ICESP X – Australia 2006
Paper 5A2

SIZING AND DESIGN OF ELECTROSTATIC PRECIPITATORS FOR IRON ORE SINTER BAND

GUO RUILIN, MA WENLIN, KANG JINHUA ,KANG JIANBIN
Xuanhua Metallurgical Environmental Protection Equipment Manufacturing (Installation) Co.,Ltd
Contact_wenlinma@sohu.com

ABSTRACT
As the development of sintering process and growing strict regulation on particulates emission, the requirement on sinter waste gas electrostatic precipitator (hereinafter referred to as ESP) becomes more and more stringent. However, processes such as high degree of alkali sintering process and operating under high negative pressure have significantly effected on process ESP. In this paper, several issues are fully discussed which should be taken into account when sizing ESPs based on the features of gas and particulates to be treated by process ESP for a sinter in order to meet the requirement of process dedusting for a sinter, to reach the aim of gas purification.

INTRODUCTION

Sinter band waste gas ESP has been in operation successfully as both process equipment and dust control equipment for decades. The company has produced more than one hundred Sinter waste gas ESPs widely used in various large-sized steel plants as designated large-scale professional dust control equipment manufacturer by metallurgical sector, having accumulated extended experience. Gas composition and dust composition for Sinter waste gas ESP have become more and more complicated along with the wide use of high alkaline degree sinter process and bigger capacity of sinter machine. This is quite adverse to dust collecting, leading to sizing difficulty of Sinter waste gas ESP. High negative pressure process brings higher demanding to ESP strength. Pointing to this we summarize our years applications and experiences as follows for reference.

FEATURES OF GAS AND DUST FROM SINTEER BAND

Gas Composition

The gas composition consists of the following parts:

- Waste gas from sinter material burning.
- Surplus air.
- Gas produced from igniter.
- Steam from blended material and crystal water burning.
- CO_2 and CO when combustibles burning among blended material.
- SO_2 when sulfide burning and waste gas when other oxides burning among blended material.
- Air leakage through gaps when blended material contracting.
- Air leakage in air chamber and dust.

So waster gas comprises mainly of N_2, O_2, CO_2, CO, and SO_2.

Dust Composition

Dust composition depends on sinter raw material (refined ore or rich ore), fuel (coke or smokeless coal), flux (lime stone, serpentine, dolomite and quick lime) and combustion process.

Raw materials vary among large steel plants domestically, and dust compositions differ accordingly. Most of the raw materials come from abroad and part of the overseas ore possesses higher content of elements such as Na, K, Zn existing in forms of K_2O, Na_2O and ZnO [1]. The content of K_2O and Na_2O in collected dust from some Sinter waste gas ESP is even over 20%, besides the particle size of K_2O and Na_2O is less and their specific weight is also less, dust reentrant is liable to occur which is quite adverse to performance of ESP[2]. Therefore the dust composition is of Fe_2O_3, SiO_2, Al_2O_3, CaO, MgO, MnO, P_2O_5, S, C, FeO and other forms of K_2O, Na_2O and ZnO as well.

Large Gas Negative Pressure

Along with the wide use of high alkaline degree sinter process and capacity increasing of sinter machine, the thickness of raw material layer gets larger and larger, with adopting imported larger air flow fan and high negative pressure process, normally between 15000 to

26000 Pa. This demands the strength and rigidity to structure of Sinter waste gas ESP.

Low Dust Concentration

Most sinter plants adopt bottom paving system to enhance rate of finished products and to protect sinter bed. With this system the dust content gets down in large scale, normally around 1 to 5g/Nm^3 with fine particulates.

Relatively High Dust Resistivity

Dust is not easy to be collected because of rather high content of SiO_2, Al_2O_3, CaO.

High Gas Humidity

Normal sinter plant is of two grades or three grades of material blending system into which large amount of water or steam is added. This water goes into the waste gas in form of steam during sinter process and this steam will condensate while gas temperature becomes below its dew point. High moisture in gas makes the sticking force of dust increase and the dust cake attached on surface of collecting electrode (CE) and discharge electrode (DE) hard to be rapped off, besides dust builds up easily on tips of DE leading to field current towards zero and collecting efficiency towards zero as well. In addition, high moisture and high SO_2 content in gas flow demands corrosion protecting to ESP.

Generally speaking, the complexity of dust composition and gas composition brings a general characteristic:

High specific resistivity: normally 10^{11} to 10^{12} O.cm
Fine dust particles: 2.5 to 100 μm
High viscosity
High moisture: 6 to 15%
High corrosion of gas

ESP SIZING AND DESIGN

The company has cooperated with engineering & research institutes and steel mills executing industrial experiments on sinter waste gas ESP such as gas velocity, type of discharge electrode and collecting electrode with their space and migration velocity[3].

Collecting efficiency n [4]

Calculation Method One

Calculating according to inlet dust content and required emission content offered by customer, the formula is:

$$n=1-Co/Ci$$

Where: Co------dust inlet content
Ci-------dust outlet content

Calculation Method Two

Calculating according to Deutsch-Anderson equation

$$n=1-e^{-AW/Q}$$

Where: Q--------gas flow at ESP inlet
A--------ESP collecting wall area
W-------dust migration velocity

Deutsch-Anderson equation is the base of ESP sizing and we can tell from it that collecting efficiency can be high enough only when both A and W are as high as possible. The higher the W design value is selected, the less the A design value is, and the more economic, the more difficult to reach the required dust collecting efficiency. In contrast the higher the cost is and the easier to reach the required dust collecting efficiency.

Find a point at which both factors are considered in selecting the design value of A and w based on extended experience.

Gas Velocity

$$V=Q/F$$ [4]

Where: Q-----gas flow
A-----ESP effective cross sectional area

Today normal Gas velocity V in electric field ranges 0.4 to 1.5m/s. We can tell from Deutsch-Anderson equation that Gas velocity V in Field has nothing to do with collecting efficiency. Over high Gas velocity V in Field to a definite collecting wall area, however, not only makes ESP longer, slenderer and occupy too much area, but also cause dust reentrant and down collecting efficiency. In contrast, under a certain gas flow to be treated the over low Gas velocity V in Field definitely leads to larger field cross sectional area, and makes ESP bigger and non uniform gas distribution[5].

Therefore the most economic Gas velocity V in Field should be selected to reach the required dust collecting efficiency. Gas velocity V in Field is considered with gas features and dust features as well. When dust particle size is large, dust quantity is large and specific resistivity is low Gas velocity V in Field can be raised properly. In contrast, when dust particle size is low, dust quantity is small and dust specific resistivity is high Gas velocity V in Field can be decreased properly.

Based on the gas and dust features of Sinter waste gas ESP, Gas velocity V in Field normally ranges 08. to 1.2m/s. Gas velocity V in Field normally does not go over 1.0m/s with Sinter waste gas ESP which deals with gas having high content of K_2O, Na_2O and ZnO.

Migration Velocity W

Migration velocity equivalent formula:

$$W=KxEd^2$$

Where: Kx----Comprehension varying factor of gas condition
A------Field operating voltage

Basic factors which affect dust migration velocity W are particle size, resistivity, chemical composition, electrode spacing and so on. Normally W is decided according to experience and ranges from 7 to 12 cm/s. W of 10cm/s is proper for Sinter waste gas ESP with electrode spacing 600mm and of 8cm/s is proper for Sinter waste gas ESP with electrode spacing 400mm. W will be lower for dust of high content of K_2O, Na_2O and ZnO.

ESP Height/Width Ratio

Pointing to the features of fine particle, high viscosity and high moisture of sinter waste gas, ESP Height/Width Ratio for Sinter waste gas ESP should be selected less than 1.2, otherwise the dust cake attached on upper part of collecting wall is hard to be rapped off, and gas distribution is affected, turbulence will occur and affect dust collecting efficiency. When ESP Height/Width Ratio is over 1.2 because of space limit, a voice-wave dust cleaning device on ESP top should be installed to ensure dust cleaning effect.

Spacing

There exist several electrode spacing for sinter waste gas ESP such as 400mm, 450mm, 500mm and 600mm. In our opinion electrode spacing 600mm is better according to our decades of experience. Generally thought that in wide electrode spacing sinter waste gas ESP electric wind (ion wind) occurred under high voltage is utilized more to strengthen the dust migration towards collecting electrode in addition to the original coulomb's force. When voltage rises over 100KV, the electric wind velocity adjacent to discharge electrode reaches 9 to 13m/s, however, only 0.8 to 1.8m/s around collecting electrode. The electric wind velocity adjacent to discharge electrode reaches 5 to 8m/s, however, only 2 to 3m/s around collecting electrode with conventional ESP [6]. From this the following advantages are obvious:

- Dust migration velocity W is higher. We can tell from Deutsch-Anderson equation that collecting efficiency rises along with rising of dust migration velocity W.
- Secondary voltage is raised with wide electrode spacing and this may enhance field strength and suppress or delay the occurrence of back corona, keep the field stable.
- The electric wind velocity adjacent to discharge electrode in wide electrode space ESP is higher than that in conventional ESP and the electric wind velocity adjacent to collecting electrode in wide electrode spacing ESP is lower than that in conventional ESP, so decreasing of collecting efficiency due to dust reentrant can be reduced and good for fine dust capture.
- Wide electrode spacing is good for gas with low inlet dust content and high

specific resistivity.

- Facilitate the erection and maintenance of ESP.
- Lower down the capital cost and save around 10% of specific steel consumption.

Electrode Geometry

There is a variety of electrode matches with domestic sinter waste gas ESPs such as electrode spacing 600mm, BS106 wire or star wire as discharge electrode and small C390 plate as collecting electrode, electrode spacing 500mm, BS116 wire as discharge electrode and big C390 plate as collecting electrode, electrode spacing 450mm, BS116 wire as discharge electrode and big C390 plate as collecting electrode, electrode spacing 450mm, ten fins wire as discharge electrode and big C390 plate as collecting electrode, which all work well.

Because of low dust content with sinter waste gas ESP, we think from our design experience with sinter waste gas ESP that electrode spacing 600mm, BS106 wire as discharge electrode and small C390 plate as collecting electrode is used for field 1 and 2, and electrode spacing 600mm, star wire as discharge electrode and small C390 plate as collecting electrode is used for field 3. This electrode match is suitable to low dust content and reduces capital cost.

- BS106 wire has good electric discharging with even distribution. It can eliminate corona blind zone and has 25 to 37.5% more discharging points than RS116 wire matched big C480 CE plate. Electric density over plate is increased and distributed more evenly with easier capture of larger particles in field 1 and 2.
- Small C390mm plate has 25 to 37.5% more wind against groove than big C390mm plate which prevents fine dust from reentrant. Small C390mm plate is narrower than big C390mm plate, having good strength and rigidity which can bear sufficient rapping force (both side rapping) and transmit rapping force well.
- Star wire is used as DE in field 3 which may raise field strength to facilitate capture of fine dust.
- Higher secondary voltage is gained with electrode spacing 600mm which features high field strength, high migration velocity and easier capture of low dust content fine particles.

This electrode match has been successfully employed with a variety of sinter waste gas ESPs in Bao Steel, An Shan Steel, Sha Steel, Mei Shan steel, Ma Anshan Steel and Wu Han Steel.

ESP Structure

None frame structure is adopted when ESP effective cross sectional area is less than $120m^2$. Frame structure single chamber is adopted when ESP effective cross sectional area is between$120m^2$ and $220m^2$. Frame structure double chamber is adopted when ESP effective cross sectional area is more than $220m^2$.

Electrodes Rapping

There are a variety of factors affecting the dust collecting performance among which rapping is. When dust is of large particle, low viscosity and low specific resistivity, the dust build-up on surface of CE by field force is easy to be rapped off. In contrast it is hard to be rapped off, so a reliable raping device is needed. Because of fine dust, high viscosity and high specific resistivity with Sinter waste gas ESP, a sufficient rapping force is required to ensure satisfactory dust collecting.

In line with power industry standard, rapping acceleration for DE is over 50g and rapping acceleration for CE is over 150g. The rapping acceleration for DE and CE with Sinter waste gas ESP must be higher than those values, otherwise dust cleaning is not sufficient.

Sinter waste gas ESP adopts both sides rapping for CE with number of hammers increased, and two sets of rapping devices for DE located at upper and lower part respectively in each power supply section. When the length of CE plate is over 13m, a combination of side rapping and voice-wave dust cleaning device shall be adopted and a reasonable rapping circle shall be planed to ensure effective dust cleaning.

Side rapping has been widely used in ESP in China with good performance and is suitable for various dust because this structure enables CE and DE get sufficient acceleration values. The acceleration on CE is over 200g and the acceleration on DE is over 80g.

In respect of structure, side rapping can withstand strong strike without breakage and this makes long term stable operation possible.

Dust Discharging

Because of the high negative pressure with sinter waste gas ESP air leakage is of significance. Air leakage at hoppers will cause not only reentrainment but also condensation, dust buildup and scaling in hoppers. Experiment has shown that collecting efficiency goes down 50% at air leakage of 5% in hoppers and collecting efficiency becomes zero at air leakage of 15% in hoppers. Therefore double dust discharging value should be used and a vibrator and heating device should be equipped with on hoppers.

Gas Distribution Device

Non-uniform gas distribution will cause flushing and reentrant from CE surface or hoppers. Gas retention time in field will also be changed. Because of these the collecting efficiency may go down 20 to 30% or even more.

Two or three gas distribution walls are installed at inlet nozzle. The opening rate is decided by gas distribution model test made in lab. And site measuring and adjusting is made to ensure root-mean-square difference under 0.25.

Labyrinth dust collecting device is installed at outlet nozzle. Setting of transverse clearance and longitudinal clearance of Labyrinth dust collecting device is the key point to reduce the pressure drop and to collect electric loaded fine dust particles.

Baffles
Baffles are installed around field and at middle and upper part of hoppers to prevent gas from going short way, which is to say, to make all gas to go through the electric field.

Corrosion Prevention and Thermal Insulation
Amount of air leakage is related with ESP negative pressure. The higher the negative pressure exists, the more the air leakage. So air tightness is of significance to sinter waste gas ESP. Special measures should be taken on parts which are liable to air leakage. Connection between parts of casing should be reasonable and site welding should be air tight. Sealing device shall be set at rapping shaft bushing. Manholes on casing should be double structure. Thermal insulation on casing makes ESP operating above dew point to prevent corrosion.

Electric heating devices and temperature measuring devices are installed in thermal hoods and porcelain shaft boxes to prevent support insulators, porcelain bushings and shaft insulators from condensation. Gas temperature will go over 200^{o}C when sinter bed becomes slow or sinter machine stops for short period. At this time there is a big temperature difference between inner wall and outside wall of support insulator due to which the support insulator is liable to break. So the power of electric heating device in the hood must be large enough to keep the temperature in the hood no less than 100^{o}C.

Power Supply
Outdoor power supply is used and installed on top of ESP which saves land occupation, reduces occurrence of breakage and does without high voltage cables.

The capacity of power supply is selected according to ESP operating voltage and current with considering requirements on non-load voltage rising. When non-load commissioning two power supplies may be run parallel to reach the criteria of non-load voltage rising. When running under load single power supply is adopted.

Power supply is controlled with micro computer which traces the varying load in each field and keeps the instant optimum dust collecting effect. High impedance transformer rectifier is adopted to suppress short circuit current and improve waveform.

Earthing
Earthing of ESP is a working one. Each ESP has its own independent earthing net that the earthing resistance is less than 2O.

There are at least 6 earthing bars of over 160mm^2 in cross sectional area between earthing net and ESP casing.

The connecting wire between earthing terminal on each rectifier and earthing bar of ESP should be copper wire of over 16mm^2 in cross sectional area. All earthing terminals on rectifier shall be connected with copper wire of over 50mm^2 in cross sectional area and be linked to control room and be connected with control room eaarthing bus row.

CONCLUSION

As the development of sintering process and growing strict regulation on dust emission, the requirement on Sinter waste gas ESP becomes more and more stringent. Therefore rational sizing of Sinter waste gas ESP is significant. Knowing the sintering process and dust characteristics well is the precondition to rational sizing of sinter waste gas ESP. Only rational sizing can meet the waste gas dust removing process requirements, to reach the purpose of gas cleaning.

REFERENCE

[1] Shen Huiguo, Du Jianxin, Wu shengli. *Experimental Research on Basic Sintering Features of Iron Ore powder,* Metallurgical Research, 2005.

[2] He Litang, Qi Fengming. *Characteristics and Applications of Sinter waste gas ESP*, 10th National Conference on Electrostatic Precipitation/2nd Desulfurization, Academic Discussion. 2003

[3] Qi Fengming, Yu Tianchi. *Research on sinter waste gas ESP in Wu Han steel,* Proceedings of 4th International Conference on Electrostatic Precipitation, 1987

[4] Liu Houqi, Lin Hong. *Electrostatic Precipitator,* China Construction Industry Press, 1987.

[5] Electrostatic Precipitator for Coal Fired Power Station. Safety and Environmental Protection Bureau, China Power Association Environmental Protection Company, 1993

[6] Tan Tianyou, Liang Fengzhen. *Industry Ventilation Dust Removing Technology,* China Construction Industry Press, 1984

[7] *Dust Removing Equipment Design*. Shanghai Science and Technology Press, 1985

[8] Tan Tianyou, Wang Liqian. *Electrostatic Precipitation*, Hydraulic and Power Press, 1983