Research on the SDT technology based on a two-stage structure

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Introduction

The technology of SDT based on a two-stage structure is introduced by H.Moulard and other researchers from French-German Research Institute of Saint-Louis and applied in the laser initiators. The first stage contains HMX mixed with 1% carbon black, which can be initiated by laser and produce high pressure to push a metal cylinder to go through a barrel. The second stage contains RDX, which is compacted by the cylinder and detonate. The structure is shown in figure 1.

This technology is also researched in Shaanxi Application Of Physical & Chemistry Institute. The first-stage charge are B/KNO3 and HMX, and the second-stage charge is RDX. The initiators are shown in figure 2.

In this paper, the SDT train based on a two-stage structure mainly includes ignition component, first-stage charge(insensitive pyrotechnic composition and high explosive), mass block, barrel and second-stage charge(high explosive), as shown in figure 3. Through the ignition component, the stimuli is given to the insensitive pyrotechnic composition, which then burns and initiate the high explosive in the first stage. The mass block is driven by the high-pressure gas generated from the high explosive and impact the high explosive in the second-stage charge, which detonates reliably through the convergence of shock wave.

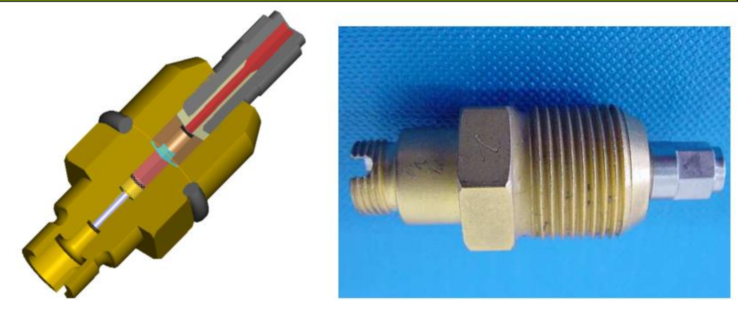

Figure 1 : SDT laser detonator

Figure 2 : The initiators of Shaanxi Application Of Physical & Chemistry Institute

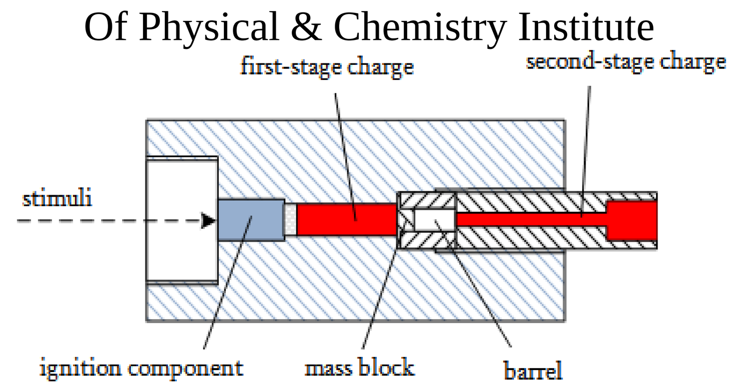

Figure 3 : The structure of SDT technology

Calculations of the mass block's velocity

a. The relationship between the primary charge and initial velocity of the block

The initial velocities of the block corresponding to different primary charges were estimated with Matlab. The block's mass was set to 100 mg and the estimated results are shown in figure 4.

Therefore, when the primary charge is being designed, its mass could be increased adequately to improve the initial velocity of the block; the mass ratio of RDX should be increased as possible on the premise of B/KNO_3 being able to ignite RDX when determining the mass ratio of B/KNO_3 and RDX.

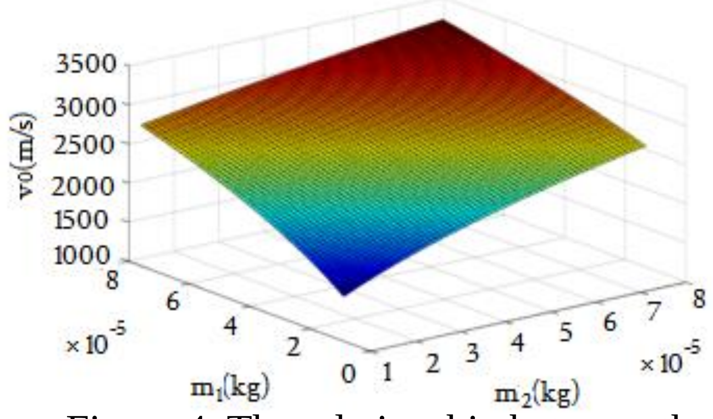

Figure 4. The relationship between the mass of the primary charge and v_0

b. The relationship between the block's mass and the initial velocity

It could be known from figure 5 that the block's mass has a significant influence on the initial velocity, which could be improved from 2200 m/s to 3300 m/s theoretically as the mass changes from 150 mg to 50 mg. Therefore, in the case of satisfying other indexes, the mass should be reduced as possible and low density material should be employed.

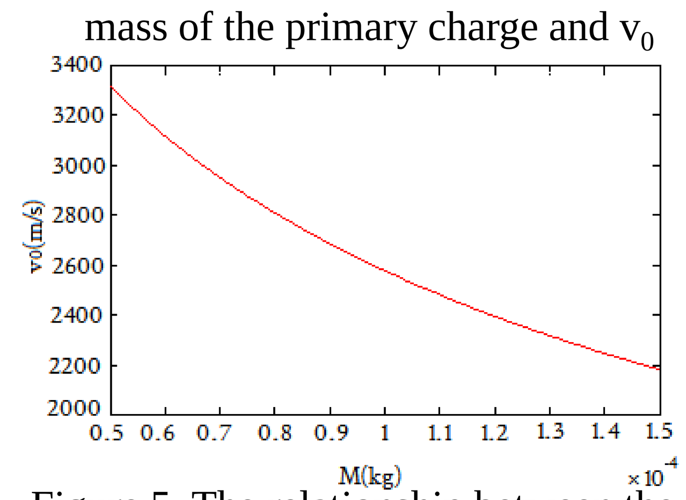

Figure 5. The relationship between the block's mass and v_0

c. The relationship between the length of accelerating barrel and the shock velocity

It could be seen from figure 6 that the length of the barrel has accelerating effect to some extent, while it is not as significant as the mass of the primary charge and the block's mass; the block's velocity just increases from 2270 m/s to about 2450 m/s (the variation less than 200 m/s), as the barrel's length increases from 0 mm to 5 mm; the acceleration effect of the barrel reduces gradually with the barrel's length increasing. Thus, the way of increasing the barrel's length could not be used to lift the block's velocity up greatly in the following design.

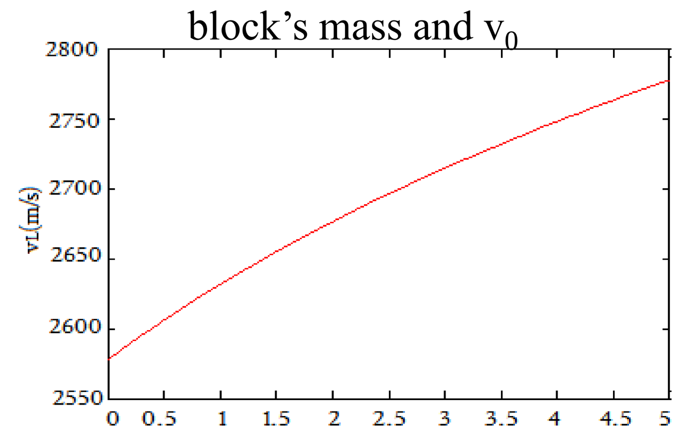

Figure 6. The relationship between the shock velocity and the barrel's length

Simulations of the mass block shocking the second-stage charge

There were some stress states at different time during the process of the block shocking the second-stage charge, as shown in figure 7. It can be seen that the pressure where the block contacted with the constrained body was much larger than that where the block contacted with the charge at the moment of the collision; as the time goes by, the higher pressure converged in the direction of the charge's axis at a certain angle and reached the axis at 0.52 μs approximately, which made the pressure near the charge's axis much higher than that where the block contacted with the charge. As shown in figure 8, there are pressure-time curves at different gauges. The peak pressure at gauge 6 where the block contacted with the constrained body was much higher than that at gauge 1 where the block contacted with the charge; the peak pressure at gauge 2(the convergence point) was much higher than that at gauge 1. The phenomena mentioned above reveals the shock-wave effect in the two-stage SDT structure during the process of the block shocking the second-stage charge.

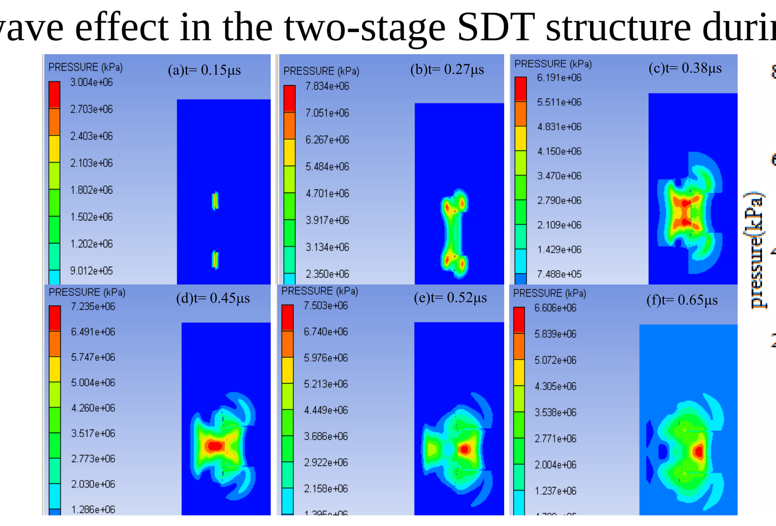

Figure 7. Stress distributions at different time during the shocking process

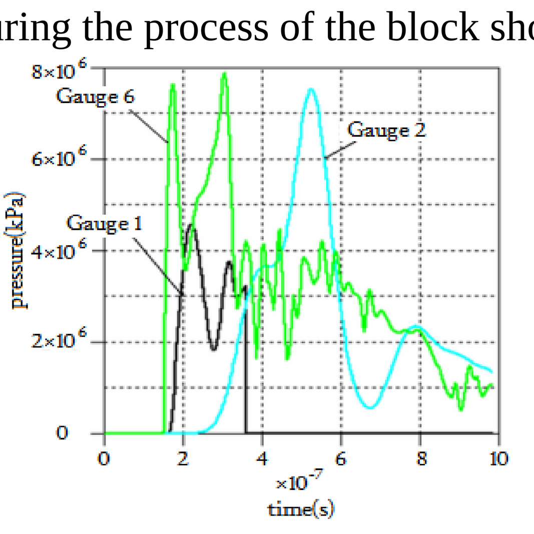

Figure 8. Pressure-time curves at different gauges

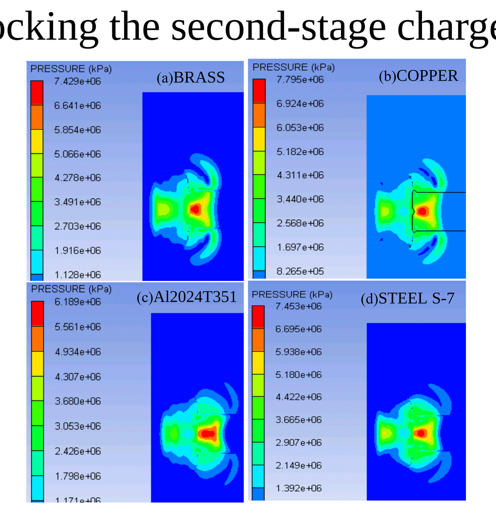

Figure 9. The stress distributions when the time is 0.53 ms with different materials

The material of the second-stage charge shell was changed and the impact processes were simulated, in which the velocity of the mass block is 600m/s. BRASS, COPPER, Al2024T351 and STEEL S-7 were chosen from the AutoDyn Material Library. Other setups stay the same. The stress distributions when the time is 0.53 ms with different materials are shown in figure 9.

The diameter ratio between the second-stage charge and the mass block was changed and the impact processes were simulated, in which the velocity of the mass block is 600m/s. The diameter of the mass block stayed the same and the diameter of the second-stage charge changed. The ratio was set between 0.412~1.059. The peak values of pressure on the axis of charge with different ratios are shown in the figure 10. As the ratio increases, the peak value has a tendency of decrease. When the ratio increases from 0.412 to 0.529, the peak value changes unobviously. which drops from 8.74 GPa to 8.48 GPa. As the ratio continues to increase, the peak value falls apparently. After the ratio reaches the 0.765, the peak value keeps around 4.5GPa.

The stress distributions of different diameter ratio between the charge and the mass block are shown in figure 11, which depicts that the effect of shock-wave convergence becomes weak gradually as the diameter ratio increases. When the ratio reaches 0.765, the pressure wave cannot converge in the axis of charge anymore.

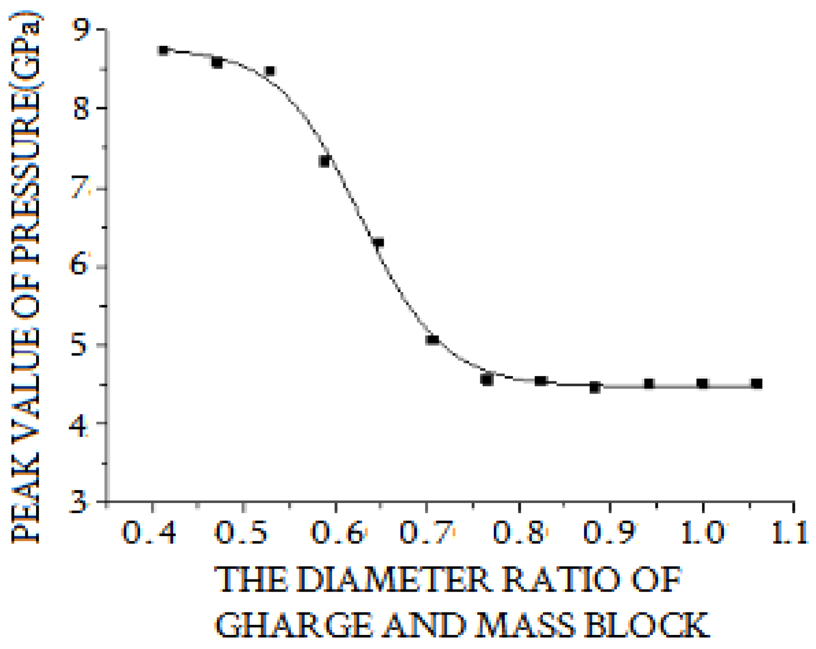

Figure 10. The peak values of pressure with different diameterratio between the second-stage charge and the mass block

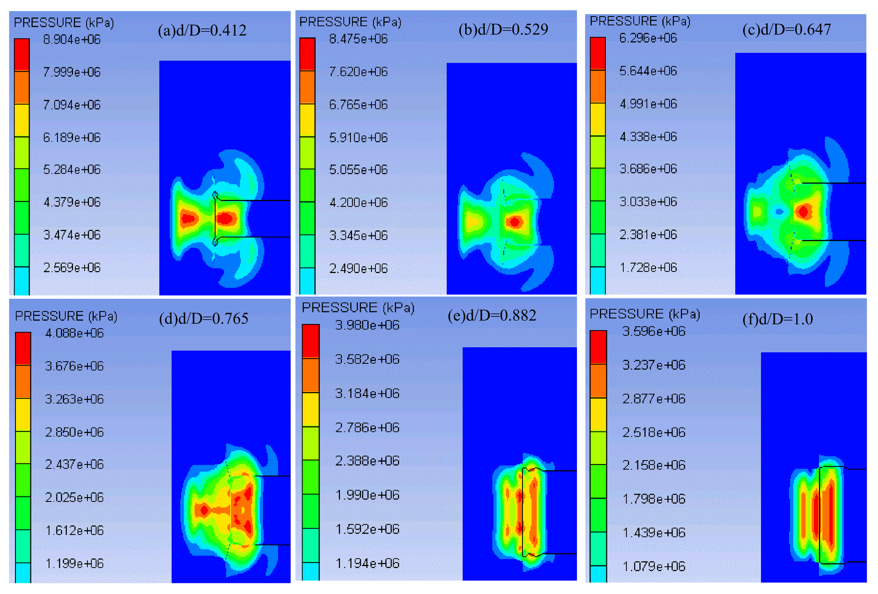

Figure 11. The stress distributions of different diameter ratio between the charge and the mass block

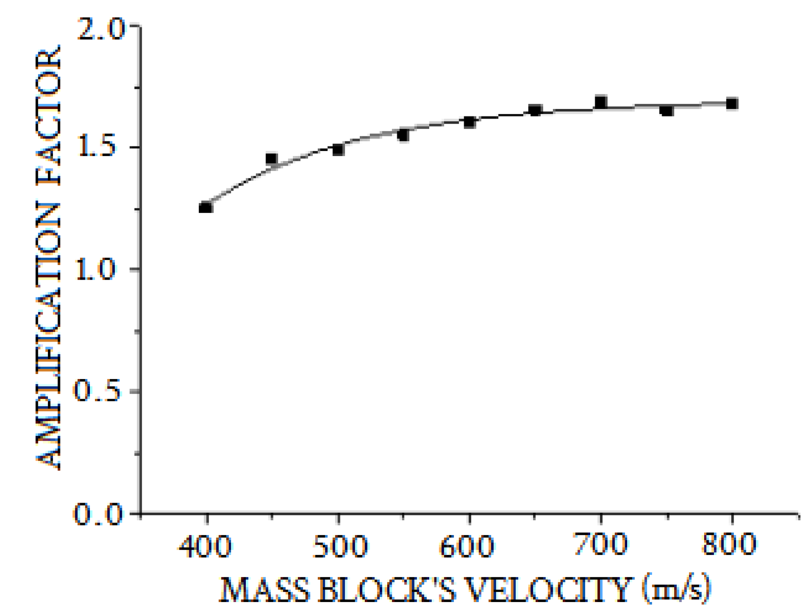

Figure 12. Amplification factors with different mass block's velocities

The ratio of peak pressure and initial pressure mentioned above is defined as amplification factor. As is shown in figure 12, when the mass block' s velocity is between 400 m/s and 650 m/s, the effect of shock-wave convergence increases slowly along with the velocity; while the velocity becomes greater, the factor stays around 1.65.

Experiment

The experiment principle is shown in figure 13. The power control unit(PCU) provides power to the diode laser and triggers the test system. Laser goes through an optical fiber and initiates the test specimen which then initiates the detonating fuse at the end. With the fuse functioning, the signal of the break of the ending target wire is sent to the test system. The test specimen is shown in figure 14.

Figure 14. The experiment specimen

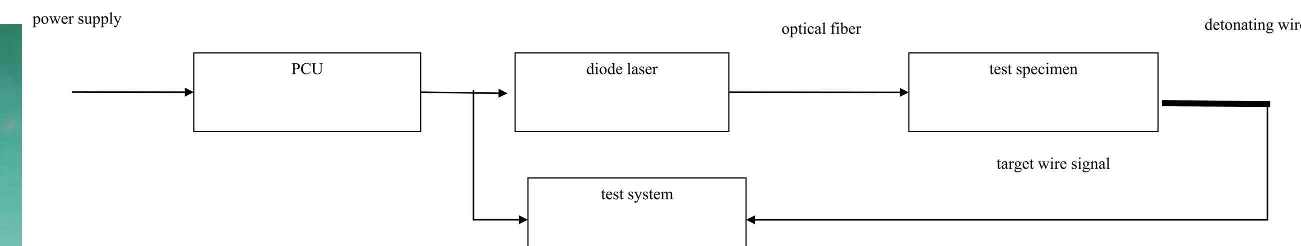

Figure 13. The experiment principle

The laser used in this test has a wavelength of 980 nm. The diameter of the optical fiber is 105 μm. The PCU is adjusted to make the output power of the fiber 2W.

Figure 15. The remains of specimens

Combined with the analysis above and experiment results from early work, the main parameters are decided. The first-stage charge is B/KNO_3(20 mg)+RDX (70 mg) and both densities are 1.5g/cm^3. The mass block's thickness is 1 mm, and the barrel's length is 2 mm. Both diameters of the mass block and the barrel is 1.3 mm. The second-stage charge is RDX(30 mg) whose density is 1.5g/cm^3. The diameter of the second-stage charge is 1.5g/cm^3. There are ten specimens, and the results of igniting time T are shown in table 1. From the data above, all specimens can initiate detonating fuses reliably, which proves the feasibility of the SDT technology. The output performance is quite excellent for the igniting time is blow 2 ms.The grope test for checking the specimens' environmental performance has been completed. The test items and results are shown in table 2. The remains of specimens are shown in figure 15.

Table 1. Test results

Sequence number	T [ms]
1	1.28ms
2	1.67ms
3	1.24ms
4	1.75ms
5	1.6ms
6	1.57ms
7	1.97ms
8	1.83ms
9	1.79ms
10	1.63ms

Table 2. The environmental test results

Group	Number	Test items		Result(igniting time)[ms]
1	3	2 m drop test		1.78~3.24
2	10	The specimens went through damp heat test, temperature cycle test, shock test, sine scan test, random vibration test, half sine shock test, overload test.	Room temperature	2.02~4.60
3	10		High temperature	2.01~3.98
4	10		Low temperature	1.74~3.88

From the data above, all specimens can initiate detonating fuses after the environment test and igniting time is below 5 ms, which proves the design state of the specimen has a good environmental adaptability.

Conclusion

The SDT (shock to detonation transition) technology based on a two-stage structure has been researched. The models of mass block's velocity and shock-wave convergence produced from mass block impacting charge have been built, which reveal the mechanism of detonation caused by the impact. The influence characteristics of some parameters on the shock-wave convergence have been obtained. According to the analysis, the related parameters have been decided and the grope experiments were carried out. The result shows that the detonator employing the SDT structure, whose igniting time is less than 2ms, has good environmental adaptability. The technique of reliable and fast detonation of high explosive without using sensitive explosive has been realized.