Investigation in the Detonation Network Layout

Manfred Held

（ *TDW/EADS* 86523 *Schrobenhausen*；*Germany*）

Abstract：With a V-shaped arrangement of explosive filled grooves the minimum allowed distance as a function of time difference between a detonating trace and neighboring later detonating trace can be continuously measured and analyzed. The technology and procedure is discussed with two examples. This behavior and knowledge is important for special detonation network layouts.

Key words：detonation；network；layout

CLC number：O389　　　　　**Document code**：A

1　Introduction

Some fragmenting warheads or shaped charges want a multi point perfect working simultaneous circumferencial ring initiation. To achieve this with small length and volume a detonation network is often used which needs no barrier material in the center of the charge，like in shaped charges with wave shaper. Fig. 1 shows an example with an sixteen fold simultaneous initiation on the base of a charge.
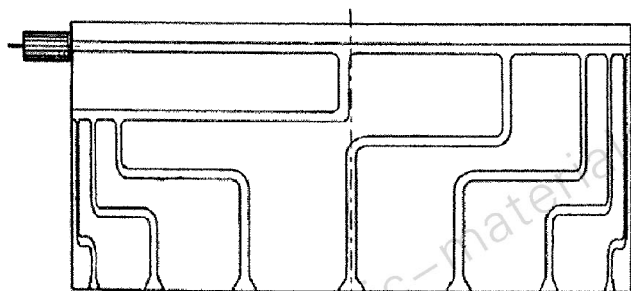

Fig. 1　Detonation network for simultaneous ring initiation with free space at the center

An exploded view of the grooves with connecting

passages of the explosive traces with equal length from the initiation point to the booster outputs is presented in Fig. 2.
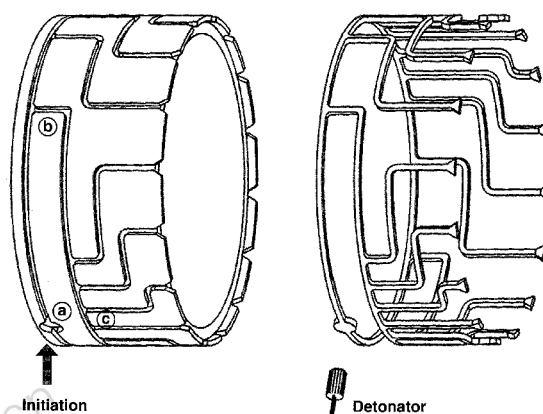

Fig. 2　Exploded view of the simultaneous ring initiation detonation network

The height of such an arrangement should be a minimum. But one problem is that the shockwave of the first detonating high explosive trace arrives much earlier than the detonation wave on some special locations.

The following test set-up should describe a diagnostic tool to defing the possible distance of the traces as a function of the time difference or inverse for a given time difference the minimum distance，to get no change in the detonation behavior of the second trace.

2　Describing the problem

In the for example selected circular detonation network of Fig. 1 and Fig. 2 should be considered the points

a and c. Point a is near to the initiation location, where then the detonation is running one quarter of the circumference on the cylindrical logic network to point b, then running down and back again the quarter of circumference to point c. The height of the forward and rearward running traces should be about $1/3$ of the radius R. The length L of the trace from a to c can be calculated with

$$L = \pi R + 1/3R \approx 3.5R$$

The detonation velocity D is around 7 mm $\cdot$ μs^{-1} for the used PETN based high explosives. This gives therefore a time difference Δt of

$$\Delta t = 3.5R/D = 0.5R(\mu s)$$

As an example, a 100 mm diameter, respectively a 50 mm radius for such an device should be taken. The time difference Δt between the points a and c will be then 25 μs. The perpendicular distance between a and c is roughly $1/3$ of 50 mm, which gives around 17 mm.

The sound and shock velocity in per example plexiglass is around 3 mm $\cdot$ μs^{-1}. This means the sound and shock waves arrive at least 19 μs earlier the trace at location c which can definitely influence the detonation behavior of the high explosive filling in the channel around the location c.

3   Defining the shock wave velocities

For the detonation network should be used a 5 mm thick plexiglass ring with machined grooves of 2 mm × 2 mm. These are filled with pasty PETN composition with 87% PETN and 13% lubricant. To get the shock velocities as a function of distance a special calibration test was fired. Some people have declared that the shock velocity can be remarkably reduced by an air gap between the traces. Therefore a 1 mm air gap through the 5 mm thick plexiglas was machined. The shock wave was measured by a rotating mirror camera where the streak slit was perpendicular adjusted to the explosive channel, respectively the 1 mm slit (Fig. 3). The plexiglas was back illuminated by an argon bomb where argon was filled in a translucent children balloon (Fig. 4). Fig. 5 shows the streak record together with the analysis. The result was a little surprising because the shock velocity was by the slit not reduced, but only delayed. At 10 mm distance the velocity was more or less identical, but 2 μs delayed by the air gap.
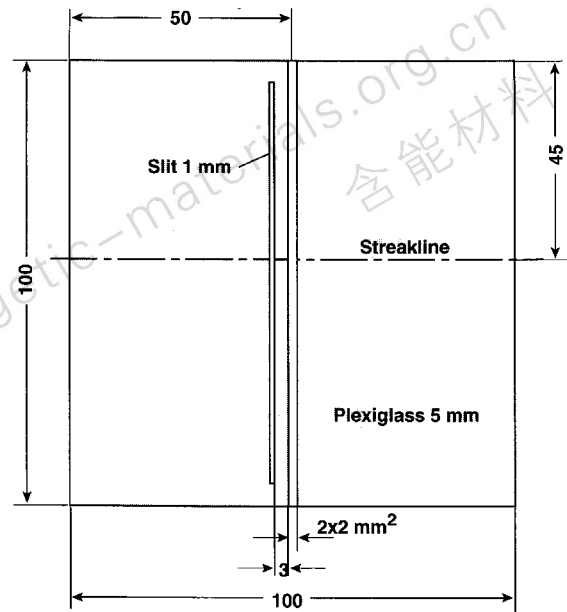

Fig. 3   Test set up for measuring the shock wave velocity in a 5 mm thick plexiglas plate, driven by a detonating explosive trace of 2 mm × 2 mm cross section with investigation of the reduction of the sock strength by a slit of 1 mm width 3 mm distance
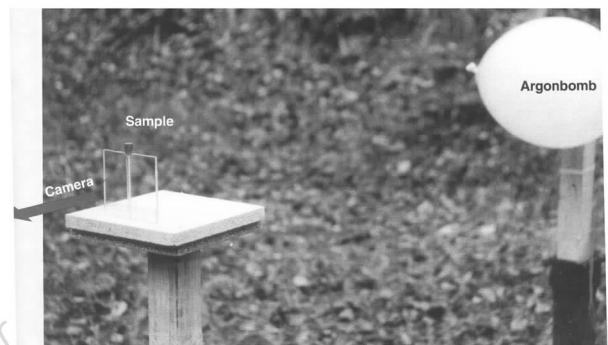

Fig. 4   Plexiglas plate of configuration after Fig. 3 in front of the rotating mirror camera with a back illumination by an argon flash bomb
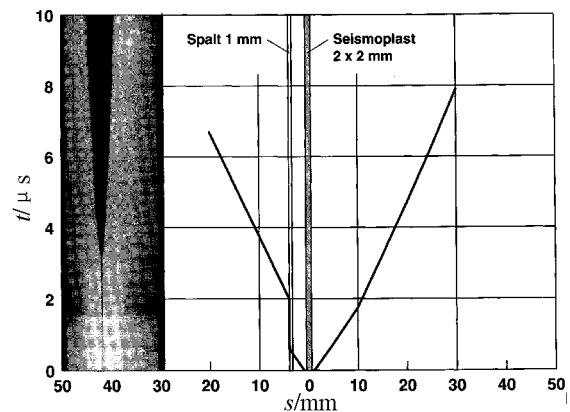

Fig. 5   Streak record with the 1 mm slit on the left side of the trace and the analysis of the shock waves

This result means that in the distance of 3 mm the plexiglas surface is spalling off and transferring a shock load to the plexiglas layer after the air gap and transferring the shock load in this form. To find out the optimum distance between a slit in the plexiglas to reduce strongly the shock wave the slit has to be arranged in larger distances where spalling will not more happen. The investigation to this topic will be published in a different paper.

4　V-shaped Channels

For defining the minimum distance for a given time difference that the detonation behavior in the channel is not influenced by the early arriving shock waves a very simple test setup for this diagnostic should be found which allows a continuously measurement of the minimum transverse distance for a given time difference. For this was selected a V-shaped channel arrangement（Fig. 6）. A picture of this set-up laying on a 10 mm thick aluminum plate shows figure 7.
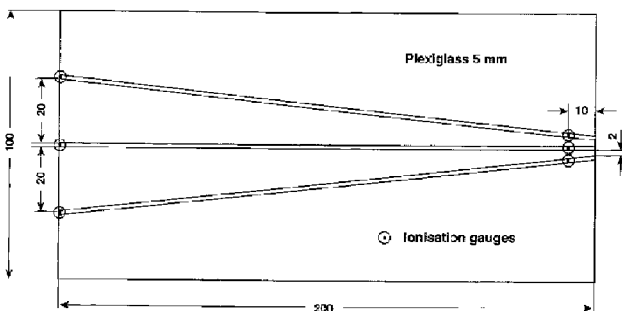

Fig. 6　Test configuration for the V-shape channels with ionization probes on the entrance and 10 mm for the exit side

Fig. 7　Arrangement of the V-shaped traces with the detonators on the left side on a 10 mm thick aluminum plate

Two performed tests with this arrangement were described in detail. In a first test（Det. 63690）2 mm grooves are machined in a 5 mm plexiglas plate of 100 mm width and 200 mm length. On the entrance side they had 20 mm distance from one another and on the end 2 mm. On the entrance side of every trace and 10 mm before the end of every trace ionization pins are installed in the high explosive filled grooves. The plexiglas plate was lying with the high explosive traces in contact to a 10 mm thick aluminum plate. The detonation signatures in the aluminum plates are very well visible on the Fig. 8.
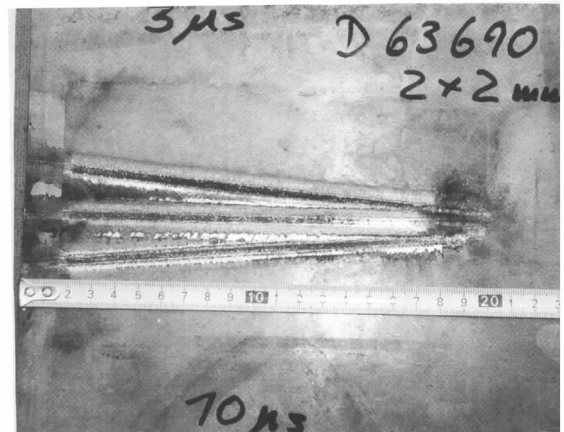

Fig. 8　Detonation signatures of the 2 mm × 2 mm grooves on the aluminum plate

The firing units for the detonators were set for 3 μs delay time on the upper trace and 10 μs on the lower trace to the middle trace. But the measured time differences are measured 2.1 μs for the upper and 8.9 μs for the lower trace by the ionization probes. The upper trace was full detonating through. The lower trace was running up to 190 mm length. There are no detonation marks more visible on the last 10 mm.

A second firing was arranged with Det. 63691 with 1.5 mm × 1.5 mm groove cross section, also filled with pasty PETN composition. The firing unit was set to the same time differences. The upper trace with the short time difference of exactly 3.2 μs was detonating to the end, but the lower trace which had exactly 11.3 μs time difference to the middle trace was running up to around 160 mm（Fig. 9）.
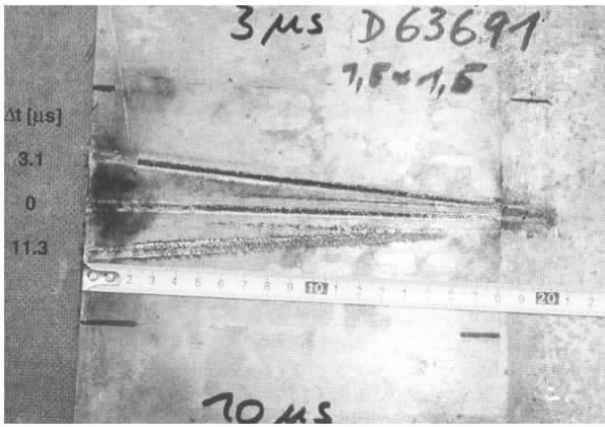
Fig. 9　Detonation signatures of the 1. 5 mm × 1. 5 mm
grooves on the aluminum plate

5　Analysis of the test results

The table 1 gives the Det. – Number, the dimensions of the grooves, the measured initiation time differences t_i and the time differences t_e after 190 mm distance, the calculated detonation velocity D from the time differences $t_e - t_i$ and finally the length x of the detonation signatures on the aluminum ground plates. The times t_e on the lower traces with the longer delay times are given in brackets and they will be special discussed.

Table 1　Test results

Det. No.	Groove /mm²	t_i /μs	t_e /μs	D /mm · μs⁻¹	Length x /mm	s /mm
63690	2 × 2	2.1	27.7	7.42	200	–
		0	25.6	7.42	200	–
		8.9	(27.1)	–	190	2. 9
63691	1.5 × 1.5	3.2	29.4	7.25	200	–
		0	26.6	7.14	200	–
		11.3	(28.0)	–	160	5. 6

The time differences to the side branches are longer than the selected initiation time differences t_i because the shock wave has to travel over the transverse distances. With increasing length the transverse distance is reduced and therefore the shock wave passing times are decreasing. The time difference of the V-shaped traces have to be considered as follows (Fig. 10).
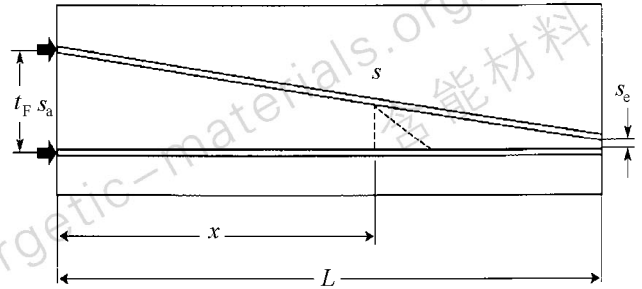

Fig. 10　The delay times of the shock wave arrivals as a
function of distance s has to be taken into account

The total time difference t_T is

$$t_T = t_F + t_{SW}$$

Where t_F is the time difference for the initiation (firing) and t_{SW} belongs to the arrival time of the shock wave.

The shock wave time is simply given by the distance s and shock wave velocity U

$$t_{SW} = s/U$$

The distance s is a function of the V-shaped design and can be generally described as follows：

$$s(x) = (L - x) \cdot (s_a - s_e)/L + s_e$$

The total time difference t_T as a function of the length x of the detonation signature on the aluminum plate can now be described as follows：

$$t_T = t_F + [(L - x) \cdot (s_a - s_e)/L + s_e]/U(s)$$

If the shock wave velocity U is known or measured as a function of distance s then these values can be used directly. If this is not known then the shock wave mean value can be considered as 3 mm · μs⁻¹ for a first rough consideration.

The transverse distance s for these two tests can be simply calculated which gives 2. 9 mm for test 63690 and 5. 6 mm for the test 63691. By assuming a shock wave velocity of 3 mm · μs⁻¹ about 1 μs can added for the first test and about 2 μs for the second test. In the first case with the trace cross section of 2 mm × 2 mm the interruption of the detonation trace was at about 3 mm distance with about 10 μs time difference (8. 9 + 1) μs and at the second test with the smaller cross section of 1. 5 mm × 1. 5 mm about 6 mm at about 13 μs time difference.

Ionization probes were installed 10 mm for the end of the traces. At the first test the ionization probe in the lower trace was contacted after 27. 1 μs. This is 1. 5 μs later than the middle trace after 25. 6 μs. This means this ionization probe is shortened by the shock wave of the neighboring detonation and not by the detonation wave on the lower trace. The same event was happening at the second described test where the ionization probe in the lower trace was shortened after 28 μs, also again 1. 4 μs after the shortening of the middle trace with 26. 6 μs. In repetition the ionization probes are been shortened by the shock and/or reaction products of the detonating middle traces.

Taken the time differences of t_i and t_e for the upper and middle traces into account the achieved detonation velocities are 7. 4 mm · μs^{-1} for the 2 mm × 2 mm and around 7. 2 mm · μs^{-1} for the 1. 5 mm × 1. 5 mm trace cross sections.

6 Conclusion

The minimum allowed distance of explosive traces in detonation networks can be tested with V-shaped traces in a continuously way. This method allows to find out the minimum allowed distance with no mutual influence as a function of time difference.

With these two described tests it was found out that the the smaller dimension of the cross sections with 1. 5 mm × 1. 5 mm is more sensitive compared to the larger cross section 2 mm × 2 mm.

The results with a slit for damping the shock load in the near distance is not really given. The measured delayed time of 1. 5 μs is not really from great influence.

网络炸药装置爆轰研究

摘要：采用沟槽中充满炸药的 V 形装置,可以连续测量和分析网络炸药线之间所允许的最小距离,这个距离是炸药线和它后面相临的炸药线之间时间差的函数。通过两个例子来讨论了这种技术和方法。对于特殊的网络炸药装置,这种性能和知识是很重要的。

关键词：爆轰；网络炸药