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ARTICLE

Preparation and Application of Porous Stainless Steel Cone/Tube in Coal Gasification Engineering

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Abstract: In the Shell Coal Gasification Process (SCGP), porous stainless steel cone is used as a gas-distributor to make pulverized coal entering fluidization which can insure the continuous transportation of coal powder and improve the combustion efficiency. In the service conditions the porous cone must have not only high and uniform permeability, but also a proper strength. This study focuses on the preparation of porous stainless steel cone and tube with high performances such as permeability and strength etc. for applications. The porous cone/tube with 32%-35% in porosity, 20 micron in maximum pore size was prepared by CIP. After welding and sealing, the breaking pressures of cone/tube are larger than 2.5 MPa which meet the requirements for fluidization transportation of coal powder in SCGP.

Key words: porous stainless steel; cone; shell coal gasification process; gas-distributor

The clean coal technique is an important measure for full utilizing coal resource, improving combustion coefficient, reducing environment pollution[1,2]. The clean synthetic gas can be generated by advanced SCGP, which is used in power generation, chemical and fertilizer industry[3,4]. In the SCGP, large size porous cones/tubes are required as the distributors and delivers with fluidization[5-7], so they need high permeability to prevent coal powder/fly ash penetration and better strength to resist the gas flow impact and pressure. The sintered metal powder porous materials are suitable for fluid distribution and fluidization delivery because of their higher strength and random winding channel. According to the requirements of the pore characteristic and chemical properties for the porous cones, the preparation and properties of stainless steel porous cone/tube were presented in this paper.

1 Preparation of Porous Metal Cone/Tube

There are two kinds of porous elements, porous cone and tube, used for fluidization of coal powder and accelerator of fly ash. The shape of porous cone/tube is shown in Fig.1. The service temperature of the cone or the tube is 250-400 °C, and

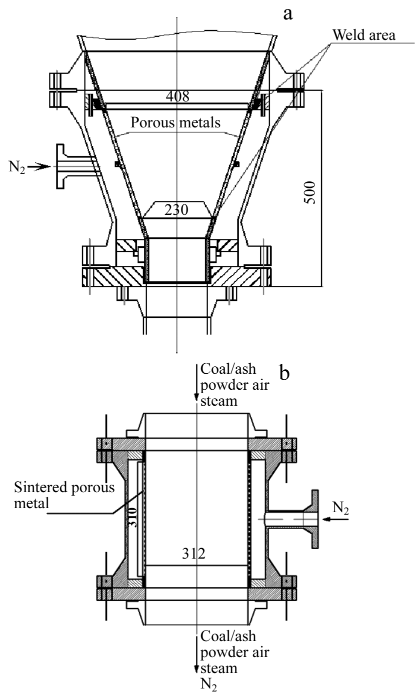

Fig.1 Porous cone (a) and tube (b)

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service pressure is about 2.5 MPa. The constitutions of the solid particle sizes of the coal powder and in the fly ash are as follows: (1) for the powder: >50 μm, <10%; 50-5 μm, 80%-85%; <5 μm, 5%-10%; (2) for the ash: >20 μm, <5%; 20-1 μm, 80%-85%; <1 μm, 10%-20%. According to the above mentioned requirement, the preparation of the porous metal cone/tube was designed as follows:

Atomized 316L stainless steel powder was used as starting material, which was classified into three classes: –280 to +350 mesh, –160 to +230 mesh, –60 to +120 mesh.

Two different forming processes for the porous cone/tube were adopted, i.e. powder rolling process and cold isostatic pressing. In the case of the powder rolling process, the powder was rolled into a plate green, and then the green was sintered into a porous plate at 1200-1250 °C in high purity hydrogen atmosphere. Afterwards, the sintered plate was cut into three pieces of sectors, followed by welding into a cone-shaped component. When the cold isostatic pressing was adopted, the powder was pressed into greens, and then they were machined into cone/tube greens. After a shape-fixed treatment for the cone/tube greens, they were sintered into porous cones/tubes at a relatively high temperature (1300 °C) in high purity hydrogen atmosphere.

The outer appearances and the sizes of all porous cones/tubes were inspected. The maximum pore size and permeability of the samples were determined by ISO 4003 and ISO 4022, respectively. The mechanical performances were tested by GB/T7964-1987. In order to evaluate the pressure-resistant ability of the porous material prepared by the two different processes, tube-broken tests were conducted using a pressure infliction testing device, shown in Fig.2a according to GB/T6886-2001. Each tube with 50 mm (O.D)×2 mm (thickness)×100 mm (length) was first welded to a dense flange to get porous element, then the pores of the element was closed with wax, afterwards the treated element was sealed into the pressure infliction testing device and a breaking pressure was measured.

As the same procedure of the above mentioned tubes test, a treated cone was sealed into the pressure infliction testing device, shown in Fig.2b, for a breaking pressure measuring of cone with overall dimension. The steps of the test were as follows: first make the fluid pressure gradual increase up to 1.2 MPa for 5 min holding, and then the fluid pressure was enhanced continuously until the porous element was broken.

2 Results and Discussion

2.1 Effects of forming process on characteristics of the porous cone/tube

The effect of forming process on the pore characteristic of the porous cone/tube is listed in Tab.1.

It can be seen from Tab.1 that the forming process has obvious influence on the filter efficiency and permeability of the sintered metal porous media. Whatever forming processes is

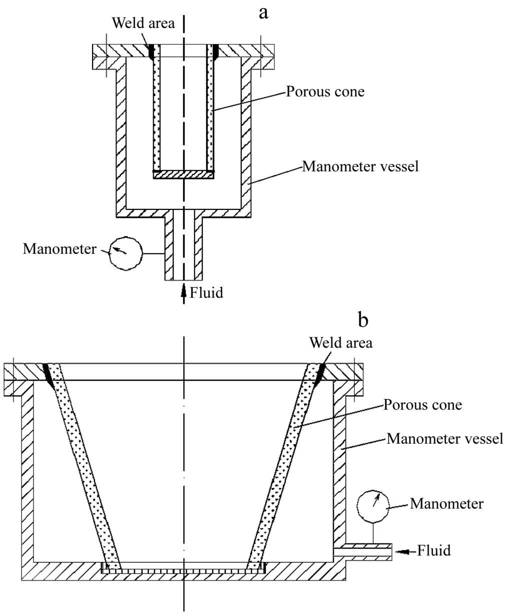

Fig.2 Schematic of breaking pressure test: (a) for tube; (b) for cone with overall dimension

adopted, the changes of characteristics of the porous metal media with powder particle sizes have the same trends, that is to say, with increasing of powder particle size, the max pore size, the relative permeability and the filter efficiency increase. According to the results in Tab.1, the powder with intermediate particle size (G40, B40) has more proper characteristics for preparing the cone/tube. The tubes by powder rolling have higher relative permeability, smaller filter efficiency compared with the tubes by isostatic pressing, while the max. pore sizes of the tubes by the two forming process are almost the same. From point of views of forming process, the filtering characteristics obtained by powder rolling are superior to that by cold isostatic pressing; the permeability by powder rolling is about 2 times of that by cold isostatic pressing.

2.2 Effect of sinter process on mechanical performances

In order to investigate the effects of sinter process on the mechanical performances of the porous media, two different sinter temperatures were selected in the condition of the same holding time and the same atmosphere, i.e. the normal sinter temperature and high sinter temperature. The former tem-

Table 1 Characteristics of porous metal media

Sample code	Powder size/ mesh	Porosity/ %	Max pore size/μm	Relative permeability/ $m^3(h\cdot kPa\cdot m^2)^{-1}$	Filter efficiency/ μm
G30	280-350	27-28	13-15	52.6-58.3	7.5
B30	280-350	30-32	13-15	91.6-103	6.0
G40	160-230	32-35	22-24	110-129	9.6
B40	160-230	34-38	22-25	236-291	6.6
G50	60-120	35-38	32-34	259-296	12.7
B50	60-120	37-39	31-34	439-491	7.2

Note: G denotes cold isostatic pressed tube, B denotes powder-rolled tube perature was 1200-1250 °C, and the later was 1250-1300 °C. The results are shown in Tab.2. It is quite obvious that the tensile strength of the sample sintered at high temperature is higher than that at normal temperature, which is beneficial to improving the anti-deformation ability of the cone/tube in their service environment.

Actually, the high temperature sinter process consists of two steps, i.e. shape-fixed treatment and high temperature sintering. The purpose of the former step is to fix the shape of the cone/tube at a lower temperature and to reduce the reaction of the cone/tube with some harmful material during treating. It is clear that the purpose of the later step is to properly enhance the strength under the precondition of keeping good characteristics of the porous metal cone/tube. So following finding can be drawn that the sinter temperature for the cone/tube is as high as possible compared with the normal sinter temperature under the precondition of undamaging the characteristics of the porous metal cone/tube.

2.3 Effect of preparation process on pressure-resistant ability

In the present experiment the pressure resistant ability of the porous metal media is characterized by a breaking pressure, which is much dependent on the preparation process of the porous tube/cone. The measurement results of the breaking pressures for the seamless porous tubes by isostatic pressing and for the welded porous tubes by powder rolling are listed in Tab.3 and Tab.4. It is found from the tables that the breaking pressure of the tubes by isostatic pressing is over 6 MPa (owing to restricting of the manometer, its shown max. value is 6 MPa), while the later is less than 4 MPa. However, the breaking pressure for all of the porous media can meet the requirements of GBT6886, specifying not less than 3.0 MPa.

It is also clear to see from Tab.3 and Tab.4 that annealing has influence on the breaking pressure of the porous element. The broken sites of the elements annealed and unannealed are quite different, which means that annealing enhances the breaking pressure, and thus improves the pressure-resistant ability of the porous metal media.

2.4 Breaking test for cone/tube with overall dimension

The test results of the breaking pressure for cone/tube with overall dimension are listed in Tab.5 and Fig.3. It can be seen that the anti-breaking pressure of cone/tube with overall dimension is much dependent on their wall thickness and dimensional factor. The larger the dimension of the cone/tube is, the thicker the required wall thickness. In order to guarantee the service safety, the minimum wall thickness of the cone with overall dimension is not smaller than 8.2 mm, and that of the tube is not smaller than 5.1 mm.

Table 2 Tensile strength of porous metal media upon adopting different sintering processes

Sample code	Sinter process	Tensile strength/MPa
G40	Normal sintering	94.5
B40	Present sintering	135
G50	Normal sintering	73.5
B50	Present sintering	86

Table 3 Breaking pressures of porous tubes by isostatic pressing

Sample code	Breaking pressure/MPa	Broken site
G40	>6.0	Weld thermolabile area
G50	>6.0	Weld thermolabile area
G40T	>6.0	Porous medium in itself
G50T	>6.0	Porous medium in itself

Note: T denotes annealed medium

Table 4 Breaking pressures of porous tubes by powder rolling and welding

Sample code	Breaking pressure/MPa	Broken site
B40	3.3	Weld thermolabile area
B50	3.1	Weld thermolabile area
B40T	3.8	Porous medium in itself
B50T	3.5	Porous medium in itself

Table 5 Anti-breaking pressures of cone/tubes with overall dimensions

Sample No.	Forming process	Part shape	Size/ mm	Thickness/ mm	Breaking pressure/ MPa
B40-1	Powder rolling	Cone	Φ406/Φ233 ×500	1.96	0.4 (deformed)
G40-1	Isostatic pressing	Cone	Φ406/Φ233 ×500	8.2	2.8 (broken)
G40-2	Isostatic pressing	Tube	Φ312×310	5.1	2.6 (broken)

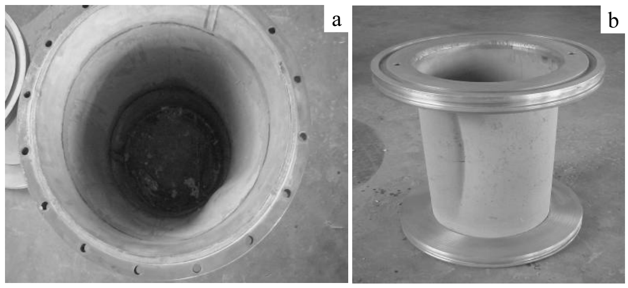

Fig.3 Photographs of broken porous cone (a) and tube (b)

2.5 Applications of porous cone/tube

The products have been successfully used in the production line of SCGP for coal chemical project of Shuanhuan company Hubei[8-10], and qualified for production quality certification of Shell Company in Holland in 2005. It is proved that the porous metal cone/tube can completely meet the requirements for specification of coal gasification for porous mental elements. Up to now there are 11 domestic enterprises to use the sintered porous metal medias for coal chemical projects. Fig.4 shows the photograph of assembly with the porous stainless steel cone.

Fig.4 Photo of assembly with porous cone used in coal gasification

3 Summary

In order to manufacture a proper cone/tube with overall dimension, the following technical factors are required:

1) The powder with intermediate particle size (G40, B40) is selected.

2) Isostatic pressing is more proper than powder rolling.

3) Sinter temperature is as high as possible under the precondition of undamaging the characteristics of porous metal media.

4) The minimum wall thickness of the cone should not be smaller than 8.2 mm, and that of the tube should not be smaller than 5.1 mm.

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多孔不锈钢通气锥/管在煤气化工程中的应用研究

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摘 要：在壳牌煤气化工程中，需要多孔不锈钢通气锥/管作为气体分布元件，以保证煤粉和飞灰的流态化连续输送。本研究针对使用要求，主要研究了粉末轧制和冷等静压技术制备的多孔不锈钢通气锥/管的渗透性能和强度。结果表明，冷等静压成形后经过烧结和复烧的通气锥/管，孔隙度在32%-35%范围，最大孔径为20 μm，通气锥的整体耐压强度都大于2.5 MPa，符合壳牌煤气化技术流态化输送的要求。

关键词：多孔不锈钢；通气锥；壳牌煤气化技术；气体分布器

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