Numerical simulation for mine rescue capsule gas explosion dynamic response

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Abstract

In order to ensure the research and development production of coal mine "KJYF - 96/8 portable hardware capsule" in the coal mine use can effectively resist gas explosion shock pressure, structural strength meet the safety requirements. The finite element model is set up, to take specific gas coal dust explosion triangle under the action of shock waves, the stress, strain and displacement response. The results show that the peak of 0.6 MPa and 1.2 MPa, 300ms triangle shock wave, the capsule basic no plastic deformation, overall no failure parts, ships were able to be whole, the structure safety. Depending on the overall displacement nephogram view of displacement nephogram and components parts after shock wave action, maintain the overall coordination deformation, minimal relative displacement, sealing well.

Keywords: capsule, gas explosion, shock wave, dynamic response, numerical simulation

1 Sample description and explanation

1.1 THE CAPSULE GAS MAIN STRUCTURE, MATERIAL, SIZE

KJYF-96/8 mine mobile hardware lifesaving cabin assembled into a split. The body is divided into four parts from the structure: transition cabin, cabin escape pod, personnel, equipment cabin, transition cabin crew capsule 1.2 meters, 3.6 meters, 1 meter of escape pod, equipment cabin crew capsule 3.9 meters, are provided with personnel doors and maintenance hatch. The escape pod length is 1 meter, the escape pod unilateral with escape door, equipment cabin length is 3.9 meters, the size structure.

Intermediate basic cabin unit is whole steel structure, both ends are flange structure, the basic unit of the adjacent cabin flange connection structure. Capsule thickness is 12 mm basic cabin, cabin bolted flange thickness of 25 mm. The basic bodies through flange structure are connected by bolts. Both ends of the flange plate and the plate adopt welding connection. When assembling the internode with M16 bolts, internodes with seal. The front door plate is in thickness of 25 mm. The main doors hole size is 600 mm×1200 mm, 420 × 670 mm emergency escape door. Observation window for explosion-proof glass is 70 mm, materials for the FBZ-B-70-HX. Reinforcing rib is arranged outside the cabin, 5 channels, reinforced chassis is provided with 8 channels consisting of slipper, chassis is provided with 10 channels. The door is connected by a shaft seat and the end shaft. Lifesaving cabin chassis slipper and slide placed with [1-4].

1.2 THE CAPSULE GAS FIXED WITH THE GROUND

Chassis slipper of KJYF-96/8 coal mine mobile hardware capsule is provided with 10 steel compositions, capsule chassis slipper and slide placed with. It can be capsule and the tunnel bottom surface constraint simplification is determined according to the actual size, simply supported connection.

1.3 THE ANTIKNOCK STRESS ANALYSIS REQUIREMENTS

The peak of 0.6 MPa, for 300 ms gas and coal dust explosion triangle shock wave; limit peak triangular shock reaching overall structural damage, damage of the key parts of 1.2 MPa wave.

2 The numerical calculation

2.1 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.

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2.2 CALCULATION MODEL

2.2.1 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 [5-9].

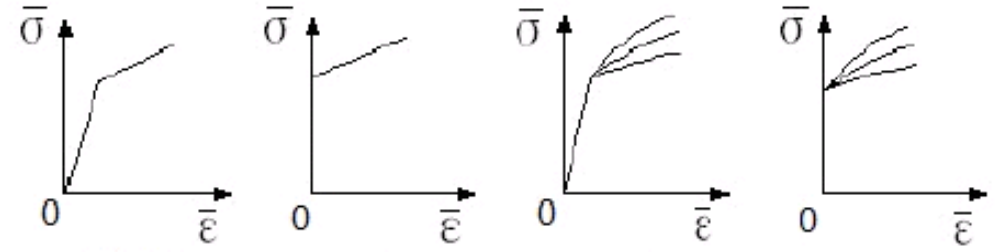
2.2.2 The mesh

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 Material model

Nonlinear material constitutive relation are elastoplastic finite element method, the rigid plastic finite element method, elastic viscoplastic 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.



elastic-plastic rigid plastic elastic viscoplastic rigid viscoplastic

FIGURE 2 Metal material nonlinear constitutive curves

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 pre-stressed.

4.1 BOUNDARY CONDITIONS

In the ANSYS implicit finite element analysis program, the contact interaction between moving objects, the

contact element to simulate, it makes the analysis process is extremely complex and very difficult to understand. In the ANSYS/LS-DYNA program, no contact element, as long as the definition may contact surface, the contact type and contact with some related parameters, the contact interface does not occur between the penetration guaranteed in the calculation process, and consider the effect of friction at the contact interface for relative motion. Contact types include single contact (Single Surface), the node to surface contact (Nodes to Surface) and surface to surface contact (Surface to Surface) several. The simulation of blast wave to the rescue capsule, directly to the lifesaving cabin pressure, there is no definition of contact problems.

Chassis slipper of KJYF-96/8 coal mine mobile hardware chassis is provided with 10 steel compositions, lifesaving cabin chassis slipper and slide placed with. It can be lifesaving cabin and the tunnel bottom surface constraint is modeled as a simply supported is determined according to the actual size of the connection.

4.2 THE INITIAL CONDITIONS

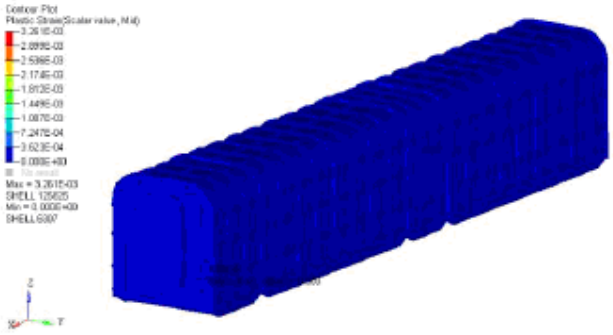
After a simple model analysis showed that, lifesaving cabin elastoplastic deformation under explosive blast wave, deformation mainly occurred in the capsule and blast shock wave contacts the outer boundary, the deformation amplitude relative to the rescue capsule size is very small, the reasonable mesh, mesh deformation is not too serious, in view of the Lagrange algorithm to deal with the free surface and material the interface intuitive and natural, and can track material boundary accurately and describe the material interface and other advantages, the Lagrange algorithm. The initial conditions of static, in addition to the capsule itself gravity, do not consider other load. Method there is usually several create shock wave pressure, one is to build a preset pressure time curve, and the other is the numerical simulation of explosive effect. Generated by explosive explosion pressure pulse in the air grid, will limit the pressure pulse amplitude, duration and other parameters. Considering the calculation procedure and the actual effect of explosion shock wave, calculated using the method of loading the pressure wave simulation of shock wave on the class action.

The lifesaving cabin under explosive blast wave may damage into consideration, take lifesaving cabin front, back end face is positive, according to the peak load; the rest of the surface according to half peak. Due to the presence of certain errors between the numerical simulation calculation and real situation, and it is necessary to consider the safety factor, the calculation of the shock wave overpressure is tentatively scheduled for 0.6 MPa, peak value and pressure of explosion shock wave 1.2 MPa calculations.

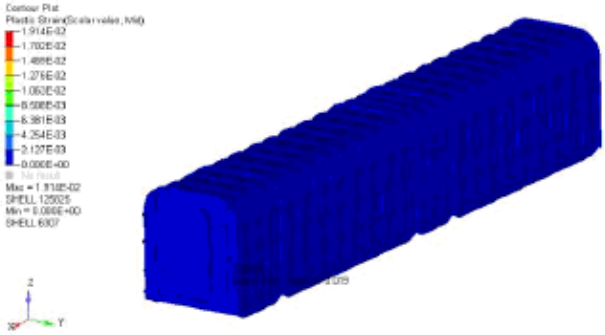
5 Hull structure response calculation results and analysis

At 0 ms, forward propagating shock wave reaches the capsule surface, the KJYF-96/8 mine mobile hardware lifesaving cabin applied peak for 0.6 MPa, 1.2 MPa for 300 ms, triangle shock wave pressure, the computation time is 400 ms. Read the waves on the lifesaving cabin effect of explosion, achieve the deformation results, nephogram rendering nodes or unit, the interception of the required information.

Two kinds of loads, lifesaving cabin structure stress and displacement nephogram because of the limited space omission but strain, shown in Figure 3.



a) Peaks at 0.6 MPa, the capsule overall plastic strain field



b) Peaks at 1.2 MPa, the capsule overall plastic strain field

FIGURE 3 Capsule overall plastic strain field

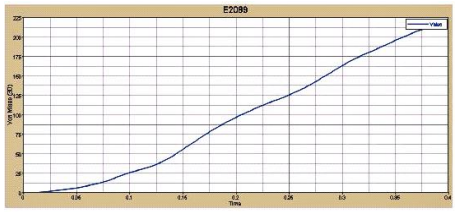
The lifesaving cabin overall typical nodes (unit) as an example, the KJYF-96/8 mine mobile hardware lifesaving cabin in the coal mine gas explosion under conditions of stress and displacement time history.

1) Capsule whole stress maximum unit stress time history results.

Two kinds of loads, the stress reaches the maximum value at the unit 125825th unit and 2089th unit, extraction of σ-t curve (stress time curve), shown in Figure 4.

Visible, the lifesaving cabin under the wave crest is 0.6 MPa and 1.2M Pa two kinds of load, stress values were 0~260.0 MPa, 0~363.5 MPa, lifesaving cabin to meet the strength requirements.

a) Peaks at 0.6 MPa, the capsule stress peak position unit σ-t curve



b) Peaks at 1.2 MPa, the capsule stress peak position unit σ-t curve

FIGURE 4 Capsule stress peak positions unit σ-t curve

2) The displacement peak 42307 nodes and 42308 nodes, extract the delta time curve δ-t (displacement time curve), curve, shown in Figure 5.

Therefore, two kinds of loads, lifesaving cabin overall displacement values are 0~7.941 mm, 0~15.82 mm. Capsule is meeting the stiffness requirements, and no failure.

a) Peaks at 0.6 MPa, the capsule reach maximum displacement of the nodes of the δ-t curve

b) Peaks at 1.2 MPa, the capsule reach maximum displacement of the nodes of the δ-t curve

FIGURE 5 Capsule stress peak positions unit δ-t curve

6 Conclusion

To ensure that the R & D and production of the "KJYF-96/8 mine mobile hardware capsule" can effectively resist the impact pressure of gas explosion in coal mine use, structure strength to meet the safety requirements, using explicit nonlinear dynamic analysis program, the finite element model is established, more comprehensively and objectively shows the gas explosion accident occurred, bear peak is 0.6 MPa 300 ms, 1.2 MPa, duration of gas and coal dust explosion triangle waves, KJYF-96/8 mine mobile hardware lifesaving cabin generated stress, plastic strain, displacement response.

Crest 0.6 MPa, persistent 300 ms triangular shock wave, lifesaving cabin no plastic deformation without failure, the whole parts, cabin remain intact, structural safety. According to the overall displacement nephogram and parts displacement nephogram view, parts in the shock wave, keep the overall coordination of deformation, displacement minimum, seal intact.

Crest 1.2 MPa, persistent 300 ms triangular shock wave, lifesaving cabin produces only approximate to the plastic deformation in the flange, zero rib frame, shell structure of the minimal unit, no overall failure components, cabin remain intact, structural safety. According to the overall displacement nephogram and parts displacement nephogram view, parts in the shock wave, keep the overall coordination of deformation, displacement minimum, seal intact.

By the analysis of visible, capsule displacement maximum value appeared in the middle position of the two side capsule shell, such as the need to further improve the lifesaving cabin anti impact capability, can strengthen the internal reinforcement structure and quantity of the structure was strengthened, increase its flexural rigidity. Capsule stress reached the maximum at the connection position of the capsule shell and the flange frame structure, can strengthen the material and structure of these structures by local, to become further strengthen the anti-shock strength of the rescue capsule.

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