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Improvement of cement plant dust emission by bag filter system

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Abstract. The limestone quarry in PT Indocement Tunggal Prakarsa (ITP) in Cirebon is considered as a complex quarry in terms of chemical composition and material hardness. From the beginning of the plant operation up to the end of 2015, the dust removal was rely on electrostatic precipitator (EP) system. Whenever limestone from specific quarry zones were incorporated into Raw Mill (RM) feed or there was an upset condition, the dust emission increased significantly. Beside higher demand of electricity, an EP system requires lower gas inlet temperature in order to remove the dust effectively which requires larger cooling water in the previous gas conditioning tower to cool down gas from 400 ^{o}C to about 100 ^{o}C. By considering the drawbacks, the EP system was replaced by a bag filter (BF) system. The BF allows higher temperature of gas inlet and it has higher dust removal efficiency. In this study, the efficiency of the two different dust removal systems is compared. The effect of process variables i.e. RM feed, kiln feed, inlet temperature and pressure, and small size particle fraction to the dust emission are studied by multivariate linier regression analysis. It is observed that the BF system can reduce significantly the dust emission from 30 to 6 mg/m^3 and in the same time reducing CO_2 emission by 0.24 ton/year from the electricity consumption saving.

Keywords: Dust emission; Bag Filter; Electrostatic precipitation.

1. Introduction

The air emission in cement industry is considered as the major environmental issue particularly for carbon dioxide, sulfur dioxide, nitric oxide and dust emission [1,2]. For instance in China, cement industry contributes at about 14% of the total PM2.5 emission throughout the countries [3]. Many efforts have been made to control this type of emission such as raw material modification, energy efficiency, and modification of the dust removal system in this industry [1,3]. On the other hand, the regulation of the dust emission is getting stringent for this business from time to time which drives the former constructed plants to improve their dust removing facility. The limit of dust emission for cement industry in the world is varied for instance in EU the limit is 0.15 kg/ton clinker [4,5], while in India the limit is depend on the production capacity from 250 mg^2/Nm^3 (plant capacity ≤ 200 tons/day) to 150 mg^2/Nm^3 [6].

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In terms of dust emission reduction, there are two main gas cleaning systems implemented in cement industry i.e. electrostatic precipitator (EP) and bag filter (BF). It has been recorded that these two efficient gas cleaning system have a significant contribution to particulates emission reduction of cement plants from time to time [7]. Between the two dust removal system, EP technology has been widely applied due to ease of operation and maintenance and also lower pressure drop requirement. Most of early constructed cement plants were equipped with this dust cleaning system due to its established technology. In fact, an EP system requires a high electric power requirement and the performance during operation is strongly affected by operating condition (gas temperature, flowrate and dust content) and particulate properties such as particle size and dust resistivity [6]. Meanwhile, particulate resistivity is affected by chemical composition as well as gas temperature. Higher operating temperature will increase the resistivity thus the dust is getting harder to be separated by negatively charged electrodes.

Table 1. Design Specification of Electrostatic Precipitator and Bag Filter

Description	Unit	EP	BF
Size (LxWxH)	m x m x m	21.5 x 12.5 x 15.8	
inlet gas temperature	^oC	120	180
Inlet dust content	g/Nm^3	95	200
Outlet dust content	mg/Nm^3	50	10
Gas volume	m^3/h	688900	547000
Removal efficiency	%	99.950	99.995
Total collecting area	m^2	15300	17603

Nowadays, BF system is getting famous to be used in cement plants due to stringent regulation and environmental standards [8,9]. By using special fabric for special separation purpose, the high efficiency of this system can be guaranteed. Even tough, BF is susceptible from leakages and higher maintenance cost due to bag replacement after certain years [10]. Most of the newly constructed cement plants are equipped with this air pollution prevention system, while older plants have to replace or improve their existing de-dusting system by BF system. PT Indocement Tunggal Prakarsa (ITP) is no exception, ITP has replaced EP by BF system in their 9th clinker production line. The specification of the two system is summarized in Table 1.

Table 2. XRF composition and compressive strength of selected quarry samples

Quarry zone ID	XRF result in weight %								Compressive strength (kg/m^2)
	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	Na_2O	K_2O	
A 1.1	12.88	2.66	0.37	46.39	0.94	0.15	0	0.03	664
A 1.4	0.62	0.89	0.28	54.84	0.29	0.03	0.02	0.01	128
BC150 3	11.54	3.12	1.11	43.78	2.15	0.6	0.13	0.18	691
BC120K2	0.1	0.5	0.18	51.63	3.36	0.16	0.06	1.26	96
C90SM 2	10.91	1.93	0.77	44.79	1.99	0.39	0.02	0.1	768
C90SM 3	8.98	1.69	0.46	48.14	0.89	0.18	0.02	0.11	432
SLS 1	5.87	2.23	0.77	47.92	3.1	0.44	0.08	0.1	248

Meanwhile, the quarry of ITP is considered as a complex quarry due to the variation of the chemical compound and also the material hardness in terms of compressive strength among the zones as listed in Table 2. It is common that there is a large raw material properties variation even in the same zone (A, B, C or D). The limestone content in the Raw Mill feed basically is a mixture from

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different zones to produce desired feed composition for clinker production. The limestone properties variation will affect the dust properties such as dust resistivity and particle size distribution. In an EP system, dust resistivity is a critical factor in determining the effectiveness of this dust removal system [6].

In this study, the two system of dust removal (EP and BF) are compared using real plant data. Some operating condition variables correlated with the separation performance are observed by a statistical method to determine the main variables for each separation equipment system.

2. Materials and Methods

Multivariate linier regression analysis is used to statistically interpret the correlation between dust emission data as the single dependent variable (Y) and selected plant data as the independent variables. The plat data are RM feed in ton/day (X1), kiln feed in ton/day (X2), inlet gas temperature (Tin) in ^{o}C (X3), inlet gas pressure or Pin in mmHg (X4), and residue in wt. % (X5). Residue in here is the mass fraction in percent of RM product with particle size less than 200 mesh. The both dust removal system (EP and BF) are analyzed using daily real plant data before (July to September 2015) and after (November 2015 to January 2016) system replacement that can be obtained in the supplement data (Table A.1 and A.2) rsepectively. The complete equation of the regression result is represented in Eq. 1. Then, P-value will be used to remove insignificant variables with the limit of 15%. Thus, the variable which has P-value lower than 0.15 will be rejected and the model is re-evaluated using only the remaining variables. The regression was done using Microsoft Excel 2013.

$$\text{Dust emission (Y)} = C0 + C1(\text{RM feed}) + C2(\text{kiln feed}) + C3(\text{Tin}) + C4(\text{Pin}) + C5(\text{residue}) \quad (1)$$

Beside the dust emission, the power consumption between the two systems is also compared using data of electrical capacity and average usage.

3. Results and Discussion

The comparison performance of the former EP versus the new BF system in terms of outlet dust emission (Y) is shown in Figure 1. In general the BF performance is far above EP in minimizing the dust emission. Indeed, EP design specification stated that outlet dust is 50 mg/m^3 in Table 2, thus most of the real dust emission is still below the targeted value. However, the fluctuation of the emission from the EP system is quite frequent during 80 days of observation while in the new BF system the dust emission is much stable at below 10 mg/m^3.

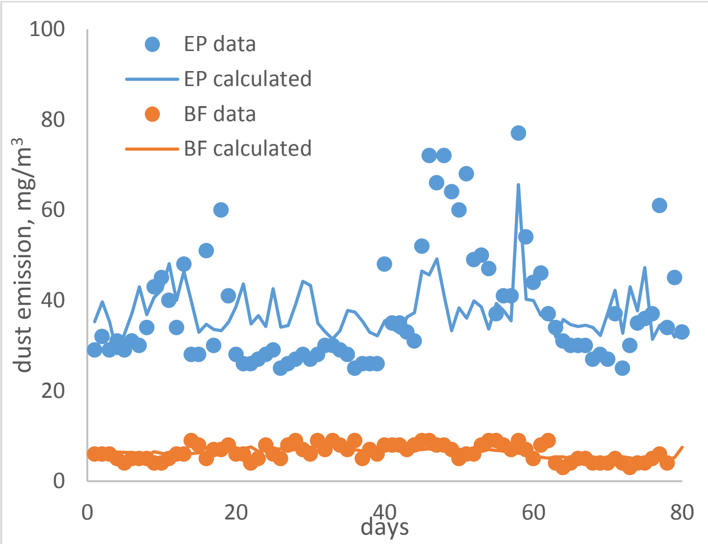

Figure 1. Dust emission data of EP and BF system, real plant data and calculated from regression

The five process variables (X_1-X_5) were used to model the dust emission (Y) for each system using simple multivariate regression method. The variables were chosen because they are easy to be collected from the plant data record and mostly available in a real time basis. The method is used to determine the important variables which has significant effect on the dust emission rather than to predict the emission. Because the emission is actually an intertwined parameter, many factors get involved in this air quality indicator.

Table 3. The regression result of EP system

	5 variables		3 variables	
Multiple R	0.4245		0.4219	
R Squared	0.1802		0.1780	
Significance F	0.0096		0.0016	
Regression	Coefficient	P value	Coefficient	P value
C_0	242.2133	0.050245	282.8821	0.000378
C_1	-0.36878	0.095111	-0.34985	0.102161
C_2	-0.56704	0.013869	-0.60454	0.001136
C_3	0.364608	0.65621	0	-
C_4	0.012802	0.889859	0	-
C_5	7.161029	0.035398	7.19346	0.030258

The regression result of EP system is listed in Table 3. By using complete set of variables, the calculated R^2 value is 0.18 with a quite good significance F test value which indicate that some of the selected dependent variables (X_1 to X_5) have correlation with the fluctuation of the independent variables. Meanwhile, the P value of some variables i.e. X_1, X_3 and X_5 are higher than 0.15 which represent a low correlation to the related independent variables. If these variables are omitted, the significance is increased with negligible reduction of R^2 value. It is confirmed that the RM feed (X_1), kiln feed (X_2) and residue (X_5) are the most important variables to determine the dust emission of EP system. Among the three variables, the small size particle fraction is the most significant variable due to the highest value of the corresponding coefficient. It can be said that the increase of small fraction particles will significantly increase the dust emission or lowering the efficiency of EP dust removal.

$$\text{Dust emission } (Y_{EP}) = 282.8821 - 0.3498.X_1 - 0.6045.X_2 + 7.1935.X_5 \quad (2)$$

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Table 4. The regression result of BF system

	5 variables		2 variables	
Multiple R	0.5457		0.4900	
R Squared	0.2978		0.2401	
Significance F	$9.0559.10^{-5}$		$2.5565.10^{-5}$	
Regression	Coefficient	P value	Coefficient	P value
C_0	14.2749	0.0057	7.1962	0.0103
C_1	-0.0072	0.5609	0	
C_2	-0.0116	0.4516	0	
C_3	0.0272	0.1414	0.0306	0.0917
C_4	0.0374	0.0007	0.0387	0.0001
C_5	-0.3910	0.2036	0	

For a new installed dust removal system of bag filter, the regression results are listed in Table 4. Quite high R squared value indicated that the variation of dust emission can be explained by the selected independent variables. The very low of significance F value confirm that there is a strong correlation between dependent and independent variables. From the P test value, only two variables (X_3 and X_4) which contribute significantly to the dust emission. Equation 3 shows the final equation of the dust emission correlation in the BF system.

$$\text{Dust emission } (Y_{BF}) = 7.1962 + 0.0306.X_3 + 0.0387.X_4 \quad (3)$$

In terms of electric energy, the BF has lower energy demand compared to EP. The energy saving mainly from the omitted electrode side while the energy surplus is from the motor fan since BF requires higher pressure drop than EP. The other excess energy of BF system are from additional conveyor and air dryer. The energy reduction in one side with new energy demand on the other sides caused the energy saving is not so high that can be observed in Table 5.

Table 5. Electrical energy real demand and installed capacity

	EP		BF	
Equipment	Capacity, kW	Usage, kW	Capacity, kW	Usage, kW
motor fan	890	830	1800	1200
electrode	680	630	-	-
compressor	-	-	396	130
conveyor	30	27	67	60
air dyer	-	-	22	20
total		1487		1410

The reduction of power consumption here is approximately 70 kW, by having the correlation of CO_2 specific emission of each KWh generated is equal to 726 gCO_2 according to International Energy Agency (IEA), the CO_2e reduction can be estimated. Thus by modification EP to BF system, the CO_2 reduction is equal to 240 kg per year.

4. Conclusion

The EP replacement to BF system is successfully reduce and solve the problem of emission fluctuation in ITP plant. The dust reduction is significant from around 35 to 6 mg/m^3. By multivariate regression analysis it is observed that the raw material properties and quantity were statistically significant to the dust emission during electrostatic precipitation usage. However after replacement to fabric filter, only the process variables of inlet temperature and pressure are significant to the particulate emission. In terms of power consumption, BF system has a reasonably lower power demand than EP system by approximately 70 kW which is equal to reduction of CO_2 emission by 0.240 ton/year.

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