Capsule Explosion Shock Wave Structure Under the Action of Transient Response Analysis

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Abstract

According to the data analysis of the serious shortage to the production of mine rescue capsule, the transient response analysis of structures of mine rescue capsule. Analysis of the cabin window of different pressure and time under the condition of stress, strain, deformation and rebound situation. The calculation results show that the peak of 0.6 MPa, 1.2 MPa: two load, the maximum displacement observation window appears in the observation window lower position, respectively in 350 ms, 390 ms, 3.453 mm, 6.807 mm, reach. Check according to displacement nephogram, observation window parts in the shock wave; keep the overall coordination of deformation, the seal is still intact, relative displacement is approximately zero. Crest 0.6 MPa loading, observation window deformation value in the range of 0~3.453 mm, less than 10 mm, no local brittle fracture and crack. Crest 1.2 MPa loading, observation window deformation value in the range of 0~6.807 mm, less than 10 mm, no local brittle fracture and crack. Observation window meet the stiffness requirements.

Keywords: MINE RESCUE CAPSULE GAS EXPLOSION, SHOCK, TRANSIENT RESPONSE ANALYSIS, OBSERVATION WINDOW

1. Introduction

A large number of mining accidents caused casualties in the process of coal production has been plagued in recent years coal industry issues[1-2]. Therefore the main coal producing countries in the world have been devoted to the integration of mechanical design, ventilation equipment, electrical control, dust control to make mine rescue capsule, lifesaving cabin to safety, power supply, living security system with perfect. Therefore, to ensure that the system can normally run in shock, the shock resistance performance of cabin requirements; on the other hand, the lack of relevant design and practical experience. In order to improve the reliability, module structure design to reduce design time. To satisfy the high security requirements of blasting experiment, the analysis theory was used to simulate the impact resistance performance of the designed capsule in gas explosion in the process of the transient response for capsule and provide it theoretical basis [3-4].

2. The Transient Response Analysis theory

Transient response analysis is used to the dynamic calculation of time-varying incentive structure and the system response under the dynamic load. The direct method of transient response analysis of all the system coupling motion differential equation of the direct numerical integration to solve, this paper simulated the cabin head front and side, increases in the peak stress, deformation observation of lifesaving cabin. What the direct method of transient response analysis of coupled differential equations of motion of the system is that[5-10].

$$M\ddot{u}(t)+B\dot{u}(t)+Ku(t)=p(t) \tag{1}$$

Where M , B , and K are the mass matrix, damping matrix, stiffness matrix, respectively; and $u(t)$ and $p(t)$ are the displacement vector, forcing function vector. The equation of the motion, discrete time points at a fixed time interval, the integral solution of system response. In each of the discrete point in time, by the central finite difference method $\dot{u}(t)$ and $\ddot{u}(t)$, namely

$$\{\dot{u}_n\} = \frac{1}{2\Delta t}\{u_{n+1} - u_{n-1}\} \qquad (2)$$

$$\{\ddot{u}_n\} = \frac{1}{\Delta t^2}\{u_{n+1} - 2u_n - u_{n-1}\} \qquad (3)$$

The coupled differential equations of motion are solved by numerical integration method.

3. Transient Response Finite Element Analysis

3.1. The calculation software

Calculation under shock wave loading KJYF-96/8 mine mobile hardware lifesaving cabin stress and plastic deformation, large displacement problem is non-linear, time-varying shock wave loading. The explicit nonlinear dynamic analysis program ANSYS/LS-DYNA for numerical simulation, mechanical model of cabin under shock wave response.

3.2. Calculation model

3.2.1. The choice of unit type

The KJYF-96/8 mine mobile hardware capsule simulation antiknock performance numerical modeling on the basis of the actual need, the size, modeling preserved during the main structure characteristics, reasonable simplification for small parts. Reasonable selection of unit types, to shorten the time for solving the model for improving the precision of simulation, the effective rescue capsule plays an important role in the shift of shock wave. ANSYS/LS-DYNA in the application display may use in the dynamic analysis of unit: bar element, beam element BEAM161, LINK160 surface unit PLANE162, SHELL163 thin shell element, solid element SOLID164, spring damper element COMBI165, MASS166 and other quality unit.

Simulation by finite element under impact load values of the rescue capsule, the selecting unit, to consider the need to model the actual size and calculation, the lifesaving cabin basic cabin skin thickness relative to the rescue capsule size thickness is very thin, so the basic hull skin plate shell element SHELL163 mesh is reasonable. Need to door key processing, according to the size, determine the entity unit SOLID164 divided the main doors and doors mesh is more reasonable. The solid elements SOLID164 flange structure grid division. Bolt connection, using spring damper element COMBI165 mesh.

3.2.2. The mesh

The structural characteristics of cabin model, the shape is irregular, the different combinations of parameters after many experiments, a general parameters and the mesh parameter: ratio coefficient is the default value of 1, set the maximum cell size of 50 mm shell element, solid element maximum element size is 25 mm, the details at the maximum unit size is 10~15 mm, is divided into thin shell element, solid element, rigid unit 429545, the final model selected grid more appropriate parameters. KJYF-96/8 mine mobile hardware lifesaving cabin model grid, see Figure 1. The finite element model of node and element number is moderate, the lifesaving cabin loading explosive shock wave calculation accuracy. The grid quality check, cell size is uniform, meet the engineering requirements.

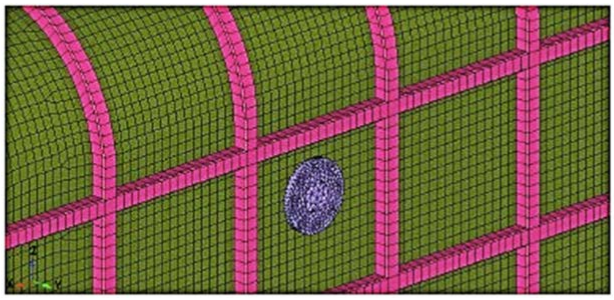


Figure 1. KJYF - 96/8 mine mobile hardware capsule mesh model

3.3. Material model

Nonlinear material constitutive relation are elastoplastic finite element method, the rigid plastic finite element method, elastic visco plastic finite element method, the rigid viscoplastic finite element method four types, as shown in Figure 2. Metal material constitutive relationship can reflect the accuracy of material properties of metal with finite element simulation. The capsule will produce plastic deformation under shock wave, the main concern of plastic deformation, therefore, lifesaving cabin in the wave finite element analysis using LS-DYNA Johnson-Cook in shock when the strain rate effect and the effect of temperature on the elastic-plastic constitutive model considering.

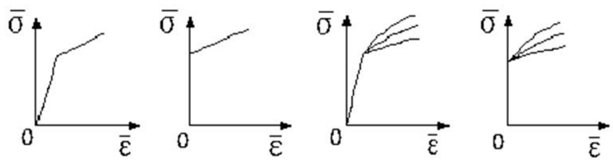


Figure 2. Metal material nonlinear constitutive curves

3.4. The initial conditions and boundary conditions

Because the KJYF-96/8 coal mine mobile hardware lifesaving cabin structure mainly by welding and bolt connecting part, not the relative movement of the parts, so the hypothesis: welding structure is completely reliable, structural parts have penetration, there is no welding stress, welding leg length of structure has no effect; the capsule structure does not exist any the manufacture or installation deformation; bolt connection is reliable, it has no effect on the structure of prestressed.

4. The Calculation Results and Analysis

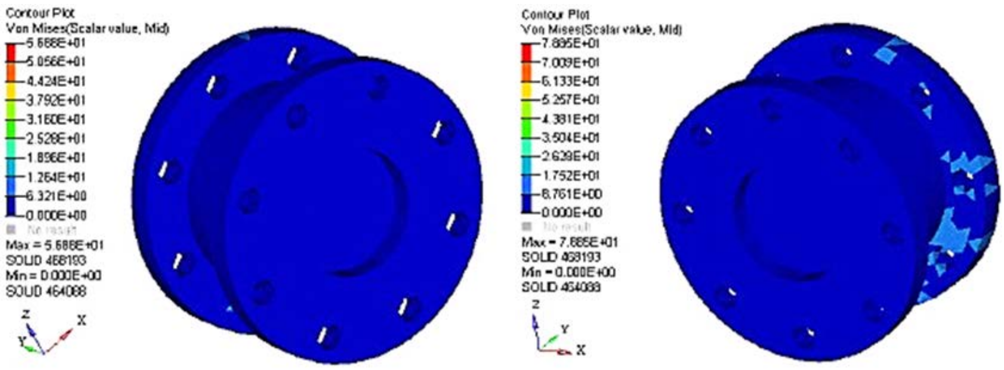
4.1. The stress, strain and displacement nephogram observation window

Extraction of two kinds of loads, the observation window stress, plastic strain and displacement results.

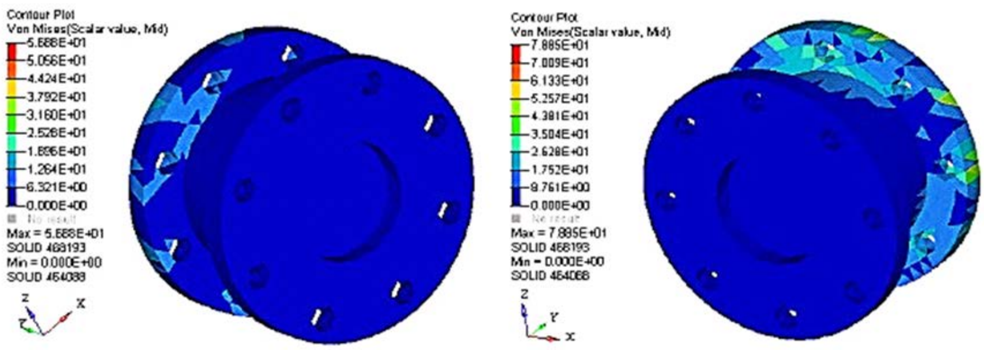
(1) Capsule window stress results

Extraction of the stress results, see Figures 3 (a) ~ (d), drawing stress units are MPa. Observation window stress reached the maximum at the unit for 468193 rd units, extraction of σ -t curve of the unit (stress time curve), see figure 4.

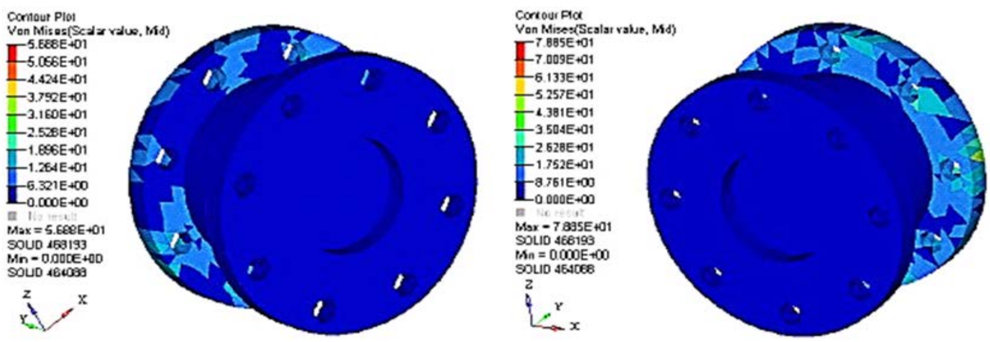
The crest is 0.6 MPa, 1.2 MPa two kinds of loads, the observation window maximum values appeared near the window internal connection, respectively in 350 ms, 390 ms, 56.88 MPa, 78.85 MPa, reach. Visibly, KJYF-96/8 mine mobile hardware lifesaving cabin window under the wave crest is 0.6 MPa, 1.2 MPa two kinds of load, can meet the strength requirements.



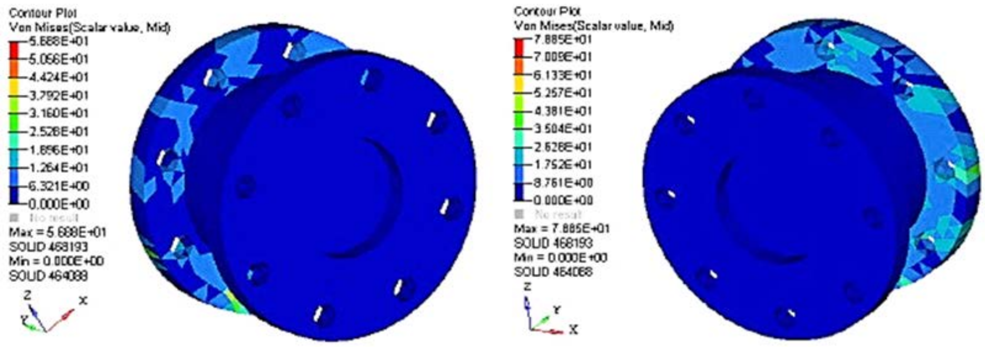
(a) 0.07 s



(b) 0.21 s

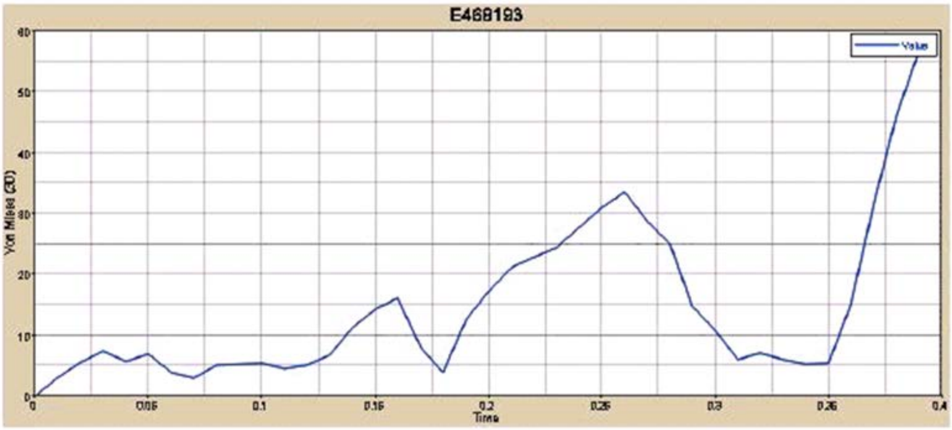


(c) 0.35 s

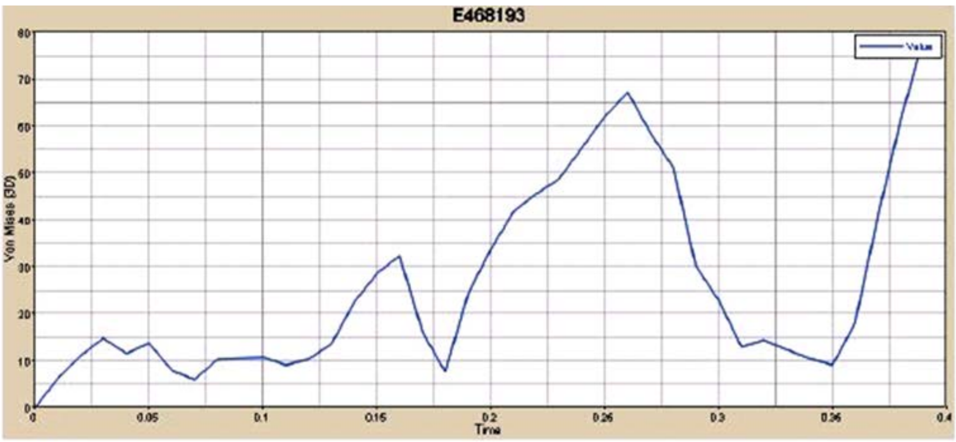


(d) 0.39 s

Figure 3. Capsule stress field observation window (Illustration: lift is capsule observation window stress field at 0.6 MPa; right is capsule observation window stress field at 1.2 MPa)



(a) Peaks at 0.6 MPa, the capsule observation window stress reaches a maximum unit position of σ-t curve

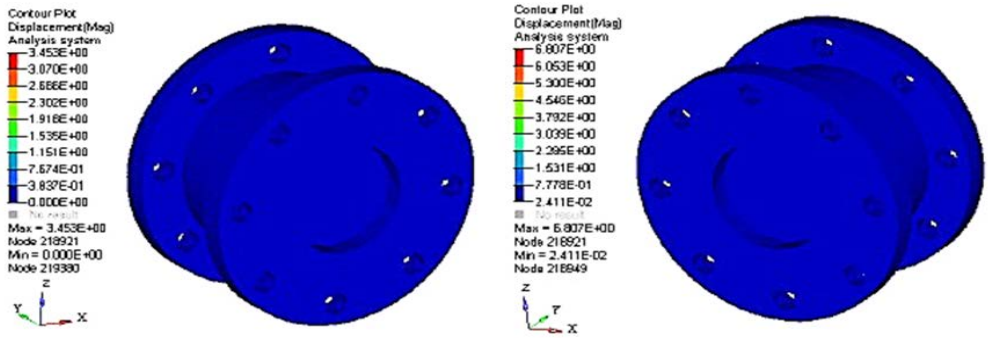


(b) Peaks at 1.2 MPa, the capsule observation window stress reaches a maximum unit position of σ-t curve

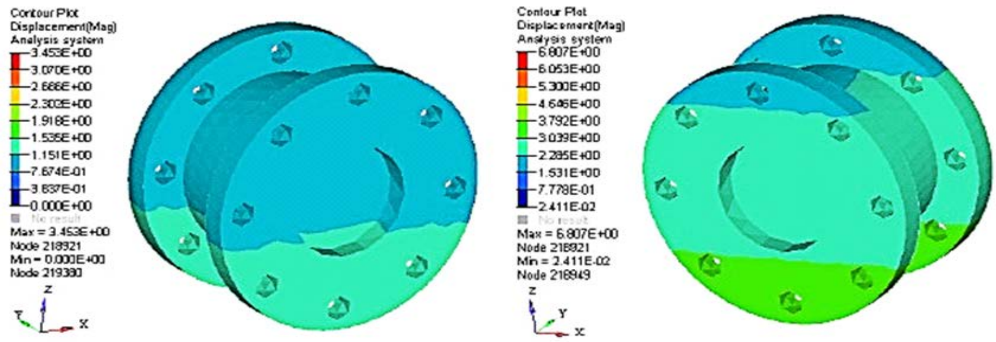
Figure 4. Capsule observation window stress reaches a maximum unit position of σ-t curve

(2) Capsule window displacement results, see Figures 5 (a) ~ (d), unit of displacement diagram for mm. Observation window displacement reaches the maximum value at the node into 218921st nodes, extraction of δ -t curve of the node (displacement time curve), see figure 6.

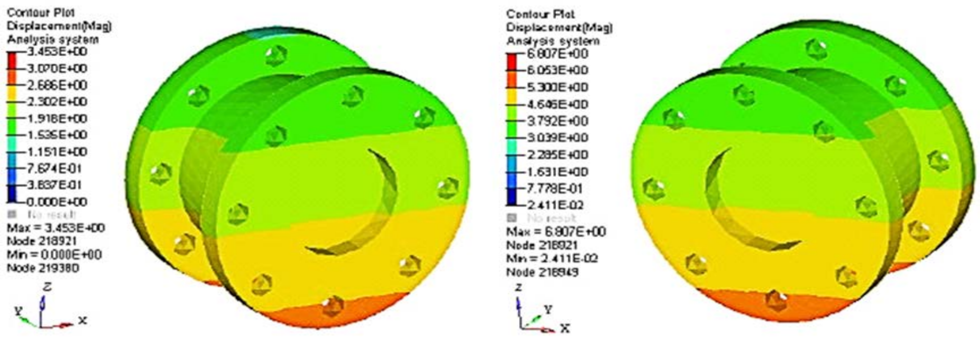
The crest is 0.6 MPa, 1.2MPa two kinds of loads, the maximum displacement observation window appears in the observation window lower position, respectively in 350 ms, 390 ms, 3.453 mm, 6.807 mm, reach. Check according to displacement nephogram, observation window parts in the shock wave; keep the overall coordination of deformation, the seal is still intact, relative displacement is approximately zero. Crest 0.6 MPa loading, observation window deformation value in the range of 0~3.453 mm, less than 10 mm, no local brittle fracture and crack. Crest 1.2 MPa loading, observation window deformation value in the range of 0~6.807 mm, less than 10mm, no local brittle fracture and crack. Observation window is meeting to the stiffness requirements.



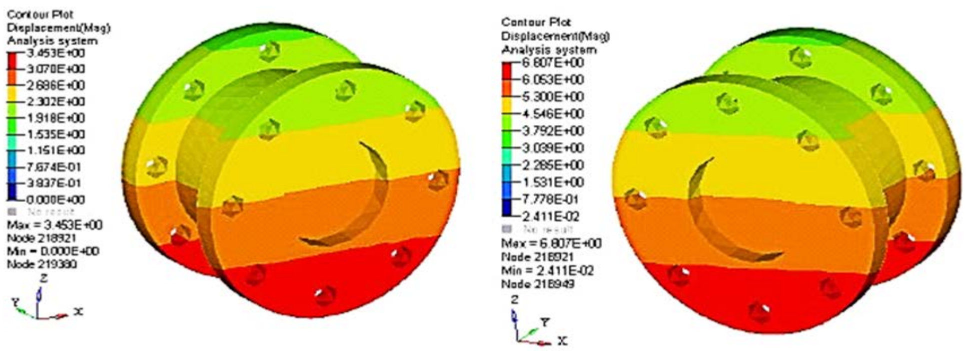
(a) 0.07 s



(b) 0.21 s

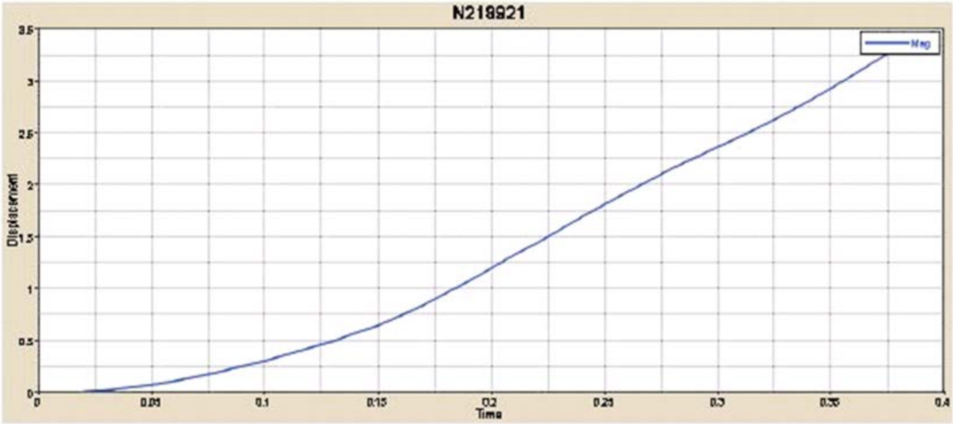


(c) 0.35 s

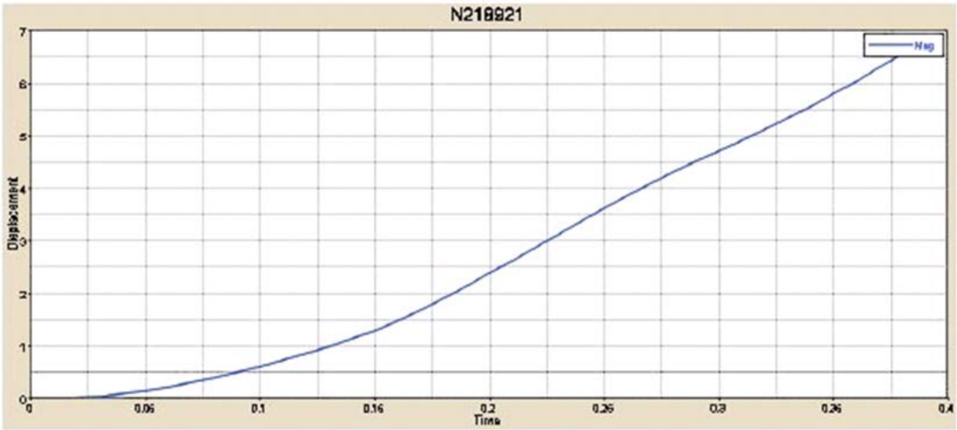


(d) 0.39 s

Figure 5. Capsule observation window displacement field (Illustration: lift is capsule observation window stress field at 0.6 MPa; right is capsule observation window stress field at 1.2 MPa)



(a) Peaks at 0.6 MPa, the capsule observation window stress reaches a maximum unit position of σ-t curve



(b) Peaks at 1.2MPa, the capsule observation window stress reaches a maximum unit position of σ-t curve

Figure 6. Capsule observation window maximum displacement node position and the δ-t curve

5. Conclusions

For transient response analysis of structures of the mine rescue capsule observation window of different pressure and time under the condition of stress, strain, deformation and rebound situation, draws the following conclusion:

(1) With the increase of peak pressure, the decay time will increase, the mine lifesaving cabin window damage increased, pressure impact value is nonlinear.

(2) In the cabin body impact, because of the relative homogeneity of structure deformation, the springback increases, but the overall deformation is sharply increasing trend.

(3) For 0.6 MPa, 1.2 MPa peaks under two loads, the maximum displacement observation window appears in the observation window lower position, respectively in 350 ms, 390 ms, 3.453 mm, 6.807 mm, reach. Check according to displacement nephogram, observation window parts in the shock wave, keep the overall coordination of deformation, the seal is still intact, relative displacement is approximately zero. Crest 0.6MPa loading, observation window deformation value in the range of 0~3.453 mm, less than 10mm, no local brittle fracture and crack. Crest 1.2 MPa loading, observation window deformation value in the range of 0~6.807 mm, less than 10mm, no local brittle fracture and crack. Observation window is meeting to the stiffness requirements.

Conflict of interest

The author confirms that this article content has no conflict of interest.

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Improving the technology parameters of drivage workings by the high – performance equipment considering geomechanical and organizational factors

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