

MEDIUM-CARBON LOW-ALLOY STEEL MATERIAL, CONVEYING PIPE, PREPARATION METHOD FOR MEDIUM- CARBON LOW-ALLOY STEEL MATERIAL, AND CONCRETE PUMP TRUCK

Cross-Reference to Related Applications

The present application claims the priority right of the Chinese patent application No. 202211490716.5, entitled "MEDIUM-CARBON LOW-ALLOY STEEL MATERIAL, CONVEYING PIPE, PREPARATION METHOD FOR CONVEYING PIPES, AND CONCRETE PUMP TRUCK" filed on Nov. 25, 2022, which is incorporated herein with reference in its entirety.

Technical Field of the Invention

The present application relates to the field of engineering machinery materials, in particular, to a medium-carbon low-alloy steel material, a conveying pipe, a preparation method for the conveying pipe and a concrete pump truck.

Background Art of the Invention

A conveying pipe is a quick-wear part of concrete pump trucks and it is primarily used for conveying of concrete materials. The conveying pipe bears high-pressure and high-speed impacts of concrete during work, and it is required to have high wear resistance, good strength and impact resistance. Pipe bursting and wears are principal failure forms of the conveying pipe, which will directly affect the service life. Due to an insufficient service life, the conveying pipe is frequently replaced, which not only produces impacts on construction periods but also increases use costs, thereby influencing the competitiveness of products in the market.

The conveying pipes are mainly classified into single-layer pipes and double-layer pipes, wherein the double-layer pipes, according to different materials of inner

pipes thereof, can be classified into alloy steel pipe, high-chromium cast iron pipes and ceramic pipes. The double-layer pipes, due to high wear resistance, are primarily used as pump trucks conveying pipes of 40m and more than 40 m. While the single-layer pipes have inferior wear resistances to the double-layer pipes, they, due to low prices and simple preparation processes, are widely used as pump trucks conveying pipes of less than 40 m-long.

In the industry, the single-layer conveying pipes are prepared by inductively quenching the inner wall of a seamless pipe of medium carbon manganese steel (40Mn2, 50Mn, NM55, NM62), and they have a quenching hardened layer thick in about 2.8 mm, and an inner wall hardness between 55 and 60 HRC, an overall tensile strength of about 800 MPa, an impact power of about 20 J, and a C30 concrete-pumping service life of about 30,000 squares.

While current single-layer pipes have undergone inductively quenching treatment, internal wall surfaces can achieve a relatively high hardness, they also have the following defects: (1) the conveying pipes are subjected to inductively quenching and water-spraying cooling, and thus there are large residual stresses in the interiors, which easily lead to deformations and cracks. (2) The conveying pipes have relatively low strength and impact power, and a poor ability of resisting concrete-impact deformations, which results in quick wears of the inlets of the conveying pipes under strong concrete impacts. (3) A hardness gradient is present from the inner wall to the outer wall of the conveying pipes, and once the quenching hardened layer is worn, the base body will be quickly worn due to low hardness. (4) A straight pipe 1' and an end flange 2' of the conveying pipes are connected in a welding form, and a wear-resistant sleeve 3' is disposed inside the end flanges; as shown in FIG. 1, the material of the straight pipe uses a medium carbon manganese steel which is high in the carbon equivalent and ready to crack upon welding, and early failures will be raised.

Summary of the Invention

The present application provides a medium-carbon low-alloy steel material, a conveying pipe, a preparation method for the conveying pipe and a concrete pump truck, to solve the problem that conveying pipes are quickly worn.

A first aspect of the present application provides a medium-carbon low-alloy steel material which is made up of the following chemical components in mass fraction: C: 0.55-0.60%, Mn: 0.80-1.40%, Si: $\leq 0.3\%$, Cr: 0.2-0.4%, Ni: 0.2-0.4%, P: $\leq 0.020\%$, S: $\leq 0.020\%$, Ti: 0.04-0.10%, V: 0.05-0.15%, Re: 0.001-0.003%, and the balance being Fe.

Further, the above Re is any one selected from lanthanum, cerium, praseodymium, and neodymium or a combination of more of them.

A second aspect of the present application provides a conveying pipe, comprising a pipe body, the pipe body being prepared by integrally forming any one medium-carbon low-alloy steel material of the above first aspect.

Further, the pipe body has a hardness between 40 HRC and 45 HRC, and/or a tensile strength ≥ 1300 MPa, and/or an impact powder ≥ 50 J, and/or a microstructure being a tempered martensite.

Further, the pipe body comprises a straight pipe and two end flanges, the two end flanges being integrally formed with the straight pipe and arranged at the two ends of the straight pipe in a one-to-one form.

Furthermore, the conveying pipe further comprises a wear-resistant sleeve, the wear-resistant sleeve being arranged in the inner cavity of the end flanges and in an interference fit with the end flanges.

A third aspect of the present application provides a preparation method for any one of the above conveying pipes, the method comprising: preparing a medium-carbon

low-alloy steel material with a raw material made up of the following chemical components in mass fraction: C: 0.55%-0.60%, Mn: 0.80%-1.40%, Si: $\leq 0.3\%$, Cr: 0.2%-0.4%, Ni: 0.2%-0.4%, P: $\leq 0.020\%$, S: $\leq 0.020\%$, Ti: 0.04%-0.10%, V: 0.05-0.15%, Re: 0.001%-0.003%, and the balance being Fe, the medium-carbon low-alloy steel material being a seamless steel pipe; and successively subjecting the seamless steel pipe to size-fixed saw cutting, end flange-forming processing and a heat treatment, to obtain a conveying pipe, the heat treatment comprising heating, thermal insulating, primary cooling and secondary cooling which are conducted successively, wherein the cooling speed of the primary cooling is from 25 °C/s to 35 °C/s, and the cooling speed of the secondary cooling is lower than that of the primary cooling.

Further, the step of the end flange-forming processing comprises an upsetting treatment and a cutting processing, which are successively conducted to form an end flange.

Further, the upsetting treatment comprises, after heating the ends of the seamless steel pipe to 1100 °C -1200 °C, upsetting them to a target thickness.

Further, the upsetting treatment comprises, after inductively heating the ends of the seamless steel pipe to 1100 °C -1200 °C, upsetting them to a target thickness with a hydraulic press.

Further, the heat treatment comprises: heating a workpiece obtained from the end flange forming treatment to 850 °C -880 °C and thermally insulating it for 1 hour-2 hours; after the thermal insulating is finished, conducting the primary cooling, the primary cooling is preferably accomplished by using a forcible cooling, the forcible cooling preferably being a wind cooling or an oil cooling; after the primary cooling is conducted to 200 °C -150 °C, conducting the secondary cooling, in secondary cooling residual heat is utilized for self-tempering, the secondary cooling preferably being an air cooling.

Furthermore, the conveying pipe further comprises a wear-resistant sleeve, and the preparation method further comprises the process of compression fitting the wear-resistant sleeve at the two ends of the workpiece obtained after the heat treatment.

Further, the preparation method, after compression fitting the wear-resistant sleeve, further comprises the processes of shot blasting and powder spraying coating, and a temperature of the powder spraying coating is preferably from 150 °C to 200 °C.

Further, the process of preparing the medium-carbon low-alloy steel material comprises the processes of smelting, casting, piercing, pipe rolling, sizing and straightening the raw material.

A fourth aspect of the present application provides a concrete pump truck, comprising a conveying pipe which is any one conveying pipe of the second aspect of the present application.

In the present application, the presence of C can increase a strength of the steel, whereas excessive carbon will greatly increase a hardness of the steel, further to increase a processing difficulty. When the C is in a mass fraction between 0.55% and 0.60%, it can increase the strength of the steel and make the hardness in a range suitable for subsequent processing. Si is an effective deoxygenating element, whereas with a too high silicon content, it will reduce a toughness of the steel, and thus the mass fraction of the Si is selected to be $\leq 0.3\%$. Mn, with a mass fraction in the range of 0.80%-1.40%, can increase the strength and the toughness at the same time. Cr, with the mass fraction controlled from 0.2 % to 0.4%, can increase the hardenability of the steel, further increase the hardness uniformity of conveying pipes formed thereby and reduce the hardness gradient. V has the effects of precipitation hardening and refining grains, and it can significantly

increase the strength and the toughness. Ti can form Ti(CN) with carbon and nitrogen in the steel, and it can refine grains whilst significantly increasing the hardenability, strength and toughness of the steel. Rare earth element Re can refine grains, purify grain boundaries and improve toughness. P and S are impurity elements, and both of them are controlled in a content not more than 0.020%. Thus, for the medium-carbon low-alloy material of the present application, on the basis of controlling the contents of these principal chemical components C, Mn, Si, Cr and Ni, by further utilizing traces of alloying elements Ti, V and Re and controlling their respective contents, a goal of increasing the toughness and wear resistance of the material is realized and therefore further increasing an impact resistance of the conveying pipes formed with this material and mitigating the wears thereon.

Brief Description of the Drawings

To more clearly illustrate the technical solutions of the examples of the present application, the drawings desirably used in the examples of the present application will be briefly described below. Obviously, the drawings described below are only some examples of the present application, and for those skilled in the art, other drawings can be obtained according to the drawings without paying any creative efforts.

FIG. 1 is a diagram for showing the sectional structure of conveying pipes in the prior art.

FIG. 2 is a diagram for showing the sectional structure of the conveying pipe according to one embodiment of the present application.

FIG. 3 is a drawing for showing the metallographic structure of the conveying pipe of Example 1 of the present application.

FIG. 4 is a drawing for showing the metallographic structure of the conveying pipe of Comparative Example 10 of the present application.

In the drawings, the drawings are not plotted according to actual scales.

Illustrations of reference symbols

1'. a straight pipe; 2'. an end flange; 3'. a wear-resistant sleeve.

1. a tube body; 11. a straight pipe; 12. an end flange; 2. a wear-resistant sleeve.

Detailed Description of the Invention

Embodiments of the present application will be further described below in detail with references to the drawings and the examples. The following detailed depictions to the examples and the drawings are used for illustratively illustrating the principles of the present application, but not for limiting the scope of the present application. That is, the present application is not limited to the described examples.

As analyzed in the background art of the present application, the conveying pipes have relatively low strength and impact power, and a poor ability of resisting concrete-impact deformations, which results in quicker wears of the inlets of the conveying pipes under strong concrete impacts. In order to solve the problem, the present application attempts to improve an impact resistance of the conveying pipes from the perspective of optimizing element composition, further to mitigate wears thereon. Based on this, the present application provides a medium-carbon low-alloy steel material, a conveying pipe, a preparation method for the conveying pipe and a concrete pump truck.

In one typical embodiment of the application, a medium-carbon low-alloy steel material is provided, which is made up of the following chemical components in mass fraction: C: 0.55%-0.60%, Mn: 0.80%-1.40%, Si: $\leq 0.3\%$, Cr: 0.2%-0.4%, Ni: 0.2%-0.4%, P: $\leq 0.020\%$, S: $\leq 0.020\%$, Ti: 0.04%-0.10%, V: 0.05%-0.15%, Re: 0.001%-0.003%, and the balance being Fe.

The presence of C can increase the strength of a steel, whereas excessive carbon will greatly increase a hardness of the steel, further to increase a processing difficulty. When the C is in a mass fraction between 0.55% and 0.60%, it can increase the strength of the steel and make the hardness in a range suitable for

subsequent processing. Si is an effective deoxygenating element, whereas with a too high silicon content, it will reduce the toughness of the steel, and thus the mass fraction of the Si is selected to be $\leq 0.3\%$. Mn, with a mass fraction in the range of $0.80\%-1.40\%$, can increase the strength and the toughness at the same time. Cr, with the mass fraction controlled from 0.2% to 0.4% , can increase the hardenability of the steel, further increase the hardness uniformity of conveying pipes formed thereby and reduce the hardness gradient. V has the effects of precipitation hardening and refining grains, and it can significantly increase the strength and the toughness. Ti can form Ti(CN) with carbon and nitrogen in the steel, and it can refine grains whilst significantly increasing the hardenability, strength and toughness of the steel. Rare earth element Re can refine grains, purify grain boundaries and improve toughness. P and S are impurity elements, and both of them are controlled in a content not more than 0.020% . Thus, for the medium-carbon low-alloy material of the present application, on the basis of controlling the contents of these principal chemical components C, Mn, Si, Cr and Ni, by further utilizing traces of alloying elements Ti, V and Re and controlling their respective contents a goal of increasing the toughness and wear resistance of the material is realized, and therefore further increasing the impact resistance of the conveying pipes formed with this material and mitigating the wears thereon.

In some embodiments, the rare earth element Re may be any one selected from lanthanum, cerium, praseodymium, and neodymium or a combination of more of them, further to better refine grains, purify grain boundaries and improve toughness of steels.

In another typical embodiment of the present application, a conveying pipe is further provided, which comprises a pipe body, the pipe body being prepared by integrally forming any one of the above medium-carbon low-alloy steel materials.

As described above, for the medium-carbon low-alloy material of the present application, on the basis of controlling the contents of these principal chemical

components C, Mn, Si, Cr and Ni, by further utilizing traces of alloying elements Ti, V and Re and controlling their respective contents, the goal of increasing the toughness and wear resistance of the material is realized, and therefore further increasing the impact resistance of the conveying pipes formed with this material and mitigating the wears thereon.

In some embodiments, the pipe body has a hardness between 40 HRC and 45 HRC, and/or a tensile strength ≥ 1300 MPa, and/or an impact energy ≥ 50 J, and/or a microstructure being a tempered martensite.

Therein, when the hardness of the pipe body is between 40 HRC and 45 HRC, on one hand, the pipe body has a relatively high overall hardness, and on the other hand, the pipe body, as a whole, does not have an evident hardness gradient. Hence, the problem about the quick wears of the pipe body will not be raised due to the wears of the surface quenching hardened layer.

When the tensile strength of the pipe body is ≥ 1300 MPa, the machinability of the pipe body is improved. Thus, connecting an end flange and a straight pipe does not necessarily depend on a welding process, and the flanges may be manufactured at the end by utilizing an integral forming process, further avoiding the problem about the early failure of the conveying pipe which is raised due to welding cracking.

When the impact energy of the pipe body is ≥ 50 J, the ability of the conveying pipe of resisting concrete-impact deformations is stronger, thereby effectively improving the wear-resisting ability of the inlet end of the conveying pipe and making the service life of the conveying pipe reach more than 50,000 squares.

When the microstructure is the tempered martensite, the pipe body has relatively high hardness and wear resistance, and due to low internal stress of the tempered martensite structure, the toughness of the pipe body is improved.

In some embodiments of the present application, refer to FIG. 2, the pipe body 1 comprises a straight pipe 11 and two end flanges 12, the two end flanges 12 being integrally formed with the straight pipe 11 and arranged at the two ends of the straight pipe 11 in a one-to-one form.

By utilizing an integral forming process to produce the end flanges at the end, the problem about the early failure of the conveying pipe which is raised due to cracking at the welding positions when the end flanges and the straight pipe are connected in a welding form is avoided.

In some embodiments of the present application, refer to FIG. 2, the conveying pipe further comprises a wear-resistant sleeve 2, the wear-resistant sleeve 2 being arranged in the inner cavity of the end flanges 12 and in an interference fit with the end flanges 12. The arrangement of the wear-resistant sleeve improves the wear-resisting ability of the inlet.

In another typical embodiment of the present application, a preparation method for any one of the conveying pipes is provided, which comprises:

preparing a medium-carbon low-alloy steel material with a raw material made up of the following chemical components in mass fraction: C: 0.55%-0.60%, Mn: 0.80%-1.40%, Si: $\leq 0.3\%$, Cr: 0.2%-0.4%, Ni: 0.2%-0.4%, P: $\leq 0.020\%$, S: $\leq 0.020\%$, Ti: 0.04%-0.10%, V: 0.05-0.15%, Re: 0.001%-0.003%, and the balance being Fe, the medium-carbon low-alloy steel material being a seamless steel pipe; and successively subjecting the seamless steel pipe to size-fixed saw cutting, end flange-forming processing and a heat treatment, to obtain a conveying pipe, the heat treatment comprising heating, thermal insulating, primary cooling and secondary cooling which are conducted successively, wherein a cooling speed of the primary cooling is from 25 to 35 °C/s, and a cooling speed of the secondary cooling is lower than that of the primary cooling.

As described above, for the medium-carbon low-alloy material of the present application, on the basis of controlling the contents of these principal chemical components C, Mn, Si, Cr and Ni, by further utilizing traces of alloying elements Ti, V and Re and controlling their respective contents, a goal of increasing the toughness and wear resistance of the material is realized, and therefore further increasing the impact resistance of the conveying pipes formed with this material and mitigating the wears thereon. Further, according to requirements for designing sizes, saw machines or other tools are utilized to conduct the size-fixed saw cutting of the seamless steel pipe; the end flange forming processing is utilized to manufacture flanges at the end, to further avoid the problem about the early failure of the conveying pipe which is raised due to cracking at the welding positions when the end flanges and the straight pipe are connected in a welding form. Meanwhile, the cooling speed of the primary cooling of the heat treatment is controlled so that the internal residual stress is fully released to reduce the deforming and cracking probabilities of the conveying pipe.

In some embodiments of the present application, the step of the end flange-forming processing comprises an upsetting treatment and a cutting processing, which are successively conducted to form an end flange. The use of the upsetting treatment and the cutting processing to realize the integral forming of the end flanges and the straight pipe is simply operated and easily accomplished.

To better control the sizes and mechanical properties during the flange forming, preferably, the upsetting treatment comprises, after heating the ends of the seamless steel pipe to 1100 °C -1200 °C, upsetting them to a target thickness. Further, the upsetting treatment comprises, after inductively heating the ends of the seamless steel pipe to 1100 °C -1200 °C, upsetting them to a target thickness with a hydraulic press. The ends of the seamless steel pipe are heated to 1100 °C to 1200 °C so that the steel pipe has good forgeability; upsetting to a target thickness with a hydraulic press assures the processing stability and increase the processing efficiency.

To further remove the internal residual stresses of the conveying pipe, in some embodiments, the heat treatment comprises: heating a workpiece obtained from the end flange forming treatment to 850 °C -880 °C and thermally insulating it for 1 hour -2 hours; after the thermal insulating is finished, conducting the primary cooling, preferably the primary cooling accomplished by using a forcible cooling, the forcible cooling preferably being a wind cooling or an oil cooling; after the primary cooling is conducted to 200 °C -150 °C, conducting the secondary cooling, in the secondary cooling residual heat is utilized for self-tempering, the secondary cooling preferably being a wind cooling. The workpiece, after thermally insulated, is cooled at a moderate speed of 25 °C/s -35 °C/s so that the internal residual stress of the workpiece is remarkably reduced, the overall hardness is more uniform, and the deforming and cracking tendencies of the obtained conveying pipes are remarkably reduced. Preferably, the cooling speed of 25 °C/s -35 °C/s is accomplished by the means of a wind cooling or an oil cooling, thereby achieving temperature decreases in low costs.

In some embodiments, the conveying pipe further comprises a wear-resistant sleeve, and the preparation method further comprises the process of compression fitting the wear-resistant sleeve at the two ends of the workpiece obtained after the heat treatment. To further increase the wear resistance of the conveying pipe. For example, the wear-resistant sleeve and the end flanges are in an interference fit, and by using a special compression fitting apparatus, the wear-resistant sleeve is compression fitted into the end flanges.

After compression fitting the wear-resistant sleeve, the preparation method of some embodiments further comprises the processes of shot blasting and powder spraying coating. The shot blasting is aimed to removing impurities such as oxidized skin and the like on the outer wall of a conveying pipe, and the powder spraying coating refers to spraying a powder coating on the outer surface of a conveying pipe, to increase the quality of the conveying pipe. To increase the

coating stability, the temperature of the powder spraying coating is preferably from 150 °C to 200 °C.

Modes for preparing medium-carbon and low-carbon alloy steel materials with the raw material may be realized by routine processes in the art. For example, in some embodiments, the above process for preparing the medium-carbon and low-carbon alloy steel materials comprises the processes of smelting, casting, piercing, pipe rolling, sizing and straightening the raw material, wherein the specific operations of the smelting, casting, piercing, pipe rolling, sizing and straightening can refer to corresponding operation processes and conditions for existing medium-carbon and low-carbon alloy steel materials, and no detail is further provided in the present application.

In still another typical embodiment of the present application, a concrete pump truck is provided, which comprises a conveying pipe, the conveying pipe being any one of the above conveying pipes. Since the conveying pipes of the present application have good wear resistance and long service life, the concrete pump trucks with the conveying pipes which are replaced in a less frequency have better working stability and working efficiency.

To further appreciate the present invention, the conveying pipes provided by the present invention and the preparation method thereof are specifically described by combining the examples provided below:

Example 1

1) Preparing a seamless steel tube: the seamless steel tube was made up of the chemical components: C: 0.55%, Mn: 0.9%, Si: 0.25%, Cr: 0.2%, Ni: 0.4%, P: 0.010%, S: 0.010%, Ti: 0.05%, V: 0.10, Re (lanthanum, cerium, praseodymium and neodymium): 0.001% and the balance being Fe; a hot-rolled seamless steel pipe $\phi 133 \times 4.5$ mm was obtained by subjecting the above alloying components to smelting, casting, piercing, pipe rolling, sizing, straightening, and hydrostatic

testing.

2) Size-fixed saw cutting of the seamless steel pipe: a saw machine was utilized to conduct the size-fixed saw cutting of the seamless steel pipe.

3) End flange-forming processing: the processing means of upsetting and cutting were used for the forming, i.e., a 100 mm-long area at the ends of the size-fixed saw cut seamless steel pipe was inductively heated to 1100 °C, then immediately transferred into the molding cavity of a hydraulic press to be upset to 10 mm, and further end flanges structure was processed and formed by using a cutting processing method.

4) Heat treatment: the workpiece obtained in the above step 3) was heated to 880 °C, thermally insulated for 2 h, and it was discharged and rapidly transferred into a wind cooling chamber where it was cooled to 180 °C at a cooling speed of 35 °C /s; the workpiece was transferred out of the wind cooling chamber and cooled in air to room temperature, and then it was self-tempered by utilizing residual heat.

5) Compression fitting of a wear-resistant sleeve: the wear-resistant sleeves were in an interference fit with the end flanges, and the wear-resistant sleeves were compressed into the flange rings with a compression fitting apparatus.

6) Shot blasting: a shot blasting apparatus was used to remove impurities such as oxidized skin or the like on the external wall of the conveying pipe.

7) Powder-spraying coating: the external surface of the conveying pipe was sprayed with a polyester-type low temperature powder coating, at a powder spraying temperature 150 °C, to obtain the conveying pipe of Example 1. FIG. 3 is a metallographic structure drawing of the conveying pipe of Example 1 measured with a metallographic microscopic, to show that the metallographic structure was a tempered martensite.

Example 2

1) Preparing a seamless steel tubes: the seamless steel tube was made up of the chemical components: C: 0.57%, Mn: 1.2%, Si: 0.25%, Cr: 0.3%, Ni: 0.3%, P: 0.010%, S: 0.010%, Ti: 0.10%, V: 0.15, Re (lanthanum, cerium, praseodymium

and neodymium): 0.002% and the balance being Fe; a hot-rolled seamless steel pipe $\phi 133 \times 5$ mm was obtained by subjecting the above alloying components to smelting, casting, piercing, pipe rolling, sizing, straightening, and hydrostatic testing.

2) Size-fixed saw cutting of the seamless steel pipe: a saw machine was utilized to conduct the size-fixed saw cutting of the seamless steel pipe.

3) End flange-forming processing: the processing means of upsetting and cutting were used for the forming, i.e., a 90 mm-long area at the ends of the size-fixed saw cut seamless steel pipe was inductively heated to 1150 °C, then immediately transferred into the molding cavity of a hydraulic press to be upset to 10 mm, and further end flanges structure was processed and formed by using a cutting processing method.

4) Heat treatment: the workpiece obtained in the above step 3) was heated to 850 °C, thermally insulated for 1 h, and it was discharged and rapidly transferred into a wind cooling chamber where it was cooled to 180 °C at a cooling speed of 25 °C/s; the workpiece was transferred out of the wind cooling chamber and cooled in air to room temperature, and then it was self-tempered by utilizing residual heat.

5) Compression fitting of a wear-resistant sleeve: the wear-resistant sleeves were in an interference fit with the end flanges, and the wear-resistant sleeves were compressed into the flange rings with a compression fitting apparatus.

6) Shot blasting: a shot blasting apparatus was used to remove impurities such as oxidized skin or the like on the external wall of the conveying pipe.

7) Powder-spraying coating: the external surface of the conveying pipe was sprayed with a polyester-type low temperature powder coating, at a powder spraying temperature 150 °C, to obtain the conveying pipe of Example 2.

Example 3

1) Preparing a seamless steel tube: the seamless steel tube was made up of the chemical components: C: 0.60%, Mn: 1.4%, Si: 0.25%, Cr: 0.4%, Ni: 0.2%, P: 0.010%, S: 0.010%, Ti: 0.08%, V: 0.05, Re (lanthanum, cerium, praseodymium and neodymium): 0.003% and the balance being Fe; a hot-rolled seamless steel

pipe $\phi 133 \times 5.5$ mm was obtained by subjecting the above alloy components to smelting, casting, piercing, pipe rolling, sizing, straightening, and hydrostatic testing.

2) Size-fixed saw cutting of the seamless steel pipe: a saw machine was utilized to conduct the size-fixed saw cutting of the seamless steel pipe.

3) End flange-forming processing: the processing means of upsetting and cutting were used for the forming, i.e., a 82 mm-long area at the ends of the size-fixed saw cut seamless steel pipe was inductively heated to 1200 °C, then immediately transferred into the molding cavity of a hydraulic press to be upset to 10 mm, and further end flanges structure was processed and formed by using a cutting processing method.

4) Heat treatment: the workpiece obtained in the above step 3) was heated to 850 °C, thermally insulated for 1 h, and it was discharged and rapidly transferred into a wind cooling chamber where it was cooled to 180 °C at a cooling speed of 25 °C/s; the workpiece was transferred out of the wind cooling chamber and cooled in air to room temperature, and then it was self-tempered by utilizing residual heat.

5) Compression fitting of a wear-resistant sleeve: the wear-resistant sleeves were in an interference fit with the end flanges, and the wear-resistant sleeves were compressed into the flange rings with a compression fitting apparatus.

6) Shot blasting: a shot blasting apparatus was used to remove impurities such as oxidized skin or the like on the external wall of the conveying pipe.

7) Powder-spraying coating: the external surface of the conveying pipe was sprayed with a powder coating, at a powder spraying temperature 150 °C, to obtain the conveying pipe of Example 3.

Example 4

The example differed from Example 1 in the conditions of the heat treatment of the step 4), and the heat treatment process of the present example was described below: the workpiece obtained in the above step 3) was heated to 900 °C, thermally insulated for 1 h, and it was discharged and rapidly transferred into a wind cooling chamber where it was cooled to 180 °C at a cooling speed of 40 °C

/s; the workpiece was transferred out of the wind cooling chamber and cooled in air to room temperature, and then it was self-tempered by utilizing residual heat.

Example 5

The example differed from Example 1 in the conditions of the heat treatment of the step 4), and the heat treatment process of the present example was described below: the workpiece obtained in the above step 3) was heated to 830 °C, thermally insulated for 1 h, and it was discharged and rapidly transferred into a wind cooling chamber where it was cooled to 180 °C at a cooling speed of 20 °C /s; the workpiece was transferred out of the wind cooling chamber and cooled in air to room temperature, and then it was self-tempered by utilizing residual heat.

Comparative Example 1

The example differed from Example 1 in the chemical components of the seamless steel pipe, particularly, C: 0.55%, Mn: 0.9%, Si: 0.25%, Cr: 0.2%, Ni: 0.4%, P: 0.010%, S: 0.010%, Ti: 0.02%, V: 0.10%, Re (lanthanum, cerium, praseodymium and neodymium): 0.001% and the balance being Fe. The others were the same as those in Example 1.

Comparative Example 2

The example differed from Example 1 in the chemical components of the seamless steel pipe, particularly, C: 0.55%, Mn: 0.9%, Si: 0.25%, Cr: 0.2%, Ni: 0.4%, P: 0.010%, S: 0.010%, Ti: 0.12%, V: 0.10%, Re (lanthanum, cerium, praseodymium and neodymium): 0.001% and the balance being Fe.

Comparative Example 3

The example differed from Example 1 in the chemical components of the seamless steel pipe, particularly, C: 0.55%, Mn: 0.9%, Si: 0.25%, Cr: 0.2%, Ni: 0.4%, P: 0.010%, S: 0.010%, V: 0.10%, Re (lanthanum, cerium, praseodymium and neodymium): 0.001% and the balance being Fe. The others were the same as those in Example 1.

Comparative Example 4

The example differed from Example 1 in the chemical components of the seamless steel pipe, particularly, C: 0.55%, Mn: 0.9%, Si: 0.25%, Cr: 0.2%, Ni: 0.4%, P: 0.010%, S: 0.010%, Ti: 0.05%, V: 0.03%, Re (lanthanum, cerium, praseodymium and neodymium): 0.001% and the balance being Fe. The others were the same as those in Example 1.

Comparative Example 5

The example differed from Example 1 in the chemical components of the seamless steel pipe, particularly, C: 0.55%, Mn: 0.9%, Si: 0.25%, Cr: 0.2%, Ni: 0.4%, P: 0.010%, S: 0.010%, Ti: 0.05%, V: 0.17%, Re (lanthanum, cerium, praseodymium and neodymium): 0.001% and the balance being Fe. The others were the same as those in Example 1.

Comparative Example 6

The example differed from Example 1 in the chemical components of the seamless steel pipe, particularly, C: 0.55%, Mn: 0.9%, Si: 0.25%, Cr: 0.2%, Ni: 0.4%, P: 0.010%, S: 0.010%, Ti: 0.05%, Re (lanthanum, cerium, praseodymium and neodymium): 0.001% and the balance being Fe. The others were the same as those in Example 1.

Comparative Example 7

The example differed from Example 1 in the chemical components of the seamless steel pipe, particularly, C: 0.55%, Mn: 0.9%, Si: 0.25%, Cr: 0.2%, Ni: 0.4%, P: 0.010%, S: 0.010%, Ti: 0.05%, V: 0.1%, Re (lanthanum, cerium, praseodymium and neodymium): 0.004%, the balance being Fe. The others were the same as those in Example 1.

Comparative Example 8

The example differed from Example 1 in the chemical components of the seamless

steel pipe, particularly, C: 0.55%, Mn: 0.9%, Si: 0.25%, Cr: 0.2%, Ni: 0.4%, P: 0.010%, S: 0.010%, Ti: 0.05%, V: 0.1 percent and the balance being. The others were the same as those in Example 1.

Comparative Example 9

The example differed from Example 1 in the heat treatment process, and the heat treatment process of Comparative Example 9 was described below: the workpiece obtained in the above step 3) was heated to 880 °C, thermally insulated for 2 h, and it was discharged and rapidly transferred into a quenching chamber where it was cooled to 180 °C at a cooling speed of 60 °C /s; the workpiece was transferred out of the quenching chamber and cooled in air to room temperature, and then it was self-tempered by utilizing residual heat. The others were the same as those in Example 1.

Comparative Example 10

The example differed from Example 1 in the heat treatment process, and the heat treatment process of Comparative Example 10 was described below: the workpiece obtained in the above step 3) was heated to 880 °C, thermally insulated for 2 h, and it was discharged and rapidly transferred into a cooling chamber where it was cooled in air to room temperature, and self-tempered by utilizing residual heat. The others were the same as those in Example 1. FIG. 4 is a metallographic structure drawing of the conveying pipe of Comparative Example 10 measured with a metallographic microscopic, to show that the metallographic structures were ferrite + pearlite.

Comparative Example 11

The example differed from Example 1 in that it did not conduct the heat treatment process of the step 4) in Example 1, and it directly conducted the compression fitting of the wear resistant sleeve after the end flange-forming processing.

The conveying pipes obtained in the individual examples and comparative

examples were detected in terms of mechanical properties with the following detecting methods:

Tensile strength: with reference to GB/T228.1 standards, arc tensile test samples were processed and the tensile strength was detected with a tensile testing machine.

Impact powder: with reference to GB/T229 standards, V-shaped notch test samples were processed and the room-temperature impact powder of the test samples was detected with a pendulum impact testing machine.

Overall hardness: with reference to GB/T230.1 standards, the hardness of the inner wall of steel pipes was detected with a digital-display Rockwell hardness meter.

Wear resistance: with reference to ASTM G105-16 standards, the weights of test samples before and after wears were detected with an abrasion testing machine with wet-sand rubber wheels, to evaluate the wear resistance with wear losses.

The results were recorded in Table 1.

Table 1

	Metallographic structure	Tensile strength/MPa	Impact powder/J	Overall hardness/HRC	Wear resistance/g
Example 1	Structures from surface to core each are a tempered martensite structure	1350	65	40-43	0.0232
Example 2		1400	60	41-44	0.0229
Example 3		1450	55	42-45	0.0221
Example 4		1460	52	43-46	0.0235
Example 5		1330	66	40-42	0.0240
Comparative Example 1		1300	55	38-41	0.0371
Comparative Example 2		1310	50	39-42	0.0351
Comparative Example 3		1200	45	37-40	0.0380
Comparative Example 4		1180	46	37-40	0.0376
Comparative Example 5		1360	55	40-43	0.0266
Comparative Example 6		1025	70	38-41	0.0271
Comparative Example 7		1250	50	40-43	0.0275
Comparative Example 8		1180	45	39-42	0.0315

Comparative Example 9		1500	40	44-47	0.0332
Comparative Example 10	Ferrite+pearlite	810	120	200-220HBW	0.0625
Comparative Example 11		650	110	180-200 HBW	0.0758

On the basis of a medium-carbon low-alloy steel material, by adding traces of appropriate alloying elements Ti, V and Re and controlling their respective contents and by combining a heat treatment process, the goal of improving the toughness and wear resistance of the steel was realized and further improving the impact resistance of the conveying pipes formed with the material and mitigating the wears thereon, and thus the service life of the conveying pipes can reach more than 50,000 squares.

It is necessary to illustrate that the present application is not limited to the above embodiments. The above embodiments are only illustrative, and embodiments in the scope of the technical solution of the present application, which have constitutions with essentially the same technical concept and exert the same functions and effects, each are included in the technical scope of the present application. In addition, in a scope that does not depart from the purpose of the present application, other modes configured by applying various deformations by combining a part of the constitutional elements in the embodiments are also included in the scope of the present application.

The claims

1. A medium-carbon low-alloy steel material, characterized in that it is made up of the following chemical components in mass fraction: C: 0.55%-0.60%, Mn: 0.80%-1.40%, Si: $\leq 0.3\%$, Cr: 0.2%-0.4%, Ni: 0.2%-0.4%, P: $\leq 0.020\%$, S: $\leq 0.020\%$, Ti: 0.04%-0.10%, V: 0.05%-0.15%, Re: 0.001%-0.003% and the balance being Fe.
2. The medium-carbon low-alloy steel material according to claim 1, characterized in that the Re is any one selected from lanthanum, cerium, praseodymium, and neodymium or a combination of more of them.
3. A conveying pipe, comprising a pipe body, characterized in that the pipe body is prepared by integrally forming the medium-carbon low-alloy steel material as claimed in claim 1 or 2.
4. The conveying pipe according to claim 3, characterized in that the pipe body has a hardness between 40 HRC and 45 HRC, and/or a tensile strength ≥ 1300 MPa, and/or an impact energy ≥ 50 J, and/or a microstructure being a tempered martensite.
5. The conveying pipe according to claim 3, characterized in that the pipe body comprises a straight pipe and two end flanges, the two end flanges being integrally formed with the straight pipe and arranged at the two ends of the straight pipe in a one-to-one form.
6. The conveying pipe according to claim 5, characterized in that the conveying pipe further comprises a wear-resistant sleeve, the wear-resistant sleeve being arranged in the inner cavity of the end flanges and in an interference fit with the end flanges.
7. A preparation method for the conveying pipe as claimed in any one of claims 3 to 6, characterized in that the preparation method comprises:

preparing a medium-carbon low-alloy steel material with a raw material made up of the following chemical components in mass fraction: C: 0.55%-0.60%, Mn: 0.80%-1.40%, Si: $\leq 0.3\%$, Cr: 0.2%-0.4%, Ni: 0.2%-0.4%, P: $\leq 0.020\%$, S: $\leq 0.020\%$, Ti: 0.04%-0.10%, V: 0.05-0.15%, Re: 0.001%-0.003%, and the balance being Fe, the medium-carbon low-alloy steel material being a seamless steel pipe; successively subjecting the seamless steel pipe to size-fixed saw cutting, end flange-forming processing and a heat treatment, to obtain a conveying pipe, the heat treatment comprising heating, thermal insulating, primary cooling and secondary cooling which are conducted successively, wherein a cooling speed of the primary cooling is from 25 °C/s to 35 °C/s, and a cooling speed of the secondary cooling is lower than that of the primary cooling.

8. The preparation method according to claim 7, characterized in that: the step of the end flange-forming processing comprises an upsetting treatment and a cutting processing, which are successively conducted to form an end flange; preferably, the upsetting treatment comprises, after heating the ends of the seamless steel pipe to 1100 °C -1200 °C, upsetting them to a target thickness; further preferably, the upsetting treatment comprises: after inductively heating the ends of the seamless steel pipe to 1100 °C -1200 °C, upsetting them to a target thickness with a hydraulic press.

9. The preparation method according to claim 7, characterized in that: the heat treatment comprises: heating a workpiece obtained from the end flange forming treatment to 850 °C - 880 °C and thermally insulating it for 1 hour -2 hours; after the thermal insulating is finished, conducting the primary cooling, preferably the primary cooling accomplished by using a forcible cooling, the forcible cooling preferably being a wind cooling or an oil cooling; after the primary cooling is conducted to 200 °C -150 °C, conducting the secondary cooling, in the secondary cooling residual heat is utilized for self-tempering; preferably, the secondary cooling being an air cooling.

10. The preparation method according to any one of claims 7 to 9, characterized in that: the conveying pipe further comprises a wear-resistant sleeve, and the preparation method further comprises the process of compression fitting the wear-resistant sleeve at the two ends of a workpiece obtained after the heat treatment.

11. The preparation method according to claim 10, characterized in that the preparation method, after compression fitting the wear-resistant sleeve, further comprises the processes of shot blasting and powder spraying coating, and a temperature of the powder spraying coating is preferably from 150 °C to 200 °C.

12. The preparation method according to any one of claims 7 to 11, characterized in that: the process of preparing the medium-carbon low-alloy steel material comprises the processes of smelting, casting, piercing, pipe rolling, sizing and straightening the raw material.

13. A concrete pump truck comprising a conveying pipe, characterized in that the conveying pipe is a conveying pipe as claimed in any one of claims 3 to 6.