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Chemical Grinding Aids as Chemical Agents to Enhance the Efficiency of Clinker Grinding in Cement Plants

Chemical Grinding Aids Sebagai Bahan Kimia Untuk Mengeffisiensikan Penggilingan Clinker Pada Pabrik Semen

Akhwan Purwoko*, Djoko Setyanto
Professional Engineer Certification, Faculty of Engineering, Atma Jaya Catholic University of Indonesia, Indonesia

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Abstract

Chemical Grinding Aids, hereinafter referred to as Grinding Aids, are chemical additives used to optimize the grinding process of clinker and other supplementary materials into cement powder. In practice, these Grinding Aids enhance the efficiency of the grinding process, thereby increasing the capacity of the grinding equipment. As a result of this increased capacity, the electrical energy consumption per ton of cement produced is reduced, leading to a proportional decrease in production costs per ton. In addition to improving productivity, the use of Grinding Aids also contributes to better cement quality. Experimental data presented in this article show that the application of Grinding Aids has a positive impact, increasing production by up to 17% with an optimal dose of 350 ppm when using concentrated Grinding Aids without dilution. Meanwhile, the optimal dose for a Grinding Aid solution diluted in water at a ratio of 1:4 (Grinding Aids : water) is 300 ppm. This improvement in productivity also leads to a 5% reduction in electricity consumption during the cement grinding process.

Keywords: chemical grinding aids, cement production, cement.

***SDGs*:**

9 INDUSTRY, INNOVATION AND INFRASTRUCTURE

Abstrak

Chemical Grinding Aids yang selanjutnya disebut juga dengan *Grinding Aids* merupakan bahan kimia yang digunakan dan berfungsi untuk mengoptimalkan proses penggilingan *clinker* (terak) dan bahan tambahan lain menjadi bubuk semen. Dalam prakteknya *Grinding Aids* ini akan membantu meningkatkan proses penggilingan sehingga kapasitas mesin penggilingan akan meningkat dan sebagai akibat dari peningkatan kapasitas ini adalah konsumsi energi listrik per ton produksinya akan menurun sehingga biaya produksi per ton semennya juga akan menurun secara proporsional dengan kenaikan kapasitas produksi mesinnya. Di sisi lain penggunaan *Grinding Aids* juga membantu meningkatkan qualitas semen yang dihasilkan. Pengujian yang dibahas dalam artikel ini menunjukkan bahwa penggunaan *Grinding Aids* memberikan manfaat dampak positif peningkatan produksi sebesar 17% dengan dosis optimal pada penggunaan Grinding Aids pekat tanpa pencampuran sebesar 350 ppm sedangkan dosis optimal pada penggunaan Larutan Grinding Aids dalam air dengan komposisi (Grinding Aids : air) 1:4 adalah sebesar 300 ppm. Peningkatan produksi ini menghasilkan penurunan konsumsi listrik untuk proses penggilingan semen sebesar 5%.

Kata Kunci: bahan kimia pembantu penggilingan, produksi semen, semen.

*Correspondence Author
email : akhwan030565@yahoo.co.id

1. INTRODUCTION

National development is a series of structural change processes that are carried out continuously and sustainably. In developing countries, this situation occurs with the shift in the economic structure from being based on the agricultural sector to the industrial sector. Cement industry is one of the industries that drives the growth of the Indonesian industry and economy. Cement is very important for development, especially infrastructure (Sunarsih *et al.*, 2024).

One of the largest cost components in the cement manufacturing process is electricity, with approximately 110 to 120 kWh required to produce one ton of cement (Gharehgheshlagh, Chehreghani and Seyyedi, 2023) and the largest electricity consumer within a cement plant is the cement grinding process, in which clinker, as a semi-finished material is ground into the finish product in the form of cement powder. As shown in Figure 1, the proportion of electricity consumption across the various components of the cement manufacturing facility.

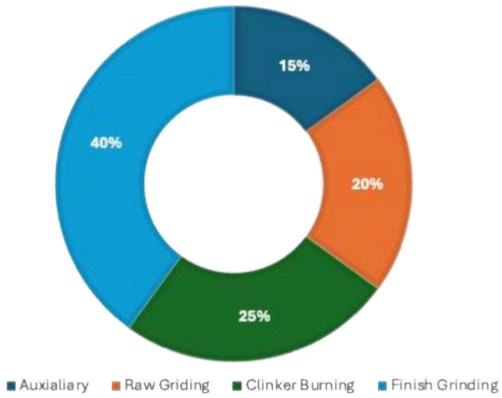

Figure 1. Electricity consumption distribution in cement plant (Gharehgheshlagh, Chehreghani and Seyyedi, 2023).

From the illustration on Figure 1, it is evident that the clinker grinding process accounts for 40% of the total electricity consumption in a cement plant (Gharehgheshlagh, Chehreghani and Seyyedi, 2023). Cement production is one of the most energy-intensive manufacturing industries, and the milling circuit of cement plants consumes around 4% of a year's global electrical energy production, so it is a big challenge for cement factory managers to be able to reduce their factory's electricity consumption (Fatahi *et al.*, 2022; Lavagna and Nisticò, 2023).

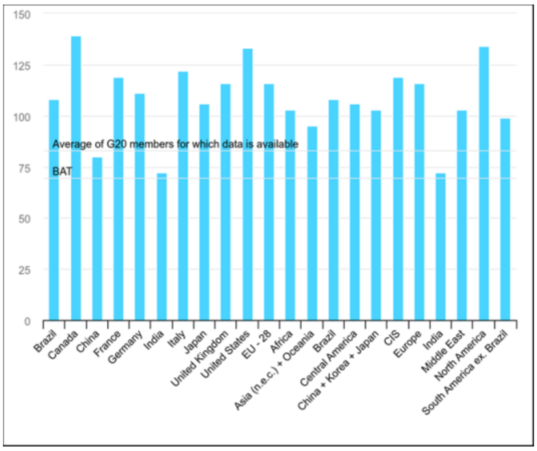

Figure 2. Electricity consumption per ton cement in selected countries and region (IEA, 2021).

Figure 2 shows electricity use per ton cement in selected countries and regions in 2018. The figure shows that the electricity consumption is 72 - 139 kWh/t cement (IEA, 2021).

Numerous efforts have been made to reduce electricity costs in the cement finish grinding process, one of which involves adding specific liquid chemicals during the grinding operation. These chemicals are commonly referred to as Chemical Grinding Aids (CGA) in practical applications. Besides helping to increase the grinding production capacity—thereby reducing electricity consumption per ton of cement produced-CGAs also improve the quality of the cement, such as enhancing compressive strength and setting time (Jiang *et al.*, 2023).

Several studies have demonstrated that certain chemicals, including amines, ethylenes, and glycols, not only improve cement properties but also enhance concrete performance (Gharehgheshlagh, Chehreghani and Seyyedi, 2023). This research is conducted to study the impact of chemical grinding aids in increasing production rate and reducing electrical consumption in the cement grinding process. Which was carried out on an operational scale at cement plant in Cilacap, Central Java by adding chemical grinding aids to the material to be ground in the Finish Mill.

2. METHODOLOGY

2.1. Equipment and Material

The study on the impact of using grinding aids in the clinker grinding process to produce cement, as presented in this article, was conducted at a national cement plant located in Cilacap, Central Java. The grinding of clinker into cement, commonly referred to as cement grinding, finish grinding, or finish milling.

2.1.1. Equipment

As illustrated in Figure 3, which shows the sequence of the cement grinding system. The figure depicts a closed-circuit cement grinding system composed of the following components:

1) Weight Feeder: A mechanical device used to measure and control the weight of material fed into the production process.
2) Pre-grinder: A grinding stage aimed at refining the material before the main grinding process.
3) Ball Mill (Tube Mill): A grinding machine that uses steel balls as the grinding media to crush the material into fine particles. These steel balls are placed inside a large steel cylinder. The initial capacity is 200 tons per hour.
4) Separator: Equipment used to separate fine material from coarse material resulting from the grinding process.
5) Bucket Elevator: A device used to vertically lift bulk materials.
6) Bag Filter: A dust filtering device consisting of fabric bags that absorb and separate material from the air.
7) ID Fan: A device used to generate suction airflow.

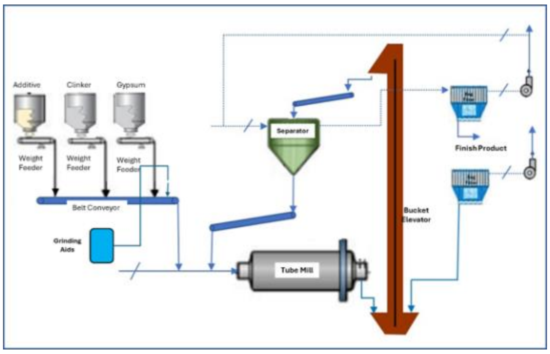

Figure 3. Flow diagram of the clinker grinding process into cement.

Measuring instruments are calibrated periodically following established standards (Alfaredo, Nugraha and Uddin, 2022).

2.1.2. Materials

Material used in this research includes:

1) Clinker: is the primary raw material for cement grinding. It is a semi-finished product of cement, typically coarse granules resembling gravel.
2) Gypsum: An additive that functions as a retarder in cement, controlling the setting time when the cement is applied or used.
3) Chemical Grinding Aids: Liquid chemicals that enhance the efficiency of cement grinding. In this study, the grinding aid used is based on Triethanolamine (TEA), with the chemical formula $N(CH_2CH_2OH)_3$ and a specific gravity of 1.124 g/ml (Popov and Chernev, 2024).
4) Process Water: Used as a diluent for the grinding aids.

2.2. Experimental Set Up

It is referred to as a closed-circuit system because after the ball mill product passes through the separator, the material is separated into particles that meet the required fineness standards and those that are still too coarse. The coarse material is returned to the ball mill for regrinding. The material that meets the fineness standard is then drawn by a fan and subsequently separated from the air in the bag filter, becoming the final cement product. Meanwhile, the coarse material is recirculated back into the tube mill for further grinding until the desired fineness is achieved as shown at Figure 3.

2.3. Experimental Design Test Parameter

The tests were conducted under two conditions where each condition conducted 3 times. The data we display in this article is the average data from the test results. Test variables are grouped into two, namely fixed variables and differing variables.

a. Fix Variable
    1) Type of Cement: OPC cement
    2) Product Fineness (blaine): 3600 cm2/gr.
    3) Raw Materials Used:
        (a) Clinker: 95%,

(b) Gypsum: 5%
4) Interval Between Dose Changes: 2 Hours

b. Differing Variable
   1) Chemical Grinding Aids Concentration:
      (a) Un dilute (pure Grinding Aids)
      (b) Dillute 1:4 (Grinding Aids: Water)
   2) Dosage: (ppm)
      0, 50, 100, 150, 200, 250, 300, 350, 400, 450, 500

2.4. Testing Method

2.4.1. Initial stage

Prepare all the necessary equipment for the dosing system, then assemble it as shown in Figure 4. The required equipment includes:

1) Clean water supply line, used to provide water needed to dilute the grinding aids liquid.
2) Grinding aids storage tank.
3) Mixing tank equipped with an agitator.
4) Flow meters to measure flow rates; three flow meters are needed—one each for measuring the flow of water, grinding aids, and the mixed liquid fed onto the belt conveyor mill feed.

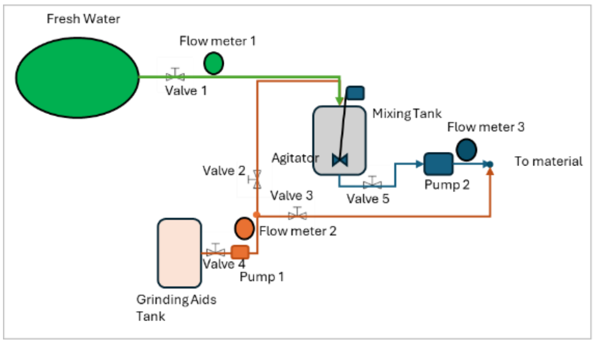

Figure 4. Grinding aids dosing system arrangement.

2.4.2. Non-diluted grinding aids

The first test is conducted, which involves adding concentrated grinding aids without dilution. The observation steps are as follows and follow as reference:

1) Operate the tube mill without adding grinding aids and observe the feed rate and power readings for 2 hours.
2) Add the grinding aids without the addition of water by closing the water valve, as shown in Figure 4, to the material that will be fed into the finish mill, at a dosage of 50 ppm. Observe the feed rate for 2 hours and monitor for any positive impact in the form of an increased feed rate by observing the ball mill motor load. When the motor load begins to rise, it indicates that the mill is becoming empty due to smoother material flow. At this point, gradually increase the feed rate until a stable condition is achieved, signalled by the motor load returning to its normal level.
3) Implement the procedure described in point 2 above and increase the dosages as shown in Table 1.

Table 1. Non diluted grinding aids adding.

ppm	Lt/Minute
100	0.3
150	0.44
200	0.59
250	0.74
300	0.89
350	1.04
400	1.19
450	1.33
500	1.48

4) Monitor the electrical consumption once the finish mill reaches stable operating conditions following the addition of 500 ppm grinding aids.
5) Ensure the pump delivers right dose by monitoring flow meter number 2 at Figure 4. Since the flow meter reading is in litre per hour (l/min), it must be converted to ppm using the following formula:

$$\rho_{\text{(density)}} = m/v, \quad (1)$$

to convert ppm to litre per minute:

$$v = (((ppm/1.000.000) \times FR)/\ \rho)/60 \quad (2)$$

where:
m = mass (g)
v = volume (l)
FR = feed rate (t/hr)
ρ = density (g/l)
Density grinding aids : 1,124 g/ml = 1124 g/l
Production : 200 t/ hr = 200.000.000 g/hr
For 50 ppm/hr = (((50/1.000.000) x 200.000.000)/1124)/60 = 0,15 l/min

2.4.3. Diluted grinding aids

The second phase of testing was conducted under different conditions by observing the positive impact on production increase from the use of chemical grinding aids diluted with water. The observation steps are as follows:

1) Fill the mixing tank with a solution of grinding aids and water at a ratio of 1 part grinding aids to 4 parts waters (1:4) by following flow of Figure 4.
2) Operate the tube mill without adding grinding aids and observe the feed rate and power readings for 2 hours.
3) Add the grinding aids, which have been diluted with water, to the material that will be fed into the finish mill at a dosage of 50 ppm. Observe the feed rate for 2 hours to have steady state condition (Gharehgheshlagh, Chehreghani and Seyyedi, 2023) and monitor for any positive impact in the form of an increased feed rate by observing the ball mill motor load. When the motor load begins to rise, it indicates that the mill is becoming empty due to smoother material flow. At this point, gradually increase the feed rate until a stable condition is achieved, signalled by the motor load returning to its normal level.
4) Repeat step 3 with different dosing levels as shown at Table 2.

Table 2. Diluted grinding aids adding dosage.

ppm	Lt/Minute
50	0.74
100	1.48
150	2.22
200	2.97
250	3.71
300	4.45
350	5.19
400	5.93
450	6.67
500	7.41

5) Ensure the dosing flow rate is 50 ppm by monitoring flow meter number 3 at Figure 4. Since the flow meter reading is in litre per minute (l/min). Therefore, it must convert the ppm to litre per minute.
6) Considering the 1:4 dilution ratio as follows:

$$v = (((ppm/1.000.000) \times FR)/ \rho \times 5)/60 \quad (3)$$

where :

m = mass (g)
v = volume (l)
FR = feed rate (t/hr)
ρ = density (g/l)
Density of grinding aids : 1,124 g/ml = 1124 g/l
Composition: 1 part of GA : 4 part of water
Production: 200 tons/hour = 200.000.000 g/hr
For 50 ppm/hr = (((50/1.000.000) x 200.000.000)/1124 x 5)/60 = 0,74 l/min

2.5. Data Collection

2.5.1. Production rate

Production rate data were obtained from log sheets recorded every hour by the Central Control Room (CCR) operator. Given that grinding aid dosing was performed at intervals of two hours, only data from the second hour were used for analysis, as this period reflects conditions in which the system is expected to have reached a steady state (Gharehgheshlagh, Chehreghani and Seyyedi, 2023). These data were then averaged with results from two additional trials conducted under similar operating conditions at different times. Final values were rounded to the nearest ton per hour.

2.5.2. Electrical consumption

Electrical energy consumption was measured by plant electrical personnel under two operational conditions. The first measurement was taken during operation without the use of grinding aids. The second measurement was taken once optimal grinding aid conditions had been achieved, defined as the point at which further additions no longer resulted in an increase in feed rate. These measurements were used to assess the effect of grinding aids on specific energy consumption.

2.5.3. Observation period per dosage

Each dosage of grinding aid was observed over a period of 2 hours to ensure that steady operating conditions had been established. Based on practical experience and supporting literature that steady state is typically reached after approximately 60 minutes (Gharehgheshlagh, Chehreghani and Seyyedi, 2023). This condition was confirmed by the stabilization of mill motor load as well as consistent inlet and outlet pressure readings of the mill.

2.6. Data Analysis

There are two categories of data that were collected in this study:

1) Data on the increase in finished mill production due to the addition of grinding aids, which was measured under two conditions, the addition of pure grinding aids without dilution of water and the addition of grinding aids diluted with water. Each condition will be tested three times. The average data from the three tests then will be calculated. As shown at Equation 4, While to calculate the production increase, the production output at a specific dosage was subtracted from the output during the blank condition, where no grinding aids were used. This difference was then divided by the output during blank conditions follow Equation 5, and to calculate production increase divide the ΔP by initial production rate then multiplied by 100 to get a percentage increase in production, follow Equation 6.

$$\bar{P} = \frac{\Sigma Pi}{n} \quad (4)$$

$$\Delta P = \bar{P} - P0 \quad (5)$$

$$\Delta\% = \left(\frac{\Delta P}{P0}\right) \times 100\% \quad (6)$$

where:

$\bar{P}$: Average feed rate at each GA dosage
Pi : Production rate at certain GA dosage
$P0$: Production rate at blanko
n : Number of data at each dosage and condition
$\Delta\%$: Production increase

2) Data on electricity consumption measured when the finished mill was operated without the addition of grinding aids at the beginning of the test, and when the addition of grinding aids no longer affected the finish mill feed rate, which occurred at a dosage of 500 ppm. Subsequently, the kWH data recorded during the blank operation was subtracted from the kWH data after reaching the steady state at 500 dosages, therefore it resulted with reduction on electricity usage as a positive impact of using grinding aids.

3. RESULTS AND DISCUSSION

3.1. Addition of Concentrated Chemical Grinding Aids Without Dilution

The first observation was conducted by adding concentrated chemical grinding aids without dilution, with doses gradually increased from 0 g/t, 50 g/T, up to a maximum of 500 g/T, at intervals of 2 hours each. This interval was necessary to ensure that the operational conditions reached a steady state, so the impact of the grinding aids addition could be considered optimal.

Table 3. Dosage vs Production increase using undiluted grinding aids.

Dosage (GA)	Production (TON)	Production Increase (%)
0	200	0
50	200	0
100	205	3
150	210	5
200	216	8
250	222	11
300	228	14
350	233	17
400	233	17
450	233	17
500	233	17

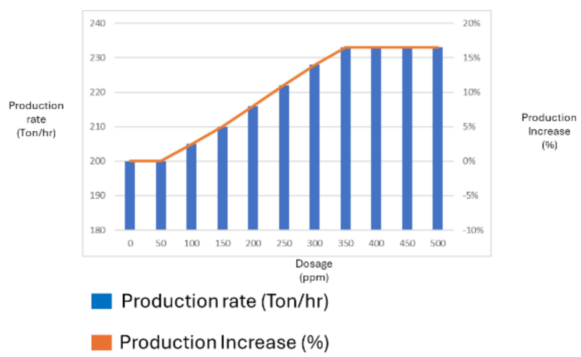

Figure 5. Dosage vs Production increase using undiluted grinding aids.

Table 3 and Figure 5 illustrates that the effect of grinding aids became noticeable starting at a dose of 100 g/T (commonly referred to as 100 ppm), with a production increase of 3%. Production continued to rise in line with the increasing dosage, reaching a peak at 350 ppm. Further dosage increases did not result in additional production gains. The maximum production increase achieved was 17% higher compared to the condition without the use of chemical grinding aids, as show at Table 3 and Figure 5.

3.2. Addition of Chemical Grinding Aids with Water Dilution

The second test involved adding grinding aids diluted with water in a ratio of 1 part grinding aids to 4 parts waters. Table 4 and Figure 6 illustrate that the impact of grinding aids on production increase became apparent at a dose of 100 ppm, resulting in a 4% increase in production. The effect peaked at a dose of 300 ppm, with a maximum production increase of 17%. Further increases in dosage did not result in additional production improvements.

Table 4. Dose vs Production increase using diluted grinding aids.

Dosage (GA + Water) (ppm)	Production (TON)	Production Increase (%)
0	200	0
50	200	0
100	208	4
150	215	8
200	223	12
250	228	14
300	233	17
350	233	17
400	233	17
450	233	17
500	233	17

When comparing the production increase between the use of diluted grinding aids and undiluted (concentrated) grinding aids, the results indicate that the use of diluted grinding aids is more effective in enhancing the production capacity of the tube mill, as illustrated in Figure 7.

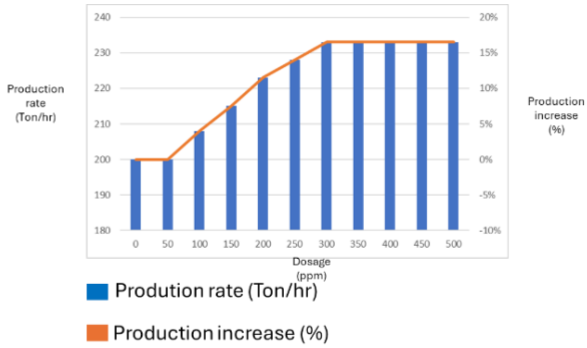

Figure 6. Dose vs Production increase using diluted grinding aids.

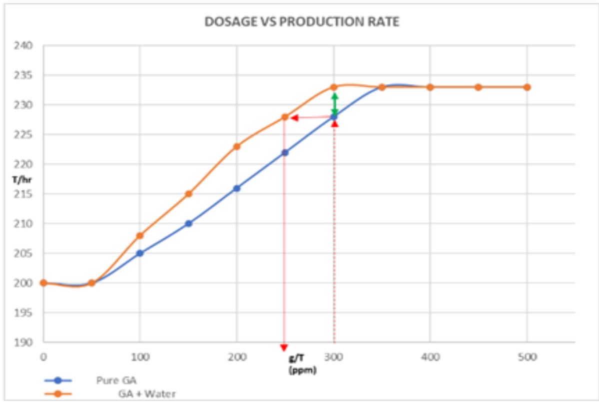

Figure 7. Comparison of production increase between using pure grinding aids and grinding aids diluted with water.

Although both methods show a similar range of production increase, the magnitude of the production improvement is greater with the use of grinding aids diluted with water. The addition of grinding aids that had been diluted with water reached its optimal point first, at a dosage of 300 ppm, as shown in the red-colored graph, while the addition of concentrated grinding aids without water only reached its optimal point at a dosage of 350 ppm, as shown in the blue-colored graph.

3.3. Reduction in Electricity Consumption per Ton of Cement Produced

Before the use of grinding aids, the production rate was recorded at 200 tons per hour with a specific electricity consumption of 39.26 kWh/ton. After the application of grinding aids, an optimum productivity increase of 17% was observed alongside a reduction in specific power consumption to 37.43 kWh/ton, representing approximately a 5% decrease in energy consumption. It aligned with result of earlier study whcih done by Kalkan in 2023, where TEA was able decrease the electric anergy consumption more than 8% as shown at Figure 8 (Kalkan, 2023).

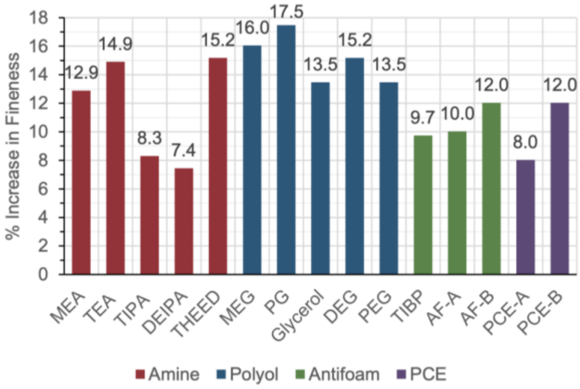

Figure 8. Energy saving by grinding aids (Kalkan, 2023).

According to another study, with the increasement in grinding energy, the beneficial effects of grinding aids become more accentuated leading to significantly higher gains in mill productivity (Assaad, Asseily and Harb, 2009).

In this research, data was collected three times for each condition. To ensure the reliability of the research result, the standard deviation was calculated using the Equation 7 (Febriani, 2022):

$$S = \sqrt{[\sum \frac{fi(xi-\bar{x})2}{(n-1)}]} \qquad (7)$$

where:

s: standard deviation
fi: frequency in every group
xi: mean in every group
$\bar{x}$: average data in group
n: total data amount

Based on the calculations, it was found that:

1) The standard deviation results on the test using grinding aids without dispersing agent can be seen as follows:

$$s = \sqrt{[\frac{11(216.5-219.1818182)^2+11(216.5-219.45455)^2+11(216.5-219.454455)^2}{33-1}]}$$

$= 2.91$

2) The standard deviation on the test results using grinding aids that were first mixed with dispersing agent can be seen as follows:

$$s = \sqrt{[\frac{11(216.5-221.272723)^2+11(216.5-222)^2+11(216.5-221.9090999)^2}{33-1}]}$$

$= 5.318$

The standard deviation results support the reliability of the test results, indicating that the application of grinding aids at a specific dosage during cement grinding process can effectively enhance production capacity.

How do Chemical Grinding Aids (CGA) assist in the clinker grinding process to increase the production capacity of the cement mill and reduce electricity consumption? Fundamentally, the grinding of clinker into cement follows the principles of anisotropic material grinding. According to Griffith's theory, the process is directly influenced by weak points represented by microcracks or defects within the crystal structure of the material (Urbaniak *et al.*, 2021). During the impact process, namely the clinker material and other materials still in the form of gravel or small lumps, which usually occurs in Ball Mill chamber #1, as well as during the grinding process of semi-fine materials that usually occurs in Ball Mill chamber #2, the highest compressive force occurs at those weak points. This causes the breaking of molecular bonds and crystal lattices, leading to cracking and a reduction in particle size.

However, the breaking of ionic bonds caused by mechanical processes results in the formation of highly reactive positive and negative charges on the newly fractured surfaces. The main drawback of this charge formation is the occurrence of agglomeration, which directly affects the efficiency of the grinding process. Agglomeration occurs due to adhesive forces between particles, caused by Van der Waals forces and electrostatic attraction. This agglomeration leads to the formation of material layers or clusters on the surface of the grinding media, which reduces the grinding efficiency in the ball mill as shown at Figure 6 (Max *et al.*, 2023; Njiru *et al.*, 2023).

Grinding aids in the cement grinding process fundamentally function to prevent material agglomeration during grinding as shown at Figure 9 and Figure 10.

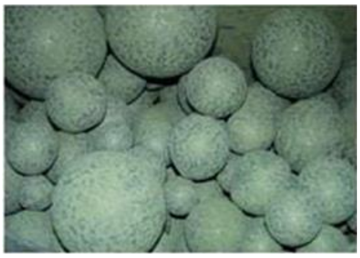

Figure 9. The surface of steel balls in the ball mill without CGA (Kalkan, 2023).

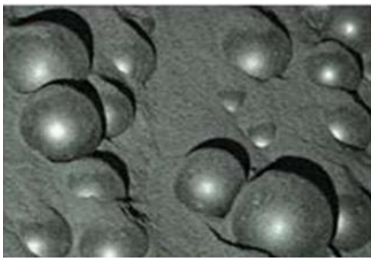

Figure 10. The surface of steel balls in the ball mill with CGA (Kalkan, 2023).

Broadly speaking, their mechanism can be divided as follows:

1) Changes in the surface and mechanical properties of particles, such as surface energy (i.e., the Rehbinder effect). The Rehbinder effect is a physical phenomenon that causes a reduction in material strength; with decreased material strength, clinker becomes easier to grind (Kalkan, 2023).
2) Changes in particle arrangement and material flow characteristics through flocculation/dispersion, or the prevention of agglomeration, or the control of material flowability (Zhao, 2021).
3) With the increased grindability of clinker and improved material flowability inside the ball mill, the capacity will increase. This production increase occurs only within a certain dosage range, as shown in the graph in Figure 11.
4) Excessive GA amounts above theoptimum concentration will lead to a decreasing grinding performance (Prziwara and Kwade, 2021).
5) This capacity increase will reduce electricity consumption per ton of cement produced (Zhao, 2021).

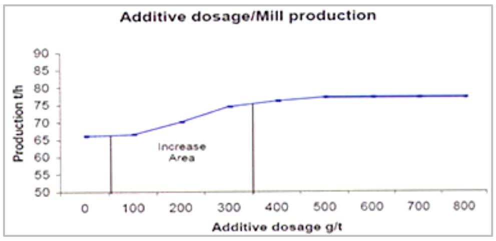

Figure 11. Production increasement area (Mapei, 2005).

There are some materials used as grinding aids are classified into two groups: organic and inorganic compounds. Some examples of grinding aids based on organic chemical compounds include:

1) Amines, Amines-based grinding aids not only enhance the performance of the cement grinding process but also contribute to improving the quality of concrete. Some examples of amine-based grinding aids include (Popov and Chernev, 2024):
   a. Monoethanolamine (MEA): $HOC_2H_4NH_2$
   b. Diethanolamine (DEA): $C_4H_{11}NO_2$
   c. Trieathanolamine (TEA): $N(CH_2CH_2OH)_3$
   d. Triisopropanolamine (TIPA): $C_9H_{21}NO_3$
2) Glycol, Glycol-based grinding aids function to enhance the performance of the cement grinding process and help accelerate the cement hydration process, thereby improving the quality and final strength of the concrete. Some examples of glycol-based grinding aids include (Popov and Chernev, 2024):
   a. Ethylene glycol (EG): $C_2H_6O_2$
   b. Diethylene glycol (DEG): $(HOCH_2CH_2)_2O$
3) Poly Carboxylate Ether (PCE) (Yang *et al.*, 2022): $CH_2 = C(CH_3)CH_2CH_2O(CH_2CH_2O)NH$
4) In addition to organic compounds, certain inorganic salts such as chlorides can also be used as grinding aids (Chipakwe *et al.*, 2020). This study is expected to provide an overview of the positive effects of using grinding aids in the cement grinding process.

However, considering that the objective of our test is to increase the productivity of the Ball Mill, we chose to use a grinding aid based on Triethanolamine (TEA) (Popov and Chernev, 2024).

4. CONCLUSION

Observations indicate that the addition of chemical grinding aids has a positive impact on the productivity of the tube mill in the clinker grinding process to produce cement.

In the first test, using undiluted grinding aids, production increase effects began to appear at a dosage of 100 ppm, with a production increase of 3%, reaching an optimum point at 350 ppm with a production increase of 17%.

In the second test, where the grinding aids were diluted at a ratio of 1:4 before being added to the material fed into the tube mill, the increase in tube mill production was greater compared to using pure, undiluted grinding aids. The production increase became visible at a dosage of 100 ppm with a 4% increase and reached the optimum point at 300 ppm with a 17% increase. This shows that administering grinding aids at a lower consistency or more diluted form has a more positive impact compared to using undiluted grinding aids. This occurs because a more diluted solution facilitates easier dispersion of the liquid on the material.

The increase in production was also accompanied by a decrease in specific power consumption (SPC) or electricity consumption per ton of production, where before using grinding aids, the average SPC was 39.26 kWh, and records show that after using grinding aids, the average SPC was 37.43 kWh, indicating a decrease of 5%.

Furthermore, more in-depth research on the benefits of chemical grinding aids in the cement grinding process. This research could focus on grinding aids with different base materials, such as glycol or ether, and include a broader range of variables, for example, the impact of grinding aids on the quality of concrete produced using the cement.

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