

## Study on initiation reliability according to bunch-series coupling structures of shock tubes

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### Abstract

The bunch blocks are currently used for initiating many shock tubes by detonator in blasts and its coupling structures affect the initiation reliability. The initiation reliability of bunches of shock tubes according to structures of bunch blocks has studied in experimenters. Experiments compared initiation reliability of frontal bunch block with lateral for many shock tubes and evaluated initiation reliabilities according to structure factors. Initiation reliabilities of shock tubes in a bunch for frontal block were higher than that for lateral. And the thicker and the smaller standoff distance between detonator and the inlet of a bunch of shock tubes, the more the experimentally obtained initiation reliabilities increased. Finally, the results are used in research of bunch blocks initiating many shock tubes.

**Keywords:** Shock Tube; Bunch-Series Coupling; Initiation; Bunch Block

### 1. Introduction

Shock tube initiation system is Non-electric (NONEL) and consists of detonator, shock tubes (also known as none tube, detonating tube, signal transmission line and etc.) and coupling tools. Shock tube consists of a thin plastic tube with a layer of explosive material adhered on its interior wall. The explosive material generally includes powder of HMX or RDX and powder of aluminum [1]. For tunneling work and building demolition, a number of shock tubes must initiate at once by a detonator, and consequently for shock tube initiation system it is necessary not only the high ability but also the high reliability of initiation [2]. For reliable initiation of shock tubes, it must be affected the sufficient energy to the shock tubes [3]. Explosive material within shock tube initiates and detonates pressing adiabatically by a pressure impulse generated by external action [4, 5]. Reliable initiation of shock tubes, accordingly, requires sufficient pressure impulse to affect the shock tubes for initiate them. According to mutual arrangement of a detonator and shock tubes, coupling of a detonator and shock tubes have several modes. The present time widely utilize the lateral bunch-series coupling modes that bunch of shock tubes are positioned adjacently to a detonator and in a parallel [6, 7] or perpendicular [8, 9, 10] to the axis of a detonator body. However, these coupling modes have the insufficient ability to initiate shock tubes owing to a small charge of a detonator and failures of initiation often appear in case of many shock tubes in a bunch.

Until now, studies on bunch-series coupling modes of a detonator and shock tubes have been published to some extent. However, almost researches have focused on tests of lateral coupling mode of a detonator and shock tubes. The principal objectives of the study were as follows.

- To study the influence of coupling modes on initiation reliabilities of a bunch of many shock tubes by a detonator.

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- To study the influence of coupling structure of frontal bunch block and a bunch of shock tubes on initiation reliabilities of shock tubes by a detonator.

In the present article, the authors present the results of an experimental study into the coupling modes on the initiation reliability of a bunch of many shock tubes by a detonator. A Frontal bunch-series coupling mode compared with a lateral mode in experiments. And the influences of coupling structures of frontal bunch block with many shock tubes to the initiation reliabilities also investigated and compared for initiating experiments of a bunch of shock tubes.

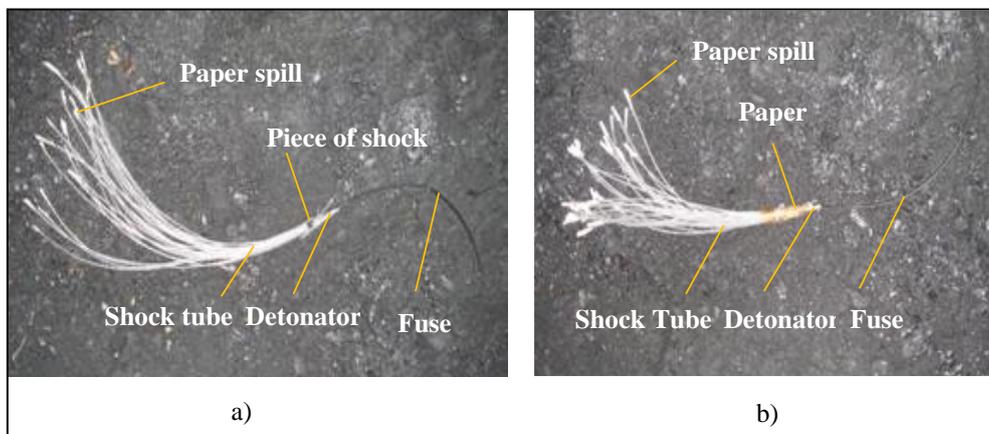
## 2. Experiments and Results

In this section, we present the experimental setup and result for initiation reliability of a bunch of shock tubes by a detonator according to coupling structures.

### 2.1. Experimental setup

The specimens include shock tubes made of polyethylene plastic tube: outer diameter 3mm, inside diameter 1.5 mm and 50 cm of length. It is utilized #8 detonator; outer diameter 7.5 mm, length 50 mm and total mass of lead nitride and HMX 1.5 g, loaded length 20 mm.

For experiments of coupling mode of a detonator and shock tubes use two coupling modes, shown in Figure 1. A detonator and a bunch of shock tubes are coupled using a piece of shock tube or paper. Lateral bunch-series coupling mode surrounds parallel a detonator coupled with fuse by shock tubes, wraps in paper and couple by line or a piece of shock tube. Frontal coupling mode couples a detonator and shock tubes with 10mm interval away from charge end in the same axis.

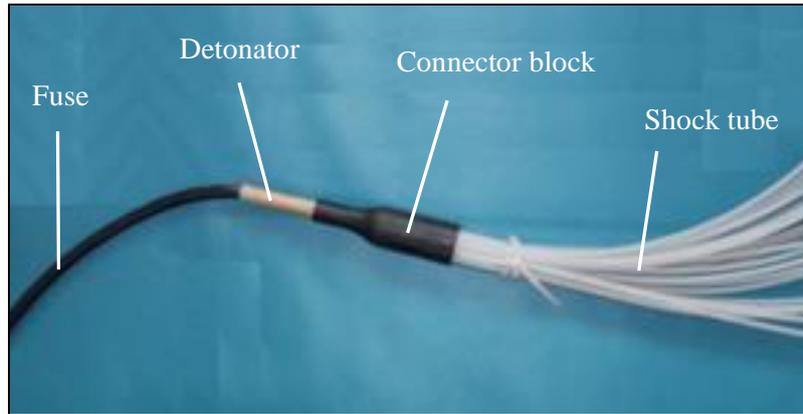


**Figure 1** Initiation experiment of a bunch of shock tubes for no existing of bunch block

- Frontal bunch-series coupling mode; b) Lateral bunch-series coupling mode.

For experiments of coupling structure, the combination of a bunch of shock tubes and a detonator uses frontal bunch block. Frontal bunch block, as shown in Figure 2, have a structure for receiving a detonator and a structure for receiving and retaining shock tubes. The inlets of a bunch of shock tubes place in certain standoff distance from a detonator as a result of receiving and retaining one end of a shock tube bunch in a shock tubes receptacle (big hole) of hopper-type bunch block and receiving and supporting a detonator in a detonator receptacle (opposite small hole) of hopper-type bunch block. Bunch blocks constructed of a consumable material, such as polyethylene plastic. The dimension of bunch blocks set according to the number of tested shock tubes within bunch blocks.

The initiation reliabilities according to the coupling structures determined by investigation of initiation or initiation failure of the specimens with a variable number of shock tubes in a state that the bunch blocks not be in existence. Experiment changed variously the number of shock tubes. For decreasing consumption of shock tubes, limited the number of shock tubes in bunch under 50 lines and the experiment number for same bunches at five times. The initiation or misfire of shock tubes distinguished by state investigation of a paper tap plugged an inlet of shock tubes after initiating of a detonator.



**Figure 2** Initiation experiment of a bunch of shock tubes for existing of frontal bunch block

The initiation reliabilities experiment according to the coupling structure investigated and compared the influence of the number of shock tubes within bunch blocks, the thickness of bunch blocks and the standoff distance between a detonator and a shock tube bunch on the initiation reliability of shock tubes in a bunch. In experiments according to the thickness of bunch block bodies investigated the initiation reliability a bunch of 50 shock tubes in conditions, using the bunch blocks of thickness 0.5 mm, 1.0 mm, 1.5 mm, 2 mm manufactured by injection molding of plastic. In experiments according to the standoff distance between a detonator and a bunch of shock tubes within bunch block investigated the initiation reliability of a bunch of 50 shock tubes, changing the standoff distance to 0 mm, 5 mm, 10 mm. Experiment performed, changing the number of these shock tubes variously. The state of a bunch of shock tubes after experiments as shown in Picture 3.



**Figure 3** The state of a bunch of shock tubes after experiments

## 2.2. Results

After initiating a detonator investigate the number of initiated shock tubes in a bunch. Experimental results for frontal and lateral bunch-series initiation are as shown in Table 1.

**Table 1** Initiation experimental results according to coupling modes

for frontal coupling mode						for lateral coupling mode					
Number of shock tubes in a bunch	Number of initiated shock tubes in a bunch					Number of shock tubes in a bunch	Number of uninitiated shock tubes in a bunch				
	Exp. 1	Exp. 2	Exp. 3	Exp. 4	Exp. 5		Exp. 1	Exp. 2	Exp. 3	Exp. 4	Exp. 5
15	15	15	15	15	15	15	15	15	15	15	15
20	20	20	20	20	20	20	20	20	20	20	20
25	25	25	25	25	25	25	25	25	25	25	25
30	30	30	30	30	30	30	30	30	30	30	30
35	35	35	35	35	35	35	35	35	35	35	35
40	40	40	40	40	40	40	40	40	39	40	40
45	45	45	45	45	45	45	45	44	45	44	43
50	47	50	47	50	47	50	47	48	45	48	44

The initiation reliabilities according to thickness of bunch block bodies and standoff distance between a detonator and a bunch of shock tubes within bunch block were estimated by results of initiation of a bunch of shock tubes (Table 2). As show in Table 2, the initiation reliabilities concerned with thickness of connector block bodies and standoff distance.

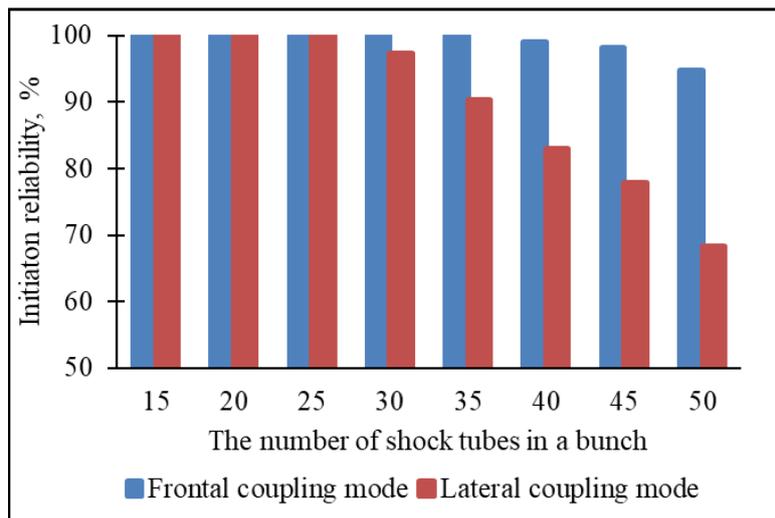
**Table 2** Results of initiation of a bunch of shock tubes according to thickness of bunch block bodies and standoff distance

Material	Number of shock tubes in a bunch	Thickness, mm	Standoff distance, mm	Number of initiated shock tubes					
				Test 1	Test 2	Test 3	Test 4	Test 5	Average
Without bunch block	35	0	10	35	35	35	35	35	35
Without bunch block	40	0	10	40	40	39	40	40	39.8
Without bunch block	45	0	10	45	44	45	44	43	44.2
Polyethylene	50	0.5	0	50	50	50	49	50	49.8
Polyethylene	50	0.5	5	50	49	50	50	49	49.6
Polyethylene	50	0.5	10	48	50	49	50	50	49.4
Polyethylene	50	1.0	0	50	50	50	50	50	50
Polyethylene	50	1.0	5	50	50	50	50	50	50
Polyethylene	50	1.0	10	50	50	50	50	50	50
Polyethylene	50	1.0	15	50	50	50	50	50	50
Polyethylene	50	1.0	20	50	50	50	50	50	50
Polyethylene	50	1.5	10	50	50	50	50	50	50
Polyethylene	50	1.5	20	50	50	50	50	50	50
polyethylene	50	2.0	10	50	50	50	50	50	50

### 3. Discussion

#### 3.1. Coupling mode

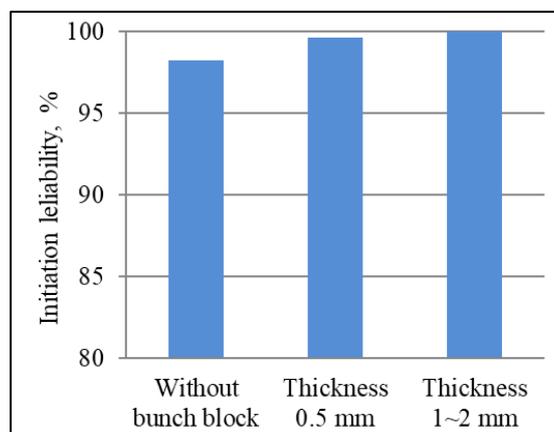
We compared the initiation reliabilities for frontal and lateral bunch-series coupling mode. The initiation reliability according to the number of shock tubes is as shown in Figure 4. As shown in Figure 4, bunches of shock tubes to 35 lines for frontal and to 25 lines for lateral coupling mode were initiated completely by a detonator. Experiment shows the frontal bunch coupling mode has the more initiation ability and can initiate more shock tubes than lateral mode. For frontal mode, the peak pressures within shock tubes are bigger than lateral mode besides first layer around a detonator. thus, the stronger pressure impulses are affected because. For lateral mode, the shock tubes around a detonator have energy absorbent function in materially and structurally, thus, the more layers of shock tubes far away from a detonator, the more action on shock tubes decrease rapidly. So, we can predict that frontal coupling mode can initiate reliably many shock tubes by a detonator.



**Figure 4** The relationship between the number of shock tubes in a bunch and the initiation reliability

#### 3.2. The thickness of the bunch block bodies

Experimentally obtained initiation reliabilities of a bunch of shock tubes by detonator were compared in two cases of the absence and the present of bunch block. As shown in Figure 5, for initiating a bunch of shock tubes with 50 lines and in the present of bunch block the whole shock tubes were initiated for 1.0 mm~2.0 mm thickness of bunch block bodies. In the absence of bunch block and on the same experiment conditions some shock tubes were not initiated for 35 lines over of shock tubes in a bunch.



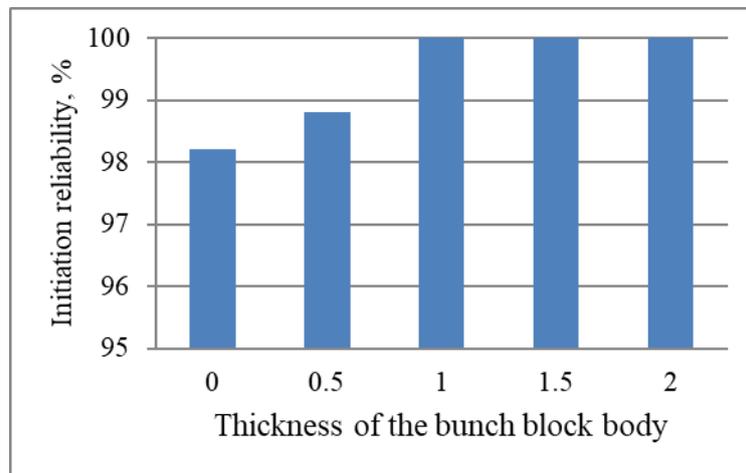
**Figure 5** Initiation reliabilities of a bunch of shock tubes for the absence and the present of bunch block

Initiation reliabilities of a bunch of shock tubes by a detonator obtained experimentally were analyzed according to the thickness of bunch block bodies. As shown in Figure 5, for initiating a bunch of shock tubes with 50 lines and in the present of bunch block the whole shock tubes were initiated for 1.0 mm~2.0 mm of thickness. For 0.5 mm of the thickness were initiated 98% of a bunch of shock tubes.

For a bunch-series coupling mode, blast wave and explosive product expanded respectively in lateral face and end of detonator charge affect shock tubes. In the initial stage after explosion of a detonator the bunch block body limits the propagation of blast wave and expanding of explosive product in the lateral direction and increase in the direction of inlet of a bunch of shock tubes. The blast wave affected a bunch of shock tubes nearby bunch block body is increased duo to the reflection of blast wave at the inner surface of bunch block body. Thus, estimate that bunch block bodies will increase the blast wave affected shock tubes.

### 3.3. The standoff distance within connector block

Experimentally obtained initiation effects of a bunch of shock tubes were compared according to the standoff distance between a detonator and the inlet of a bunch of shock tubes within bunch block. Initiation reliabilities according to thickness for 10mm of standoff distance is as shown in Figure 6. For initiating a bunch of shock tubes with 50 lines the whole shock tubes were initiated for the standoff distance of 20 mm and less. Experiments shows that the space position of a detonator affects the travel direction and the action intensity of blast wave and explosive production in standoff space. reliability



**Figure 6** Initiation reliabilities according to the standoff distance between a detonator and the inlet of a bunch of shock tubes within bunch block

## 4. Conclusion

This paper presents results of the experiments studies into the bunch-series coupling modes and structures of many shock tubes. The influences of coupling modes were investigated. Experiments show that the frontal bunch-series coupling mode has the most dominant initiation reliability than the lateral bunch-series coupling mode.

The influences of thickness of bunch blocks and the standoff distance between a detonator and inlet of a bunch of shock tubes to the initiation reliability were also investigated. Experiments show that thickness and the standoff distance for bunch blocks with the frontal coupling structure affect the initiation reliability of a bunch of shock tubes by the changing the magnitude of blast load due to a detonator on the shock tubes.

*The key contributions of this work are as follows*

- In comparison with lateral bunch-series coupling mode, new frontal bunch-series coupling mode has much higher initiation reliability, which is a great potential bunch block with high initiation reliability.
- The thicker and the smaller standoff distance, the more the initiation reliability were increased.
- For bunch blocks manufactured by injection molding with polyethylene and 1.0 mm~2.0 mm thickness of bodies and the standoff distance of 10 mm and less bunches of 50 shock tubes were initiated at 100 percent.

Finally, the results can be employed for design of bunch blocks for the simultaneously bunch-series initiating a large number of shock tubes.

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## Compliance with ethical standards

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### *Disclosure of conflict of interest*

The authors declare that there is no conflict of interest regarding the publication of this paper. No potential conflict of interest was reported by the authors.

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## References

- [1] KC Sek, C Raymond, TR John. Blast initiation device. United States Patent US 6,513,437. 2003 February 4.
- [2] LC Yang, FH Do. Key parameters for controlling of function reliability in “none1 tube” explosive transfer system. 35th AIAA/ASME/SAE/ASEE Joint Propulsion Conference and Exhibit. American Institute of Aeronautics and Astronautics. 1999:1-17.
- [3] G Hegde, A Pathak, G Jagadeesh, C Oommen. Spectroscopic studies of micro-explosions. In: Hannemann K, Seiler F, eds. Shock Waves. Berlin, Heidelberg: Springer; 2007.p. 377-82.
- [4] C Oommen, GNB Jagadeesh. Studies on micro explosive driven blast wave propagation in confined domains using NONEL tubes. Shock Waves, 2009; 2: 1515-20.
- [5] IO Samuelraj, G Jagadeesh, K Kontis. Micro-blast waves using detonation transmission tubing. Shock Waves, 2013; 23: 307-16.
- [6] SH Hu. Experimental study on detonation propagating performance of nonel detonating tube and Its detonator. Wu Han, China: Wuhun University of Technology press; 2013.
- [7] X Li, J Yang, B Yan, X Zheng. Reliability calculation of large-scale complex initiation network. IOP Conf. Ser.: Earth Environmental Science. 2018;113(012002).
- [8] SK Chan. Connector block configured to induce a bend in shock tubes retained therein. Canadian Patent Application, CA2,357,082 A1. 2003 March 7.
- [9] P John, PO' Brien. Detonator junction for blasting networks. United States Patent Application Publication, US 0,055,494 A1. 2004 April 25.
- [10] Y Xu, XH Gu, HC Zhang, XS Li. Connector block of initiation system with lock function. China Patent, CN 100,561,109C. 2009, November 18