Influence of Negative Pressure on Separation Performance of Cyclone Separator

Qing Wang, Zhiliang Zhang

Southwest Petroleum University, China.

Abstract

Pressure is an important operating parameter that affects the efficiency of the cyclone separator and the degree of coking of the reactants. Based on the existing research results, the optimized geometry model by ( ) was used to simulate and analyze the effect of exhaust port pressure boundary conditions on the separation efficiency, particle volume fraction, velocity field, and residence time of the cyclone separator. The results show that under the condition of a certain inlet volume fraction, the negative pressure boundary has a major influence on the separation efficiency of particle size 5-15um, and after the negative pressure is higher than 2000pa, the separation efficiency drops significantly; the effect on the particle volume fraction and velocity field Smaller; while shortening the gas residence time. Comparing the separation model with the experiment, it is found that the experimental results are basically consistent with the model calculation results. Basically, it is possible to predict the influence of pressure boundary conditions on the separation efficiency, velocity field, and gas residence time of the cyclone separator, but it cannot be quantified. Calculate the effect of boundary conditions on the separation performance.

Keywords

Negative pressure cyclone separator fluent Gas-solid two-phase flow.

1. Foreword

Cyclone separator is a relatively common separation equipment in the gas-solid separation process, because of its compact, simple structure, high efficiency, five operating parts, suitable for high temperature and high pressure characteristics, is widely used in chemical, petroleum, metallurgy, energy, Environment and many other areas. However, in the catalyst separation process at the end of the catalytic cracking, high pressure will promote the over-cracking of crude oil, and it is easy to produce an anxious phenomenon, blocking the cyclone separator, and seriously affecting the separation efficiency of the cyclone separator.

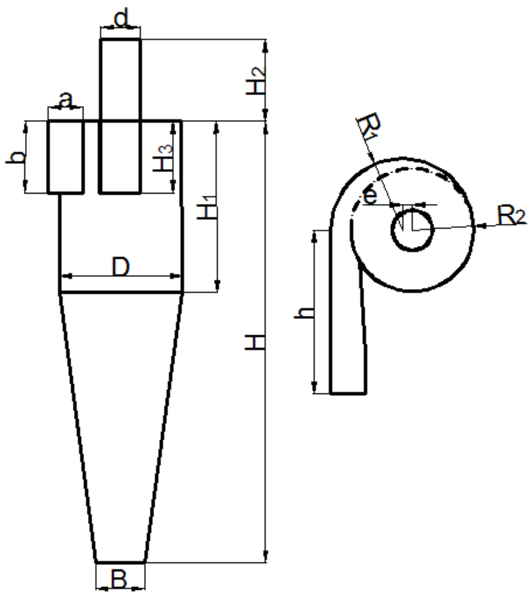
The development of the oil and gas industry urgently requires separation technologies that are more adaptable, efficient, and stable. Wanjunjun pointed out that the increase in pressure caused the axial velocity in the central region of the inner swirl to decrease, the high pressure increased the particle diffusion, and the particle concentration in the cyclone region in the cyclone increased, which was detrimental to the separation of the particles. Xu Shisen and others believe that pressure has little effect on the efficiency of cyclone separation. Dong Ruiqian pointed out that pressure drop increased with operating pressure. So far, although many researchers have done research on the effect of geometry size on the performance of cyclone separators, there are only a few studies on the effect of boundary conditions on the performance of separators. Therefore, the study explores the boundary conditions on the performance of cyclones. Influencing the rate of regulation has become an urgent and novel topic.

In this study, the CFD method was used to study the effect of pressure boundary conditions on the separation efficiency, velocity field, particle volume fraction, and gas residence time of the cyclone separator. This reduced the coking and over-catalytic cracking of the gas during production. Residence time is of great significance.

2. Geometric and Mathematical Model

2.1 Geometric Model Selection

The physical model selects the optimal structure of the cyclone separator analyzed in the journal (1). The model is shown in figure (1-1) and the specific parameters are shown in table (1-1).



具体参数如下

参数	参数值/mm
进口宽度a	84
进口高度b	176
进口长度h	400
筒体直径D	300
升气管直径d	96
集灰出口直径B	120
主体高度H	880
上段高度H_1	420
升气管高度H_2	200
升气管插入深度H_3	176
偏心距e	24.5
蜗形管半径R_1	174.5

2.2 Numerical Models and Boundary Conditions

The simulation uses DM in ANSYS for physical modeling. Use ICEM for meshing and use FLUENT for simulation. The two-phase flow model uses Euler-Euler two-fluid model, assuming that both gas-solid phases are continuous media, and the pressure-velocity coupling equation is solved using semi-implicit method for pressure linked equations (SIMPLE). Momentum equations, turbulent kinetic energy equations and turbulence diffusion rate equations are all discretized using quadratic upwind interpolation of convective Kinematics (QUICK). The RNG k-ε turbulence model, which can well process the convection line with a large degree of bending, can be used to simulate the gas flow field in the cyclone separator. The boundary parameters are set as follows:

(1) The inlet boundary is selected as the velocity inlet. The inlet gas velocity is evenly distributed across the inlet cross section. The inlet gas velocity is selected as 20 m/s. The inlet particle volume fraction is 10%. The turbulent kinetic energy k and the turbulent diffusion rate of the gas at the inlet can be indirectly defined by the hydraulic diameter and the turbulence intensity I. The formula is calculated as follows:

$$D_h = \frac{4A}{P} = \frac{2ab}{(a+b)} \quad ()$$

Where A represents the inlet cross-sectional area and P represents the perimeter of the inlet cross-section $I = 0.16(R_e)^{-\frac{1}{8}} \times 100\%$ ()

With $R_e = \frac{vD_h\rho}{\mu}$.

The specific parameter settings are as follows：

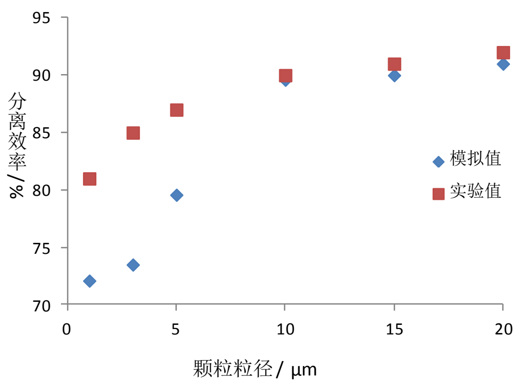
入口速度 V/ m/s	入口面积 A m^2	水力学直径 D_h /m	湍动强度 I /%	颗粒体积分数 F /%
20	0.01408	0.1083	3.7074	10

(2) The outlet boundary selects the pressure outlet and the hydraulic diameter is 0.096m.

(3) The wall inside the experimental device was set as a standard non-slip wall.

2.3 Model Validation

The flow field in the cyclone separator was simulated and compared with the experimental results in [2], as shown in Fig. (). From the figure (), we can see that the simulation results obtained from the numerical model and the calculation method in this paper have a good agreement with the experimental data.

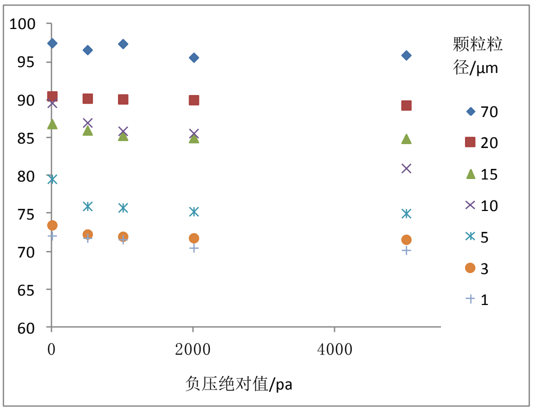


3. Calculation Results and Analysis

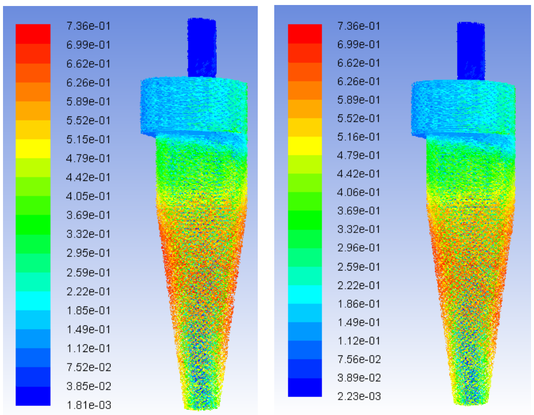
3.1 Influence of Negative Pressure on Separation Efficiency of Cyclone Separator

The separation efficiency is an important index to determine the performance of the cyclone separator. Therefore, this paper first analyzes the influence of different negative pressure on the separation efficiency of the cyclone separator to obtain the negative pressure boundary conditions for the reduction of the separation efficiency, and then the velocity flow field. Such as performance analysis and comparison.

In this paper, the separation efficiencies of different particle sizes under different negative pressures were simulated and analyzed at the particle inlet volume fraction of 10%. Figure 3 shows the separation efficiency of different particle sizes under different negative pressure conditions. From Fig. 3, it can be seen that when the negative pressure is 2000pa, the particle separation efficiency of particles with a particle size of 10um is reduced by 4%. After more than 2000pa, the separation efficiency decreased significantly. It can be seen from the figure that the negative pressure has no great influence on the particle separation efficiency of large particle size and fine particle size. Therefore, when considering the separation performance, this paper mainly considers that the particle size is 10um and the negative pressure is 2000pa.

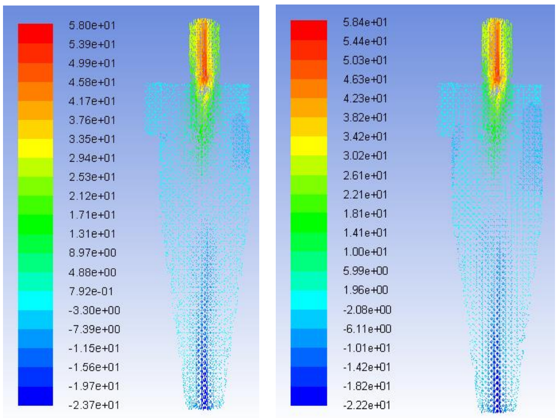


3.2 Influence Of Negative Pressure on Particle Volume Fraction in Cyclone Separator



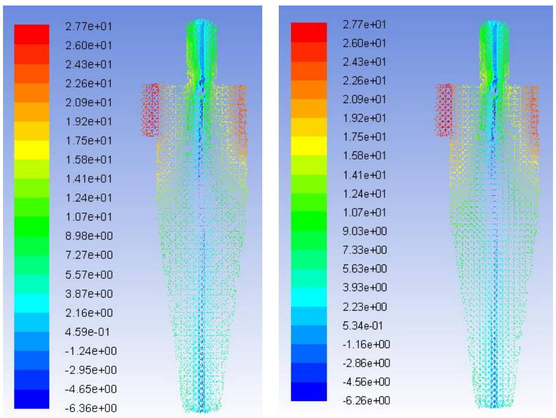
As can be seen from the figure (), the gas and solid phases enter the cyclone separator from the entrance and are thrown to the wall under the centrifugal force. They spirally spiral, and the width of the spiral band gradually expands, forming at the cone section. The transition from the dilute phase zone to the dense phase zone, at the same time, the gas phase is reversed from the axial center of the cyclone under the pressure and the confinement of the cone, forming an internal swirl upward movement, and discharged from the exhaust pipe to realize gas and solid phases. Separated. As can be seen from the cloud diagram in the figure, the introduction of negative pressure has no significant change in the overall trend of the particle volume fraction in the cyclone separator. From the left scale, it can be analyzed that the numerical value of the volume fraction has changed significantly and the negative pressure has been introduced. There was no significant decrease in the volume fraction of particles in the cone section, indicating that the separation trend did not change, but there was a slight increase in the volume fraction of the particles at the outlet, indicating that the introduction of negative pressure increased the amount of gas entrapped particles while accelerating the gas extraction. , Reduced separation efficiency.

3.3 Effect of Negative Pressure on Axial Velocity in Cyclone Separator



The axial velocity can indirectly reflect the velocity of the gas in the cyclone separator and the sedimentation velocity of the catalyst particles. It can qualitatively analyze the change trend of the separation efficiency and gas residence time. It can be seen from the axial velocity vector diagram in the figure that the negative pressure The introduction does not change the distribution trend of the axial velocity within the cyclone, but it can be seen from the scale that the introduction of negative pressure at the outlet position increases the upward axial velocity, so the introduction of negative pressure will accelerate the cyclone separation. Gas out of the device. Reduce the gas residence time and reduce the possibility of excessive catalytic cracking.

3.4 Effect of Negative Pressure on the Tangential Velocity in a Cyclone Separator



The tangential velocity is an important indicator to measure the separation performance of the cyclone separator. It can be seen from the vector diagram and the scale in the figure that the introduction of the negative pressure has no significant effect on the overall distribution trend and size of the tangential velocity, and the incision in the cone section There is also a slight increase in speed, which increases the centrifugal force of the particles, making them easier to trap on the walls and increasing the separation efficiency.

4. Conclusion

(1) The introduction of negative pressure will not change the distribution trend of particle volume fraction, tangential velocity and axial velocity within the cyclone separator, but on the order of magnitude, the particle volume fraction of the exhaust port increases slightly, and the tangential velocity of the cone segment is slightly With an increase, the upward axial speed also increases slightly.

(2) The introduction of negative pressure has little effect on the separation efficiency of large and small particles. Mainly affect the 5-10um particles.

(3) The introduction of negative pressure greatly shortens the gas residence time, which is beneficial to avoid oil gas scorch and excessive catalytic cracking.

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