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The comparative experimental study of the porous materials suppressing the gas explosion

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Abstract

The paper studied the suppression performance and mechanism of the porous materials with our designed experimental system. The experimental results showed that the wire mesh and the foam ceramic materials have a certain capability of the fire retardant and the reduction pressure. The anti-blast damage performance of the wire mesh was good but the sintering resistance performance was bad. The anti-blast damage performance of the foam ceramic was bad but the sintering resistance performance was good. The absorbing sound ability of the foam ceramic was better than the wire mesh. The decay rate of the gas explosion maximum overpressure of the certain parameters wire mesh and foam ceramic for pipeline could reach 50%. The decay rate of the wire mesh for the maximum flame temperature could reach 60% and the fire retardant effect was better than the foam ceramic.

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Keywords: Gas explosion,ceramic foam,explosion isolating material;

1. Introduction

The gas explosion accidents are the primary disaster for the coal mines. With the increase of the mining depth and the productions, the gas pressure and the gas emission will also increase and at the same time the occurrence rate of the gas explosion accident increases dramatically, which severely restricts the safety production of the coal mines. However, the applied traditional explosion barrier facilities such as water shed and rock powder shed can not achieve the desired explosion barrier effects. The study of the effective barrier gas explosion materials and the explosion barrier device is imminent. It is important to

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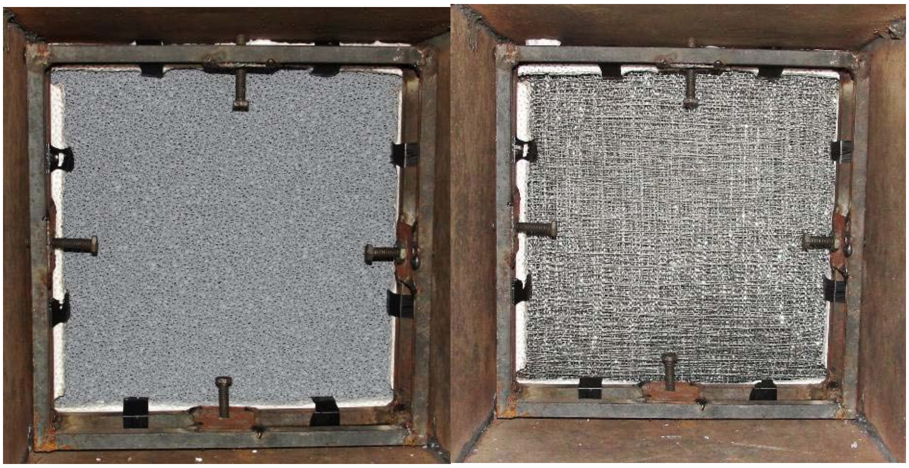
study the new gas explosion barrier device and the explosion suppression materials which adapt to the coal mines.

1.1. The materials selection

In recent years, we have paid close attention to the porous material because of its better suppression effects of the explosion flames and the pressure waves. And the porous material has been widely used in the field of the military and the civil engineering protection. Because of its toughness and the good quenching performance, the wire mesh has become a common material for the industrial pipe flame arrester. Based on the quenching effect of combustible gas explosion flame of the petroleum fire retardant device and the suppression effect of the pressure wave, Wu Zhengyan etc. [1] provides an new idea that the wire mesh and the corrugated-type structure are used to suppress the gas explosion propagation of the coal mines. The foam ceramic is a new type material developed in the 1970s which has the feature of the high through-hole rate, the sintering resistance and the good seismic performance and the foam ceramic is mainly used in the field of the molten metal filtration, military protection, fire equipment, vehicle exhaust purification and acoustic noise reduction. The heat resistance performance and the seismic performance of the wire mesh and the foam ceramic are good and they are suitable to be used in the environment of the temperature and pressure variation range. The wire mesh belongs to the metal materials and the foam ceramic belongs to the non-metallic materials which have the representative significance.



(a) (b)

Fig.1.(a)the wire mesh foam ceramic placed in the pipeline; (b) the SiC foam ceramic placed in the pipeline

In recent years, some scholars have studied the explosion suppression effects and the law of the porous materials. By the experiment, the Japanese scholars Bei Tiao Ying Guang and Jin Tian Jian etc. [2] found that the critical quenching speed had a certain relationship with the geometry parameter of the wire mesh and the quenching performance of the wire mesh had nothing to do with the materials. Yu Jianliang etc. [3] provided the new concept of describing the fire retardant properties with the critical quenching overpressure difference and the critical volume and got the relationship between the multi-wire geometry parameters and the critical quenching rate and the critical quenching overpressure. Nie Baisheng and He Xueqiu etc.[4] studied the influence of the foam ceramic for the gas explosion process and the experimental results showed that the reduction effects of the explosion maximum overpressure of the foam ceramic were obvious and it could quench the gas explosion flame. The reports for the comparative study of the explosion suppression effects of the different materials and the influence of the explosion temperature of the porous materials are rare. The paper will make the comparative experimental study for the explosion suppression effects of the wire mesh and the foam ceramic and sum up the material its own characteristics with the guide of the mine application to do the preferred selection.

Use the 30 wire mesh diameter 0.204mm (2.54cm arranged within the mesh) and the 40 stainless steel wire mesh diameter 0.187mm to compose the wire mesh body, because of its high hardness and low price. customize the Al_2O_3, and SiC ceramic foam materials :through-hole rate of 80% to 90%, density 0.42-0.48g/cm^3, the aperture (2.54cm long holes are arranged in number) 30 small holes, 20 middle holes and 10 large holes, 3 sizes, the flat size 28cm×28cm, the thickness of 2cm, 3cm, 5cm.

1.2. Experimental system

The experimental pipe is our own designed square steel pipe with the fracture surface for the 300mm ×300mm and the total length is 6.5m and the working pressure is 10MPa. The whole pipe is made up with a 0.3m gas chamber and four 1.5m pipelines, which is connected with the flange and can be divided into equipment removal. The gas chamber and each section of pipe have four test holes and all pipe wall has a total of 20 test holes. This experiment use eight test holes. Install the flame temperature and pressure sensor, get the voltage data with the acquisition card and turn the data to be the temperature and pressure value.

Fig. 2. the figure of the experimental pipeline

1.3. Experiment scheme

Select the gas of the concentration of 7.68% and beyond this concentration the gas is in the easy explosive boundaries. After vacuum pipe, fill the entire tube with the gas mixture, close the back-end with the kraft and ignite the front-end. First do the empty pipe experiment. In the pipe at 3.5m away from the ignition point, use the steel bracket fixing the specimen and the foam and the seal edge gap do the explosion suppression experiment.

1.4. Experimental result

Place the foam ceramic or the wire mesh body in the pipe, the explosion flame rushed out the kraft and the distance away from the pipe export decreased. After placing the foam ceramic material, the explosion sound decreased. The thicker the foam ceramic was, the silencing effect was better and the explosion sound was small, which showed that the foam ceramic had the ability to absorb sound waves. After the experiment, the sintering phenomenon of the wire mesh surface was obvious, the wire broke easily, the intensity decreased and some parts were damaged which showed that the sintering resistance performance of the wire mesh was bad. As shown in figure 3 (a), the sintering phenomenon of the foam ceramic surface was not obvious, some part of the pore surface were burnt into black, and the color change of the internal pore was not obvious, which showed that the sintering resistance performance of the foam ceramic was good. As shown in figure 3 (b), during the experimental process many pieces of the foam ceramics fractured, especially the large aperture and the smaller thickness foam ceramic material was easy to be broken, which showed that the intensity of the foam ceramic was low, the anti-blast damage ability was weak and the sintering resistance performance was good. The anti-blast damage ability of the wire mesh body was much stronger and the sintering resistance performance was weak.

(a) (b)

Fig. 3.(a) the sintering resistance condition of the AL_2O_3 foam ceramic;(b) the damage condition of the AL_2O_3 foam ceramic

1.5. The influence of the overpressure of the pipe

By analyzing the explosion overpressure data, both the wire mesh and the foam ceramic materials reduced the explosion strength of the same conditions of no obstacles, which indicated that the wire mesh and the foam ceramic material had the ability to absorb energy and decay waves. During the experiments, the decay rate of the gas explosion maximum overpressure of the wire mesh for pipeline could reach 31.0% -52.1% and that of the foam ceramic could reach 25.7% -58.3%. As shown in Figure 4, on the whole the reduction effects of the explosion overpressure of the foam ceramic materials are better than that of the wire mesh.

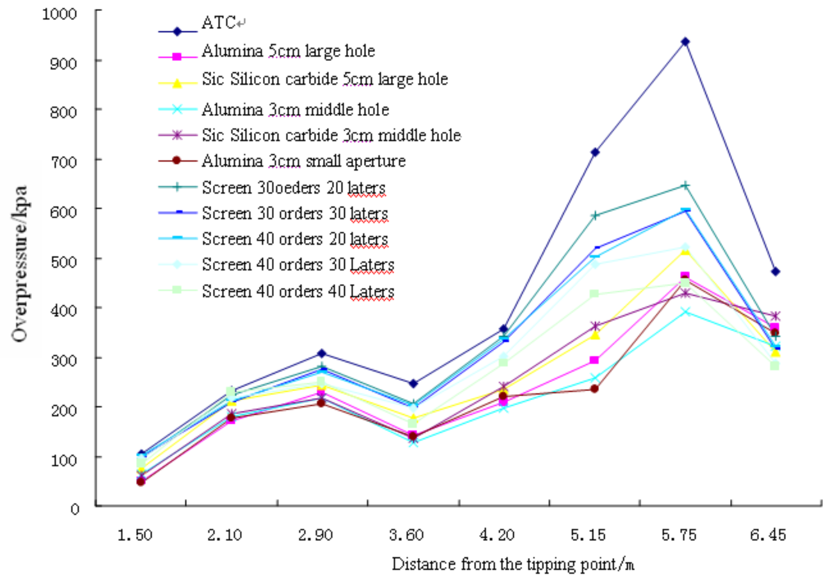


Fig.4. the impact preferred selection of the explosion overpressure of the wire mesh and the foam ceramic material

1.6. The influence of the flame temperature of the pipe

Both the wire mesh and the foam ceramic materials reduced the flame temperature of the same conditions of no obstacles. The decay rate of the maximum flame temperature of the wire mesh could reach 25.7% -63.6% and that of the foam ceramic could reach 18.9% -42.4%. As shown in Figure 5, on the whole the reduction effects of the flame temperature of the wire mesh are better than that of the foam ceramic.

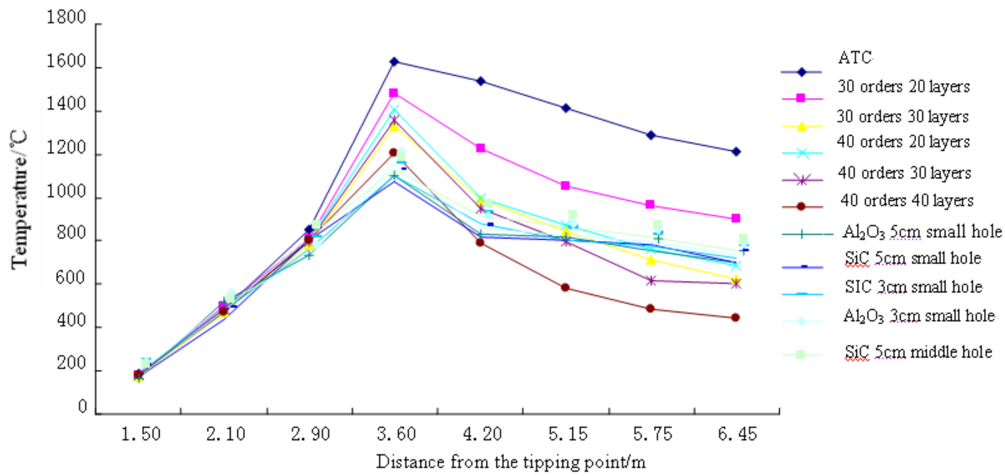


Fig.5. the impact preferred selection of the flame temperature of the wire mesh and the foam ceramic material

2. The comparative analysis of the explosion suppression mechanism

2.1. The comparative analysis of the explosion overpressure attenuation mechanism

Porous materials' reduction effects on the shock waves can be summarized as: when the shock wave reached the surface of porous materials, the solid reflectivity of the material surface weakened some energies of the shock wave, the energy in the pipe section was compressed on the pores, thus some of the impact energy turned into the plastic properties, the shock wave within the porous material, the hole wall occurs the elastic deformation and some impact energies turned into the elastic energy. The porous material has a large number of irregular pore structures, when the shock wave entered, passed the gas of the pores and hit the internal hall of the pores, it would lead to the reflection and scattering effects. Because of the internal complicated network structure, the shock wave of the reflection and scattering met the internal wall of the pores again which led to the new reflection and scattering effects. During the process of the repeated reflection and scattering, some energy would be consumed. Shock wave on the pore structure of shear failure during the load, impact damage to the matrix of mutual friction, energy consumption.After the above process, the shock wave through the porous material tends to spread and uneven state, the progressive wave can not produce the cycle reversed, and the reflected waves can not produce standing waves with each other, thus shock pressure peak reduces and the porous materials achieve the attenuation effect on the shock wave. The propagation attenuation effect of the shock wave in porous materials depends largely on the absorption and dissipation of the energy of the various stages.

Of the multi-layer wire mesh body, the layers are almost no space. The formed space network structure, pore and pore connectivity is low and the shock compression of it is lower. Because the wire is relatively smooth and the area is smaller, in its internal reflection and scattering of the shock wave is low and consumes less energy. The foam ceramic has the three-dimensional network pore structure and pore wall is roughness, which compress the shock wave energy. The energy consume of the internal mesh pore elastic deformation is large, the repeated reflection and scattering of the shock wave are much more, and the reduction effects are better than that of the wire mesh.

The experimental results show that the foam ceramic has a good muffler performance: the thicker the foam ceramic is, the muffler performance is better which illustrates the foam ceramic has the ability to absorb sound waves but the ability of absorbing sound waves of the wire mesh is not strong. The suppression effects of the explosion sound waves of the foam ceramic are better than that of the wire mesh.

2.2. The comparative analysis of the explosion flame temperature attenuation mechanism

When the flame passes the small pores of the porous materials, a chain reaction effect will lead to drastically reduce the number of free radicals of the participation in the combustion reaction and reduce the intensity of reaction. The heat exchange effect with the hole walls of the porous materials makes the loss of the combustion heat through the porous walls and large holes adjacent structures which makes the flame temperature quickly reduce below the quenching temperature and the quenching occurs to prevent some flames to continue to spread. Pressure wave is absorbed which also contributed to the decline the flame energy.

The flame front in three-dimensional through the pore structure of the foam ceramic is easy to be continuous. The layers of the wire mesh are almost no space, the flame front is not easy to be continuous which is subdivided into a number of small stocks, the heat can not be added and lose the thermal equilibrium, resulting in some of the flame extinguished. On the basis of the material characteristics of its own, the hot-melt of the metal mesh is high, the heat spread quickly which strengthens the role of heat transfer, and the flame temperature decreases rapidly which is prone to quenching.

3. Conclusions

The paper studied the explosion suppression effects of the porous materials with our designed experimental system. The experimental results showed that the wire mesh and the foam ceramic materials have a certain capability of the fire retardant and the reduction pressure and the absorbing sound ability of the foam ceramic was better than the wire mesh. The anti-blast damage performance of the wire mesh was good but the sintering resistance performance was bad. The anti-blast damage performance of the foam ceramic was bad but the sintering resistance performance was good.

The experimental data show that the decay rate of the gas explosion maximum overpressure of the certain parameters wire mesh and foam ceramic for pipeline could reach 50% and on the whole the reduction pressure effects of the foam ceramic were better than the wire mesh. The decay rate of the wire mesh for the maximum flame temperature could reach 60% and the fire retardant effect was better than the foam ceramic.

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