Interior ballistic design of gas-driven special opening system

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Abstract. Aiming at the problems of slow opening speed and high power of hydraulic system for traditional special opening and closing mechanism, a gas-driven opening scheme is proposed. Combined with the working environment of the special opening and closing mechanism, the opening mode and principle of the opening and closing mechanism were analyzed. The gas ejection system was designed, and the dynamic model of the opening and closing mechanism was established according to the actual mechanical structure. The focus is on the design of the internal ballistics of the system, and the relevant parameters of the gas ejection system are finally determined based on the simulation results. The numerical test results show that the method can be opened within the specified requirements of the opening and closing mechanism. Compared with the traditional method, the opening time is greatly shortened, which has theoretical feasibility and can provide reference for the opening of the special opening and closing mechanism.

1. Introduction
Special opening and closing devices are widely used in many fields, and require quick and steady opening in the process of opening. The traditional way of opening usually adopts hydraulic drive, which has the problems of slow opening speed and high power of hydraulic system. Using other power sources to realize rapid opening is an effective way to improve special opening and closing devices. Based on the advanced technology of foreign countries, this paper uses gas as the power source to realize the fast opening of special opening and closing device.

Gas power plant used in the equipment such as ejection, unmanned aerial vehicle (UAV) emission, is convert chemical energy into kinetic energy load movement, has the advantages of large energy density, small volume, is widely used in the rescue, aircraft and other equipment. The research on gas explosion has been attracting the attention of scholars all over the world. Akihiiko Miura [1] et al. studied the characteristics of gas explosion by combining experiment with simulation, and focused on the characteristics of pressure wave propagation during explosion. D.V.M. [2] Akarov et al. studied air and hydrogen mixtures in a closed spherical space, and studied the combustion and explosion process in terms of calculation methods and model grid establishment. Wang Hua [3] et al. analyzed the explosion process of the first space flammable gas, and compared and analyzed the influence of container factors, initial turbulence, gas ratio, initial pressure and other factors on the explosion process. Wang Rongzhi and Jiang Juncheng et al. designed an experimental device for studying gas explosion under confined condition and tested the law of gas explosion process.

Although the study of gas explosion has been praised by the attention of scholars, but based on the special opening and closing mechanism on system gas ejection are rarely reported, the American scholar
Charles K and Marietta G [4, 5] invented an explosive ejection gear oil source type, implements a short take-off and landing aircraft, but the device structure is complex, difficult to control. Biting combustion machine based on the analysis of the gas expansion mechanism, combined with the special mechanical model of opening and closing mechanism, established the mathematical model of gas ejection process, with reference to design the open process of monotable curve, through to the opening and closing mechanism simulation, the gas ejection related parameters of the power plant is determined.

2. problem description

The traditional special opening and closing device usually consists of hydraulic cylinder, electromagnetic proportional valve, protective cover and oil source. In this paper, a fast opening model based on gas ejection is proposed.

The motor drives the piston rod of the driving cylinder, driving the rotating arm and the front pulley to rotate along the axis of the support. When the highest point of the rotating arm comes into contact with the front end of the slide, the roller in front of the cover slides into the slide. At this point, the generator gas ignition, its produce the high temperature and high pressure gas drive piston component movement, thus promote the lid to accelerate, moving along the slide rail cover movement after a certain distance, through variable damping hydraulic cylinder with the brake braking force to realize the lid, the lid of a complete open.

The key of the above structure to realize the quick opening of the opening and closing device is the rationality of the design of gas ejection system. When analyzing the internal trajectory in this paper, the following assumptions are made about the system:

1. The structural strength meets the requirements, the connection is confined and the seal is intact.
2. The flow process of gas in high and low pressure rooms is zero-dimensional single flow.
3. Gas is evenly distributed in high and low pressure Chambers.

3. Simulation of gas ejection system

Through the analysis of the principle of the ejection technology of the open cylinder, the mathematical model of interior ballistic was established. The entire ejection process was divided into two stages, specifically:

a. First period: the moment when the protective cover enters the sliding track, it will reach the moment when the high pressure chamber burns. The characteristic is that only two different processes of gas inflow and the movement of protective cover are carried out simultaneously in the open cylinder. This period is the most important and representative working period of the opening cylinder.

The ballistic equations in this period are:

\[
\frac{dY_i}{dt} = \dot{Y}_i = \frac{\phi_{21}K_0Sp_1}{\sqrt{\chi_1RT_0}}\ p_1
\]

\[
\frac{dv}{dt} = \frac{Sp_2 - mg\sin\theta}{\rho m}
\]

\[
\frac{dl}{dt} = \nu
\]

\[
p_2 = \frac{\chi_1\chi_2\tau_{2}RT_0Y_i}{W_{20} + S_l}
\]

b. The second stage: from the end point of high pressure chamber combustion to the moment when the speed of protective cover reaches an instant. This period: when the high pressure chamber combustion is over, the gas inflow in the opening cylinder drops rapidly, the pressure of the opening cylinder also drops rapidly, and the protective cover speed increases slowly.

The ballistic equations in this period are:
When ejection process into the second period, end of the high pressure chamber charge combustion, without the gas generation, pressure decreases rapidly, high and low pressure chamber pressure value is more close, vents the influence of back pressure increases, when the gas from high pressure chamber into low pressure chamber originally can also maintain the critical flow rate, but with the pressure and decreases when the high and low pressure chamber pressure met \( p_2 > \left( \frac{2}{k+1} \right)^{\frac{k}{k-1}} \), low pressure chamber inflows cannot maintain the critical flow rate, gas flow formula into subsonic flow equation, in the equations is given.

\[
V(t) = \begin{cases} 
0 & 0 \leq t \leq 0.5 \\
1.25(t-0.5) & 0.5 \leq t \leq 2.5 \\
2.5 & 2.5 \leq t \leq 3 
\end{cases}
\]

The ideal velocity curve is shown in figure 1
The internal ballistic simulation theory is applied to simulate the internal ballistic process of an open-cylinder projectile for many times. Finally, the driving curve similar to the design curve is obtained. The simulation results are shown in the table.

| Parameter                          | Value    |
|-----------------------------------|----------|
| Low pressure warehouse maximum pressure | 0.125MPa |
| Final drive speed                 | 2.6m/s   |
| Drive time                        | 2.66s    |
| Maximum acceleration              | 0.3g     |
| controll                          | 0.5Kg    |

The simulation curve is shown in the figure 2-5.

**Figure 2.** High pressure chamber pressure

**Figure 3.** Low pressure warehouse pressure
4. Conclusion

(1) In view of the disadvantages of hydraulic drive of traditional special opening and closing mechanism, an opening scheme with gas ejection as the power is proposed, and the opening time is greatly improved compared with the traditional way.

(2) The design and 3d modeling of the gas ejection system are carried out, and the mathematical model of the ejection system is established, which provides a basis for subsequent simulation.

(3) The ideal curve was designed according to the use of the opening and closing mechanism, and the key parameters of the gas ejection system and the driving curve similar to the design curve were obtained through multiple simulations.

References

[1] RAZUS D, BRINZEA V, et al. Inerting effect of the combustion products on the confined
deflagration of liquefied petroleum gas-air mixtures [J]. Journal of Loss Prevention in the process Industries, 2008, 22: 463 - 468.

[2] MIURA A, MIZUKAKI T, SHIRAISHI T et al. Spread behavior of explosion in closed space [J]. Journal of Loss Prevention in the process Industries, 2004, 17: 81 - 86.

[3] F. Van den Schoor, F. Norman, F. Verplaetsenl. Influence of the ignition source location on the determination of the explosion pressure at elevated initial pressures [J]. Journal of Loss Prevention in the process Industries, 2006, 19: 456 - 462.

[4] Charles K, Marietta G. Jump strut landing gear apparatus and system. United States Patent: 4687158, 1987.08.18.

[5] Caliskan, H, Balkan, T, Platin, B E, DEMIRER, S. Servo Hydraulic Position Control with Variable Speed Pumps [J]. Proceeding of V. National Hydraulic and Pneumatics Congress, 2008, 50 (587): 1 - 12.