Performance test and application of the large diameter multi-point ring initiator for a shaped charge

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Abstract. A series of experiments were conducted to investigate the synchronicity of the large diameter multi-point ring initiator applied to a shape charge(SC). With the multi-point ring initiator applied to SC, the penetration capability of the SC to penetrate in the reinforced concrete targets were studied. The output Synchronicity of all points of the multi-point ring initiator with diameter of 366mm was measured by the DL-3211 time interval tester. It shows that the output synchronicity of all points is good and the maximum time difference is less than 105ns. The SCs with two different initiation diameters were initiated to penetrate into the reinforced concrete targets. Experimental results show that the dimension of crater and inlet increase with initiation diameter of SCs.

1. Introduction
The tandem penetrating blast warhead is mainly used to strike the enemy's underground or semi underground solid targets. The warhead usually adopts two-stage series structure, the former stage is SC warhead, the latter stage is penetration blast warhead. The front SC is mainly used to penetrate the reinforced concrete targets and form a reliable channel for the rear warhead. The rear follow-up warhead penetrates into the target and explodes to destroy it. The penetration depth and diameter of the front SC are the key factors that affect the follow-up and operational effectiveness of the rear warhead.

The explosion formed rod-like penetrator (EFRP) is formed by the explosion of SC. It has better anti-interference ability, longer than the explosive formed penetrator(EFP), higher flight speed, larger section specific kinetic energy and stronger penetration ability for its larger diameter, better continuity and higher strength than the conventional jet [1]. EFRP has a wide application prospect in the pre-stage penetration of the two-stage tandem penetrating blast warhead and SC subject to underwater targets, and scholars have also carried out a lot of research [2-6]. Waveform control technology is usually used to improve the power of EFRP, such as the detonation structure of secondary charge plus wave-shaper or the electronic control technology of multi-point initiation. The core of these technologies is to realize the annular initiation in the front stage charge, and form the axisymmetric "concave" cone (or horn shaped) detonation wave so that the detonation wave converge to the symmetrical axis in the crushing direction of the liner. The total kinetic energy and penetration power increase with the increase of crushing speed of the liner. For reliable flameproof, the wave-shaper need a certain thickness if the structure of secondary charge plus wave-shaper is applied in the SC which will increase the length of the charge. On the premise that the total length of the warhead is constant,
the damage power will be affected with the decrease of charge for the reduced length of rear charge. If the SC adopts the electric control technology of multi-point initiation, it is difficult to guarantee the accuracy of multi-point initiation due to the superposition of synchronicity of circuit and initiating explosive device. The multi-point ring initiator designed for the above problems has a simple structure, which realizes a central point detonation input and a multi-point circular synchronous detonation output, which advantageously controls the detonation wave.

A multi-point, 24-point, ring initiator with a maximum initiation diameter of 120mm was designed by DUAN Zhuoping et al [7-8] and an experiment on the penetration of concrete was carried out. In this paper, a multi-point ring initiator with a large initiation diameter of 366 mm was designed and output points of 36. Synchronicity and opening performance experiments on reinforced concrete were carried out, matching law between the initiation diameter of multi-point initiator and the penetration performance of the SC to reinforced concrete was obtained.

2. Multi-point ring initiator with large initiation diameter
The structure of the Multi-point ring initiator with large initiation diameter designed in this paper is shown in figure 1, the metal parts are made of 2A12 hard aluminum. The diameter and height of the central detonation explosive charge are 50mm and 3mm, respectively. There are 36 detonating cords with diameter of 1.58mm in the circumferential direction to detonate and propagate. The charge of detonating cord is JO-6 with detonation velocity of 8000m/s. One end of the detonating cord is connected to the output charge with diameter of 7mm and height of 8mm, the other end is connected to the central initiating charge. Both the output charge and the central charge are JH-14 with density less than 1.66g/cm3.

The central 1-point input and the circumferential 36-points output are realized by first detonating the central charge and then detonating the output charge through the detonation and propagation of the detonation cords. The detonating diameter of multi-point annular detonator can be realized by adjusting the length of detonation cord.

![Figure 1. The structure of multi-point ring initiator.](image)

3. Experiment on synchronicity of multi-point ring initiator with large diameter
Experiment was carried out to investigate the synchronicity of the multi-point ring initiator with initiation diameter of 366mm. The experiment was carried out a total of 1 round, the prototype used in experiment is shown in figure 2.
Figure 2. Large diameter multi-point annular detonator prototype.

DI-32 II time interval tester (figure 3) is used to test the synchronous initiation accuracy of the experimental prototype. The equipment has 32 test channels with a test accuracy of ± 2ns.

Figure 3. DI-32 II time interval tester.

The schematic diagram of the experimental layout is shown in figure 4. The experimental prototype was placed on 2 steel ingots and set up a certain distance from the ground. LD-45 # electric detonator → two-way detonation assembly → prototype initiation sequence was applied in the experiment. LD-45 # electric detonator is connected to one channel of DI-32 II time interval tester. The initiation signal is given by the DI-32 II time interval tester, and is taken as the zero time of other test channels. Except one of the channel is disabled due to the unstable le signal in the 32 channels, one channel is taken to record the initiation signal, and the remaining 30 channels are used to record the initiation time of 30 output points. Fold the enameled wire in half and cut, twist one end to twist shape as a break target. Randomly select 30 initiation points of the experimental prototype, then use white tape to stick one end of the break target to the bottom of the output grain, and connect the other end to one of the 30 selected channels of DL-32II time interval tester by wire. When the output grain explodes, the formed detonation product instantly disconnects the enameled wire from the target, and the tester records the output time at that point. Figure 5 is a photo of the experimental site layout.
The experimental results show that the central detonation charge, 36 detonating cords and 36 output charges of the multi-point ring initiator are fully detonated. And the initiation time are shown in table 1. The calculated maximum time difference $\Delta T_{\text{max}}$ of the 30 points is 105ns, and the synchronous initiation accuracy is good, which can meet the requirements of the initiation of SC.

### Table 1. Factors in the table 1.

| No. | Time  | 1  | 2  | 3  | 4  | 5  |
|-----|-------|----|----|----|----|----|
| No. | 1     | 100.011 | 99.995 | 100.032 | 100.057 | 99.986 |
| No. | 6     | 6 | 7 | 8 | 9 | 10 |
| No. | 11    | 99.996 | 99.975 | 100.039 | 99.989 | 99.981 |
| No. | 16    | 12 | 13 | 14 | 15 |
| No. | 16    | 100.055 | 99.970 | 99.982 | 100.088 | 99.995 |
| No. | 21    | 17 | 18 | 19 | 20 |
| No. | 26    | 100.098 | 99.998 | 100.044 | 99.996 | 99.976 |
| No. | 26    | 22 | 23 | 24 | 25 |
| No. | 26    | 99.978 | 99.991 | 100.082 | 100.075 | 99.979 |
| No. | 26    | 27 | 28 | 29 | 30 |
| No. | 26    | 99.983 | 99.979 | 100.022 | 99.977 | 99.975 |

### 4. Effect of different initiation diameters on the opening performance of concrete

Experiment of SC penetrating the reinforced concrete were carried out to study the effect of different initiation diameters on the performance of SC penetrating the reinforced concrete and evaluate the structure compatibility of SC and the initiation diameter. The diameter of SC is 410mm, material of the cone liner is titanium alloy. The charge is Octal (TNT/HMX=25/75) which density and detonation velocity are $1.83\text{g/cm}^3$ and $8278\text{m/s}$, respectively. The experimental SC and initiator are shown in figure 6. Two experiments were carried out, which were initiated by 36-points initiator with initiation diameter of 266mm and 366mm respectively.
The experimental site layout is shown in figure 7. The size of the experimental reinforced concrete target is $5.5m \times 5.5m \times 2.5m$, and the reinforcement ratio is 0.68% (mass fraction). The SC was detonated with a special experimental fuse. A missile simulation front cabin is installed in the front of the SC to ensure that the experimental state is consistent with the actual use of the product. And the overall test device is placed on a wooden frame, and the simulated front cabin is placed close to the center of the front of the target. 25 pieces of $300 \text{ mm} \times 300 \text{ mm} \times 10 \text{ mm}$ Q235 steel plates are placed at the center of the back of target as witness targets to evaluate the remaining penetration power of EFRP which formed by the SC. The reinforced concrete and the witness targets after experiment are shown in figure 8 and figure 9, respectively. The results are shown in table 2, where $d$ is the initiation diameter of the multi-point initiator.

From table 2, it can be seen that both of the two SCs can penetrate the reinforced concrete target with a thickness of 2.5m, and the remaining jet can penetrate all 25 pieces of Q235 steel plates with a thickness of 10 mm. However, the penetration capacity of SC to reinforced concrete is closely related to the initiation diameter. There is a significant improvement in the key indicators such as the sizes of inlet, outlet and average diameter of the hole with a larger initiation diameter of the SC.

**Table 2.** Factors in the table.

| No. | $d$/mm | Damage of targets                  |
|-----|---------|-----------------------------------|
| 1   | 266     | Penetration                       |
|     |         | Crater: $1.7m \times 1.8m$, Depth: 303mm |
|     |         | Inlet: $300\text{mm} \times 310\text{mm}$ |
|     |         | Scabbing: $2.2m \times 2m$, Depth: 300mm |
Outlet: 180mm × 190mm  
Average diameter of the hole: 212mm  
Witness target: Penetration of 25 Q235 steel plates with a thickness of 10mm

Penetration  
Crater: 1.8m × 1.9m, Depth: 330mm  
Inlet: 340mm × 320mm

2  366  
Scabbing: 2.1m × 2.2m, Depth: 290mm  
Outlet: 210mm × 200mm  
Average diameter of the hole: 244mm  
Witness target: Penetration of 25 Q235 steel plates with a thickness of 10mm

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5. Conclusion

(1) A 36-points ring initiator is designed and manufactured in this paper, which initiation diameter is up to 366mm. The synchronicity of this initiation is good, and the output time difference of each point is not more than 105ns.

(2) The SC with multi-point ring initiator can penetrate 2.5m-thick C35 reinforced concrete target, which maximum average diameter of the hole can be up to 244mm. The remaining jet can penetrate 25 pieces of Q235 steel plates with the thickness of 10mm, which basically meets the requirements for the opening capacity of pre-stage charge of a tandem penetration warhead to penetrate the reinforced concrete.

(3) The penetration capacity of SC with a larger diameter ring initiation on reinforced concrete is greater than a smaller diameter. The multi-point annular detonator has a larger penetration diameter when the initiation diameter is larger than 366mm.

References

[1] Blache A and Weimann K 1998 Proceedings of the 17th International Symposium on Ballistics South Africa 2 207-15
[2] Blache A and Weimann K 1996 Proceedings of the 16th International Symposium on Ballistics San Francisco CA 337-46
[3] Cauret M, Delmas A and Petit 1998 Proceedings of the 17th International Symposium on Ballistics. Midrand South Africa 2 357-64
[4] TAN Duo-wang, SUN Cheng-wei and ZHAO ji-bo et al 2003 Chinese Journal of High Pressure Physics 17(3) 204-8
[5] WU Han-ling, DUAN Zhuo-ping and LI Jin-zhu 2004 Journal of Nanjing University of Science and Technology 28(6A) 11-6
[6] Baker E L, Daniels A S and Turci J P et al. 2002 Proceedings of the 20th International Symposium on Ballistics Orlando USA 589-96
[7] DUAN Zhuo-ping, WEN Li-jing and SHEN Jian et al. 2011 Acta Armamentarii 32(1) 101-5
[8] DUAN Zhuo-ping, WEN Li-jing and ZHANG Lian-sheng et al. 2010 Explosion and Shock Waves 30(06) 664-8