Internal Ballistic Simulation and Optimum Design of Gas-fired Rodless Cylinder Ejection Device

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Abstract

A kind of gas-fired rodless cylinder ejection device which was stoke and weight controlled and suitable for mobile launch was designed . The leakage test of the ejection device was carried out based on the principle prototype of rodless cylinder ejection device and the empirical formula between leakage rate and pressure and travel length was fitted. The mathematical model of gas-fired rodless cylinder ejector internal ballistic with considering the leakage rate was established based on the assumption of zero-dimensional internal ballistic. When comparing the results of internal ballistics considering and not considering the leakage rate ,it could be seen that the influence of leakage rate on the results of internal ballistics could not be ignored. The internal ballistic model which coupled the leakage rate was optimized, taking the shortest design stroke and smallest ejection stability index as design target and the parameters of the grain were used as design variables. The results show that after the optimization , the mass flow rate of gas at the end of ejection is increased by 19%, the stroke required for piston speed reaching the design target is shortened by 13.1% , and the launch stability index is increased by 10.7%.

1. Introduction

In this paper, the leakage test of the ejection device was carried out on the principle prototype of the rodless cylinder ejector using high-pressure gas source.

1) The leakage rate of the rodless cylinder ejector under different cylinder pressure and piston stroke was obtained, and the empirical formulas of leakage rate, pressure and stroke were fitted.

2) The mathematical model of internal ballistics of gas-fired rodless cylinder ejector considering leakage was established, and the results of internal ballistics considering leakage and not considering leakage were compared.

3) Finally, the multi-objective optimization of internal ballistics considering leakage was carried out to obtain the optimized results of internal ballistics and provided the theoretical support for further engineering design.

2. Research process

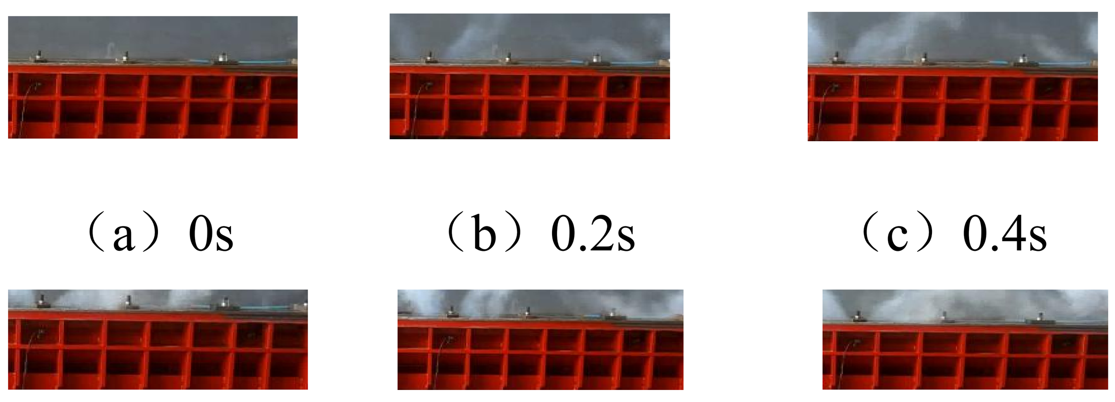
1) Leakage test of rod less cylinder ejector

2) Interior ballistic modeling of gas-fired rodless cylinder ejector

3) Comparative analysis of the results without considering leakage and leakage rate coupling interior ballistics

4) Comparison of interior ballistic calculation results without considering leakage and considering leakage.

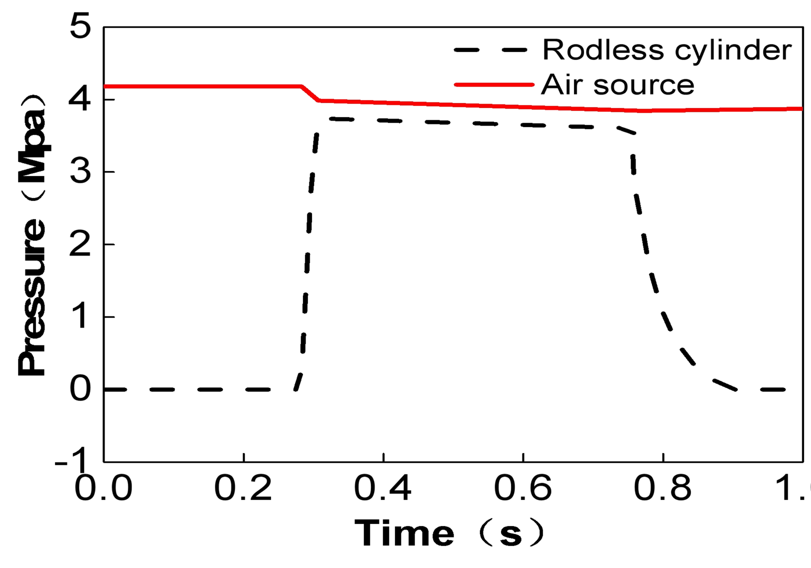
3. Result



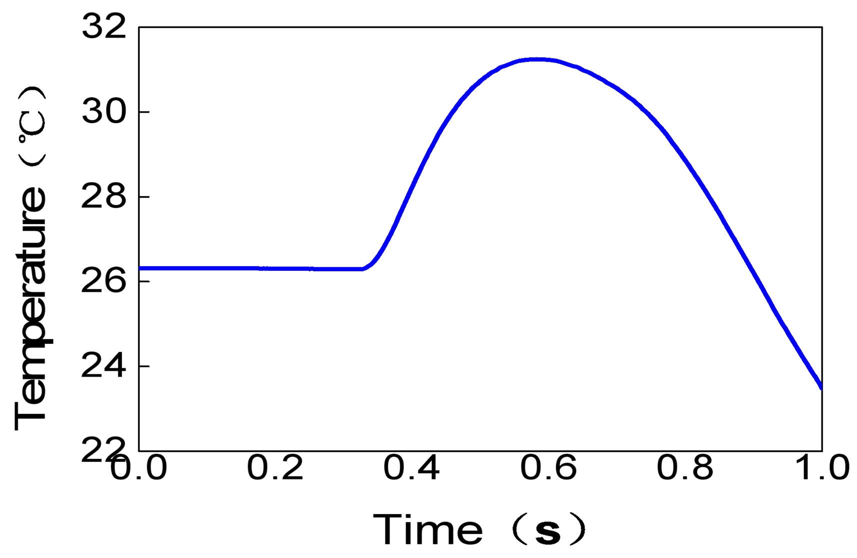
（a）0s （b）0.2s （c）0.4s

（a）0.6 （b）0.8s （c）1.0s

Working fluid leakage process



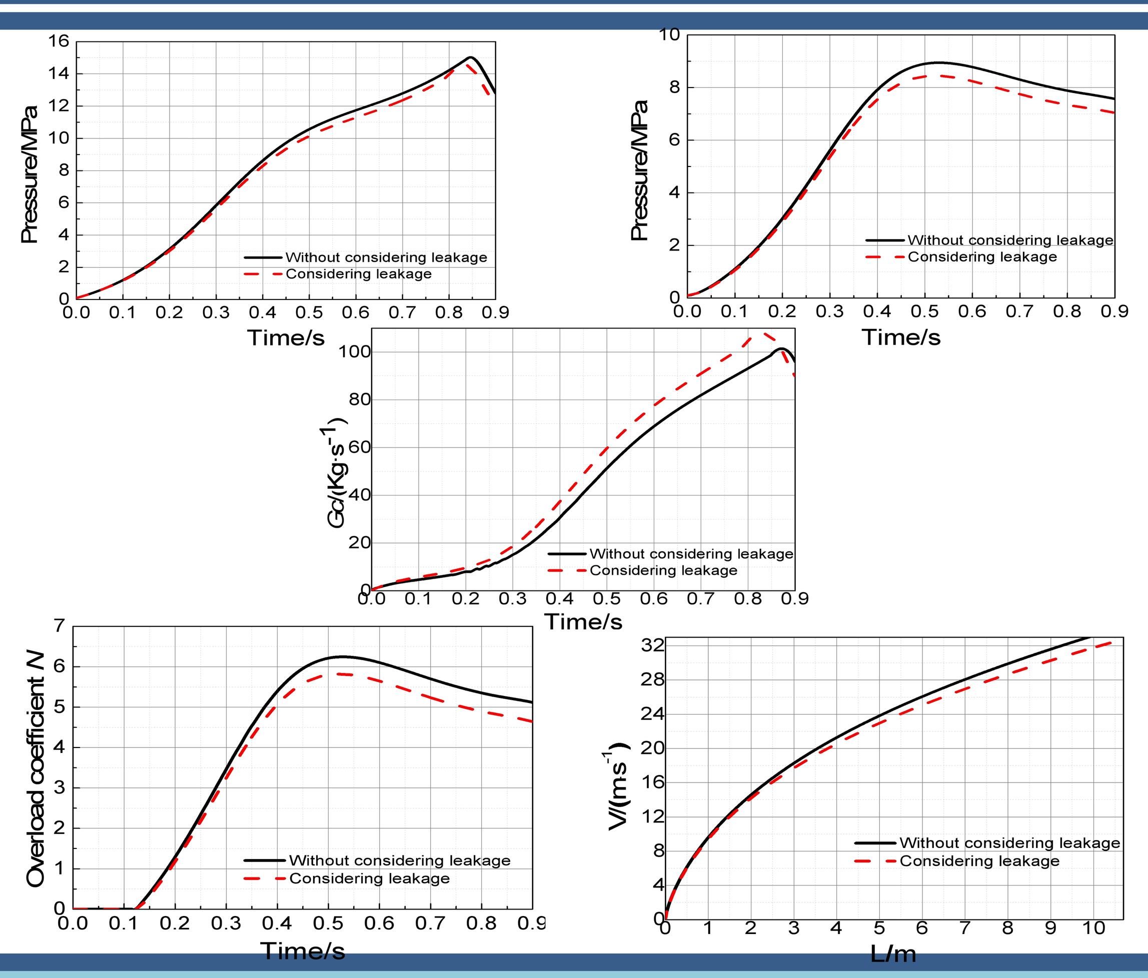
Working fluid leakage process



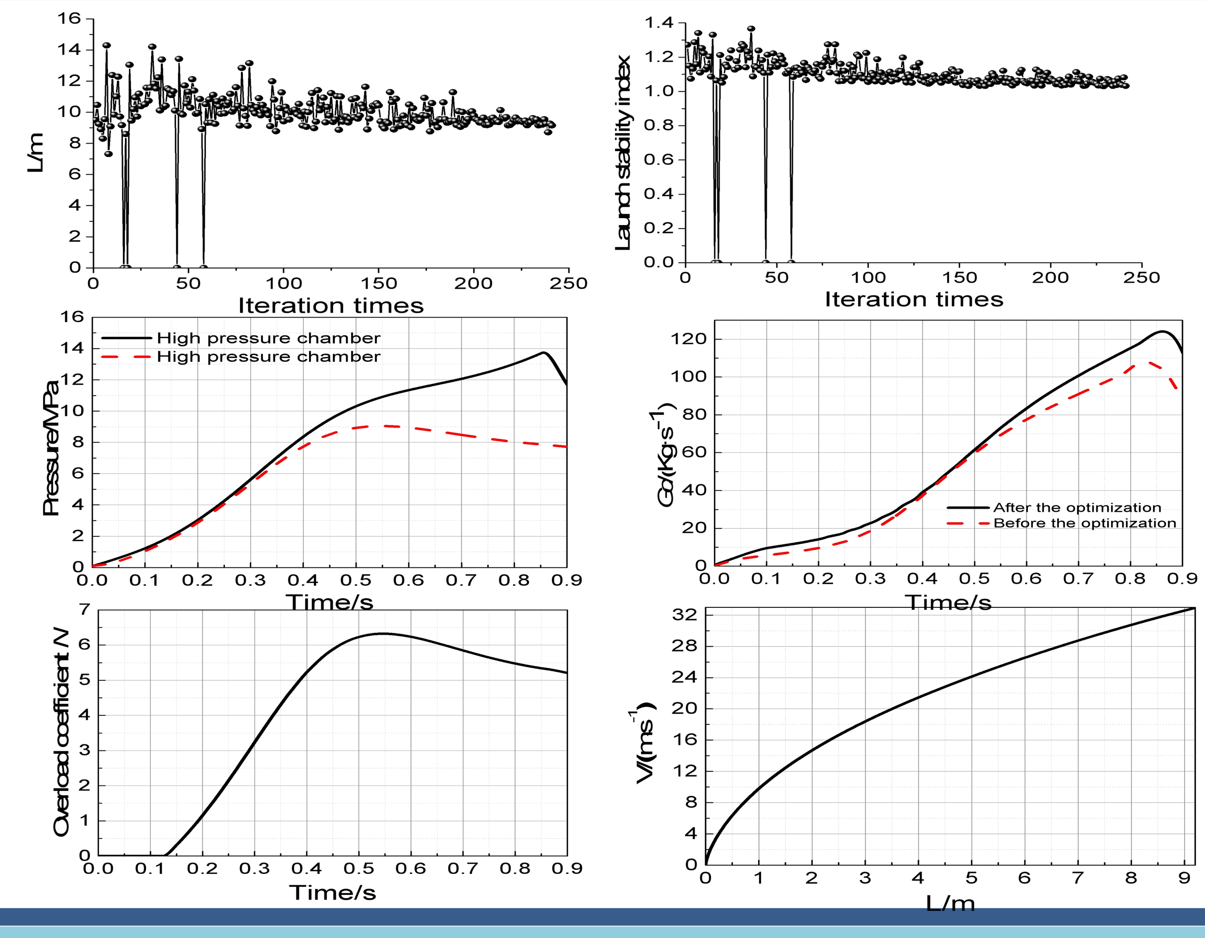
Temperature time history curves

Tab. Leakage rate under different pressure and stroke

	1.77MPa	2.76MPa	3.76MPa	4.85MPa	5.92MPa
0m	8.01%	7.86%	7.71%	7.52%	7.30%
1.11m	8.28%	8.05%	7.90%	7.71%	7.54%
2.18m	8.48%	8.31%	8.11%	7.85%	7.66%
3.24m	8.60%	8.42%	8.28%	8.06%	9.84%
4.18m	8.80%	8.62%	8.43%	8.20%	8.02%
5.18m	8.98%	8.77%	8.61%	8.39%	8.20%



It could be seen from Figure that the pressure and overload coefficient of the high and low pressure chamber after considering the leakage were lower than those without considering the leakage, and the required stroke when the piston speed reached the design index was longer than that without considering the leakage, so the influence of the leakage rate on the internal ballistic results could not be ignored.



The interior ballistic optimization results were shown above . It can be seen that the maximum pressure of the high pressure chamber before and after the optimization is the same; the pressure of the low pressure chamber after the optimization is significantly increased in the middle and later stages of the ejection. It can be seen that in the optimized scheme, the gas mass flow into the low pressure chamber is always greater than that before the optimization. The decreased value of overload coefficient of missile is obviously smaller, and the ejection process is more stable.

4. Conclusion

1）The leakage test of ejection device was designed and carried out to obtain the leakage rate of rodless cylinder under different cylinder pressure and piston stroke.

2）With considering the leakage, the pressure and overload coefficient of the high and low pressure chamber were lower than those without considering the leakage. The influence of the leakage rate on the interior ballistic results couldn’t be ignored.

3）Genetic algorithm was used to optimize the grain shape. The optimization results showed that at the end of the ejection, the maximum gas mass flow rate increased by 19%, the stroke required for the piston speed to reach the design target shortened by 13.1%, the launch stability index increases by 10.7%

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ACKNOWLEDGEMENT

This work was financially supported by the natural science foundation of Jiangsu Province for the project “Research on prediction of lubrication state of sealing structure of rodless cylinder under extreme conditions”(Project number:BK20170837).