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Reliability Calculation of Large-scale Detonation Network Based on Fault Tree Analysis

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Reliability Calculation of Large-scale Detonation Network Based on Fault Tree Analysis

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Abstract. The reliability of the string of detonation network is calculated by using the fault tree analysis. The definition of large-scale detonation network reliability is that the secondary detonator nodes outside the hole are all detonated. The fault tree of the nonel tube Bind-bind-series initiation network is drawn, and the calculation equations are deduced.

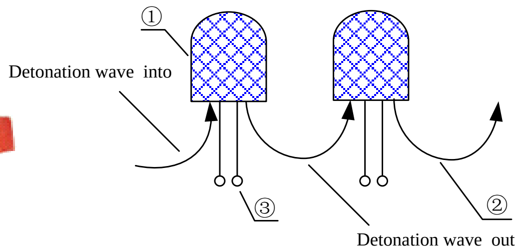
1. Introduction

Blasting engineering is usually divided into open blasting, underground blasting, underwater blasting, demolition blasting and special blasting. Among these blasting types, the most complicated blasting network is large-scale demolition blasting. The reliability calculation of large-scale demolition blasting network is more complicated than that of other types of detonation networks.

Large-scale electric initiation network is used in demolition blasting long time ago. The resistance of every electric detonator and the whole network can be measured with ohmmeter. So, it can ensure the reliability of the network. However, the network is vulnerable to external stray current, static electricity, lightning and other effects, there is the risk of early explosion, accordingly it can not be used in the thunderstorms and the existence of electrical interference within the dangerous range(1); Secondly, the number of primary electric detonator is limited, which can not meet the requirements of the current large-scale demolition blasting. Therefore, it is seldom used in large-scale demolition blasting(2,3); The non-electric blasting network is not affected by external electricity. Its detonating capacity is not limited by the number of detonators, and it can realize multi-stage and micro-detonation according to the design requirements. Therefore, the non-electric detonation network or electrical detonation non-electric detonation hybrid network are widely used in the large-scale building demolition project. However, there is no practical instrument detection method in non-electric detonation network, the phenomenon of rejection occurred in the process of application. It is very important to select the detonable network with high reliability to minimize the rejection rate and to reduce or avoid detonation failure (4).

2. Definition of blasting components and network reliability

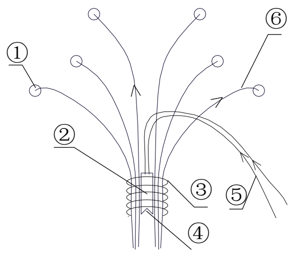
Initiation network is mainly composed of primer, detonators, connectors and Nonel tubes which connect all the components. Bind-bind-serial initiation network is shown in Figure 1. Reliability data of network components is listed in Table 1. Reliability data of network components is listed in Table 1.



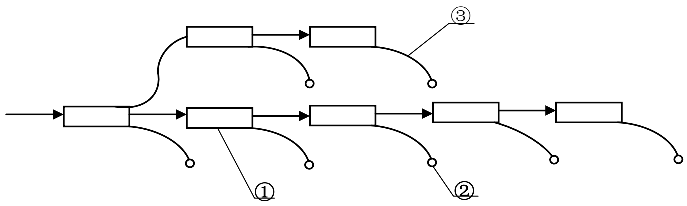
①Plastic four-path connector ②Nonel tube
③Nonel detonator in blast hole

Figure 1. Plastic reflective four-path connector Figure 2. Binding detonator-nonel tube node

At present, only the reliability of the node formed by the detonator and the detonator can be found, but the reliability of the node formed by the electric detonator and the detonator is not credible. The principle of the two nodes is similar, so the reliability of the two nodes is assumed to be equal. The detonator-detonator cluster node is shown in Figure 2.



①blast hole ②detonator
③adhesive tape ④Detonator cavity
⑤electric detonator wire (Nonel tube) ⑥Nonel tube



①Nonel detonator of explosion propagation outside blast hole
②Nonel detonator in blast hole ③Nonel tube

Figure 3. Binding detonator-nonel tube node Figure 4. Definition of reliability of blasting network

Table1. Reliability of components of initiating device

component used in blasting	Reliability (%)	mark	onfidence Level	Data source
Reflective four -way connector	0.9843	r_0	0.95	[6]
electric detonator	0.9975	r_e	0.95	[6],BenGangNanfen Opencast Mine
Nonel detonator	0.9612	r_N	0.95	[5],Fushun Coal Research Institute and Mining Bureau No. 11

This method is the reliability of the blasting network. Although some characteristics of the network are described from different angles, it is unreasonable to use it as a measure of network reliability. If the "minimum value" is used to describe the reliability of the blasting network, the detonator initiation probability in all holes in the network shown in Figure 3 is equal, which is the lowest of all detonators. With the increase of the number of three-stage series electric detonator nodes outside the hole, the detonator initiation probability in the hole will remain unchanged, and the reliability of the system will not change. But in fact, the more detonators are, the larger the system is and the more complex the system is. The lower the reliability is, the less reliable it is to describe the large-scale detonation network.

In this paper, the detonation network is defined as the secondary detonation of the secondary detonator. The node detonation refers to the composition of the node of the two burst detonators detonated at least one detonation here. With the detonation of all these nodes , even if the first level of detonator detonation exists a small amount, it will not affect the demolition blasting effect generally(21). If a hole outside the secondary bundle cluster detonator non-explosive detonator, there will be about 20 holes blasting, may affect the demolition blasting effect. Therefore, it is reasonable to define the two detonation networks as the detonation of all secondary detonating cluster detonator detonators.

3. Introduction of detonation network with bale bundles.

First, the detonators produced by each hole in the blasting site were assembled into bundles in groups of not more than 20, and then two detonators were bundled with plastic tape in reverse. When bundled, 2 detonators are taken as the center; Once again, the detonators produced by detonators are assembled into bundles with no more than 20 detonators, and then the two detonators are bound in reverse direction, and the two detonators are taken as the center when bundled. The last two detonators are connected in parallel and then connected in series with other parallel electric detonators. The electric detonators are ignited by electric detonators, which form a hybrid detonator initiation network as shown in Figure 3. In Figure 4, l ≤ 20, m ≤ 10, n is determined by the primer's initiation capacity and network resistance, and should be selected by consulting the initiator instruction.

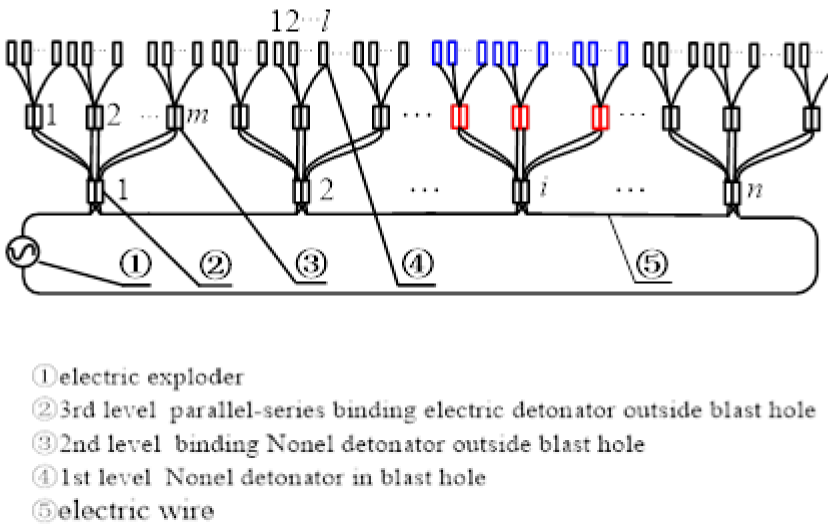


Figure 5. Introduced of detonation network with bundles.

4. Calculation of the detonation network reliability of bind-bind-series initiation network

Currently there are three major demolition blasting detonation network(22), namely nonel tube Bind-bind-serial detonation network, Detonating tube bundles double - cross - mixed initiation network and non-electrical network of pure four-way connection. This paper mainly analyzes the reliability of nonel tube Bind-bind-serial detonating network.

If a hole outside the secondary bundle cluster fuse detonator detonator node is to detonate, that is, at least one of the node's two detonators detonated. The node connected to the three-stage and series electric detonator node must be detonated, and the cluster of electric detonators - non-detonating pipe joints must be reliable. The fault tree is shown in Figure 4 is drawn(15,23,28).

$$\begin{aligned} S &= \overline{T} \\ &= B_1 \cdots B_i \cdots B_n \\ &= (A_{11}+A_{12})C_1[(B_{111}+B_{112})\cdots(B_{1m1}+B_{1m2})]\cdots(A_{i1}+A_{i2})C_i[(B_{i11}+B_{i12}) \\ &\quad \cdots(B_{ij1}+B_{ij2})\cdots(B_{im1}+B_{im2})]\cdots(A_{n1}+A_{n2})C_n[(B_{n11}+B_{n12})\cdots(B_{nm1}+B_{nm2})] \end{aligned} \tag{1}$$

The network initiation reliability P (S) can be expressed

$$\begin{aligned} P(S) &= 1-P(T) = [1-(1-r_e)^2]^n \left\{[1-(1-r_N)^2]^m r_n\right\}^n \\ &= \left\{r_n[1-(1-r_e)^2][1-(1-r_N)^2]^m\right\}^n \end{aligned} \tag{2}$$

(Where S-blasting network is reliable; T-blasting network failure)

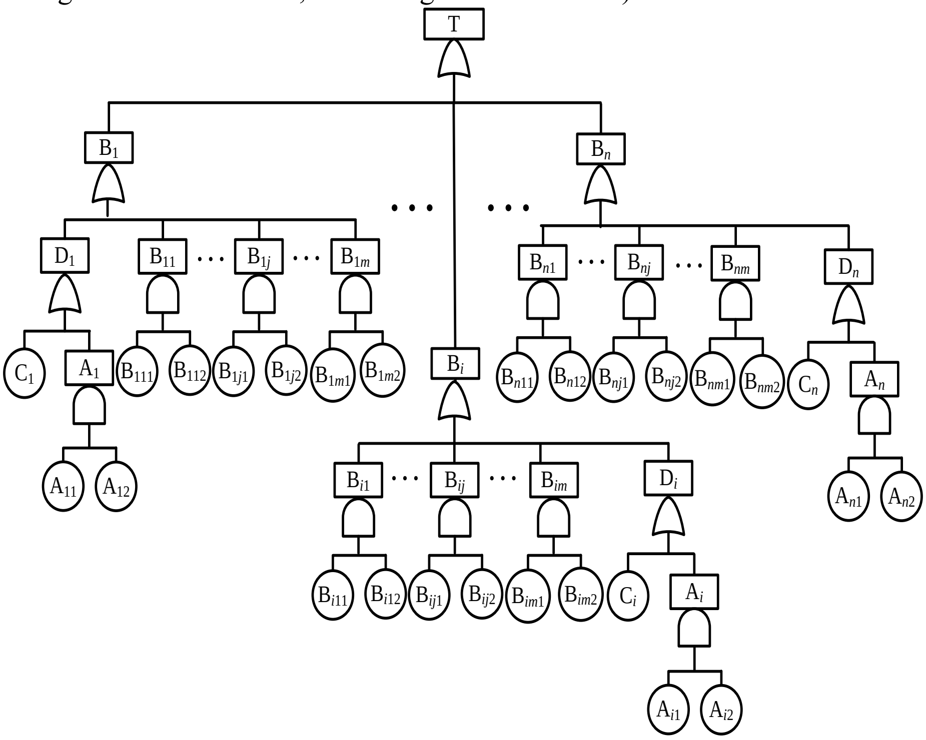
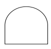
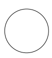


Figure 6. Fault tree of detonation network with bundles and bundles

Table 2. Notations of the fault tree

	Description Symbol: Text describing the logical result of the gate event
	OR Gate: Output events occurs if any one of the input events occur
	AND Gate: Output events occurs if all of the input events occur
	Basic event

A_i-the first i three holes outside the three-tier electric detonator failure at the same time; i=1,2,…,n; A_{i1},A_{i2}-respectively, for the first i-hole outside the three-tier electric detonator node in the first detonator failure and the second detonator failure, i=1,2,…,n; B_i-at least one of the m secondary detonator nodes connected to the ith outer electric detonator is not detonated, i=1,2,…,n; B_{ij} - the first i-hole outside the three-tier electric detonator connected j-th secondary detonator node is not detonated,， i=1,2,…, n, j=1,2,m; B_{ij1}， B_{ij2}- not with the first i-hole electric detonator connected to the j-level secondary detonator node of the first detonator failure and the second detonator failure, i=1,2,…,n , j=1,2,…,m; C_i- the i-th hole outside the three-tier electric detonator and the explosion-proof tube bundles consisting of nodes to send explosion failure, i=1,2,…,n； D_i-The first i hole outside the three-level electric detonator node does not output detonation wave, i=1,2,…,n.）

By the formula above, we can calculate the number of detonators and the network reliability in Table 3. Suppose L equals 20, m equals 10 respectively.

Table 3. The relationship between the number of detonators and network reliability P (S)

The number of detonators in blast holes	200	600	1000	1600	2000	3000	6000	10000
Bundle in series P(S)	0.9881	0.9647	0.9419	0.9086	0.8871	0.8356	0.6982	0.5495

5. Conclusion.

With the increase of the number of blast holes, the reliability of the networks becomes higher. Of course, with the non-detonating tube length increases, its reliability will certainly became lower. The use of the length of the latter tube is determined according to the scene, it is difficult to measure, the length of the two networks is difficult to compare the use of nonel tube.

This paper only compares the detonation reliability of the networks. In fact, the selection of the network must also consider other factors such as construction efficiency, safety and economy.

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