# Numerical Simulation of Influence of Baffler in Electric Field Entrance to Form Skewed Gas Flow

HU Manyin[1], SUN Xijuan[1], MA Chunhong[1], LIU Yujing[1], WANG Li-qian[2]
(1 School of Environmental Science and Engineering, North China Electric Power University, Baoding 071003, PR China E-mail: humanyin@163.com
2 The Chinese Society of Electrostatic Precipitation, Nanjing 210008, PR China
E-mail: Wanglq4602@.163.com)

**Abstract:** This article proposed that baffle plates should be added on the air current distribution boards in inlet box in order to form skewed gas flow. Air distribution was simulated and studied by Software FLUENT. The $k$ - $\varepsilon^2$ equation model was taken in the Flow field simulation, and the computation was based on SIMPLE algorithm. There are five sorts of baffle plates which have different fixing angles and fixing spaces to simulate skewed gas flow. Eventually the simulative results indicated that setting baffle plates could form the skewed gas flow and the simulation accorded with the experimental data at 45 degree, space 504 mm. Comprehensively analysed, the angle of 55° was more ideal. All of these offer a basis to design, running and improving of electrostatic precipitator (ESP).

**Keywords:** ESP, Skewed gas flow, Numerical simulation

## 1 INTRODUCTION

Flow pattern is an important basic parameter to design, adjust operation of ESP and is a vitally influencing factor for the running effect of ESP. There are two methods to study air current distribution pattern, one is model experiment, and the other is numerical calculation. Model experiment can display the air velocity distribution of inlet section, whose results is visual and credible. Numerical solutions are got via numerical calculation which can contribute to describe the flowing law of fluid, avoid blindness in design process and shorten design cycle. By changing the characteristics of flow distribution considering the actual dust loading, skewed gas flow technology made the dust collecting area to be used as much as possible. The conventional uniform air-stream is beaten. Skewed flow pattern is formed through adjusting the equipment of incoming stream distribution in ESP fields. SGFT can proportion gas flow, so in this way, corona wires and collecting plates are not excessively vibrated, MTTF and the reliability of ESP are enhanced. Forming right skewed gas flow plays an important role in enhancing the efficiency of ESP. Via computer analysis, it is proved that skewed flow and concavo-convex gas flow are potential in enhancing the effect of ESP[1].

## 2 MATHEMATICAL MODELS

Continuity equation:

$$\frac{\partial \overline{u}}{\partial x}+\frac{\partial \overline{v}}{\partial y}+\frac{\partial \overline{w}}{\partial z}=\frac{\partial (u_i)}{\partial x_i}=0 \tag{1}$$

Momentum-equation:

$$\frac{\partial}{\partial t}(\rho u_i)+\frac{\partial}{\partial x_j}(\rho u_i u_j)=-\frac{\partial p}{\partial x_i}+\frac{\partial \tau_{ij}}{\partial x_j}+\rho g_i+F_i \tag{2}$$

In this equation, $p$ is static pressure; some source terms such as porous media and self-defined source term are contained in $F_i$. Stress tensor is determined by following equation:

$$\tau_{ij}=[\mu(\frac{\partial u_i}{\partial x_j}+\frac{\partial v_j}{\partial x_i})]-\frac{2}{3}\mu\frac{\partial u_i}{\partial x_i}\delta_{ij} \tag{3}$$

The $k$ - $\varepsilon^2$ equation model was taken in this article.

*K*-equation (A form of turbulent pulsation energy equation):

$$\frac{\partial}{\partial t}(\rho k)+\frac{\partial}{\partial x_i}(\rho k u_i)=\frac{\partial}{\partial x_j}[(\mu+\frac{\mu_t}{\sigma_k})\frac{\partial k}{\partial x_j}]+(G_k+G_B-Y_M)-\rho\varepsilon+S_k \tag{4}$$

$\varepsilon$-equation (energy dissipation rate equation):

$$\frac{\partial}{\partial t}(\rho\varepsilon)+\frac{\partial}{\partial x_i}(\rho\varepsilon u_i)=\frac{\partial}{\partial x_j}[(\mu+\frac{\mu_t}{\sigma_\varepsilon})\frac{\partial \varepsilon}{\partial x_j}]+C_{1\varepsilon}\frac{\varepsilon}{k}(G_k+G_{3\varepsilon}G_b)-C_{2\varepsilon}\rho\frac{\varepsilon^2}{k}+S_\varepsilon \tag{5}$$

Respectively, in $k$-equation and $\varepsilon$-equation, the first six terms are unsteady state item, convection item, diffusion item, generation item, disappearance item, source item where $\varepsilon$ is energy dissipation rate, and $\mu$ is molecular viscous. In these equations, $u, v, w$ is each component of gas velocity, m.s$^{-1}$; $k$ is turbulent kinetic energy, m$^2$/s$^2$; ε is dissipation rate of turbulent kinetic energy, m$^2$/s$^3$; $\mu$ is kinetic viscosity of laminar flow; Pa.s; $\mu_t$ is kinetic viscosity of turbulent flow, Pa.s; $\rho$ is fluid density, kg/m$^3$; $G_k$ represents turbulent energy generated by mean velocity gradient; $G_b$ is turbulent energy generated by buoyancy; $Y_M$ represents pulsation expansion in turbulent model of compressible flow; $C_{1\varepsilon}$, $C_{2\varepsilon}$ and $C_{3\varepsilon}$ are empirical parameter; $\sigma_k$ and $\sigma_\varepsilon$ are corresponding turbulent Prandtl in k-equation and ε-equation; $S_k$ and $S_\varepsilon$ are self-defining source term; $C_{1\varepsilon}$=1.44, $C_{2\varepsilon}$=1.92, $C_{3\varepsilon}$=0.09, $\sigma_k$ =1.0, $\sigma_\varepsilon$=1.3.[2-3]

## 3 MESH GENERATION AND BOUNDARY CONDITION

### 3.1 Simplified Structure of Precipitator

The ESP studied in this article had double chambers and four electric fields and we used two dimensional simplified model of ESP. Three air current distribution plates were installed in inlet box and baffle plates with different baffle angles and different baffle intervals were installed on distribution plates. In this way, skewed gas was formed which could improve the efficiency of ESP.

### 3.2 Mesh Generation

GAMBIT was used to establish models for calculation region where Structured/unstructured grids were generated. And finite volume scheme was employed about mesh generation in computational domain.

### 3.3 Boundary Conditions

Boundary conditions of inlet and outlet used Velocity-inlet model and Outflow model respectively; the boundary condition of baffle plates was Wall model; the porous media was adopted on air current distribution boards which used Porous-jump model.

Uncoupled solving method, implicit formation, 2D space attribute, steady time attribute and absolute velocity formulation were used in numerical simulation. Turbulence model whose acquiescent constants are maintained is k-epsilon equation. Air is used as flow and its acquiescent properties are maintained.

These datum needed to be set contain the initial conditions and boundary conditions, play a determinative effect in the final results and influence convergence speed and stability of iterative calculation.

## 4 CALCULATION RESULTS AND ANALYSIS OF VELOCITY DISTRIBUTION

### 4.1 Results Analysis about Onfluence of Baffle Angle on Forming Skewed Gas Flow

The assemble graphs below are simulation results of velocity distribution when the angle varies. (Respectively, four downwards baffles and six upwards baffles are installed on the second and the third air current distribution plates. Interval between baffle plates is 504 mm.) Below, the influence of baffle angle on forming skewed gas flow is only considered.

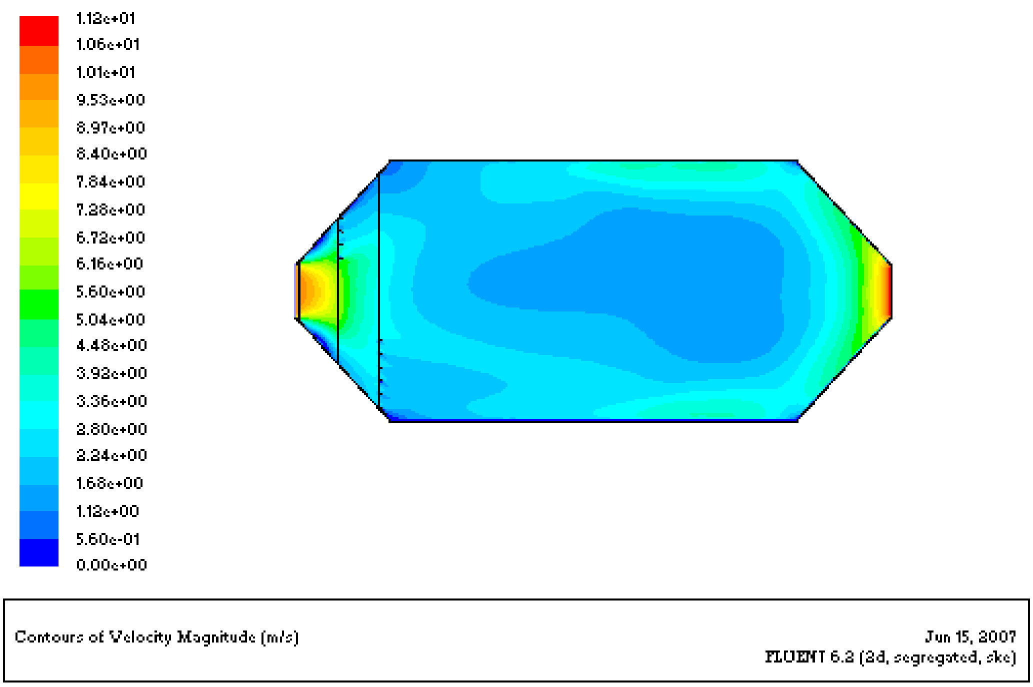


**Fig. 1** Baffle angle is 65°

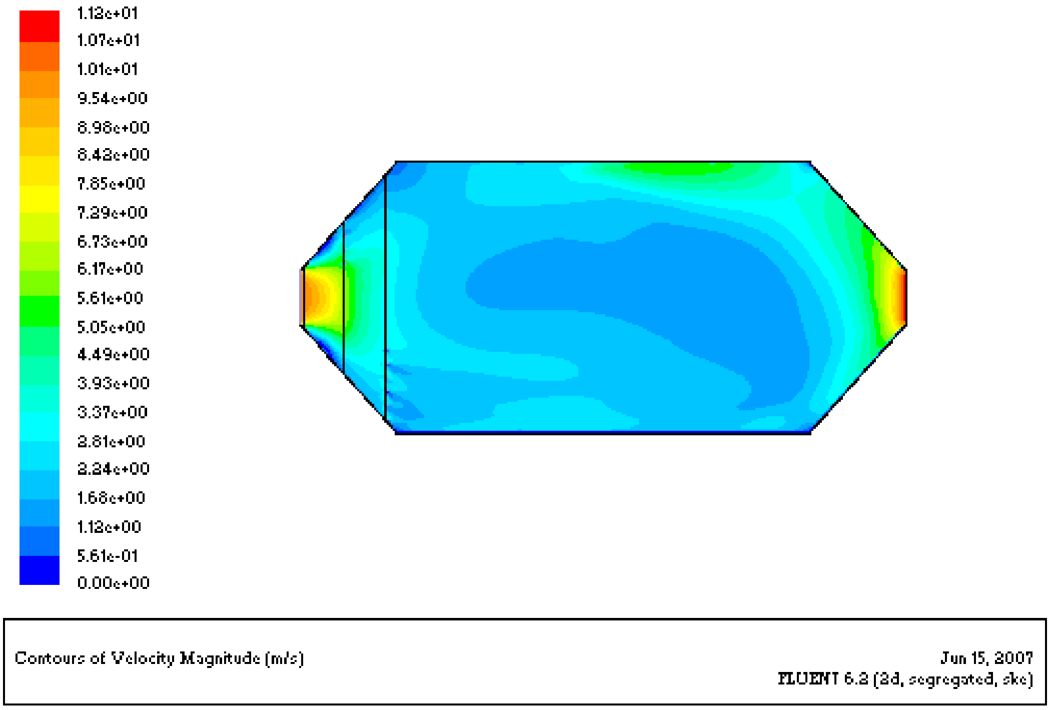


**Fig. 2** Baffle angle is 55°

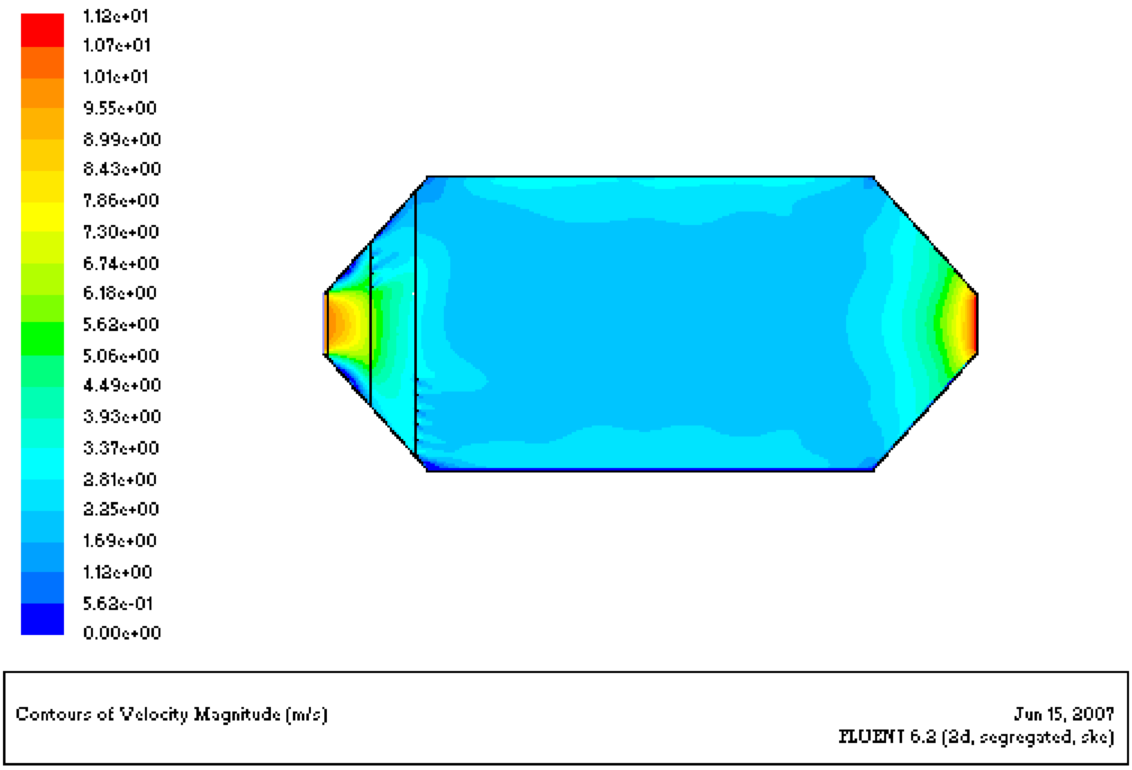


**Fig. 3** Baffle angle is 45°

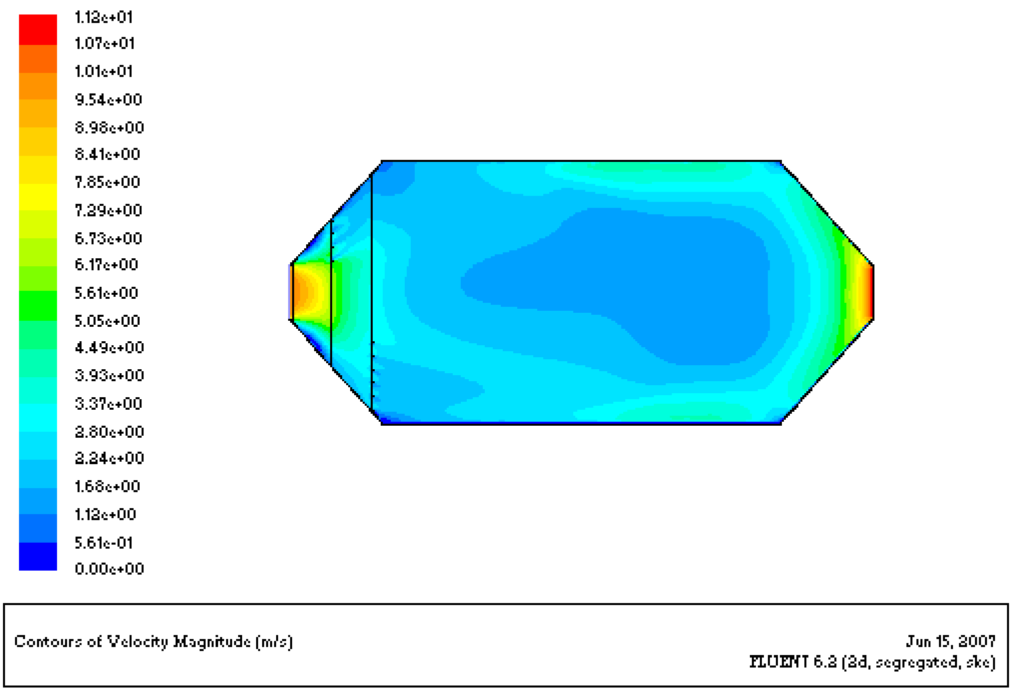


**Fig. 4** Baffle angle is 35°

The simulation results indicated that the regular skewed gas flow had been formed at inlet of the first electric field, but the velocity distribution of other electric fields changed continually, which made the outlet of the forth electric field difficult to form expected skewed gas flow. Four velocity distribution pictures are analysed comprehensively. We concluded that it is the skewed gas flow of 55° baffle angle condition that is more ideal.

### 4.2 Results Analysis about Influence of Baffle' Interval on Forming Skewed Gas Flow

The assemble graphs below are simulation results of velocity distribution when the interval varies. (Respectively, four downwards baffles and six upwards baffles are installed on second and third air current distribution plates. angle of every baffle is 45°)

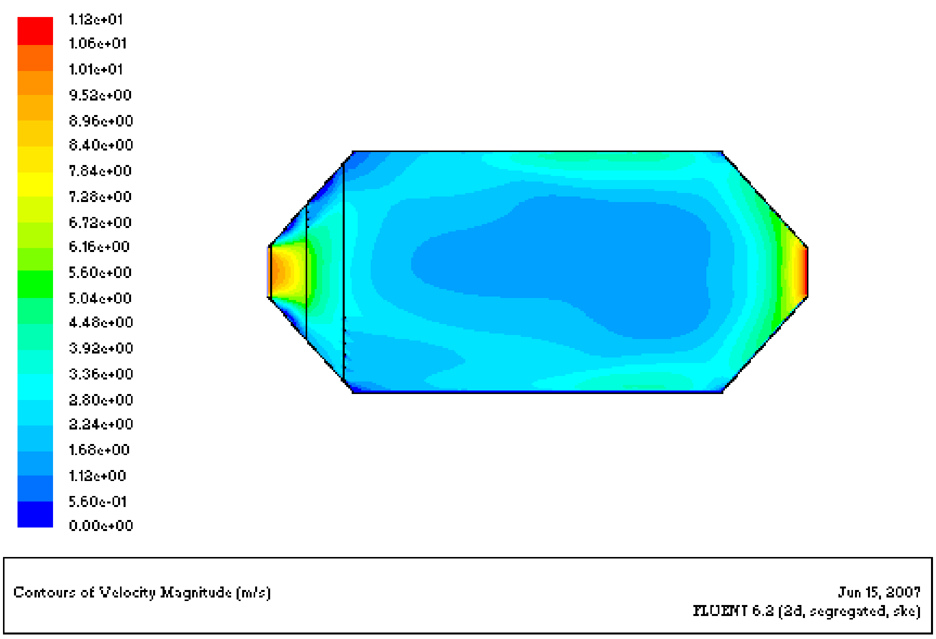


**Fig. 5** Baffle interval is 300 mm

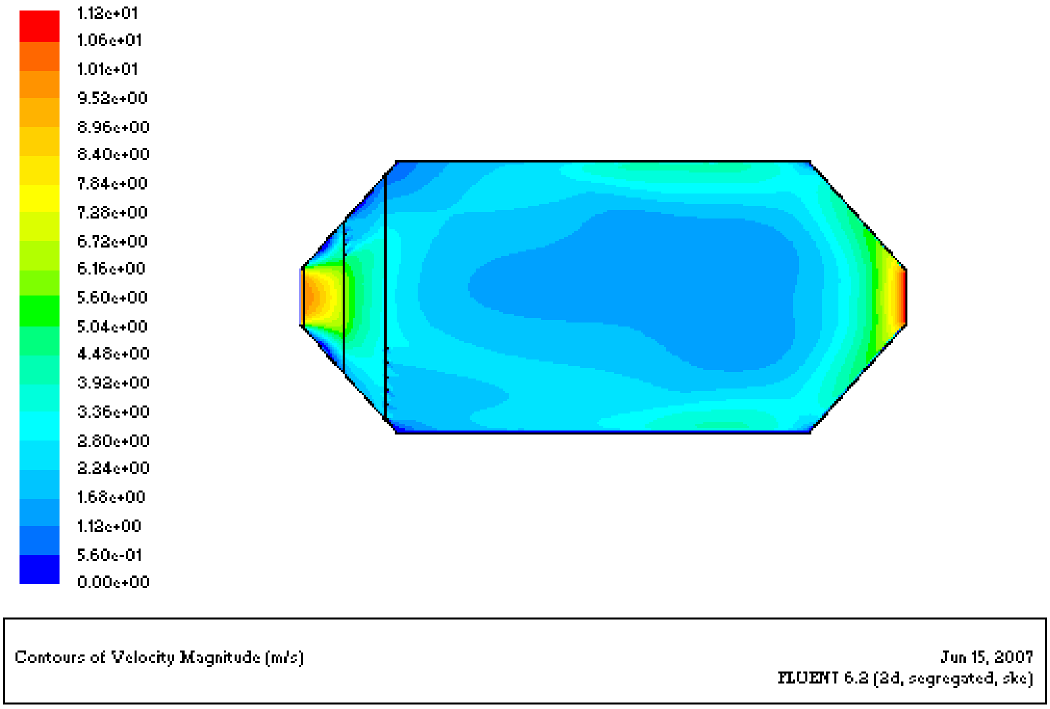


**Fig. 6** Baffle interval is 400 mm

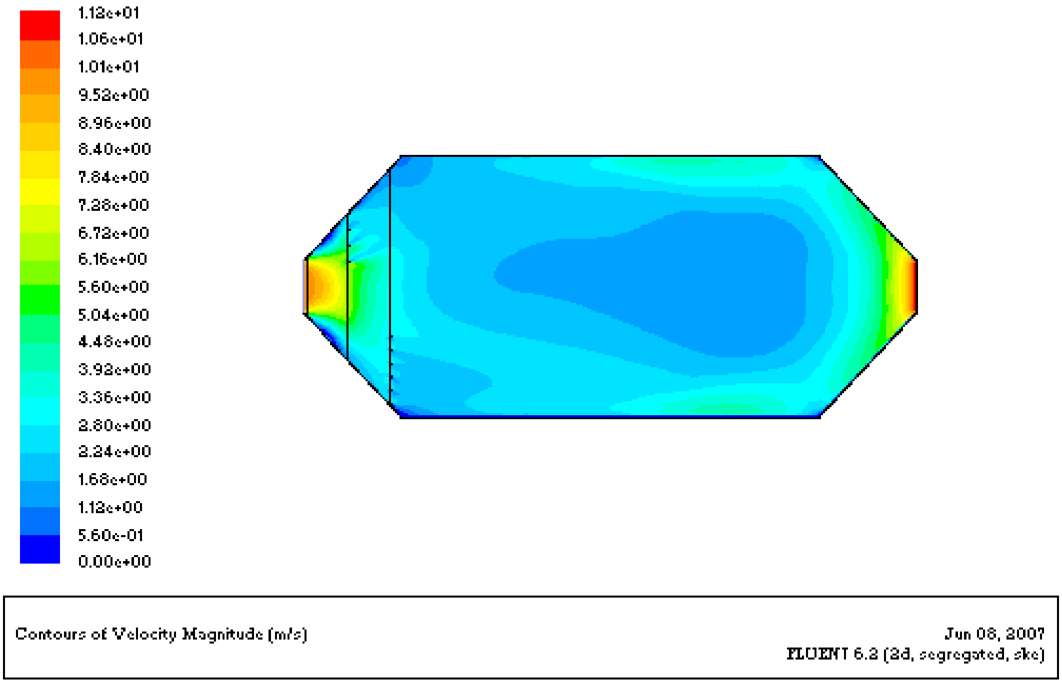


**Fig. 7** Baffle interval is 504 mm

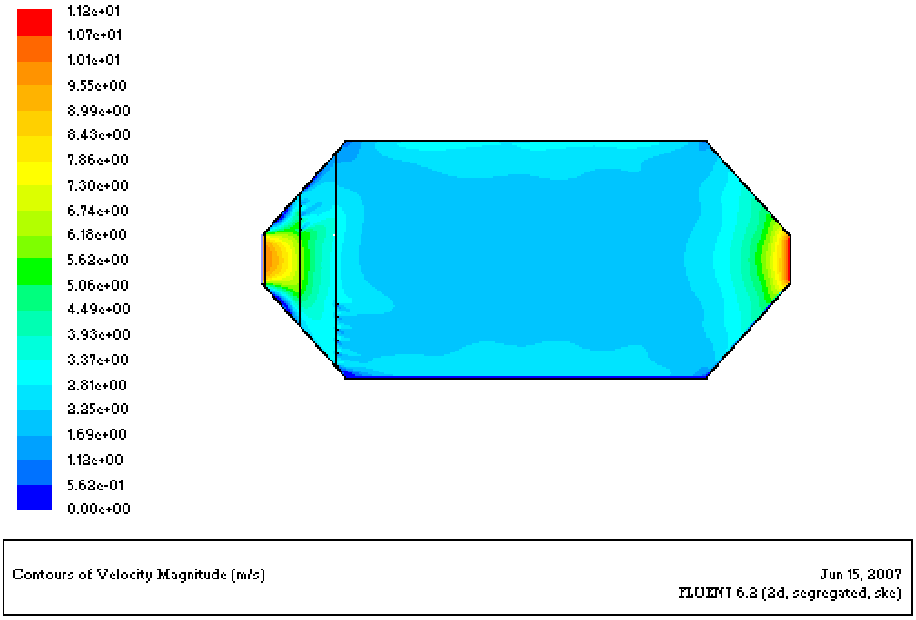


**Fig. 8** Baffle interval is 600 mm

Above, the influence of baffle interval on forming skewed gas flow is only considered. The figures of velocity distribution indicated that the irregular skewed gas flow was formed at the inlet of the first electric field, but had no influence on outlet of the forth electric field. So we conclude that the ideal skewed gas can not be formed by modifying the baffle internal only.

## 5 COMPARISON OF EXPERIMENTAL DATA AND SIMULATION RESULTS

In practical experiment, the baffle interval is 504 mm and the baffle angle is 45°. Nine monitoring points are selected respectively at the inlet of the first electric field from bottom to top and the instantaneous strain wind speed is tested at every monitoring point. In order to decrease error from various factors, every point is tested twelve. Table 1 shows experimental data.

**Table 1** Experimental data of electric fields

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | Average |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.74 | 0.61 | 0.39 | 0.40 | 0.52 | 0.92 | 0.38 | 0.38 | 0.48 | 0.91 | 0.45 | 0.83 | 0.58 |
| 2 | 0.77 | 0.85 | 0.48 | 046 | 0.45 | 0.66 | 0.68 | 0.45 | 0.46 | 0.62 | 0.31 | 0.76 | 0.58 |
| 3 | 0.92 | 0.83 | 0.77 | 0.61 | 0.64 | 0.63 | 0.79 | 0.87 | 0.64 | 0.53 | 0.67 | 1.29 | 0.77 |
| 4 | 1.62 | 1.32 | 1.02 | 0.71 | 0.97 | 1.56 | 1.52 | 0.97 | 0.45 | 0.34 | 1.73 | 1.42 | 1.14 |
| 5 | 1.36 | 1.97 | 1.93 | 1.81 | 1.63 | 1.83 | 1.73 | 0.73 | 1.57 | 0.47 | 1.58 | 1.87 | 1.60 |
| 6 | 0.84 | 0.72 | 2.17 | 1.87 | 0.96 | 0.37 | 1.52 | 0.46 | 0.97 | 0.38 | 0.75 | 1.54 | 1.05 |
| 7 | 1.38 | 1.40 | 1.29 | 1.13 | 1.28 | 0.72 | 1.28 | 0.62 | 0.82 | 0.58 | 0.87 | 0.64 | 1.00 |
| 8 | 0.46 | 0.65 | 0.46 | 0.97 | 0.87 | 1.15 | 0.67 | 0.44 | 0.75 | 0.53 | 1.15 | 0.41 | 0.71 |
| 9 | 0.68 | 0.71 | 0.49 | 0.81 | 0.82 | 0.46 | 0.61 | 0.64 | 0.57 | 0.41 | 0.45 | 0.46 | 0.59 |

**Table 2** Velocity of electric fields after correction

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | Average |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.39 | 0.37 | 0.30 | 0.27 | 0.30 | 0.48 | 0.32 | 0.34 | 0.33 | 0.50 | 0.32 | 0.39 | 0.36 |
| 2 | 0.60 | 0.61 | 0.64 | 0.59 | 0.60 | 0.64 | 0.66 | 0.11 | 0.61 | 0.67 | 0.60 | 0.70 | 0.59 |
| 3 | 0.90 | 0.91 | 0.93 | 0.90 | 0.92 | 0.91 | 0.95 | 0.95 | 0.92 | 0.90 | 0.91 | 1.01 | 0.93 |
| 4 | 1.34 | 1.25 | 1.21 | 1.19 | 1.22 | 1.32 | 1.30 | 1.24 | 1.19 | 1.21 | 1.41 | 1.34 | 1.27 |
| 5 | 1.31 | 1.46 | 1.44 | 1.42 | 1.35 | 1.43 | 1.34 | 1.19 | 1.33 | 1.20 | 1.36 | 1.43 | 1.36 |
| 6 | 1.26 | 1.21 | 1.48 | 1.42 | 1.28 | 1.20 | 1.32 | 1.19 | 1.25 | 1.19 | 1.23 | 1.33 | 1.28 |
| 7 | 1.01 | 1.02 | 0.99 | 0.94 | 0.98 | 0.94 | 0.97 | 0.90 | 0.97 | 0.90 | 0.92 | 0.90 | 0.95 |
| 8 | 0.90 | 0.92 | 0.90 | 0.98 | 0.92 | 0.96 | 0.93 | 0.90 | 0.90 | 0.90 | 0.96 | 0.90 | 0.92 |
| 9 | 0.34 | 0.36 | 0.27 | 0.41 | 0.42 | 0.23 | 0.31 | 0.36 | 0.32 | 0.21 | 0.24 | 0.22 | 0.31 |

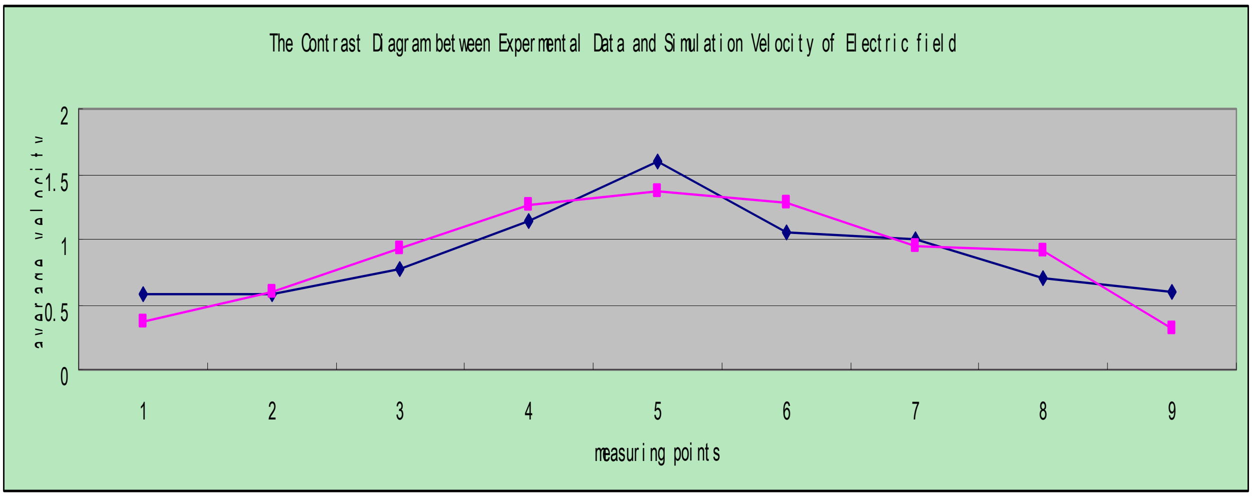


**Fig. 9** Comparison diagram between actual wind speed and simulation results

The average wind speed 0.884 m/s is calculated. The Fluent software is used to describe velocity curve on which we select nine points respectively for monitoring. The velocity of every point is got. Through calculating, the average velocity is 1.6688m/s. Finally, the simulation value is calibrated and the correction coefficient is $r$=1.6688/0.884 =1.886. Velocity after correction show in Table 2, and the average wind speed o.886m/s after correction is got.

From the above chart, we can conclude that the simulation results are consistent with the experimental datum and the trend of velocity is consistent on vertical section.

## 6 CONCLUSIONS

[1] Installing baffle plates, the skewed gas flow whose forming is related to the baffle angle and baffle interval is formed;

[2] When baffle angle is 55° and baffle interval is 504 mm, the more ideal skewed gas flow that the inlet flow distributes in the way of small-top and big-bottom but the outlet flow distributes in the way of big-top and small-bottom is formed. Therefore, uneven flow distribution can make the dust concentration distribution more uniform and improve collection efficiency;

[3] The forming reason of skewed gas flow is complicated, so the skewed gas flow which is beneficial to improve collection efficiency is difficult to form only by changing the baffle interval only;

[4] The simulated results of this article correspond to experimental data and have a certain rationality, so it can offer a reference to design, running and improving of ESP.

## ACKNOWLEDGEMENTS

The authors gratefully acknowledge the contribution of North China Electric Power University Founding 93405501.

## REFERENCES

1. Marian Sarna. Influence of Dust Reentrainment and Skewed Gas-Flow Technology on ESP Efficiency [J]. Selected Translations of the Proceedings of the Eighth International Conference on Electrostatic Precipitation, 2001, 16-19 (in Chinese).
2. Tao Wenquan. Numerical Heat Transfer (the Second Edition) [M]. Xi'an: Xi'an jiao tong University Press, 1988.
3. F. Dubois, Wu Huamo. New Advances in Computational Fluid Dynamics—Theory, Methods and Applications [M]. Beijing: Higher Education Press. 2001: 1-10 (in Chinese).
4. Wang FuJun. Computational Fluid Dynamics—CFD Principle and Application [M]. Beijing: Tsinghua University Press, 2004.