ICESP X – Australia 2006
Paper 2A2

MODEL EXPERIMENTAL RESEARCH ON SKEWED GAS-FLOW TECHNOLOGY

XU GUOSHENG, HE JIAN, LI LIMEI, GUO HUI AND LI ZHE
Environmental Research Institute of Xi'an University of Technology
xuguosheng@xaut.edu.cn

ABSTRACT
Aiming to the research project of renovation of electrostatic precipitators for large-scale Sinter of iron and steel plants, this paper has carried out model experiments through installing guide plates and baffler to adjust the airflow inside precipitator to the predestined skewed profile pattern and analyzed the impact of adjusting device on airflow distribution and finally ascertained the executive plan of skewed gas-flow technology (SGFT).

1 INTRODUCTION

Electrostatic precipitator (ESP) holds important status and has been widely used for gas dedusting in many industries, the airflow distribution inside which is one of important factors affecting the dust removal efficiency.

Since long ago, uniform airflow distribution is simply regarded as the prerequisite of high collection efficiency according to the Deutsch formula. In recent years some experts are suspicious of that and advance that skewed gas flow will help to improve the efficiency than uniform flow pattern, in which with lower flow at the top of the precipitator and greater flow at the bottom at the inlet and the opposite at the outlet and introduce SGFT into industrial application and make prominent success.

So it has a double important significance in theory and practice to adjust original uniform flow pattern into required skewed flow pattern to improve the performance of ESP. Through model experiments, this paper uses several types of adjusting measurements to gain control of gas flow inside ESP and gets the influence law of each measurement to gas flow fields, which establishes the base of determination of SGFT plan and its wide application.

2 EXPERIMENTAL SYSTEM

This experimental system is strictly reduced from a two-chambered three-fielded precipitator by scale of 1:14 and the size of each chamber is 957×836mm. In order to adjust the airflow distribution expediently and control the gas flow inside the model freely, in the inlet, between the first and the second field, between the second and the third field and in the outlet all is loaded with different structural style flow-guide installments (airflow guide plates, airflow uniformization plates and window shade type flow-guide device).

Four typical test sections A, B, C, D, corresponding to the inlet face, gap between the first and the second field, gap between the second and the third field and the outlet face (showed with dashed line in figure 1), are selected to hold the airflow changing conditions of entire model. In each section, 8 anemometers are fixed on a movable pole to move and settle at the eight pre-designed typical positions with the pole and test the 64 measurements. As that to test all four sections in turn, a total 256 measurements are collected, after analysis of which the overall airflow movement inside the model in this work-condition is obtained.

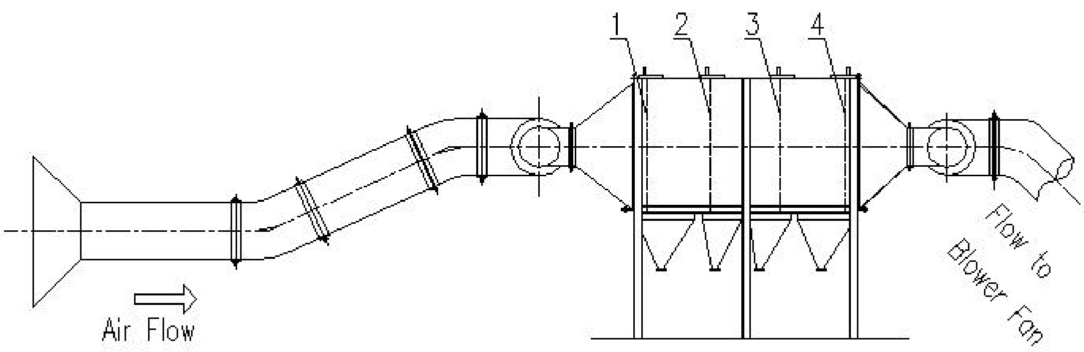


Figure1: Disposing view of test sections

1.Section A 2 Section B 3. Section C 4. Section D

3 SGFT ANALYSES STANDARD

It is well known that the gas flow distribution is an important factor affecting the performance of ESP. The traditional views believed that "the more uniform is the gas flow, the better of the performance" and made the stipulation according to this in the electrostatic precipitator technical standard to take uniform flow distribution as design goal. Current standard widely applied is US'S relative root mean square standard (the RMS standard),

$$s = \sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(\frac{v_i - \bar{v}}{\bar{v}}\right)^2}$$

Where

n = number of measurements in the section

v_i = flow velocity of the i point, m/s

$\bar{v}$ = average flow velocity of the section, m/s

when $s < 0.25$ for qualified, when $s < 0.20$ for good, when $s < 0.15$ for excellent. But for SGFT, there is not a unitive evaluation criterion at present.

The key of determining the evaluation criterion of SGFT is establishing the optimal skewed configuration from inlet to outlet, generally which can be obtained by numerical simulation by using of CFD with the size of precipitator, the operation parameters, the initial flow profile as input data and with the consideration of dust re-entrainment and the non-uniform distribution profile of vertical dust.

Marian.Sarna divided ESP into four work areas along the airflow direction and used the SYMULA-X computer program to study the impact of the linear flow (be perpendicular to cross section of main flow direction) and re-entrainment on removal efficiency. In order to judge the degree of the skewed profile, parameter q is introduced, which is the ratio of the difference between the velocity of linear flow of top and bottom to 1 m/s. It is showed in figure 2 that coefficient of re-entrainment changes between 0 to 0.25 and the change of precipitator performance in flow pattern of $-0.9 = q1 < 0$ is larger than in $0 < q1 = 0.9$ for the first area. That is to say that the pattern of greater flow at the bottom and lower flow at the top at inlet is better than the opposite pattern and it can be deduced that the pattern of q1= - 0.9,q2= 0,q3= 0,q4= 0.9 can provide much higher removal efficiency than uniform pattern.

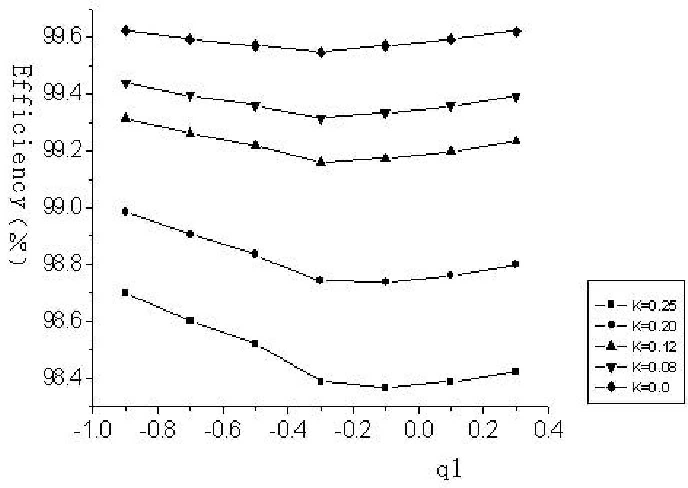


Figure 2: efficiency curve of skewed gas flow

Based on the foundation of predecessors, this paper has analyzed the dust sample of ESP for Sinter and got the law of dust subsidence in electric field and granularity distribution. By taking the target value of ideal airflow velocity profile (showed in table 1) and deviation coefficient as evaluate criterion, the concrete computational method is showed as follows:

1) In the vertical direction, at each position the average measurement of eight anemometers is divided by the average flow velocity of the section firstly, and the difference between the quotient and the target value is multiplied by the average flow velocity of the section in follows. If the product (horizontal deviation) is less than 0.15m/s, it can be considered acceptable, i.e.

$$\left(\frac{\overline{v_i}}{\bar{v}} - m_i\right) \times \bar{v} < 0.15,\ \text{m/s}$$

where

v_i = the average measurement of the i position in the vertical direction(i=1, 2... ...8)

$\bar{v}$ = the average flow velocity of the section

m_i = the target value of the i position in the vertical direction(i=1, 2... ... 8)

2) In the horizontal direction, if the difference between the average measurement of each anemometer at the eight positions of vertical direction and the average flow velocity of the section (vertical deviation) is less than 0.15m/s, the section is qualified.

Table 1 Target value of ideal skewed profile

Section	Target value (from bottom to top)							
A	1.22	1.16	1.09	1.03	0.97	0.91	0.84	0.78
B	1.07	1.05	1.03	1.01	0.98	0.96	0.94	0.92
C	0.92	0.94	0.96	0.98	1.01	1.03	1.05	1.07
D	0.78	0.84	0.91	0.97	1.03	1.10	1.16	1.22

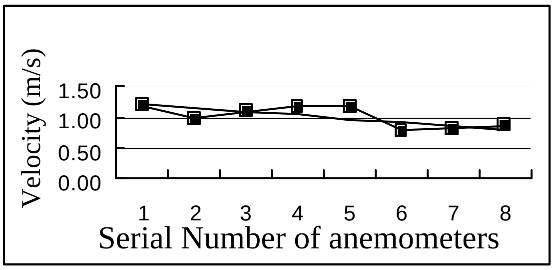
4 RESULTS AND ANALYSIS

Through repeatedly experiments, the optimal combination and characteristic parameters of airflow adjusting device are obtained, which consist of the angle, spacing and quantity of airflow guide plates, the position, angle and width of plates of window shade type guide device and the position of airflow-uniformization plates, and the target skewed airflow configuration is achieved at last. The concrete project is made up of fixing three airflow guide plates(with angle by 25°and width 22mm)on the front of smaller inlet uniform porosity gas flow distribution screen from the top to bottom, installing the window shade type guide device (made up with plates with angle by 30°and width 16mm) between the fist and the second field, assembling airflow-uniformization plates (bestrewed with holes by size of 20mm ×20mm and with opening ratio of 50%) between the second and the third field and setting two porosity screens with the same opening ratio at the outlet face.

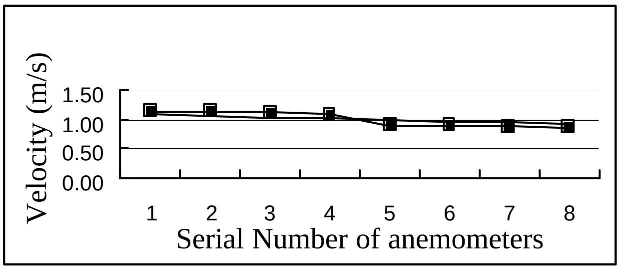
Table 2 Results of experiments m/s

Horizontal deviation	Test section				Vertical deviation	Test section			
	A	B	C	D		A	B	C	D
The fist position	0.08	-0.05	0.02	-0.06	Measurement of the first anemometer	0.02	0.18	-0.08	-0.05
The second position	-0.02	-0.06	-0.01	0.05	Measurement of the second anemometer	-0.16	-0.01	-0.04	0.03
The third position	-0.13	-0.07	0.00	0.08	Measurement of the third anemometer	-0.01	-0.18	0.06	0.04
The fourth position	0.19	-0.08	0.04	0.08	Measurement of the fourth anemometer	0.07	-0.07	0.03	-0.02
The fifth position	0.13	0.07	0.06	0.08	Measurement of the fifth anemometer	0.00	0.01	-0.04	0.14
The sixth position	0.00	0.08	0.06	0.06	Measurement of the sixth anemometer	-0.10	-0.15	0.12	0.06
The seventh position	-0.17	0.08	0.04	-0.03	Measurement of the seventh anemometer	0.08	-0.04	-0.02	-0.27
The eighth position	-0.03	0.05	-0.13	-0.23	Measurement of the eighth anemometer	0.14	0.24	0.01	0.07

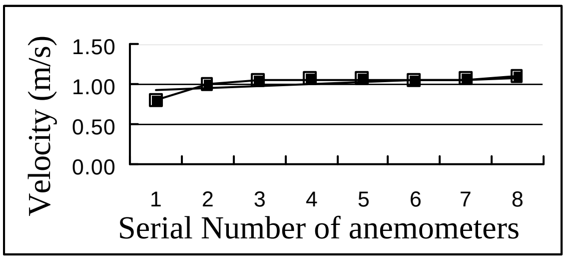
Table 2 obviously illustrates that all the four section is almost close to the desired skewed configuration and the horizontal and vertical deviation is also less than 0.15m/s with only individual value exceeded the evaluation criterion.



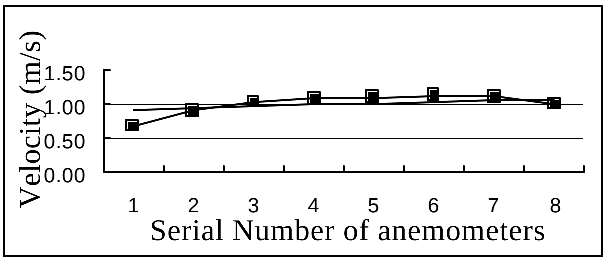
(a) Section A



(b) Section B



(c) Section C

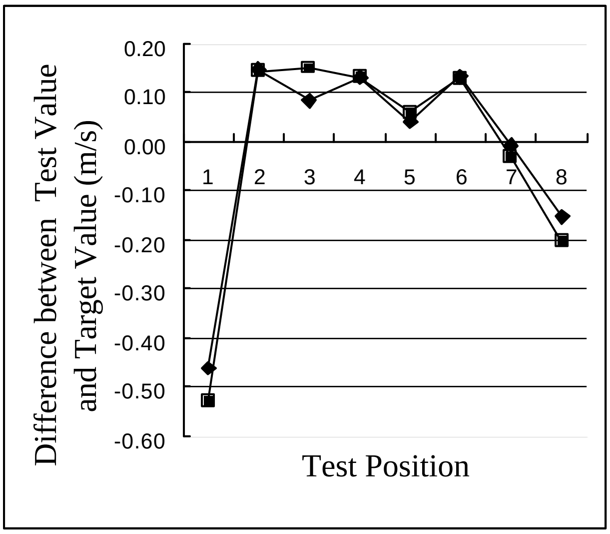


(d) Section D

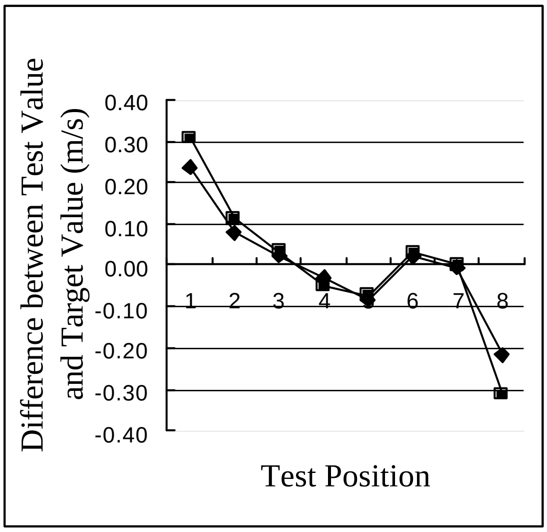
Figure 3: Comparison of the test value and target value

Figure 3 shows the comparison of the test value and target value of all four test sections, in which the line with dices is on behalf of test value by experiments and the line without dices on behalf of the target value of ideal skewed airflow configuration, from which it can be sure that the measured flow profiles is acceptably close to the desired profiles. Therefore, the plan corresponding to that test result is used in application at last. After finished the preliminary test and running for a month, the performance of the target industrial ESP has been improved markedly and reduced the dust discharge by 28.3% and the operation situation has been more smoothly in the same while. Whereas the research of SGFT is only one of the parts of the renovation of the EP for Sinter of Bao-Steel, which is influenced by many factors from the other way, so its application effect in reality needs more test and further research.

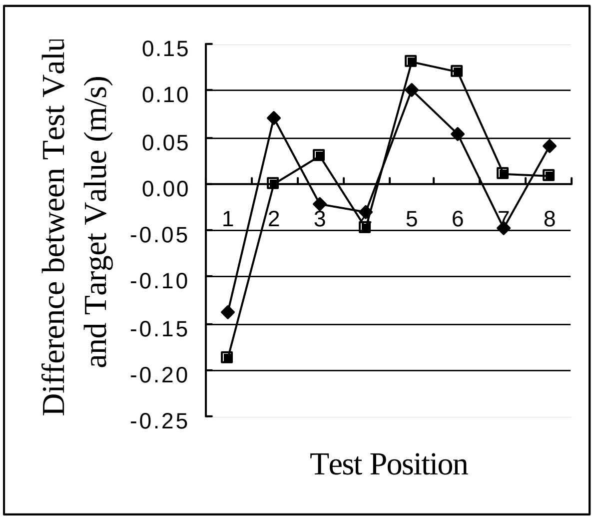
Moreover, the influence of installing adjusting devices in the interspaces of electric fields in sequence is limited in the length of one field in the direction of gas flow. Two groups of data is taken to carry on the comparison as Figure 4, in which the line with stars is on behalf of the test value after adding airflow guide plates in the interspaces of the three fields and the line with dices on behalf of before adding these plates and with the same adjusting devices in other positions.



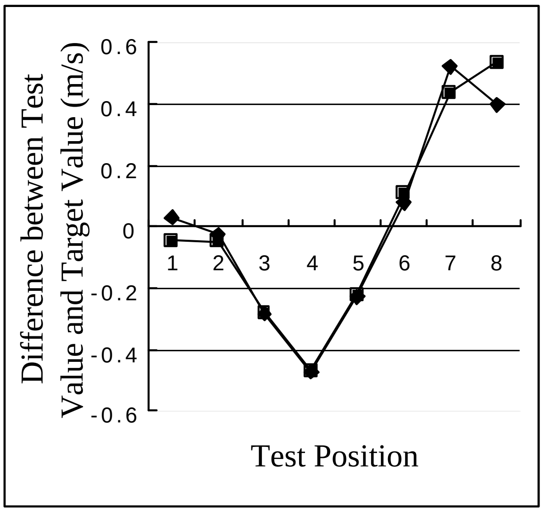
(a) Section A



(b) Section B



(c) Section C



(d) Section D

Figure 4: Comparison of the test value before and after adding a adjusting device

Figure 4 shows that the two groups of data of section A, B, D is very close and there is obvious difference in section C, which illustrates the influence of adding adjusting devices between fields is limited in the length of one field in the direction of gas flow because of the lower of airflow speed caused by the enlarge of flow passing area after flow passed the smaller flange of inlet and the effect of two porosity plates with small apertures, which results that the turbulence by adding adjusting devices between fields is slight and the influence of airflow area is also limited. This discovery provides much convenience to test all sections in turn and put forward the experiments.

5 CONCLUSIONS

(1) The impact of adding adjusting devices in the interspaces of electric fields on skewed profile is limited in the length of one field in the direction of gas flow.

(2) Too much adjusting devices is not good for adjusting the skewed gas flow, which should be installed in the suitable position according to the actual situation. For example, installing the window shade type guide device at the inlet of the first field will make the "hook" of skewed air flow profile laid aboard the entrance side excessively, cause the dust distribution not ideal and make the performance worsen finally.

(3) The final plan of actualizing SGFT in this renovation consists of fixing three airflow guide plates(with angle by 25°and width 22mm)on the front of smaller inlet uniform porosity gas flow distribution screen from the top to bottom, installing the window shade type guide device (made up with plates with angle by 30°and width 16mm) between the fist and the second field, assembling airflow-uniformization plates (bestrewed with holes by size of 20mm ×20mm and with opening ratio of 50%) between the second and the third field.

(4) Because of the impact of the factors of dust granularity, dust physical character and chemical character etc on SGFT, the determination of target skews of gas flow should be carefully decided in view of the real situations.

REFERENCES

[1] He Jian. Research of airflow distribution of electrostatic precipitator-experimental analysis of factors affecting uniform distribution of airflow. Master' degree paper of XAUT. 2004

[2] Christian Andersson, Leif Lind. A Critical Review on the Concept of Gas Distribution. Proceedings of the Eighth International Conference on Electrostatic Procipitation.71-82, 2001

[3] Ron Ojanpera, Arthur G.Hein. Skewed Gas Flow Technology-A Method to Improve Precipitator Performance. Babcock&Wilcox.BR-1671

[4] Marian Sarna. Influence of Dust Re-entrainment and Skew Gas-Flaw Technology on ESP Efficiency, ISESP Proceedings of the Eighth International Conference on Electrostatic Precipitation. 16-19,2001