SabancıDX

TOWARDS COMPOSITE DIGITAL TWINS

FACULTY OF ENGINEERING AND NATURAL SCIENCES

Sabancı Üniversitesi

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ABSTRACT

The global cement market size has passed the value of USD 355.6 billion in 2016 and continues to grow due to the growing requirement for the construction of institutional and healthcare buildings. Megaprojects all around the world such as China's One Belt and One Road program increases the demand for cement. In Turkey, cement industry had sold over 70 million tons (mt) and exported more than 10 million mt.

In cement production, majority of the costs come from energy consumption (around 65%) and improvements that target the efficiency in energy consumption can contribute greatly to the profit of the company as well as environment through decreasing the special energy consumption. Since cement is produced through a continuous production line, any malfunctioning in the critical equipment can cause greater, unexpected costs.

In the project, we have used the advancements of digitalization by implementing sensors to the critical equipment. These sensors continuously monitor the temperature, vibration, input current and enable us to gather data to have a better understanding of the root causes of breakdowns. The collected data will be used to predict an upcoming breakdown in critical equipment and decrease the downtime in cement plants. Our motivation is to improve the predictive maintenance policies with continuously monitoring the vertical grinding mill and crushers. Through controlling the operational parameters, the data will be used to decrease the special energy consumption in equipment, therefore decrease the energy costs.

INTRODUCTION

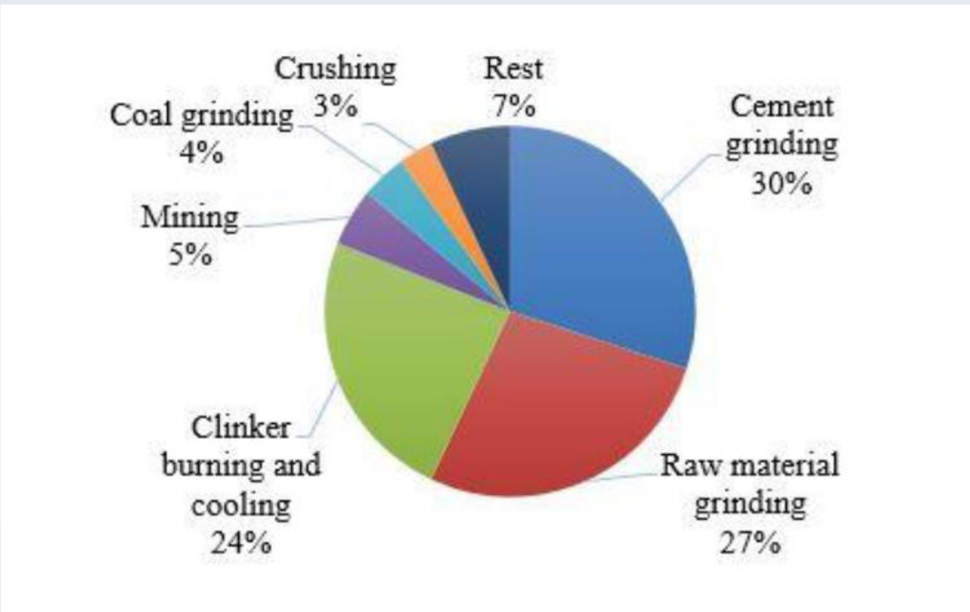


Figure 1. The use of electrical energy in cement production

About one third of the electrical power is consumed during the farine production in a conventional cement factory as it is seen in the above representation. In a manufacturing point of view Farine is the semi product of clinker thus is an important material. Even though the production of farine consists of only grinding with the improvement of machine design and choosing optimal operating conditions, new approaches toward energy saving in cement production might be developed. According to Katsioti M, Tsakiridis PE, Giannatos P, Tsibouki Z, Marinos J.(2009) About 2% of the electricity produced in the whole world is used during the grinding process of raw materials. While total electrical energy consumption for cement production is about 100 kWh/ton of cement, roughly two thirds are used for particle size reduction. About 65% of the total electrical energy used in a cement plant is utilized for the grinding of coal, raw materials and clinker.

Efficient usage of energy during grinding process will lower the production cost considerably and the carbon dioxide emission rates. A wide range of options exists to reduce carbon dioxide emissions but this is our of the scope of this project. Nevertheless it would not be appropriate to not mentioning the effect of energy consumption in carbon dioxide.

On the other hand, the correlation analyses between energy consumption and vertical raw mill parameters are carried out with respect to different types of vertical raw mill equipment. Literature survey provides a wide range of outputs and effects on energy. Some of the studies focus on increasing the efficiency of the unit and some of them emphasize the effects of some different parameters on the vibration values of the system to establish the optimal operating conditions by recording and analyzing the vibration on the unit regularly. Knowing the working mechanism of the mills indicates that the studies on industrial scale raw mill under real working conditions are limited number. In order to understand and emphasize these result, elaboration of those require a deep understanding of vertical raw mill parameters.

Commonly used analyses focuses on the specific energy consumption, effects of ball charge tonnage, humidity and size of the feeding materials on vibration values of the system. In most of the cases the results show strong correlation between those parameters and energy consumption.

OBJECTIVES

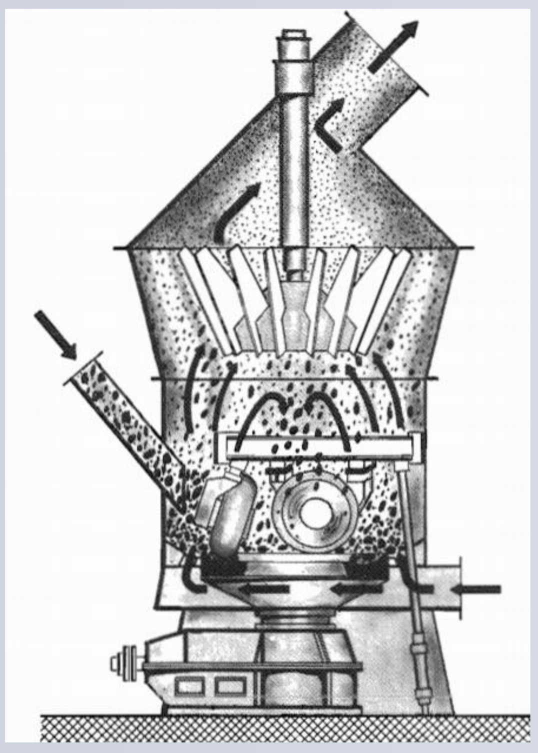
Main objective of this project is to minimize the specific energy consumption by controlling the operational parameters without sacrificing the quality of the product. In cement production, majority of the cost comes from energy consumption and every improvement that decreases the consumption will also contribute to the environment as well.

Collected the data using sensors with digital twinning methodology will be used to predict an upcoming breakdown in the critical equipment beforehand. Improving the predictive maintenance policies will also contribute to the energy savings since any breakdown will cause a complete system failure. Reinitiating any equipment requires high amounts of energy, therefore, any improvement in the prediction methodology has the potential to improve the profits as well as environment conditions.

METHODS

Commonly used methods for vibration analysis of raw mill consists of several steps thus the collection and processing of the vibration signals are very critical during the investigation of the system. A sensitive portable SKF Microlog Vibration Analyzer device is used during the diagnosis and analysis of vibration on the main driving motors of the unit. With the help of data recorder module the signals from sensors connected to the device are digitally recorded and stored as standard time waveform files (WAV). The data is collected and transferred to a computer for additional analysis. The data acquisition is governed by the SKF Aptitude Analyst programming environment which is a software development package designed specifically for instrument control and measurement.

PROJECT DETAILS



The raw mills are big grinding facilities and there are many different parameters affecting the grinding behavior of the unit. Mill size, ball charge rate, shape, temperature and humidity of the entering raw materials, circulating load within the system, ambient air conditions, rotational speed of the mill, temporary stops for the periodical maintenance of the system, chemicals used to speed the pulverization and to eliminate the sticking problem, efficiency and performance of each machinery used, the microstructure of the raw materials and vibration characteristics of the system are some of these parameters. Detailed examination of these parameters in terms of correlation coefficient give insight about the improvement of energy consumption.

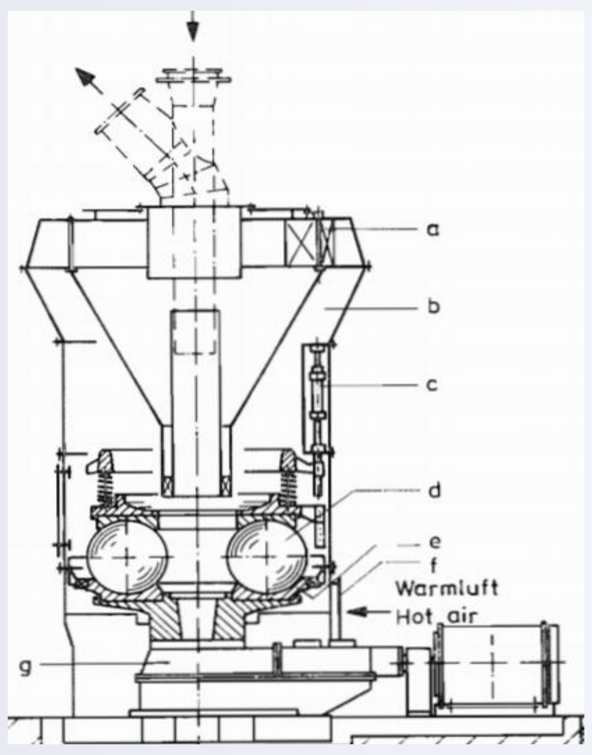


Figure 2 – The representations of vertical raw mill

Figure 3 – The representations of vertical raw mill

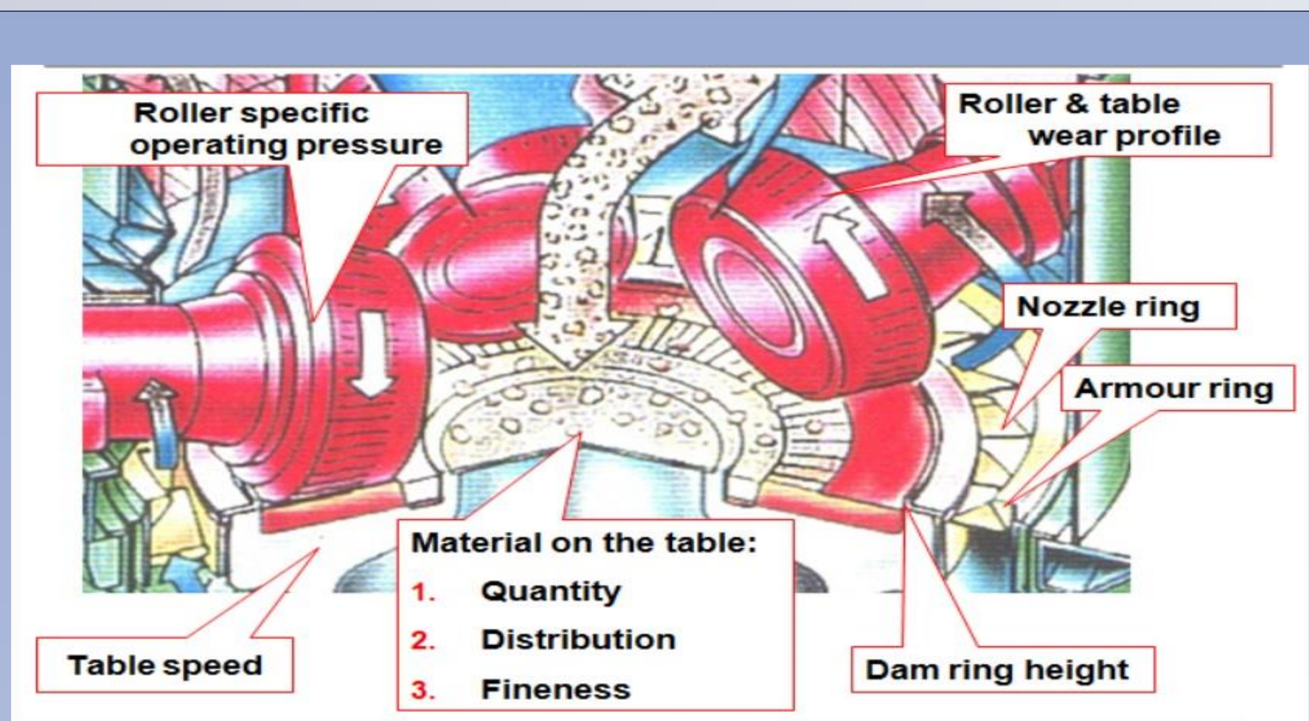


Figure 4 – The operational parameters of vertical raw mill

Good conditions (days)	Average vibration on 1st motor (mm/s)	Average vibration on 2nd motor (mm/s)	Electricity consumption (kWh/day)	Farine production (ton/day)	SEC (kWh/ton)
1	2.308	2.102	52,919	2121	24.95
2	2.622	2.466	49,894	1969	25.34
3	2.235	2.059	56,168	2263	24.82
4	2.497	2.198	59,759	2399	24.91
5	2.403	2.263	47,591	1909	24.93
6	2.245	2.033	56,453	2269	24.88
7	2.336	2.107	52,429	2098	24.99
Average	2.978	2.719	53,602	2147	24.97

* Ball charge tonnage (113 tons) and production rate (101 ton/h) is kept constant and standard conditions with 8% humidity and 30 mm feed material size are provided during the comparison

Figure 5 – Maintanance Effect on SEC

Cases	Ball tonnage (ton)	Farine production (ton/h)	Vibration (mm/s)		Electricity consumption (kWh/month)	Production (tons/month)	SEC (kWh/ton)
			1st motor	2nd motor			
1	107	98	2,319	1,702	1,451,990	57,165	25.40
2	110	100	2,491	2,180	1,477,230	57,999	25.47
3*	113	101	2,912	2,625	1,482,606	58,096	25.52
4	115	104	3,486	2,942	1,499,980	58,297	25.73
5	116	105	4,792	3,723	1,509,962	58,277	25.91
6	121	109	5,179	4,276	1,561,360	59,187	26.38
7	124	111	5,623	4,837	1,596,120	59,579	26.79

* Standard conditions with 8% humidity and 30 mm feed material size

Figure 6 – Ball Tonnage Effect on Vibration

Cases	Raw materials' moisture contents and sizes	Vibration (mm/s)		Total production (tons/week)	Electricity consumption (kWh/week)	SEC (kWh/ton)
		1st motor	2nd motor			
1	4/7% - < 20mm	2,569	2,302	15,613	393,291	25.19
2	7/9% - < 30mm	2,969	2,715	15,168	384,964	25.38
3	9/11% - < 35mm	3,366	2,907	14,863	380,939	25.63
4	11/13% - < 40mm	3,469	3,299	14,559	377,224	25.91
5	13/17% - < 45mm	4,098	3,791	14,290	373,112	26.11

Figure 7 – Raw Materials Moisture Content

CONCLUSIONS

The effect of ball charge tonnage to vibration is examined while keeping the production capacity, humidity and size of the feeding materials constant. The gradual increase in tonnage leads to an increase on vibration of motors. İn general, if machine has an unexpectedly high vibration level, the special energy consumption level increases accordingly. The same effect can be seen in here. Increase in tonnage leads to an increase in energy consumption rate.

It is intuitive that the size and the moisture content of the feeding material should be low as possible in order to improve performance and quality of the product. The reduction in moisture content of raw material decreases the vibration and driving motors so the SEC decreased accordingly. It is crucial to emphasize that the moisture level of raw material and the humidity inside the vertical raw mill are different aspects. The humidity level or the water injection rate into the plate of the mill decreases the vibration regardless the fact that the low moisture level of raw material decreases it too.

one of the major non physical parameter is the periodical maintenance of the unit. With the help of strictly ensured maintenance, the vibration values on the main driving motors might be reduced up to 20%. Keeping all the variable constant, periodical maintenance decreases SEC and annual carbon dioxide emission per ton farine.

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