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Numerical simulation of gas-solid flow in the axisymmetric inlets square separator

Diao Yong-Fa†, Li Xun, Gu Ping-Dao, and Li Hao

School of Environment Science and Engineering, Donghua University, Shanghai 201620, China
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Abstract−Numerical simulation was used to research the two-phase flow in the axisymmetric inlet square separator, including the basic flow characteristics, separation efficiency and comparing the difference between single-inlet and double-inlet separator. The effect of the reflecting cone's geometrical sizes on pressure loss and efficiency was discussed. And the wall erosion condition because of solid particle impingement was calculated and analyzed. The tangential inlet diffuse square separator using RSM modeling that considers anisotropic situation was researched. The distribution of axial, tangential and radial velocity and the pressure loss calculated were analyzed. The results show that there is the typical double deck flow structure in the separator, the square section influences the tangential velocity in the corner, the pressure distribution divides in the inlet on the reflecting cone, and the pressure loss increases with the increase of inlet velocity.

Key words: Axisymmetric Inlets, Diffuse Square Separator, RSM, Reflecting Cone, Numerical Simulation

INTRODUCTION

Cyclones have been one of the oldest and most popularly used devices for the removal of dispersed particles from their carrying gas flow because of their simple designs, low investment and maintenance costs. A large number of experimental and theoretical works have been done on the cyclone's performance [1-3]. And the square separators have an advantaged structure to dispose the water screen tube. They are an integral part in circulating fluidized bed boilers. In square separators, the reflecting cone is a particular part that can improve the structure and enhance the separating efficiency. In this paper, the three-dimensional flow field and particle collection efficiencies of a square separator with axisymmetric inlets were analyzed numerically.

SETUP OF THE SIMULATIONS

The software GAMBIT was used to divide the Grid in the axisymmetric inlet square separator. The grid division in some important zones used the non-structured grid [4,5]. The type of elements is Tet & Hybird. The type used was the TGrid. The grid's density used by interval size and the space is 0.5. The model of the separator is composed by the main body, the reflecting cone and the exhaust pipe. A homogeneous grid density was used. It is advantageous for the grid block splicing and amounts to 457696 grids. RSM turbulence model was adopted for the simulation of highly swirling turbulent flow.

The boundary conditions of numerical simulation about gas-solid flow in the axisymmetric inlets square separator were as follows:

a) The flow velocity of the inlet is 10-20 m/s;

b) The particle density of ash is 1,400 kg/m^3;

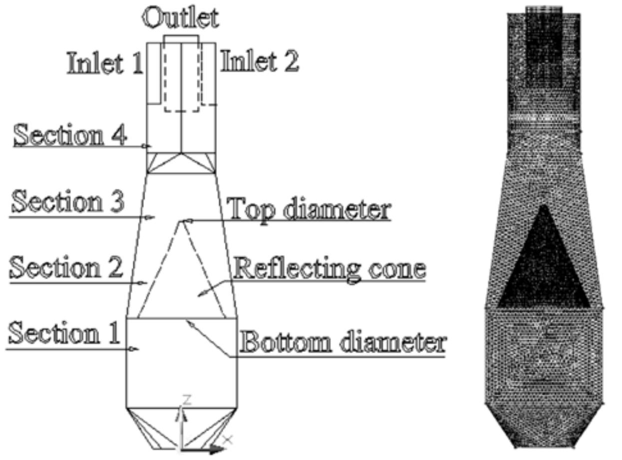

Fig. 1. Geometric model and mesh.

c) Assume these particles are spherical;

d) The inlet concentration of particles is 15 g/m^3;

e) When computing the total efficiency of axisymmetric inlet square separator, assume the particle diameter deferred Rosin-Rammler distribution.

RESULTS AND DISCUSSION

It is found that the velocity fields have a great influence on the separating efficiency because reasonable air flow will reduce the pressure drop and increase the separating efficiency.

1. Velocity Field

The flow field in the cyclone separator is complex turbulent two-phase flow, and the flow fields greatly affect the separating efficiency. The distribution of axial, tangential and radial velocity and calculating the pressure loss were analyzed. The results show that there is the typical double deck flow structure in the separator. See Fig. 2. The air flow at the outer layer goes downwards, and inner

†To whom correspondence should be addressed.
E-mail: diaoyongfa@dhu.edu.cn
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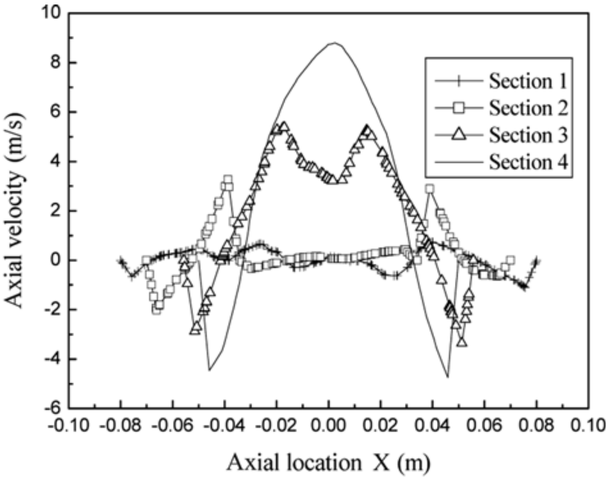

Fig. 2. Axial velocity with axial location (0-180º, 10 m/s).

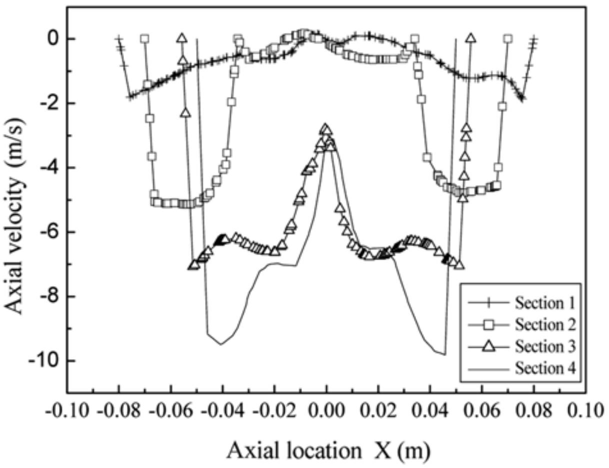

Fig. 3. Tangential velocity curve (0-180º, 10 m/s).

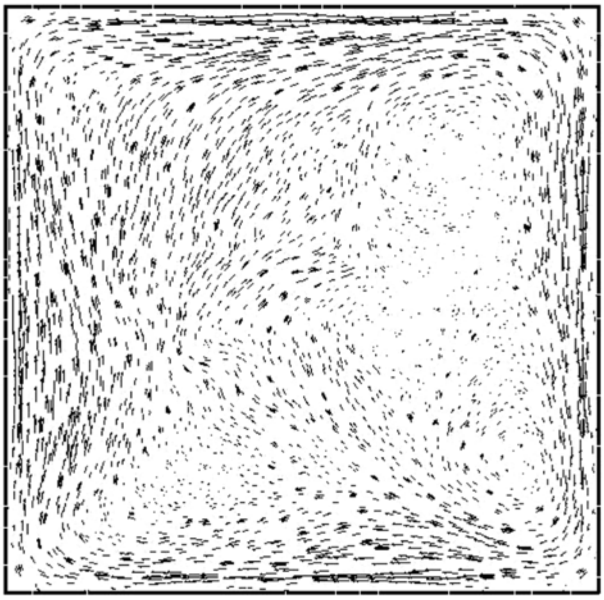

Fig. 4. The square corner's impacts on tangential velocity (section 1).

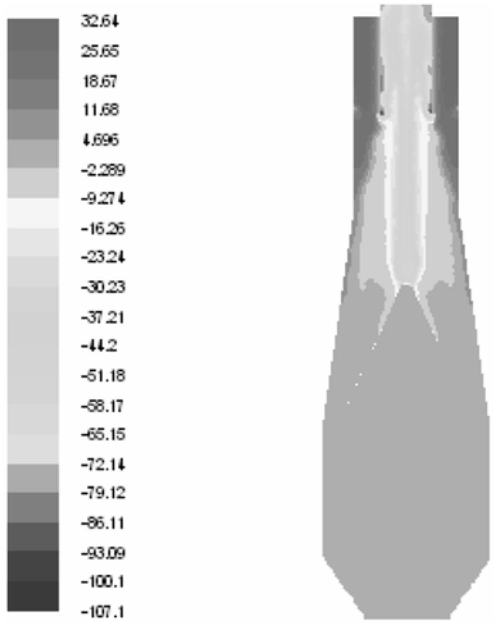

Fig. 5. Total pressure distribution.

layer upwards. The velocity of section 3 and section 4 is clearly much smaller than that of sections 1 and 2, because of the influence of the reflecting cone. This kind of situation is helpful to prevent the trapped particles from being carried away by the upward gas flow. The square section influences the tangential velocity in the corner and pressure distribution divides in the inlet on reflecting cone. Also, the pressure loss increases with the increase rate of inlet velocity.

The tangential velocity field is shown in Fig. 3 and Fig. 4. The results indicated that the distribution of tangential velocity was taking on a good symmetry. From Fig. 3 and Fig. 4 we can see the tangential velocity becomes bigger as the axial location increases, but the velocity near the corner is depressed. The reason was that the air flow was disturbed by the square section; the square corner mostly impacted on tangential velocity. Below the reflecting cone, the velocity was relatively lower and the static pressure was higher.

Fig. 5 shows the distribution of the total pressure in the cyclone separator. The pressure at the center is smaller relatively, even becoming negative somewhere. And the pressure does not change much below the reflecting cone. Chen [6] did some research on the pressure drop on this kind of cyclone separator. The experimental results compared with calculated results under different inlet velocities are shown in Fig. 6. It was shown that the pressure drop increased with the inlet velocity increase.

2. Pressure Distribution

This paper presented two type inlet separator's five typical particle trajectories and discussed the pressure loss by the velocity. The performance of them was compared. The results showed that cyclones with double inlets had air flow with better symmetry, and the tangential velocity became smaller. That is why the double inlet cyclone's inlet velocity is about half of the inlet velocity of the single inlet cyclone.

With the same inlet velocity, the double-inlet separator had better separating efficiency. For example, under the condition of 10 m/s

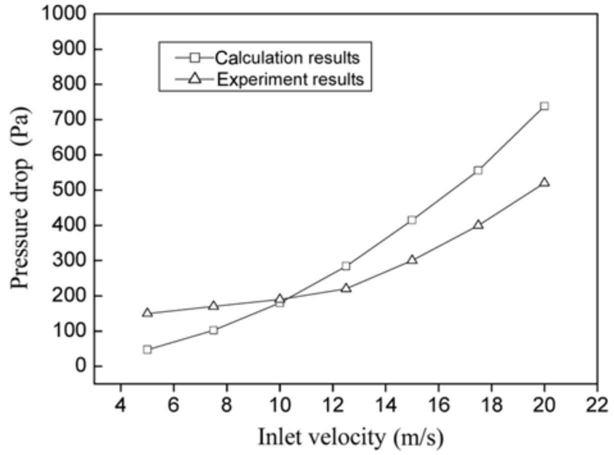

Fig. 6. Comparison of pressure drop between the experiments and calculation results.

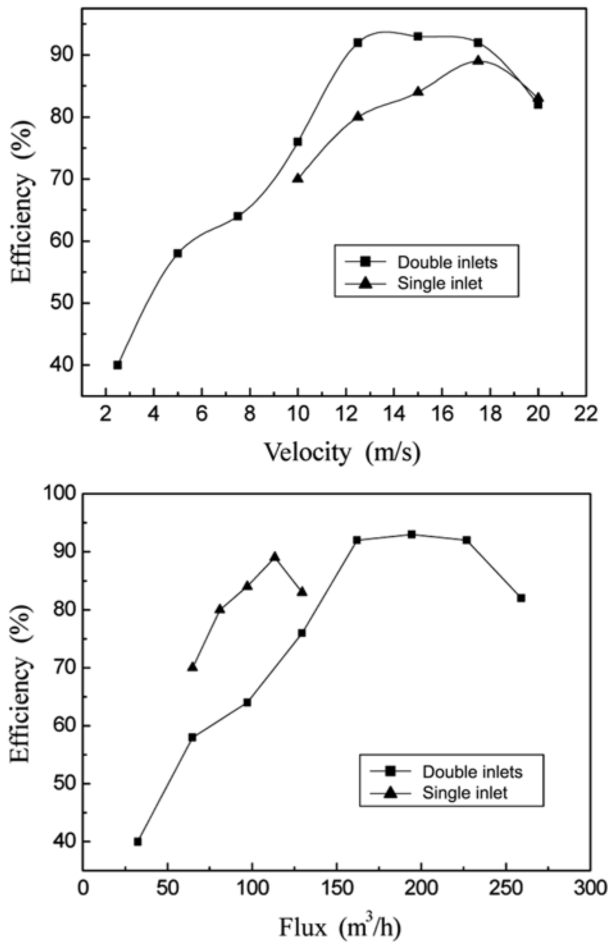

Fig. 7. Efficiency curves of different inlets.

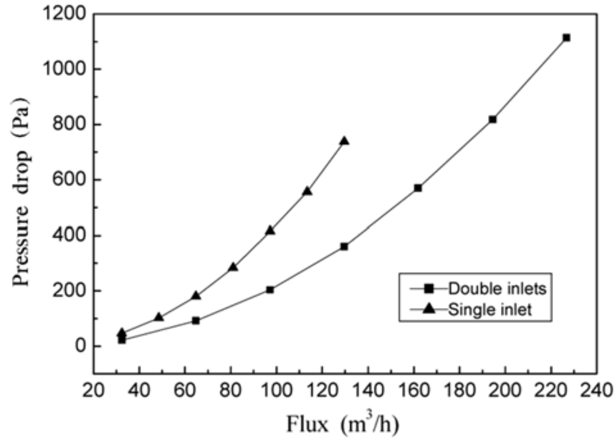

Fig. 8. Pressure drop with different inlets.

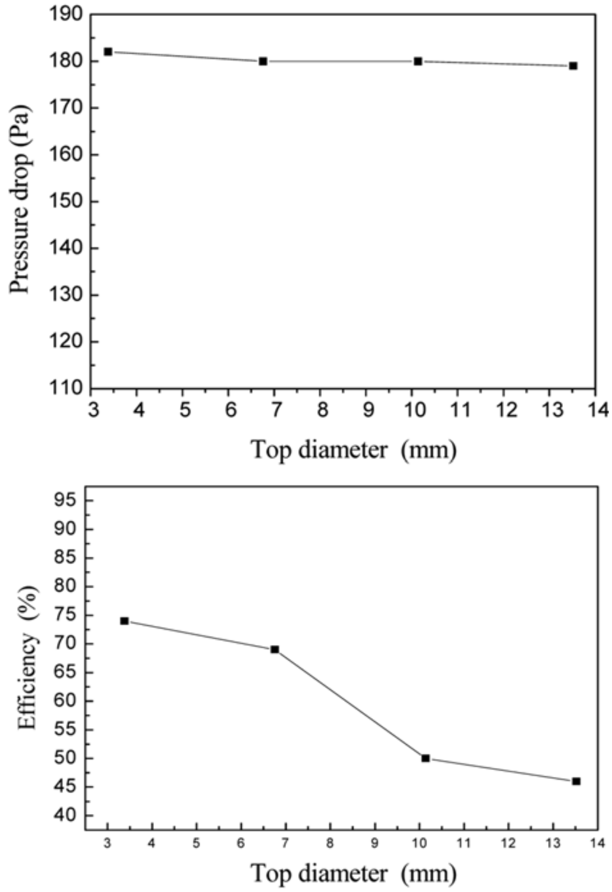

Fig. 9. Profiles of pressure drop & efficiency with different top diameters of reflecting cone.

inlet airflow velocity, the single-inlet separator had good effect on particles bigger than 15 μm, and the double-inlet separator had good effect on particles whose diameter is above 8 μm. The results are shown in Fig. 7.

And also from Fig. 8, with same flux the pressure drop of double-inlets cyclone was smaller than that of a single-inlet cyclone.

While, under the conditions of the same flux, the single-inlet separator's inlet velocity was higher than the double-inlet separator and the tangential velocity was much higher. Then the centrifugal force in the single-inlet separator would be bigger, so the separation efficiency would be somewhat better; but on the other hand, the pressure loss is higher.

3. Influence of Reflecting Cone

The reflecting cone was a specific part of the diffusion separator.

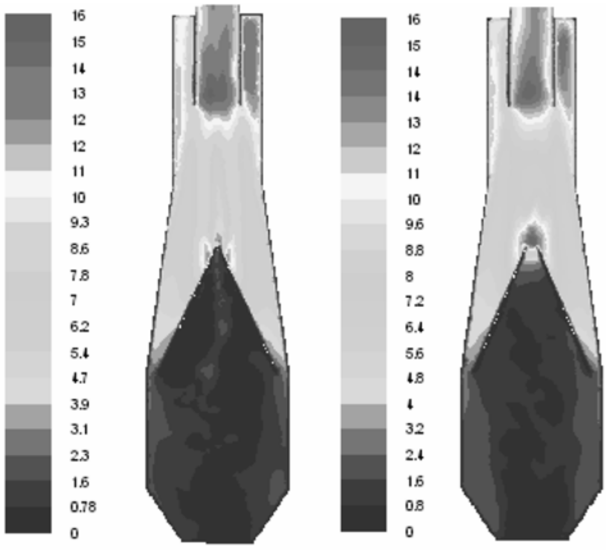

Fig. 10. Velocity graph with different top diameters.

Results showed that the top parameter had little effect on the separator resistance, but a greater impact on the efficiency. As shown in Fig. 9, that is why the increase of the top diameter may enhance the particle to be captured by the air flow upwards. At the same time the velocity increased when the top diameter of the reflecting cone was enlarged. The results are shown in Fig. 10.

On the other hand, when the bottom diameter of the reflecting cone was changed, the situation was different. If the bottom diameter of the reflecting cone was increased and the height of cone kept constant, then the space between the reflecting cone and the separator wall was reduced and the air flow downwards to the inside of the cone became little; then, the efficiency was reduced. The results are shown in Fig. 11.

4. Erosion Situation

Erosion damage is common in a solid particle separator because of particle impingement and other reasons. In the end, the erosion damage is discussed on different walls. From Fig. 12, we can see that the upside surface of the reflecting cone and the wall of gathering-dust cone are the parts eroded worse than other places. On the

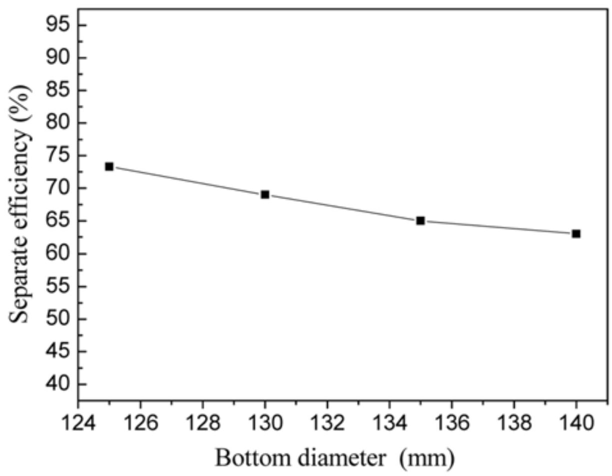

Fig. 11. Separate efficiency at different bottom diameters.

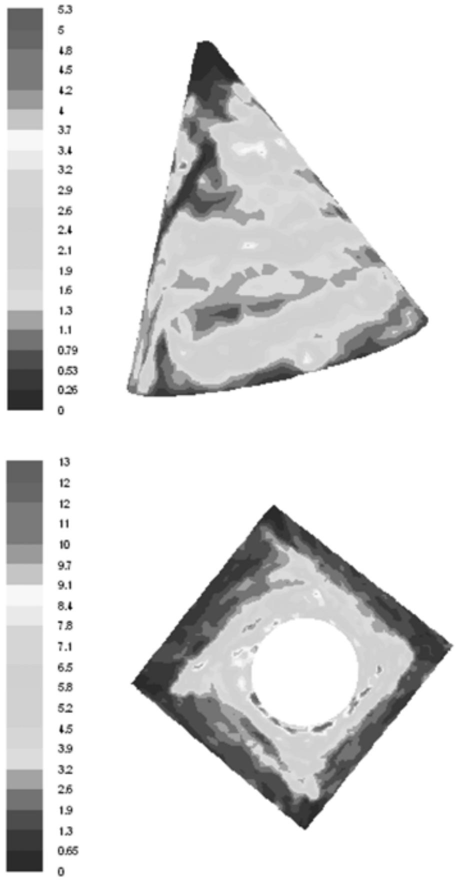

Fig. 12. Erosion at different parts of the separator.

upside surface of the reflecting cone, the particle's consistency and velocity is bigger than other places. At the same time, when the interfacial area becomes smaller, the erosion becomes severe. While on the inner surface of the cone, the velocity is not so big, and the erosion situation is slight.

Some ways or measures to lower wall erosion are put forward based on the results of numerical simulation.

CONCLUSION

The distribution of axial, tangential and radial velocity and calculating the pressure loss were analyzed. The square corner mostly impacts on tangential velocity. The reflecting cone's structure had little effect on the separator resistance, but a greater impact on the efficiency. When the top or bottom diameter was enlarged, the efficiency would decrease.

Under the conditions of the same inlet airflow velocity, the double-inlet separator had an effect on particle diameter above 8 μm. The single-inlet separator's separation efficiency was somewhat better, but the pressure loss was higher.

The upside surface of the reflecting cone and the wall of gathering-dust cone were the parts eroded worse than other places.

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