PONENCIA Nº 2
Survey of Glaze preparation in discontinuous Ball-Mills and measurement of grinding media charging by computer softwares

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Key words: tile, ball mil, glaze, Grinding media

1. Introduction

In an aspect to the importance of the glazing stages in ceramic tile manufacturing, it is vital to have a thorough understanding of the optimum glaze preparation and application conditions to obtain technically and aesthetically high quality products with the highest possible productivity.

The purpose of this paper is therefore to describe how the characteristics have evolved of the glazes preparation in discontinues ball mills.

When you are using discontinuous Ball-Mills, regularly you must add grinding media to the batch, because the grinding phenomenon during glaze preparation has a valid proportion of grinding media to raw materials in it's cycle to optimize the grinding time and size distribution.

Therefore ball-mill volume and grinding media charging must be calculated first as well as the rhythm of grinding.

2. Calculating ball mill volume

As is well known, at the first step the characteristics of the ball-mills must be measured.

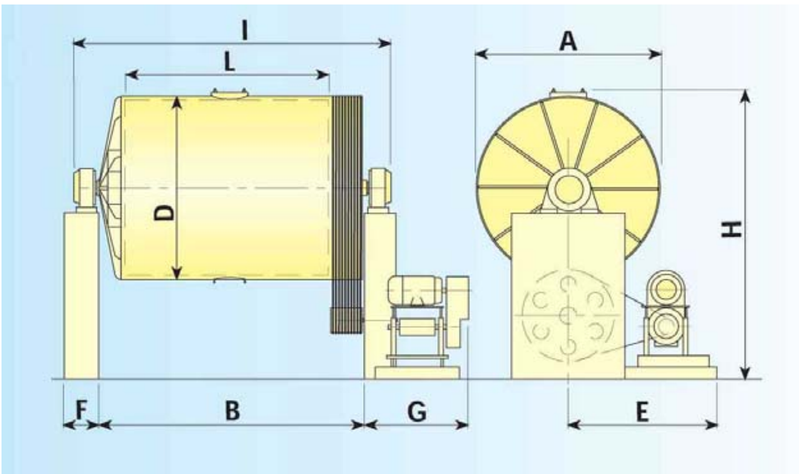

Figure 1- The schematic picture of the ball mill

D_B= Internal diameter of ball mill with the liner
L_B= Length of the ball mill
A= External diameter of ball mill
B= External length of ball mill
D_L= Liner diameter

For calculating the real volume of ball mill it must be subtracted the liner diameter from the ball mill diameter.

V_B: π (DB- DL) × LB (Formula 1)

Which V_B is Ball mill volume

3. Grinding media percentage in ball mill

For continuous ball mill it is recommended to use grinding media about 40 to 45% of ball mill volume, this data is 50 to 55% for discontinues ball mill (55% in this article). There is approximately 35 to 40% vacancy in charged grinding media (40% in this article). Therefore the real volume quantity of grinding media in ball mill can be calculated by decreasing of vacancy of the space between grinding media from total volume which has been occupied by grinding media. The real volume of grinding media in ball mill is 60×55 % = 33% and is 40×55%= 22% of total volume of the ball mill. This data shows that if we have charged materials less than 22% of the total volume of the ball mill, the friction between grinding media will happen.

4. Density of grinding media

The grinding media was "Alubit 90" from Industrie Bitossi S.P.S Company with 3.57 gr/cm^3 density. But for ensuring, density of grinding media was measured with two different methods:

In the first method the diameter for calculating volume and weight of the grinding media was measured with the 0.01 gram precision and the density was obtained from the following formula:

$$\text{Density} = \frac{Weight}{Volume} \qquad \text{(Formula 2)}$$

In the other way the grinding media was put in the glass with 200 ml volume. By considering the density of the water equal to 1 and adding water to the glass to fit the container, the density of grinding media is equal to water weight.

The grinding media in 5 sizes: 2, $1\frac{3}{4}$, $1\frac{1}{2}$ and $1\frac{1}{4}$ inch was used. In table 1, the density of calculated grinding media has been shown.

By calculating the density and having the volume of the grinding media the weight of the ball mill can be calculated:

W= V × D (Formula 3)

Which in this formula, W is Weight of grinding media, V is volume of grinding media and D is density of grinding media.

Size (inch)	Weight (gr)	Diameter (cm)	Volume calculated by measuring the size of grinding mills	Volume (cm^3)	Density (gr/cm^3)	calculated by measuring the volume of grinding mills in a container with constant volume which filled with	Volume (cm^3)	Density (gr/cm^3)
1	38.50	2.725		10.59	3.63		10.18	3.78
1 1/4	66.86	3.298		18.78	3.56		19.18	3.48
1 1/2	107.76	3.830		29.42	3.66		32.38	3.33

1 3/4	170.50	4.46		46.45	3.67		50.5	3.38
2	247.32	5.145		71.31	3.46		74.36	3.32
Ave					3.59			3.46

Table 1- The density of the grinding media

The weigh of slip can be calculated by this formula:

Dry weight = $(0.45 \times V \times D_p) / 100$ (Formula 4)

Water weight = $(0.45 \times V \times W_p) / 100$ (Formula 5)

Which V is real volume of the ball mill, D_p is Dry percentage of materials in a slip (approximately 68~69%) and W_p is water percent in a slip (31~32%)

Slip weight is the total of Dry weight & Water weight.

5- Calculating height of grinding media in ball mill

Cross section of ball mill can be calculated by:

$a = 2 \text{ A Cos } (1-(\frac{h}{R}))$ (Formula 6)

$A' = 0.5 R^2[(0.01745 \times a) - \text{Sin } a]$ (Formula 7)

$V = [(\pi R^2) - A'] \times L$ (Formula 8)

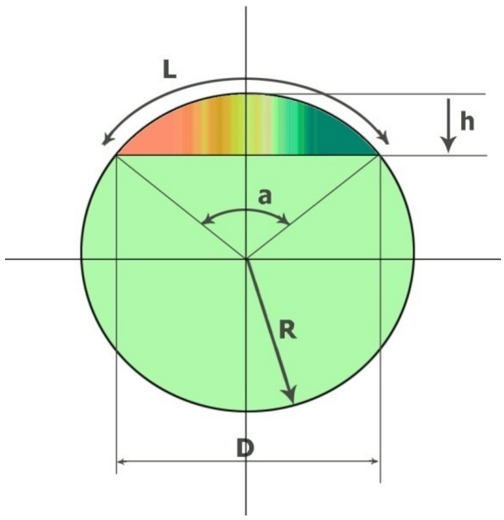

Figure 2 – cross section of ball mill

Which R is the radius of ball mill, h is height of empty space in ball mill and L is length of the ball mill. The desired height extent of grinding media in ball mill can be calculated by Microsoft excel software to obtain 55% of total volume of the ball mill. In this study, parameters in table 2 are calculated to attain the suitable extent of grinding media height.

Volume of slip with grinding media	Empty space	Empty surface	Ball mill radius	Height of empty space	a (Degree)	Total Volume of ball mill
5.88	4.80	1.80	1.13	1.04	170.86	10.68

Table 2- Theory calculation of grinding media content in ball mill for 55% of ball mill volume

Volume of slip with grinding media	Empty space	Empty surface	Ball mill radius	Height of empty space	a (Degree)	Total Volume of ball mill
5.52	5.16	1.94	1.13	1.10	176.96	10.68

Table 3- Calculation of grinding media content in used ball mill

6- Size distribution of grinding media with image analyzing

To obtain size distribution of grinding media in ball mill some images prepared from ball mill grinding media by high resolution digital camera and the images was estimated by Adobe Photoshop software to deal size distribution approximately.
In this method total surface and the percent of each size of grinding media calculated to obtain the weight of grinding media charging in ball mill.
For ensuring the grinding media size, the size of some used grinding media was measured. In figure 4 to 8 there are measurements for 2 to 1 inch grinding media.

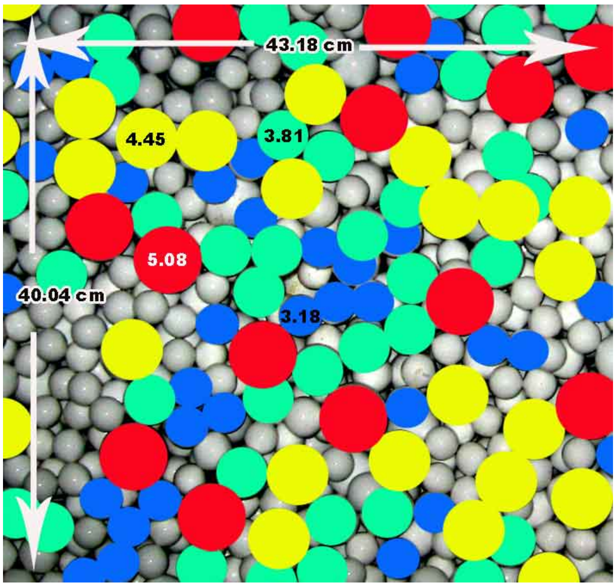

Figure 3 – Size distribution of used Grinding media by Image analyzing

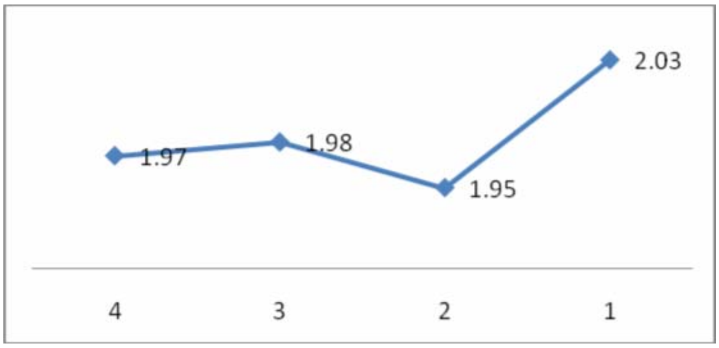

Figure 4- From right to left biggest, smallest , average and the abundant size of used grinding media for 2 inch size.

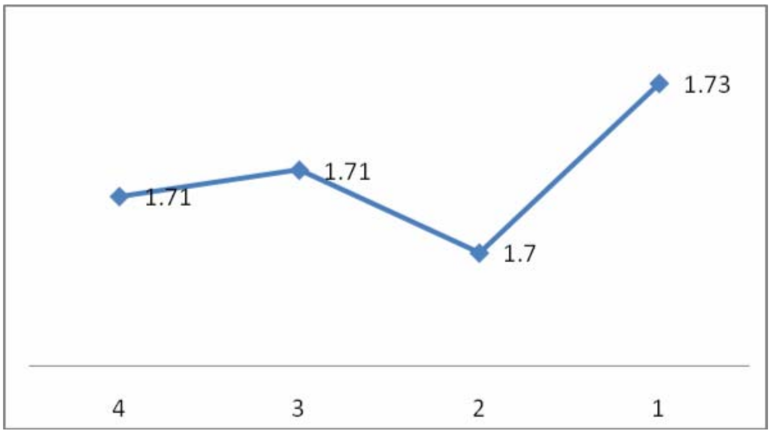

Figure 5- From right to left biggest, smallest, average and the abundant size of used grinding media for $1^3/_4$ inch size

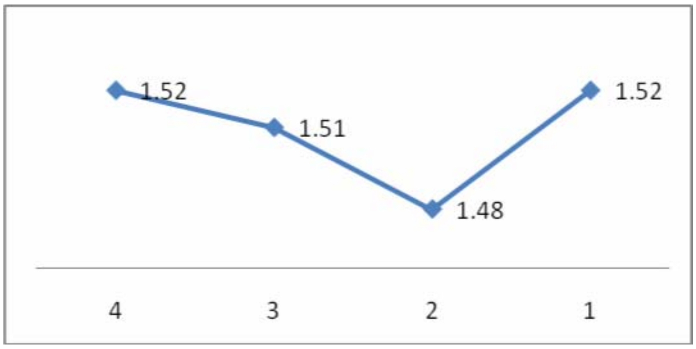

Figure 6- From right to left biggest, smallest, average and the abundant size of used grinding media for $1^{1}/_{2}$ inch size

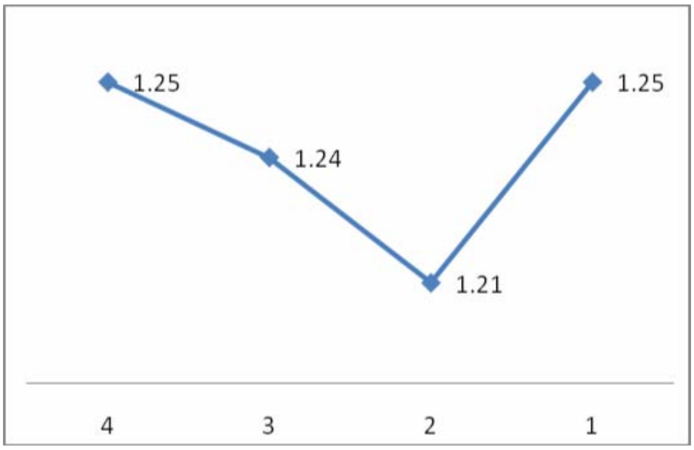

Figure 7- From right to left biggest, smallest, average and the abundant size of used grinding media for $1^{1}/_{4}$ inch size

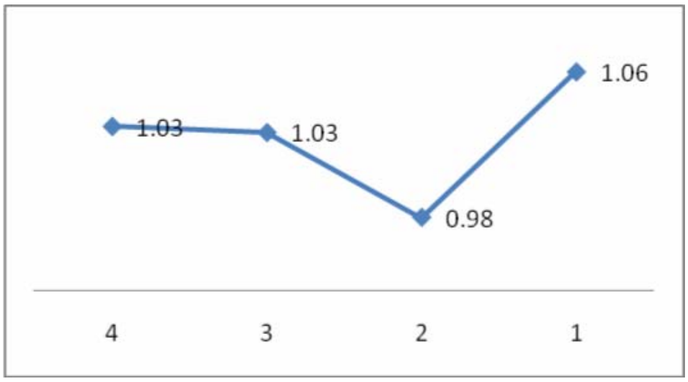

Figure 8- From right to left biggest, smallest, average and the abundant size of used grinding media for 1inch size

7- Summary

By comparing table 2 and 3 and manual measuring the height of grinding media in ball mill, the difference between practically used ball mill and it's theory can be calculated. By measuring the shortage of the height of grinding media, the charging content can be estimated.

The size distribution of grinding media can be measured by image analysis to calculate the percentage of each grinding media size.