Study on Ejecting Characteristics of Gas Gun Gas-Gas Super-ejector Combustor

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Abstract. Aiming at the low success rate of gun firing with gas gun in the airport, the launch characteristics of gas-gas ejector were studied based on Fluent software to improve the ejection performance. Through the multivariate statistical analysis model, the single-value influence curve of each structural parameter of ejector on the ejector coefficient is obtained, and the theoretical ejector coefficient corresponding to the main component of the gas is obtained by stoichiometric analysis. Matching ejector structure parameters and ejector coefficients, the numerical simulation results of the optimized model show that the gas filling rate increases, the gas distribution in the combustion chamber is uniform and the concentration is increased. The previous ignition combustion product has no obvious effect on the secondary ignition, and is effective Solves the problem that the success rate of the original model is too low and achieves a continuous ignition of the ejector for a short time and enhances the ejecting performance comprehensively.

Key words: Characteristics, Multivariate Statistical Analysis, Structural Parameter, Numerical Simulation

1 INTRODUCTION

Ejectors are widely used in petrochemicals, navigation and other fields, such as exhaust emissions, jet aeration, airport birds repelling.The research on the parameters related to ejector and ejector characteristics at domestic and abroad aims to continuously improve its ejecting performance.Dvorak et al. analyzed the effect of pressure recovery on the parameters of the iso-section ultra-super ejector system [1]; Winoto et al. analyzed the influence of the shock wave in the diffuser section on the ejector characteristics [2].Tang Jianfeng et al. conducted an indoor simulation test on the structural parameters of the ejector and obtained the influence of the structural parameters on the ejector performance [3]. Y. Bartosiewicz et al. [4] optimized the ejector boost ratio and efficiency, ejected Mach number, and other parameters. At present, there are few numerical simulations based on practical applications for ejectors, which results in random products with high randomness, and continuous ignition at short intervals, insufficient explosion loudness, so the success rate of firing is too low, and the bird repellent effect is not ideal[5-6].

Based on this phenomenon, this article uses the gas gun combustor and ejector as a platform to study the influence of structural parameters on the ejection coefficient, and establishes a multivariate statistical analysis model to comprehensively evaluate the merits of the ejection performance and to perform overall flow of the combustion chamber. The field analysis aims to improve the success rate of gas gun ignition, improve the requirements for continuous ignition, and comprehensively improve the launch performance.

2 The establishment of a numerical simulation model

The structure of the gas-air super ejector is shown in Fig.1, it consists of a pressure inlet, a tapered section, a mixing room, an expansion section and pressure outlet. Creating a three-dimensional model of the combustion chamber where the ejector is located as show in Fig.2, and divide the calculation grid. The combustor uses an unstructured mesh, the ejector is hexahedral meshed and encrypted, and the connection is a wedge-shaped mesh transition.

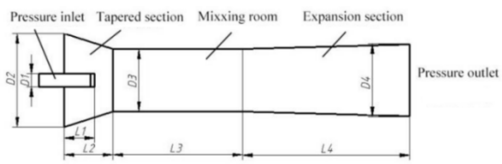


FIGURE 1. Ejector Structure and Flow Fields

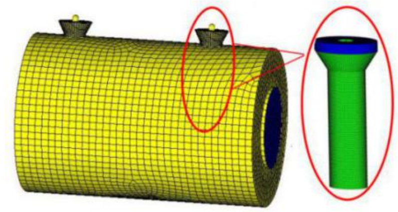


FIGURE 2. Numerical Simulation Model of Combustion Chamber

In order to simplify the calculation model, it is assumed that gas and air are evenly distributed at the inlet, there is no chemical reaction during aeration and no friction between the fluid and the wall; there is no heat exchange during operation.The ejector uses liquefied gas as the driving gas. The initial boundary conditions are shown in Table 1.

TABLE 1. Initial and boundary conditions setting table

Problem Setup	
Type	Density-Based
Time	Unsteady, Steady
Turbulent model	Standard k-ε model
Species	Species transport
Materials	Air, propane, n-butane carbon dioxide water(gas)
Boundary Conditions	Pressure-inlet:0.1MPa Pressure-inlet:0MPa Pressure-outlet:0MPa Operating pressure:1atm Intensity and Hydraulic Diameter
Solution	
Formulation	Implicit
Turbulent Kinetic Energy	1nd Order Upwind
Turbulent Dissipation Rate	1nd Order Upwind

According to Fig.3 and Fig.4, the original ejector fills slowly, the gas does not fully fill the combustion chamber at the end of inflation, and the gas distribution in the room is uneven and the concentration is too low, so it is manifested as insufficient mixing of gas and air, which can easily cause ignition failure and affect ejection. performance.

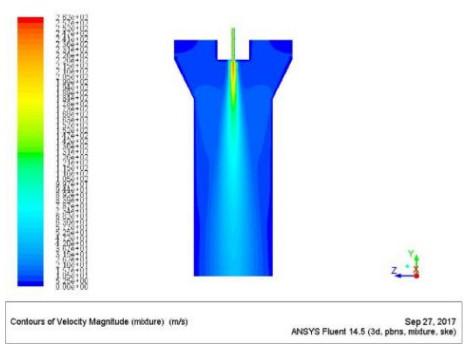


FIGURE 3 Ejector Speed Cloud

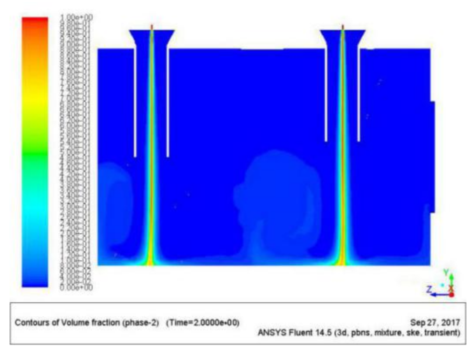


FIGURE 4 Combustion chamber gas concentration cloud

3 Research on key parameters of ejection performance

The ejector performance of gas-air super ejector is closely related to the parameters of ejector characteristics, and can be divided according to working condition parameters and structural parameters.Working conditions include working pressure, priming pressure, etc. The structural parameters are mainly ejector geometric model parameters. The ejection performance is mainly characterized by the ejection coefficient U_a.

2.1 Structural parameters and ejection coefficient U_a matching

Based on the previous assumptions, both gas and air are ideal gases and the flammable components are completely burned.The ejection coefficient M_0 is the ratio of gas to air inside the combustion chamber when the ejector is fully inflated, and is defined as the air quality required for complete combustion of the unit mass gas.The gas composition is simplified to propane and butane based on the primary and secondary relationship.

A multivariate statistical analysis model for ejectors was established using a structural equation model.The ejection parameter Y is expressed as $Y=\{Y(X_1),Y(X_2),Y(X_3),\}=\xi_1(p_1+p_2)+\xi_2[y(d_1,l_1)+y(d_2,l_2)+y(d_3,l_3)]+\xi_3 e$, find the optimal solution for the numerical model[6]. The influence factors of the same type of array are changed, the results of sampling and analysis of each group are statistically analyzed, the relationship between the main influence factors and the ejection coefficient is obtained.

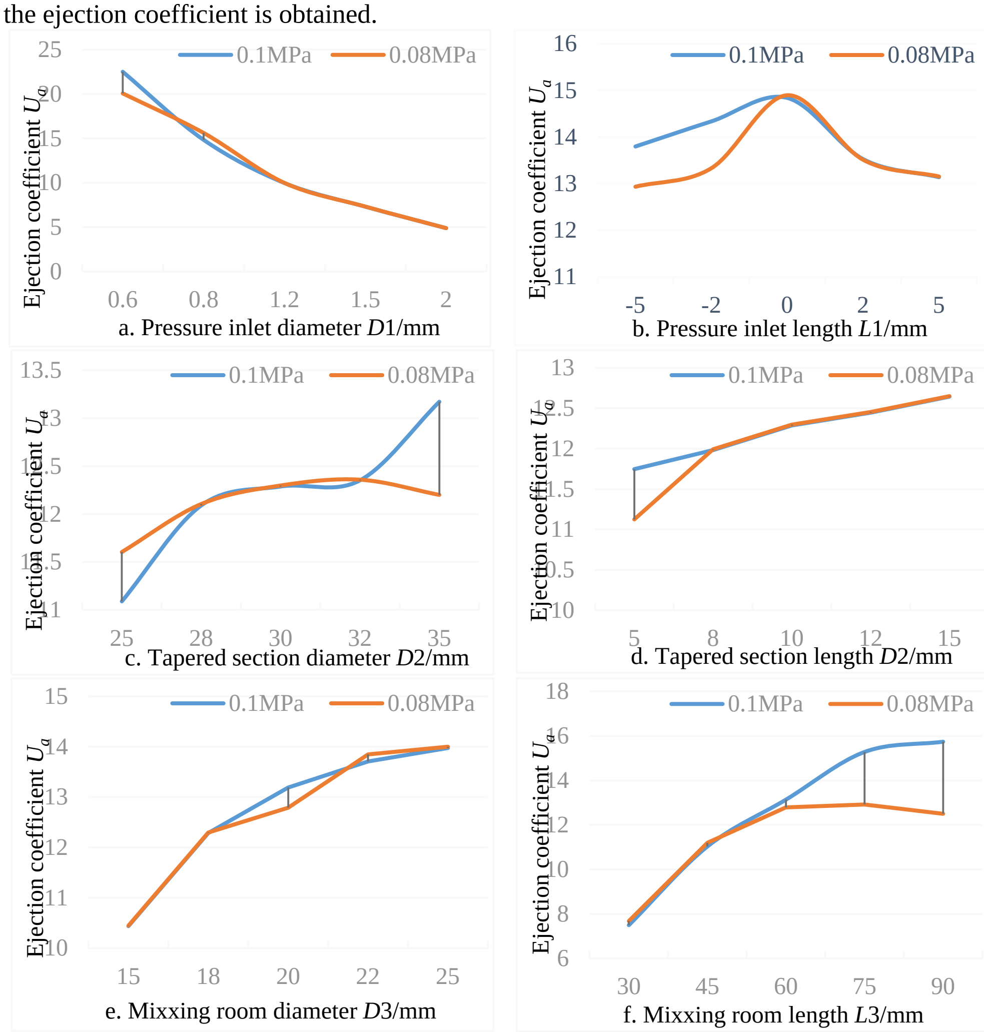


FIGURE 5. Relationship between structural parameters and U_a

From Fig.5-a, under a certain working pressure, the ejector coefficient decreases rapidly with the increase of the pressure inlet diameter and tends to be stable. As the pressure inlet diameter increases, the gas and air flow are directly increased, and both are controlled by the ejector. For factors such as back pressure, the growth is not proportional, and combined with the curve, gas flow increases faster than air flow. Secondly, the curve under different working pressures does not change much, and the ejector coefficient is not sensitive to working pressure, so the ejector can work stably under different environments. From Fig.5-b, the ejection coefficient reaches its maximum when Pressure inlet diameter is 0mm.

From Fig.5-c, when the inlet diameter of the tapered section is 28~32mm, the ejection coefficient is stable. Within this range, the working pressure affects little, and the ejection coefficient outside this range shows an unstable trend. When the diameter of the tapered section is set too small, the resistance of the air into the ejector is large, so that the gas and air flow are unbalanced, the ejection coefficient is too low, and the phenomenon is improved as the diameter increases. From Fig.5-d, the ejection coefficient increases with the length of the tapered section. The longer the tapered section is, the more fully the high-speed jet develops, and the more the amount of gas to be ejected, the larger the ejection coefficient. In order to ensure the stability of the ejection performance and properly reduce the manufacturing cost, the diameter of the tapered section is preferably 28 to 32 mm and the length is 8 to 12 mm.

From Fig.5-e, the ejection coefficient increases with the diameter of the mixing room, and finally converges to a constant value. If the diameter of the mixing room is too small, the fluid entry resistance increases. After the diameter increases to a certain range, the flow resistance reaches a minimum. The flow rate entering this interval changes constantly, so the ejection coefficient is approximately constant. Secondly, the ejection coefficient has small variation in diameter of the mixing section under different controlled working pressures. To ensure the mixing ratio of gas and air, the diameter of the mixing section is preferably 18-22 mm. From Fig.5-f, the ejection coefficient increases with the increase of the length of the mixing section within a certain interval, and then decreases. When the length is too small, the fluid collision process is insufficient, and the phenomenon improves with the increase of the length. After reaching a certain length, only Increase the fluid movement resistance, the increase of the amount of radiation does not increase, showing the decrease of the ejection coefficient. The expansion segment simulation result is similar to the mixing segment and will not be described again.

4 Numerical simulation of flow field in combustor

3.1 Ejector Key Parameters Optimization

The optimization parameters of the ejector for group simulation are shown in Table 2. In practice, due to the complex gas composition of the combustion chamber and the content of the gas component being slightly lower than the theoretical value, in order to ensure full combustion of the gas, the ejection coefficient must be properly reduced, and the optimal injection coefficient U_a should be taken based on the conclusion in the previous section.

TABLE 2. Optimization of ejection parameters

Object parameters	U_a	$D1$/ mm	$L1$/ mm	$D2$/ mm	$L2$/ mm	$D3$/ mm	$L3$/ mm	$D4$/ mm	$L4$/ mm	α/°
Optimal value	15	1	0	25	10	15	30	25	40	7°

3.2 Combustion chamber simulation results

Gas flows through the pressure inlet to outlet so as to form a high-speed jet , the outlet velocity magnitude as shown in Fig.6 . From Fig.7 ,when the gas inflated to the combustion chamber , it passes through the exit of the expansion section and reaches the inner wall of the combustion chamber. It diffuses rapidly along the wall and drives the indoor low-speed air. Flow mixing accelerates filling, until the combustion chamber has initially formed a stable concentration , which can solve the phenomenon of uneven charging of the original model.

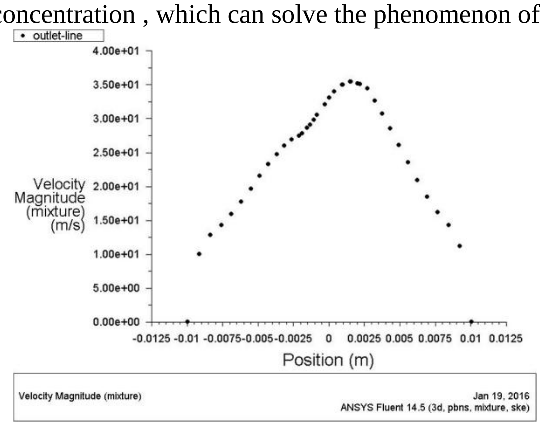


FIGURE 6. Velocity Magnitude of outlet

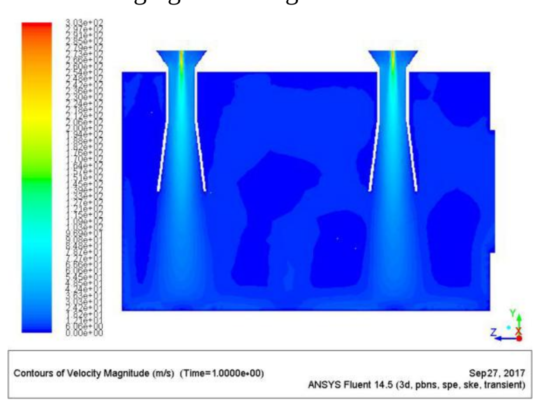
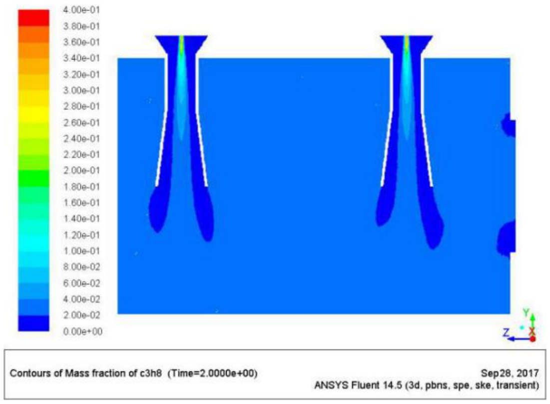


FIGURE 7. Contours of velocity Magnitude

In order to further optimize the continuous ignition performance of the ejector, the composition of the main fluid in the combustion chamber after decomposing the secondary charge and before ignition is performed. From Fig.8, the mass fraction of C_3H_8 is between 2% and 6% after the completion of the aeration, which has reached the ignition requirements. The main combustion products of the initial ignition are CO_2 , From Fig.9, the mass fraction of CO_2 is less than 5×10^{-6}, the value of the minimum micro-secondary ignition does not have a significant impact, and its ejection performance is still to meet the requirements.



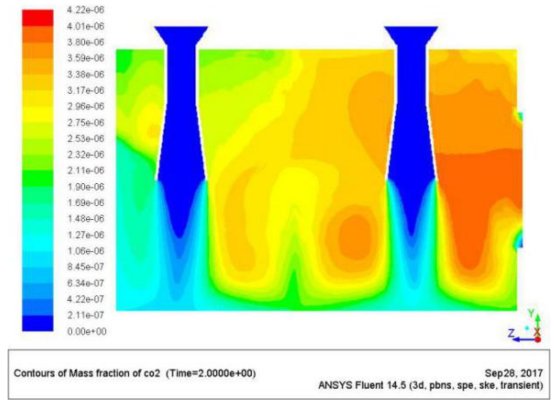


FIGURE 8. Contours of Mass fraction of C_3H_8 **FIGURE 9. Contours of Mass fraction of CO_2**

5 CONCLUSION

In this paper, stoichiometric analysis shows that the theoretical eductor coefficients are required for the main components of gas, and a multivariate statistical analysis model for ejectors is established using the structural equation model. The fitted curves of the observed variables and potential variables in each structural parameter are obtained. advanced optimization. The analysis of the flow field of the optimized combustion chamber shows that the filling rate of the gas jet is obviously increased, the gas concentration in the combustion chamber is increased and evenly distributed, which effectively solves the problem of high ignition failure rate of the original model; secondary ejector is used for secondary ignition. Before that, each component in the combustion chamber was higher than the ejector's requirement, and the ejector could realize the condition of continuous ignition at short intervals, and the ejector's ejection performance was comprehensively improved.

ACKNOWLEDGMENTS

This work was financially supported by B2016436 fund (2016 scientific research guidance project of the Hubei Provincial Education Department, with the support and help of leaders and colleagues from Hubei Provincial Department of Education and City College, Wuhan University of Science and Technology).

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