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(54) **CORROSION-RESISTANT AND WEAR-RESISTANT STEEL PLATE AND MANUFACTURING METHOD THEREFOR**

(57) Disclosed in the present disclosure are a corrosion-resistant and wear-resistant steel plate and a manufacturing method therefor. The steel plate comprises, in percentages by weight: C: 0.15%≤C≤0.25%; Si: 0.10%≤Si≤0.50%; Mn: 0.50%≤Mn≤1.50%; Mo: 0.01%≤Mo≤0.50%; Nb: 0.005%≤Nb≤0.050%; V: 0.01%≤V≤0.10%; Ti: 0.005%≤Ti≤0.050%; Al: 0.010%≤Al≤0.060%; Cr: 2.00%≤Cr≤5.00%; B: 0.0005-0.0050 wt%; and P: 0.010%<P<0.030%. In addition,

the steel plate further comprises one or more of Cu: 0.10%≤Cu≤0.40%, Ni: 0.20%≤Ni≤1.00%, RE: 0.01%≤RE≤0.10%, and Sb: 0.01%≤Sb≤0.20%, with the balance being Fe and inevitable impurities. The manufacturing method for the steel plate comprises the steps of: (1) a smelting and casting step; (2) a heating step; (3) a rolling step; and (4) an online cooling step. The steel plate of the present disclosure has both good acid and alkali resistance and wear resistance.

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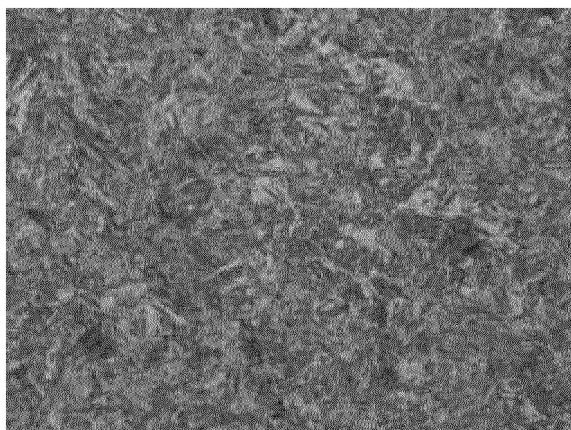


Fig. 1

Description**Technical Field**

- 5 **[0001]** The present disclosure relates to a steel plate and a manufacturing method thereof, in particular a corrosion-resistant and wear-resistant steel plate and a manufacturing method thereof

Background Art

- 10 **[0002]** The working conditions of mechanical equipment used for engineering, mining, cement production, ports, electric power and metallurgy and the like are particularly harsh. For example, scraper conveyors, dump truck boxes and other products need to have high strength, high hardness and high toughness. However, in some special working conditions, such as the processing of industrial garbage, the service life of wear-resistant equipment is very short. This is mainly because that the environment caused by garbage rust and decay tends to cause corrosion of the equipment and shorten the service life.

- 15 **[0003]** At present, researches on acid-resistant steel plates are ongoing, such as the patent application number 201480021680.3 with a title of "steel plate for thick-walled high-strength wire pipe with excellent acid resistance, crush resistance and low temperature toughness and wire pipe", which provides a steel plate for a thick-walled high-strength wire pipe with excellent acid resistance, crush resistance and low-temperature toughness and a manufacturing method thereof, but the steel plate only has acid resistance.

- 20 **[0004]** In addition, researches on alkali-resistant steel plates are also ongoing, such as the patent application number 201010168491.2, with a title of "steel for hot-rolled U-shaped steel plate piles resistant to alkaline soil corrosion and production method thereof", which provides a steel for hot-rolled U-shaped steel plate piles resistant to alkaline soil corrosion and a production method, but the steel plate only has alkali resistance.

- 25 **[0005]** However, in response to environmental changes, there is no steel plate that can resist alkalis and acids, and at the same time have excellent wear resistance.

- 30 **[0006]** In view of the above-mentioned defects of the prior art, it is expected to obtain a low-carbon low-alloy steel plate with both corrosion resistance and wear resistance, which has excellent acid resistance and alkali resistance while ensuring that the material has excellent wear resistance, and can reduce the manufacturing cost, and is suitable for mass production.

Summary

- 35 **[0007]** The purpose of the present disclosure is to provide a corrosion-resistant and wear-resistant steel plate and a manufacturing method thereof. The corrosion-resistant and wear-resistant steel plate has both excellent wear resistance, acid resistance and alkali resistance, can meet the requirements of wear resistance and corrosion resistance of the steel plate in a particularly harsh working environment, and reduce the manufacturing cost.

- [0008]** In order to achieve the above purpose, the present disclosure provides a corrosion-resistant and wear-resistant steel plate, which comprises, in percentages by weight:

- 40 C: $0.10\% \leq C \leq 0.30\%$;
 Si: $0.10\% \leq Si \leq 0.50\%$;
 Mn: $0.50\% \leq Mn \leq 1.50\%$;
 Mo: $0.01\% \leq Mo \leq 0.50\%$;
 45 Nb: $0.005\% \leq Nb \leq 0.050\%$;
 V: $0.01\% \leq V \leq 0.10\%$;
 Ti: $0.005\% \leq Ti \leq 0.050\%$;
 Al: $0.010\% \leq Al \leq 0.060\%$;
 Cr: $2.00\% \leq Cr \leq 5.00\%$;
 50 B: $0.0005\% \leq B \leq 0.0050\%$;
 Sb: $0.01\% \leq Sb \leq 0.20\%$;
 P: $0.010\% \leq P \leq 0.030\%$;

- 55 **[0009]** In addition, it comprises one or more of Cu: $0.10 \leq Cu \leq 0.40\%$, Ni: $0.20 \leq Ni \leq 1.00\%$ and RE: $0.01 \leq RE \leq 0.10\%$ with a balance of Fe and unavoidable impurities.

- [0010]** Another embodiment of the present disclosure is a corrosion-resistant and wear-resistant steel plate, in addition to Fe and unavoidable impurities, which comprises, in percentages by weight:

C: $0.10\% \leq C \leq 0.30\%$;
 Si: $0.10\% \leq Si \leq 0.50\%$;
 Mn: $0.50\% \leq Mn \leq 1.50\%$;
 Mo: $0.01\% \leq Mo \leq 0.50\%$;
 Nb: $0.005\% \leq Nb \leq 0.050\%$;
 V: $0.01\% \leq V \leq 0.10\%$;
 Ti: $0.005\% \leq Ti \leq 0.050\%$;
 Al: $0.010\% \leq Al \leq 0.060\%$;
 Cr: $2.00\% \leq Cr \leq 5.00\%$;
 B: $0.0005\% \leq B \leq 0.0050\%$;
 Sb: $0.01\% \leq Sb \leq 0.20\%$;
 P: $0.010\% \leq P \leq 0.030\%$;

and further comprises: one or more of Cu: $0.10\% \leq Cu \leq 0.40\%$, Ni: $0.20\% \leq Ni \leq 1.00\%$ and RE: $0.01\% \leq RE \leq 0.10\%$.

[0011] In some embodiments, the corrosion-resistant and wear-resistant steel plate of the present disclosure comprises, in percentages by weight: C: $0.15\% \leq C \leq 0.25\%$; Si: $0.10\% \leq Si \leq 0.50\%$; Mn: $0.50\% \leq Mn \leq 1.50\%$; Mo: $0.01\% \leq Mo \leq 0.50\%$; Nb: $0.005\% \leq Nb \leq 0.050\%$; V: $0.01\% \leq V \leq 0.10\%$; Ti: $0.005\% \leq Ti \leq 0.050\%$; Al: $0.010\% \leq Al \leq 0.060\%$; Cr: $2.00\% \leq Cr \leq 5.00\%$; B: $0.0005\% \leq B \leq 0.0050\%$; and P: $0.010\% \leq P \leq 0.030\%$; further comprises: one or more of Cu: $0.10\% \leq Cu \leq 0.40\%$, Ni: $0.20\% \leq Ni \leq 1.00\%$, RE: $0.01\% \leq RE \leq 0.10\%$ and Sb: $0.01\% \leq Sb \leq 0.20\%$, with a balance of Fe and unavoidable impurities.

[0012] In some embodiments, the corrosion-resistant and wear-resistant steel plate of the present disclosure comprises, in percentages by weight:

C: $0.10\% \leq C \leq 0.30\%$;
 Si: $0.25\% \leq Si \leq 0.45\%$;
 Mn: $0.65\% \leq Mn \leq 1.50\%$;
 Mo: $0.10\% \leq Mo \leq 0.35\%$;
 Nb: $0.01\% \leq Nb \leq 0.045\%$;
 V: $0.01\% \leq V \leq 0.08\%$;
 Ti: $0.010\% \leq Ti \leq 0.045\%$;
 Al: $0.020\% \leq Al \leq 0.050\%$;
 Cr: $2.30\% \leq Cr \leq 4.60\%$;
 B: $0.0015\% \leq B \leq 0.0040\%$;
 Sb: $0.06\% \leq Sb \leq 0.19\%$;
 P: $0.010\% \leq P \leq 0.016\%$;
 S: $\leq 0.005\%$;
 Cu: $\leq 0.35\%$;
 Ni: $\leq 0.75\%$;
 RE: $\leq 0.10\%$;

with a balance of Fe and unavoidable impurities.

[0013] The steel plate of the present disclosure further comprises, in percentages by weight:

$0.10\% \leq Mo \leq 0.40\%$;
 $0.010\% \leq Nb \leq 0.045\%$;
 $0.02\% \leq V \leq 0.10\%$;
 $0.015\% \leq Ti \leq 0.050\%$.

[0014] The steel plate of the present disclosure further comprises, in percentages by weight:

$2.50\% \leq Cr \leq 5.00\%$;
 $0.012\% \leq P \leq 0.030\%$;
 $0.12\% \leq Cu \leq 0.40\%$;
 $0.20\% \leq Ni \leq 0.90\%$.

[0015] Further, in the steel plate of the present disclosure, among the unavoidable impurities, S is $< 0.010\%$ by weight.

[0016] In the corrosion-resistant and wear-resistant steel plate of the present disclosure, the design principles of each chemical element are as follows (the following contents are measured in mass percentages):

Carbon (C): Carbon is the most basic and important element in wear-resistant steel, which can improve the strength and hardness of steel, and thus improve the wear resistance of steel, but it is not good for the toughness and welding performance of steel. Therefore, in the present disclosure, the carbon content is controlled to be $0.10\% \leq C \leq 0.30\%$, and further preferably $0.12\% \leq C \leq 0.29\%$.

Silicon (Si): Silicon solid solutions in ferrite and austenite increase their hardness and strength, however, too much silicon can cause a sharp decrease in the toughness of steel. At the same time, considering that the affinity between silicon and oxygen is stronger than that between iron and oxygen, it is easy to produce silicates with low melting points during welding, which increases the fluidity of slags and molten metals, and affects the quality of welds. Therefore, the content should not be too high. The content of silicon is controlled to be $0.10\% \leq Si \leq 0.50\%$ and further preferably $0.15\% \leq Si \leq 0.50\%$. In some embodiments, the silicon content is controlled to be $0.25\% \leq Si \leq 0.45\%$.

Manganese (Mn): Manganese strongly increases the hardenability of steel and reduces the transition temperature of a wear-resistant steel and the critical cooling rate of steel. However, when the content of manganese is high, it has a tendency to roughen the grains, increases the tempering brittleness sensitivity of steel, and it is easy to cause segregation and cracks in the casting billet, which reduces the performance of the steel plate. The content of manganese is controlled to be $0.50\% \leq Mn \leq 1.50\%$, and further preferably $0.60\% \leq Mn \leq 1.50\%$. In some embodiments, the content of manganese is controlled to be $0.65\% \leq Mn \leq 1.50\%$.

Molybdenum: Molybdenum can refine grains and improve strength and toughness. Molybdenum exists in both the solid solution phase and the carbide phase in steel. Therefore, molybdenum-containing steel has the effect of solution strengthening and carbide diffusion strengthening at the same time. Molybdenum is an element that reduces tempering brittleness and can improve tempering stability. The content of molybdenum is controlled to be $0.010\% \leq Mo \leq 0.50\%$, and further preferably $0.10\% \leq Mo \leq 0.40\%$.

Niobium (Nb): The grain refining and precipitation strengthening effects of Nb are extremely significant to improve the strength and toughness of materials, and Nb is a strong carbide and nitride formation element, and strongly inhibits the growth of austenite grains. Nb improves the strength and toughness of steel at the same time through grain refinement, Nb improves and enhances the properties of steel mainly through precipitation strengthening and phase change strengthening, and Nb has been used as one of the most effective reinforcing agents in HSLA steel. Therefore, the content of niobium is controlled to be $0.005\% \leq Nb \leq 0.050\%$, and further preferably $0.010\% \leq Nb \leq 0.045\%$.

Vanadium (V): The addition of vanadium is mainly to refine the grains, so that the austenite grains of a billet will not grow too coarse in the heating stage. In this way, the grains of steel can be further refined in the subsequent multi-pass rolling process, and the strength and toughness of steel can be improved. Therefore, the content of vanadium is controlled to be $0.01\% \leq V \leq 0.10\%$, and further preferably $0.02\% \leq V \leq 0.10\%$. In some embodiments, the content of vanadium is controlled to be $0.01\% \leq V \leq 0.08\%$.

Titanium (Ti): Titanium is one of the strong carbide forming elements, and can form fine TiC particles with carbon. The TiC particles are fine and distributed in the grain boundaries to achieve the effect of refining the grain. Hard TiC particles can improve the wear resistance of steel. Therefore, the content of titanium is controlled to be $0.005\% \leq Ti \leq 0.050\%$, and further preferably $0.015\% \leq Ti \leq 0.050\%$.

Aluminum (Al): Aluminum and nitrogen in steel can form fine insoluble AlN particles, which refine the grains of steel. Aluminum can refine the grains of steel, fix nitrogen and oxygen in steel, reduce the sensitivity of steel to notching, reduce or eliminate the aging phenomenon of steel, and improve the toughness of steel. Therefore, the content of aluminum is controlled to be $0.010\% \leq Al \leq 0.060\%$, and further preferably $0.015\% \leq Al \leq 0.060\%$. In some embodiments, the content of aluminum is controlled to be $0.02\% \leq V \leq 0.05\%$.

Chromium (Cr): Chromium can reduce the critical cooling rate and improve the hardenability of steel. Chromium can form a variety of carbides such as $(Fe, Cr)_3C$, $(Fe, Cr)_7C_3$ and $(Fe, Cr)_{23}C_7$ in steel, improving strength and hardness. Chromium can prevent or slow down the precipitation and aggregation of carbides during tempering, which can improve the tempering stability of steel. In addition, it can also improve the resistance of steel to acid corrosion. In the oxidizing medium, a strong and dense layer of chromium oxide is formed on the surface of steel, so that the steel is protected. The dissolution of chromium in steel can significantly increase the electrode potential of the steel and reduce the electrochemical corrosion caused by different electrode potentials. Therefore, the content of chromium is controlled to be $2.00\% \leq Cr \leq 5.00\%$, and further preferably $2.50\% \leq Cr \leq 5.00\%$.

Boron (B): Boron increases the hardenability of steel, but an overly high content will lead to hot embrittlement, affecting the welding performance and hot working performance of steel, so it is necessary to strictly control the content of B. Therefore, the content of boron is controlled to be $0.0005\% \leq B \leq 0.0050\%$, and further preferably $0.0008\% \leq B \leq 0.0050\%$. In some embodiments, the content of boron is controlled to be $0.0015\% \leq B \leq 0.0040\%$.

Antimony (Sb): Antimony can improve the resistance of steel to acid corrosion and increase the hardness of alloys. In an acidic environment, passivation occurs due to dissolution, and a passivation layer rich in alloying elements such as Sb forms on the surface of steel, which has a high resistance to acid corrosion. Therefore, the content of antimony is controlled to be $0.01\% \leq Sb \leq 0.20\%$, and further preferably $0.03\% \leq Sb \leq 0.20\%$. In some embodiments, the antimony content is controlled to be $0.05\% \leq Sb \leq 0.20\%$.

Copper (Cu): In steel, it mainly exists in the state of solid solution and elemental phase precipitation, and the solid solution Cu plays a role in solution strengthening; since the solid solubility of Cu in ferrite decreases rapidly with the decrease of temperature, the supersaturated solid solution Cu is precipitated in the form of an element at a lower temperature, which plays a role in precipitation strengthening. At the same time, the addition of Cu to steel can significantly improve the resistance of the steel to atmospheric corrosion, and the effect is particularly significant when it coexists with phosphorus. Therefore, when copper is added, the content of copper can be controlled to be $0.10\% \leq \text{Cu} \leq 0.40\%$, and further preferably $0.12\% \leq \text{Cu} \leq 0.40\%$. The content of phosphorus is controlled to be $0.010\% \leq \text{P} \leq 0.030\%$, and further preferably $0.012\% \leq \text{P} \leq 0.030\%$.

Nickel (Ni): Nickel has the effect of significantly reducing the cold brittleness transition temperature, however, if the content is too high, it will tend to cause the oxide scale on the surface of the steel plate to be difficult to fall off and the cost will increase significantly. Therefore, when nickel is added, the content of nickel is controlled to be $0.20\% \leq \text{Ni} \leq 1.00\%$, and further preferably $0.45\% \leq \text{Ni} \leq 0.8\%$.

Rare Earth (RE): The addition of rare earths to steel can reduce the segregation of elements such as sulfur and phosphorus, improve the shape, size and distribution of non-metallic inclusions, and refine grains to achieve ultra-high hardness. In addition, rare earths can improve the corrosion resistance of steel. The content of rare earth should not be too high, otherwise it will cause serious segregation and reduce the quality and mechanical properties of the casting billet. Therefore, the content of RE is controlled to be $0.01\% \leq \text{RE} \leq 0.10\%$ and further preferably $0.02\% \leq \text{RE} \leq 0.90\%$. Sulfur: Sulfur is a harmful element, and the content should be strictly controlled. The sulfur content in the steel grades involved in this disclosure is controlled to be $\text{S} \leq 0.010\%$.

[0017] Further, the Brinell hardness of the steel plate of the present disclosure is 350-520HBW, such as 350~500HBW. In some embodiments, the Brinell hardness of the steel plate of the present disclosure is 370-520HBW.

[0018] Further, the steel plate of the present disclosure comprises a lath martensitic structure, bainite and residual austenite, wherein the volume fraction of the bainite is 10-40% and the volume fraction of the residual austenite is 5-15%.

[0019] Further, the thickness of the steel plate of the present disclosure is 15~40mm.

[0020] The second aspect of the present disclosure is a method for manufacturing the corrosion-resistant and wear-resistant steel plate, comprising the following steps:

- (1) a smelting and casting step;
- (2) a heating step;
- (3) a rolling step; and
- (4) an on-line cooling step.

[0021] In the manufacturing method of the corrosion-resistant and wear-resistant steel plate of the present disclosure, in the heating step (2), the slab heating temperature is 1000-1200 °C, and the holding time is 1-3 hours; in the rolling step (3), the start rolling temperature of rough rolling is 900-1150 °C (such as 1000~1100 °C), and the final rolling temperature of finish rolling is 780-880 °C (such as 810~870 °C); in the on-line cooling step (4), the cooling can be carried out by water-cooling, and it can be water-cooled to a temperature not higher than 350 °C (such as 150~350 °C) and then air-cooled to room temperature, and the cooling rate of the water cooling can be 15-50 °C/s.

[0022] Further, in the steel plate of the present disclosure, the finish rolling deformation rate of the steel plate is 60~80%.

Beneficial effects

[0023] Compared with the prior art, the corrosion-resistant and wear-resistant steel plate of the present disclosure and the manufacturing method thereof have the following advantages and beneficial effects:

The corrosion-resistant and wear-resistant steel plate involved in the present disclosure has obvious advantages, and the wear-resistant steel plate with both excellent acid resistance and wear resistance is obtained by controlling the contents of carbon and alloying elements and each heat treatment process, and it can be manufactured at low cost with a simple process, and it has high strength and hardness, excellent machining performance, easy weldability, and excellent acid corrosion resistance. Specifically:

1. From the point of view of chemical composition, the corrosion-resistant and wear-resistant steel plate of the present disclosure mainly has an alloy composition of low-carbon and low-alloy, and makes full use of the characteristics of refinement and strengthening of alloying elements such as Cr, Mo, Ni, Cu, Nb, Ti, etc., to ensure that the steel plate has good mechanical properties and good corrosion resistance, etc., and the corrosion-resistant and wear-resistant steel plate of the present disclosure has the advantages of high strength, high hardness and excellent acid resistance and alkali resistance, and has good welding performance.

2. From the point of view of production process, the corrosion-resistant and wear-resistant steel plate of the present

disclosure improves the structural refinement and strengthening effect by controlling the process parameters such as the start and final rolling temperature, finish rolling deformation rate and cooling rate in the manufacturing method, thereby reducing the content of carbon and alloying elements, and obtaining a steel plate with excellent mechanical properties and welding properties. In addition, the process also has the characteristics of short production process, high efficiency, energy saving and low cost.

3. The corrosion-resistant and wear-resistant steel plate of the present disclosure makes full use of the addition of alloying elements and the controlled rolling and cooling process to obtain the lath martensitic structure and residual austenite, which is beneficial to the good matching of the strength, hardness and toughness of the wear-resistant steel plate. The higher the residual austenite content, the higher the self-corrosion potential, the lower the residual austenite content, the lower the self-corrosion potential, and the increase of residual austenite helps to improve the corrosion resistance of the material.

Description of the drawings

[0024] Fig. 1 is the metallographic structure of the steel plate in the present disclosure.

Embodiments

[0025] The embodiments of the present disclosure are illustrated below by specific examples, and those skilled in the art can easily understand other advantages and effects of the present disclosure from the contents disclosed in the present specification. Although the description of the present disclosure will be presented in conjunction with the preferred example, this does not mean that the features of the present disclosure are limited to those examples. On the contrary, the purpose of the description of the present disclosure in conjunction with embodiments is to cover other options or modifications that may be extended from the claims of the present disclosure. In order to provide an in-depth understanding of the present disclosure, many specific details will be included in the following description. This disclosure may also be implemented without these details. In addition, in order to avoid confusion or obscurity of the main points of the present disclosure, some specific details will be omitted from the description.

Example 1-8 and Comparative Example 1

[0026] Table 1 lists the mass percentage of each chemical element of the corrosion-resistant and wear-resistant steel plates of Example 1-8 and Comparative Example 1.

Table 1: Chemical compositions of Example 1-8 and Comparative Example 1 (wt.%)

	Example 1	Example 2	Example 3	Example 4	Example 5	Example 6	Example 7	Example 8	Comparative Example 1
C	0.1	0.15	0.17	0.19	0.22	0.25	0.27	0.3	0.17
Si	0.36	0.3	0.25	0.45	0.4	0.35	0.28	0.3	0.25
Mn	1.5	1.45	1.25	0.95	1.05	0.65	0.75	0.83	1.56
P	0.015	0.012	0.011	0.013	0.01	0.013	0.015	0.016	0.012
S	0.003	0.005	0.002	0.003	0.004	0.003	0.003	0.002	0.005
Cr	2.3	3	2.5	4	3.2	4.6	3.15	4.35	-
Mo	0.15	0.1	0.35	0.2	0.3	0.25	0.2	0.35	-
Nb	0.015	0.01	0.035	0.025	0.03	0.045	0.015	0.015	-
V	0.05	0.05	0.03	0.08	0.02	0.06	0.03	0.01	-
Ti	0.03	0.015	0.025	0.01	0.035	0.045	0.04	0.035	-
Al	0.035	0.02	0.04	0.035	0.025	0.05	0.03	0.02	0.05
B	0.002	0.004	0.002	0.0035	0.0025	0.0015	0.0025	0.002	-
Sb	0.06	0.1	0.08	0.16	0.11	0.19	0.15	0.12	-
Cu	0.15	-	0.2	-	-	0.3	0.25	0.35	-
Ni	0.35	-	0.45	-	-	0.75	0.6	0.75	-

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(continued)

	Example 1	Example 2	Example 3	Example 4	Example 5	Example 6	Example 7	Example 8	Comparative Example 1
RE	0.05	0.08	0.02	-	-	-	0.1	0.09	-

[0027] The corrosion-resistant and wear-resistant steel plates of Example 1-8 of the present disclosure were prepared by adopting the following steps:

The manufacturing method of the wear-resistant steel plates of Example 1-8 was as follows:

- (1) a smelting and casting steps, heating, rolling, online quenching and other steps;
- (2) a heating step, wherein the heating temperature of the slab was 1000-1200 °C, and the holding time was 1-3 hours;
- (3) a rolling step, wherein start rolling temperature of rough rolling was 900-1150 °C, and the final rolling temperature of finish rolling was 780-880 °C;
- (4) an online quenching step, wherein water cooling was used to cool the steel plate to a temperature not greater than 350 °C (stop cooling temperature) and then the steel plate was air cooled to room temperature, wherein the cooling rate of the water cooling was 15-50 °C/s.

[0028] For the wear-resistant steel plate of Comparative Example 1, except that the composition of the raw material and the specific process parameters in each step were different from those of the above Example 1-8, the wear-resistant steel plate was manufactured with the same steps described above. The specific process parameters of Example 1-8 and Comparative Example 1 are shown in Table 2.

Table 2: specific process parameters in Example 1-8 and Comparative Example 1

	slab heating temperature, °C	holding time, h	start rolling temperature, °C	final rolling temperature, °C	finish rolling deformation rate, %	Cooling manner	stop cooling temperature, °C	cooling rate, °C/s	thickness of steel plate, mm	volume fraction of residual austenite, %	volume fraction of bainite, %
Example 1	1110	2	1050	865	75	water cooling	265	45	15	8	12
Example 2	1090	1	1000	810	65	water cooling	350	32	30	13	38
Example 3	1120	1.5	1060	835	63	water cooling	200	19	20	8	15
Example 4	1200	2	1020	870	60	water cooling	280	27	35	9	29
Example 5	1160	2	1020	835	76	water cooling	230	30	40	8	21
Example 6	1140	2	1100	820	62	water cooling	150	25	25	6	10
Example 7	1175	2	1090	855	77	water cooling	315	32	20	11	35
Example 8	1180	2	1110	820	79	water cooling	275	28	20	9	25
Comparative Example 1	1165	2	1000	920	50	Air cooling	-	-	20		

[0029] Acid resistance test, alkali resistance test and mechanical property test were carried out on the corrosion-resistant and wear-resistant steel plates of Example 1-8 and Comparative Example 1, and the obtained test results were listed in Table 3~5.

[0030] The acid resistance test method was as follows: the corrosion test was carried out under the conditions of "temperature $23\pm 2^{\circ}\text{C}$, $10\%\text{H}_2\text{SO}_4+3.5\%\text{NaCl}$, and total immersion for 24 hours" using a constant temperature test tank. For the specific method, please refer to the "JB/T7901-2001 Laboratory Uniform Corrosion Total Immersion Test Method for Metallic Materials".

[0031] The alkaline resistance test method was as follows: an alternate immersion test was carried out under alkaline atmosphere, the experimental temperature was $45\pm 2^{\circ}\text{C}$, the relative humidity was $70\pm 5\%$, the alternate immersion speed was 1/60 (cycles/min), and the PH value was 9.5.

[0032] Brinell hardness test: SCL246 Brinell hardness testing machine was used at room temperature according to GB/T 231.1 standard for Brinell hardness test. The hardness test was carried out on the surface position of the wear-resistant steel samples of Example 1-8 and Comparative Example 1 respectively to obtain the corresponding Brinell hardness.

Table 3: Corrosion properties of Example 1-8 and Comparative Example 1

Example/Comparative Example No.	test time, h	acid corrosion rate, $\text{g}/(\text{m}^2\cdot\text{h})$
Example 1	24	0.31
Example 2	24	0.33
Example 3	24	0.30
Example 4	24	0.28
Example 5	24	0.35
Example 6	24	0.23
Example 7	24	0.26
Example 8	24	0.22
Comparative Example 1	24	3.51

Table 4: Alkaline Corrosion Resistance of Example 1-8 and Comparative Example 1

Example/Comparative Example No.	test time, h	alkali corrosion rate, $\text{g}/(\text{m}^2\cdot\text{h})$
Example 1	290	0.49
Example 2	290	0.51
Example 3	290	0.48
Example 4	290	0.45
Example 5	290	0.58
Example 6	290	0.41
Example 7	290	0.44
Example 8	290	0.39
Comparative Example 1	290	2.56

Table 5: mechanical properties of Example 1-8 and Comparative Example 1

Example/Comparative Example No.	hardness, HBW
Example 1	375
Example 2	416
Example 3	426
Example 4	449
Example 5	440

(continued)

Example/Comparative Example No.	hardness, HBW
Example 6	463
Example 7	495
Example 8	513
Comparative Example 1	235

[0033] As can be seen from Table 1-5, the maximum acid corrosion rate of the steel plates of Example 1-8 obtained by optimizing the chemical elements and controlling the manufacturing process is only 0.33 g/(m²·h), the maximum alkali corrosion rate is only 0.51 g/(m²·h), and the minimum hardness (HBW) is 375. The chemical element and manufacturing method of Comparative Example 1 are different from those of the present disclosure, and the acid corrosion rate of Comparative Example 1 is 3.51g/(m²·h), the alkali corrosion rate is 2.56g/(m²·h), and the hardness (HBW) is 235. The acid corrosion and alkali corrosion rates of the steel plate of Comparative Example 1 are much greater than the corrosion rates of the steel plates of the present disclosure, that is, the acid resistance and alkali resistance are poorer, and the hardness is also poorer. That is, the acid resistance and alkali resistance of the steel plate of the present disclosure obtained by optimizing the chemical elements and controlling the manufacturing process have been greatly improved. The wear-resistant steel plate has excellent acid and alkali resistance, and the hardness HBW is greater than 375.

[0034] In summary, it can be seen that through the reasonable chemical composition design in combination with the optimized process, the steel plate of the present disclosure has excellent acid resistance, alkali resistance and wear resistance at the same time, and its production process is simple, can be used in harsh working environments, improve the service life, and has broad application prospects.

[0035] It should be noted that the prior art part of the scope of protection of the present disclosure is not limited to the examples given in the application documents, and all prior art that does not contradict the solution of the present disclosure, including but not limited to prior patent documents, prior publications, prior public use, etc., can be included in the scope of protection of the present disclosure. In addition, the combination of various technical features in this case is not limited to the combination mode recorded in the claims of this case or the combination mode recorded in the specific embodiment, and all the technical features recorded in this case can be freely combined or combined in any way, unless there is a contradiction between them.

[0036] It should also be noted that the examples listed above are only specific examples of the present disclosure. Obviously, the present disclosure is not limited to the above examples, and similar changes or modifications made thereby are directly derived from the contents of the present disclosure by those skilled in the art or can be easily envisaged, and shall fall within the scope of protection of the present disclosure.

Claims

1. A corrosion-resistant and wear-resistant steel plate comprising, in percentages by weight: C: 0.15%≤C≤0.25%; Si: 0.10%≤Si≤0.50%; Mn: 0.50%≤Mn≤1.50%; Mo: 0.01%≤Mo≤0.50%; Nb:

0.005%≤Nb≤0.050%; V: 0.01%≤V≤0.10%; Ti: 0.005%≤Ti≤0.050%; Al: 0.010%≤Al≤0.060%; Cr: 2.00%≤Cr≤5.00%; B: 0.0005%≤B≤0.0050%; and P: 0.010%≤P≤0.030%; and further comprising one or more of Cu: 0.10%≤Cu≤0.40%, Ni: 0.20%≤Ni≤1.00%, RE: 0.01%≤RE≤0.10% and Sb: 0.01%≤Sb≤0.20%, with a balance of Fe and unavoidable impurities.

2. A corrosion-resistant and wear-resistant steel comprising, in percentages by weight:

0.10%≤C≤0.30%; 0.10%≤Si≤0.50%; 0.50%≤Mn≤1.50%; 0.01%≤Mo≤0.50%; 0.005%≤Nb≤0.050%; 0.01%≤V≤0.10%; 0.005%≤Ti≤0.050%; 0.010%≤Al≤0.060%; 2.00%≤Cr≤5.00%; 0.0005%≤B≤0.0050% and P: 0.010%≤P≤0.030%; and further comprising one or more of Cu: 0.10%≤Cu≤0.40%, Ni: 0.20%≤Ni≤1.00%, RE: 0.010%≤RE≤0.10% and Sb: 0.01%≤Sb≤0.20% in addition to Fe and unavoidable impurities.

3. A corrosion-resistant and wear-resistant steel plate comprising, in percentages by weight: C: 0.10%≤C≤0.30%; Si: 0.10%≤Si≤0.50%; Mn: 0.50%≤Mn≤1.50%; Mo: 0.01%≤Mo≤0.50%; Nb:

0.005%≤Nb≤0.050%; V: 0.01%≤V≤0.10%; Ti: 0.005%≤Ti≤0.050%; Al: 0.010%≤Al≤0.060%; Cr:

2.00%≤Cr≤5.00%; B: 0.0005%≤B≤0.0050%; Sb: 0.01%≤Sb≤0.20%; P: 0.010%≤P≤0.030%; and further comprising one or more of Cu: 0.10%≤Cu≤0.40%, Ni: 0.20%≤Ni≤1.00% and RE: 0.01%≤RE≤0.10%, with a balance of Fe and unavoidable impurities.

- 5 **4.** The corrosion-resistant and wear-resistant steel plate of any one of claims 1-3, comprising, in percentages by weight: 0.10%≤Mo≤0.40%; 0.010%≤Nb≤0.045%; 0.02%≤V≤0.10%; 0.015%≤Ti≤0.050%; and/or comprising, in percentages by weight: 2.50%<Cr<5.00%; 0.012%≤P≤0.030%; 0.12%≤Cu≤0.40%; 0.20%≤Ni≤0.90%.
- 10 **5.** The corrosion-resistant and wear-resistant steel plate of any one of claims 1-3, wherein among the unavoidable impurities, S is < 0.010% by weight.
- 15 **6.** The corrosion-resistant and wear-resistant steel plate of any one of claims 1-3, wherein the content of B is: 0.0015%≤B≤0.0040% by weight.
- 20 **7.** The corrosion-resistant and wear-resistant steel plate of any one of claims 1-3, wherein the corrosion-resistant and wear-resistant steel plate comprises, in percentages by weight C: 0.10%≤C≤0.30%; Si: 0.25%≤Si≤0.45%; Mn: 0.65%≤Mn≤1.50%; Mo: 0.10%≤Mo≤0.35%; Nb: 0.01%≤Nb≤0.045%; V: 0.01%≤V≤0.08%; Ti: 0.010%≤Ti≤0.045%; Al: 0.020%≤Al≤0.050%; Cr: 2.30%≤Cr≤4.60%; B: 0.0015%≤B≤0.0040%; Sb: 0.06%≤Sb≤0.19%; P: 0.010%≤P≤0.016%; S: ≤0.005%; Cu: ≤0.35%; Ni: ≤0.75%; RE: ≤0.10%; with a balance of Fe and unavoidable impurities.
- 25 **8.** The corrosion-resistant and wear-resistant steel plate of any one of claims 1-7, wherein the steel plate has a Brinell hardness of 350-520HBW, preferably 350~500HBW.
- 30 **9.** The corrosion-resistant and wear-resistant steel plate of any one of claims 1-8, wherein the steel plate comprises a lath martensitic structure, bainite and residual austenite, wherein the volume fraction of the bainite is 10-40% and the volume fraction of the residual austenite is 5-15%.
- 35 **10.** A method for manufacturing the corrosion-resistant and wear-resistant steel plate of any one of claims 1-9, comprising the following steps:
 - (1) a smelting and casting step;
 - (2) a heating step;
 - (3) a rolling step, wherein the final rolling temperature of finish rolling is 780-880 °C; and
 - (4) an on-line cooling step.
- 40 **11.** The method for manufacturing the corrosion-resistant and wear-resistant steel plate of claim 10, wherein the on-line cooling step (4) is performed by water cooling and the cooling rate of the water cooling was 15-50 °C/s.
- 45 **12.** The method for manufacturing the corrosion-resistant and wear-resistant steel plate of claim 10, wherein in the heating step (2), the slab heating temperature is 1000-1200 °C, and the holding time is 1-3 hours; in the on-line cooling step (4), the steel plate is water-cooled to a temperature not higher than 350 °C and then air-cooled to room temperature.
- 50 **13.** The method for manufacturing the corrosion-resistant and wear-resistant steel plate of claim 10, wherein the finish rolling deformation rate of the steel plate is 60~80%.
- 55 **14.** The method for manufacturing the corrosion-resistant and wear-resistant steel plate of claim 10, wherein in step (3), the start rolling temperature of rough rolling is 900-1150 °C.
- 15.** The method for manufacturing the corrosion-resistant and wear-resistant steel plate of claim 12, wherein in the rolling step (4), the steel plate is water-cooled to 150-350 °C and then air-cooled to room temperature.

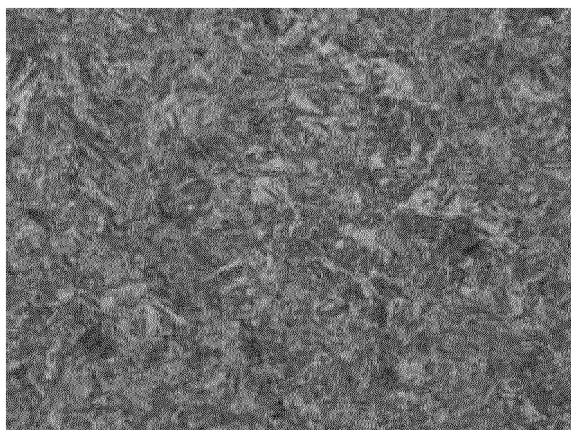


Fig. 1

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2023/110178

A. CLASSIFICATION OF SUBJECT MATTER

C22C38/02(2006.01)i; C22C38/04(2006.01)i; C22C38/06(2006.01)i; C22C38/44(2006.01)i; C22C38/46(2006.01)i;
C22C38/48(2006.01)i; C22C38/50(2006.01)i; C21D8/02(2006.01)i; C22C33/04(2006.01)i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC:C22C C21D

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

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

CNABS; DWPI; WPABS; CNKI; CNTXT; USTXT; WOTXT; EPTXT; ISI_Web of Science: 宝山钢铁股份有限公司, 碳, 硅, 锰, 钼, 铌, 钽, 钛, 铝, 铬, 硼, 磷, 铜, 镍, 铈, 稀土, C, carbon, Si, silicon, Mn, manganese, Mo, molybdenum, Nb, niobium, V, vanadium, Ti, titanium, Al, aluminum, Cr, chrome, B, boron, P, phosphate, Cu, copper, Ni, nickel, Sb, antimony, RE, rare earth

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	CN 101258257 A (NIPPON STEEL CORP.) 03 September 2008 (2008-09-03) claims 1-4, description, page 5, lines 17-21	1-15
X	CN 104662193 A (JFE STEEL CORP.) 27 May 2015 (2015-05-27) claims 1-5	1-15
X	CN 114402086 A (JFE STEEL CORP.) 26 April 2022 (2022-04-26) claims 1-3	1-15
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A	CN 107937806 A (WUHAN IRON & STEEL CO., LTD.) 20 April 2018 (2018-04-20) claims 1-5	1-15

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents:

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“D” document cited by the applicant in the international application

“E” earlier application or patent but published on or after the international filing date

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

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

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

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

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

“&” document member of the same patent family

Date of the actual completion of the international search

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Date of mailing of the international search report

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Name and mailing address of the ISA/CN

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Beijing 100088

Authorized officer

Telephone No.

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
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