

Composite multi-layer pipe and preparation method thereof

Technical Field

The present invention belongs to the field of concrete engineering machinery, in particular to a light-weight wear-resistant composite multi-layer pipe and a preparation method thereof, and more particularly to a light-weight wear-resistant composite multi-layer pipe for concrete pumping equipment and a preparation method thereof.

Background Art

The function of a conveying pipe for a concrete pumping equipment is to convey materials such as concrete. A boom-type concrete pumping truck is a commonly used concrete pumping equipment. Materials are transported to high-rise buildings through long-distance conveying pipes of a pumping truck for aerial concrete pouring operations. In the above working conditions, by reducing the weight of the conveying pipe, the conveying height of concrete can be increased, thereby reducing cost, and obtaining high economic benefits. Some boom-type concrete pumping trucks in the related art use steel conveying pipes, but the steel conveying pipes have a disadvantage of being heavy.

In addition, since the conveying operation of concrete has characteristics of fast flow rate and large flow amounts, the conveyed materials constantly cause large impact, wear, corrosion and other damages to the wall of pipes.

There is a need in the art for better conveying pipes.

Contents of the present invention

The present invention discloses a novel composite multi-layer pipe and a preparation method thereof. The composite multi-layer pipe has the advantages of light weight, good wear resistance and high rigidity.

According a first aspect of the invention there is provided a composite multi-layer pipe, comprising an inner-layer pipe, an outer-layer pipe, and a middle-layer pipe positioned between the inner-layer pipe and the outer-layer pipe;

the inner-layer pipe having a material comprising a SiC particle reinforced aluminum-based composite material;

the middle-layer pipe having a material comprising a foamed aluminum-based material;

the outer-layer pipe having a material comprising an aluminum-lithium alloy.

The inner-layer pipe made of SiC particle reinforced aluminum-based composite material has an advantage of good wear resistance. The middle-layer pipe made of foamed aluminum-based material has an advantage of light weight. The outer-layer pipe made of aluminum-lithium alloy has an advantage of high rigidity. Therefore, the above-mentioned composite multi-layer pipe has advantages of good wear resistance, light weight and high rigidity.

In some embodiments, the SiC particle reinforced aluminum-based composite material is prepared by a method comprising the following steps:

(b1) mixing silicon powder, carbon powder and aluminum-based powder according to a mass ratio of Si: C: Al=37-47: 22-32: 1-5 to obtain a mixed powder;

(b2) placing the mixed powder in a mold and performing hot pressing and sintering to obtain preforms, wherein the preforms have dimensions ranging from 10 mm to 50 mm in at least one direction;

(b3) providing a molten aluminum alloy;

(b4) putting the preform into the molten aluminum alloy so that the preforms decompose and react in the molten aluminum alloy; and

(b5) manufacturing the product of the previous step into a green body by a spray forming technique.

The preforms have dimensions ranging from 10 mm to 50 mm independently in each of at least two mutually perpendicular directions.

The preforms have dimensions ranging from 10 mm to 50 mm independently in each of at least three mutually perpendicular directions.

The preforms have dimensions in three mutually perpendicular directions as follows:

10mm-50mm × 10mm-50mm × 10mm-50mm.

The preforms have dimensions in three mutually perpendicular directions as follows:

20mm-40mm × 20mm-40mm × 20mm-40mm.

In some embodiments, the hot-pressing and sintering is performed under parameters including: a hot-pressing temperature of 230-270°C, a hot-pressing pressure of 35-70 MPa (preferably 52 MPa), and a pressure holding time of 5-15 minutes.

In some embodiments, in step (b4), 5-15 weight parts of the preforms are put into 85-95 weight parts of the molten aluminum alloy.

In some embodiments, the SiC particle reinforced aluminum-based composite material has a 7050 aluminum alloy matrix with SiC particles dispersed therein.

In some embodiments, the SiC particle reinforced aluminum-based composite material has a SiC particle content of 5-10 wt%.

In some embodiments, the foamed aluminum-based material has a porosity of 50-65% (preferably 62.5%).

In some embodiments, the aluminum-lithium alloy is 2195 aluminum-lithium alloy.

In some embodiments, the inner-layer pipe, the middle-layer pipe and the outer-layer pipe have thicknesses of 4-7 mm, 2-4 mm, 2-4 mm, respectively; preferably 5mm, 3mm, 3mm, respectively.

In some embodiments, the composite multi-layer pipe is a concrete conveying pipe for concrete pumping equipment.

In some embodiments, the composite multi-layer pipe is a concrete conveying pipe for a boom-type concrete pumping truck.

In some embodiments, the composite multi-layer pipe has one or more of the following performances:

(1) the inner-layer pipe has a wear rate (ASTM G105-2020 standard test method for conducting wet sand/rubber wheel abrasion tests) of 0.050% to 0.150%;

(2) the multi-layer pipe has a density of 1.8-2.2 g/cm³; and

(3) the multi-layer pipe has a rigidity (deformation ratio) of 80% or more of that of a steel structure having the same specification.

According a second aspect of the invention there is provided a method for preparing the abovementioned composite multi-layer pipe, comprising the following steps:

(a1) providing a green body, wherein said green body having a material comprising a SiC particle reinforced aluminum-based composite material;

(a2) extruding the green body into a pipe by using an extrusion forming device to form an inner-layer pipe;

(a3) placing a middle-layer pipe at an extrusion outlet of the extrusion forming device so that the extruded inner-layer pipe is nested in the middle-layer pipe; and

(a4) nesting the middle-layer pipe in an outer-layer pipe.

In some embodiments, in (a3), the inner-layer pipe and the middle-layer pipe are in an interference fit with an interference amount of 0.5-1.5 mm.

In some embodiments, in (a4), the middle-layer pipe and the outer-layer pipe are in an interference fit with an interference amount of 0.5-1.5mm.

In some embodiments, the middle-layer pipe has a first end and a second end.

in step (a3), along a direction from the first end to the second end, the inner-layer pipe is gradually nested in the middle-layer pipe;

in step (a4), along a direction from the second end to the first end, the middle-layer pipe is gradually nested in the outer-layer pipe.

In some embodiments, in step (a2), the step of extruding forming is characterized in one or more of the following:

- (1) an extrusion ratio of 3-4: 1 is applied;
- (2) an extrusion temperature of from 380°C to 420°C is applied;
- (3) an extrusion speed of 5-15 mm/s is applied;
- (4) an oil-based molybdenum disulfide is used as a lubricant between the pipe and the device during an extrusion process; and
- (5) a friction coefficient at 0.1 to 0.3 is applied between the pipe and the device during an extrusion process.

In some embodiments, the green body is prepared by a method comprising:

- (b1) mixing silicon powder, carbon powder and aluminum-based powder according to a mass ratio of Si: C: Al=37-47: 22-32: 1-5 to obtain a mixed powder;
- (b2) placing the mixed powder in a mold and performing hot-pressing and sintering to obtain preforms;
- (b3) providing a molten aluminum alloy;
- (b4) putting the preforms into the molten aluminum alloy so that the preforms decompose and react in the molten aluminum alloy; and
- (b5) manufacturing the product of the previous step into a green body by a spray forming technique.

In some embodiments, in step (b1), the silicon powder, the carbon powder and the aluminum-based powder are mixed in a mass ratio of Si: C: Al=39-45: 25-30: 1-4.

In some embodiments, in step (b1), the silicon powder, the carbon powder and the aluminum-based powder are mixed in a mass ratio of Si: C: Al=41-43: 26-28: 1-3.

In some embodiments, the hot-pressing and sintering is performed under parameters including: a hot-pressing temperature of 230-270 °C, a hot-pressing pressure of 35-70 MPa (preferably 52 MPa), and a pressure holding time of 5-15 minutes.

In some embodiments, in step (b4), 5-15 weight parts (e.g., 10 weight parts) of the preforms are put into 85-95 weight parts (e.g., 90 weight parts) of the molten aluminum alloy.

In some embodiments, the preforms decomposes into smaller particles in the molten aluminum alloy and become uniformly dispersed in the molten aluminum alloy.

In some embodiments, step (b1) is characterized in one or more of the following:

- (1) the silicon powder has a particle size of 30-40 μm ;
- (2) the carbon powder has a particle size of 5-15 μm ; and
- (3) the aluminum-based powder has a particle size of 40-70 μm .

In some embodiments, in step (b5), the spray forming technique has parameters characterized in one or more of the following:

- (1) a superheat degree of a molten body is kept at from 200°C to 210°C;
- (2) a nitrogen gas is used as an atomizing gas; and
- (3) an atomizing gas pressure of 0.8-0.9 MPa is applied.

In some embodiments, between steps (b4) and (b5) the method further comprises:

adding 0.4 wt% of hexachloroethane into the molten aluminum alloy to perform a refining.

In some embodiments, the middle-layer pipe is prepared by a method comprising:

(c1) nesting a plurality of aluminum-based pipes with each other (matches with each other in a nesting manner), and disposing a foaming agent between adjacent aluminum-based pipes;

(c2) pressing the plurality of aluminum-based pipes along a thickness direction thereof with a press ratio of 1.2 to 2; and

(c3) heating the pressed pipes to 600-700°C to make the foaming agent foam and form a foam structure.

In some embodiments, step (c3) comprises:

providing a heating device, in which the heating device comprises a heating chamber, and said heating chamber comprising a first temperature zone, a second temperature zone, a third temperature zone, a fourth temperature zone and a fifth temperature zone along a direction from an inlet to an outlet of the heating chamber, the temperature zones respectively have temperatures of 250-350°C, 400-500°C, 600-700°C, 400-500°C, 250-350°C in sequence; and

moving a pipe at a preset speed along a direction parallel to a length of the pipe so that a product of the previous step enters from an inlet of the heating chamber, is heated in the heating chamber, and finally leaves an outlet of the heating chamber.

In some embodiments, the first temperature zone, the second temperature zone, the third temperature zone, the fourth temperature zone and the fifth temperature zone respectively have lengths of: 15-25 mm, 25-35 mm, 35-45 mm, 25-35mm, 15-25 mm in sequence, and the pipes move at a speed of 3-5 mm/min.

In some embodiments, in step (c1), said plurality of aluminum-based pipes are 3 to 5 aluminum-based pipes.

In some embodiments, in step (c1), said foaming agent is TiH_2 powder.

In some embodiments, a method for making a composite multi-layer pipe comprises:

preparing a foamed aluminum middle-layer pipe by extrusion and stacking in combination with high-temperature foaming technique;

providing an aluminum-lithium alloy pipe as an outer-layer pipe;

using an aluminum-silicon alloy as a matrix phase, using SiC particles as a reinforcing phase, preparing a green body (e.g., an ingot) by a spray deposition technique;

processing the green body into a silicon carbide-reinforced aluminum-based composite material pipe by an extrusion forming technique, which is used as an inner-layer pipe;

rigidly fixing the foamed aluminum middle-layer pipe at an outlet of an extrusion forming device, and matching the middle-layer pipe with the inner-layer pipe in a nesting manner by interference fit; and

matching an outer-layer pipe with the rigidly fixed middle-layer pipe in a nesting manner by interference fit.

The foamed aluminum middle-layer pipe matches with the inner-layer pipe and the outer-layer pipes in a nesting manner by interference fit, forming a prestress which can effectively resist the load and impact energy in the process of concrete transportation.

Terminology description:

When the present invention uses the following terms, they may have the following meanings:

Various relative terms such as "front", "rear", "top" and "bottom", "upper", "lower", "over", "below" and the like may be used to facilitate the description of the various embodiments. Relative terms are defined with respect to the conventional orientation of the structure and do not necessarily indicate the actual orientation of the structure at the time of manufacture or use.

As used in the description and the appended claims, the singular forms "a," "an," and "the" include plural referents unless the context clearly dictates otherwise.

Beneficial effects

One or more embodiments of the present disclosure have one or more of the following beneficial effects.

(1) In some embodiments, the inner-layer pipe has SiC particle reinforced aluminum-based composite material. The inner-layer pipe has improved wear resistance and toughness.

(2) In some embodiments, the middle-layer pipe has foamed aluminum-based material. Having a density about one tenth of that of steel materials, the usage of foamed aluminum can significantly reduce the weight of the multi-layer pipe. The foamed aluminum has the properties including good impact resistance, shock resistance and energy absorption. The usage of foamed aluminum can effectively reduce the impact load to the inner-layer pipe.

(3) In some embodiments, the outer-layer pipe comprises an aluminum-lithium alloy. The aluminum-lithium alloy outer-layer can enhance the rigidity of the multi-layer pipe, which is beneficial for stable and fixed installation of the multi-layer pipe in various working scenarios, and ensures the stable operation of the composite multi-layer pipe and prevents the buckling and deformation of the conveying pipe due to insufficient rigidity.

(4) In some embodiments, a green body is prepared by a spray deposition method, and then the inner-layer pipe is prepared by an extrusion method, therefore the inner-layer pipe has enhanced strength and toughness.

(5) In some embodiments, the inner-layer pipe has an interference fit with the middle-layer pipe, and the middle-layer pipe has an interference fit with the outer-layer pipe. The interference fit is beneficial for enhancing the overall performance of the composite material conveying pipe.

Brief Description of the Drawings

Figure 1 shows a schematic cross-sectional view of a composite multi-layer pipe of an example.

Figure 2 shows a schematic diagram of matching the inner-layer pipe, the middle-layer pipe, and the outer-layer pipe in a nesting manner according to some examples.

Figure 3 shows a schematic diagram of the preparation of middle-layer pipe in some examples.

Specific Models for Carrying Out the present invention

The embodiments of the present invention will be described in detail below in conjunction with the examples, but those skilled in the art will understand that the following examples are only used to illustrate the present invention, and should not be regarded as limiting the scope of the present invention. If the specific conditions are not indicated in the examples, they are carried out according to the conventional conditions or the conditions suggested by the manufacturer. The reagents or instruments used without the manufacturer's indication are conventional products commercially available in the market.

Example 1

Figure 1 shows a schematic view of the composite multi-layer pipe of Example 1. As shown in Figure 1, the multi-layer pipe comprised an inner-layer pipe 1, an outer-layer pipe 3, and a middle-layer pipe 2 located between the inner-layer pipe 1 and the outer-layer pipe 3; the inner-layer pipe 1 had a material comprising a SiC particle reinforced aluminum-based composite material; the middle-layer pipe 2 had a material comprising a foamed aluminum-based material; and the outer-layer pipe 3 had a material comprising an aluminum-lithium alloy.

The preparation method of the above-mentioned multi-layer pipe was described in detail below:

1) Preparation of 8.5%SiC/7050 aluminum-based composite:

Silicon powder (particle size of 35 μ m, purity of 98.5%), carbon powder (particle size of 9 μ m, purity of 99.5%), aluminum powder (particle size of 55 μ m, purity of 98.5%) were mixed according to a mass ratio of Si: C: Al=42: 27: 2, the total mass of the three was 4 kg, and a mixed powder was obtained.

The mixed powder was placed in a mold and subjected to a hot-pressing treatment with a 320-ton hydraulic press. The heating temperature of the hot-pressing treatment was 250°C, the

hot-pressing pressure was 52 MPa, and the pressure-holding time was 10 minutes, and preforms with dimensions of 30×30×30 mm were obtained.

According to the composition ratio of the 7050 aluminum alloy, 40kg of 7050 aluminum alloy was smelted in an intermediate frequency induction furnace to obtain a molten alloy with a temperature of 925°C.

A graphite bell jar was used to press 4 kg of the preforms into the molten alloy, and heat was preserved for 15 minutes so that the preforms decomposed and reacted in the molten aluminum alloy. Then hexachloroethane was added to the solution in an amount of 0.4% for refining.

A spray forming technique was applied to manufacture the product of previous step into a green body made of SiC particle reinforced aluminum alloy composite material. The composite-material green body had a SiC content of 8.5 wt%, which was referred to as “8.5% SiC/7050 aluminum-based composite material” for short. The dimension of the composite material green body was Φ150mm×800mm. The specific parameters of spray forming process were as follows: the superheat degree of the solution was kept at 205°C, the pressure of the atomizing gas (nitrogen) was 0.85MPa, the jet height was 250mm, the impeller rotation speed was 310r/min, and the catheter diameter was 4.2mm.

2) Preparation of foamed aluminum middle-layer pipe:

Four pure-aluminum pipes (No. L2) with layer thicknesses of 2mm were provided. The outer diameters of the four aluminum pipes decreased sequentially so that they could be matched with each other in a nesting manner with a gap of 0.5mm. The four aluminum pipes were subjected to surface treatment to remove grease and oxide film on the surface.

Foaming agent TiH_2 powder (300 mesh), in an amount of 1.5% by weight of the pure aluminum pipes, was combined with an appropriate amount of binder, then was evenly coated on the outer surfaces of the three inner layer pure aluminum pipes, and the four pure aluminum pipes were matched together in a nesting manner. The four pipes matched in a nesting manner were extruded firstly with an extrusion ratio of 1.5: 1 (the ratio of the pipe cross-sectional areas before and after extrusion was 1.5: 1), and a to-be-foamed pipe was obtained.

Figure 2 shows a schematic diagram of the preparation of middle-layer pipe in some examples.

A pipe induction heating device 30 was provided. The device had an outer-ring induction heating device and an inner-ring-core induction heating device. The pipe induction heating device 30 comprised a heating chamber 35, and along the direction from an inlet to an outlet of

the heating chamber 35, the heating chamber 35 comprised a first temperature zone 301, a second temperature zone 302, a third temperature zone 303, a fourth temperature zone 304 and a fifth temperature zone 305 arranged in sequence, the temperatures of these temperature zones were 300°C, 450°C, 650°C, 450°C, 300°C, respectively; the lengths of these temperature zones were 20mm, 30mm, 40mm, 30mm, 20mm, respectively.

The to-be-foamed pipe 20 was moved along a length direction of the pipe 20 at a speed of 4 mm/min, the pipe entering, passing through, and leaving the heating chamber 35 of the pipe induction heating device 30. The to-be-foamed pipe 20 was foamed mainly in the third temperature zone 303 (having a temperature of 650°C). Based on the above process parameters, the time to pass through the third temperature zone for the to-be-foamed pipe 20 was 10 minutes.

A foamed aluminum middle-layer pipe was obtained from the outlet of the heating device 30.

3) Providing aluminum-lithium alloy outer-layer pipe:

Commercially available extruded 2195 aluminum-lithium alloy pipe was used.

4) Extruding, nesting and forming:

The green body made of a wear-resistant SiC particle reinforced aluminum-based composite material was extruded to form an inner-layer pipe by an extrusion forming technique. The extrusion ratio of the extrusion forming was set to 3.2: 1, the extrusion temperature was 405°C, the extrusion speed was 10 mm/s, oil-based molybdenum disulfide was used for lubrication, and the friction coefficient was controlled to 0.2. The inner-layer pipe was extruded from the extrusion outlet.

Figure 3 shows a schematic diagram for matching the inner-layer pipe 1, the middle-layer pipe 2, and the outer-layer pipe 3 in a nesting manner in some examples.

The foamed aluminum middle-layer pipe 2 was rigidly fixed at the extrusion outlet, and the extruded inner-layer pipe 1 nested into the middle-layer pipe 2 from a first end of the middle-layer pipe 2, and the two were matched in a nesting manner by interference fit (with an interference amount of 1.3mm).

At the same time, an aluminum-lithium alloy outer-layer pipe 3 was matched with the foamed aluminum middle-layer pipe 2 rigidly fixed at the extrusion outlet in a nesting manner (in a direction from the second end to the first end of the middle-layer pipe 2), and the two were matched in a nesting manner by interference fit (with an interference amount of 0.9mm).

The foamed aluminum middle-layer pipe 2 was in interference fit with the inner-layer pipe 1 and the outer-layer pipe 3 respectively, forming a prestress, which could effectively resist the load and impact energy during the concrete conveying process.

The dimensional parameters of the composite multi-layer pipe were as follows:

Table 1

Inner diameter	122mm
Outer diameter	133mm
Wall thickness of inner-layer pipe	5mm
Wall thickness of middle-layer pipe	3mm
Wall thickness of out-layer pipe	3mm

Comparative Example 1

The difference between Comparative Example 1 and Example 1 lied in step (1), that was, the preparation process of the 8.5% SiC/7050 aluminum-based composite material.

The scheme of step (1) of Comparative Example 1 was as follows:

Silicon powder (particle size of 35 μ m, purity of 98.5%), carbon powder (particle size of 9 μ m, purity of 99.5%) and aluminum powder (particle size of 55 μ m, purity of 98.5%) were mixed according to a mass ration of Si: C: Al=42: 27: 2, the total mass of the three was 4 kg, and a mixed powder was obtained.

According to the composition of the 7050 aluminum alloy, 40kg of 7050 aluminum alloy was smelted in an intermediate frequency induction furnace, and a molten alloy with a temperature of 925°C was obtained.

4kg of the mixed powder was added to the molten alloy, and the product of the previous step was made into a SiC particle reinforced aluminum alloy composite material green body by a casting forming technique. The composite material green body had a SiC content of 8.5 wt%, which was referred to as 8.5% SiC/7050 aluminum-based composite material for short. The dimension of the composite material green body was Φ 150mm $\times$ 800mm.

The steps (2) to (4) were the same as in Example 1.

Analysis and Test

The multi-layer composite pipes prepared in Example 1 and Comparative Example 1 were tested as follows by referring to the national/industry standard testing methods.

(1) Wear resistance of SiC particle reinforced aluminum alloy composite

In order to compare the wear resistance of the SiC particle reinforced aluminum alloy composite materials of Example 1 and Comparative Example 1, the composite material green bodies of Example 1 and Comparative Example 1 were extruded into pipes by an extrusion forming equipment to form inner-layer pipes herein, and samples were taken from the same position of the pipes and prepared for performance testing and comparison.

With reference to the standard of "ASTM G105-2020 Standard Test Method for Conducting Wet Sand/Rubber Wheel Abrasion Tests", the wear resistance of the products of Example 1 and Comparative Example 1 was tested for three times under the same test conditions and an average value was calculated. The results were as follows:

The wear rate of Example 1 was 0.089%, and the wear rate of Comparative Example 1 was 0.138%. Compared with Comparative Example 1, the wear performance of Example 1 was increased by 35.5%.

At the same time, the wear resistance of the products of Example 1 and Comparative Example 1 was tested through a working condition simulation bench test. Under the same pumping frequency, the wear rate of Example 1 per 10,000 square meters was 15.59%, and the wear rate per 10,000 square meters of Comparative Example 1 was 22.34%. Compared with Comparative Example 1, the wear performance of Example 1 was increased by 30.2%.

(2) strength performance of SiC particle reinforced aluminum alloy composite

In order to compare the strength performance of the SiC particle reinforced aluminum alloy composite materials of Example 1 and Comparative Example 1, the composite material green bodies of Example 1 and Comparative Example 1 were extruded by an extrusion forming device to form inner-layer pipes, and samples were collected at the same position of the pipes and prepared for performance testing and comparison.

Referring to the standard of "GB/T 228.1-2021, Metallic materials—Tensile testing—Part 1: Method of test at room temperature", the strength performance of the products of Example 1 and Comparative Example 1 was tested for three times under the same test conditions and an average value was calculated. The results were as follows:

The tensile strength of Example 1 was 598 MPa, and the tensile strength of Comparative Example 1 was 533 MPa. Compared with Comparative Example 1, the strength performance of Example 1 was increased by 12.2%.

(3) Overall density of composite multi-layer pipe

With reference to the standard of "GB/T 4472-2011, Determination of density and relative density for chemical products", the hydrostatic weighing method (drainage method) was used to measure the densities of the composite multi-layer pipes of Example 1 and Comparative Example 1. The results were as follows:

The density of Example 1 (the whole composite pipe of the present invention) was 2.143g/cm^3 , and the density of Comparative Example 1 was 2.834g/cm^3 . Compared with Comparative Example 1, Example 1 had a weight reduction of 24.4%.

(4) Rigidity (deformation ratio) of composite multi-layer pipe

A cantilever beam constant load test method was used to test the rigidity (deformation ratio) of a steel conveying pipe and composite multi-layer pipes of Example 1 and Comparative Example 1, all of which had the same size and specifications, and the results were as follows.

The deformation amount of the steel conveying pipe was 44.7 mm (a deformation ratio of 1.49%), and the deformation amount of Example 1 (the whole composite pipe of the present invention) was 48.6 mm (a deformation ratio 1.62%).

The deformation amount of Comparative Example 1 was 62.7mm (a deformation ratio of 2.09%). The rigidity (deformation ratio) of Example 1 (the whole composite pipe of the present invention) could reach 92.0% of that of the steel structure, while the rigidity (deformation ratio) of Comparative Example 1 could reach 71.3% of that of the steel structure.

In conclusion, the inner-layer of the multi-layer pipe of the present invention had an improved wear resistance, and the multi-layer pipe had lower overall density and better rigidity.

According to the comparison of the different preparation methods of SiC particle reinforced aluminum alloy composite materials in Example 1 and Comparative Example 1, it could be seen that the method of Example 1, in which the mixed powder of silicon powder, carbon powder and aluminum-based powder was subjected to hot-pressing and sintering to obtain preforms, and then the preforms were added to molten aluminum alloy, and then the product of the previous step was processed by a spray forming technique to form a SiC particle reinforced aluminum alloy composite material green body, had the following advantages.

(1) The prefabricating operation to the mixed powder by hot-pressing and sintering is beneficial for obtaining high-performance SiC particles, and improves the metallurgical bonding effect and strength between SiC particles and aluminum-based powder. This is because that the preforms, which are formed by hot-pressing and sintering of carbon powder, silicon powder and aluminum powder, can be better dispersed and reacted in the subsequent molten aluminum alloy,

a uniformly dispersed reinforcement phase can form in the composite material, and the reinforcement phase is well bound to the matrix.

(2) A specific composition ratio of silicon powder, carbon powder and aluminum-based powder is critical for obtaining a high-quality composite material. The inventors had found through extensive experiments that the weight ratio of silicon powder, carbon powder and aluminum-based powder is preferably Si: C: Al=37-47: 22-32: 1-5, more preferably Si: C: Al=39-45: 24-30: 2-4; more preferably Si: C: Al=41-43: 26-38: 2-3, most preferably Si: C: Al=42: 27: 2.

(3) A composite material with fine grain size and uniform distribution of high-performance microstructure can be formed by spray forming technique.

Based on the above innovative preparation method, the SiC particle reinforced aluminum alloy composite material prepared in the present application has significantly improved wear resistance and strength.

Although specific embodiments of the present invention have been described in detail, those skilled in the art will understand that in light of all the teachings disclosed, various changes of the details can be made and are within the scope of this invention. The full scope of the present invention is given by the appended claims and any equivalents thereof.

What is claimed is:

1. A composite multi-layer pipe, comprising an inner-layer pipe, an outer-layer pipe, and a middle-layer pipe positioned between the inner-layer pipe and the outer-layer pipe;

the inner-layer pipe having a material comprising a SiC particle reinforced aluminum-based composite material;

the middle-layer pipe having a material comprising a foamed aluminum-based material;

the outer-layer pipe having a material comprising an aluminum-lithium alloy;

wherein the SiC particle reinforced aluminum-based composite material is prepared by a method comprising the following steps:

(b1) mixing silicon powder, carbon powder and aluminum-based powder according to a mass ratio of Si: C: Al=37-47: 22-32: 1-5 to obtain a mixed powder;

(b2) placing the mixed powder in a mold and performing hot pressing and sintering to obtain preforms, wherein the preforms having dimensions ranging from 10 mm to 50 mm in at least one direction;

(b3) providing a molten aluminum alloy;

(b4) putting 5-15 weight parts of the preforms into 85-95 weight parts of the molten aluminum alloy so that the preforms decompose and react in the molten aluminum alloy; and

(b5) manufacturing the product of the previous step into a green body by a spray forming technique.

2. The composite multi-layer pipe according to claim 1, characterized in one or more of the following:

(1) the SiC particle reinforced aluminum-based composite material has an aluminum-silicon alloy matrix with SiC particles dispersed therein;

(2) the SiC particle reinforced aluminum-based composite material has a SiC particle content of 5-10 wt%;

(3) the foamed aluminum-based material has a porosity of 50-65%;

(4) the aluminum-lithium alloy is 2195 aluminum-lithium alloy; and

(5) the inner-layer pipe, middle-layer pipe and outer-layer pipe have thicknesses of 4-7mm, 2-4mm and 2-4mm, respectively.

3. The composite multi-layer pipe according to claim 1, wherein the composite multi-layer pipe is a concrete conveying pipe for concrete pumping equipment.

4. The composite multi-layer pipe according to claim 1, wherein the composite multi-layer pipe is a concrete conveying pipe for a boom-type concrete pumping truck.

5. The composite multi-layer pipe according to claim 1, wherein the composite multi-layer pipe has one or more of the following performances:

(1) the inner-layer pipe has a wear rate of 0.050% to 0.150%;

(2) the multi-layer pipe has a density of 1.8-2.2 g/cm³; and

(3) the multi-layer pipe has a rigidity of 80% or more of that of a steel structure having the same specification.

6. A method for preparing the composite multi-layer pipe according to claim 1, comprising the following steps:

(a1) providing a green body, wherein said green body having a material comprising a SiC particle reinforced aluminum-based composite material;

(a2) extruding the green body into a pipe by using an extrusion forming device to form an inner-layer pipe;

(a3) placing a middle-layer pipe at an extrusion outlet of the extrusion forming device so that the extruded inner-layer pipe is nested in the middle-layer pipe; and

(a4) nesting the middle-layer pipe in an outer-layer pipe;

wherein the green body is prepared by a method comprising:

(b1) mixing silicon powder, carbon powder and aluminum-based powder according to a mass ratio of Si: C: Al=37-47: 22-32: 1-5 to obtain a mixed powder;

(b2) placing the mixed powder in a mold and performing hot-pressing and sintering to obtain preforms, wherein the preforms having dimensions ranging from 10 mm to 50 mm in at least one direction;

(b3) providing a molten aluminum alloy;

(b4) putting 5-15 weight parts of the preform into 85-95 weight parts of the molten aluminum alloy so that the preforms decompose and react in the molten aluminum alloy; and

(b5) manufacturing the product of the previous step into a green body by a spray forming technique.

7. The method according to claim 6, characterized in one or more of the following:

in (a3), the inner-layer pipe and the middle-layer pipe are in an interference fit with an interference amount of 0.5-1.5 mm;

in (a4), the middle-layer pipe and the outer-layer pipe are in an interference fit with an interference amount of 0.5-1.5mm.

8. The method according to claim 6, wherein the middle-layer pipe has a first end and a second end;

in step (a3), along a direction from the first end to the second end, the inner-layer pipe is gradually nested in the middle-layer pipe;

in step (a4), along a direction from the second end to the first end, the middle-layer pipe is gradually nested in the outer-layer pipe.

9. The method according to claim 6, wherein in step (a2), the step of extruding forming is characterized in one or more of the following:

(1) an extrusion ratio of 3-4: 1 is applied;

(2) an extrusion temperature of from 380°C to 420°C is applied;

(3) an extrusion speed of 5-15 mm/s is applied;

(4) an oil-based molybdenum disulfide is used as a lubricant between the pipe and the device during an extrusion process; and

(5) a friction coefficient at 0.1 to 0.3 is applied between the pipe and the device during an extrusion process.

10. The method according to claim 6, wherein step (b1) is characterized in one or more of the following:

- (1) the silicon powder has a particle size of 30-40 μm ;
- (2) the carbon powder has a particle size of 5-15 μm ; and
- (3) the aluminum-based powder has a particle size of 40-70 μm .

11. The method according to claim 6, wherein in step (b5), the spray forming technique has parameters characterized in one or more of the following:

- (1) a superheat degree of a molten body is kept at from 200°C to 210°C;
- (2) nitrogen gas is used as an atomizing gas; and
- (3) an atomizing gas pressure of 0.8-0.9 MPa is applied.

12. The method according to claim 6, wherein between steps (b4) and (b5) further comprising: adding 0.4 wt% of hexachloroethane into the molten aluminum alloy to perform a refining.

13. The method according to claim 6, wherein the middle-layer pipe is prepared by a method comprising:

- (c1) nesting a plurality of aluminum-based pipes with each other, and disposing a foaming agent between adjacent aluminum-based pipes;
- (c2) pressing the plurality of aluminum-based pipes along a thickness direction thereof with a press ratio of 1.2 to 2; and
- (c3) heating the pressed pipes to 600-700°C to make the foaming agent foam and form a foam structure.

14. The method according to claim 13, wherein step (c3) comprises:

providing a heating device, in which the heating device comprises a heating chamber, and said heating chamber comprising a first temperature zone, a second temperature zone, a third temperature zone, a fourth temperature zone and a fifth temperature zone along a direction from an inlet to an outlet of the heating chamber, the temperature zones respectively have temperatures of 250-350°C, 400-500°C, 600-700°C, 400-500°C, 250-350°C in sequence; and

moving the pipes at a preset speed along a direction parallel to a length of the pipes so that a product of the previous step enters from an inlet of the heating chamber, is heated in the heating chamber, and finally leaves an outlet of the heating chamber.

15. The method according to claim 14, wherein the first temperature zone, the second temperature zone, the third temperature zone, the fourth temperature zone and the fifth temperature zone respectively have lengths of: 15-25 mm, 25-35 mm, 35-45 mm, 25-35mm, 15-25 mm in sequence, and the pipes move at a speed of 3-5 mm/min.

16. The method according to claim 13, characterized in one or more of the following:

(1) in step (c1), said plurality of aluminum-based pipes are 3 to 5 aluminum-based pipes;

(2) in step (c1), said foaming agent is TiH_2 powder.