SIMULATION STUDY OF CLINKER/GRINDING PLANT

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SIMULATION STUDY OF CLINKER/GRINDING PLANT

By

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DECLARATION

I hereby declared that I have conducted, completed the research work and written the dissertation entitled: "Simulation Studies of Clinker/Grinding Plant". I also declared that it has not been previously submitted for the award for any degree or diploma or other similar title of this for any other examining body or University.

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LIST OF SYMBOLS

%	Percent
°C	Celsius
GJ	Gigajoule
cm	Centimeter
MW	Megawatt
µm	Micron
kWh	Kilowatt per hour
B	Breakage distribution function
R	Selection function
I	Unit matrix
p and f	Vectors representing the product and the feed size distribution
C	the classification function
r	The rate of breaking,
a_{ij}	The appearance function, and
s	The amount of material in the size fraction in question.
D	Diameter of the mill
L	Length of the mill
Q	Volumetric Flow rate
Fc	Centrifugal force
Fd	Air drag force

LIST OF ABBREVIATIONS

PBM	Population Balance Model
HGPR	High pressure grinding rolls
HES	High-efficiency classifiers
DEM	Discrete element method
JKMRC	Julius Kruttschnitt Mineral Research Centre
RTD	Residence time distribution

KAJIAN SIMULASI KLINKER/ /LOJI PENGISARAN

ABSTRAK

Industri simen ialah pengguna tenaga utama, menyumbang kira-kira 1% daripada pengeluaran bahan api di seluruh dunia dan 2% daripada penjanaan elektrik global. Oleh kerana proses kecekapan rendah yang digunakannya, termasuk sebagai pembakaran, penyejukan, dan terutamanya pengisaran, sektor ini telah dikritik kerana membazirkan tenaga. Dalam tahun-tahun kebelakangan ini, kemajuan ketara telah dicapai dalam meningkatkan kecekapan komunisi, baik dari segi membangunkan mesin yang boleh memaksimumkan kecekapan tenaga dan dari segi mengoptimumkan sistem pengisaran supaya mesin semasa boleh digunakan dengan lebih cekap. Walau bagaimanapun, jika prestasi optimum ingin dicapai, pemahaman yang lebih mendalam tentang kesan pembolehubah operasi mesin masih diperlukan. Objektif kajian ini adalah untuk mengenal pasti masalah yang berlaku semasa pengisaran dan klasifikasi klinker dan untuk mencipta model yang boleh menentukan operasi pengisaran klinker. Kajian ini akan terdiri daripada persampelan berulang dan teliti bagi litar pengisar klinker, dengan data yang digunakan untuk membina model mesin pengisar bebola yang mempunyai dua bahagian dan mesin pengelas udara. Model yang dibangunkan juga akan diikuti dengan pengesyoran simulasi dan pengoptimuman. Data akan dianalisis, dinilai dan dipasang ke dalam JKSimMet, program perisian pemprosesan mineral untuk menyediakan parameter model mesin pengisar bebola yang mempunyai dua bahagian dan mesin pengelas udara, yang boleh digunakan untuk simulasi litar klinker, pengoptimuman dan pengimbangan jisim. Simulasi komputer menawarkan kelebihan yang jelas dari segi ramalan prestasi metalurgi litar alternatif yang lebih tepat supaya ia digunakan untuk mengoptimumkan reka bentuk, sebahagian besarnya menghapuskan keperluan untuk ujian loji yang memakan masa dan mahal.

SIMULATION STUDY OF CLINKER/AGGREGATE CRUSHING/GRINDING PLANT

ABSTRACT

The cement industry is a major energy consumer, accounting for around 1% of worldwide fuel production and 2% of global electricity generation. Because of the low efficiency processes it uses, such as burning, cooling, and especially grinding, the sector has been blamed for wasting energy. In recent years, significant progress has been made in improving comminution efficiency, both in terms of developing machines that can maximize energy efficiency and in terms of optimizing grinding systems so that current machines may be used more efficiently. However, if optimum performance is to be reached, a deeper understanding of the effects of mill operating variables is still required. The objective of this study is to identify problems occurring during clinker grinding and classification and to create a model that can describe the clinker grinding circuit's grinding operation. This study would comprise repeated and thorough sampling of the clinker grinding circuit, with the data used to construct models of the two-compartment ball mill and the air classifier. The developed model also would be followed by simulation and optimization recommendations. The data will be analysed, evaluated, and fitted into JKSimMet, a mineral processing software programme to provide the model parameter of the two-compartment ball mill and air classifier, which can be utilized for clinker circuit simulation, optimization, and mass balancing. Computer simulation offers clear advantages in terms of accurate predictions of metallurgical performances of alternative circuits that can be used to optimize design, largely eliminating the need for time-consuming and costly plant trials.

CHAPTER 1

INTRODUCTION

1.1 Cement Overview

The term "cement" comes from the Ancient Roman term opus caementicium, which was used to describe masonry that looked like modern concrete. Cementum, cimentum, cäment, and cement were the names given to the volcanic ash and pulverised brick supplements that were added to the burnt lime to create a hydraulic binder. Organic polymers are sometimes utilised as cements in modern concrete.

Cement production is a lengthy process that begins with the extraction and grinding of raw materials such as limestone and clay into a fine powder known as raw meal, which is then heated to a sintering temperature of up to 1450 °C in a cement kiln. The basic materials' chemical bonds are broken down and then recombined into new compounds in this process. Clinker is a rounded nodule that ranges in size from 3 to 25 millimetres in diameter. Cement is made by grinding clinker into a fine powder and mixing it with gypsum

Clinker quality is determined by the raw material composition, which must be continuously managed to assure cement quality. Excess free lime, for example, has negative consequences such as volume expansion, prolonged setting time, and decreased strength. To maintain process control in each phase of the cement manufacturing process, including clinker generation, a variety of laboratory and online technologies can be used.

1.2 Clinker Overview

Cement clinker is a solid substance used as an intermediate product in the production of Portland cement. Clinker appears as lumps or nodules with a diameter ranging from 3 millimetres (0.12 in) to 25 millimetres (0.98 in). During the cement kiln stage, limestone and aluminosilicate elements such as clay are sintered (fused together without melting to the point of liquefaction).

Clinker is used as a binder in cement products after it has been mixed with additives and ground into a fine powder. Different compounds are added to the cement to give it specific qualities. The addition of gypsum to the grinding of clinker regulates the setting time and provides the most significant quality of cement, compressive strength. It also prevents powder agglomeration and coating on the surface of the balls and mill walls.

1.2.1 Clinker Production

The raw material is pyroprocessed (thermally treated) in the kiln, which is the heart of the Portland cement manufacturing process. Pyroprocessing turns the raw material into clinkers, which are grey, glassy, spherically shaped nodules with diameters ranging from 3.0 to 25 mm. The rotary kiln is a refractory-lined, long cylindrical, slightly inclined furnace. In a countercurrent way, the raw mix is put into the kiln at the elevated end, and the combustion fuels are introduced into the kiln at the lower end. The raw material is transported from the upper end to the lower end by the kiln's rotational action. Calcination requires energy, which is provided by fuel (coal, oil, etc.). See Figure 1.1 for further information.

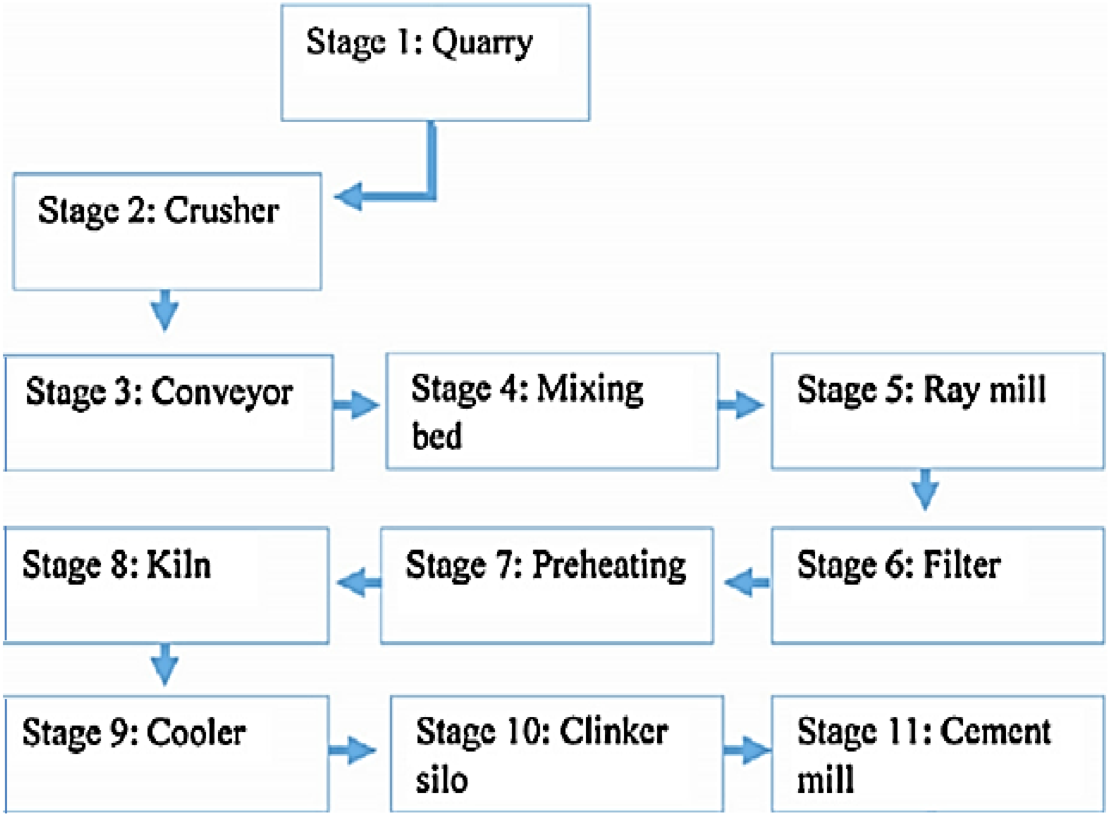

Figure 1.1: Clinker production process

1.2.2 Clinker Milling

The finish grinding of clinker with a tiny amount of gypsum is the final step in the cement making process (3-5 percent). Grinding aids are sometimes used to help with the grinding of all forms of portland cement. It helps by boosting production rate or fineness while maintaining the same rate without affecting any of the qualities of the produced cement. Clinker milling's major goals are to enhance cement hydration and ensure thorough coating of inert material commonly used with cement. The fineness to which the clinker should be ground is determined by the cement's physical qualities of strength, plasticity, and setting time.

Many factories used two-stage open grinding circuits in the early stages of clinker grinding. After that, the circuits were combined into a single mill with up to four compartments. In recent years, the cement industry has standardised finish mill circuits that may generate a variety of cements. This typical circuit (see Figure 1.2) consists primarily of weigh feeders for proportioning clinker and gypsum, as well as a two-chamber ball mill in open or closed circuit with one or two separators through pneumatic gravity conveyors and one or two bucket elevators. Due to the increased energy consumption in cement grinding, newer forms of energy efficient equipment such as Vertical Roller Presses in conjunction with ball mills/closed circuit ball mills, and Horro Mills are now being utilised to grind cement clinker.

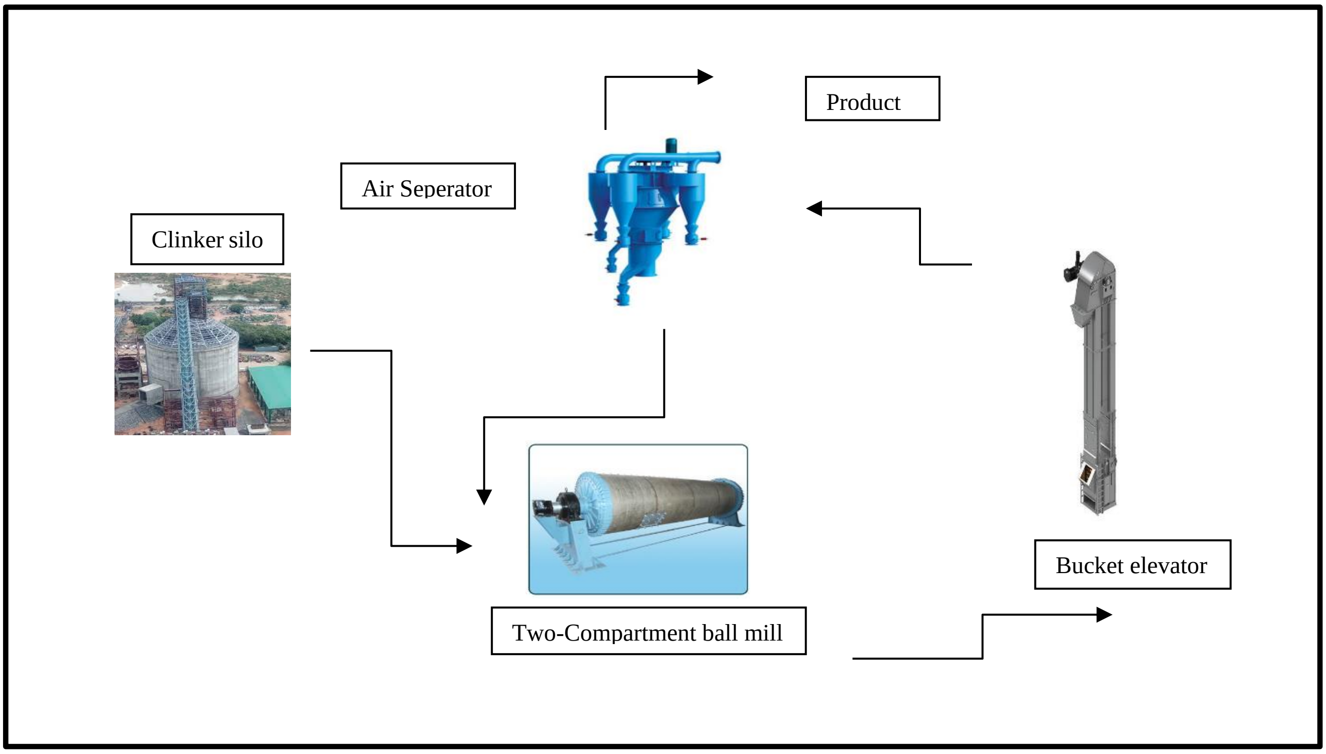

Figure 1.2: Typical cement milling circuit

1.3 Cement Industries

Cement manufacturing plants' manufacturing processes are often energy-intensive and resource-intensive as we observe at the figure 1.3 below. To make one tonne of cement, a typical well-equipped plant uses roughly 4 GJ of energy, while global cement output is around 3.6 billion tonnes per year. The cement manufacturing process is estimated to require roughly 7% of industrial energy consumption, which accounts for 30–40% of world energy consumption.

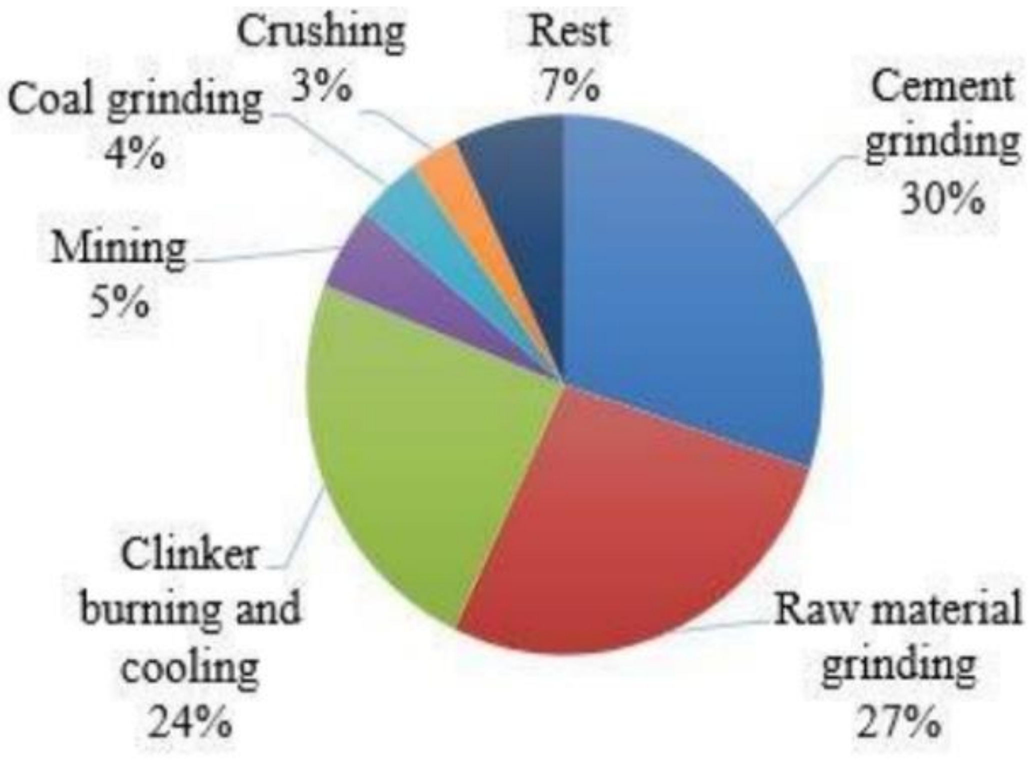

Figure 1.3: Electrical energy consumption in cement manufacturing

Given the manufacturing industry's considerable impact on global sustainability, as well as the increasing economic pressures imposed by a competitive market and the scarcity of accessible energy resources, improving the energy efficiency of production systems has become a top priority. It is possible to act both technologically and economically to cut energy usage in the cement business. Regarding technological aspects, one of the solutions to be used is to improve industrial plants by optimising them using simulation to obtain better-performing and less energy-intensive processes.

1.4 Cement Manufacturing Process

The cement manufacturing process, according to (Su et al. 2013), can be split into three key stages: raw material processing, clinker production, and end grinding processing (finished cement production). Figure 1.4 shows a schematic illustration of the cement manufacturing process. Raw material processing lowers the size of limestone and clay recovered from quarries, resulting in a homogeneous mixture with the desired chemical composition.

The raw material is first broken down by one or more consecutive crushers, which reduce the size of the rocks from 120 cm to 1.2–8 cm. The crushed rocks are then pre-blended using stackers and reclaimers, which are special machines. Following that, the ingredients are dosed and fed to the mills, which grind them. Rocks are pulverised to fine particles in this phase, then transferred to homogenising silos by mechanical conveyors or fluidized channels fed by blowers.

The blending process, as the final step in raw material processing, allows for a homogenous chemical makeup. The homogenised components are delivered to the preheater tower, where they pass through a succession of cyclones before entering the kiln. Fine particles are warmed using the kiln's exhaust gases, lowering the amount of energy needed for the subsequent heating operation.

The kiln, which can be positioned vertically or horizontally, is responsible for the heating process. The temperature of the material is raised to 1000 °C (sometimes even 1400 °C) in the kiln, resulting in the creation of calcium silicate crystals-cement clinker. The clinker is directed to a cooler at the kiln exit, where it is cooled.

The cooling process is essential to cease chemical reactions at the appropriate time, allowing for proper product quality. In addition, the cooling process permits some heat to be recovered from the hot clinker.

Finally, the cooled clinker is kept in silos before being fed to particular mills for finishing grinding. Depending on the final product's requirements, elements such fly ash, limestone, slag, gypsum, and pozzolana are added to the clinker during the final milling process.

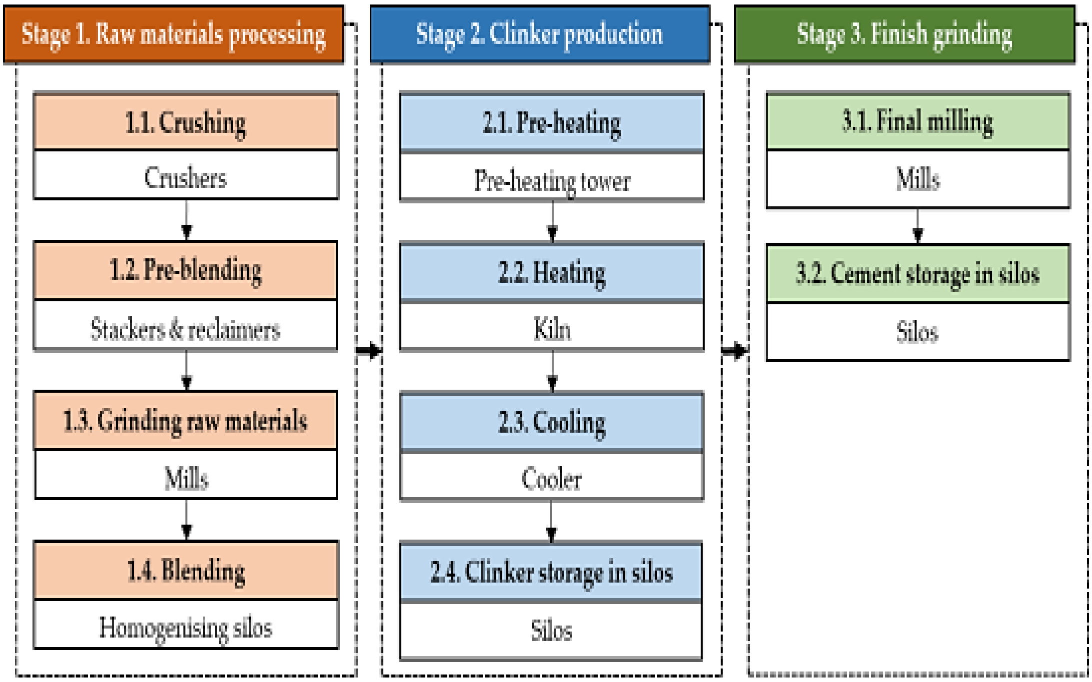

Figure 1.4: Cement production process. The colored boxes show the sequential operations, while the white boxes summarize the process machinery

1.5 Simulation and Modeling

A simulation uses models to simulate the operation of real-world processes or systems. The model describes the specified process or system's key behaviours and properties, while the simulation depicts how the model changes over time under various conditions. Simulations are often computer-based, with a software-generated model used to assist managerial and engineering decisions as well as for training purposes. Because the models are both visual and interactive, simulation approaches enhance learning and experimentation.

Discrete event simulation, process simulation, and dynamic simulation are examples of simulation systems. All of these technologies can be used by businesses at different levels of the organisation. A simulation uses models to simulate the operation of real-world processes or systems.

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1.6 Efficient Grinding Circuit by the help of Simulation

When global energy consumptions are considered, the industrial sector consumes a substantial quantity of energy. Reports have been created to explicitly expose the statistics and to underline the importance of managing energy efficiently for economic and environmental reasons. According to (] Y.H. Huang, Y.L. Chang, T. Fleiter, 2016) the industrial sector accounts for around 28–70% of global final energy consumption, which varies by area. Several research came to similar conclusions.

The non-metallic industry was reported to be the third largest energy user among industries, accounting for around 12% of worldwide energy use (] Y.H. Huang, Y.L.

Chang, T. Fleiter, 2016). The cement sector accounted for the majority of the utilisation, at 8.5–12 percent (Y.H. Huang, Y.L. Chang, T. Fleiter, 2016). The cement sector is the most energy intensive among manufacturing businesses, according to the US Energy Information Administration (EIA), and estimates show that its contribution to energy consumption will increase in the coming years.

In its research, the International Energy Agency (IEA) established a goal for this industry to considerably cut its energy use by 2025. Many of the research concentrated on energy evaluations of the cement industry in order to assess and then quantify potential energy savings. These studies found that by optimising existing circuits, evaluating potential investments, and changing control procedures in the overall production chain, savings of 20 to 50 percent might be realised (] J. Sirchis, 2005).

Raw meal handling, pyrometallurgy, and comminution are only a few of the unit processes that go into cement production. Comminution occurs in both raw meal and final grinding operations in cement manufacturing, accounting for around 60% of total electrical energy consumption (J. Sirchis, 2005). According to worldwide energy assessments, comminution is a high-energy-consuming operation that accounts for 2–4% of global energy consumption. Because this field consumes a significant amount of energy, attention should be paid to its decrease, which could include a variety of options.

These can be performed by either inventing a new product or by optimising the operating conditions/flow sheets of the manufacturing process, which can be accomplished by replacing old technologies. The International Energy Agency (IEA) determined in 2015 that technology shifts alone were not deemed to be sufficient for energy savings, and that product innovation/improvement or other options should be examined as well.

Many studies have focused on improving the energy efficiency of a circuit. (] A. Jankovic, W. Valery, E. Davis, 2004) investigated cement grinding circuit optimization options. (Benzer,2005) investigated the possibility of optimising a fully air-swept raw mill grinding circuit, while (] H. Dundar, H. Benzer, N.A. Aydogan, O. Altun, N.A. Toprak, O. Ozcan, D. Eksi, A. Sargin, 2011) investigated the possibility of optimising a cement grinding circuit. With the use of modelling studies, (Altun, 2016) enhanced the circuit's energy usage. The goal of the research was to improve the energy efficiency and product quality of a traditional cement grinding circuit during cement manufacture.

In this case, an accurate sampling process was used, which was backed up by computer simulations and assessments of the finished product's quality properties. It should be underlined that within the existing flow chart, the mill filter stream was sent to the classifier feed that was thought to be sending to the final product silo. The circuit's energy usage and product qualities improved as a result of the research.

1.7 Ball Mill

The most popular type of tumbling mill is the ball mill, presumably because it may be used for everything from small laboratory units drawing a few watts to massive industrial systems using 10–12 MW. From a few millimetres to a few tens of microns in size, they predominate in the comminution of minerals.

Ball mills are used in secondary, tertiary, and regrinding operations with fine feed and products as well as primary grinding mills with feed up to 20 mm.Ball mills have continuously gotten bigger throughout the course of this century due to scale and economic considerations.

Large diameter ball mills dominated high-capacity primary grinding in the 1950s and 1960s. However, since the middle of the 1970s, AG/SAG circuits have almost entirely replaced multi-stage crusher and coarse primary grind ball mill circuits.

Ball mills still dominate secondary grinding, but closed-circuit AG/SAG and a variety of stirred mills are fierce competitors. Tower mills and other stirred mills are also being used for fine grinding jobs, particularly when the feed size is greater than 80% passing 50 µm. The ball mills in a mineral concentrator are often the ones that use the most energy. Their effective utilisation has significant performance and financial ramifications.

1.8 Problem Statement

Cement production uses a lot of energy. Due to the low efficiency processes, it employs, such as burning, cooling, and, most significantly, grinding, the sector has been accused of wasting energy. In a heterogeneous environment, a material's grindability is greatly influenced, which is of relevance in the context of energy conservation in the cement industry. The grindability of intergrinding cement raw materials, limestone, and clay appears to be less energy demanding than separate grinding, especially at high fineness levels, according to the relevant literature. The mill's grinding efficiency is also affected by the physical qualities of the raw material, such as feed size and moisture content. Due to the well-known qualities of silica, which is hard and abrasive, the silica moduli of the raw mix and the free quartz concentration in the clay will affect the grindability of the raw mix in terms of chemical properties. To obtain the optimal grinding operation and control of the grinding mill, an understanding of the cement raw mix grinding process must include machine design, physical and chemical qualities of the raw materials.

1.9 Thesis Objective

- To identify problems occurring during clinker grinding and classification
- To create a model that can describe the clinker grinding circuit's grinding operation.

1.10 Thesis Outline

In chapter 1, this thesis states a brief explanation and overview of cement and clinker including on how it was produced. It starts with cement and clinker industries and manufacturing process.

In chapter 2 which is literature review, the author reviews the journal related to the research study. For example, grinding parameter, ball mill model and model fitting procedure.

In chapter 3, the author listed the methodology needed to be done which is on how to do a sampling and data recording for simulation purpose.

In chapter 4, the author displayed the result achieved and gathered from the simulation process using a software which is JKSIMMET.

In last chapter, the author concludes the research project and give recommendations for future uses.

CHAPTER 2

LITERATURE REVIEW

2.1 Grinding Parameter

The most important property of cement is its setting strength in concrete, and cement quality is assessed and controlled by measuring its strength under standard conditions. It is well known that the compressive strength of cement increases with fineness, or specific surface area, and that for equal surface area, cements with a narrow particle size distribution have a higher strength than those with a wide size distribution (A. Kato and K. Hirose, 1969, F.W. Locher, S. Sprung and P. Korf, 1973, G. Frigione and S. Marra, 1976, L.G. Austin, P.L. Luckie and H.M.V. Seebach, 1576-1588, K. Kuhlmann, H.G. Ellerbrock and S. Sprung, Zem. Kalk-Gips, 1985, M.S. Sumner, N.M. Hepher and G.K. Moir, 1989, G. Frohnsdoff and J.R. Clifton, 1980, H.F. Welles, Zem. Kalk-Gips, 35, 1982).

The size distribution of cement produced in clinker grinding processes can now be predicted with some confidence using population balance comminution and classification models (L.G. Austin, N.P. Weymount and O. Knobloch, 1980, Y.M. Zhang, A. Kavetsky, T.J. Napier-Munn and D.S. Rapson, 1987, Y.M. Zhang, T.J. Napier-Munn and A. Kavetsky, 1988). The possibility therefore exists of optimizing cement production using process simulation procedures.

However, in order to obtain true process optimization, it would be desirable to employ as the optimization criterion an economic property such as strength, rather than a solely process property such as the size distribution or surface area of the powder. To achieve this, two issues must be addressed:

- the chemical composition of the cement is a major determinant of its setting strength (H.F. Welles, Zem. Kalk-Gips, 1982) and must be incorporated in the simulation models; and

- in the cement industry, the fineness of the cement is usually expressed not as a size distribution but by surface area. (Indeed, clinker grinding processes are often monitored and controlled by measuring the product surface area off-line using a simple air-permeability procedure such as the Blaine test.) It would therefore be desirable to model the relationship between size distribution and surface area.

2.2 Uses of computer simulation in grinding

Cement grinding is a high-cost operation consuming approximately 40% of the total electrical energy expenditure in a typical cement plant (Fujimoto, 1993). It is traditionally carried out in multi-compartment tube mills, which seem to retain their importance despite developments in energy saving grinding mills such as vertical roller mills, high pressure grinding rolls and Horomills.

In recent years, considerable steps have been taken to improve comminution efficiency both in the development of machines with the ability to enhance energy utilisation and in the optimal design of grinding systems to enable more efficient use to be made of existing machines. But it is still necessary to have better knowledge of the effects of mill operating variables if optimum performance is to be achieved. Some of the more important variables are ball size and load, air flow rate through the mill, aperture size of mill partitions, feed rate and hardness of the clinker.

Simulation is a valuable tool in process technology if the process models are accurate and if model parameters can be determined in a laboratory or plant. It is now used extensively for the design and optimisation of wet grinding circuits and has brought large economic benefits. Its success has come because of the learning process involved in many years of development. It is possible that economic benefits are also available in dry grinding.

A few studies have focused on modelling cement grinding circuits (for example Austin er al, 1984; Viswanathan and Narang, 1988) and Zhang (1992) developed a mathematical model for dry ball tube mills using the perfect mixing approach. These studies were successful in explaining existing conditions, but they did not have the capability of explaining the effect of variables such as the internal partition between two compartments because they did not include comprehensive data on sizing distributions inside the mill.

At Hacettepe University in Turkey a research program is in progress to develop models for dry grinding and to investigate the value of simulation. The approach involves building accurate models based on extensive data collected from operating plants and using data from laboratory machines where appropriate. This paper is concerned with the model of a two-compartment tube mill operating in open circuit mode.

2.3 Optimization of grinding circuit by aid of the simulation

Cement manufacturing is an energy intensive process. It is estimated that the energy utilized within the industry corresponds to 10–15% of the total industrial energy consumed by the countries (N.A. Madlool, R. Saidur, M.S. Hossain, N.A. Rahim, 2011). Although it is a significant portion, the demand on cement increases gradually owing to the construction business growing around the globe. The international cement review (T. Armstrong, 2013) showed that there is a linear increase in global cement demand and the trend is expected to go up in the coming years. Consequently, attention should be drawn by researchers and plant people on optimizing the energy consumptions of the processes for a given product specifications.

Cement process is comprised of many sub operations, which are quarrying, crushing, raw milling, burning, cooling and cement grinding. Of these, the grinding process accounts for about 50% of the total energy consumption (110–150 kWh per tonne of cement), which may vary with the process modernization and raw materials used (] E. Villa, F. Spada, M. Santini, 2005), therefore optimizing the energy consumption of this operation is of crucial importance.

Improvements within an existing circuit can be achieved both by investing in recent technologies (innovations) and optimizing the equipment or circuit flow sheet with the aid of modelling and simulation tools. To date, serious innovative solutions have emerged where the energy consumption decreases significantly (International Energy Agency, 2008). As shown in Fig. 2.1, most of the countries have experienced a general improvement between 1990 and 2004 that can be attributed to the shift from wet to dry-process cement kilns, coupled with the replacement of older kilns by the latest technology using pre-heaters and pre-calciners and newly introduced grinding technologies (HPGR, VRM, high efficiency classifiers).

Modelling and simulation tools can be used for process optimization, but this requires accurate model structures development. So far modelling studies performed by many researchers have focused on design features of the machines as well as the material characteristics, i.e., work index, size distribution and breakage distribution have been taken into consideration (L.G. Austin, P.T. Luckie, D. Wightman, 1975, L.G. Austin, P.T. Luckie, K. Shoji, R.S.C. Rogers, K. Brame, 1984, K. Viswanathan, 1986, Y.M. Zhang, T.J. Napier-Munn, A. Kavetsky, et al., 1988, K. Viswanathan, C.S. Reddy, 1992, H. Benzer, L. Ergun, A.J. Lynch, M. Oner, A. Gunlu, I.B. Celik, N. Aydogan, 2001, A. Jankovic, W. Valery, E. Davis, 2004, H. Dundar, H. Benzer, N.A. Aydogan, O. Altun, N.A. Toprak, O. Ozcan, D. Eksi, A. Sargin, 2011, O. Altun, H. Benzer, 2014, O. Genc, 2015).

The study aimed at changing the current flow sheet of a cement grinding circuit with the aid of a simulation tool to improve the specific energy utilization of the circuit. In this context, not only the size distribution but also the quality analysis was taken into account and used in simulation studies.

The study focussed on the static separator fine stream, which was originally sent to feed stream of the dynamic classifier, but the possibility of directing it to final product silo was considered for different cement types (CEM I 42.5R, CEM II B-M (L-W) 42.5R, CEM IV B (P-W) 32.5R). These studies concluded that such a change could improve the specific energy consumption of the overall circuit for each type of cement.

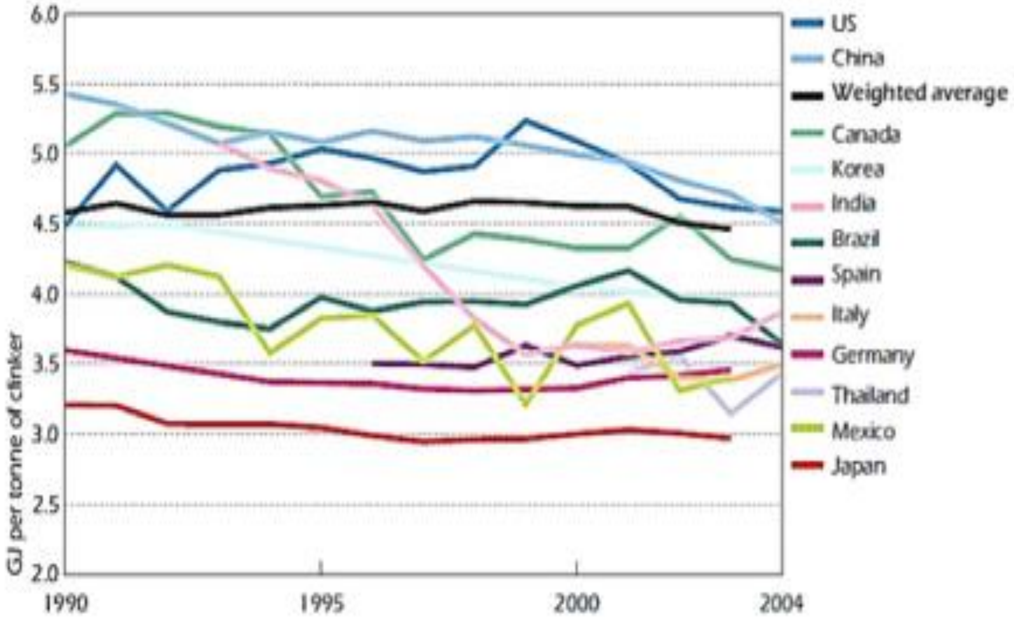

Figure 2.1: Energy consumption per tonne of clinker by country (International Energy Agency, 2008)

2.4 Modelling grinding circuit

The cement industry is one of the large industrial energy users consuming about 1,5% of the total world fuel production and about 2% of the global electricity production (Norholm, 1995). The industry has been accused of wasteful energy use due to the low efficiency processes that it employs, such as burning, cooling and particularly grinding. In these processes the efficiencies are said to be, at best, 67%, 70% and 1% respectively (Schoenert, 1967; Leimen and Ellerbrock, 1992).

Several variables can affect the efficiency and productivity of a dry grinding line such as operating conditions of the separators, air flow through the mill, and ball sizes in the mill compartments. Optimizing the variables in the grinding lines is an important step in minimising the cost of production of cement per tonne.

Simulation of the wet grinding lines using mathematical models of the mills and separators is a technique which is being used increasingly in comminution because of its low cost and its ability to consider many variables simultaneously (Lynch, 19771. Its value depends on the accuracy of the models. The problems encountered with these over the years are diminishing as experience with simulation is gained in the design and optimization of circuits, and models are being refined

Some modelling studies for cement grinding circuits are reported in the literature (Austin et.al., 1975, Austin, 1984, Viswanathan, 1986: Viswanathan and Narang, 1988; Viswanathan and Reddy, 1992, Zhang ct.al., 1988). The authors of the present paper have developed a model for a two-compartment ball mill operating in bmh open and closed circuit based on the data from samples collected along every meter within the mills (Lynch et.al, 2000; Benzer et.al, 2001) Turkey produces 35 million tonnes of cement annually from more than 100 grinding circuits and the production rate is increasing. The grinding circuits are complex and processing units include vertical roller mills, high pressure grinding rolls (HPGR), tube mills, Horomills and several types of air separators.

Studies in several cement plants by a research group at Hacettepe University have shown that the performance of existing circuits can be improved. The aim of this paper is to summarize current efforts at Hacettepe University to develop mathematical models for these circuits. The experimental approach involves extensive data collection from operating plants and laboratory measurements where appropriate

2.5 Grinding Circuit for Clinker Milling

Unlike the mineral processing sector, the clinker milling process grinds clinker into cement using an air swept ball mill. In the cement industry, a clinker milling grinding circuit typically consists of two (or three) compartment air-swept ball mills (Figure 2.2) closed with a dry mechanical air separator. In other circumstances, cement grinding took place in an open circuit. A centre grate or diaphragm separates each compartment, controlling the filling ratio and size distribution between them.

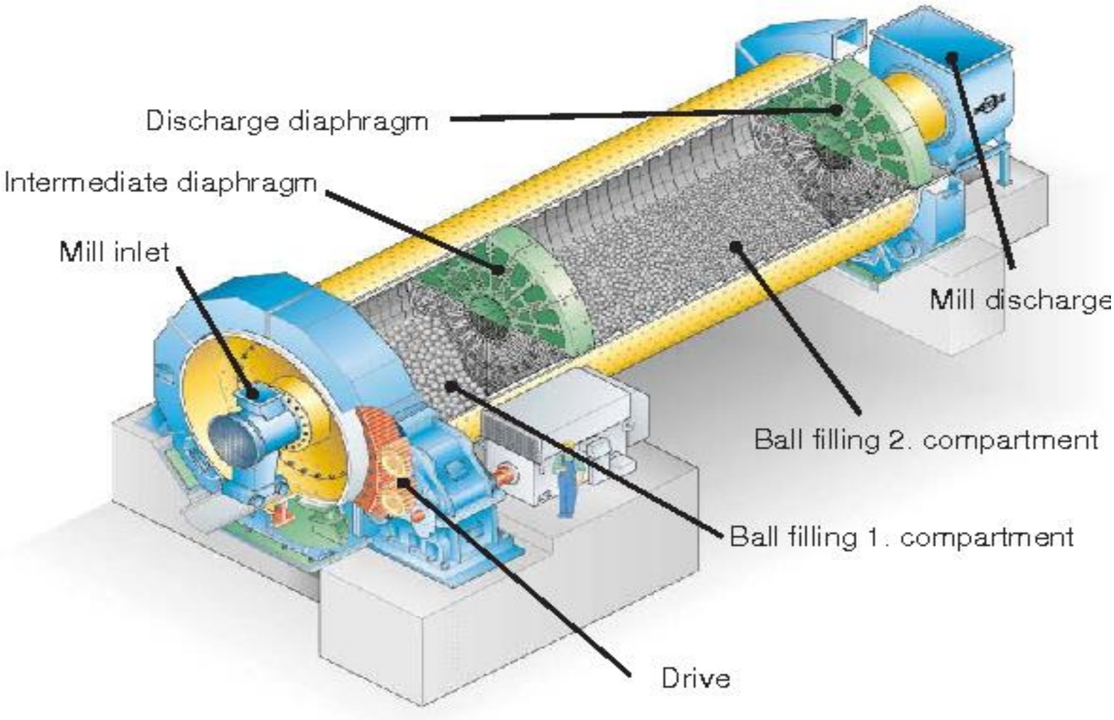

Figure 2.2: Two compartment mill

Many scholars had created mathematical models for the air swept ball mill and the air separator in the field of cement grinding (Austin et al, 1984), (Benzir, 2000; Viswanathan and Narang, 1988; Zhang, 1992; Viswanathan and (Narang, 1988). Such models have aided in the design of circuit layouts and have been used to simulate cement grinding.

Despite the fact that the outcomes of such models have been encouraging, some of the model structures remain complex, requiring the determination of many parameters. Furthermore, literature revealed that several of the models only employed a few data sets from full-scale plants. Furthermore, the models developed are empirical, meaning that they only work within the parameters of the model. As a result, a simple, realistic, and flexible technique to simulating cement grinding based on mathematical modelling is required.

For the two-compartment air swept ball mills, a variety of models have been developed and suggested over the years. The models range from traditional energy-size reduction relationships to current comminution kinetics-based models. Most of the previous study's models for the two-compartment are based on population balancing and perfect mixing ball mill models, which are widely utilised in the mineral processing industry.

As a result, it's critical to talk about ball mill and air classifier models and how they're used in modelling the two-compartment mill. We will go through the ball mill model and its application in clinker grinding in detail in the following sections. It will then be utilised to construct more appropriate models for the two-compartment mill and air classifier.

2.6 Ball Mill Model

2.6.1 Relationship Between Energy and Size Reduction

The relationship between size reduction and electrical energy is well understood. As a result, it is critical to investigate the element of size reduction in order to consume the least amount of electrical energy possible. Size reduction is based on a variety of factors:

- Number of new particle surface after grinding
- Volume of material to be broken down
- Finer product or desired diameter of the product

The majority of the approaches presented for examining ball mill performance are to understand and establish energy-size reduction correlations, due to the high energy consumption of ball mills and evident economic motivations to optimise energy use. Rittinger (1867), Kick (1885), Bond (1952), and Charles produced the first ball mill models (1957). The models connect the amount of energy required to break down a specific feed size to a specific product.

Although the energy-size relationship has application in comminution design, it cannot be utilised to estimate the actual energy required for size reduction. Furthermore, the empirical nature of these connections has been discovered to place severe limitations on their use outside of typical operating conditions. For many years, Bond's relationship has been a crucial design help for mill selection. Since it was developed empirically, however, the relationship has been discovered to impose numerous limitations on their use.