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Research Article

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Parameter design and simulation of fan baffle foam generator

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Abstract To simulate and analyze the internal flow field of the fan baffle foam generator, using the computational fluid dynamics software FLUENT, and based on the Mixture model in the multiphase flow model, the - model in the flow model, and the SIMPLE algorithm, the velocity streamlines distribution program inside the foam generator was obtained by simulating the internal flow field of the foam generator with different baffle numbers, different baffle fan numbers, and different flow angles, Cloud picture of outlet gas phase volume distribution and gas phase distribution curve of outlet section. The simulation results show that the outlet velocity of the foam generator with four baffles, four fan blades, and 90 flow nozzles is higher, and the outlet gas volume distribution is more uniform, which is more conducive to producing a large number of delicate forms

Keywords foam generator; Gas-liquid two-phase flow; numerical simulation; structured

1. Introduction

China is relatively rich in coal resources, and coal is an important material base for China's leading energy [1]. the process of coal mining is often accompanied by fire, explosion, and other accidents, and pneumoconiosis caused by coal dust will also bring great harm to the miners' bodies [2]. At present, the ventilation dust removal method is generally used in coal mines, but the dust removal efficiency is not high. Foam dust removal technology has the advantages of high dust removal efficiency and low water consumption, which is of great significance for suppressing the harm of coal dust and protecting the safety of mining workers [3].

The quality of the foam is one of the important factors affecting the foaming efficiency, and the different foam generator structures play a decisive role in the quality of the foam generated. At present, domestic scholars have carried out certain research on the internal flow field performance of foam generators. Liu Chengting et al. conducted experimental research on the effect of vapor phase pressure on baffle foam generators [4]. Luo Jiaqi et al. conducted simulation research and structural optimization of the structure of different angles of the baffle in the baffle foam generator [5]. Zhang Weiwei et al. analyzed and experimentally studied the internal flow field of the spiral foam generator [6]. Li Jiacheng simulated the internal flow field of the jet foam generator [7]. In this paper, the foaming performance of the former is analyzed by numerical simulation of the internal flow field of the former with different numbers of baffles, different numbers of baffle blades, and different angles of spoilers, to provide a basis for the structural optimization of the former.

2. Model Structure

Solid Works software was used to model the fan 3D geometry of the fan blade foam generator, and the basic dimensions of the fan blade foam generator are shown in Table 1.

Table 1: Basic model size of fan-bladed baffle foam generator (mm)

Entrance to the larynx （㎜）	Inlet diameter （㎜）	Laryngeal length （㎜）	Mixing chamber diameter （㎜）	Mixing cavity length （㎜）	Outlet throat length （㎜）	Exit segment length （㎜）	Outlet section diameter （㎜）
60	40	40	100	800	40	100	50

The structure of the former is shown in Figure 1, and this paper uses SolidWorks software to model the fan-bladed baffle foam generator in three dimensions, which consists of five structures: gas-liquid phase inlet, spoiler, baffle, gas-liquid mixing chamber, and foam liquid outlet. The total length of the model is 1040mm, the gas-liquid phase inlet length is 60mm, and the inlet diameter is φ40mm. The length of the reducer inlet section is 40mm, the outer diameter of the gas-liquid mixing chamber is φ100mm, the length of the gas-liquid mixing chamber is 800mm, and the length of the foam liquid outlet section is 100mm. The entire model has a wall thickness of 5mm. The thickness of the baffle is 5mm, the number of baffles is 4, 6, and 8, the number of sector baffles is 2, 3, and 4, and the spoiler angles are 60°, 90°and 120°.

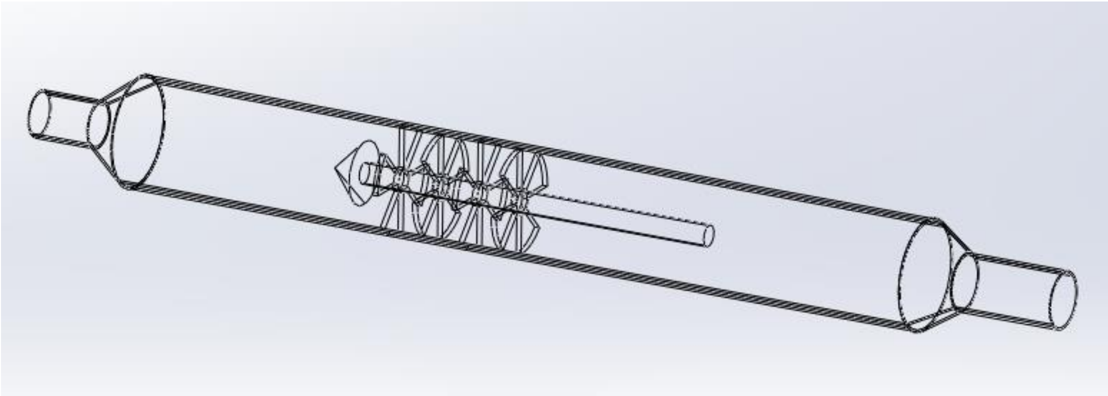


Figure 1: Model of fan blade baffle foam generator

3. Calculation pre-processing

3.1 Meshing

The quality of the grid is an important factor affecting the numerical simulation calculation results, and the number of grids will inevitably increase while requiring the quality of the grid, but the number of grids is too large not only occupies computer memory but also increases the calculation time and reduces work efficiency. In this paper, the maximum deviation of the grid quality requirements of the calculation domain of the fan-shaped baffle foam generator cannot exceed 0.98, the minimum orthogonal mass cannot be less than 0.01, the aspect ratio is less than 100, and the average element mass is greater than 0.7. In this simulation, the number of grid cells is 326334, the number of grid nodes is 63013, and the mesh quality is good.

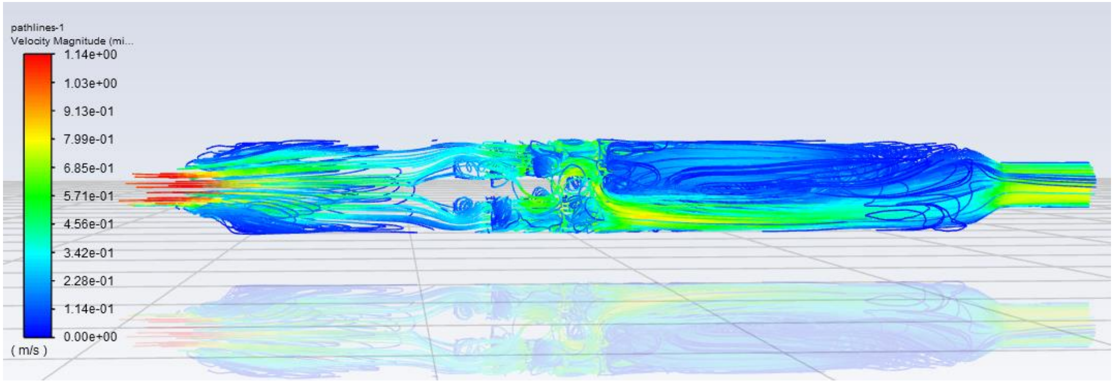
3.2 Simulation parameter settings

The fan-shaped baffle foam generator involves mixing the gas phase and liquid phase flow, so the calculation model uses the Mixture model in the multiphase flow model. The inlet flow rate of the foam generator is 1m/s, and the Standard k-epsilon model is selected for the turbulence model. To simulate the two-phase flow in the foam generator, the flow medium is set to air and base liquid. The K12 blowing agent is added to the water and mixed well to form a base solution. The density of the base solution: 1020kg/m3, viscosity: 0.016Pa·s, air density: 1.225kg/m3, viscosity: 1.789×10-5Pa·s. The gravity direction is the negative direction of the y-axis, the size is -9.81m/s2, and the inlet boundary conditions: the gas-liquid two-phase inlet is the velocity inlet boundary (Velocity inlet), and the gas and liquid inlet velocity is 1m/s (under standard working conditions), where the volume fraction of the gas phase is 40%. Outlet boundary conditions: Pressure outlet boundary (Pressure outlet), the pressure is atmospheric. Solid wall boundary conditions: the wall surface and baffle are set to the wall boundary of thermal insulation and no slip.

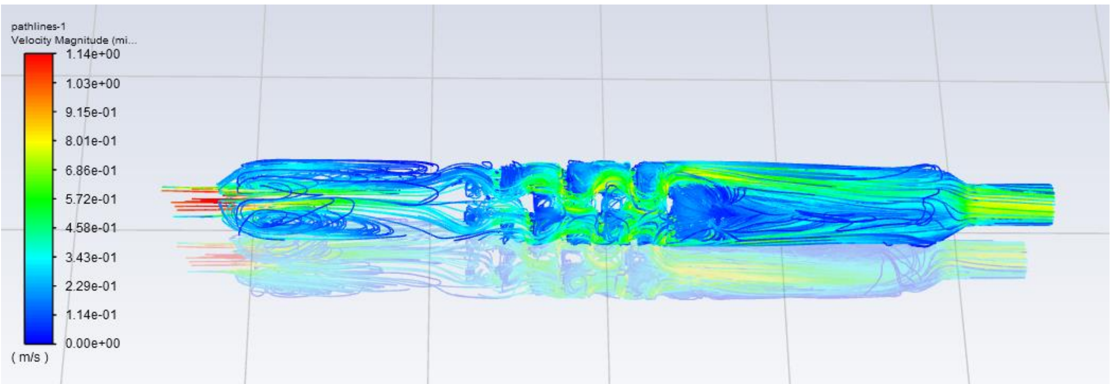
4 Analysis of simulation results

4.1 Simulation analysis of formers with different numbers of baffles

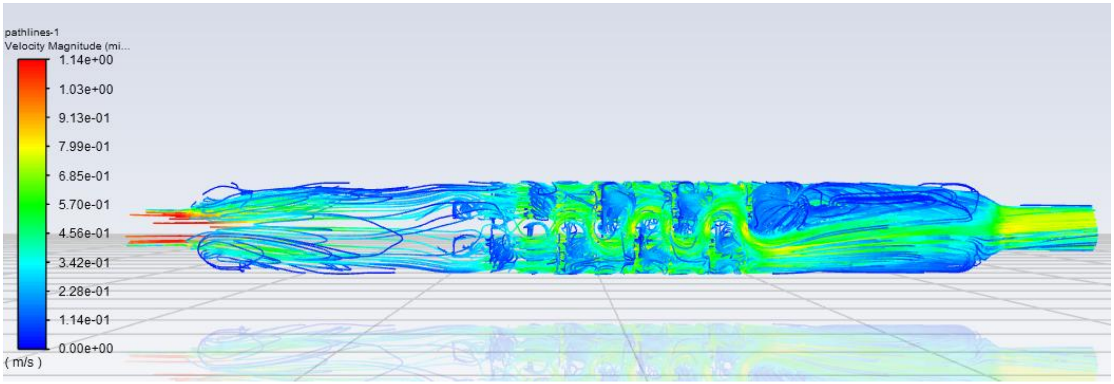
Set the number of baffles in the foam generator to take 4 baffles, 6 baffles, and 8 baffles, respectively, the foam generator is numerically simulated, the gas-liquid two-phase velocity and gas phase volume distribution are analyzed, and the optimal number of baffles is determined.



(a) Four baffles



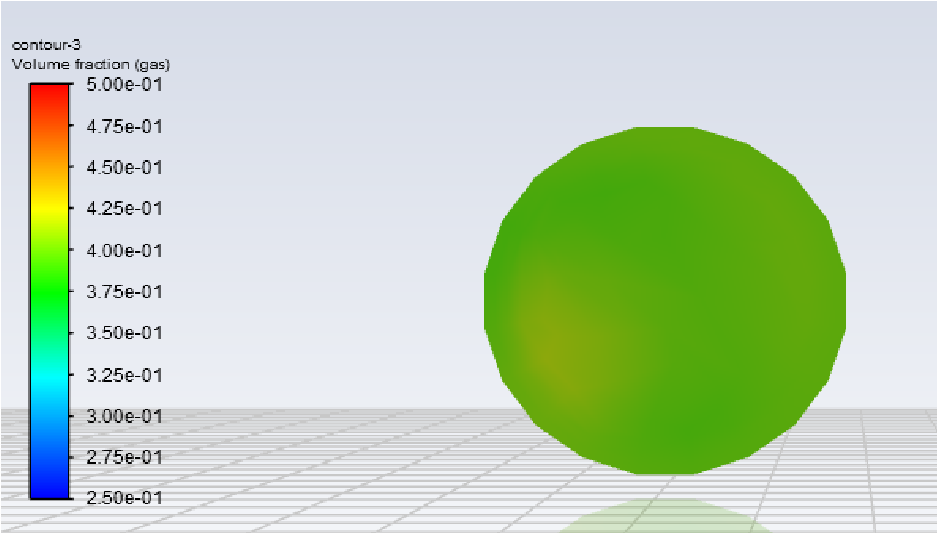
(b) Six baffles



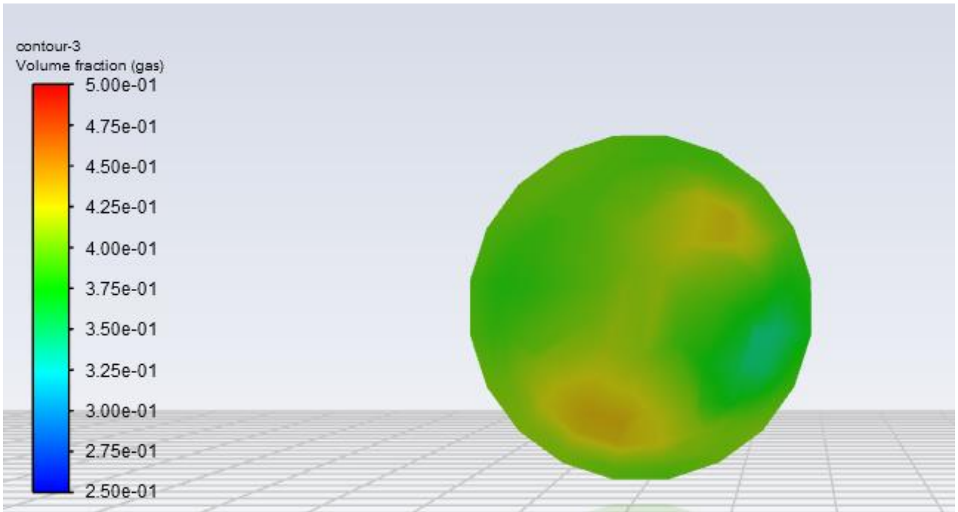
(c) Eight baffles

Figure 2: Cloud map of the velocity distribution of formers with different baffles and number of baffles

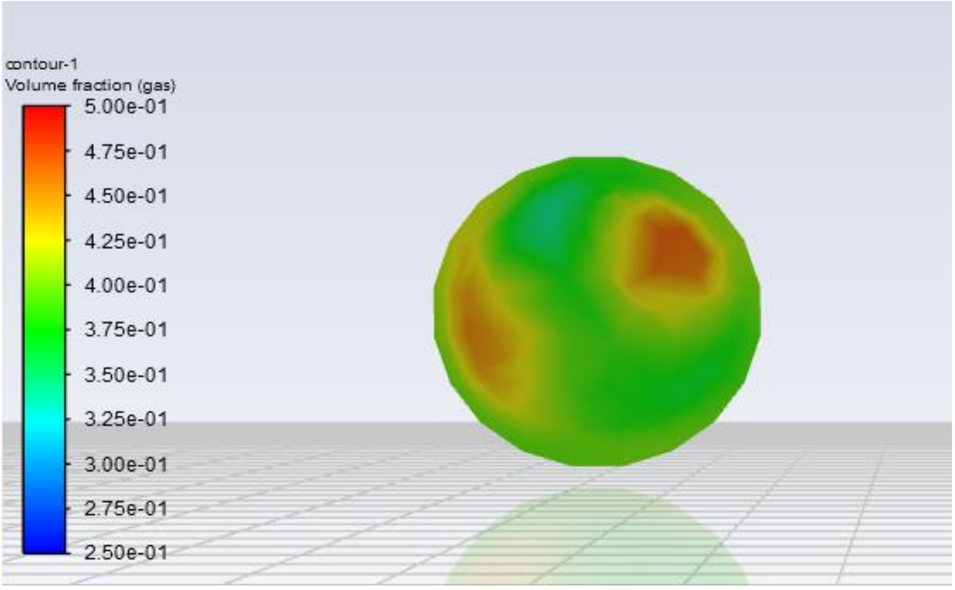
From the above velocity streamline diagram, it can be seen that the gas-liquid two phases enter at a speed of 1 meter per second, and the disturbance at the entrance of the former with 4 baffles is the most obvious, followed by the former of 6 baffles, and the former disturbance of 8 baffles is the weakest; when the gas-liquid two phases pass through the baffle, a small vortex is generated, and the velocity streamline is distributed in a serpentine shape where the velocity is large, and then the gas is fully disturbed, and large eddies are presented in the three cases of the gas-liquid disturbance section. The vortex area generated by the former of 4 baffles is the largest to make the gas-liquid mixture the most complete, the vortex generated by the former of 6 baffles and 8 baffles is second, the gas-liquid mixing is relatively full, for the outlet section from the above figure, it can be seen that the speed of the baffle of the 8 plates is slightly greater than the speed of the 4 plates and the 6 plates. Therefore, among the three cases, the most adequate gas-liquid mixing disturbance is the foam generator of the 4 plates, and the outlet speed of the three cases is relatively large.



(a) Four baffles



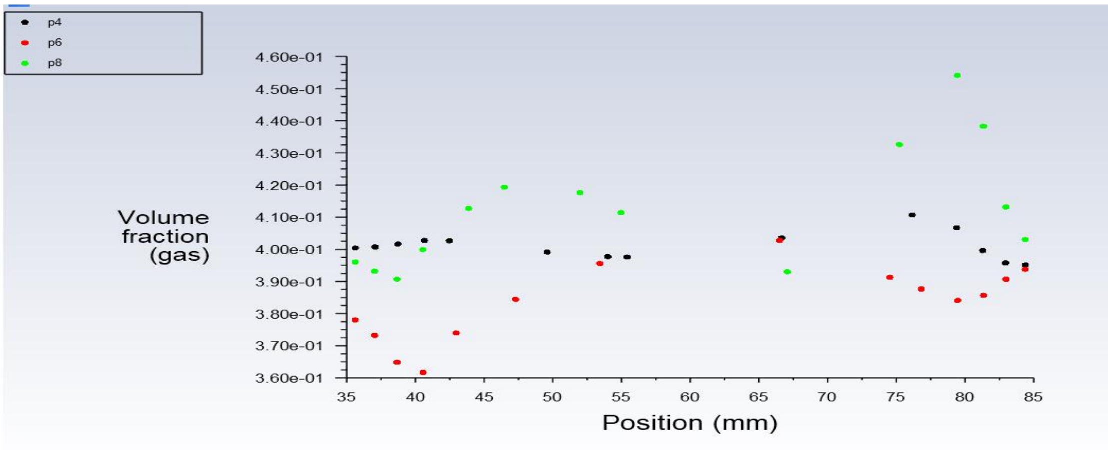
(b) Six baffles



(c) Eight baffles

Figure 3: Volume distribution cloud of former with different baffles and number of plates

The above three figures are the outlet section gas phase distribution diagram of 4 baffles, 6 baffles, and 8 baffles, from which it can be concluded that the gas phase distribution of the outlet section of the foam generator of 4 baffles is the most uniform and 40%, indicating that the gas and liquid mixing disturbance is the fullest, most uniform and most conducive to the production of fine foam, the gas-liquid mixing of the foam generator of the 6 baffles is relatively uniform, and the gas phase distribution of the outlet section of the foam generator of the 8 baffles is the most uneven, the highest place is 48%, and the bottom is 32%, indicating that the gas and liquid mixing situation, in this case, is less sufficient, and it is not conducive to the production of fine foam.



Axial distance Y

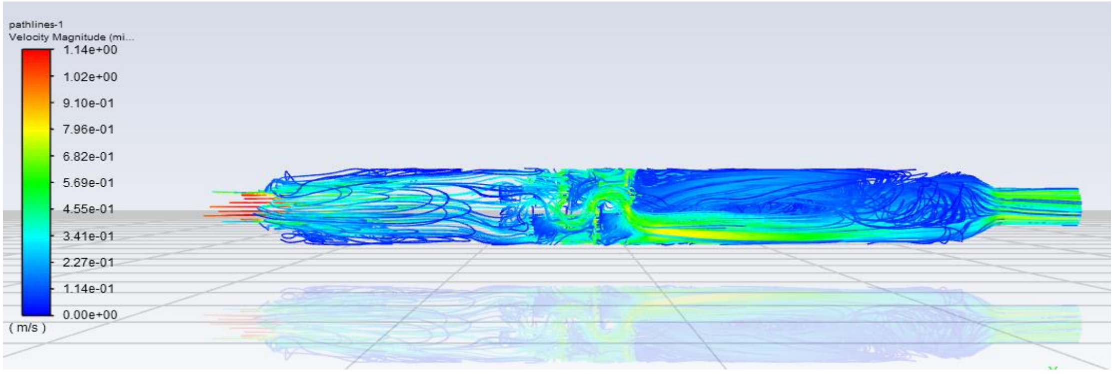
Figure 4: Volume distribution of the gas phase of the former outlet section with different numbers of baffles

Figure 4, it can be concluded that the foam generator with four baffles fluctuates smoothly in the vapor phase volume range between 40% and 41% on the outlet section surface, and the trend is stable. The foam generator with 6 baffles and 8 baffles fluctuates greatly in the gas volume range on the outlet section surface. The foam generator with 4 baffles is most conducive to producing fine and uniform foam.

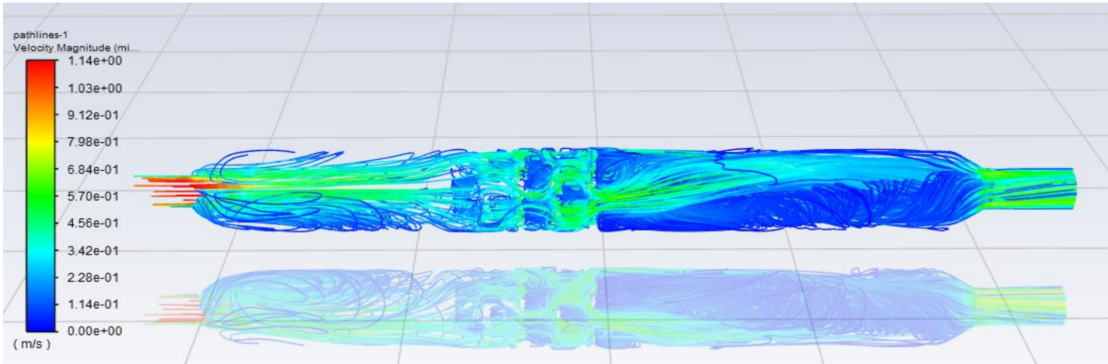
Combined with the internal velocity streamline distribution and gas phase volume distribution of the three foam generators, it can be seen that the area of vortex disturbance of the foam generator of the four baffles is larger, the gas-liquid phase is more uniform and fully mixed in the mixing chamber, the volume fraction of the gas phase is evenly distributed in the outlet section, and the relatively large velocity at the outlet is more conducive to the formation of stable and dense foam fluid.

3.2 Simulation analysis of formers with different numbers of fan blades

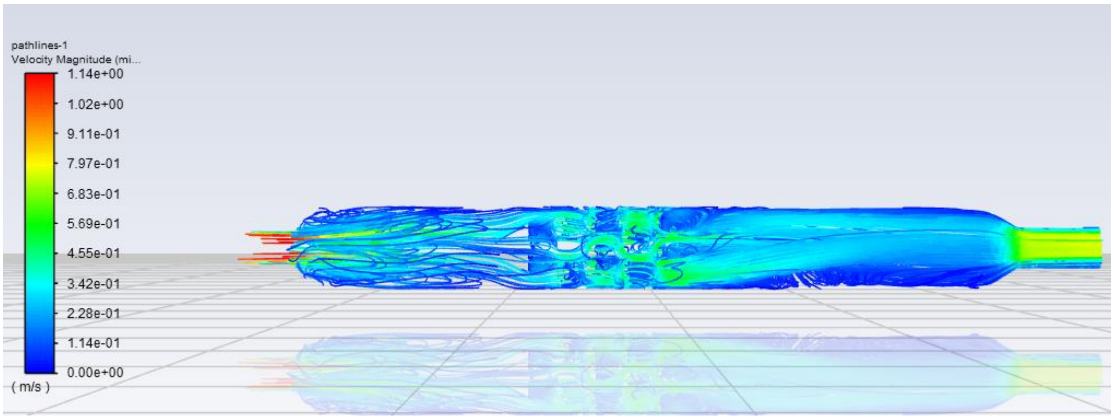
Set the number of baffle fan blades in the foam generator to take 2 fan blades, 3 fan blades, and 4 fan blades, and the numerical simulation of the foam generator is carried out, and the gas-liquid two-phase velocity and gas phase volume distribution are analyzed to determine the optimal number of baffle fan blades



(a) 2-leaf former



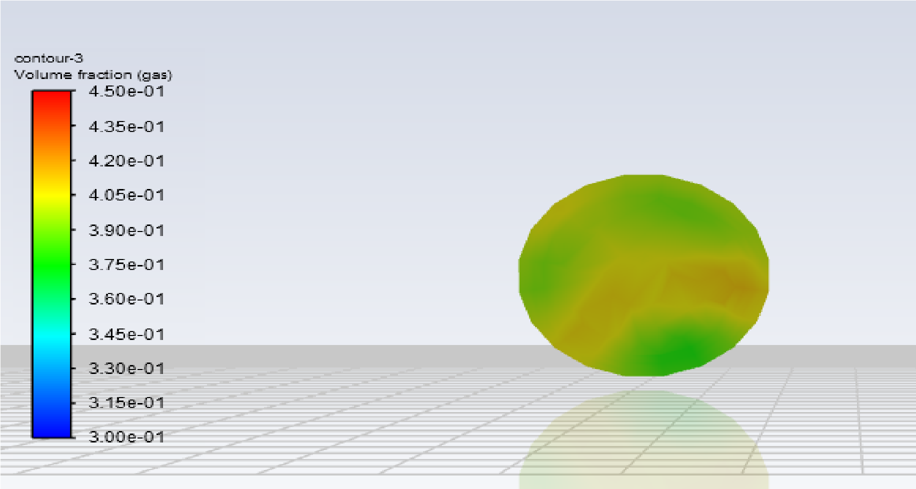
(b) 3-leaf former



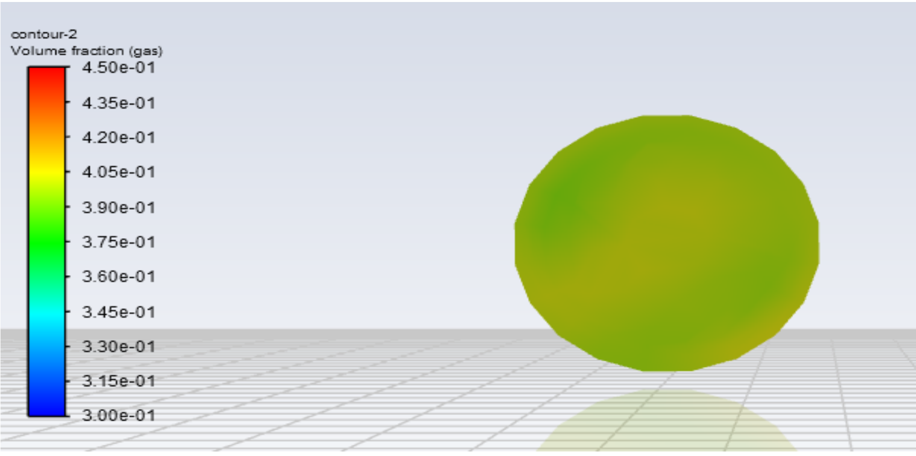
(c) 4-leaf former

Figure 5: Cloud distribution of former velocity with different blade numbers

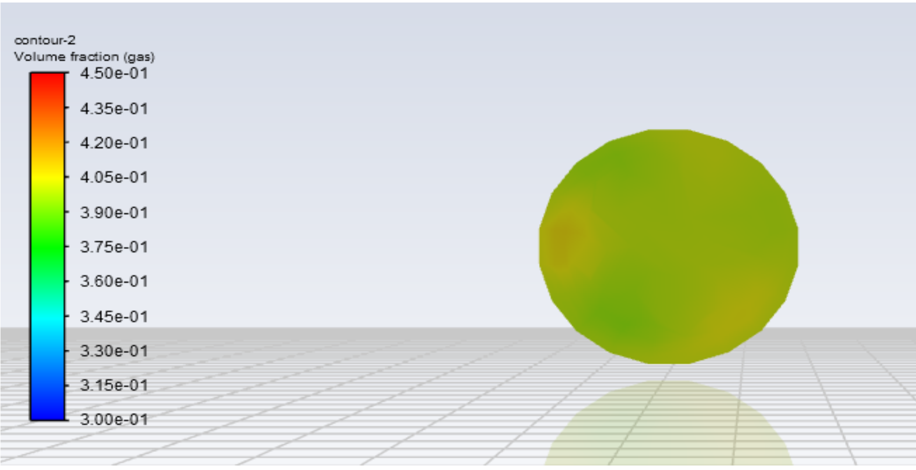
From the above three figures, it can be seen that after the gas-liquid enters the inlet, it is mixed in the front mixing cavity, and the speed of the former of the 3 leaves is larger after mixing, and then the gas-liquid phase is through the baffle for turbulence, and the speed streamlines shape is different when passing through the baffle, but all produce small eddies to make the gas-liquid mixing disturbance, in the rear mixing cavity, the speed of the 4-leaf former is relatively large to produce a vortex area is not large, and the speed of the 2-leaf and 3-leaf former is relatively small There are vortex areas generated. At the exit, the foam generator speed is the highest for 4 leaves, followed by the foam generator speed for 2 and 3 leaves.



(a) 2-leaf former

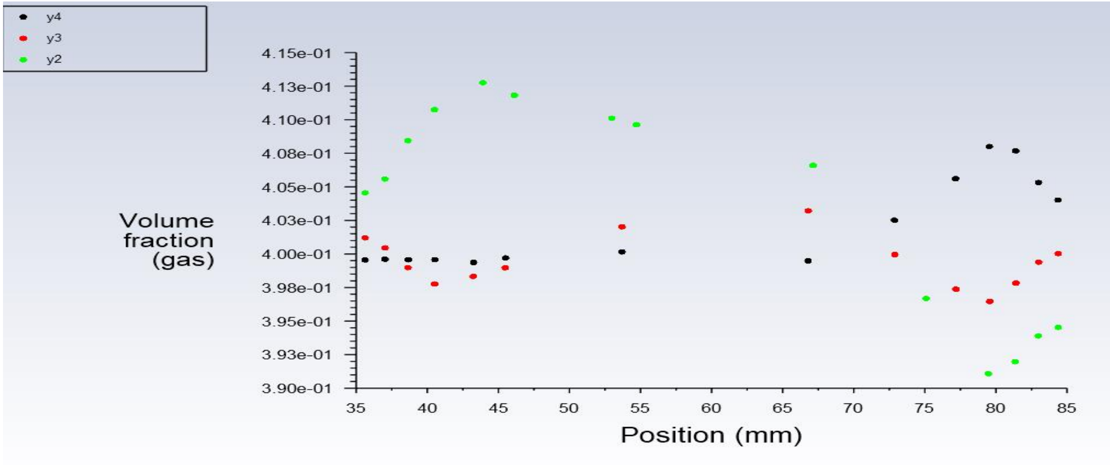


(b) 3-leaf former



(c) 4-leaf former

Figure 6: Volume distribution of former gas with different blade counts



Axial distance Y

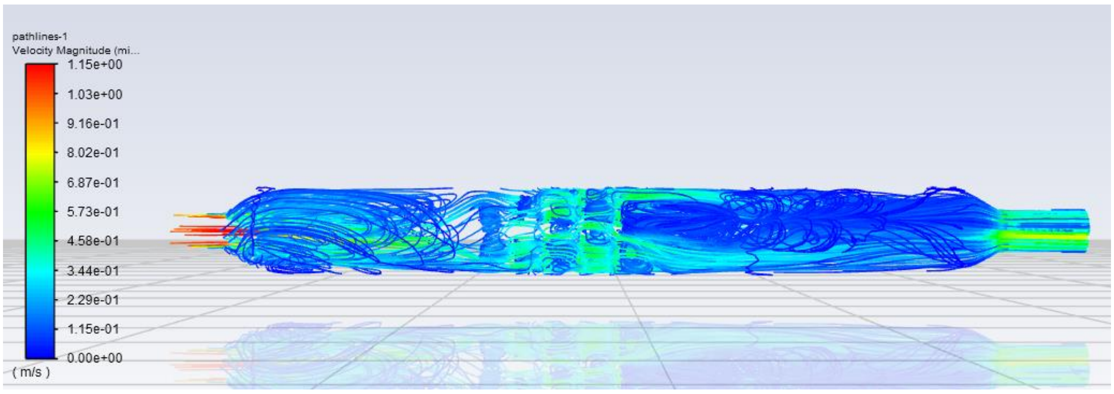
Figure 7: Volume distribution of the gas phase of the former outlet section with different numbers of fan blades

Figure 7, it can be concluded that the foam generator with four fan blades has a stable vapor phase volume on the outlet section, fluctuates slightly, and tends to be stable. The foam generator with 2 blades fluctuates the most in the gas volume range on the outlet section, ranging from 39.1% to 41.4%. The gas phase volume fluctuation range of the foam generator with 3 fan blades is relatively secondary. A foam generator with 4 blades is best used to produce fine, uniform dense foam.

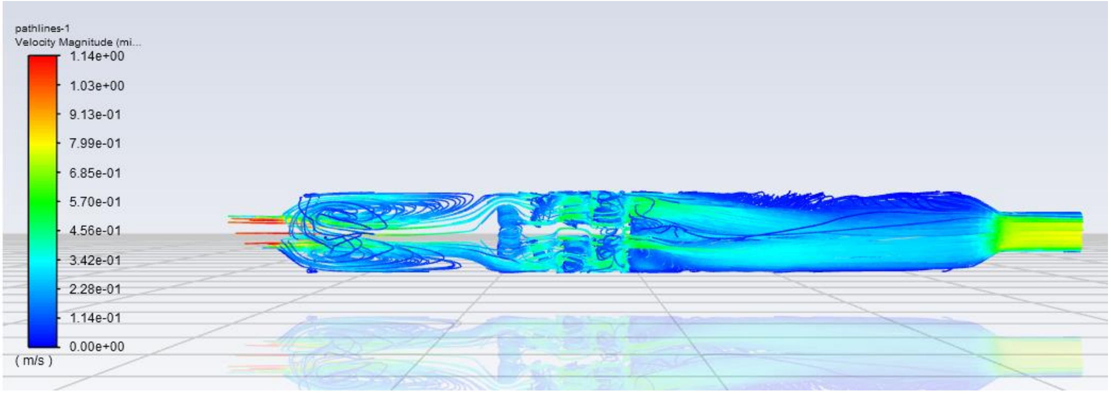
Combined with the internal velocity streamline distribution and gas phase volume distribution of the foam generator of 3 types of fan blades, it can be seen that the outlet speed of the foam generator with 4 fan blades is larger, the volume cloud distribution of the gas phase at the outlet section is more uniform, and the mixing effect of the gas phase liquid phase in the mixing chamber is the best, which is more conducive to the formation of a large, stable and dense foam fluid.

3.3 Simulation analysis of formers with different spoiler angles

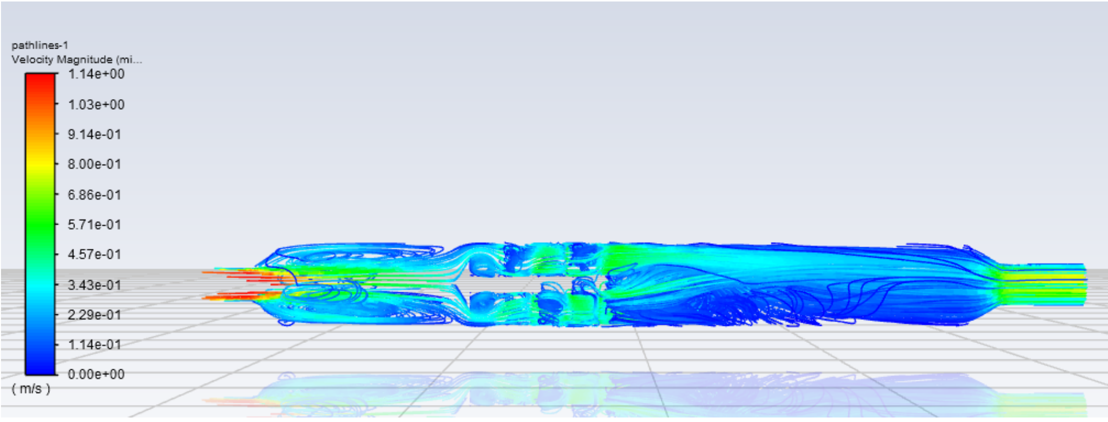
Set the spoiler angles in the foam generator to 60°, 90°, and 120°, respectively, the foam generator is numerically simulated, the gas-liquid two-phase velocity and gas phase volume distribution are analyzed, and the optimal spoiler angle is determined.



(a) 60° spoiler



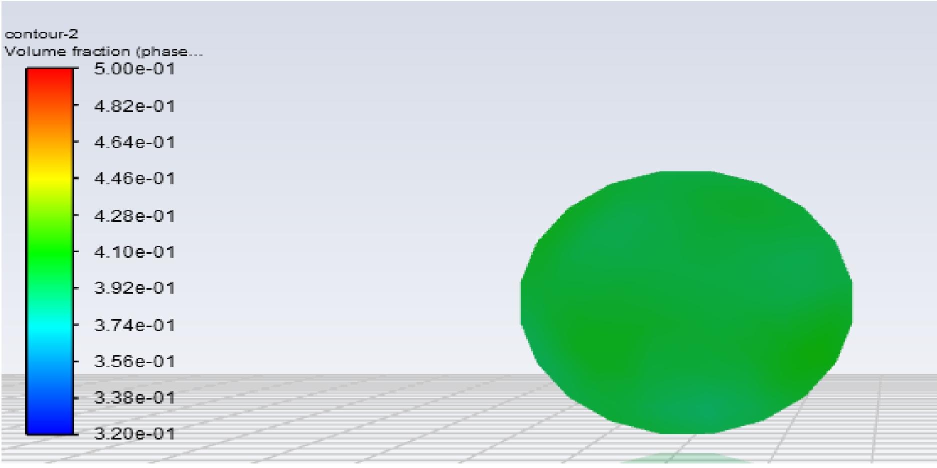
(b) 90° spoiler



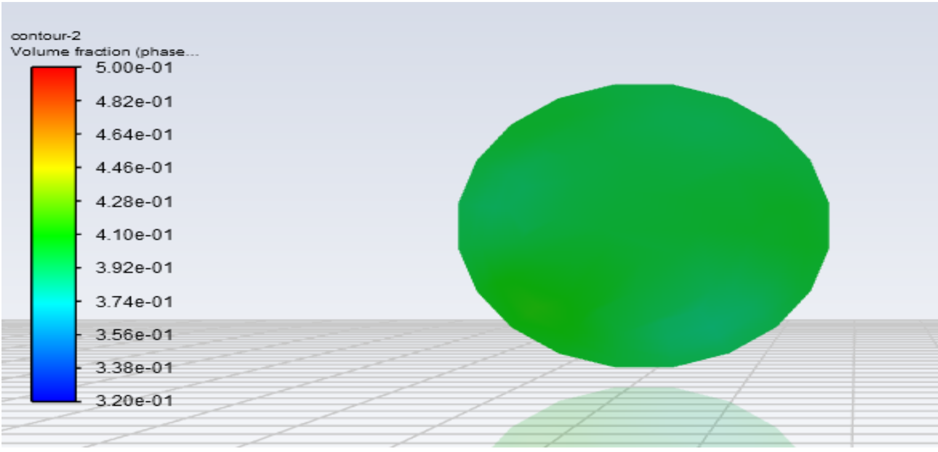
(c) 120° spoiler

Figure 8: Cloud distribution of former velocity at different angles of spoiler

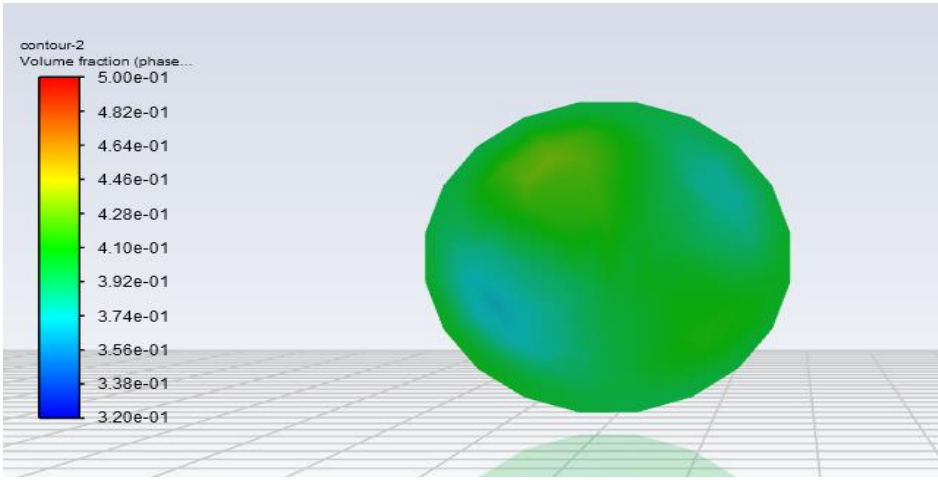
From the above diagram of the foam generator of the three different angles of the spoiler, it can be seen that the area of vortex generation is the largest in the foam generator of the 60° spoiler at the inlet, and the foam generator of the 120° spoiler has a relatively large speed after entering, and then each former produces small vortexes when passing through the baffle, and the gas and liquid can be mixed, at the rear of the mixing chamber. The 30°spoiler foam generator has a large velocity of fluid flowing through the upper and lower parts of the cavity and produces a large number of vortex areas, the 90° spoiler foam generator has a large velocity of fluid flowing through the middle of the cavity to produce a small amount of vortex but the outlet velocity is relatively large, and the fluid with a large velocity of the foam generator of the 120° spoiler flows through the upper part of the cavity to produce a large vortex area, and the outlet velocity is moderate.



(a) 60° spoiler



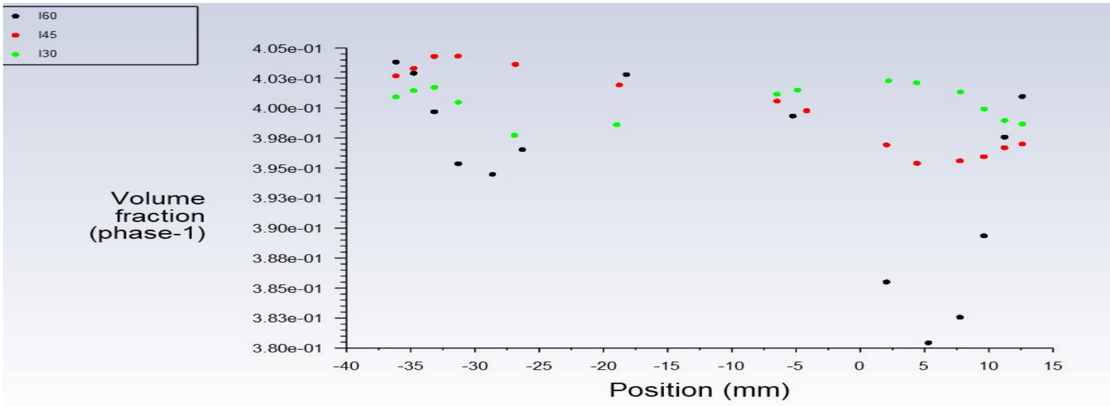
(b) 90° spoiler



(c) 120° spoiler

Figure 9: Volume distribution of former gas at different angles of the spoiler

The above gas phase volume distribution diagram of three types of former outlet sections with different spoiler angles shows that the foam generator of the 60° spoiler and the foam generator of the 90° spoiler have a very uniform volume distribution of the gas phase at the outlet section, indicating that when the gas and liquid are fully in contact with the spoiler baffle and the mixing chamber, the mixing effect of gas and liquid is very good, and it is more conducive to the generation of fine foam, 120°The volume distribution of the gas phase of the foam generator of the spoiler at the outlet section is relatively uneven, and the gas-liquid mixing effect is relatively poor, which is not conducive to the formation of dense and uniform foam.



Axial distance Y

Figure 10: Volume distribution diagram of former outlet section at different angles of spoiler

From the gas phase volume distribution diagram of the outlet section, it can be seen that the gas phase volume trend of the foam generator of the 120° spoiler is unstable, and the gas phase volume trend of the foam generator of the 60° spoiler and the foam generator of the 90° spoiler is relatively stable, and the gas-liquid blending effect is relatively good, which is more conducive to the production of dense foam.

Combined with the velocity streamline cloud and the gas volume distribution cloud, it can be concluded that the foam generator of the 90° spoiler has a relatively faster outlet speed, a more uniform gas volume distribution in the outlet section, and is more conducive to producing a large number of fine foams.

5. Conclusion

Using FLUENT simulation to simulate and analyze the internal flow field of the foam generator from the aspects of the number of baffles, the number of baffle blades and the angle of the spoiler, the velocity streamline distribution, and gas phase volume distribution of the internal flow field of the foam generator are obtained, and the results show that:

(1) For the internal velocity streamline distribution diagram and gas phase volume distribution diagram of the three foam generators, it can be seen that the area of vortex disturbance of the foam generator of the four baffles is larger, the gas-liquid phase is more uniform and fully mixed in the mixing chamber, and the gas phase volume fraction is evenly distributed in the outlet section, which is more conducive to the formation of stable and dense foam fluid.

(2) For the internal velocity streamline distribution map and gas phase volume distribution diagram of the foam generator of the three types of fan blades, it can be seen that the outlet speed of the foam generator of the four fan blades is larger, the distribution of the gas phase volume cloud at the outlet section is more uniform, and the gas phase liquid phase has the best mixing effect in the mixing chamber, which is more conducive to the formation of a large, stable and dense foam fluid.

(3) For the foam generator velocity streamline cloud and gas volume distribution cloud of different angle baffles, it can be concluded that the foam generator of the 90° spoiler has a relatively faster outlet speed, and the volume distribution of gas in the outlet section is more uniform, which is more conducive to generating a large number of fine foam.

(4) Based on FLUENT software, the numerical simulation of the gas-liquid two-phase flow of foam generators with different types of structures is carried out, and the internal structure design of foam generators is optimized to improve the foaming effect of foam generators, which has certain theoretical basis and significance.

Declarations

Ethical Approval

Applicable for both human and animal studies. This study was approved by the Henan Polytechnic University, Henan Province, China.

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Availability of data and materials

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Consent to Publish

The authors agree to publish the article in English in the journal Experiments in Fluids.

Declaration of Competing Interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Authors Contributions Statement

Xuanxuan WEI: Conceptualization、Methodologgy Formal analysis and Data Curation.

Zhongliang LU: Conceptualization and Writing-Review & Editing.

References

[1]. Daniel Zhang. Research and countermeasures for the development of China's coal industry[J].Mining equipment,2011(Z1):36-38.

[2]. ZHANG Jiangtao, WANG Wenbin, CHENG Xiaowei. Numerical simulation of gas-liquid two-phase flow of foam generator based on Mixture model[J].Hydropneumatics and seals,2021,41(09):34-37.

[3]. GAO Panjun, HUANG Xin, TAN Xue. Development and application of high-power foam dust collector for excavation face[J].coal mining machinery,2015,36(05):213-215.

[4]. LIU Chengting, LIU Gang, YAN Zuoxiu et al. Experimental study on the effect of vapor phase pressure on baffle foam generator[J]. contemporary chemical industry,2019,48(01):144-146+217.

[5]. LUO Jiaqi, LI Zhongshuai, LIU Chengting. Research on flow law and structure optimization of high-efficiency foam generator[J].China petroleum and chemical standards and quality,2018,38(17):11-12.

[6]. LIU Chengting, ZHANG Weiwei, YAN Zuoxiu et al. Analysis and experimental study of the internal flow field of spiral foam generator[J].petroleum machinery,2018,46(07):75-79.

[7]. LI Jiacheng, LUAN Bochuan. Numerical simulation of the internal flow field of a jet foam generator[J].Liaoning Chemical Industry,2017,46(09):920-922+925.

[8]. ZHANG Chengwu, WU Yuerong, Wan Xianghui, et al. Flow modeling and finite element simulation of hedge foam generators[C]//Xi'an Shiyou University, Shaanxi Petroleum Society, Beijing Zhenwei Exhibition Co., Ltd.2023 Proceedings of the International Conference on Petroleum and Petrochemical Technology.[Publisher unknown],2023:7.

[9]. YAN Yuejuan, CAO Yuhang, LIU Chongjiang et al.Structural design and numerical simulation of foaming performance of downhole nitrogen foam generator[J].Mechanical design,2021,38(01):64-71.

[10]. WANG Qunxing, LI Junxia. Numerical simulation study of the internal flow field of foam generator based on FLUENT[J].mining machinery,2014,42(11):94-97.

[11]. LIU Chengting, Uricle, LUAN Bochuan. Internal flow field analysis of baffle foam generator[J].Contemporary chemical industry,2017,46(07):1422-1425+1429.

[12]. LIU Chengting, SU Ying, LI Huifang et al. Application of gas-liquid two-phase flow mathematical model in optimization of concentric foam generator[J].Practice and understanding of mathematics,2016,46(21):127-133.

[13]. LIU Chengting, DAI Yunlong, Hu Yuanyuan et al. Study on the unstable flow law of gas and liquid in the foam generator[J]. Contemporary chemical industry,2016,45(08):1777-1779+1787.

[14]. Sunday peak, LANG Xuqing, ZHANG Jianzhong. Flow field simulation analysis of multistage plate spoiler foam generator[J].safety, health and environment,2016,16(04):18-21.

[15]. LI Songyan, LI Zhaomin, LI Binfei et al. Numerical simulation of the flow field inside a foam generator[J].oil mine machinery,2009,38(02):5-11.