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HIGH-STRENGTH CORROSION-RESISTANT MARINE ENGINEERING STAINLESS STEEL AND PREPARATION METHOD THEREOF.

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The invention discloses a high-strength corrosion-resistant marine engineering stainless steel and a preparation method thereof, and relates to the technical field of stainless steel. Calculated by mass percentage, the high-strength corrosion-resistant marine engineering stainless steel consists of the following elements: Mn 14.0-19.0 percent, Si ≤ 0.45 percent, Cr 16.0-21.0 percent, Ni 2.0-4.0 percent, Mo 2.0-3.5 percent, N 0.5-1.0 percent, V 0.1-0.3 percent, Y 0.1-0.2 percent, La 0.1-0.4 percent, C ≤ 0.04 percent, S ≤ 0.01 percent, P ≤ 0.02 percent, Nb 0.1-0.2 percent, Ti 0.15-0.25 percent, and the balance is Fe and inevitable impurities. By optimizing the alloy composition and preparation process of stainless steel, the seawater corrosion resistance and related mechanical properties of the material are improved on the premise of reducing the cost of stainless steel.

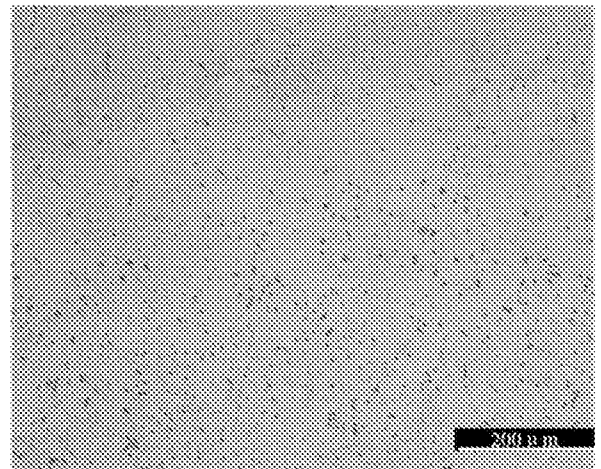


Fig.4

HIGH-STRENGTH CORROSION-RESISTANT MARINE ENGINEERING STAINLESS STEEL AND PREPARATION METHOD THEREOF

TECHNICAL FIELD

The invention relates to the technical field of stainless steel, in particular to a high-strength corrosion-resistant marine engineering stainless steel and a preparation method thereof.

BACKGROUND

With the progress of science and technology in the new situation, the efforts of marine development are constantly increasing, which puts forward new requirements for the development of new materials in the marine environment. With the rapid development of the economy and the continuous improvement of the overall technical level, the development and utilization of marine resources and the maintenance of world shipping's security are becoming more and more important. In order to accomplish these tasks, it is necessary to improve the level of marine facilities, marine equipment and ships. These equipment and facilities need long-term and stable work in the marine environment. However, the existing traditional stainless steel has some problems such as high cost and insufficient corrosion resistance, and the corrosion of these equipment and facilities by marine environment has become the key to restrict its normal work and operation.

At present, there are two main types of corrosion-resistant metal materials used in marine engineering: one is traditional stainless steel materials (such as 316L and 304 stainless steel), which are relatively low in cost, but have general corrosion resistance in marine environment and short structural life;

Second, titanium alloy, Hastelloy, B10 and other corrosion-resistant precious metal materials, although these materials have good corrosion resistance, but some of them rely on imports, which are expensive and the use cost is too high, which affects their application. Under this background, it is an urgent technical problem in this field to develop a low-cost, high-performance, green and environment-friendly high-strength corrosion-resistant stainless steel suitable for marine engineering environment.

SUMMARY

The invention aims to provide a high-strength corrosion-resistant marine engineering stainless steel and a preparation method thereof, so as to solve the problems existing in the prior art. By optimizing the alloy composition and the preparation process of the stainless steel, the seawater corrosion resistance and related mechanical properties of the material are improved on the premise of reducing the cost of the stainless steel.

In order to achieve the above objectives, the present invention provides the following scheme:

Technical scheme 1: provide a high-strength corrosion-resistant marine engineering stainless steel, which consists of the following elements in percentage by mass:

Mn 14.0-19.0%, Si ≤ 0.45%, Cr 16.0-21.0%, Ni 3.0-4.0%, Mo 2.5-3.5%, N 0.5-1.0%, V 0.1-0.3%, Y 0.1-0.2%, La 0.1-0.4%, C ≤ 0.04%, S ≤ 0.01%, P ≤ 0.02%, the balance is Fe and inevitable impurities.

Technical scheme 2: provide a high-strength corrosion-resistant marine engineering stainless steel, which consists of the following elements in percentage by mass:

Mn 14.0-19.0%, Si ≤ 0.45%, Cr 16.0-21.0%, Ni 2.0-4.0%, Mo 2.0-3.5%, N 0.5-1.0%, V 0.1-0.3%, Y 0.1-0.2%, La 0.1-0.4%, C ≤ 0.04%, S ≤ 0.01%, P ≤ 0.02%, Nb 0.1-0.2%, Ti 0.15-0.25%, the balance is Fe and inevitable impurities.

More preferably, the high-strength corrosion-resistant marine engineering stainless steel of the invention consists of the following elements in percentage by mass:

Mn 14.0-19.0%, Si \leq 0.45%, Cr 16.0-21.0%, Ni 3.0-4.0%, Mo 2.5-3.5%, N 0.5-1.0%, V 0.1-0.3%, Y 0.1-0.2%, La 0.1-0.4%, C \leq 0.04%, S \leq 0.01%, P \leq 0.02%, Nb 0.1-0.2%, Ti 0.15-0.25%, The balance is Fe and inevitable impurities.

Technical scheme 3: provide a preparation method of high-strength corrosion-resistant marine engineering stainless steel in technical scheme 1, which comprise that following steps:

(1) iron raw materials are smelted to 30-80% and converted into alloy solution, then molybdenum raw materials and vanadium raw materials are added, and smelting is continued until all raw materials are melted to obtain molten liquid a;

(2) adding a nickel raw material into the molten liquid a, then sequentially adding a manganese raw material and a silicon raw material, and deoxidizing to obtain a molten liquid b;

(3) ferrochrome nitride is added into the molten liquid b for smelting to obtain molten liquid c;

and (4) transferring the molten liquid c into a ladle with heavy yttrium rare earth and lanthanide rare earth at the bottom, and air cooling and casting to obtain the high-strength corrosion-resistant marine engineering stainless steel.

After further experimental verification, it is found that compared with the preparation method of adding manganese raw materials and silicon raw materials into molten liquid c, adding manganese raw materials and silicon raw materials in step (2) has the following obvious advantages: First, manganese is an element that expands austenite phase region, so the first addition of manganese is beneficial to its full dissolution, and is beneficial to the dissolution and homogenization after ferrochrome nitride is added in the next step, which effectively improves the nitrogen-dissolving ability of molten steel. Secondly, the early addition of manganese can effectively inhibit the formation of low-carbon high-temperature ferrite, so as to expand the amount of nitrogen dissolved.

As a further optimization of the invention, according to the mass percentage, the high-strength corrosion-resistant marine engineering stainless steel in the second technical scheme consists of the following elements:

Mn 19.0%, Si \leq 0.25%, Cr 21.0%, Ni 3.6%, Mo 3.0%, N 0.87%, V 0.10%, Y 0.15%, La 0.30%, C \leq 0.04%, S \leq 0.01%, P \leq 0.02%, Nb 0.20%, Ti 0.25%, The balance is Fe and inevitable impurities.

As a further optimization of the invention, the high-strength corrosion-resistant marine engineering stainless steel in technical scheme 2 is austenitic nonmagnetic stainless steel.

According to the invention, Nb and Ti elements are added on the basis of the original formula of high-strength corrosion-resistant marine engineering stainless steel, and titanium can be dissolved into austenite to form a solid solution, so that a solid solution strengthening effect can be generated. The addition of titanium improves the strength of this steel, the thermoplasticity and cold bending properties of the steel, and the weldability of the steel. In austenite, titanium and niobium precipitate compounds of the insoluble alloy in the form of Nb(C,N) and Ti(C,N) to form hard spots, which are distributed in liquid metal species, increasing the nucleation rate on particles and refining the grains.

At the same time, the amount of precipitates mainly depends on the temperature and the content of related elements. Fine compounds of niobium and titanium are precipitated in austenite at low temperature, and these fine compounds prevent grain growth through the pinning mechanism acting on grain boundaries, thus obtaining a fine grain structure.

By adding rare earth elements and appropriate manganese and nickel elements, the nitrogen content in steel can be effectively improved, and at the same time, a unique alloying element addition method is adopted in smelting environment to achieve the purpose of improving seawater corrosion resistance and controlling steel magnetism.

Technical scheme 4: the preparation method of high-strength corrosion-resistant marine engineering stainless steel in technical scheme 2 is provided, which comprises the following steps:

(1) adding molybdenum raw material, vanadium raw material and niobium raw material after iron raw material is converted into molten liquid alloy by smelting to 30-80%, and continuing smelting until all raw materials are melted to obtain molten liquid a;

(2) adding a nickel raw material and a titanium raw material into the molten liquid a for smelting, then heating the molten liquid, sequentially adding a manganese raw material and a silicon raw material, and deoxidizing to obtain a molten liquid b;

(3) ferrochrome nitride is added into the molten liquid b for smelting to obtain molten liquid c;

and (4) transferring the molten liquid c into a ladle with heavy yttrium rare earth and lanthanide rare earth at the bottom, and air cooling and casting to obtain the high-strength corrosion-resistant marine engineering stainless steel.

As a further preference of the invention, the raw material of iron is pure iron, the raw material of molybdenum is ferromolybdenum, the raw material of vanadium is ferrovanadium, and the raw material of niobium is ferroniobium. In step (1), the melting temperature is 1540-1560°C; the nickel raw material is electrolytic nickel, the titanium raw material is pure titanium, the manganese raw material is industrial raw material manganese, and the silicon raw material is ferrosilicon. The melting temperature after adding the nickel raw material and the titanium raw material in step (2) is 1590-1610°C.

As a further preference of the invention, the manganese raw material and the silicon raw material are added into the molten liquid through a ceramic bell jar type adder; the melting temperature of that manganese raw material and the silicon raw material added in the step (2) is 1610°C; in step (3), ferrochrome nitride is added in batches. Preferred: ferrochrome nitride will be added in five batches, with each batch accounting for 20% of the total amount of ferrochrome nitride.

As a further preference of the present invention, the step (4) further comprises a slugging step and a fine-tuning alloy composition step before the molten liquid c is transferred.

The times of slugging in the slugging step are not less than 3 times; the step of fine-tune that alloy components specifically comprise the following steps: standing and cool to 1540-1560°C, sampling and casting to prepare a sample, detecting the components of the sample, adding raw materials to adjust the alloy components according to the detection results, and repeating the above process until the content of the alloy components reaches the design standard.

Slugging can remove smelting impurities in the melting process, reduce the impurity content in the final product and improve the product performance; Fine-tuning the alloy composition can reduce the error value between the final product and the target product and ensure the accuracy of the alloy composition content.

In the step (4), the transition temperature of the molten liquid c is 1540-1560°C, and 3-6mm particles made of heavy yttrium rare earth and lanthanide rare earth, in particular rare earth yttrium and lanthanum, are coated with a pure iron screen, the ladle is preheated to 300-500°C, and the air cooling time is 1-5min.

As a further preference of the present invention, step (4) further comprises solution treatment after casting, with the solution treatment temperature of 1100-1300°C and the solution treatment time of 4-8h.

In that high-strength corrosion-resistant marine engineer stainless steel of the invention:

Mn: manganese is an austenite-forming element, which has the function of stabilizing austenite structure. At the same time, the solubility of nitrogen in steel is very low, but the addition of manganese can improve the solubility of nitrogen in steel. Manganese can also form manganese sulfide from sulfur impurities in molten steel, eliminating the harmful effect of residual sulfur in steel. However, the production of excessive non-metallic inclusion manganese sulfide will affect the strength and corrosion resistance of steel to a certain extent.

The passivation film at the interface between steel matrix and Mn S is weak, and corrosion occurs first at the interface, which eventually leads to. At the same time, the materials used in marine environment will also be corroded by Mn S non-metallic inclusions and marine microorganisms; therefore, the content of manganese in high-strength corrosion-resistant marine engineering stainless steel is limited to 14.0-19.0%.

Si: adding silicon to stainless steel can effectively remove oxygen impurities in steel and improve the oxidation resistance of the material. However, silicon is a ferrite-forming element, and excessive addition will affect the formation of austenite structure of the material. Therefore, the invention limits the silicon content to $\leq 0.45\%$.

Cr: the main element in austenitic stainless steel, which mainly plays a role in improving the corrosion resistance of stainless steel.

Ni: it can promote the formation of austenite and stabilize the austenite structure, but it is expensive. By adding a proper amount of nitrogen, the invention plays a role in replacing nickel, reducing the addition amount of nickel and saving the cost on the premise of ensuring the stability of austenite structure.

Mo: it can improve the corrosion resistance of stainless steel. Compared with stainless steel without adding molybdenum, the corrosion resistance of stainless steel containing molybdenum is better, but molybdenum is a ferrite forming element, and excessive addition will affect the formation of austenite structure in stainless steel, so the molybdenum content is limited to 2.0-3.5%.

N: It can stabilize the austenite structure, partially replace the use of nickel in austenitic stainless steel, delay the precipitation of carbide and improve the intergranular corrosion resistance. However, the solubility of nitrogen in stainless steel is not high, and too much addition will lead to the precipitation of nitrogen. In this invention, the addition amount of nitrogen in stainless steel can be increased to 0.5-1.0% by controlling the addition amount of manganese.

V: the addition of vanadium can refine the structure and grain of steel, and make stainless steel with high strength, toughness and wear resistance, which is more suitable for industrial application.

At the same time, vanadium is a strong C-N compound forming element, and Nb(C,N) and Ti(C,N) formed by strong binding force with C-N have extremely high solubility in austenitic stainless steel, so the addition of vanadium can further improve the solubility of nitrogen in steel.

Y: cooperating with La to strengthen grain boundaries and refine grains, and with manganese and nickel, the nitrogen content in steel can be effectively increased. In addition, the radius of Y element is large, which can produce large lattice distortion when dissolved in austenitic stainless steel, so that the interface can be reduced and the grain growth can be hindered, which also improves the microhardness of austenitic stainless steel, thus obtaining high-performance, green and environment-friendly high-strength corrosion-resistant marine engineering stainless steel.

La: and Y cooperate with each other to strengthen grain boundaries and refine grains, and with Mn and Ni, the nitrogen content in steel can be effectively increased. In addition, the radius of La element is large, and it can produce large lattice distortion when dissolved in austenitic stainless steel, so that the interface can be reduced and the grain growth can be hindered, which also improves the microhardness of austenitic stainless steel, thus obtaining high-performance, green and environment-friendly high-strength corrosion-resistant marine engineering stainless steel.

C: non-raw material addition, introduced by the preparation process or raw materials, can stabilize and expand the austenite region in austenitic stainless steel, but too high carbon content will affect the plasticity of steel and reduce the corrosion resistance of stainless steel. In addition, elements such as manganese, nitrogen, rare earth and nickel have been added in the invention to form and stabilize the austenite structure, so in order to ensure the corrosion resistance of stainless steel, the invention limits carbon to $\leq 0.04\%$.

S and P: non-raw materials are added as impurity elements, which are introduced by the preparation process or raw materials. Sulfur will cause "hot brittleness" of steel (S and Mn are easy to form MnS with low melting point, hard and brittle, and tend to segregate to grain boundaries, reducing the strength and plasticity of steel, which should be strictly limited in smelting), and phosphorus will cause "cold brittleness" of steel; therefore, it is necessary to limit the content of both to not be too high.

Ti, Nb: Titanium has strong chemical activity and can easily form compounds with N, O, S, C and other elements. The atomic radius difference between titanium atom and iron atom is very small, and the face-centered cubic structure of TiC and TiN is coherent with the steel matrix, which can be dissolved and precipitated under certain conditions. The addition of titanium mainly plays the role of degasser, deoxidizer and alloying additive. After adding titanium to steel, titanium-containing composite compounds can be formed (in the grain), which can promote manganese sulfide, make most inclusions in the grain spherical in shape, obviously reduce the size, and reduce the tendency of manganese sulfide to segregate to the grain boundary.

By adding rare earth elements, the invention has a metamorphic effect in the solidification process, so that the primary dendrite spacing and the secondary dendrite spacing of the solidified structure of high-strength corrosion-resistant marine engineering stainless steel are gradually reduced, and a fine dendrite structure is obtained. The addition of rare earth elements changes the morphology and types of inclusions in high-strength and corrosion-resistant marine engineering stainless steel. Before casting, a certain amount of rare earth elements are added for modification, so that the intermetallic compounds of C and N are homogenized and distributed in the grain. Because rare earth elements form tiny particles in austenitic stainless steel, the nucleation work is reduced and the nucleation rate is improved during solidification, which promotes spontaneous nucleation and makes the steel grain finer. The finer the grain, the larger the grain boundary area and the finer and more uniform the structure, thus improving the strength and hardness of austenitic stainless steel.

By adding rare earth elements and appropriate manganese and nickel elements, the nitrogen content in steel is effectively improved, and at the same time, a unique alloying element addition method is adopted in smelting environment, so as to achieve the purposes of improving seawater corrosion resistance of steel and controlling steel magnetism.

In the invention, the manganese raw material is added into the molten liquid b through the ceramic bell jar type adder to fully deoxidize it, improve the purity of molten steel and improve the material performance.

Ferrochrome nitride is added several times (3-8 times), in order to prevent the temperature of alloy melt around ferrochrome nitride from dropping sharply due to the excessive addition of metal nitride at one time, so that the alloy melt forms a solidified layer on the upper layer of the alloy solution, which will affect the uniform distribution of alloy elements and the final performance of high-strength corrosion-resistant marine engineering stainless steel products.

In this invention, the molten steel is modified by using rare earth elements in the way of ladle flushing. The addition of rare earth elements refines the solidified structure of stainless steel, reduces the structural segregation of Mn, Cr, Ni and Si elements, and promotes the refinement of as-cast structure of low-nickel austenitic stainless steel. It is found that the grain size of stainless steel without heavy Y rare earth and La rare earth elements is $108\mu\text{m}$, and the grain size is about grade 3. When adding rare earth Y-0.15 wt% and La-0.35wt%, the grain size is reduced to $55\mu\text{m}$, and the grain size is increased from grade 3 to grade 5.

With the addition of rare earth elements and the limitation of air-cooling time, the primary dendrite spacing and secondary dendrite spacing of high strength and corrosion-resistant marine engineering stainless steel structure gradually decrease. With the increase of rare earth elements, the primary dendrite spacing and secondary dendrite spacing of high-strength and corrosion-resistant marine engineering stainless steel also decrease obviously, and fine dendrite structure is obtained.

It is found that during the solidification process of high-strength corrosion-resistant marine engineering stainless steel, with the acceleration of solidification speed, the shape of liquid-solid interface changes from cellular to dendritic interface.

Solution treatment after casting can improve the dendrite segregation in the casting, make the composition of steel uniform, and overcome the technical problems that the uneven distribution of elements in each part of the casting affects the performance of the product.

In order to avoid the bad influence of nitride precipitation in the steel after subsequent forging on its mechanical properties, it is necessary to carry out solid solution treatment on the forged materials of this steel. In the solid solution process, nitrogen atoms are dissolved in austenite in the form of interstitial atoms, which promotes the uniform distribution of alloying elements, inhibits precipitation and increases the stability of austenite.

The invention discloses the following technical effects:

The product of that invention: accord to the alloying theory of metal material and the function of alloy elements in stainless steel, the content of chromium, nickel, manganese, molybdenum and nitrogen is reasonably adjusted and a proper amount of alloy elements such as vanadium, titanium, niobium and rare earth are added to obtain an austenite structure with fine grains, so that the content of the alloy element nickel of low-carbon austenitic stainless steel is reduced to the maximum extent under the service condition of static and low-salinity seawater corrosion resistance; through the synergistic effect of various alloying elements, many interstitial compounds (strengthening phases) with very fine atomic radius are formed, which improves the heterogeneous nucleation rate, thus improving the strength index of stainless steel on the premise of ensuring the corrosion resistance. In the invention, through the comprehensive action of these elements, the overall regulation of the organization and properties of the material itself is realized, and the steel grade is ensured to have good corrosion resistance and comprehensive mechanical properties.

Compared with the traditional 316L and 304 stainless steels, the cost of the stainless steel products of the invention is basically the same, but the comprehensive performance is much higher than that of the traditional stainless steels; Compared with corrosion-resistant precious metals, the performance index is basically the same, but the cost and price are greatly reduced, so the high-strength corrosion-resistant marine engineering stainless steel has obvious cost-performance advantages, is a low-cost, high-performance and non-magnetic stainless steel for marine engineering, and has broad application prospects in the field of marine military industry.

The preparation method of the product of the invention: by limiting the content of each element and simultaneously adopting a unique alloying element adding method (alloy adding sequence and method) in the smelting process, the purposes of improving the seawater corrosion resistance of steel and controlling the steel magnetism are achieved; in the smelting process of the invention, refractory elements of molybdenum, vanadium, titanium and niobium are added into the semi-molten alloy melt at first, so that the high-temperature smelting time is longer, which is beneficial to the melting of the semi-molten alloy, so that the semi-molten alloy can be fully dissolved in the subsequent long-time melting process, and because the melting points of molybdenum, vanadium, niobium and the like are higher, the component loss will not be too large due to the subsequent long-time melting process; then the temperature is raised until all the raw materials are melted, and then the nickel and titanium raw materials are added. At this stage, the temperature of the molten liquid is stable, and the melting points of ferromanganese and nickel are similar to that of iron, which is beneficial to the uniform distribution of manganese and nickel elements in the alloy solution, promotes the formation of subsequent austenite, and ensures the technical effect of removing oxygen impurities from steel by manganese. After all the nickel elements are melted, ferrochrome nitride is added to introduce nitrogen elements and chromium elements in stages, which can prevent nitrogen atoms from being molecularized and overflowing the alloy solution, and effectively improve the solubility of nitrogen in steel; Manganese has a low melting point (1244°C), so it is easy to lose a lot in the melting process if it is added too early.

After the above melting treatment, the molten liquid is slagged to remove impurity elements and the alloy composition is fine-tuned, and then transferred to a ladle containing a certain amount of rare earth elements for in-ladle scouring and metamorphism treatment, so that the intermetallic compounds of C and N in the molten liquid are homogenized and distributed in the crystal grains. At the same time, it is helpful for rare earth elements to form tiny particles in austenitic stainless steel. During solidification, the nucleation work is reduced, the nucleation rate is improved, and the spontaneous nucleation is promoted, so that the grain size of steel is refined, and the finer the grain size, the larger the grain boundary area and the finer and more uniform the structure, thus improving the microhardness value of austenitic stainless steel and improving the product performance. According to the invention, a certain amount of rare earth elements and nitrogen alloys are added into the steel to reduce the addition of precious metal nickel, so that the steel has excellent comprehensive properties such as high corrosion resistance, high strength, high toughness, non-magnetism, good biocompatibility, high temperature resistance and the like, and the content of precious metal nickel is reduced to the maximum extent in the preparation process to achieve the purpose of reducing the cost.

The high-strength seawater corrosion-resistant stainless steel prepared by the invention is widely used in the field of marine military industry, mainly including: naval ship barrel materials, offshore oil platform underground drilling, submarine oil and gas transportation pipelines and pump valves, and high-strength corrosion-resistant parts of marine ships. In addition, the high-strength seawater corrosion-resistant stainless steel can also be used to prepare various structural parts in marine equipment, corrosion-resistant high-pressure gas cylinders, high-temperature and high-pressure reaction vessels, high-temperature and high-pressure valves, pipe fittings, high-strength and low-relaxation fasteners, etc., which can resist corrosion in marine environment, prevent hydrogen embrittlement and wear resistance, and effectively improve the service life of parts.

In the field of marine shipbuilding, high-strength seawater corrosion-resistant stainless steel can also be used to make intake valves, exhaust valves, screw propellers for diesel engines, military stealth ship components, aircraft carrier catapult brackets, masts, nonmagnetic antennas and wire ropes. High-strength and corrosion-resistant marine engineering stainless steel can also be applied to seawater pipelines, cam devices, plate heat exchangers, seawater desalination systems, shells, tube heat exchangers, centrifugal separators, gravity separators, platform supporting structures, fire-proof and explosion-proof walls, wall cladding, cable reels, stairs, passages, elevators, natural gas systems and other components above offshore platforms, all of which can meet their performance requirements.

BRIEF DESCRIPTION OF THE FIGURES

In order to explain the embodiments of the present invention or the technical scheme in the prior art more clearly, the drawings needed in the embodiments will be briefly introduced below. Obviously, the drawings described below are only some embodiments of the present invention, and other drawings can be obtained according to these drawings without creative work for ordinary people in the field.

Fig. 1 is a metallographic diagram of as-cast products prepared in Embodiment 1 of the present invention after electrolytic corrosion;

Fig. 2 is a metallographic diagram of a solid solution product prepared in Embodiment 1 of the present invention after electrolytic corrosion;

Fig. 3 is a metallographic diagram of the as-cast product prepared in Embodiment 14 of the present invention after electrolytic corrosion;

Fig. 4 is a metallographic diagram of a solid solution product prepared in Embodiment 14 of the present invention after electrolytic corrosion.

DESCRIPTION OF THE INVENTION

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A number of exemplary embodiments of the present invention will now be described in detail, and this detailed description should not be considered as a limitation of the present invention, but should be understood as a more detailed description of certain aspects, characteristics and embodiments of the present invention.

It should be understood that the terminology described in the present invention is only for describing specific embodiments and is not used to limit the present invention. In addition, for the numerical range in the present invention, it should be understood that each intermediate value between the upper limit and the lower limit of the range is also specifically disclosed. The intermediate value within any stated value or stated range and every smaller range between any other stated value or intermediate value within the stated range are also included in the present invention. The upper and lower limits of these smaller ranges can be independently included or excluded from the range.

Unless otherwise specified, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this invention relates. Although the present invention only describes the preferred methods and materials, any methods and materials similar or equivalent to those described herein can also be used in the practice or testing of the present invention. All documents mentioned in this specification are incorporated by reference to disclose and describe methods and/or materials related to the documents. In case of conflict with any incorporated document, the contents of this specification shall prevail.

It is obvious to those skilled in the art that many improvements and changes can be made to the specific embodiments of the present invention without departing from the scope or spirit of the present invention. Other embodiments will be apparent to the skilled person from the description of the invention. The description and example of that present invention are exemplary only.

The terms "including", "comprising", "having" and "containing" used in this article are all open terms, which means including but not limited to.

In the embodiment of the invention, the raw materials used include industrial pure iron, industrial pure titanium, ferromolybdenum, ferrovanadium, ferroniobium, electrolytic nickel, ferrochrome nitride (60% Cr, 10% N), pure metal manganese, heavy yttrium rare earth particles (3-6mm) and lanthanide rare earth particles (3-6mm).

Embodiments 1-11

(1) weighing each raw material according to the element content in Table 1;

(2) placing the industrial pure iron in a smelting furnace, raising the temperature to 1540-1560°C, adding ferromolybdenum and ferrovanadium after 30-80% of the industrial pure iron is melted into an alloy solution, and continuing to melt until all the raw materials are converted into an alloy solution, which is recorded as molten liquid a;

(3) raising the temperature of molten liquid a to 1590-1610°C, adding electrolytic nickel, raising the temperature to 1610°C after nickel is completely melted, adding pure metal manganese by a ceramic bell jar type additive, and adding ferrosilicon by a ceramic bell jar type additive after melting, so as to fully deoxidize the melt to obtain molten liquid b;

(4) the furnace temperature of molten liquid b is reduced to 1540-1560°C, and ferrochrome nitride is added in five times (20% of the total amount of ferrochrome nitride is added each time), and molten liquid c is obtained after all ferrochrome nitride is melted;

(5) the molten liquid c is repeatedly slagged for three times to remove floating oxides on the surface, and then cooled to 1,500°C at rest, sampled and analyzed quickly before furnace by using a direct reading spectrometer, and then the alloy composition is finely adjusted by adding raw materials according to the analysis results, and then the molten liquid d is analyzed quickly before furnace again until the alloy composition content is accurate;

(6) the furnace temperature of the molten liquid d is raise to 1540-1560°C, the ladle is dried at 300-500°C, and the prefabricate heavy Y rare earth and La rare earth with the size of 3-6mm are coated with a pure iron screen and placed at the bottom of the preheat ladle; the molten liquid d is poured into the ladle, washed and deteriorated in the ladle, cooled in air for 1min, and then cast to obtain an ingot.

(7) solid solution treatment of the ingot prepared in step (6) at 1100-1300°C for 4-8h. U506100

See Table 2 for specific temperature conditions in steps (1)-(7).

Embodiments 12-14

(1) weighing each raw material according to the element content in Table 1;

(2) placing the industrial pure iron in a smelting furnace, raising the temperature to 1,540-1,560°C, adding ferromolybdenum, ferroniobium and ferrovanadium after 30-80% of the industrial pure iron is melted into an alloy solution, and continuing to melt until all the raw materials are converted into an alloy solution, and recording as molten liquid a;

(3) raising the temperature of molten liquid a to 1590-1610°C, adding electrolytic nickel and industrial pure titanium, raising the temperature to 1610°C after nickel is completely melted, adding pure metal manganese by a ceramic bell jar type adder, and adding ferrosilicon by a ceramic bell jar type adder after melting, so as to fully deoxidize the melt to obtain molten liquid b;

(4) the furnace temperature of molten liquid b is reduced to 1540-1560°C, and ferrochrome nitride is added in five times (20% of the total amount of ferrochrome nitride is added each time), and molten liquid c is obtained after all the ferrochrome nitride is melted;

(5) the molten liquid c is repeatedly slagged for three times to remove floating oxides on the surface, and then cooled to 1,500°C at rest, sampled and analyzed quickly before furnace by using a direct reading spectrometer, and then the alloy composition is finely adjusted by adding raw materials according to the analysis results, and then the molten liquid d is analyzed quickly before furnace again until the alloy composition content is accurate;

(6) the furnace temperature of the molten liquid d is raise to 1540-1560°C, the ladle is dried at 300-500°C, and the prefabricate heavy Y rare earth and La rare earth with the size of 3-6mm are coated with a pure iron screen and placed at the bottom of the preheat ladle; the molten liquid d is poured into the ladle, washed and deteriorated in the ladle, cooled in air for 1min, and then cast to obtain an ingot.

(7) solid solution treatment of the ingot prepared in step (6) at 1100-1300°C for 4-8h.

See Table 2 for specific temperature conditions in steps (2)-(7).

Table 1

LU506100

	Mn	Si	Cr	Ni	Mo	N	V	Y	La	Nb	Ti
Embodiment 1	14.0	0.33	20.0	2.5	3.5	0.55	0.30	0.20	0.10	0	0
Embodiment 2	19.0	0.35	18.0	3.2	3.3	0.61	0.15	0.10	0.20	0	0
Embodiment 3	15.5	0.45	16.0	3.5	3.2	0.78	0.20	0.13	0.25	0	0
Embodiment 4	16.5	0.25	21.0	2.6	3.0	0.87	0.10	0.15	0.30	0	0
Embodiment 5	17.5	0.20	17.5	3.8	2.8	0.95	0.25	0.18	0.35	0	0
Embodiment 6	18.5	0.30	19.5	4.0	2.5	0.98	0.30	0.17	0.40	0	0
Embodiment 7	18.0	0.32	18.0	3.2	3.3	0.66	0.15	0.10	0.20	0	0
Embodiment 8	10.0	0.35	16.0	2.5	3.0	0.32	0.15	0.15	0.25	0	0
Embodiment 9	15.5	0.35	20.0	3.0	3.2	0.75	0.20	0.17	0.10	0	0
Embodiment 10	18.5	0.30	17.0	2.6	3.3	0.75	0.25	0.16	0.25	0	0
Embodiment 11	18.2	0.30	19.5	3.0	3.5	0.87	0.30	0.15	0.35	0	0
Embodiment 12	19.0	0.35	18.0	3.2	3.3	0.61	0.15	0.10	0.20	0.10	0.15
Embodiment 13	19.0	0.45	16.0	3.5	3.2	0.78	0.20	0.13	0.25	0.15	0.20
Embodiment 14	19.0	0.25	21.0	3.6	3.0	0.87	0.10	0.15	0.30	0.20	0.25

Table 2

LU506100

	Step (2) Temperat ure	Step (2) Transforma tion amount of alloy solution	Step (3) Temperat ure	Step (4) Temperat ure	Step (6) Temperat ure	Step (7) Temperature/ Time
Embodim ent 1	1550	50	1600	1550	1550/300	1200/4
Embodim ent 2	1560	80	1590	1540	1540/500	1300/5
Embodim ent 3	1540	40	1610	1560	1560/400	1100/8
Embodim ent 4	1550	30	1600	1550	1550/300	1200/4
Embodim ent 5	1550	80	1590	1540	1540/400	1200/6
Embodim ent 6	1560	50	1590	1550	1560/300	1150/8
Embodim ent 7	1550	50	1600	1550	1550/300	1200/4
Embodim ent 8	1550	50	1600	1550	1550/300	1200/4
Embodim ent 9	1550	50	1600	1550	1550/300	1200/4
Embodim ent 10	1550	50	1600	1550	1550/300	1200/4
Embodim	1550	50	1600	1550	1550/300	1200/8

	Step (2) Temperature	Step (2) Transformation amount of alloy solution	Step (3) Temperature	Step (4) Temperature	Step (6) Temperature	Step (7) Temperature/ Time
Embodiment 11						
Embodiment 12	1555	60	1590	1540	1550/350	1200/4
Embodiment 13	1550	65	1590	1540	1550/350	1300/5
Embodiment 14	1550	60	1590	1540	1550/350	1100/8

Comparative example 1

Compared with Embodiment 1, the difference is that the addition of heavy Y rare earth and La rare earth in the ladle is omitted. After the ladle is dried at 300°C, the molten liquid is poured into the ladle for scouring and metamorphism, and after cooling for 1min, it is cast to obtain an ingot.

The solidification rate of Embodiment 1 and Comparative Example 1 during casting was measured. The results showed that the solidification rate of Embodiment 1 was 200μm/s, while that of Comparative Example 1 was 32 μ m/s. It shows that the addition of rare earth elements accelerates the solidification speed. The solidification rate is determined by adding alloying elements and using a temperature measuring device.

Effect verification example 1

The final products prepared in Embodiments 1-14 and Comparative Example 1 were analyzed by ICP. The results showed that the content of each element was consistent with the target content, and $C \leq 0.04\%$, $S \leq 0.01\%$ and $P \leq 0.02\%$ in all products.

According to the corresponding testing standards, the properties of the solid solution products of Embodiments 1-14, Step (6) of Comparative Example 1 (as forged) and Step (7) were verified, and the results are shown in Table 3-5. Specific:

Tensile strength and yield strength: GB/T228.1-2010 tensile test standard for metallic materials;

Salt spray corrosion rate: GB/6458-86 People's Republic of China (PRC) national standard salt spray test standard;

Seawater erosion corrosion rate: GB-5776-89 conventional exposure corrosion test method for metal materials in surface seawater;

Table 3 Performance of as-forged products

	Tensile strength at room temperature (MPa)	Room temperature yield strength (MPa)	Room temperature elongation (%)	Impact work at 20°C(J)	Salt spray corrosion rate(mm/a)	Seawater erosion corrosion rate(mm/a)
Embodiment 1	820	760	34	48	0.0022	0.017
Embodiment 2	800	680	35	49	0.0023	0.019
Embodiment 3	825	755	36	49	0.0022	0.018
Embodiment 4	823	735	34	47	0.0024	0.020
Embodiment 5	813	732	37	50	0.0023	0.019

	Tensile strength at room temperature (M P a)	Room temperature yield strength (MPa)	Room temperature elongation (%)	Impact work at 20°C(J)	Salt spray corrosion rate(mm/a)	Seawater erosion corrosion rate(mm/a)
Embodiment 6	795	721	38	52	0.0022	0.021
Embodiment 7	805	684	39	53	0.0025	0.020
Embodiment 8	774	723	36	49	0.0026	0.019
Embodiment 9	838	772	38	52	0.0027	0.020
Embodiment 10	805	765	37	50	0.0028	0.021
Embodiment 11	801	725	39	54	0.0018	0.015
Comparative example 1	802	652	37	50	0.0022	0.018
Embodiment 12	912	762	40	55	0.0017	0.013
Embodiment 13	910	750	42	58	0.0018	0.012
Embodiment 14	914	823	43	59	0.0015	0.012

Table 4 Properties of Solid Solution Products

LU506100

	Tensile strength at room temperature (M P a)	Room temperature yield strength (M P a)	Room temperature elongation (%)	Impact work at 20°C(J)	Salt spray corrosion rate(mm/a)	Seawater erosion corrosion rate(mm/a)
Embodiment 1	961	780	50.2	104	0.0016	0.014
Embodiment 2	942	754	50.2	105	0.0014	0.018
Embodiment 3	968	760	50.1	105	0.0017	0.016
Embodiment 4	956	757	49.5	103	0.0013	0.016
Embodiment 5	965	762	49.3	103	0.0012	0.017
Embodiment 6	956	766	50.5	106	0.0018	0.018
Embodiment 7	960	725	51.0	106	0.0018	0.019
Embodiment 8	965	752	48.5	103	0.0016	0.018
Embodiment 9	958	775	52.3	107	0.0020	0.018
Embodiment 10	957	787	50.1	104	0.0018	0.017
Embodiment 11	964	775	50.2	104	0.0013	0.012

	Tensile strength at room temperature (M P a)	Room temperature yield strength (M P a)	Room temperature elongation (%)	Impact work at 20°C(J)	Salt spray corrosion rate(mm/a)	Seawater erosion corrosion rate(mm/a)
Comparative example 1	958	760	50.5	105	0.0018	0.017
Embodiment 12	1032	772	54	123	0.0018	0.010
Embodiment 13	1090	781	55	128	0.0013	0.010
Embodiment 14	1098	830	55	128	0.0011	0.008

Table 5 Product performance after 30% cold deformation

LU506100

	Tensile strength at room temperature (MPa)	Room temperature yield strength (MPa)	Room temperature elongation (%)	Impact work at 20°C(J)	Salt spray corrosion rate (mm/a)	Seawater erosion corrosion rate(mm/a)
Embodiment 1	1340	1120	35.9	96	0.0025	0.015
Embodiment 2	1209	1134	35.9	97	0.0031	0.017
Embodiment 3	1245	1141	35.2	95	0.0029	0.019
Embodiment 4	1360	1112	35.6	96	0.0031	0.015
Embodiment 5	1313	1123	36.3	99	0.0030	0.020
Embodiment 6	1254	1122	35.9	97	0.0029	0.019
Embodiment 7	1309	1146	34.8	95	0.0026	0.019
Embodiment 8	1210	1137	34.2	94	0.0031	0.038
Embodiment 9	1217	1128	35.2	96	0.0030	0.029
Embodiment 10	1257	1098	35.1	96	0.0030	0.031
Embodiment 11	1326	1178	37.2	99	0.0020	0.011

	Tensile strength at room temperature (MPa)	Room temperature yield strength (MPa)	Room temperature elongation (%)	Impact work at 20°C(J)	Salt spray corrosion rate (mm/a)	Seawater erosion corrosion rate(mm/a)
Comparative example 1	1321	1121	35.0	95	0.0021	0.031
Embodiment 12	1456	1128	38.6	102	0.0022	0.011
Embodiment 13	1480	1154	39.2	104	0.0021	0.011
Embodiment 14	1467	1138	40.9	105	0.0020	0.010

Effect verification example 3

After electrolytic corrosion (voltage 5.5V, current 0.5A, 4.5min) of the ingot in step (6) of Embodiment 1, the metallographic structure was analyzed, and the results are shown in Fig. 1.

Because high nitrogen nickel-free austenitic stainless steel needs to maintain a relatively high concentration of nitrogen in steel during smelting, it needs to be rapidly alloyed with nitrogen in molten steel, and then poured at the fastest speed after uniform stirring. In this process, all Cr-N alloy particles should be dissolved in molten steel, and the pouring time should be short. It can also be seen from the figure that nitrides are precipitated during the solidification of molten steel, and lamellar nitrides are formed during the cooling process due to the segregation of nitrogen elements between dendrites. This shows that with the continuous transfer of latent heat of crystallization and the gradual decrease of undercooling, the power required for the formation of fine grain regions begins to decrease, and some grains grow inward to form columnar crystals, so a large number of equiaxed dendrites with uniform distribution appear in the as-cast structure due to the rapid cooling rate during casting.

With the continuous advancement of solidification layer into the ingot, a large number of nucleation particles are gathered at the junction of liquid phase and solid phase, forming constitutional supercooling region. In the process of growing into the ingot, the columnar crystals meet the columnar crystals produced by the nucleation of foreign particles at the front end of the interface, and the columnar crystals stop growing, forming a central equiaxed crystal region in the ingot.

After electrolytic corrosion (voltage 4V, current 0.44A, 3min) of the ingot in step (7) of Embodiment 1, the metallographic structure was analyzed, and the results are shown in Fig. 2. It can be concluded from Figure 2 that the dendrite structure in the original as-cast structure is basically eliminated due to the solution treatment. At this time, the matrix microstructure is austenite, and the austenite grain boundary is a curved interface, but the curvature radius is large, and the nitride has been dissolved.

At the same time, through further experimental verification, it is also found that the product of the invention effectively improves the effect of stabilizing austenite due to the addition of nitrogen and manganese, and can keep the austenite structure stable in the temperature range of -196°C-1150°C even under the condition of large deformation, thus ensuring the stability of austenite state and maintaining the non-magnetic state of the material.

After electrolytic corrosion (voltage 4V, current 0.44A, 3min) of the ingot in step (6) of Embodiment 14, the metallographic structure was analyzed, and the results are shown in Fig. 3. After electrolytic corrosion (voltage 4V, current 0.44A, 3min) of the ingot in step (7) of Embodiment 14, the metallographic structure was analyzed, and the results are shown in Fig. 4.

It can be seen that due to the addition of niobium and titanium and the synergistic effect of rare earth elements, the uniformity of austenite grains in raw steel is improved, which leads to the formation of fine dispersed second-phase particles in the later forming and cooling process, and at the same time plays a role in refining grains, thus improving the strength and toughness and other related indexes.

The above-mentioned embodiments only describe the preferred mode of the invention, and do not limit the scope of the invention.

Under the premise of not departing from the design spirit of the invention, various modifications and improvements made by ordinary technicians in the field to the technical scheme of the invention shall fall within the protection scope determined by the claims of the invention.

CLAIMS

LU506100

1. A high-strength corrosion-resistant marine engineering stainless steel, characterized by comprising the following elements in percentage by mass:

Mn 14.0-19.0%, Si \leq 0.45%, Cr 16.0-21.0%, Ni 3.0-4.0%, Mo 2.5-3.5%, N 0.5-1.0%, V 0.1-0.3%, Y 0.1-0.2%, La 0.1-0.4%, C \leq 0.04%, S \leq 0.01%, P \leq 0.02%, the balance is Fe and inevitable impurities.

2. A high-strength corrosion-resistant marine engineering stainless steel, characterized by comprising the following elements in percentage by mass:

Mn 14.0-19.0%, Si \leq 0.45%, Cr 16.0-21.0%, Ni 2.0-4.0%, Mo 2.0-3.5%, N 0.5-1.0%, V 0.1-0.3%, Y 0.1-0.2%, La 0.1-0.4%, C \leq 0.04%, S \leq 0.01%, P \leq 0.02%, Nb 0.1-0.2%, Ti 0.15-0.25%, the balance is Fe and inevitable impurities.

3. A preparation method of the high-strength corrosion-resistant marine engineering stainless steel according to claim 1, which comprises the following steps:

(1) iron raw materials are smelted to 30-80% and converted into alloy solution, then molybdenum raw materials and vanadium raw materials are added, and smelting is continued until all raw materials are melted to obtain molten liquid a;

(2) adding a nickel raw material into the molten liquid a, then sequentially adding a manganese raw material and a silicon raw material, and deoxidizing to obtain a molten liquid b;

(3) ferrochrome nitride is added into the molten liquid b for smelting to obtain molten liquid c;

and (4) transferring the molten liquid c into a ladle with heavy yttrium rare earth and lanthanide rare earth at the bottom, and air cooling and casting to obtain the high-strength corrosion-resistant marine engineering stainless steel.

4. The high-strength corrosion-resistant marine engineering stainless steel according to claim 2, characterized in that the high-strength corrosion-resistant marine engineering stainless steel consists of the following elements in percentage by mass:

Mn 19.0%, Si \leq 0.25%, Cr 21.0%, Ni 3.6%, Mo 3.0%, N 0.87%, V 0.10%, Y 0.15%, La 0.30%, C \leq 0.04%, S \leq 0.01%, P \leq 0.02%, Nb 0.20%, Ti 0.25%, the balance is Fe and inevitable impurities.

5. The high-strength corrosion-resistant marine engineering stainless steel according to claim 2, characterized in that the high-strength corrosion-resistant marine engineering stainless steel is austenitic nonmagnetic stainless steel.

6. The preparation method of the high-strength corrosion-resistant marine engineering stainless steel according to claim 2, characterized by comprising the following steps:

(1) adding molybdenum raw materials, vanadium raw materials and niobium raw materials after the iron raw materials are melted to 30-80% and converted into alloy solution, and continuing to melt until all the raw materials are melted to obtain molten liquid a;

(2) adding a nickel raw material and a titanium raw material into the molten liquid a for smelting, and then sequentially adding a manganese raw material and a silicon raw material for deoxidation to obtain a molten liquid b.

7. The preparation method according to claim 6, characterized in that in step (1), the iron raw material is pure iron, the molybdenum raw material is ferromolybdenum, the vanadium raw material is ferrovanadium, and the niobium raw material is ferroniobium, and the melting temperature is 1540-1560°C; in step (2), the nickel raw material is electrolytic nickel, the titanium raw material is pure titanium, the manganese raw material is industrial raw material manganese, and the silicon raw material is ferrosilicon, and the melting temperature after adding the nickel raw material and the titanium raw material is 1590-1610°C.

8. The preparation method according to claim 6, characterized in that the manganese raw material and the silicon raw material are added into the molten liquid through a ceramic bell jar type adder; the melting temperature of that manganese raw material and the silicon raw material added in the step (2) is 1610°C.

9. The preparation method according to claim 6, characterized in that step (4) further comprises a slagging step and a fine-tuning alloy composition step before the molten liquid c is transferred.

10. The preparation method according to claim 6, characterized in that the step (4) further comprises solution treatment after casting, and the solution treatment temperature is 1100-1300°C and the solution treatment time is 4-8h.

REVENDEICATIONS

LU506100

1. Un acier inoxydable de génie maritime résistant à la corrosion et à haute résistance, caractérisé en ce qu'il comprend les éléments suivants en pourcentage massique:

Mn14.0-19.0%, Si≤0.45%, Cr 16.0-21.0%, Ni 3.0-4.0%, Mo 2.5-3.5%, N0.5-1.0%, V 0.1-0.3%, Y 0.1-0.2%, La 0.1-0.4%, C≤0.04%, S≤0.01%, P≤0.02%, l'équilibre est Fe et impuretés inévitables.

2. Un acier inoxydable de génie maritime résistant à la corrosion et à haute résistance, caractérisé en ce qu'il comprend les éléments suivants en pourcentage massique:

Mn 14.0-19.0%, Si≤0.45%, Cr 16.0-21.0%, Ni 2.0-4.0%, Mo 2.0-3.5%, N0.5-1.0%, V 0.1-0.3%, Y 0.1-0.2%, La 0.1-0.4%, C≤0.04%, S≤0.01%, P≤0.02%, Nb 0.1-0.2%, Ti 0.15-0.25%, l'équilibre est Fe et impuretés inévitables.

3. Un procédé de préparation de l'acier inoxydable d'ingénierie marine à haute résistance à la corrosion selon la revendication 1, caractérisé en ce qu' il comprend les étapes suivantes:

(1) les matières premières de fer sont fondues à 30-80% et converties en solution d'alliage, puis les matières premières de molybdène et les matières premières de vanadium sont ajoutées, et la fusion est poursuivie jusqu'à ce que toutes les matières premières soient fondues pour obtenir le liquide fondu a;

(2) ajouter une matière première de nickel dans le liquide fondu a, puis ajouter séquentiellement une matière première de manganèse et une matière première de silicium, et désoxyder pour obtenir un liquide fondu b;

(3) le nitrure de ferrochrome est ajouté dans le liquide fondu b pour fondre pour obtenir le liquide fondu c;

et (4) transférer le liquide fondu c dans une poche avec la terre rare d'yttrium lourd et la terre rare de lanthanide au fond, et refroidir à l'air et couler pour obtenir l'acier inoxydable de génie marin résistant à la corrosion à haute résistance.

4. L'acier inoxydable de génie maritime résistant à la corrosion et à haute résistance selon la revendication 2, caractérisé en ce que l'acier inoxydable de génie maritime résistant à la corrosion à haute résistance se compose des éléments suivants en pourcentage massique:

Mn 19.0%, Si \leq 0.25%, Cr 21.0%, Ni 3.6%, Mo 3.0%, N 0.87%, V 0.10%, Y 0.15%, La 0.30%, C \leq 0.04%, S \leq 0.01%, P \leq 0.02%, Nb 0.20%, Ti 0.25%, l'équilibre est Fe et impuretés inévitables.

5. L'acier inoxydable de génie maritime résistant à la corrosion et à haute résistance selon la revendication 2, caractérisé en ce que l'acier inoxydable de génie maritime résistant à la corrosion à haute résistance est l'acier inoxydable non magnétique austénitique.

6. L'acier inoxydable de génie maritime résistant à la corrosion et à haute résistance selon la revendication 2, caractérisé en ce qu'il comprend les étapes suivantes:

(1) ajouter les matières premières de molybdène, les matières premières de vanadium et les matières premières de niobium après que les matières premières de fer ont fondu à 30-80% et ont été converties en solution d'alliage, et continuer à fondre jusqu'à ce que toutes les matières premières soient fondues pour obtenir le liquide fondu a;

(2) ajouter une matière première de nickel et une matière première de titane dans le liquide fondu a pour fusion, puis ajouter séquentiellement une matière première de manganèse et une matière première de silicium pour désoxydation pour obtenir un liquide fondu b.

7. Le procédé de préparation selon la revendication 6, caractérisé en ce que dans l'étape (1), la matière première de fer est le fer pur, la matière première de molybdène est le ferromolybdène, la matière première de vanadium est le ferrovanadium, et la matière première de niobium est le ferroniobium, et la température de fusion est de 1540-1560 °C; dans l'étape (2), la matière première de nickel est du nickel électrolytique,

la matière première de titane est du titane pur, la matière première de manganèse est de LU506100 la matière première industrielle du manganèse, et la matière première de silicium est du ferrosilicium, et la température de fusion après ajout de la matière première de nickel et de la matière première de titane est de 1590-1610 °C.

8. Le procédé de préparation selon la revendication 6, caractérisé en ce que la matière première de manganèse et la matière première de silicium sont ajoutées dans le liquide fondu par l'intermédiaire d'un additionneur de type cloche en céramique; la température de mel de cette matière première de manganèse et de la matière première de silicium ajoutées à l'étape (2) est de 1610°C.

9. Le procédé de préparation selon la revendication 6, caractérisé en ce que l'étape (4) comprend en outre une étape de laitier et une étape de composition d'alliage de réglage fin avant le transfert du liquide fondu c.

10. Le procédé de préparation selon la revendication 6, caractérisé en ce que l'étape (4) comprend en outre un traitement de la solution après la coulée, et la température de traitement de la solution est de 1100-1300 °C et la durée de traitement de la solution est de 4-8h.

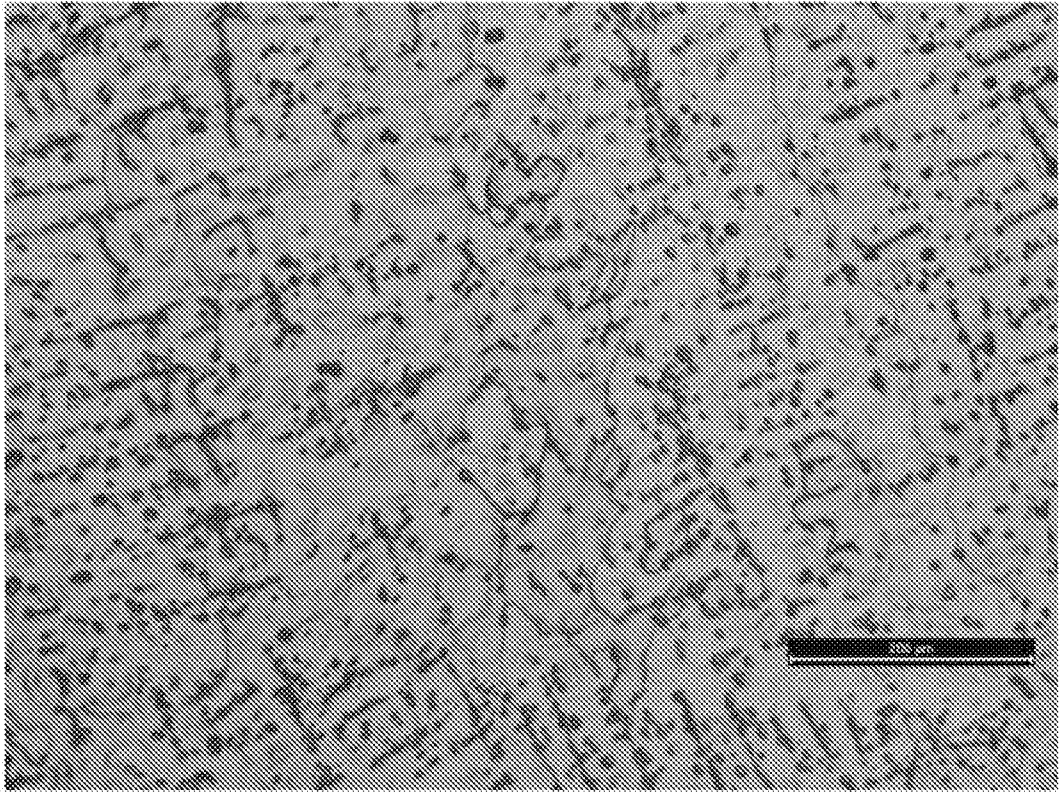


Fig.1

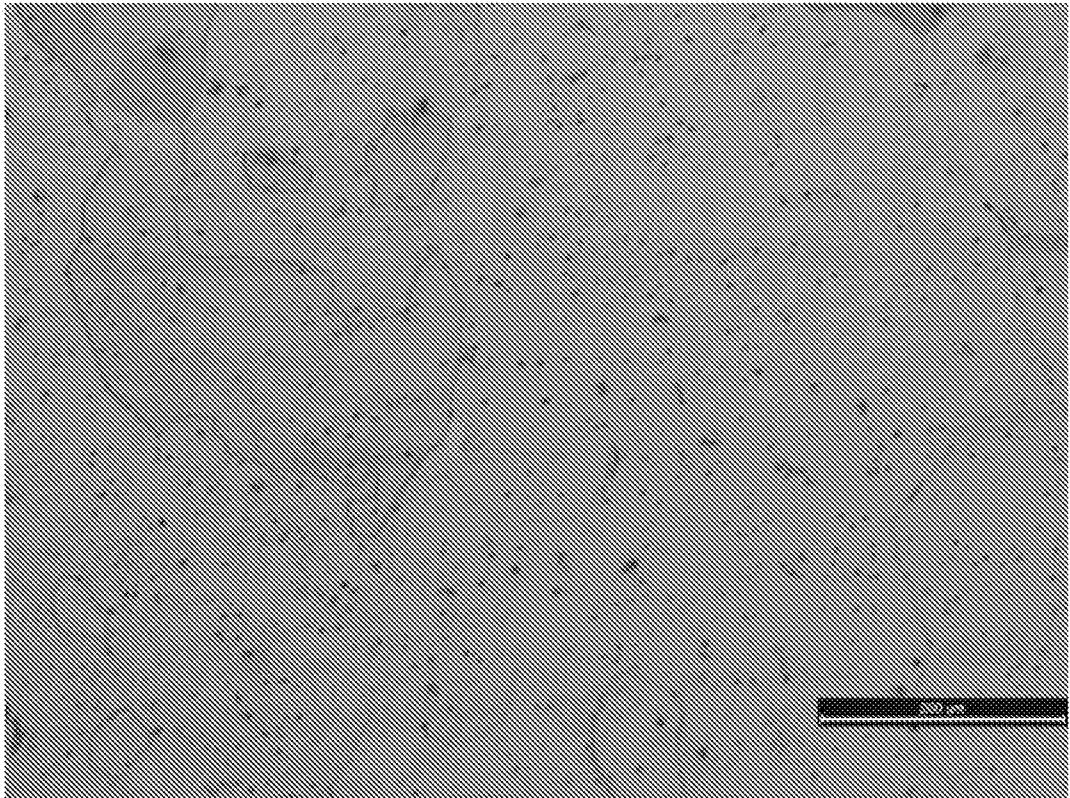


Fig.2

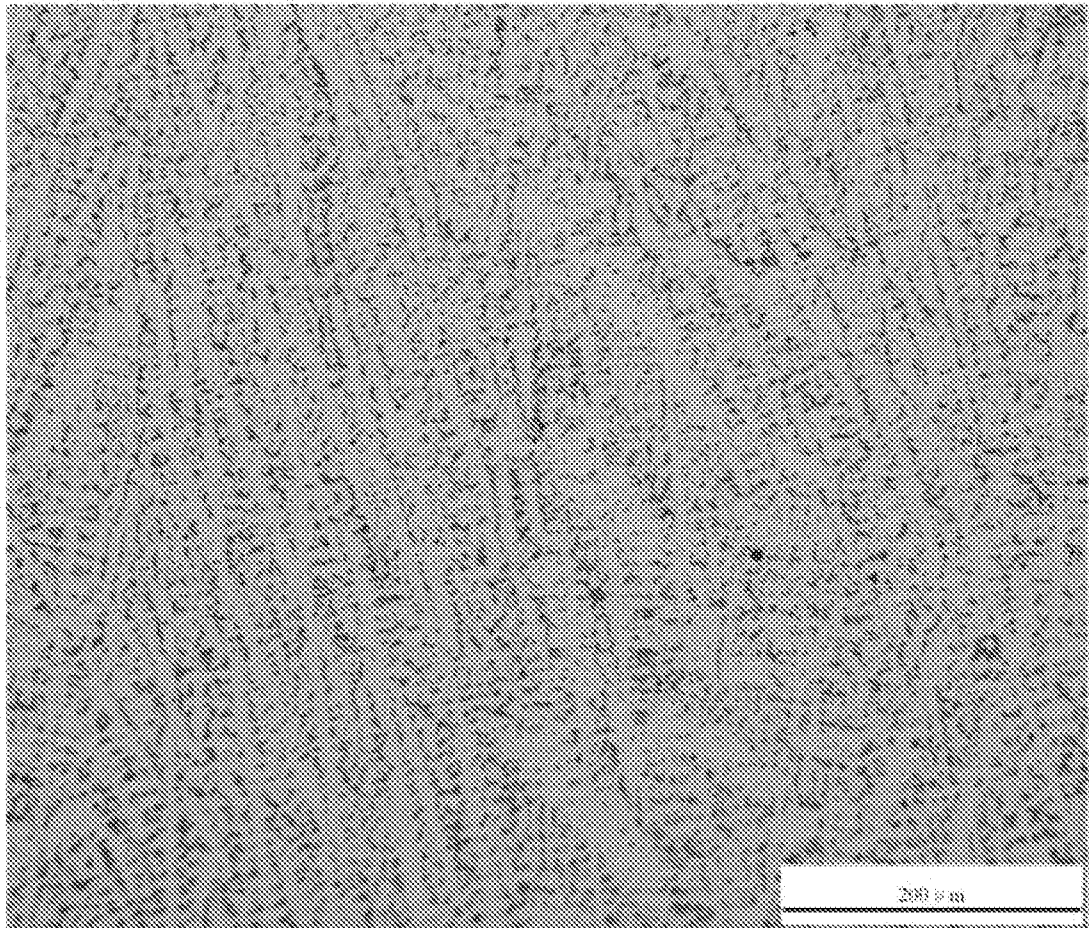


Fig.3

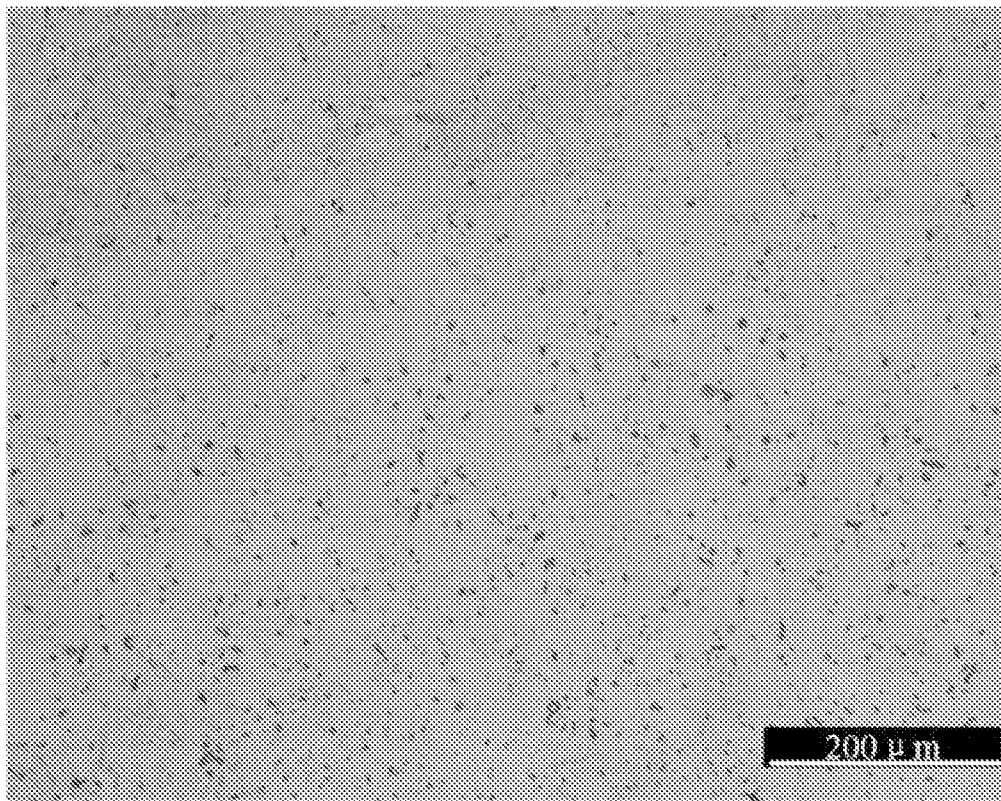


Fig.4