Strategy and Criterion of Gas Distribution about EFIP

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Abstract: Three key focuses about gas distribution of EFIP(Electrostatic Fabric Integrated Precipitator) is proposed .Mathematic relation between efficiency of electrostatic and uniformity of flow distribution is deduced. Upper limit of Sedimentation velocity is acquired with Stokes equation. Another relations between bags life and eroding velocity , costs and flow uniformity of outlet damper are also discussed.

Keywords: EFIP, gas distribution ,criterion, eroding velocity, Sedimentation velocity

1. Introduction

ESP is the main type of dust collector serving in coal-fired power plant in many countries. however, ESP has difficulties on meeting more and more severe emission standard of air pollutants in many countries. Meanwhile FF and EFIP become more welcome because their low particulate emission. For the same flue volume, the higher the removal efficiency is required, the choice between ESP and FF or EFIP tends to favor the FF or EFIP.

EFIP was developed in recent years and had many successful cases especially on retrofitting projects in coal-fired power plant. EFIP has many advantages as that dust removal efficiency has nothing to do with types and specific resistance of coals. Electrostatic coagulation property helps to capture the fine particles as PM10 and PM2.5.

Comparing with ESP and FF's Nearly a century of history, EFIP is also a new product. There are many technologies including gas distribution and structure strength and so on are needed to be explored. Among these complicated technologies, gas distribution of EFIP should be solved firstly, because it has very important influence on bags life ,dust emission ,pressure drop ,etc. More efforts should be made to get the optimal scheme about gas distribution of EFIP.

2. Operation Mechanism of EFIP

EFIP is a new type high efficient dust collector combining electrostatic and filtration mechanism. When it is in operation, most of the coarse particles are captured by electrostatic force and the remaining particles are captured by bags. EFIP is composed of inlet duct, vessel, porous plates, collecting plates ,emitting-electrodes, power supplies, bags, nozzle house, outlet duct, support structure, etc. As shown in Fig 1.

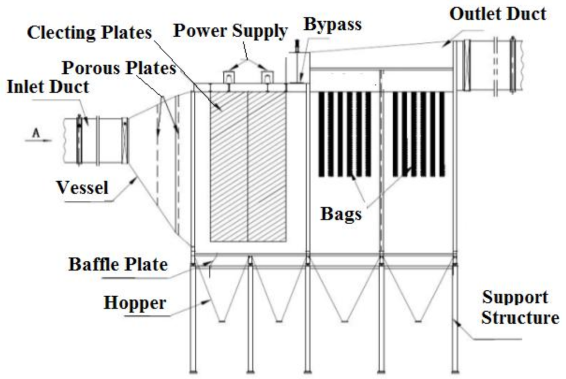

Fig. 1 Sketch of EFIP

3. Strategy about Gas Distribution of EFIP

There are three main focuses about gas distribution of EFIP in the process of collecting dust from inlet duct to induced draft fan.

1）Mean velocity in the section of inlet duct is about 15m/s, however, mean velocity in the electric field needs to be less than 1 m/s and flow velocity should have enough uniformity to acquire enough treatment time. So a diffusing vessel with porous plates and guiding vanes is needed .

2）When electrostatic process is finished ,flues enters into filtration process and another problems about gas distribution produces. One is eroding velocity relating with bags life, another is sedimentation velocity relating with re-entrainment of dust. The theoretical estimation and many practices on engineers showed that eroding velocity and sedimentation velocity should be in a special range.

3）The last focus is about uniformity of filtration velocity and deviation of outlet dampers flow which is closely related with costs of bags and pressure drop.

4. Criterion about Gas Distribution of EFIP

4.1 Eroding velocity

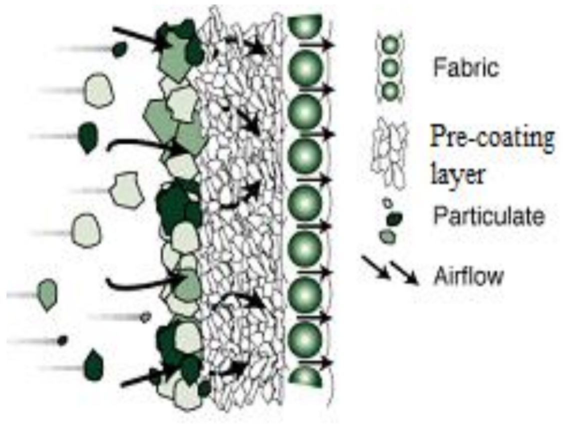

Fig. 2 Sketch of filtration principle

Most bags abrading failure was caused by high eroding velocity in local region. However ,particle abrading character also have relation with hardness, density and size of particle besides value of eroding velocity. So it is difficult to determine a accurate value of eroding velocity.

However, several measures can be adopted to avoid or lighten abrading damages to bags as making gas distribution schemes of EFIP .

1)Reasonable layout is very important to control eroding velocity. The ratio of bags' area and gap in the dust-facing section is one key factor on controlling eroding velocity.

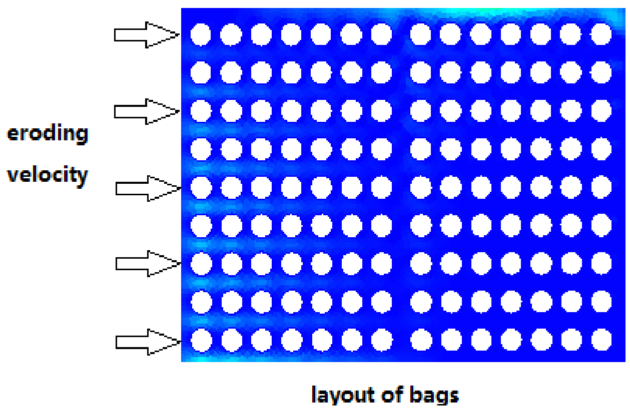

Fig. 3 Reasonable layout of bags

2）Appropriate measures as baffles or porous plates should be installed in the position existing high velocity to protect bags from being abased.

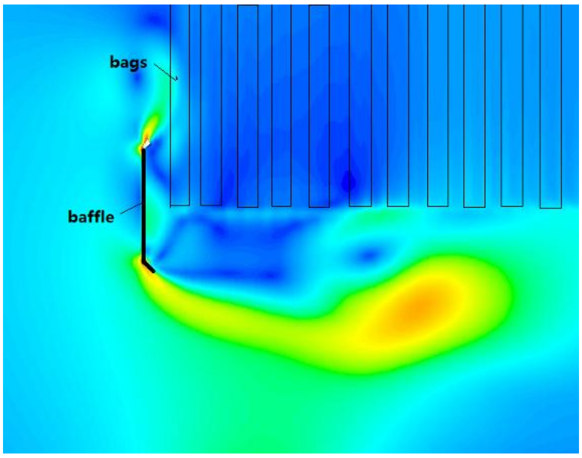

Fig. 4 Magnification of baffles in local position

3）Dust cake on the surface of bags can avoid dust and fabric contacting directly and protect bags from abrasion effectively. So pre-coating dust and lowering cleaning intensity become very important to keep the dust cake on the surface of bags .As shown in Fig.2.

4.2 Sedimentation velocity

It depends on the resultant force of gravity and Stokes buoyancy that the dusts can settle into the hopper other than Re-entrainment.

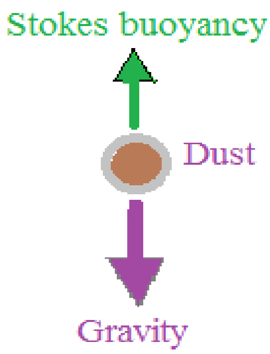

Fig. 5 Force diagram of dust

Sedimentation velocity can be derived according to the Stokes formula(4-1).

$$v_s = \frac{g \rho_c d_c^2}{18 \mu} \qquad (4\text{-}1)$$

where g is the gravity acceleration(m/s^2),ρ_c is the density of dust (kg/m^3), d_c is the diameter of dust(m),μ is the dynamic viscosity of air (pa • s).

An actual example about EFIP was taken to analyze the relationship between sedimentation velocity and re-entertainment.

It's parameters are ρ_c=2.1x103(kg/m^3), μ=2.4e-5(pa s). The size distribution of dusts obtained by Mastersizer 3000 is shown in Fig 6.

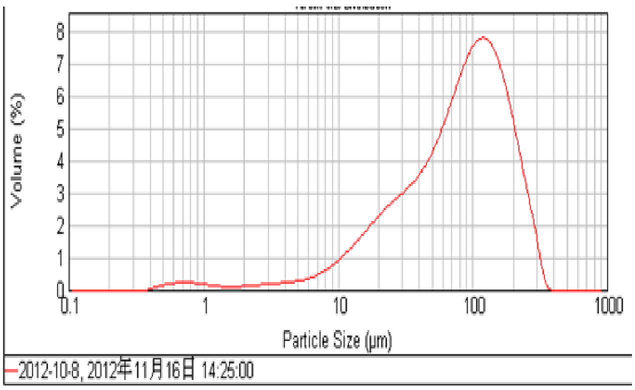

Fig. 6　Particle size distribution

Several points was chosen as characteristic value to calculate the sedimentation velocity in Table1. An curve reflecting the relation between particle size and sedimentation velocity can be acquired .As shown in Fig 7.

Table 1：Relation of particle size and Sedimentation velocity

Scale of particle size (μm)	<44	<89	<126	<178	<316
Percent(%)	10	30	54	80	99
Sedimentation velocity(m/s)	0.09	0.38	0.76	1.51	4.76

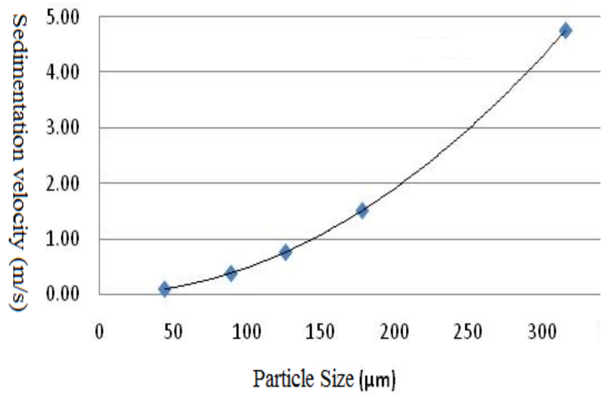

Fig. 7 Relation of particle size and sedimentation velocity

The curve in Fig 7 show that it is enough to raise 54% dusts only if the gas velocity's up component is larger than 0.76m/s. and if the particle size is more than 178μ m ,the gas velocity's up component should be larger than 1.5m/s .

Normally the gas velocity's up component in EFIP is more than 1.5m/s. So re-entrainment will not happen only if particle size is larger than 178μ m .

Therefore, several measures should be adopted to prevent re-entrainment and ensure the dusts can settle into hopper easily.

1)The guiding vanes should be installed in front of the bags to acquire a downward velocity .This measure helps dusts to settle into hopper easily and prevent re-entrainment.

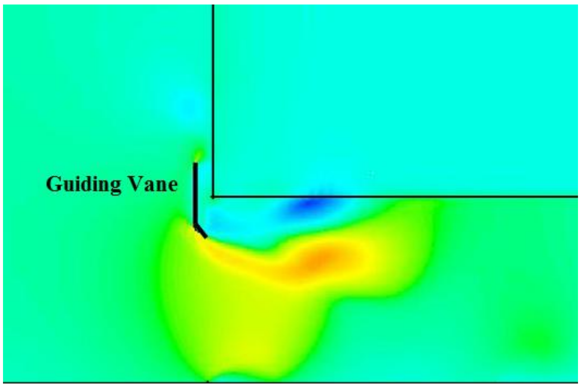

Fig. 8 Downward velocity by guiding vane

2) Appropriate cleaning intensity is very important to help dusts to settle into hopper. Bulk dust cake is similar with a big particle with large diameter and it needs very large gas velocity to blow it up. As shown in Fig.9.Excessive cleaning intensity doesn't benefit the formation of bulk dust cake, so it become very important to acquire a optimal value of cleaning intensity.

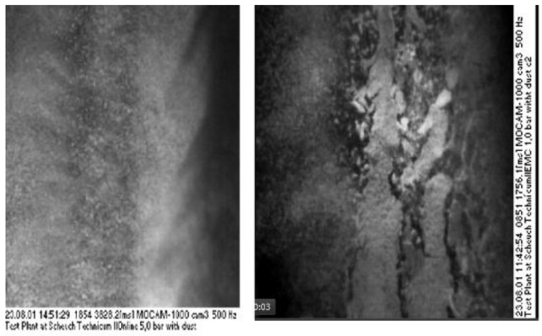

Fig.9　Excessive and appropriate cleaning intensity

3) It can be found that diameter of charged dusts is bigger than uncharged dusts, as shown in Fig.10. So Electric coagulation also helps to prevent re-entrainment.

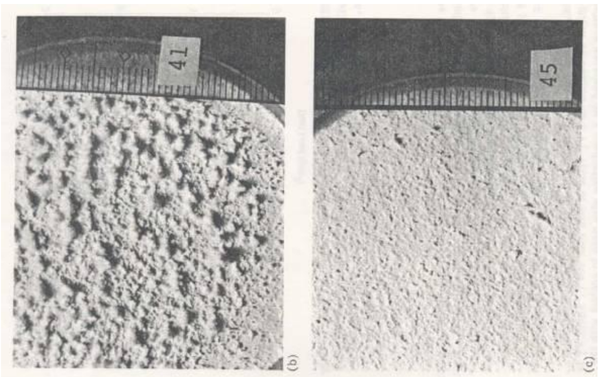

Fig.10　Charged dusts and uncharged dusts

4.3 Efficiency and Uniformity in Electric Field

In electric field, suitably velocity and flow uniformity have important effect on electrostatic dust removal efficiency. However, high efficiency usually corresponds with more high pressure drop and more complicated gas distribution parts. On the other hand, if most of the coarse dusts are captured and most of the rest dusts are fine particles, the fine particles will not only damage the formation of dust cake but also increase PM 2.5 emission. So a suitable efficiency of electrostatic dust removal and uniformity of gas distribution in field is needed to be confirmed.

According to the modified Deutsch formula, the efficiency of electrostatic precipitator is expressed by the following formula:

$$\eta = 1 - e^{-(\frac{A \bullet \omega}{Q \bullet f_0})} \qquad (4\text{-}2)$$

$$f_0 = 1 + 0.766\,\eta_0 \bullet \sigma_r^{1.786} + 0.0755\,\sigma_r \bullet \ln(\frac{1}{1-\eta_0}) \qquad (4\text{-}3)$$

$$\sigma_r = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}\left(\frac{v_i - v}{v}\right)^2} \qquad (4\text{-}4)$$

where ω is dust drift velocity（m/s）,A is total collecting area(m^2),Q is flow rate(m^3/s)， f_0 is the correction coefficient of ω and it is a function of airflow uniformity σ_r.(4-3)， v_i is the velocity of measuring point, v is the mean velocity of measuring points, n is the total number of measuring points,$\eta_0$is the ideal efficiency as σ_r=0 ， η is actual efficiency.

A type FAA2X20M-2X96-140-8 EFIP was taken as the example to verify the relation between η and σ_r. As shown in Fig.11.

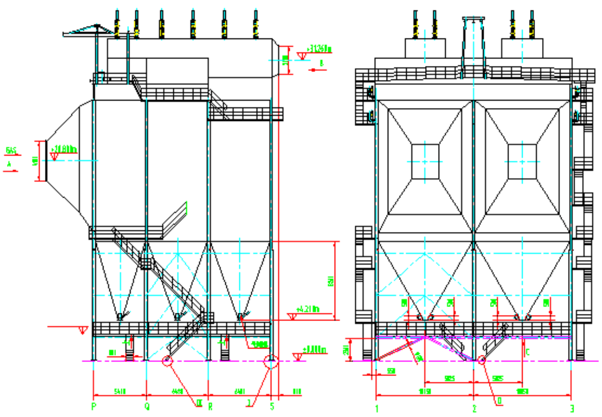

Fig.11 Sketch of FAA2X20M-2X96-140-8 EFIP

A=5376(m^2),Q=1100079(m^3/h),ω=10(cm/s)(difficultly collected dusts）.

So it's ideal efficiency can be acquired as σ_r=0:

$$\eta_o = 1 - e^{-(\frac{5376\times 0.1}{1100079/3600})} = 82.783326\ \%$$

and then the relation between f_o , σ_r andη can be acquired. As shown in table 2:

Table 2: Relation between σ_r ,f_o , andη

σ_r	0.10	0.20	0.30	0.40	0.50
F_o	1.02	1.06	1.11	1.18	1.25
η（%）	82.07	80.91	79.40	77.58	75.51

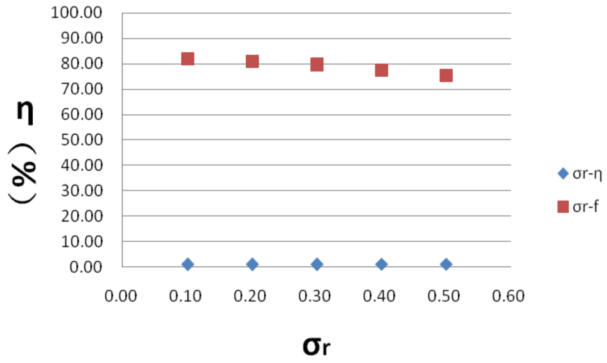

Fig.12 Relation between σ_r ,f_o , andη

Usually the electrostatic dust removal efficiency is set to about 80% on engineering . It can be found that the dust removal efficiency is about 79.4% even if σ_r increases to 0.3， the value of η is also enough to meet the design requirement of EPIP. The dust removal efficiency will be 82.07% when σ_r decreases to 0.1, Only 2.67 percentage points is increased. however, so good gas distribution quality will not only need very complicated guiding devices but also more high pressure drop will happen.

Nowadays ,it is very usual that CFD technology is used on analysis of ESP,FF,and EFIP gas distribution. so the model based on the above example was setup and the results were acquired as Fig.13.

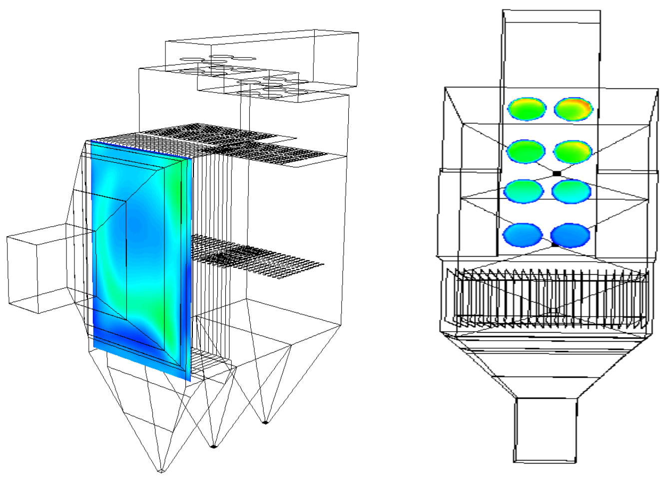

Fig.13 Contours of velocity in electric field an outlet dampers

Table3:Distribution of Measure point Velocity

Points	1	2	3	4	5	6	7	8	9	10
1	1.4	1.3	1.1	1.1	1.2	1.3	1.4	1.6	2.0	1.8
2	1.1	1.2	1.3	1.2	1.2	1.3	1.4	1.7	2.0	1.6
3	1.0	1.4	1.4	1.2	1.2	1.3	1.4	1.7	2.1	1.6
4	1.2	1.5	1.2	1.1	1.0	1.1	1.2	1.4	2.0	1.7
5	1.3	1.5	1.1	0.9	0.9	1.0	1.1	1.2	1.7	1.5
6	1.4	1.5	1.0	0.9	0.9	0.9	1.0	1.1	1.5	1.2
7	1.5	1.5	1.0	1.0	0.9	1.0	1.0	1.2	1.4	1.0
8	1.4	1.6	1.1	1.1	1.1	1.1	1.1	1.3	1.4	0.5
9	1.3	1.7	1.3	1.2	1.3	1.3	1.3	1.5	1.4	0.4
10	1.1	1.7	1.6	1.4	1.5	1.6	1.6	1.7	1.4	0.4
11	0.9	1.6	1.9	1.8	1.8	1.8	1.9	2.0	1.4	0.4
12	0.7	1.3	1.6	1.7	1.6	1.6	1.9	2.1	1.5	0.5
13	0.6	1.0	0.9	0.8	0.7	0.8	1.1	1.8	1.6	1.0
14	0.4	0.6	0.4	0.4	0.4	0.4	0.5	1.1	1.5	1.2
15	0.7	0.8	0.9	0.9	0.9	0.9	0.9	0.9	1.0	1.0

It can be calculate that v=1.24(m/s), σ_r=0.32 and η =79.06%. It means that 79.06% particles can be captured and only 20.91% particles need to be captured by bags. This is very low load to fabric filter and it benefits bags life very much.

Table4: Distribution of volume

	Volume (m^3/h)	Deviation (%)		Volume (m^3/h)	Deviation (%)
L1	49039	-8.3	**R1**	49039	-8.3
L2	50345	-5.9	**R2**	50345	-5.9
L3	56646	5.9	**R3**	56646	5.9
L4	57911	8.3	**R4**	57911	8.3

It can be found that volume of outlet dampers increases Along gas flow direction, meanwhile, dust concentration decreases along gas flow direction. so it demonstrate that the design of outlet dampers benefit uniform distribution of dust loads on bags.

5. Conclusion and Discussion

1）Gas distribution performance has important influence on EFIP operation , costs ,bags life, pressure drop and so on. It is one of the most important technologies and should be pay more attention.CFD is a good choice on analysis of gas distribution.

2）Eroding velocity and sedimentation velocity should be controlled in a certain range when make the EFIP plan. Baffles should be setup to avoid too high velocity in local position. Proper arrange of bags helps to keep the sedimentation velocity in the range and cleaning intensity also have import influence on re-entrainment.

3)Gas distribution uniformity have influence on dust removal efficiency of electrostatic ,however it is not needed too high as ESP. It is enough to keep EFIP operation normally only if σ_r is less than 0.3.

4)Deviation of outlet dampers' volume rate is not very good. however the trend helps to balance the dusts load on bags. This problem should be continued to research in the future.

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