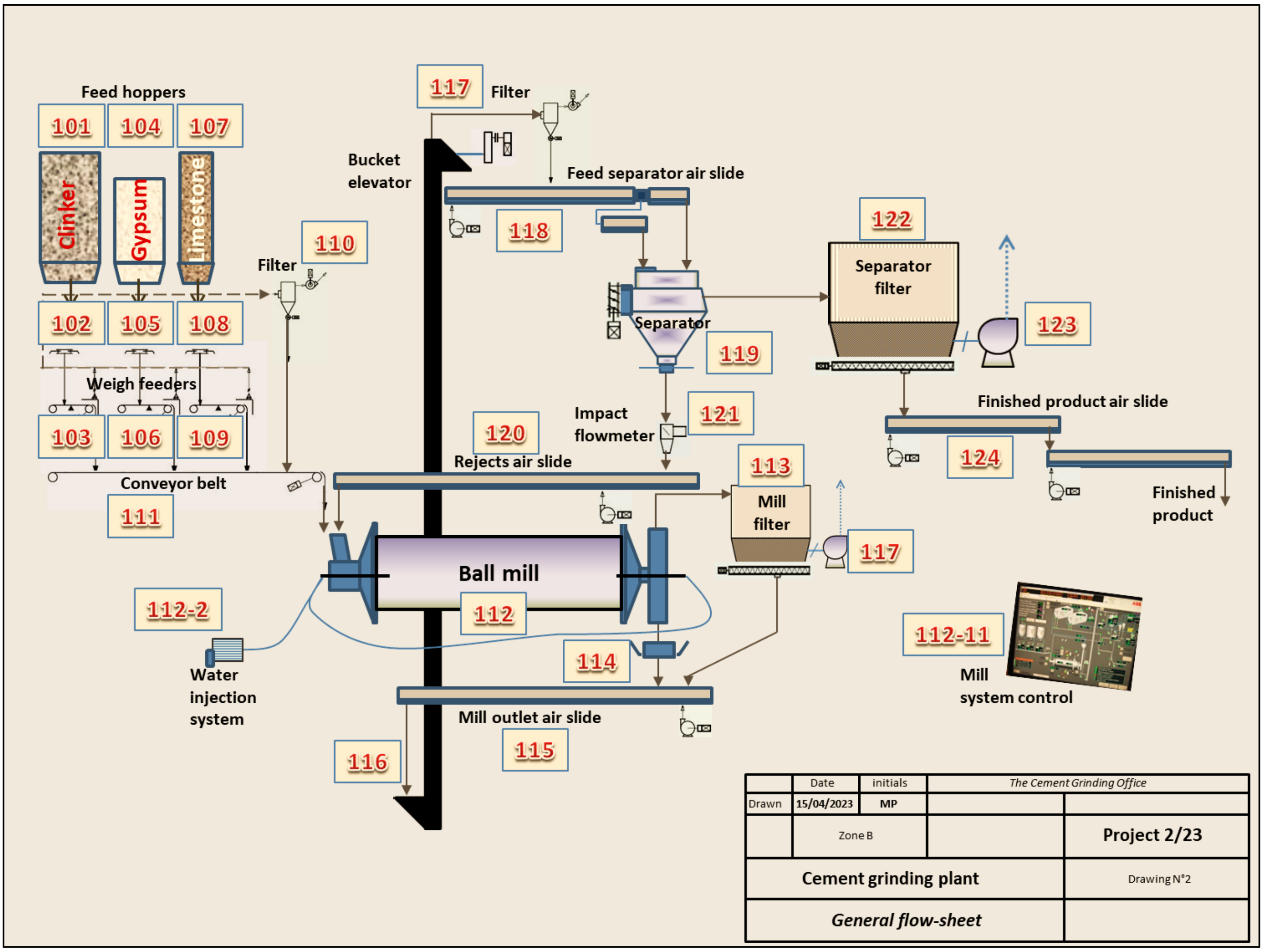
Chapter 63

Cement grinding plant cost list

1. Introduction

- This short presentation to introduce the cement grinding plant cost list calculator.
- This calculator gives a rough and initial idea for the cost of a cement grinding plant.
- Normally a detailed list is a very long document.
- To go ahead, a more detailed study is needed with the suppliers.
- The list is based on the following flowsheet:



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Chapter 64

Financial notions on the improvement of equipment

1. Introduction

- In business, the calculation of the profitability of an investment is to measure, per period, the rate of return on the money invested in an economic unit in order to decide whether or not to proceed with the investment.
- As a performance measure, it is used to estimate the return on an investment or to compare its effectiveness to other types of investments.
- In purely economic terms, it is a way of considering the profits in relation to the capital invested.
- Three indicators are used to determine the profitability of an investment:
•Payback
• ROI (return on investment)
• IRR (internal rate of return)

2. Payback

2.1. Definition:

- Payback period is the time in which the initial cash outflow of an investment is expected to be recovered from the cash inflows generated by the investment.
- It is one of the simplest investment estimation techniques.
- The formula to calculate the payback period of a project depends on whether the cash flow per period from the project is even or uneven.
- In case they are even, the formula to calculate the payback period is:

$$\text{Payback Period} = \frac{\text{Initial Investment}}{\text{Cash Inflow per Period}}$$

- When cash inflows are uneven, we need to calculate the cumulative net cash flow for each period and then use the following formula for payback period:

$$\text{Payback Period} = A + \frac{B}{C}$$

Where:
A is the last period with a negative cumulative cash flow,
B is the absolute value of cumulative cash flow at the end of the period A and
C is the total cash flow during the period after A

2.1. Example for even cash flows:

- A Cement Plant is planning to undertake a project requiring initial investment of 10,5 euros million.
- The project is expected to generate 3,8 million euros per year for 8 years.
- Calculate the payback period of the project.

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Chapter 65

Study example 1

1. Study summary

1.1. Problems encountered in the mill and the circuit:

Mill's configuration
- The first problem we have identified is the configuration of the mill.
- In fact, the plant produces two types of cement (Portland and GGBS) that require different configurations.
- To produce Portland cement, the mill must be configured as follows:

Drying chamber	no
Grinding chamber (s)	2
Ch.1 power	10-12 kWh/t
Ch.1 balls	90-60mm
Ch.2 balls	60-17mm

- At the contrary, to produce Slag cement, the mill must be configured as follows:

Drying chamber	yes
Grinding chamber (s)	1
Ch.1 power	no
Ch.1 balls	no
Ch.2 balls	60-17mm

- It means that the present configuration is a compromise and it will be difficult to optimize this mill for cement CEM II taking into account that CEM II represents 43% of the total production and GGBS 37%, i.e. practically the same percentage.

Mill underloaded
- Both chambers have a too low filling degree.
- The problem for chamber 1 is more critical due to the fact that this situation can induce important wear and also breakage of the balls and lining.
- The mill has also available power.

Separator
- The efficiency of the separator is not good.
- Mechanical reasons can be the reason of the bad performances of the separator.

1.2. Recommandations:

- To add balls in both chambers
- To adjust the intermediate diaphragm
- To investigate the problem of the separator
- To carry out some tests of mill's ventilation
- To have a good idea of the clinker grindability
- NB: See detail of these recommendations at the end of the report

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Chapter 66

Study example 2

Study summary:

1. Problems encountered in the mill and the circuit:

- Mill inlet clogged by material and doesn't allow good ventilation
- First chamber ball charge a bit too fine
- First chamber filling degree too low
- Too much material inside the mill (high circulating load, overfilling, mill absorbed power decreasing) and unstable operating conditions the majority of the time
- Second chamber with a lot of too small balls
- Poor flowability of the cement
- Disturbed classification
- Tendency of uncrushed particles in the second chamber
- Important wear of the grinding media
- Slots of outlet diaphragm grate plates completely clogged by nibs and uncrushed particles
- Separator performances are not of the best
- Product of mill filter which is coarse is sent in the finished product
- Lecture of ears in control room are subject to doubt

2. Recommendations:

- Add balls in chamber 1
- Empty the second chamber
- Put a new ball charge in chamber 2
- Periodic checking of the grinding media wear rate
- Periodic cleaning of the slots of both diaphragms
- To remove material from mill inlet
- To check electronic ears and recalibrate it
- To send the filter product back to the elevator (and separator)
- To see the possibility to fill more both chambers (up to 31-32%) in order to increase absorbed power and mill production
- In the future, other solutions can be recommended in order to increase the mill production as:
  • Use of grinding aid
  • Installation of pre-grinding system

1. Target of the visit

- The customer asked us to carry out the audit of their cement mill.
In fact, the plant knows two problems:
• Too low production
• Too high residues on 45 and 90µm
- For this reason, a complete audit of the cement mill has been realized during four days from 9 to 12 of August of this year.
- It has been decided to realize this audit for the Type 1 cement which is the one the customer wants to improve.
- According our information, the nominal capacity of this installation was 130 tph for a 3000±100Blaine cement.

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Chapter 67

Study example 3

Summary:

1. Problems encountered:

- First chamber filling degree low.
- Tendency of coating on lining and diaphragm grate plates.
- Slots of diaphragms grate plates clogged by nibs.
- Accumulation of cement inside the separator.
- Configuration of the ball mill inlet inappropriate for good ventilation.
- Separator without any efficiency.

2. Recommendations:

- Maintain the right filling degree in both chambers.
- Periodic cleaning of the slots of diaphragms.
- If the problem of deformed and broken balls continues, replace the ball charge in the future.
- Modify the ball mill inlet.
- Allow more air to the separator opening two air inlets.
- See possibility of new separator if here above modification doesn't change anything.
- Dry the slag outside the mill.
- Do a grindability test with German VDZ institute for a target of 10% residue on 32µ.
- Foresee the mill in monochamber in order to be in concordance with GGBS cement production.

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Chapter 68

Example of grinding circuit optimization

1. Introduction

- The cement plant is situated in the north of Pakistan near the Afghan border, 100 km from Peshawar
- One day, the client contacted us for a quote for the optimisation of their raw and cements mills.
- The plant target was to increase production of the existing Romanian line from 1000 tpd to 1800 tpd of clinker.
- This chapter examines the factors related to the raw mill section.

2. Situation before modification

- The raw mill is an air swept monochamber without a drying compartment, whereby material leaving the mill is drawn through a static separator.
- The tails are returned to the mill entrance, and the fines are passed through four cyclones where the separation between gas and finished product is realised.
- The gas passes to the main mill fan where part is recirculated to the mill exit (in order to help the pneumatical transport of the material), and the rest goes to the kiln electro precipitator.
- The main technical data of the circuit before modification is given in the following table:

Mill specifications		**Circuit specifications**		**Production data**	
Diameter	3,8 m	Static separator	Ø5,5 m	Average output	95 t/h
Length	7,68 m (L/D=2)	Cyclones	4	Feed composition:	
Speed of rotation	17,4 rpm (80% Crit.speed)	Mill fan data:		Limestone	95%
Installed power	1600 kW	Capacity	220000 m3/h	Clay	3%
Lining	Lifting	Ref. Temperature	80 °C	Laterite	2%
Filling degree	25%	Pressure available	650 mmWG	Average moisture	2,50%
Ball charge detail:		Power	630 kW	Maximum moisture	6%
Ø90mm	6,5 t	Speed of rotation	1000 rpm	Fineness of product	21-24%R90µ
Ø80mm	11 t			Mill absorbed power	1400 kW
Ø70mm	7,5 t			Mill specific power	14,74 kWh/t
Ø60mm	18 t			Mill inlet gas temperature	140 °C
Ø50mm	17 t				
Ø40mm	19 t				
Ø30mm	12 t				
Total	91 t				

3. Problems before modification

- The whole mill circuit was checked before any proposals were made.
- The following typical problems were found:

• Inadequate drying gas temperature, especially in the case of higher humidity content: gas was at 140 ˚C instead of 300-350 ˚C normally used.
• Granulometry of the fresh material too coarse with 12% residues on 50 mm instead of 5% R30 mm.
• Important accumulation of uncrushed stones inside the mill itself, in the first metre and in the last part.

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Chapter 69

Cement plant grinding test

1. What is the average efficiency of a ball mill?
   - A More than 10%
   - B More or less 30%
   - C Only 3-5%

2. What is the usual temperature coming from the kiln at raw mill inlet?
   - A 600°C
   - B 350°C
   - C 150°C

3. In what consists the separation area device of third generation separator?
   - A A rotating cage
   - B A distribution plate
   - C A separating ring

4. What is the specific energy of a mill absorbing 2700kW and producing 90t/h of cement?
   - A 30 kWh/t
   - B 24,3 kWh/t
   - C 3 kWh/t

5. What is the usual specific energy consumption of a ball mill in open circuit producing an OPC (clinker+gypsum) cement at 3000 Blaine?
   - A 35 kWh/t
   - B 45 kWh/t
   - C 25 kWh/t

6. What type of analysis is the Tromp curve used for?
   - A The cement fineness
   - B The clinker granulometry
   - C The separator efficiency

7. What is the usual Length/Diameter ratio for a cement mill in open circuit?
   - A 3,5
   - B 2,5
   - C 4,5

8. What is the signification of birotator mill?
   - A Ball mill with clockwise and counter clockwise rotation
   - B Mill with 2 motors
   - C Mill with central discharge

9. What is the signification of the number 325?
   - A Cement with a strength of 32,5 N/mm2 at 7 days
   - B Cement with a strength of 32,5 N/mm2 at 28 days
   - C Cement 3250 Blaine

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Chapter 70

Summary table of ball mills in the cement plants

1. The first table

1.1. The first table shows 5 types of mills:

- Monochamber
- Air swept
- Double-rotator
- Two chambers
- Three chambers

1.2. The following characteristics are defined:

- Sketch
- Drying chamber
- Number of grinding chambers
- Type of transmission (motor)
- Material to grind
- Material granulometry
- Type of circuit
- Type of separator
- Ball charge (in mm)
- Dimensions of balls for raw (limestone)
- Dimensions of balls for slag
- Dimensions of balls for coal
- Dimensions of balls for cement
- Filling degree
- Ratio Length/Diameter
- Ratio chamber lengths
- Transfer diaphragm and slots dimensions
- Intermediate diaphragm 1-2 and slots dimensions
- Intermediate diaphragm 2-3 and slots dimensions
- Outlet diaphragm and slots dimensions
- Speed of rotation
- Types of linings
- Hot gases temperature
- Maximum moisture without drying chamber
- Maximum moisture with drying chamber
- Maximum moisture with drying chamber
- Water injection
- Ventilation
- False air
- Temperature at mill outlet
- Grinding aid
- Typical fineness at mill outlet
- Grindability

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