THE ANALYSIS OF PRESSURE WAVES UNDER COMBINING TCM WITH LCM IN BI-MODULAR CHARGE

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ABSTRACT

In this paper, a two-phase and one-dimensional model of interior ballistic and the relevant computer code have been developed to study the pressure wave when Bi-modular charge was loaded in the chamber of gun with several TCM(top charge module) and one LCM(low charge module). Numerical simulations have been performed to study the effects of LCM's position on pressure waves. The analysis results can serve as a guideline for optimizing the charge which consist of TCM and LCM.

INTRODUCTION

As an advanced propellant charge technology for large calibre howitzer, the modular charge has been paid more and more attention by a lot of countries in the world, such as Germany, South Africa, the UK and the US, etc. At present, these countries have researched and developed modular charge for large calibre howitzer respectively, and the products of modular charge already has been used by army in some countries. Usually, modular charge system is bi-modular, comprising low charge modular (LCM) and top charge modular (TCM). The LCM can be used in low zone to ensure a suitable minimum range performance, and the TCM can be used in mid- and high-zone firing for providing adequate range overlaps between zones and the maximum range performance. In general, the two kinds of charge module are not used in one of the zones at the same time. However, if the zone which includes the TCM and LCM has good performance about stability and security, the two kinds of charge module can be used in one of zones in order to get a special muzzle velocity at the some combat condition. By having more muzzle velocities, the range overlaps between zones would be increased obviously, and it would be benefit to improve the performance of multiple round time-on-target technology for large calibre howitzer. But the two kinds of charge module have different propellants obviously. So the stability and security of interior ballistics of the zone including TCM and LCM are very important. In this paper, a two-phase and one-dimensional model of interior ballistics and the relevant computer code have been developed to simulate launching processes of bi-modular charges combining TCM and LCM. By analysing the pressure waves, we can get the influence of loading methods in one of zones with TCM and LCM to stability and security of interior ballistics. The analysis results can serve as a guideline for optimizing the charge which consist of TCM and LCM.

1. THE CHARACTERISTIC OF CHARGE COMBINING TCM AND LCM

On the basis of experience of general gun charge with mixing two kinds of propellants, the method of loading bi-modular charge combining TCM and LCM is to use one LCM and several TCM to compose a special zone. So there is a difference to load the LCM in the chamber of gun. The LCM can be set on the top of charge or the bottom of charge. This difference can cause the different interior ballistics process. So the two-phase and one-dimensional model of interior ballistics can be used to analysis the influence of position of LCM to chamber pressure wave in this paper.

2.PHYSCIAL MODELING AND BASIC HYPOTHESIS

Thinking about the characteristic of bi-modular charge which is loaded in chamber of gun with several TCM and one LCM, we study the interior ballistics of the zone which includes one LCM and four TCM. Because there is a high chamber pressure using this zone, and the mass of two kinds of charge module is different obviously in this zone, the stability and security are more important. The charge modules are connected each other and have the same of ignition system. The physical model studied in this paper is showed in Figure.1

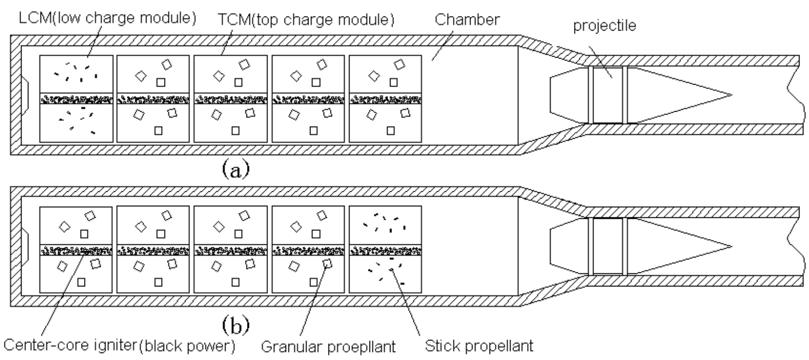

Figure 1. schematic drawing of a modular charge. (a) loading the LCM in the bottom of charge; (b) loading the LCM in the top of charge

The expected interior ballistic cycle is as follows: upon triggering, a primer generates hot gases and particles, these products ignite the black power contained in the center-core. Then, the hot gases and particles penetrate the vent holes in the walls of center-core igniters causing ignition, flame spreading and combustion of the main propelling charge in each container.

In order to simplify the physical modelling for simulation the interior ballistics of the bi-modular charge combining TCM and LCM, the theoretical modelling includes two main domain of flow field in chamber. One is the propellant domain and the other is ignition domain. The domain of main propellant is described with a set of 1-D two-phase partial differential equations with different section in chamber (including mass, momentum, energy equations, etc.). A set of 1-D two-phase partial differential equation can be used in domain of center-core igniters. There are several basic hypothesis to be used in modelling. Firstly the containers can fracture after the pressure in containers is between 5 to 10MPa, and the main propellant come in the propellant domain. Secondly, the interaction between the propellant in LCM and TCM can be taken into account. Thirdly the combustion gas of module container has the same velocity with gas of main propellant.

3. PHYSCIAL MODELING AND BASIC HYPOTHESIS

In this paper, two sets of 1-D two-phase conservation equations have been used to simulate the process of interior ballistics by loading TCM and LCM in one zone of bi-modular charge. These equations include mass, momentum and energy conservation equation for gas and solid phase. The detailed equation can be found in literature [1][2]. For the special structure of bi-modular charge loading TCM and LCM in one zone, the interaction force is described between small stick propellant and large granular propellant loading LCM and TCM respectively.

The momentum conservation equation is given in the form:

$$\frac{\partial A\rho_{p1}\sigma_1 u_p}{\partial t}+\frac{\partial A\rho_{p1}\sigma_1 u_p^2}{\partial x}+A\sigma_1\frac{\partial P}{\partial x}=-AI_1u_p+AD+A\dot{m}_{0p}u_{0p}-\frac{\partial A\sigma_1\tau_p}{\partial x} \qquad (1)$$

Where τ_p is the stress between two kinds of propellants. When there is only one kind of propellant in charge, the propellant bed can be treated as fluidized bed. Although the stress exists between the propellants, it can be ignored. If the propellant bed includes two kinds of propellant which have different size, the stress between two kinds of propellants would influence the movement of the propellant obviously. So the stress can be described in the form[3]:

$$\tau_p = -\frac{E_p}{1-\phi}\frac{\phi}{\phi_0}(\phi-\phi_0)\exp[k_0 + k_1(\phi-\phi_1)] \quad (2)$$

Where E_p is the compressibility modulus of the solid propellant, which unit is MPa, ϕ is porosity of the bed, ϕ_0 , ϕ_1 , k_0 and k_1 are coefficient which are decided by the kind of propellant.

4. SIMULATION RESULTS AND ANALYSIS

A computer code implementing the theoretical model described above is developed to simulate the interior ballistics performances for bi-modular propelling charges loading two kinds of charge module in artillery guns.

As a first step of applications, numerical predictions are conducted for a special zone charge consisting of four TCM and one LCM as shown in Figure 1(a). The experimental pressure-time curves at the breech and the chamber mouth are displayed in Figure 2. The comparisons of experimental and calculated pressure-time curves at the breech and the chamber mouth are displayed in Figure 3 and 4, respectively. The comparison of experimental and calculated pressure wave is displayed in Figure 5. By a close comparison of these figures, it can be seen that the numerical results agree well with the experimental ones.

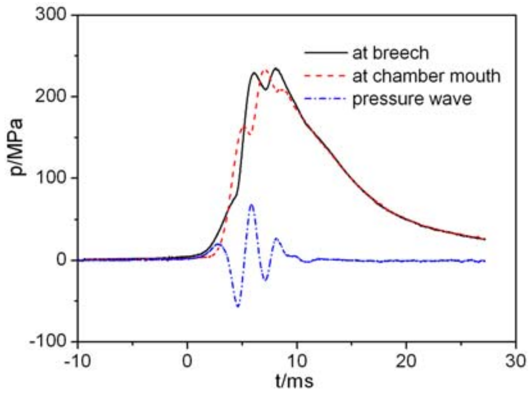

Figure 2. the experimental pressure-time curves at the breech and the chamber mouth

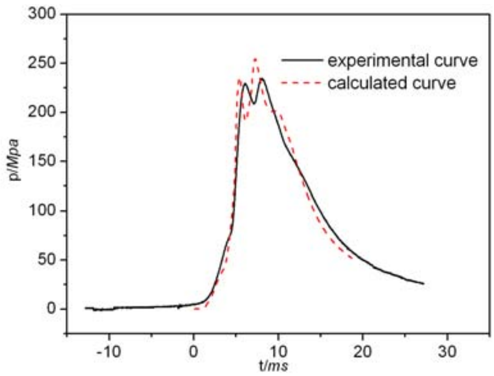

Figure 3. the comparison of experimental and calculated pressure-time curves at the breech

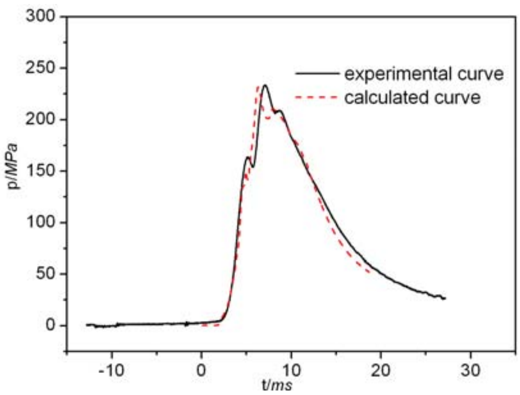

Figure 4. the comparison of experimental and calculated pressure-time curves at the chamber mouth

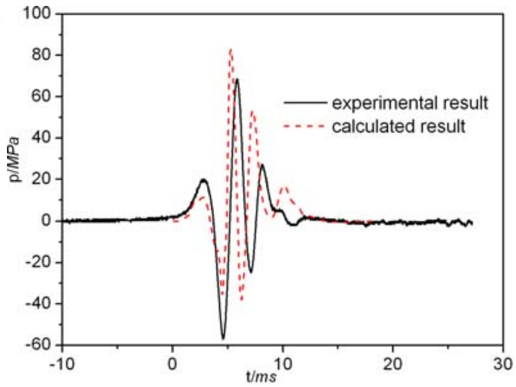

Figure 5. the comparison of pressure wave

From above these curves, it is clear that the pressure wave is very serious when the LCM is loading at the breech. The main reason is the propellant of the LCM has very thin web and combusts very quickly, which cause the pressure at the breech to increase very quickly. When the high pressure at the breech push the propellant to move towards the projectile, the propellant would be stuffed at the chamber mouth and then the large pressure gradients can happen at the chamber mouth which would develop the large amplitude of pressure waves at the next process of interior ballistics.

As the second step of applications, numerical predictions are conducted for modelling the interior ballistics process of charge which consist the four TCM and one LCM as shown in Figure1(b). In this case, the LCM is loaded at the chamber mouth. By numerical modelling, pressure-time curves at the breech and the chamber mouth are displayed in Figure 6, and the comparison of pressure waves between calculated results and experimental results as shown in Figure 5 is displayed in Figure 7. By analysis the Figure 6 and 7, it is easy to be found that the amplitude of pressure waves are clearly lower when LCM is loading at the top the charge. The main reason is that the TCMs are ignited firstly at ignition process and the LCM is ignited later. Although the propellants of LCM combust quickly at the chamber mouth, the pressure at the breech already increases by TCM ignited firstly. Because the propellant bed cannot be moved by difference of pressure between breech and chamber mouth, the serious pressure waves cannot be caused in chamber.

Thus it can be seen that when bi-modular charge is mixed to use as a special charge zone, it is better for the stability and security of interior ballistics by loading LCM at the top of charge.

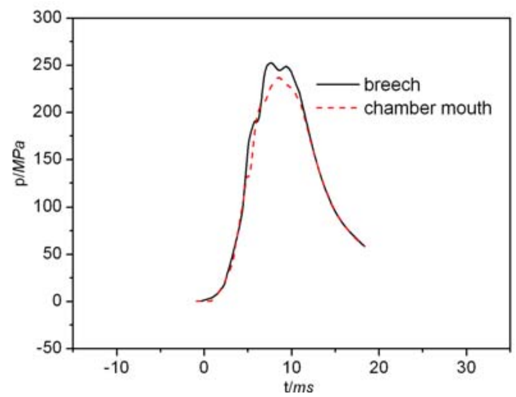

Figure 6. the calculated pressure curves at the breech and the chamber mouth when LCM is loaded at the top of the charge

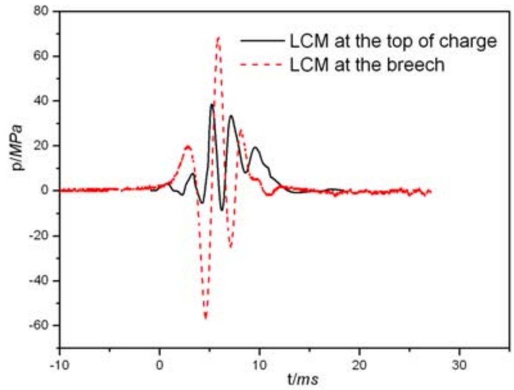

Figure7. the comparison of pressure wave

5. CONCLUSION

In conclusion, a two-phase, 1-D theoretical model of interior ballistics for bi-modular propelling charges loading two kinds of charge module in artillery guns has been developed. Numerical predictions have been carried out for loading LCM at the breech and the top of charge, respectively. The analysis of pressure waves and pressure-time curves at the breech and chamber mouth has been illuminated. The following conclusions can be drawn:

1) The position of the LCM can influence the performance of interior ballistics when two kinds charge modular of bi-modular charge are mixed to use in charge zone.

2) when a special charge zone includes two kinds of charge module of bi-modular charge, and LCM is loaded at the breech, the pressure waves is very serious. It is better for the performance of interior ballistics by loading LCM at the top of the charge.

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