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(54) METHOD FOR PREPARING SHOT FLOWING PIPE OF COMPOSITE SHOT BLASTING MACHINE

(57) The present invention relates to the technical field of a spout of a SBM, in particular to the preparation method of a composite spout of a SBM. Raw materials comprise according to a mass ratio:
- 80-85 parts of silicon nitride powder
- 5-10 parts of boron nitride nanotube powder
- 4-6 parts of aluminum oxide powder
- 3-5 parts of yttrium oxide powder

The method for preparing the spout of the SBM by the materials comprises of the following steps:
- raw material preparation
- raw material mixing
- slurry preparation
- grouting molding
- drying demoulding
- vacuum sintering
- composite casting.

The materials according to the present invention have excellent mechanical and tribology performance, the resultingspoutof the SMBis:
- extremely hard
- extremely durable
- extremely wear resistant

The production method of the spout for the SBM has the advantages of:
- simple manufacturing process
- convenient equipment requirements
- short production time
- is in line with current production company operations

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Description

Technical Field

[0001] The present invention relates to the technical field of preparation of a shot flowing tube (spout) of a shot blasting device (SBM), in particular to a preparing method of a composite shot flowing tube (spout) of the shot blasting device (SBM).

Related Art

[0002] Along with the continuous development of the industry, in the technical field of surface treatment, the application of the shot blasting technology to the current industry production is very wide, and the device used by the shot blasting technology is a shot blasting machine (SBM). The SMBis a treatment technology of blasting steel grit and steel shot at a high speed to impact onto the surfaces of materials and articles through a shot blasting device. It is used for removing burrs and iron rust on the surface of a workpiece, it can also remove pollutants on the surface of specific parts of the coating of the workpiece. Furthermore it provides a surface profile which increases the adhesion of the coating, thereby improving the quality and durability of the workpiece. When compared with other surface treatment technologies it has the advantages of higher speed and higher efficiency.

[0003] One of the core components in the SBMis the blast wheel. When the SBM is in operation the steel grit and steel shot enter the control cage through a shot flowing tube (spout), before being accelerated by centrifugal force by a rotary blast wheel and impacting onto the surface of the workpiece to achieve the aim of cleaning or strengthening.

[0004] During operation the shot continuously flowsthrough the SBM causing the component parts to experience wear.The spout of the SBM is subject to a high level of wear,therefore improving the durability and wear resistance of the spout would result in an increase in the life span and reliability of the SBM.

[0005] The spout in the current industrial production is made of a cast iron material, in long term use, due to the continuous high speed flow of the steel shot and steel grit, the spoutbecomes worn very quickly, and since the SBM is unable to operate, the production efficiency is greatly reduced, the production cost is increased, and financial loss is caused.

[0006] Ceramic is an ideal material to substitute for the traditional cast iron spout due to its properties: light weight, high pressure resistance, excellent wear resistance, etc. But currently ceramic spouts are not available - there is an urgent need for a composite spout with excellent performance to be used in SBM.

Summary

[0007] In order to overcome the inherent weaknesses and shortcomings of the cast iron spouts used in existing SBM, the present invention provides a preparation method for a composite spout, which is simple and quick to manufacture, easy to operate and offers excellent performance.

[0008] The present invention is realized by the following technical manufacturing process:

The preparation method for a composite spoutto be used in SBM comprises of the following steps:

(1) Preparation of raw materials:

- 80-85 parts by weight of silicon nitride powder
- 5-10 parts by weight of boron nitride nanotube powder
- 4-6 parts by weight of aluminum oxide powder
- 3-5 parts by weight of yttrium oxide powder respectively

(2) Mixing of raw materials

- add the raw materials in step (1) into a ball milling tank
- add alcohol according to a volume ratio of alcohol to rawmaterials of 1:1
- add steel shot according to a mass ratio of the steel shot to raw materials of 9-15:1
- seal the ball milling tank
- introduce argon gas into the ball milling tank as a protective gas
- ball-milling and mixing the raw materials in a planetary ball mill
- setthe ball-milling rotary speed to be 200-250 rpm
- the ball-milling duration is 8-12h

- dry the ball-milled raw materials for 10-12h in a vacuum drying box
- set the temperature to 75-85°C
- pass the mixed materials after the drying through a 300-mesh sieve
- collect the resulting material

(3) Preparation of slurry:

- add the mixed materials obtained in step (2) into a stirring machine
- add distilled water with a mass percent of 28-35%
- add a diluent with a mass percent of 0.3-0.5%
- stir the raw materials at a rotary speed of 250-300r/min for a duration of 1-2h

(4) Grouting molding:

- inject the slurry obtained in step (3) into a molding gypsum die for the spout
- pour excessive slurry in the die after a slurry layer is thickened to 10mm
- centrifuge the model with a blank after the slurry is poured

(5) Drying demoulding:

- place the model with a blank obtained in step (4) into a drying room with the temperature controlled at 53+/-3°C
- demould the model with a blank after a grouting opening is separated from the blank by 0.5-1 mmto obtain a blank of the shot flowing tube

(6) Vacuum sintering:

- place the blank of the spout obtained in step (5) in a die of the spout
- place into a vacuum thermal pressing sintering furnace with a vacuum degree of 10^{-2}Pa
- control the temperature rising process:
- manually heating to 200°C
- heating to 1100°C at a temperature rising rate of 10°C/min
- maintain temperature for 30min
- heat to 1750-1800°C at a rate of 7°C/min
- end the sintering after maintaining temperature for 1 h
- this results in a Si_3N_4/BNNT composite ceramic liner of the spout after theworkpiece is cooled to room temperature in the furnace

(7) Composite casting:

- load the Si_3N_4/BNNT composite ceramic liner of the spout obtained in step (6) into a casting sandbox of the spout
- pour with molten iron after die assembly to wrap an iron casting onto the outer wall of the ceramic spout
- this results in the composite spout of the SBM with outer side of cast iron and the inside of Si_3N_4/BNNT composite ceramic

[0009] The present invention has the characteristics:

The diluent in step (3) is one or combination of more of water glass or sodium carbonate or sodium phosphate or sodium hexametaphosphate; and the diluent is further preferably sodium carbonate.

[0010] The centrifuging the model with a blank after the slurry is poured in step (4) is to avoid uneven distribution of a little residual slurry on the inner surface of the blank after the slurry is poured, so as to ensure the uniform distribution of the residual slurry and avoid slurry strands.

[0011] The drying time for the model with a blank in step (5) is 2/5-3/5 of slurry charging time; further preferably, drying time for the model with a blank in step (5) is 1/2 of the slurry charging time.

[0012] The present invention has the beneficial effects:

In common with wearproof structure ceramics the silicon nitride ceramic has the advantages of:

- high strength
- high hardness
- high temperature resistance
- wear resistance
- corrosion resistance
- oxidation resistance
- good thermal shock resistance
- high density

[0013] The boron nitride nanotubes feature the following properties:

- chemical stability
- excellent mechanical properties
- heat conductivity
- low thermal expansion
- excellent oxidation resistance

[0014] Silicon nitride also reduces the brittleness of a silicon nitride ceramic product and improves the crack growth resistance after composite with the silicon nitride ceramic material, and thus becomes an ideal high-tenacity ceramic material for manufacturing the spout to be used in the SBM.

(1) High hardness

[0015] The new Si_3N_4/BNNT composite ceramic material as mentioned in the present invention has very high hardness which is up to HRA94, and if the ceramic material is taken as the liner of the spout of the SBM, the hardness of the existing pure cast iron material is greatly improved, and greater durability in actual production use is realized.

(2) Good wear resistance

[0016] The new Si_3N_4/BNNT composite ceramic material as mentioned in the present invention has very good wear resistance, the average friction coefficient is 0.285, and if the ceramic material is taken as the liner of the spout of the SBM, the wear resistance of the existing pure cast iron material is greatly improved, and the rejection rate of the spout is reduced.

(3) Simple operation

[0017] All devices used in the preparation are common devices in a laboratory or production company, the operation process is simple and convenient and does not require sophisticated conditions or preparation.
[0018] In general, the preparation method of the present invention is simple and quick, the produced spoutfeaturing a Si_3N_4/BNNT composite ceramic material liner and a cast iron jacket integrates advantages of the ceramics and cast iron, thereby improving the hardness and wear resistance of the spout, reducing the weight of the product and meeting the requirements of industrial production.

Detailed Description

[0019] The present invention is further explained in combination with the embodiments, but the present invention is not limited to specific examples herein.

Embodiment 1:

(1) Raw material preparation:

[0020]

- 80 parts by weight of silicon nitride powder
- 10 parts by weight of boron nitride nanotube powder

- 5 parts by weight of aluminum oxide powder
- 5 parts by weight of yttrium oxide powder respectively

(2) Raw material mixing:

[0021]

- (1) add the raw materials in step (1) into a ball milling tank
- add alcohol according to a volume ratio of alcohol to raw materials of 1:1
- add steel shot according to a mass ratio of steel shot to raw materials of 10:1
- seal the ball milling tank
- introduce argon gas into the ball milling tank as a protective gas
- ball-mill and mix the raw materials in a planetary ball mill
- setthe ball-milling rotary speed to be 250 rpm
- ball-milling time to be 10h
- dry the ball-milled raw materials for 10h in a vacuum drying box
- set the temperature into 75°C;
- pass the mixed materials after the drying through a 300-mesh sieve

(3) Slurry preparing:

[0022]

- add the mixed materials obtained in step (2) into a stirring machine
- add distilled water with a mass percent of 30%
- add water solution with a mass percent of 0.3%
- stir the raw materials at a rotary speed of 250r/min for a duration of 1 h

(4) Grouting molding:

[0023]

- inject the slurry obtained in step (3) into a molding gypsum die for the spout
- pour excessive slurry in the die after a slurry layer is thickened to 10mm
- centrifuge the model with a blank after the slurry is poured

(5) Drying demoulding:

[0024]

- place the model with a blank obtained in step (4) into a drying room of which the temperature is controlled at 53+/-3°C
- demould the model with a blank after a grouting opening is separated from the blank by 1 mm to obtain a blank of the spout
- the drying time of the model with a blank is 3/5 of the slurry charging time

(6) vacuum sintering:

[0025]

- place the blank of the spout obtained in step (5) in a die of the spout
- place into a vacuum thermal pressing sintering furnace for vacuum hot pressing sintering at a vacuum degree of 10^{-2}Pa
- the temperature rising process consists of:
- manually heating to 200°C
- heating to 1100°C at a rate of 10°C/min
- maintain temperature for 30min
- heat to 1750°C at a rate of 7°C/min
- maintain temperature for 1 h

- this results in a Si_3N_4/BNNT composite ceramic liner of the spout after theworkpiece is cooled to room temperature in the furnace

(7) Composite casting:

[0026]

- load the Si_3N_4/BNNT composite ceramic liner of the spout obtained in step (6) into a casting sandbox of the spout
- pour in molten iron after die assembly to wrap an iron casting onto the outer wall of the ceramic spout
- this results in the production of the composite spout of the SBM with outer side of cast iron and the inside of Si_3N_4/BNNT composite ceramic.

Embodiment 2:

(1) Raw material preparation:

[0027]

- 82 parts by weight of silicon nitride powder
- 8 parts by weight of boron nitride nanotube powder
- 6 parts by weight of aluminum oxide powder
- 4 parts by weight of yttrium oxide powder

(2) Mixing raw materials:

[0028]

- add the raw materials in step (1) into a ball milling tank
- add alcohol according to a volume ratio of alcohol to raw materialsof 1:1
- add steel shot according to a mass ratio of steel shot to raw materials of 9:1
- seal the ball milling tank
- introduce argon gas into the ball milling tank as a protective gas
- ball-mill and mix the raw materials in a planetary ball mill
- set the ball-milling rotary speed to 250 rpm for a duration of 8h
- dry the ball-milled raw materials for 12h in a vacuum drying box
- set the temperature into 85°C
- pass the mixed materials after drying through a 300-mesh sieve

(3) Slurry preparation:

[0029]

- add the mixed materials obtained in step (2) into a stirring machine
- add distilled water with a mass percent of 32%
- addsodium carbonate with a mass percent of 0.4%
- stir the raw materials at a rotary speed of 250r/min for 1.5h

(4) Grouting molding:

[0030]

- inject the slurry obtained in step (3) into a molding gypsum die for the spout of the SBM
- pour excessive slurry in the die after a slurry layer is thickened to 10mm
- centrifuge the model with a blank after the slurry is poured

(5) Drying demoulding:

[0031]

- place the model with a blank obtained in step (4) into a drying room at 53+/-3°C
- demould the model with a blank after a grouting opening is separated from the blank by 1mm
- to obtain a blank of the spout, wherein the drying time of the model with a blank is 1/2 of the slurry charging time

(6) Vacuum sintering:

[0032]

- place the blank of the spout obtained in step (5) in a die of the spout
- place into a vacuum thermal pressing sintering furnace with a the vacuum degree of 10^{-2}Pa
- the temperature rising process consists of:
- manually heating to 200°C
- heating to 1100°C at a rate of 10°C/min
- maintain temperature for 30min
- heat to 1780°C at a rate of 7°C/min
- maintain the temperature for 1 h
- this results in a Si_3N_4/BNNT composite ceramic liner for the spout after theworkpiece is cooled to room temperature in the furnace

(7) Composite casting:

[0033]

- load the Si_3N_4/BNNT composite ceramic liner of the spout obtained in step (6) into a casting sandbox of the spout
- pourmolten iron after die assembly to wrap an iron casting onto the outer wall of the ceramic spout
- this results in the production of the composite spout of the SBM with outer side of cast iron and the inside of Si_3N_4/BNNT composite ceramic.

Embodiment 3:

(1) Raw material preparation:

[0034]

- 85 parts by weight of silicon nitride powder
- 5 parts by weight of boron nitride nanotube powder
- 4 parts by weight of aluminum oxide powder
- 3 parts by weight of yttrium oxide powder

(2) Raw material mixing:

[0035]

- add the raw materials in step (1) into a ball milling tank
- add alcohol according to a volume ratio of alcohol to raw materials of 1:1
- add steel shot according to a mass ratio of steel shot to raw materials of 15:1
- seal the ball milling tank
- introduce argon gas into the ball milling tank as a protective gas
- ball-mill and mix the raw materials in a planetary ball mill
- set the ball-milling rotary speed to 200 rpm for a duration of 12h
- dry the ball-milled raw materials for 12h in a vacuum drying box
- set the temperature to 75°C
- pass the mixed materials after the drying through a 300-mesh sieve

(3) Slurry preparation:

[0036]

- add the mixed materials obtained in step (2) into a stirring machine
- add distilled water with a mass percent of 35%
- add a combination of sodium phosphate and sodium hexametaphosphate with a mass percent of 0.5% when the mass ratio of sodium phosphate to sodium hexametaphosphate is 1:1
- stir the raw materials at a rotary speed of 300r/min for 1 h

(4) Grouting molding:

[0037]

- inject the slurry obtained in step (3) into a molding gypsum die for the spout
- pour excessive slurry in the die after a slurry layer is thickened to 10mm
- centrifuge the model with a blank after the slurry is poured

(5) Drying demoulding:

[0038]

- place the model with a blank obtained in step (4) into a drying room of which the temperature is controlled at 53+/-3°C
- demould the model with a blank after a grouting opening is separated from the blank by 1mm
- the drying time of the model with a blank is 2/5 of the slurry charging time

(6) Vacuum sintering:

[0039]

- place the blank of the shot flowing tube obtained in step (5) in a die of the spout
- place into a vacuum thermal pressing sintering furnace with a vacuum degree of 10^{-2}Pa
- the temperature rising process consists of:
- manually heating to 200°C
- heat to 1100°C at a rate of 10°C/min
- maintain temperature for 30min
- heat to 1800°C at a rate of 7°C/min
- maintain temperature for 1 h
- this results in obtaining a Si_3N_4/BNNT composite ceramic liner of the spout after a workpiece is cooled to room temperature in the furnace

(7) Composite casting:

[0040]

- load the Si_3N_4/BNNT composite ceramic liner of the spout obtained in step (6) into a casting sandbox of the spout
- pour with molten iron after die assembly to wrap an iron casting onto the outer wall of the ceramic spout
- this results in the production of the composite spout of the SBM with outer side of cast iron and the inside of Si_3N_4/BNNT composite ceramic.

[0041] The comparison between performances of the composite shot flowing tube prepared by the three embodiments and those of the existing cast iron shot flowing tube is asshown in table 1.

Table 1

Performance preparing method	Embodiment1	Embodiment 2	Embodiment 3	Cast iron
Rockwell hardness	92.5	94.8	93.8	48
Density ($g \cdot cm^{-3}$)	3.27	3.39	3.35	7.31
wear rate under 40N load ($\times 10^{-7} cm^3 \cdot m^{-1}$)	1.35	1.22	1.31	75
wear rate under 100N load ($\times 10^{-7} cm^3 \cdot m^{-1}$)	6.57	6.08	6.29	120

[0042] It can be known from the above table that compared with the existing cast iron spout, the composite spout prepared by the present invention has higher hardness and lower density, which causes the weight of the composite spout to be only half that of the cast iron spout having the same volume, but the hardness of the composite spout to be twice that of the cast iron spout. In respect of wear resistance, the wear rate of the composite spoutof present invention is much lower than that of the cast iron spout under the same load action, which indicates that the wear performance of the former is far superior to that of the latter, and in the above three embodiments, the spout obtained in embodiment 2 has the best performance, therefore, the preparing process in embodiment 2 is the optimal method for preparing the composite spout.

[0043] In conclusion, the composite spout of the SBM prepared according to the present invention adopts a molding technology of a water absorption gypsum die, and features the following characteristics:

- high strength
- good wear resistance
- light weight of the Si_3N_4/BNNT composite ceramic

[0044] Therefore, the hardness and wear resistance of the currently adopted pure cast iron spout are improved, the durability of the spout caused by the flowing of shot materials in the spout in a long-term use process is reduced, such that the rejection rate of the spout is greatly reduced, the production cost is saved, the production efficiency is improved and the composite spout is an excellent and innovative spout for use in SBM.

Claims

1. The preparation method of a composite spout of a SBM comprising of the following steps:

(1) Raw material preparation:

- 80-85 parts by weight of silicon nitride powder
- 5-10 parts by weight of boron nitride nanotube powder
- 4-6 parts by weight of aluminum oxide powder
- 3-5 parts by weight of yttrium oxide powder

(2) Raw material mixing:

- add the raw materials in step (1) into a ball milling tank
- add alcohol according to a volume ratio of alcohol to raw materials of 1:1
- add steel shot according to a mass ratio of the steel shot to raw materials of 9-15:1
- seal the ball milling tank
- introduce argon gas into the ball milling tank as a protective gas
- ball-mill and mix the raw materials in a planetary ball mill with a rotary speed of 200-250 rpm and a duration of 8-12h
- dry the ball-milled raw materials for 10-12h in a vacuum drying box at a temperature of 75-85°C
- pass the mixed materials after the drying through a 300-mesh sieve

(3) Slurry preparation:

- add the mixed material obtained in step (2) into a stirring machine
- add distilled water with a mass percent of 28-35%
- add a diluent with a mass percent of 0.3-0.5%
- stir the raw materials at a rotary speed of 250-300r/min for 1-2h

(4) Grouting molding:

- inject the slurry obtained in step (3) into a molding gypsum die for the spout of the SBM
- pour excessive slurry in the die after a slurry layer is thickened to 10mm
- centrifuge the model with a blank after the slurry is poured

(5) Drying demoulding:

- place the model with a blank obtained in step (4) into a drying room at a temperature of 53+/-3°C
- demould the model with a blank after a grouting opening is separated from the blank by 0.5-1 mm
- this results in a blank of the spout

(6) Vacuum sintering:

- place the blank of the spout obtained in step (5) in a die of the spout
- place it into a vacuum thermal pressing sintering furnace with a vacuum degree of 10^{-2}Pa
- the temperature rising process consists of:
- manually heating to 200°C
- heat to 1100°C at a rate of 10°C/min
- maintain temperature for 30min
- heat to 1750-1800°C at a rate of 7°C/min
- maintain temperature for 1 h
- this results in a Si_3N_4/BNNT composite ceramic liner of the spout after a workpiece is cooled to room temperature in the furnace

(7) Composite casting:

- load the Si_3N_4/BNNT composite ceramic liner of the spout obtained in step (6) into a casting sandbox of the spout
- pour molten iron after die assembly to wrap an iron casting onto the outer wall of the ceramic spout, thus finally obtaining the composite spout of the SBM with outer side of cast iron and the inside of Si_3N_4/BNNT composite ceramic

2. The preparation method of a composite spout of a SBM according to claim 1, **characterized in that** the diluent in step (3) is one or combination of more of water glass or sodium carbonate or sodium phosphate or sodium hexametaphosphate.

3. The preparation method of a composite spout of a SBM according to claim 2, **characterized in that** the diluent is sodium carbonate.

4. The preparation method of a composite spout of a SBM according to claim 1, **characterized in that** the drying time for the model with a blank in step (5) is 2/5-3/5 of slurry charging time.

5. The preparation method of a composite spout of a SBM according to claim 4, **characterized in that** the drying time for the model with a blank in step (5) is 1/2 of the slurry charging time.

6. The preparation method of a composite spout of a SBM according to claim 1, comprising the steps in detail:

(1) Raw material preparation:

- 80 parts by weight of silicon nitride powder
- 10 parts by weight of boron nitride nanotube powder
- 5 parts by weight of aluminum oxide powder
- 5 parts by weight of yttrium oxide powder

(2) Raw material mixing:

- add the raw materials in step (1) into a ball milling tank
- add alcohol according to a volume ratio of alcohol to raw materials of 1:1
- add steel shot according to a mass ratio of steel shot to raw materials of 10:1
- seal the ball milling tank
- introduce argon gas into the ball milling tank as a protective gas
- ball-mill and mix the raw materials in a planetary ball mill at a rotary speed of 250 rpm with a duration of 10h
- dry the ball-milled raw materials for 10h in a vacuum drying box at a temperature of 75°C
- pass the mixed materials after drying through a 300-mesh sieve

(3) Slurry preparation:

- add the mixed material obtained in step (2) into a stirring machine
- add distilled water with a mass percent of 30%
- add water solution with a mass percent of 0.3%
- stir the raw materials at a rotary speed of 250r/min for 1 h

(4) Grouting molding:

- inject the slurry obtained in step (3) into a molding gypsum die for the spout of the SBM
- pour excessive slurry in the die after a slurry layer is thickened to 10mm
- centrifuge the model with a blank after the slurry is poured

(5) Drying demoulding:

- place the model with a blank obtained in step (4) into a drying room at a temperature of 53+/-3°C
- demould the model with a blank after a grouting opening is separated from the blank by 1 mmto obtain a blank of the shot flowing tube
- the drying time of the model with a blank is 3/5 of the slurry charging time

(6) Vacuum sintering:

- place the blank of the spout obtained in step (5) in a die of the spout
- place into a vacuum thermal pressing sintering furnace with a vacuum degree of 10^{-2}Pa and a temperature rising process consisting of:
- manually heat to 200°C
- heat to 1100°C at a rate of 10°C/min
- maintain temperature for 30min
- heat to 1750°C at a rate of 7°C/min
- maintain temperature for 1 h
- this results in obtaining a Si_3N_4/BNNT composite ceramic liner of the spout after a workpiece is cooled to room temperature in the furnace

(7) Composite casting:

- load the Si_3N_4/BNNT composite ceramic liner of the spout obtained in step (6) into a casting sandbox of the spout
- pour with molten iron after die assembly to wrap an iron casting onto the outer wall of the ceramic spout
- this results in obtaining the composite spout of the SBM with outer side of cast iron and the inside of Si_3N_4/BNNT composite ceramic.

7. The preparation method of a composite spout of a WBM according to claim 1, comprising the steps in detail:

(1) Raw material preparation:

- 82 parts by weight of silicon nitride powder
- 8 parts by weight of boron nitride nanotube powder
- 6 parts by weight of aluminum oxide powder
- 4 parts by weight of yttrium oxide powder

(2) Raw material mixing:

- add the raw materials in step (1) into a ball milling tank
- add alcohol according to a volume ratio of alcohol to raw materialsof 1:1
- add steel shot according to a mass ratio of steel shot to raw materials of 9:1
- seal the ball milling tank
- introduce argon gas into the ball milling tank as a protective gas
- ball-mill and mix the raw materials in the planetary ball mill at a rotary speed of 250 rpm for a duration of 8h

- dry the ball-milled raw materials for 12h in a vacuum drying box at a temperature of 85°C
- pass the mixed materials after drying through a 300-mesh sieve

(3) Slurry preparation:

- add the mixed material obtained in step (2) into a stirring machine
- add distilled water with a mass percent of 32%
- addsodium carbonate with a mass percent of 0.4%
- stir the raw materials at a rotary speed of 250r/min for 1.5h

(4) Grouting molding:

- inject the slurry obtained in step (3) into a molding gypsum die for the spout of the SBM
- pour excessive slurry in the die after a slurry layer is thickened to 10mm
- centrifuge the model with a blank after the slurry is poured

(5) Drying demoulding:

- place the model with a blank obtained in step (4) into a drying room at a temperature of 53+/-3°C
- demould the model with a blank after a grouting opening is separated from the blank by 1 mm which results in a blank of the spout
- the drying time of the model with a blank is 1/2 of the slurry charging time

(6) Vacuum sintering:

- place the blank of the spout obtained in step (5) in a die of the spout
- place into a vacuum thermal pressing sintering furnace at a vacuum degree of 10^{-2}Pa
- the temperature rising process consists of:
- manually heat to 200°C
- heat to 1100°C at a rate of 10°C/min
- maintain temperature for 30min
- heat to 1780°C at a rate of 7°C/min
- maintain the temperature for 1 h
- this results in obtaining a Si_3N_4/BNNT composite ceramic liner of the spout after the workpiece is cooled to room temperature in the furnace

(7) Composite casting:

- load the Si_3N_4/BNNT composite ceramic liner of the spout obtained in step (6) into a casting sandbox of the spout
- pour with molten iron after die assembly to wrap an iron casting onto the outer wall of the ceramic spout
- this results inobtaining the composite spout of the SBM with outer side of cast iron and the inside of Si_3N_4/BNNT composite ceramic.

8. The preparation method of a composite spout of a SBM according to claim 1, comprising the steps in detail:

(1) Raw material preparation:

- 85 parts by weight of silicon nitride powder
- 5 parts by weight of boron nitride nanotube powder
- 4 parts by weight of aluminum oxide powder
- 3 parts by weight of yttrium oxide powder

(2) Raw material mixing:

- add the raw materials in step (1) into a ball milling tank
- add alcohol according to a volume ratio of alcohol to raw materials of 1:1
- add steel shot according to a mass ratio of steel shot to raw materials of 15:1

- seal the ball milling tank
- introduce argon gas into the ball milling tank as a protective gas
- ball-mill and mix the raw materials in a planetary ball mill with a rotary speed of 200 rpm for a duration of 12h
- dry the ball-milled raw materials for 12h in a vacuum drying box at a temperature of 75°C
- pass the mixed materials after drying through a 300-mesh sieve

(3) Slurry preparation:

- add the mixed material obtained in step (2) into a stirring machine
- add distilled water with a mass percent of 35%
- add a combination of sodium phosphate and sodium hexametaphosphate with a mass percent of 0.5% and where the mass ratio of sodium phosphate to sodium hexametaphosphate is 1:1
- stir the raw materials at a rotary speed of 300r/min for a duration of 1 h

(4) Grouting molding:

- inject the slurry obtained in step (3) into a molding gypsum die for the spout of the SBM
- pour excessive slurry in the die after a slurry layer is thickened to 10mm
- centrifuge the model with a blank after the slurry is poured

(5) Drying demoulding:

- place the model with a blank obtained in step (4) into a drying room at a temperature of 53+/-3°C
- demould the model with a blank after a grouting opening is separated from the blank by 1 mmto obtain a blank of the spout
- the drying time of the model with a blank is 2/5 of the slurry charging time

(6) Vacuum sintering:

- place the blank of the spout obtained in step (5) in a die of the spout
- place into a vacuum thermal pressing sintering furnace where the vacuum degree is 10^{-2}Pa
- the temperature rising process consists of:
- manually heat to 200°C
- heat to 1100°C at a rate of 10°C/min
- maintain temperature for 30min
- heat to 1800°C at a rate of 7°C/min
- maintain temperature for 1 h
- this results in obtaining a Si_3N_4/BNNT composite ceramic liner of the shot flowing tube after a workpiece is cooled to room temperature in the furnace

(7) Composite casting:

- load the Si_3N_4/BNNT composite ceramic liner of the spout obtained in step (6) into a casting sandbox of the spout
- pour with molten iron after die assembly to wrap an iron casting onto the outer wall of the ceramic spout
- this results in obtaining the composite spout of the SBM with outer side of cast iron and the inside of Si_3N_4/BNNT composite ceramic.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2015/096787

A. CLASSIFICATION OF SUBJECT MATTER

B24C 5/00 (2006.01) i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

B24C; B22F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

CNPAT; CNKI; CNTXT; VEN: shot, blasting, ball, shooter, pipe, tube, wear, resistant, wearproof, silicon, nitride, ceram+, boron, nitride, borazon, nano+, nano tube, grind, sinter+, powder, liner, composition, mould, cacuum

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	CN 102021469 A (SHANDONG KAITAI SHOT BLASTING MACHINERY CO., LTD.) 20 April 2011 (20.04.2011) see description, paragraphs [0010]-[0015]	1-8
A	CN 201881277 U (SUZHOU TENGFA GROUP CO., LTD.) 29 June 2011 (29.06.2011) see the whole document	1-8
A	CN 102703851 A (LIAONING TECHNICAL UNIVERSITY) 03 October 2012 (03.10.2012) see the whole document	1-8
A	CN 103817607 A (JIANGSU JIULIAN METALLURG MACHINERY CO., LTD.) 28 May 2014 (28.05.2014) see the whole document	1-8
A	GB 1479589 A (BORAX CONS LTD.) 13 July 1977 (13.07.1977) see the whole document	1-8
A	RU 106580 U1 (UNIV MAGN TECH) 20 July 2011 (20.07.2011) see the whole document	1-8

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&"document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
04 May 2016	31 May 2016

Name and mailing address of the ISA	Authorized officer
State Intellectual Property Office of the P. R. China No. 6, Xitucheng Road, Jimenqiao Haidian District, Beijing 100088, China Facsimile No. (86-10) 62019451	YU, Shu Telephone No. (86-10) 62089482

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2015/096787

Patent Documents referred in the Report	Publication Date	Patent Family	Publication Date
CN 102021469 A	20 April 2011	CN 102021469 B	16 January 2013
CN 201881277 U	29 June 2011	None	
CN 102703851 A	03 October 2012	CN 102703851 B	30 July 2014
CN 103817607 A	28 May 2014	CN 103817607 B	20 January 2016
GB 1479589 A	13 July 1977	JPS 50111111 A	01 September 1975
		DE 2451774 A1	07 May 1975
		FR 2249854 A1	04 July 1975
RU 106580 II1	20 July 2011	None	

Form PCT/ISA /210 (patent family annex) (July 2009)