Analysis of End Shape Structure of Mine Refuge Chamber based on Simulation

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Abstract

In order to use rescue capsules more effectively and reduce damages that due to explosion, cylindrical mining removable capsule is took as study object, performed numerical simulations on its ends which load mainly. Under the optimal arrangement,controlling the weight and wall thickness equally of three typical ends which are sphere, oval and bionic egg shell, parameters of these three end structures above are determined. End models are established respectively by Solidworks software, and then imported to Simulation,for simulation analysis and calculation of these three typical end structures. Finally distribution nephogram of three models' deformations and stress can be obtained and analyzed. The result indicates that bionic egg shell is the most stable shape of rescue capsule ends.

Keywords

Refuge Chamber, End Shape, Numerical Simulation, Comparative Analysis.

1. Introduction

With the continuous development of country's economy, more and more coal mine are in demand. While in the coal mine production process, the poor geological conduction of coal mine and more and more high gas mines, there are many accidents such as gas explosion, water gushing, fire and roof caving and the security situation is extremely grim. According to the accident investigation conducted by the countries all over the word, the mine works who are injured or dead instantly in the accidents only have a small percentage of the total casualties. Most mine workers are died of anaerobic poisoning or lack of food and water. Therefore, refuge chamber is the key of the risk avoidance system, which can escape from danger, so as to give mine workers a safe and airtight room after accidents. Consequently, the study and construction of the cabin strength, arrangement and fixed way, and contour structure of refuge chamber in safety system is the primary. In the paper, the main research of the cylindrical mining removable capsule is carried out in the tunnel. The load condition as Fig.1. The end shape of the shell is the main load bearing part. Therefore, the main research object is the design and optimization of the rescue capsule [1-3].

The end shape is the most important part of the rescue capsule, which must have the ability of resisting impact, compression and high temperature. In this paper, the working environment of the rescue capsule is analyzed firstly, and then the end model is simplified and the Solidworks Simulation finite element analysis software is used to analyze the static stress of the three kinds of end shape, so as to find the optimal end structure shape [4, 5].

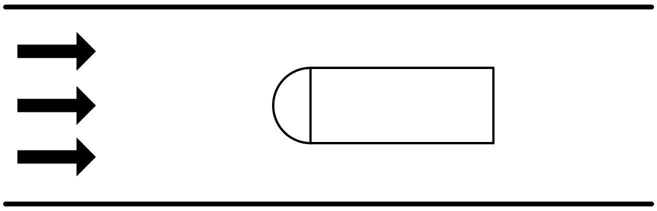


Fig.1 Stress of end shape

2. Finite element model

The end of this research structure model was set up in the same materials of alloy steel, the same weight and thickness. The study is based on the assumption that the stress load is uniformly distributed on the end of capsule in radial direction. Controlling the equal thickness of three typical ends which are sphere, oval and bionic egg shell, the radial impact load of three kinds of rescue capsule is analyzed by numerical simulation, and the static pressure transmission is simulated by Solidworks Simulation finite element analysis software, and the most stable structure is obtained. The finite element analysis procedure is shown in Fig.2.

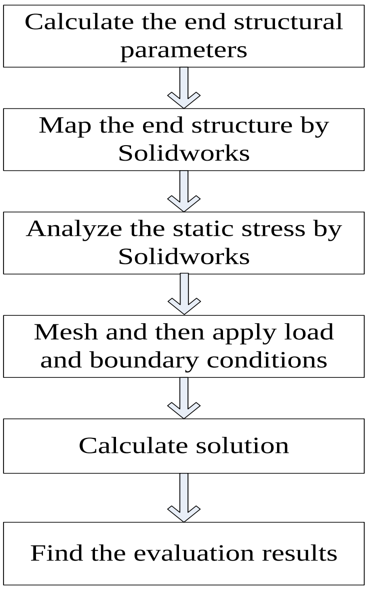


Fig.2 Static analysis step

In this study, solidworks is used to establish the model of sphere, oval and bionic egg shell. Because of the same material, the volumes of three end are in the same. Xyz cartesian space rectangular coordinate system is established.

Sphere equation:

$$x^2+y^2+z^2=r^2 \tag{1}$$

Hemisphere volume:

$$V=\int_0^r \pi\left(r^2-y^2\right)dy=\frac{2}{3}\pi r^3 \tag{2}$$

Oval equation:

$$\frac{y^2}{a^2}+\frac{x^2+z^2}{b^2}=1 \tag{3}$$

Semi oval volume:

$$V=\int_0^a \pi b^2\left(1-\frac{y^2}{a^2}\right)dy=\frac{2}{3}\pi ab^2 \tag{4}$$

Bionic egg equation:

$$\frac{y^2}{(ky+a)^2}+\frac{x^2+z^2}{b^2}=1,\left(|k|<1\right) \quad (5)$$

The tip of the bionic egg body volume:

$$V=\int_0^{\frac{a}{1-k}}\pi\left(b^2-\frac{y^2b^2}{(ky+a)^2}\right)dy=\frac{\pi b^2 a}{k^2}\left(\frac{2}{k}\ln\frac{1}{1-k}-k-2\right) \quad (6)$$

Set the size of the sphere capsule end to: inside radius r=2000mm, wall thickness δ=8mm. Hemisphere volume: $V_1=\frac{2}{3}\pi\left(1008^3-1000^3\right)=50668678mm^3$.

Set the size of the oval capsule end to: short half shaft b=900mm, wall thickness δ=8mm, Semi oval volume: $V_2=\frac{2}{3}\pi\times\left((a+8)\times(900+8)^2-a\times900^2\right)=V_1$ .By volume: $a=1217mm$.

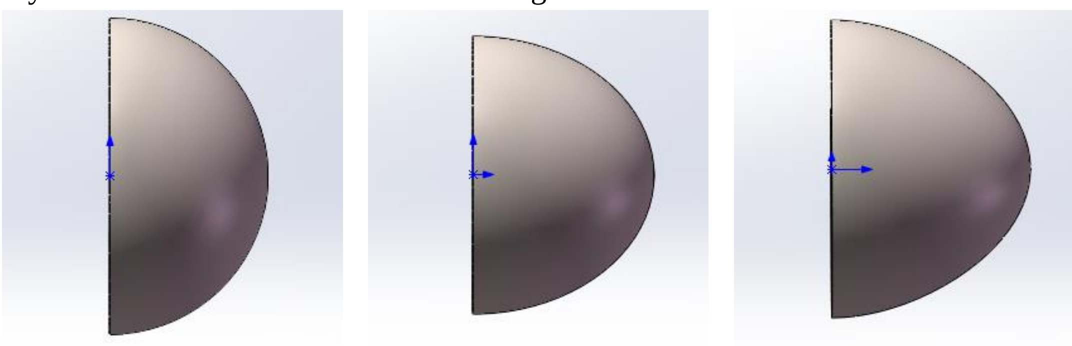
Set the size of the Bionic egg end to: short half shaft b=900mm, wall thickness δ=8mm, k=0.2, the tip of the bionic egg body volume: $V_3=\frac{\pi}{0.2^2}\left(\frac{2}{0.2}\ln\frac{1}{0.8}-2.2\right)\left[908^2\times(a+8)-900^2\times a\right]=V_1$. By volume : $a=963mm$.

In order to compare the impact resistance of the end structure, the parameters are set up as shown in Table 1.

Table 1. Parameters of end shapes

End structures	Sphere shell	Oval shell	Bionic egg shell
Wall thickness δ/mm	8	8	8
Long half shaft a/mm	1000	1217	963
Short half shaft b/mm	1000	900	900
Polar radius c/mm	1000	1217	963

According to the structure parameters of the Table 1, the model of the three kinds of end structure is modeled by Solidworks. The model is shown in Fig. 3.



(a) Sphere shell (b) Oval shell (c) Bionic egg shell

Fig.3 Three end models

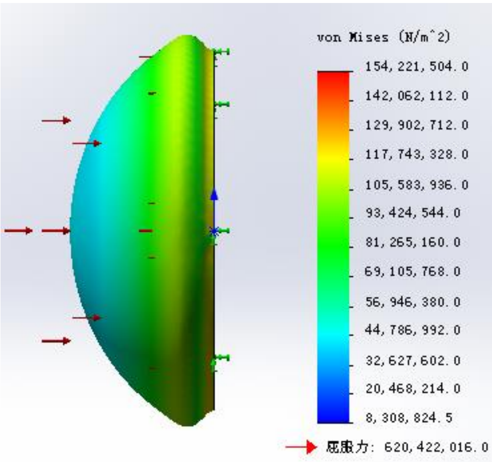
3. Finite element analysis

Simulation is used to do finite element analysis. In the method of the combination of the sweep and the free grid, the grid division of the end part of the rescue capsule is carried out. In this research, the fixed constraints are imposed on the sphere, oval and bionic egg end shell. According to the general technical condition of the movable type hardware of the portable hardware in the coal mine, the maximum peak overpressure of the flow field is not less than 2×0.3MPa (2 for safety factor).A numerical simulation analysis of the maximum positive impact force of the end part of the rescue capsule is carried out, The impact load is uniformly applied on the end, simulating the pressure transmission of the mine tunnel explosion. The load is set to 0.7MPa.

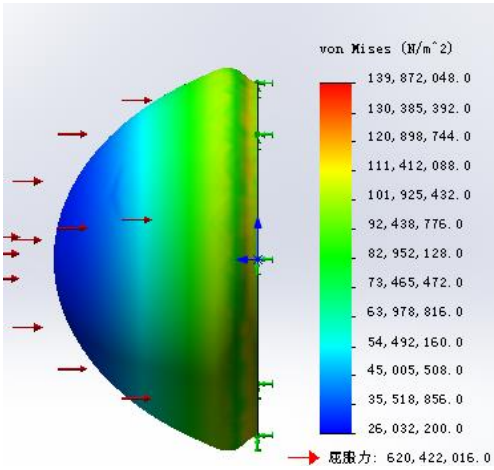
The numerical simulation and analysis of the finite element analysis method for the sphere, oval, and bionic egg shell are obtained. And then the stress distribution laws of these three end structures are obtained. Simulation results are compared with the simulation results of sphere, oval and bionic egg shell. The results are shown in Table 2.

As shown in Fig. 4, the maximum equivalent stress at the sphere end shell is at the two side of the end, about 118MPa. The maximum equivalent stress at the oval end shell is also at the two side, about 112MPa. The maximum equivalent stress at the bionic egg end shell is also at the two side, about 110MPa. According to the maximum stress comparison, combined with the distribution nephogram of three models' stress, it can be concluded that the maximum stress on the end of bionic egg shell is the least.

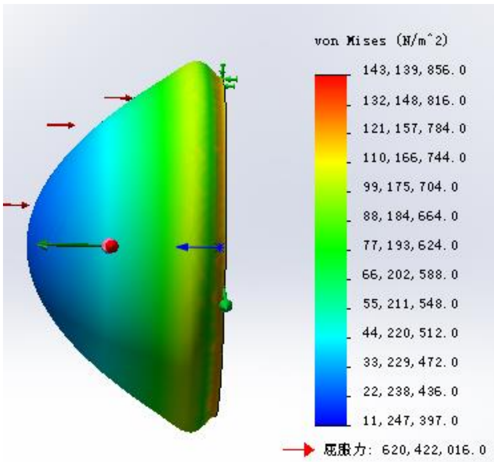
As shown in Fig. 5, the maximum deformation of the sphere end shell is at the center of the end, about 0.74mm. The maximum deformation of the oval end shell is also at the center of the end, about 0.58mm. The maximum deformation of the bionic egg end shell is also at the center of the end, about 0.52mm. According to the maximum deformation, combined with the distribution nephogram of three models' deformation, it can be concluded that the maximum deformation on the end of bionic egg shell is the least.



(a) Sphere shell

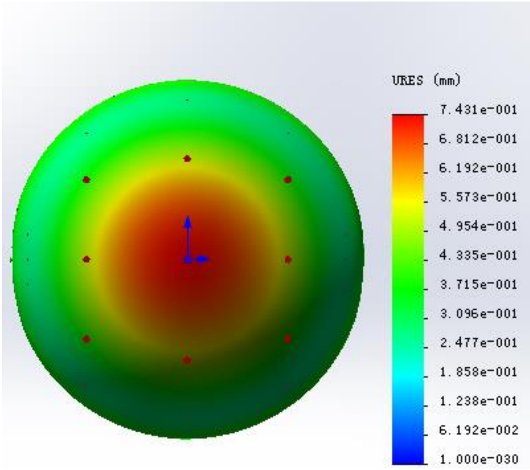


(b) Oval shell

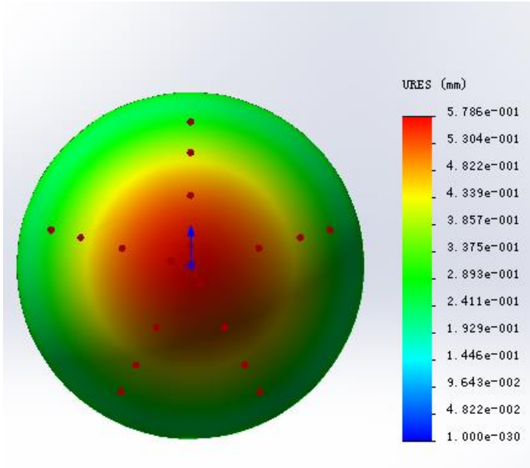


(c) Bionic egg shell

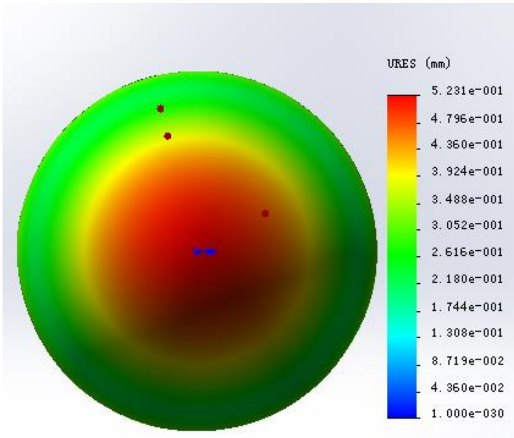
Fig.4 Distribution nephogram of three end models' stress



(a) Sphere shell



(b) Oval shell



(c) Bionic egg shell

Fig.5 Distribution nephogram of three end models' deformations

Table 2. Simulation data of three end shape

End structures	Sphere shell	Oval shell	Bionic egg shell
Maximum equivalent stress/Mpa	118	112	110
Maximum deformation/mm	0.74	0.58	0.52

Due to the fixed constraints at the bottom of the model, the actual engineering application may have some errors. But it can be concluded that the static load strength of the bionic egg shell is significantly larger than that of the sphere end shell and the oval end shell, with a good compression effect, and the end of the sphere end shell and the oval end shell cannot meet the basic requirements.

4. Conclusion

The end of the rescue capsule is the main carrier of the rescue capsule, having a great impact on the body strength. In the design of the cylindrical movable rescue capsule, the appropriate end structure should be adopted. In this study, the Solidworks finite element software Simulation is used to do the finite element numerical simulation analysis and calculation of the sphere, oval and bionic egg shell under the same static load. It can be concluded that bionic egg end shell has the best compression effect.

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