Study on the sealing properties of the sealing structure for the rotating chamber of a certain cased telescoped ammunition gun

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Abstract

To solve the spherical transient high pressure gas seal problem for the rotating chamber of a certain medium calibre cased telescoped ammunition gun, a self-impacted combined sealing system was newly designed which can be placed at semi combustible cartridge of the cased telescoped ammunition. The sealing mechanism of the structure was analysed and simulation studies on the comprehensive properties of the sealing structure were carried out via the FEM dynamic response. In addition, the simulation and verification tests were conducted to test the sealing performance of the sealing structure. The results of the simulation analysis and the experiments demonstrate that the designed sealing structure has a good sealing performance and can solve the spherical transient high pressure gas seal problem for the rotating chamber of the medium calibre cased telescoped ammunition gun, and it is expected to offer a reference value to solve related problems in engineering.

Keywords: Sealing for the Rotating Chamber, FEM, Test Verification, Cased Telescoped Ammunition

1 Introduction

Cased telescoped ammunition (CTA) gun is a kind of artillery, which use an integrative ammunition with the projectile embedded in simple cylinder cartridge case. The most important feature of CTA is its regular ammunition shape and short length. CTA gun commonly use new latching principle of rotating chamber, which will compact the loader structure, and reduce the overall size of the artillery systems [1, 2]. Due to the separate design of CTA chamber and the gun tube, and the frequent rotation of opening and closing, this special structure is inevitable to make there a gap between the chamber and the spherical interface of barrel ends. If there is no reliable sealing structure, the condition of pressure up to 400 MPa and temperatures up to 3000K in the bore and rotating chamber will lead to gas leak and serious effect on gun performance which contains great security risks. Thus, the seal problem for the rotating chamber of a CTA gun is a key technology, which must be resolved [3].

Rotating chamber high temperature and high-pressure gas make a great impact on the seal member in a very short period, which is a typical transient high-pressure seal problem at the gap of the spherical interface. In this paper, a self-impacted combined sealing system was newly designed which can be placed at semi combustible cartridge of the CTA. The sealing mechanism of the structure was analysed and simulation studies on the comprehensive properties of the sealing structure were carried out via the FEM dynamic response. In addition, the simulation and verification tests were conducted to test the sealing performance of the sealing structure.

2 How to use the template

The self-impacted combined sealing structure is placed at a non-combustible structure of both ends of semi combustible cartridge of the CTA. The structure is shown in Figure 1. Taking into account the similarities of the sealing structure and the mechanism between both ends of the cartridge, only the front sealing structure of the cartridge is analysed. There are three major leakage channels A, B, C in the sealing structure as shown in Figure 1. The sealing mechanism is as follows [4]:

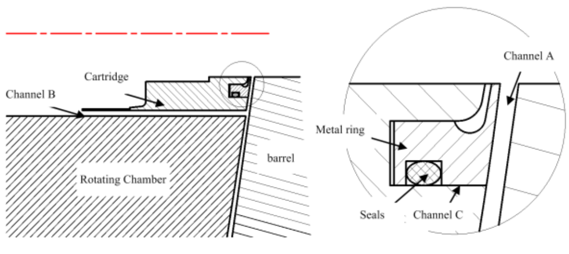

FIGURE 1 Schematic Diagram of Sealing System

Channel A: the special design of spoon-shaped metal ring makes generated gas quickly spread to the spoon-shaped area before the gas into the channel A. In addition, relative to the "spoon" area, channel A is just a small gap, so the right force along the barrel axial of metal rings is much larger than the left. At the beginning period of gunfire, the gas can quickly push the metal ring moving right along the barrel axis to meet the barrel end,

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so that the metal ring can seal the channel A. With the continual rising of chamber pressure, the force to the metal ring is gradually increasing. The more closely is the metal ring wedge to the right, the more reliable the sealing performance is.

Channel B: according to the elastic-plastic theory of the thin-walled cylinder and the thick-walled cylinder, when the chamber pressure is small, the thin-walled segment and the thick-walled segment of the cartridge come into being radial expansion and elastic deformation, and at this time, a small amount of gunpowder gas leak in channel B. When the chamber pressure continues to raise, the cartridge thin-walled segment become in contact with the rotating chamber, after that, channel B is sealed. Moreover, the contact area gradually expanded over time, channel B is further sealed. When the chamber pressure reaches a certain value, the thin-walled segment and thick-walled segment are fully fit with the rotating chamber, than there are expansions, plastic deformation. In the process of chamber pressure down to zero by the peak, the plastic deformation of the cartridge cannot be restored to the initial state, so there may be residual bonded in a local area of the cartridge and the rotating chamber.

Channel C: in the assembly, since under the preload from the metal ring of the cartridge, the seals always fit closely with the cartridge at a low pressure, which can ensure the sealing in the low-pressure. In addition, as the pressure increases, the metal ring radial expansion force progressively larger. The greater pressure metal ring passed to seals is, the better the seal performance is.

The above-mentioned sealing mechanism indicates that, channel A, C can be achieved quick seal at low pressure, and at high pressure to achieve a reliable seal. As to channel B, when to seal or whether to seal in the end of the combustible cartridge is largely dependent on the design of the thin-walled segment structure, and it is the key to the successful seal in the entire sealing system. Therefore, this paper focuses on analysing the sealing performance of channel B.

3 Dynamic Simulation Analysis of Sealing Performance of the Sealing Structure

3.1 SIMULATION MODEL

As to the semi-combustible cartridge geometry, it is a typical axisymmetric problem that boundary conditions are symmetrical to the rotary axis, and displacement under load, stress and strain are also symmetrical to this axis [5, 6, 7].

In order to analyse the impact of the metal ring and rubber seals on the contact condition of cartridge and rotating chamber, a finite element model with and without metal rings and seals of cartridge were established. In addition, the error is only 1.25% after calculating and contrasting the result, so the metal ring and rubber seals are omitted during models simplification.

Taking into account the accuracy and computation time, the model is sliced in the appropriate region, mesh refinement in the contact area, the stress concentration and other key part. On one hand, the non-contact area of the chamber, on the other hand, to increase the mesh density appropriately and reduce the element number of the non-focus part, which can reduce the calculation time and improve the efficiency of the finite element calculation. A four-node axis of symmetry hourglass control reduced integration elements are used in calculation. The mesh density in the key areas is 0.5mm, other parts is adjusted according to density [8, 9].

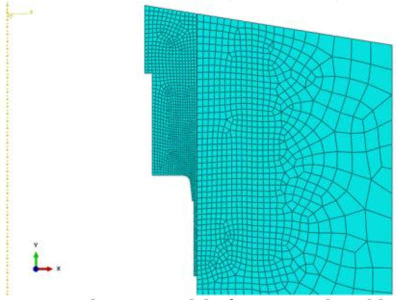

FIGURE 2 Finite Element Model of Semi-combustible Cartridge

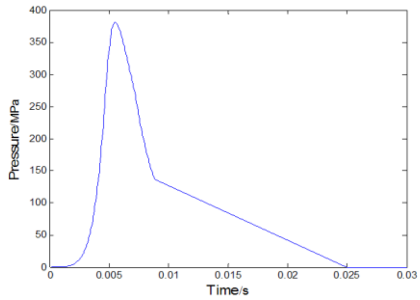

FIGURE 3 New Artillery Bore Pressure Curve

The time of the chamber pressure load curve is 0.03s. The constraints in the end surface of the model limit the axis movement of the rotating chamber and the semi-combustible cartridge. Then loading chamber pressure is exerted on each face of the cartridge. Moreover, the chamber pressure curve is shown in Figure 3.

ABAQUS/Explicit analysis is adopted to analyse nonlinear problems of the instantaneous dynamic seal. Penalty friction formula is used to define the contact parameters. ABAQUS / Explicit general contact algorithm employs the contact algorithm, and specify the master surface and the slave surface. The sampling interval, *n* of every *n* interval is set to 3000, the sampling period is 0.01ms, which not only ensure the appropriate scale data, but also achieve the purpose of smooth curves.

3.2RESULTS OF SIMULATION

Structural strength analysis. Figure 4 and Figure 5 indicate a stress contours of the sealing structure. The yield and the deformation of various parts can be seen. The results show that sharp corners, the transition portion has stress concentration, while the other regions stress fluctuation is small. No severe deformation has occurred in the sealing structure and the structural strength can meet the requirements.

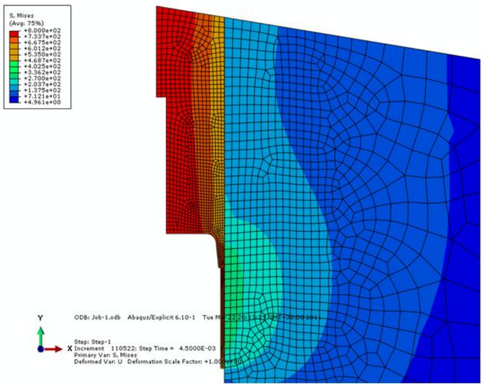

FIGURE 4 Stress Contours at 4.5ms

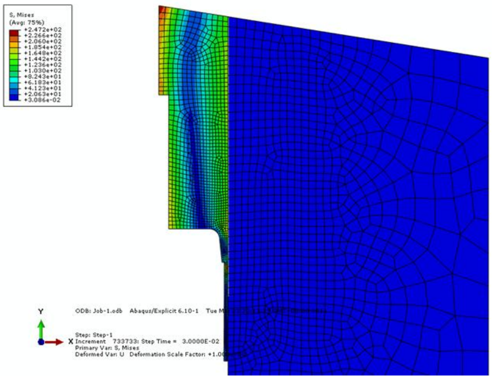

FIGURE 5 Stress Contours at 30ms

3.3 ANALYSIS OF SEALING STRUCTURE OBTURATION PERFORMANCE

In order to estimate the obturation of the sealing structure, namely the fit condition of contact area at each moment, Node7,Node143, Node164 and Node178 are selected as research subjects with a distance of 0mm, 23.0689mm, 74.5016mm and 102.550mm respectively from the top of the contacting area on the top. The contact stress vary with time is analysed:

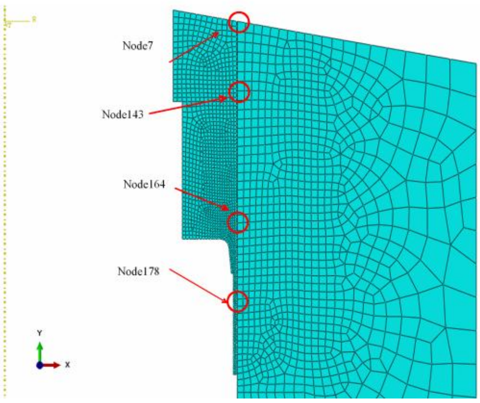

FIGURE 6 Node Coordinate in the Sealing Structure

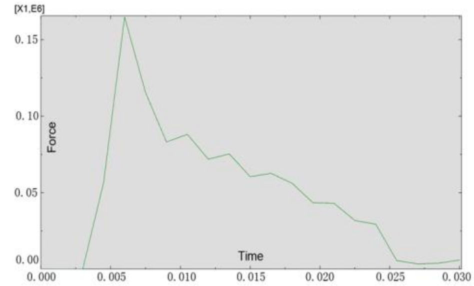

FIGURE 7 Contact Stress on Node7

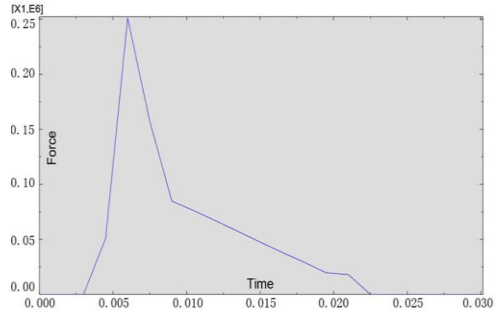

FIGURE 8 Contact Stress on Node143

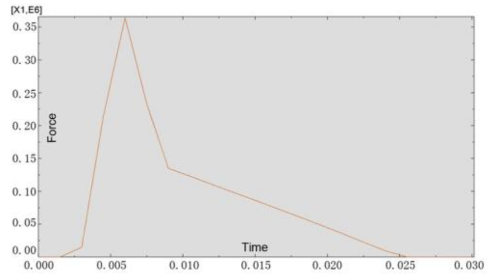

FIGURE 9 Contact Stress on Node164

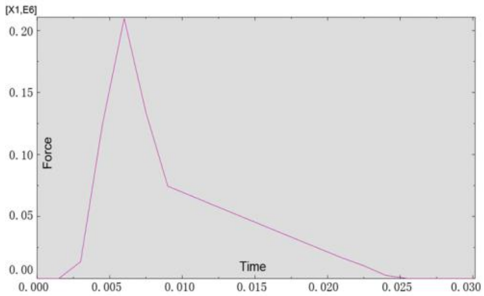

FIGURE 10 Contact Stress on Node178

It can be seen in figures 8 to 9 that Nodes 143 and 164 are in contact with chamber first when the sealing structure are exposed to the chamber pressure of 4Mpa about 2ms. With the chamber pressure rising, the bonded area gradually extends from the middle of the sealing structure to both ends as shown in figures 7 and 10. As is show in figures 7 and 10, Node 7 and Node 178 are also in contact with the chamber about 2.8ms. Therefore, the entire sealing segment has completely contacted with the chamber. Compared with the bore pressure curve, contact stress at each node reaches the maximum in 5.5ms, which is 0.3ms after the chamber pressure reaches the maximum. Since then, chamber pressure gradually decreases, and Node 143 is separated from chamber when the gas reaction time is about 23ms. Moreover, Node 164 and Node 178 are separated from chamber in 2ms later.

When the chamber pressure drops to zero, there is still residual contact stress with Node 7, which is small and exerts little effect on shell performance.

It can be seen from the above analysis that, the sealing structure seals quickly in the initial sealing and the contact pressure of the sealing structure increases while the chamber pressure increases. The performance of sealing is valid throughout the work period.

4 Sealing performance test

In order to verify the sealing performance of the self-impacted sealing structure, a seal test device is designed to test the seal effect. In the test, the gunpowder in confined device is ignited, to produce analogue bore environment of high temperature and high pressure gas, test pressure curve and the main part of the obdurate force. The test device is shown in Figure 11, and the sealing device test bench real photos are shown in Figure 12.

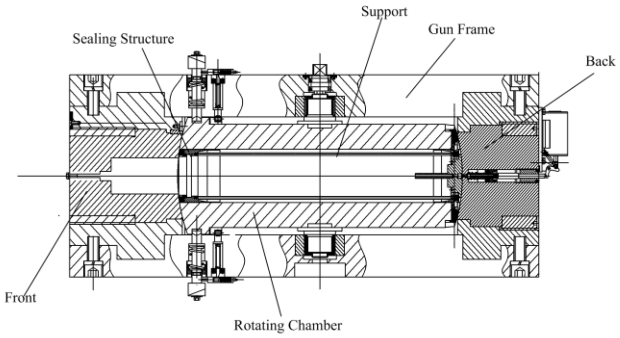

FIGURE 11 Schematic Diagram of Test Device

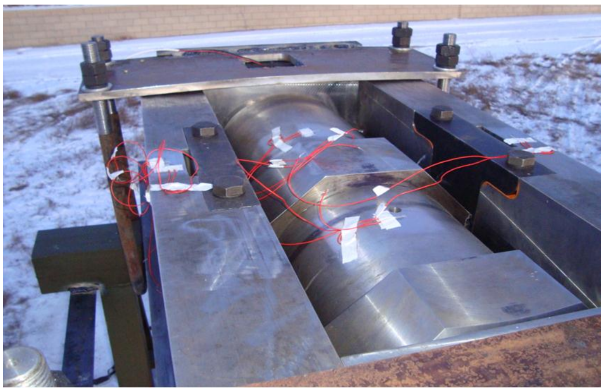
FIGURE 12 Experimental Device

Sealing performance is tested under the pressure in the bore of about 200MPa, and transient pressure curve and the strain of the three positions in rotating chamber. The specific location is shown in the Figure 13. The bore pressure curve and specific location of the stress curve is shown in Figure 14 and it can be seen that after bore crimp reaches to the peak of 221.4MPa , under the action of the sealing structure, the pressure drop almost to zero within 30 milliseconds, the pressure curve maintains the level to meet the requirements of the bore seal time of 20 milliseconds. Therefore, the sealing device and good sealing effect can meet the needs of practical engineering.

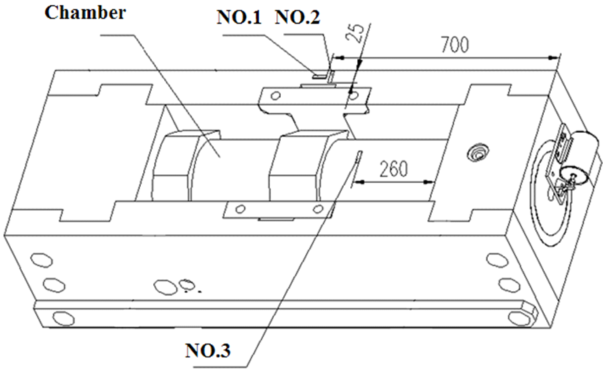

FIGURE 13 Location of Test Point

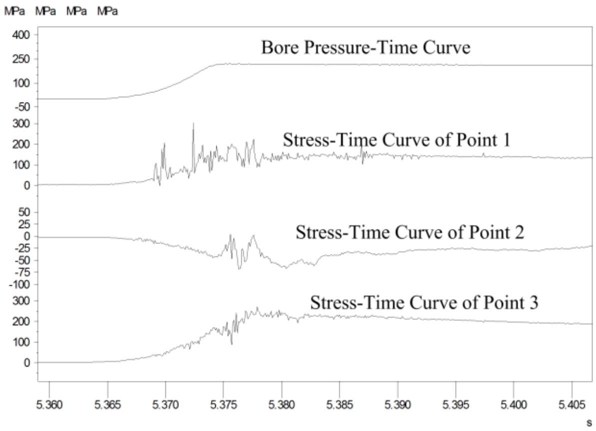

FIGURE 14 Test Results

5 Conclusions

In this paper, a self-impacted combined sealing system was newly designed which can be placed at semi combustible cartridge of the CTA. The sealing mechanism of the structure was analysed and simulation studies on the comprehensive properties of the sealing structure were carried out via the FEM dynamic response. In addition, the simulation and verification tests were conducted to test the sealing performance of the sealing structure. The results of the simulation analysis and the experiments demonstrate that the designed sealing structure has a good sealing performance and can solve the spherical transient high-pressure gas seal problem for the rotating chamber of the medium calibre CTA gun, and it is expected to offer a reference value to solve related problems in engineering.

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