Design of Gas Pressure Insurance for a Rocket Bomb Fuze

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Abstract. The insurance mechanism has an important significance for the safety of the fuze design, and the choice of environmental forces is a difficult point for non-rotating or low-rotating rocket bomb fuze. By studying the characteristics of rocket launching process and using gas pressure of rocket launch, this paper has designed a gas pressure insurance mechanism for fuze, then we use fluent fluid simulation software and SolidWorks Simulation module to calculate the force of push rod and the strength of shear blade. The results show that the design of gas pressure insurance mechanism is reasonable.

1. Introduction
For the design of non-rotating or low-rotating rocket bomb fuze, the selection of the environmental force of its insurance mechanism has become a major difficulty. When designing, we should not only ensure the safety of fuze service handling, but also ensure that the fuze can reliably remove the insurance when working. The rocket bomb in this paper belongs to a non-rotating rocket bomb and has no centrifugal force, so it is impossible to use a centrifugal insurance mechanism. But when the rocket bombs burn, they produce huge gas pressure, therefore, considering the comprehensive consideration, the gas pressure insurance mechanism was adopted when designing the first mechanical insurance institution of the fuze[1].

2. The working principle of fuze gas insurance institutions
When the rocket bomb is launched, the gunpowder burns violently, and there is a huge gas pressure in the closed cavity. After a short time, it reaches the peak. Then the maximum pressure continues for a period of time and the pressure drops rapidly, the specific characteristics can be seen in Figure 1[2]. This feature can be used as the first insurance of the fuze.

![Figure 1. P-t curve](image)

Common gas pressure insurance institutions can generally be divided into three types. The first type is a piston mechanism, this kind of mechanism pushes the piston to release the insurance by the rocket bomb burning. The mechanism is not only well sealed, but also simple in structure. The second type is the resistance spring mechanism, and this mechanism is solved by the characteristics of the rocket...
bomb's combustion chamber pressure being drastically reduced or disappeared. The agency releases insurance at the end of the activity section, so it can be delayed for a while, but the requirements for materials such as pistons are harsh and complex. The third type is a small hole mechanism, this mechanism makes full use of the principle of gas flow, and can control the time of solution by adjusting the size of the hole. The mechanism has good sealing and simple structure[3].

Taking into account the advantages and disadvantages of each organization, combined with the actual situation, this paper uses a piston mechanism. The schematic diagram of the designed gas pressure insurance mechanism is shown in Figure 2, and it is mainly composed of pressure hole, push rod, safety piece, sealing ring, piston, lock pin and other components, the push rod is close to the pressure hole to withstand the gas pressure.

In normal state, the fuse restricts the movement of the push rod, the seal ring also clamps the piston so that it cannot move, the lock pin cannot be jacked up, and the fuse is in an insurance state. When the rocket bomb is fired, the gas pressure pushes the push rod through the pressure hole to cut the fuse, and the push rod continues to push the piston to push the lock pin up to complete the insurance, the release insurance completion status diagram is as shown in Figure 3 below.

By changing the size of the pressure hole, the strength of the fuse and the tightness of the sealing ring, we can adjust the time for the release of the insurance, and one of the easiest to calculate and test is the strength of the safety piece.

3. **Force calculation and simulation of the safety piece**

3.1 **Force calculation of push rod**

In this paper, the role of the safety piece is to limit the movement of the push rod during service processing. When the launch is under sufficient pressure, it is cut to push the insurance pin to release the insurance. When we design, the strength of the push rod should be calculated.

From the momentum theorem equation and the mechanical energy conservation equation, we can get:

\[ F_t = m \nu \]  
\[ mgh = \frac{1}{2} m \nu^2 \]  

In the above formula: \( F_t \)—combined force, \( t \)—landing contact time, \( h \)—falling height, \( \nu \)—landing speed.

Combined with formula (1) and formula (2), we can know that:
\[ F = \frac{m}{t} \sqrt{2gh} \]  

So when the fuze lands on the ground, the force acting on the push rod is:

\[ F_N = F + mg \]

In this design, the quality of the fuze is 300g, the drop height is 2m and the landing contact time is 0.1s, then substituting into the above formula, we can calculate the force on the push rod: \( F_N = 21.9 \text{N} \).

However, for the force of the push rod during the launch of the rocket bomb, the influence of the pressure hole should be considered. The average pressure of rocket engine is about 28 MPa[4] and the diameter of pressure hole is 5 mm. According to the actual situation of rocket bomb engine, the cavity model of rocket bomb is established and meshed, as shown in Figure 4 below.

![Rocket bomb Cavity Model and Mesh Map](image)

Figure 4. Rocket bomb Cavity Model and Mesh Map

The upper surface of the cavity is the pressure inlet surface and the other surfaces are the stress surface. And in order to obtain the force of the push rod, it is necessary to analyze the bottom of the pressure hole[5].

We use the fluent fluid analysis software to simulate and calculate, and we can get the curve of the relationship between pressure and time on the bottom of pressure hole, and it is showed in Figure 5 below:

![Pressure diagram of bottom surface of pressure hole](image)

Figure 5. Pressure diagram of bottom surface of pressure hole

From the above figure, we can see that the pressure at the bottom surface of the pressure hole reaches a stable value of 28 MPa around 10us. Because the insurance time of the whole insurance institution is in the millisecond level, and the influence of the pressure hole here can be neglected, so when calculating the force on the surface of the push rod, it can be directly loaded on the surface of the push rod with 28MPa.

3.2 Force simulation of the safety piece

Through the calculation and simulation above, we get the force on the surface of the push rod. The
The pressure on the push rod is 21.9N when the fuze falls at 2m, while the pressure can be approximately considered as 28MPa when the rocket bomb launching. The thickness of the safety piece is 1mm and the material is beryllium red copper. After simulating the two cases of falling at 2m and rocket bomb launching, we can know the stress distribution of the safety piece from Figure 6 and Figure 7:

![Figure 6. drop stress diagram](image1)
![Figure 7. emission stress diagram](image2)

From the simulation results, it can be seen that the maximum stress when the fuze falls at 2m is 2.334MPa, while the stress when rocket bomb launches is 432.8MPa. The yield strength of beryllium red copper is 221 MPa. Therefore, it can be concluded that the gas pressure insurance institutions are safe and reliable when the fuze unexpected falling in service, and it will not cancel the insurance, while the gas pressure insurance institutions can reliably cancel the insurance when rocket bomb launches.

4. conclusion
In this paper, a kind of gas pressure insurance mechanism for rocket bomb fuze is designed by using the gas pressure generated by the rocket during the launch, and the components such as the force of the push rod and the safety piece are designed, calculated and simulated. The simulation results verify the reliability of the design and provide some references for the design of gas pressure insurance mechanism of other rocket bomb fuzes.

Reference
[1] DUAN Zhenlong, YUAN Pengju, HAO Yinun. (2011) The Method of Environmental Disarmament for the Front Detonation Field of Following-in Fuze. Journal of Detection and control[J], 33(1):1-5.
[2] Fan Qingtian, Xu Guotai. (2014) Design of gas overload pressure insurance mechanism for low overload rocket bombs. Technology innovation and application [J], 46.
[3] Jiang Qiling, Chen Xingqiu. (2006) Application of gas insurance institutions in rocket fuze. Journal of Detection and Control[J], 28(16): 25-28.
[4] Wang Hui, Chen Hejuan. (2007) Start-up characteristics of gas-powered safety switch with bottom-fused fuze[J]. Journal of System Simulation. 19(21): 4871-4873.
[5] Wang Hui. (2014) Study on the key skill of the rocket safety system of the super-short-range active protection system[D]. Nanjing: Nanjing University of Science and Technology, 54-70.