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(71) Applicant: **BAOSHAN IRON & STEEL CO., LTD.**
Shanghai 201900 (CN)

(72) Inventors:

- **XUE, Peng**
Shanghai 201900 (CN)
- **ZHU, Xiaodong**
Shanghai 201900 (CN)
- **LI, Wei**
Shanghai 201900 (CN)

(74) Representative: **Kuhnen & Wacker**

Patent- und Rechtsanwaltsbüro PartG mbB
Prinz-Ludwig-Straße 40A
85354 Freising (DE)

(54) **1300-MPA-GRADE-OR-HIGHER COLD-ROLLED STEEL SHEET AND MANUFACTURING METHOD THEREFOR**

(57) Disclosed in the present invention are a 1300-MPa-grade-or-higher cold-rolled steel sheet and a manufacturing method therefor. The cold-rolled steel sheet comprises Fe and inevitable impurity elements, and further comprises the following chemical elements in percentages by mass: 0.10-0.30% of C, 0.1-0.5% of Si, 0.8-2.5% of Mn, 0.01-0.03% of Al, 0.001-0.003% of

B, and 0-0.05% of Ti, wherein the mass percentage contents of C and Mn satisfy: $C+Mn/6 \geq 0.35\%$. By means of a reasonable chemical component design and a reasonable manufacturing process, the 1300-MPa-grade-or-higher cold-rolled steel sheet has an ultrahigh strength, and also has good resistance to delayed cracking and good bending performance.

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Description**Technical Field**

- 5 **[0001]** The present disclosure relates to a steel material and a manufacturing method thereof, in particular to a cold-rolled steel sheet and a manufacturing method thereof.

Background Art

- 10 **[0002]** In recent years, as the global energy crisis and environmental problems get increasingly severe, "energy saving" and "safety" have become the main development directions of the automobile manufacturing industry. As one of the important measures, lightweight design is adopted in the manufacture of automobiles to reduce vehicle weight, so as to save energy and reduce emissions.

- 15 **[0003]** In recent years, it's very common to use ultra-high-strength steel in the automotive industry. Ultra-high-strength steel has good mechanical properties and usability. It can be used to manufacture automotive structural parts and provide lightweight components, thereby reducing vehicle weight effectively. In the current automotive industry, for the manufacture of vehicles in practice, higher strength steel sheets are required to be used due to the need for weight reduction and safety. Ultra-high-strength steel with a tensile strength of 1000 MPa or higher is quite promising in weight reduction and safety performance. It can be used in the manufacture of safety parts, reinforcement parts and structural parts, and has good promotion prospects.

- 20 **[0004]** However, high-strength steel with a tensile strength of 1000MPa or higher has an inherent characteristic of stress corrosion cracking (delayed cracking). This high-strength steel sheet is prone to slow cracking under the action of stress and a corrosive medium. The delayed cracking has caused considerable trouble for the application of high-strength steel, and has greatly limited the application of ultra-high-strength steel.

- 25 **[0005]** The so-called delayed cracking means that a part does not crack when it's manufactured, but as time goes by, under the dual effects of stress and a corrosive medium, stress corrosion cracking occurs, which eventually leads to failure of the part and loss of safety protection. In this process, hydrogen plays a role in promoting crack initiation and propagation. Generally speaking, for the existing high-strength steel materials, the higher the strength of the steel material, the more serious the tendency to delayed cracking becomes. Delayed cracking is the biggest risk in the application of advanced high-strength steel.

- 30 **[0006]** In the current prior art, although some researchers have developed ultra-high-strength steel materials, the corresponding technical solutions have not effectively solved the problem of delayed cracking of ultra-high strength steel.

- 35 **[0007]** For example, Chinese Patent Application CN102822375A, published on December 12, 2012, and titled "ULTRA-HIGH-STRENGTH COLD-ROLLED STEEL SHEET AND METHOD FOR MANUFACTURING SAME", discloses an ultra-high-strength cold-rolled steel sheet and a method for manufacturing the same, wherein C: 0.05-0.4%, Si $\leq$ 2.0%, Mn: 1.0-3.0%, P $\leq$ 0.05%, S $\leq$ 0.02%, Al: 0.01-0.05%, and N $\leq$ 0.05%. During continuous annealing, the cold-rolled steel sheet needs to be cooled from Ac3 at a cooling rate of 20 °C/s or higher (gas cooling) to the range of from Ms point to Ms point + 200 °C, held for 0.1 to 60 s, and then cooled to 100 °C or lower at a cooling rate of 100 °C/s or higher (water cooling) to obtain the high-strength steel with a tensile strength of 1320 MPa or higher, wherein the flatness of the steel sheet is 10 mm or less.

- 40 **[0008]** For another example, Chinese Patent Application CN102776438A, published on November 14, 2012 and titled "NIOBIUM-LANTHANUM MICROALLOYED MN-B BASED ULTRA-HIGH-STRENGTH STEEL SHEET AND HEAT TREATMENT PROCESS FOR SAME", discloses a niobium-lanthanum microalloyed Mn-B based ultra-high-strength steel sheet and a heat treatment process for the same. The chemical elements of the steel sheet and their contents (by weight percentage) are: C 0.14%-0.35%, Mn 1.5%-2.0%, Si 0.6%-1.0%, P $\leq$ 0.015%, S $\leq$ 0.002%, Nb 0.01%-0.06%, B 0.0005%-0.0040%, La 0.001%-0.5%, and a balance of Fe and unavoidable impurities. In this technical solution, the heat treatment process system adopted is as follows: austenitizing temperature is 880-940 °C; holding time is 0.5-5 hours, followed by water quenching; tempering temperature is 190-250 °C; and holding time is 1-15 hours. In this patent technical solution, the designed steel sheet has excellent mechanical properties, including a tensile strength of 1200-1400 MPa, a yield strength of 1000-1300 MPa, and an elongation of 6-15%. It features low production cost, and capability of being industrially produced with a thickness of 5-25 mm.

- 50 **[0009]** For still another example, Chinese Patent Application CN102321841A, published on January 18, 2012, and titled "TRACK PLATE STEEL WITH TENSILE STRENGTH UP TO 1300 MPA AND METHOD FOR MANUFACTURING SAME" discloses a track plate steel with a tensile strength up to 1300 MPa and a method for manufacturing the same, wherein its chemical components by weight percentages are as follows: C: 0.20-0.30%, Mn: 0.80-1.40%, Si: 0.15-0.35%, P: 0-0.015%, S: 0-0.016%, Cr: 0-0.30%, Ni: 0-0.25%, Cu: 0-0.30%, Ti: 0.01-0.02%, Al: 0.02-0.06%, B: 0.0005-0.0035%, and a balance of Fe and unavoidable impurity elements. The steel designed by this technical solution has a tensile strength of 1340 MPa or higher and an elongation after fracture of less than 12%. Its "U"-shaped notch impact absorption energy is

greater than 72 J. It has a high strength, few quenching cracks and internal cracks, and a long service life.

[0010] In the above three patent documents, the steel materials obtained all have ultra-high strength and good mechanical properties. However, none of these three technical solutions involve improving the delayed cracking resistance of ultra-high-strength steel.

Summary

[0011] One of the objects of the present disclosure is to provide a novel 1300 MPa or higher grade cold-rolled steel sheet. A reasonable chemical composition design and a corresponding manufacturing process are utilized for this 1300 MPa or higher grade cold-rolled steel sheet. While having ultra-high strength, it also has excellent delayed cracking resistance and bending performance. When the preset stress is greater than or equal to 1.05 times the tensile strength, the cold-rolled steel sheet can be immersed in 1 mol/L hydrochloric acid for 300 hours or longer without delayed cracking. It is particularly suitable for manufacture of automotive safety structural parts, and has good prospects for promotion and application.

[0012] In order to achieve the above object, the present disclosure provides a 1300 MPa or higher grade cold-rolled steel sheet comprising Fe and unavoidable impurity elements, and further comprising the following chemical elements in mass percentages:

C: 0.10% - 0.30%, Si: 0.1% - 0.5%, Mn: 0.8% - 2.5%, Al: 0.01% - 0.03%, B: 0.001-0.003%; Ti: 0 - 0.05%; wherein the mass percentages of C and Mn satisfy: $C+Mn/6 \geq 0.35\%$.

[0013] Further, in the 1300 MPa or higher grade cold-rolled steel sheet described in the present disclosure, the mass percentages of the chemical elements are as follows:

C: 0.10% - 0.30%, Si: 0.1% - 0.5%, Mn: 0.8% - 2.5%, Al: 0.01% - 0.03%, B: 0.001-0.003%; Ti: 0 - 0.05%, and a balance of Fe and other unavoidable impurities; wherein the mass percentages of C and Mn satisfy: $C+Mn/6 \geq 0.35\%$.

[0014] The chemical elements in the 1300 MPa or higher grade cold-rolled steel sheet described in the present disclosure are designed according to the following specific principles:

C: In the 1300 MPa or higher grade cold-rolled steel sheet described in the present disclosure, the addition of the C element can not only improve the strength of the steel, but also improve the hardness of martensite to ensure occurrence of martensitic transformation. The inventors have discovered in the research that when the mass percentage of the C element in the steel is lower than 0.1%, the strength of the steel sheet will be affected, and it's disadvantageous with respect to the amount and stability of the austenite formed; and when the mass percentage of the C element in the steel is higher than 0.30%, it will readily cause the martensite hardness to be too high and the grains to be coarse, which is not conducive to the forming performance of the steel sheet. Therefore, in view of the influence of the C content on the properties of the steel, in the 1300 MPa or higher grade cold-rolled steel sheet described in the present disclosure, the mass percentage of the C element is controlled in the range of 0.10% - 0.30%.

[0015] Si: In the 1300 MPa or higher grade cold-rolled steel sheet described in the present disclosure, the addition of the Si element can improve the hardenability of the steel. In addition, the solid-dissolved Si in the steel may influence the interaction of the dislocations, increase the work hardening rate, and improve the elongation appropriately, which is beneficial for the steel to acquire better formability. In view of this, in order to bring into play the beneficial effects of the Si element, in the 1300 MPa or higher grade cold-rolled steel sheet described in the present disclosure, the mass percentage of the Si element is controlled in the range of 0.1% - 0.5%.

[0016] Mn: In the 1300 MPa or higher grade cold-rolled steel sheet described in the present disclosure, the addition of the Mn element can not only improve the hardenability of the steel, but also effectively improve the strength of the steel sheet. The mass percentage of Mn in the steel is selected to be 0.8% - 2.5% for the reason that: when the mass percentage of Mn in the steel is lower than 0.8%, the hardenability of the steel prepared is insufficient, a sufficient amount of martensite cannot be generated during the annealing process, and the strength of the steel sheet is insufficient; and when the mass percentage of Mn in the steel is higher than 2.5%, the carbon equivalent will increase significantly, which has a negative impact on both the welding performance and the delayed cracking resistance of the steel. Therefore, in view of the influence of the Mn content on the properties of the steel, in the 1300 MPa or higher grade cold-rolled steel sheet described in the present disclosure, the mass percentage of the Mn element is controlled in the range of 0.8% - 2.5%.

[0017] Al: In the 1300 MPa or higher grade cold-rolled steel sheet described in the present disclosure, the Al element added to the steel in a proper amount can play a role in deoxidation and grain refinement. Therefore, in order to bring into play the beneficial effects of the Al element, in the present disclosure, the mass percentage of the Al element is controlled in the range of 0.01% - 0.03%.

[0018] B: In the 1300 MPa or higher grade cold-rolled steel sheet described in the present disclosure, B is an element

that can significantly improve the hardenability of the steel. The addition of the B element can promote the formation of martensite and guarantee the strength of the martensitic steel. However, it should be noted that the content of the B element in the steel should not be too high. After the grain boundary defects are filled, if more B is added, a "boron phase" will precipitate at the grain boundary, which will increase the grain boundary energy level. At the same time, the "boron phase" will also serve as a core of a new phase to increase the nucleation rate and cause the hardenability of the steel to decrease. Therefore, in view of the influence of the B content on the properties of the steel, in the 1300 MPa or higher grade cold-rolled steel sheet described in the present disclosure, the mass percentage of the B element is controlled in the range of 0.001-0.003%.

[0019] Ti: In the 1300 MPa or higher grade cold-rolled steel sheet described in the present disclosure, Ti added as a strong carbide-forming element will show a strong effect of inhibiting the growth of austenite grains at high temperatures. At the same time, the addition of the Ti element to the steel also helps to refine the grains. Therefore, in order to bring into play the beneficial effects of the Ti element, in the present disclosure, the mass percentage of the Ti element is controlled in the range of 0 - 0.05%. Preferably, the mass percentage of the Ti element is controlled in the range of 0.01 - 0.05%.

[0020] To ensure that the strength of the steel is greater than 1300 MPa, in the 1300 MPa or higher grade cold-rolled steel sheet designed according to the present disclosure, the inventors not only control the mass percentages of the individual chemical elements, but also further control the mass percentages of the C and Mn elements in the steel to satisfy: $C+Mn/6 \geq 0.35\%$. Preferably, $0.35\% \leq C+Mn/6 \leq 0.60\%$; more preferably, $0.37\% \leq C+Mn/6 \leq 0.56\%$.

[0021] Further, in the 1300 MPa or higher grade cold-rolled steel sheet described in the present disclosure, among the unavoidable impurities, $P \leq 0.015\%$, $S \leq 0.003\%$, and $N \leq 0.006\%$.

[0022] In the 1300 MPa or higher grade cold-rolled steel sheet described in the present disclosure, the P element, the S element and the N element are all impurity elements in the steel. When technical conditions permit, in order to obtain a steel material with better properties and higher quality, the contents of the impurity elements in the steel should be minimized. Therefore, except there is a special need, the content of the P element in the steel should be reduced as much as possible, and particularly the mass percentage of P should be controlled to be $P \leq 0.015\%$.

[0023] In addition, MnS formed with the impurity element S will seriously affect the formability of the steel. Therefore, in the present disclosure, the mass percentage of the S element in the steel is strictly controlled to satisfy $S \leq 0.003\%$. In addition, since the impurity element N can easily cause cracks or bubbles to form on the surface of the slab, in the present disclosure, the mass percentage of the N element is controlled to satisfy $N \leq 0.006\%$.

[0024] Further, the microstructure of the 1300 MPa or higher grade cold-rolled steel sheet described in the present disclosure is retained austenite + fine massive tempered martensite + bainite.

[0025] Further, in the 1300 MPa or higher grade cold-rolled steel sheet described in the present disclosure, the volumetric phase fraction of the tempered martensite is $\geq 55\%$, and the volumetric phase fraction of the bainite is greater than 0 and $< 15\%$. Preferably, the volumetric phase fraction of the tempered martensite is 55 - 90% or 65 - 90%. Preferably, the volumetric phase fraction of the bainite is 5-15%.

[0026] Further, in the 1300 MPa or higher grade cold-rolled steel sheet described in the present disclosure, the diameter of the tempered martensite is not greater than 10 microns; preferably, the diameter of the tempered martensite is 4 - 9 microns.

[0027] In the present disclosure, the composition of the steel is designed to be a composition system mainly based on C+Mn+B. By coordinating the C, Mn and B elements in the design, the volumetric fraction of the martensite can be ensured to be greater than 55%. At the same time, it's ensured that the bainite C curve shifts to left, and the ferrite and pearlite C curves shift to right, so as to ensure that the final microstructure comprises a certain volumetric fraction of bainite, and the volumetric phase fraction of the bainite is less than 15%.

[0028] It should be noted that in the present disclosure, based on the previous experience and research results, by designing the alloying elements and manufacturing process reasonably according to the present disclosure, it can be ensured that the cold-rolled steel sheet acquires a microstructure of retained austenite + fine massive tempered martensite (with the diameter of the massive martensite being not more than 10 microns) + bainite. After the martensite is tempered, the stress and hardness are reduced, and at the same time, fine dispersed precipitates that can serve as hydrogen traps can be produced inside. All of these are factors that are conducive to improving the delayed cracking performance. The acquisition of the retained austenite is not only conducive to delayed cracking, but also conducive to improving the forming performance of the cold-rolled steel sheet.

[0029] Further, the properties of the 1300 MPa or higher grade cold-rolled steel sheet described in the present disclosure satisfy:

When the tensile strength is 1300-1400 MPa, the 90-degree cold bending performance characterization parameter R/t limit value is ≤ 2.5 ; when the tensile strength is greater than 1400 MPa and ≤ 1500 MPa, the 90-degree cold bending performance characterization parameter R/t limit value is ≤ 3 ; when the tensile strength is greater than 1500 MPa and ≤ 1650 MPa, the 90-degree cold bending performance characterization parameter R/t limit value is ≤ 3.5 ; when the tensile strength is greater than 1650 MPa, the 90-degree cold bending performance characterization parameter R/t

limit value is ≤ 4 , where R represents the bending radius, and t represents the plate thickness;

When the preset stress is greater than or equal to 1.05 times the tensile strength, no delayed cracking occurs after immersion in 1 mol/L hydrochloric acid for 300 hours or longer.

[0030] Preferably, when the tensile strength is 1300-1400 MPa, the 90-degree cold bending performance characterization parameter R/t limit value is 2.0-2.5; when the tensile strength is greater than 1400 MPa and ≤ 1500 MPa, the 90-degree cold bending performance characterization parameter R/t limit value is 2.5-3; when the tensile strength is greater than 1500 MPa and ≤ 1650 MPa, the 90-degree cold bending performance characterization parameter R/t limit value is 3.0-3.5; when the tensile strength is greater than 1650 MPa, the 90-degree cold bending performance characterization parameter R/t limit value is 3.5-4.

[0031] Preferably, when the preset stress is greater than or equal to 1.1 times the tensile strength, no delayed cracking occurs after immersion in 1 mol/L hydrochloric acid for 300 hours or longer. Preferably, when the preset stress is greater than or equal to 1.15 times the tensile strength, no delayed cracking occurs after immersion in 1 mol/L hydrochloric acid for 300 hours or longer. Preferably, when the preset stress is greater than or equal to 1.2 times the tensile strength, no delayed cracking occurs after immersion in 1 mol/L hydrochloric acid for 300 hours or longer.

[0032] It should be noted that, in the present disclosure, the acquisition of the combination of retained austenite + fine massive tempered martensite + bainite determines the superior forming performance of the 1300 MPa or higher grade cold-rolled steel sheet designed according to the present disclosure. For the 1300 MPa or higher grade cold-rolled steel sheet designed according to the present disclosure, when the tensile strength is 1300-1400 MPa, the 90-degree cold bending performance characterization parameter R/t limit value is ≤ 2.5 ; when the tensile strength is 1401-1500 MPa, the 90-degree cold bending performance characterization parameter R/t limit value is ≤ 3 ; when the tensile strength is 1501-1650 MPa, the 90-degree cold bending performance characterization parameter R/t limit value is ≤ 3.5 ; when the tensile strength is greater than 1650 MPa, the 90-degree cold bending performance characterization parameter R/t limit value is ≤ 4 .

[0033] Accordingly, another object of the present disclosure is to provide a method for manufacturing the above 1300 MPa or higher grade cold-rolled steel sheet, which optimizes the design of the manufacturing process. The cold-rolled steel sheet manufactured using this manufacturing method has ultra-high strength as well as excellent delayed cracking resistance and bending performance.

[0034] In order to achieve the above object, the present disclosure proposes a method for manufacturing the above 1300 MPa or higher grade cold-rolled steel sheet, comprising the following steps:

- (1) Smelting and casting;
- (2) Hot rolling;
- (3) Cold rolling;
- (4) Annealing;
- (5) Continuous tempering temperature: tempering at a tempering temperature of 400-550 °C for a tempering time of 10-300 s, and then cooling to room temperature at a rate of at least 30 °C/s;
- (6) Temper rolling;
- (7) Discontinuous tempering: tempering at a tempering temperature of 180-260 °C for a tempering time of 0.5-6 h.

[0035] In the technical solution designed according to the present disclosure, the acquisition of bainite is one of the characteristics of the present disclosure. During the cooling process in the continuous annealing of step (4), the steel can first acquire part of the bainite to ensure that the martensite generated subsequently forms fine dispersed nuclei around the bainite and does not grow violently, thereby eventually forming fine massive martensite. Fine massive tempered martensite with a diameter not greater than 10 microns can be obtained eventually.

[0036] In addition, another characteristic of the present disclosure is that two tempering processes are designed and optimized in the manufacturing method. After the first continuous tempering process is completed and after the temper rolling is completed, a discontinuous secondary tempering process is further performed. The purpose of this design is to temper the martensite structure and enrich the untransformed austenite with carbon, so as to obtain the final structure of retained austenite + fine massive tempered martensite + bainite after cooling.

[0037] In the present disclosure, in the continuous tempering process of step (5), the tempering temperature is specifically controlled to be 400-550 °C, and the tempering time is controlled to be 10-300 s, because this process determines the final morphology and size of the martensite. By using the manufacturing method designed according to the present disclosure, fine massive tempered martensite with a diameter not greater than 10 microns can be obtained finally in the present disclosure. The tempering temperature and tempering time for each specific component need to be set specifically according to the dynamic CCT curve to ensure that the fraction of the resulting bainite is 15% or less, which will not have a significant impact on the strength of the steel.

[0038] In addition, in the discontinuous tempering process of step (7), the tempering temperature is specifically

controlled to be 180-260 °C, and the tempering time is 0.5-6 h. This process is independent of the aforementioned steps (4) and (5), and is therefore called a discontinuous tempering process. It's essentially a discontinuous low-temperature over-aging tempering process, which can be implemented using a bell-type furnace. By utilizing the discontinuous tempering process, the martensite structure can be tempered, and the untransformed austenite can be enriched with carbon, so that the final structure of retained austenite + fine tempered martensite + bainite can be obtained after cooling. After tempering the martensite, stress and hardness are reduced, and at the same time, fine dispersed precipitates that can serve as hydrogen traps are generated inside, all of which are factors that are conducive to improving the delayed cracking performance. The acquisition of the retained austenite is not only beneficial to delayed cracking, but also beneficial to improving the forming performance of the steel.

[0039] It should be noted that the discontinuous tempering process of step (7) also needs to be designed reasonably according to the specific composition. When the tempering temperature is too high and/or the tempering time is too long, it is likely to reduce the strength of the steel or result in a serious yield platform in the material, affecting the stamping performance. When the tempering temperature is too low and/or the tempering time is too short, the martensite cannot be tempered significantly, so that a sufficient amount of retained austenite cannot be obtained, and the forming performance cannot be improved. Therefore, in order to guarantee the properties of the steel, in the present disclosure, the tempering temperature in the discontinuous tempering process is specifically controlled to be 180-260 °C, and the tempering time is 0.5-6 h.

[0040] Further, in the manufacturing method described in the present disclosure, in step (2), the cast blank obtained in step (1) is first heated to 1100-1250°C and held for 0.3 hours or longer (e.g. 0.3 to 2 hours), and then hot rolled at a temperature of Ar3 (austenite transformation temperature) or higher. After rolling, the blank is rapidly cooled at a rate of 30-80 °C/s, and the coiling temperature is controlled to be 530-600 °C.

[0041] Further, in the manufacturing method described in the present disclosure, in step (2), the hot rolling temperature does not exceed 920 °C.

[0042] Further, in the manufacturing method described in the present disclosure, in step (3), the cold rolling reduction rate is controlled to be 45-65%.

[0043] Further, in the manufacturing method described in the present disclosure, in step (4), the annealing soaking temperature is controlled to be 830-870 °C, and the holding time is 30-150 s, followed by cooling to 730-780 °C at a cooling rate of 5-15 °C/s, and then further cooling to the continuous tempering temperature at a rate of 50-700 °C/s.

[0044] In the above technical solution of the present disclosure, in the annealing step of step (4), the annealing soaking temperature is limited to 830-870 °C, and the holding time is 30-150 s, because what is to be achieved is soaking annealing at a temperature for complete austenitization. When the annealing soaking temperature used in step (4) is lower than 830 °C and the holding time is less than 30 seconds, sufficient tensile strength cannot be obtained; and when the annealing soaking temperature used is higher than 870 °C and the holding time is more than 150 seconds, the forming performance of the steel will be degraded greatly.

[0045] Accordingly, in some preferred embodiments, the annealing soaking temperature can be preferably controlled in the range of 850-860 °C. This can both ensure complete austenitization and prevent the resulting grains from coarsening, thereby providing better forming performance.

[0046] Further, in the manufacturing method described in the present disclosure, in step (4), the annealing soaking temperature is controlled to be 850-860 °C.

[0047] Further, in the manufacturing method described in the present disclosure, in step (5), the tempering temperature is 430-550 °C.

[0048] Further, in the manufacturing method described in the present disclosure, in step (5), the tempering time is 50-300 s.

[0049] Further, in the manufacturing method described in the present disclosure, in step (5), preferably, the cooling rate is 30-50 °C/s.

[0050] Further, in the manufacturing method described in the present disclosure, in step (6), the temper rolling elongation is controlled to be 0-0.3%.

[0051] Compared with the prior art, the 1300 MPa or higher grade cold-rolled steel sheet of the present disclosure and the method for manufacturing the same have the following advantages and beneficial effects:

A novel 1300 MPa or higher grade cold-rolled steel sheet and a method for manufacturing the same have been developed according to the present disclosure. By coordinating the components and designing the process reasonably, there is obtained a 1300 MPa or higher grade cold-rolled steel sheet having low delayed cracking sensitivity and high bending performance.

[0052] The 1300 MPa or higher grade cold-rolled steel sheet has excellent delayed cracking resistance. When the preset stress is greater than or equal to 1.05 times the tensile strength, it can be immersed in 1mol/L hydrochloric acid for 300 hours or longer without delayed cracking. At the same time, the microstructure of retained austenite + fine massive tempered martensite + bainite possessed by this cold-rolled steel sheet determines directly that the cold-rolled steel sheet designed according to the present disclosure has good forming performance. When the tensile strength of the designed

cold-rolled steel sheet is 1300-1400 MPa, the 90-degree cold bending performance characterization parameter R/t limit value is ≤ 2.5 ; when the tensile strength is greater than 1400 MPa and ≤ 1500 MPa, the 90-degree cold bending performance characterization parameter R/t limit value is ≤ 3 ; when the tensile strength is greater than 1500 MPa and ≤ 1650 MPa, the 90-degree cold bending performance characterization parameter R/t limit value is ≤ 3.5 ; when the tensile strength is greater than 1650 MPa, the 90-degree cold bending performance characterization parameter R/t limit value is ≤ 4 , wherein R represents the bending radius, and t represents the plate thickness.

[0053] As it can be seen from the above, the cold-rolled steel sheet designed according to the present disclosure has not only ultra-high strength, but also excellent delayed cracking resistance and bending forming performance. It can be used effectively to prepare automotive parts and be used in the automotive industry. It has good promotion prospects and application value.

Detailed Description

[0054] The 1300 MPa or higher grade cold-rolled steel sheet described in the present disclosure and the method for manufacturing the same will be further explained and illustrated below with reference to the specific Examples. However, such explanation and illustration do not constitute any improper limitation on the technical solution of the present disclosure.

Examples 1-18

[0055] Table 1 lists the mass percentages of the various chemical elements designed for the 1300 MPa or higher grade cold-rolled steel sheets of Examples 1-18.

Table 1. (wt%, the balance is Fe and other unavoidable impurities besides P, S and N)

No.	Chemistry elements									C+ Mn/6 (wt%)
	C (wt%)	Si (wt%)	Mn (wt%)	Al (wt%)	P (wt%)	S (wt%)	N (wt%)	Ti (wt%)	B (wt%)	
Ex. 1	0.107	0.13	2.43	0.022	0.013	0.0027	0.0056	0.012	0.0012	0.512
Ex. 2	0.106	0.13	2.42	0.021	0.013	0.0028	0.0054	0.011	0.0012	0.509
Ex. 3	0.104	0.14	2.47	0.023	0.014	0.0027	0.0055	0.011	0.0013	0.516
Ex. 4	0.215	0.45	2.01	0.025	0.009	0.0021	0.0034	0.048	0.0023	0.550
Ex. 5	0.222	0.42	2.02	0.027	0.008	0.0022	0.0035	0.049	0.0023	0.559
Ex. 6	0.213	0.43	2.00	0.029	0.009	0.0021	0.0036	0.047	0.0022	0.546
Ex. 7	0.165	0.48	1.75	0.011	0.015	0.0018	0.0027	0.031	0.0028	0.457
Ex. 8	0.167	0.49	1.76	0.012	0.012	0.0018	0.0028	0.032	0.0028	0.460
Ex. 9	0.164	0.43	1.75	0.013	0.012	0.0017	0.0026	0.033	0.0029	0.456
Ex. 10	0.291	0.31	0.95	0.015	0.004	0.0015	0.0031	0.023	0.0017	0.449
Ex. 11	0.293	0.32	1.02	0.016	0.004	0.0014	0.0031	0.026	0.0018	0.463
Ex. 12	0.292	0.31	1.03	0.017	0.004	0.0016	0.0033	0.024	0.0019	0.464
Ex. 13	0.240	0.24	0.82	0.028	0.014	0.0009	0.0047	0.036	0.0025	0.377
Ex. 14	0.249	0.23	0.83	0.026	0.015	0.0011	0.0046	0.035	0.0024	0.387
Ex. 15	0.247	0.28	0.87	0.028	0.014	0.0010	0.0045	0.037	0.0026	0.392
Ex. 16	0.175	0.18	1.44	0.017	0.008	0.0018	0.0034	0.034	0.0017	0.415
Ex. 17	0.174	0.19	1.42	0.017	0.008	0.0017	0.0033	0.034	0.0018	0.411
Ex. 18	0.173	0.20	1.45	0.017	0.008	0.0018	0.0035	0.031	0.0019	0.415

[0056] The 1300 MPa or higher grade cold-rolled steel sheets of Examples 1-18 described in the present disclosure were each prepared by the following steps:

(1) Smelting and casting were carried out according to the chemical composition shown in Table 1 to obtain a cast

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blank.

(2) Hot rolling: The cast blank obtained was first heated to 1100-1250 °C and held for 0.3 hours or longer, and then hot rolled at a temperature of Ar3 or higher. After rolling, it was rapidly cooled at a rate of 30-80 °C/s and then coiled after cooling to the coiling temperature. The coiling temperature was controlled to be 530-600 °C.

(3) Cold rolling: The cold rolling reduction rate was controlled to be 45-65%.

(4) Annealing: The annealing soaking temperature was controlled to be 830-870 °C, preferably 850-860 °C, and the holding time was 30-150 s. The resultant was then cooled to 730-780 °C at a cooling rate of 5-15 °C/s; and then cooled to the continuous tempering temperature at a rate of 50-700 °C/s.

(5) Continuous tempering temperature: The tempering temperature was controlled to be 400-550 °C, and the tempering time was controlled to be 10-300 s. The resultant was then cooled to room temperature at a rate of at least 30 °C/s.

(6) Temper rolling: The temper rolling elongation was controlled to be 0-0.3%.

(7) Discontinuous tempering: The temper rolled steel sheet was subjected to discontinuous tempering. The tempering temperature was controlled to be 180-260 °C, and the tempering time was 0.5-6 h.

[0057] The designs of the chemical element compositions and related processes of the 1300 MPa or higher grade cold-rolled steel sheets of Examples 1-18 described in the present disclosure all meet the design specification requirements of the present disclosure.

[0058] Table 2-1 and Table 2-2 list the specific process parameters for the 1300 MPa or higher grade cold-rolled steel sheets of Examples 1-18 in the above process steps.

Table 2-1.

No.	Step (2)					Step (3)
	Heating temperature (°C)	Holding time (h)	Hot rolling temperature (°C)	Cooling rate (°C/s)	Coiling temperature (°C)	Cold rolling reduction rate (%)
Ex. 1	1250	0.3	880	30	530	45
Ex. 2	1250	0.3	880	30	530	45
Ex. 3	1250	0.3	880	30	530	45
Ex. 4	1120	2	890	80	570	60
Ex. 5	1120	2	890	80	570	60
Ex. 6	1120	2	890	80	570	60
Ex. 7	1170	1.5	900	50	540	65
Ex. 8	1170	1.5	900	50	540	65
Ex. 9	1170	1.5	900	50	540	65
Ex. 10	1200	1.2	910	40	600	55
Ex. 11	1200	1.2	910	40	600	55
Ex. 12	1200	1.2	880	40	600	55
Ex. 13	1210	1	880	70	550	65
Ex. 14	1210	1	920	70	550	60
Ex. 15	1210	1	920	70	550	55
Ex. 16	1120	0.6	880	30	530	50
Ex. 17	1200	1	890	60	560	45
Ex. 18	1250	1.5	920	80	600	50

Note: In the above Table 2-1, the hot rolling temperatures used in Examples 1-18 were all > Ar3, and Ar3 within the process range required by the present disclosure in each Example was in the range of 730-850 °C.

Table 2-2

No.	Step (4)										Step (5)			Step (6)	Step (7)	
	Anneal- ing soaking tem- perature (°C)	Holding time (s)	First cooling rate (°C/s)	Start temperature of rapid cooling (°C)	Rapid cooling (second cooling) rate °C/s	End temperature of rapid cooling (°C)	Tempering temperature (°C)	Tempering time (s)	Cooling rate (°C/s)	Temper rolling elongation (%)	Tempering temperature (°C)	Tempering time (h)				
Ex. 1	870	30	15	770	50	440	440	100	30	0.1	260	0.5				
Ex. 2	870	30	15	770	50	440	440	100	30	0.1	260	0.5				
Ex. 3	870	30	15	770	50	440	440	100	30	0.1	260	0.5				
Ex. 4	830	150	5	780	150	430	430	300	30	0.2	180	6				
Ex. 5	830	150	5	780	150	430	430	300	30	0.2	180	6				
Ex. 6	830	150	5	780	150	430	430	300	30	0.2	180	6				
Ex. 7	850	80	7	730	350	530	530	50	50	0	210	2.5				
Ex. 8	850	80	7	730	350	530	530	50	50	0	210	2.5				
Ex. 9	850	80	7	730	350	530	530	50	50	0	210	2.5				
Ex. 10	860	100	10	750	700	520	520	200	50	0	240	3.5				
Ex. 11	860	100	10	750	700	520	520	200	50	0	240	3.5				
Ex. 12	860	100	10	750	700	520	520	200	50	0	240	3.5				
Ex. 13	830	50	12	760	100	490	490	150	40	0.3	200	4.5				
Ex. 14	830	50	12	760	100	490	490	150	40	0.3	200	4.5				
Ex. 15	830	50	12	760	100	490	490	150	40	0.3	200	4.5				
Ex. 16	855	70	5	730	400	500	500	250	40	0.1	180	1				
Ex. 17	855	70	10	750	600	500	500	200	40	0.1	220	1				
Ex. 18	855	70	15	780	700	500	500	150	40	0.1	260	1				

[0059] In the present disclosure, the finished 1300 MPa or higher grade cold-rolled steel sheets of Examples 1-18 obtained by the above process steps (1)-(7) were sampled respectively, and the microstructure of the steel sheet of each Example was observed and analyzed. It was found that the microstructure of the cold-rolled steel sheet of each Example was retained austenite + fine massive tempered martensite + bainite. In this disclosure, the microstructure was observed using a ZEISS Axio Imager M2m optical microscope. In addition, the details of the nano-precipitates and microstructure were further observed and analyzed by spherical aberration-corrected field emission transmission electron microscopy (TEM; model JEOL ARM-200F) with an operating accelerating voltage of 200 kV.

[0060] In addition, the inventors further analyzed the volumetric phase fraction of each component in the microstructure of the finished 1300 MPa or higher grade cold-rolled steel sheets of Examples 1-18, and measured the diameter of the tempered martensite. The relevant analysis and test results are listed in Table 3 below.

Table 3.

No.	Volumetric phase fraction of tempered martensite (%)	Volumetric phase fraction of bainite (%)	Diameter of tempered martensite (μm)
Ex. 1	75-85	8-13	7.3
Ex. 2	75-84	7-14	7.1
Ex. 3	75-87	8-13	7.8
Ex. 4	78-89	5-12	5.3
Ex. 5	78-90	5-13	5.3
Ex. 6	79-91	5-10	5.3
Ex. 7	69-80	10-13	4.6
Ex. 8	70-81	9-14	4.7
Ex. 9	68-82	9-14	4.3
Ex. 10	78-85	8-13	5.6
Ex. 11	77-82	9-13	6.7
Ex. 12	78-82	9-14	6.3
Ex. 13	70-80	8-13	7.6
Ex. 14	71-82	9-13	8.7
Ex. 15	68-82	9-14	8.3
Ex. 16	68-82	9-14	7.3
Ex. 17	71-82	9-13	5.7
Ex. 18	78-85	8-13	4.6

[0061] As it can be seen from the analysis and test, in the present disclosure, the volumetric phase fraction of the tempered martensite in the 1300 MPa or higher grade cold-rolled steel sheets of Examples 1-18 was in the range of 68-91%, the volumetric phase fraction of the bainite was in the range of 5-14%, and the diameter of the tempered martensite was in the range of 4.3-8.7 microns.

[0062] In addition, after completing the above observation and analysis, the finished 1300 MPa or higher grade cold-rolled steel sheets of Examples 1-18 were further sampled, and the cold-rolled steel sheet sample of each Example was subjected to relevant mechanical property tests to obtain its mechanical strength, elongation and bending performance. The mechanical property test results thus obtained are listed in Table 4.

[0063] The relevant mechanical property test methods are as follows:

Tensile test: The test was performed according to GB/T 228 (Metallic materials - Tensile testing - Part 1: Method of test at room temperature) to measure the yield strength, tensile strength and elongation of the 1300 MPa or higher grade cold-rolled steel sheets of Examples 1-18.

[0064] In addition, the bending performance of the cold-rolled steel sheet of each Example was characterized by the 90-degree cold bending performance characterization parameter R/t limit value, wherein the plate thickness t was fixed, and the bending radius R ensuring bending without cracking was variable. When the bending radius R ensuring bending without cracking was a minimum, an R/t limit value was obtained. A larger 90-degree cold bending performance characterization parameter R/t limit value indicates a worse bending ability; whereas a smaller 90-degree cold bending

performance characterization parameter R/t limit value indicates a better bending ability.

[0065] Table 4 lists the mechanical property test results of the 1300 MPa or higher grade cold-rolled steel sheets of Examples 1-18.

Table 4.

No.	Yield strength (MPa)	Tensile strength (MPa)	Elongation (%)	90-Degree cold bending performance characterization parameter R/t limit value
Ex. 1	1187	1434	7.8	2.5
Ex. 2	1179	1422	7.5	2.5
Ex. 3	1190	1438	7.7	2.5
Ex. 4	1453	1613	6.8	3.0
Ex. 5	1491	1626	6.9	3.0
Ex. 6	1487	1593	7.1	3.0
Ex. 7	1145	1336	10.1	2.0
Ex. 8	1137	1344	9.2	2.0
Ex. 9	1128	1322	9.7	2.0
Ex. 10	1501	1732	5.3	3.5
Ex. 11	1503	1738	6.5	3.5
Ex. 12	1492	1731	6.1	3.5
Ex. 13	1291	1407	6.7	2.5
Ex. 14	1297	1404	8.1	2.5
Ex. 15	1286	1405	7.8	2.5
Ex. 16	1134	1321	9.2	2.0
Ex. 17	1152	1364	9.3	2.0
Ex. 18	1198	1389	9.7	2.0

[0066] As shown by Table 4, the 1300 MPa or higher grade cold-rolled steel sheets of Examples 1-18 described in the present disclosure had both ultra-high strength and good cold bending deformability. They had a yield strength in the range of 1128-1503 MPa, a tensile strength in the range of 1321-1738 MPa, and an elongation in the range of 6.1% - 10.1%. At the same time, as it can be seen from Examples 1-18, when the tensile strength was 1300-1400 MPa, the 90-degree cold bending performance characterization parameter R/t limit value was ≤ 2.5 ; when the tensile strength was 1401-1500 MPa, the 90-degree cold bending performance characterization parameter R/t limit value was ≤ 3 ; when the tensile strength was 1501-1650 MPa, the 90-degree cold bending performance characterization parameter R/t limit value was ≤ 3.5 ; when the tensile strength was greater than 1650 MPa, the 90-degree cold bending performance characterization parameter R/t limit value was ≤ 4 . This shows that the cold-rolled steel sheets of Examples 1-18 had excellent bending deformability while having ultra-high strength.

[0067] Accordingly, the cold-rolled steel sheets of Examples 1-18 prepared according to the present disclosure not only had the above-mentioned excellent mechanical properties, but also had excellent delayed cracking resistance.

[0068] In order to verify the delayed cracking resistance of the cold-rolled steel sheets of Examples 1-18 prepared above, the inventors sampled the steel sheet of each Example again to perform an acid soaking test on the cold-rolled steel sheet of each Example, that is, an immersion test with a hydrochloric acid solution was used for the evaluation. The wire-cut samples were loaded with stresses of 1.05, 1.1, 1.15, and 1.2 times the tensile strength respectively by bending, and immersed in a 0.1 mol/L HCl solution for 300 h without changing the solution, or a brush was used to remove corrosion products from the surface each time before changing the solution, and the test time was controlled to be 300 h.

[0069] In the present disclosure, after completing the above acid soaking experiment, the sample was observed. If the sample had no cracks, it meant that the delayed cracking resistance under the stress condition was good, and it was reported as "OK"; if the sample cracked, it meant that the delayed cracking resistance under the stress condition was poor, and it was reported as "NG".

[0070] Table 5 lists the test results of the cold-rolled steel sheets of Examples 1-18 after the acid soaking test.

Table 5.

No.	Stress level in acid soaking experiment: 1.05*TS	Stress level in acid soaking experiment: 1.1*TS	Stress level in acid soaking experiment: 1.15*TS	Stress level in acid soaking experiment: 1.2*TS
Ex. 1	OK	OK	NG	NG
Ex. 2	OK	OK	NG	NG
Ex. 3	OK	OK	NG	NG
Ex. 4	OK	NG	NG	NG
Ex. 5	OK	NG	NG	NG
Ex. 6	OK	NG	NG	NG
Ex. 7	OK	OK	OK	NG
Ex. 8	OK	OK	OK	NG
Ex. 9	OK	OK	OK	NG
Ex. 10	OK	NG	NG	NG
Ex. 11	OK	NG	NG	NG
Ex. 12	OK	NG	NG	NG
Ex. 13	OK	OK	OK	OK
Ex. 14	OK	OK	OK	OK
Ex. 15	OK	OK	OK	OK
Ex. 16	OK	OK	OK	OK
Ex. 17	OK	OK	OK	OK
Ex. 18	OK	OK	OK	OK

[0071] As shown by Table 5 above, the cold-rolled steel sheets of Examples 1-18 prepared had excellent delayed cracking resistance. Delayed cracking occurred to none of the steel sheets of the Examples when they were immersed in 1 mol/L hydrochloric acid for at least 300 hours under a preset stress of 1.05 times the tensile strength.

[0072] It should be noted that combinations of the various technical features in this case are not limited to the combinations described in the claims of this case or the combinations described in the specific Examples. All technical features recorded in this case can be combined freely or associated in any way unless a contradiction occurs.

[0073] It should also be noted that the Examples listed above are only specific embodiments of the present disclosure. Obviously, the present disclosure is not limited to the above Examples, and changes or modifications made thereto can be directly derived from the present disclosure or easily conceived of by those skilled in the art, all of which fall within the protection scope of the present disclosure.

Claims

1. A 1300 MPa or higher grade cold-rolled steel sheet comprising Fe and unavoidable impurity elements, wherein it further comprises the following chemical elements in mass percentages:

C: 0.10% - 0.30%, Si: 0.1% - 0.5%, Mn: 0.8% - 2.5%, Al: 0.01% - 0.03%, B: 0.001-0.003%; Ti: 0 - 0.05%; and mass percentages of C and Mn satisfy: $C+Mn/6 \geq 0.35\%$.

2. The 1300 MPa or higher grade cold-rolled steel sheet of claim 1, wherein mass percentages of the chemical elements are as follows:

C: 0.10% - 0.30%, Si: 0.1% - 0.5%, Mn: 0.8% - 2.5%, Al: 0.01% - 0.03%, B: 0.001-0.003%; Ti: 0 - 0.05%, and a balance of Fe and other unavoidable impurities; and the mass percentages of C and Mn satisfy: $C+Mn/6 \geq 0.35\%$; preferably, Ti: 0.01-0.05%.

3. The 1300 MPa or higher grade cold-rolled steel sheet of claim 1 or 2, wherein among the unavoidable impurities, $P \leq 0.015\%$, $S \leq 0.003\%$, and $N \leq 0.006\%$.
4. The 1300 MPa or higher grade cold-rolled steel sheet of claim 1 or 2, wherein it has a microstructure of retained austenite + fine massive tempered martensite + bainite.
5. The 1300 MPa or higher grade cold-rolled steel sheet of claim 4, wherein the tempered martensite has a volumetric phase fraction of $\geq 55\%$, and the bainite has a volumetric phase fraction of greater than 0 and $< 15\%$; preferably, the tempered martensite has a volumetric phase fraction of 55 - 90%, preferably 65 - 90%; preferably, the bainite has a volumetric phase fraction of 5-15%.
6. The 1300 MPa or higher grade cold-rolled steel sheet of claim 4, wherein the tempered martensite has a diameter of not greater than 10 microns; preferably, the tempered martensite has a diameter of 4 - 9 microns.
7. The 1300 MPa or higher grade cold-rolled steel sheet of claim 1 or 2, wherein its properties satisfy:
when its tensile strength is 1300-1400 MPa, its 90-degree cold bending performance characterization parameter R/t limit value is ≤ 2.5 ; when its tensile strength is greater than 1400 MPa and ≤ 1500 MPa, its 90-degree cold bending performance characterization parameter R/t limit value is ≤ 3 ; when its tensile strength is greater than 1500 MPa and ≤ 1650 MPa, its 90-degree cold bending performance characterization parameter R/t limit value is ≤ 3.5 ; when its tensile strength is greater than 1650 MPa, its 90-degree cold bending performance characterization parameter R/t limit value is ≤ 4 , where R represents a bending radius, and t represents a plate thickness; when a preset stress is 1.05 times the tensile strength, no delayed cracking occurs after immersion in 1 mol/L hydrochloric acid for 300 hours or longer; preferably, when the tensile strength is 1300-1400 MPa, the 90-degree cold bending performance characterization parameter R/t limit value is 2.0-2.5; when the tensile strength is greater than 1400 MPa and ≤ 1500 MPa, the 90-degree cold bending performance characterization parameter R/t limit value is 2.5-3; when the tensile strength is greater than 1500 MPa and ≤ 1650 MPa, the 90-degree cold bending performance characterization parameter R/t limit value is 3.0-3.5; when the tensile strength is greater than 1650 MPa, the 90-degree cold bending performance characterization parameter R/t limit value is 3.5-4.
8. A method for manufacturing the 1300 MPa or higher grade cold-rolled steel sheet of any one of claims 1-7, comprising the following steps:
 - (1) Smelting and casting;
 - (2) Hot rolling;
 - (3) Cold rolling;
 - (4) Annealing;
 - (5) Continuous tempering temperature: tempering at a tempering temperature of 400-550 °C for a tempering time of 10-300 s, and then cooling to room temperature at a rate of at least 30 °C/s;
 - (6) Temper rolling;
 - (7) Discontinuous tempering: tempering at a tempering temperature of 180-260 °C for a tempering time of 0.5-6 h.
9. The method of claim 8, wherein in step (2), a cast blank obtained in step (1) is first heated to 1100-1250 °C and held for 0.3 hours or longer, then hot rolled at a temperature of Ar3 or higher, and rapidly cooled at a rate of 30-80 °C/s after rolling, wherein a coiling temperature is controlled to be 530-600 °C.
10. The method of claim 9, wherein preferably, the temperature for hot rolling does not exceed 920 °C.
11. The method of claim 8, wherein in step (3), a cold rolling reduction rate is controlled to be 45-65%.
12. The method of claim 8, wherein in step (4), an annealing soaking temperature is controlled to be 830-870 °C, and a holding time is 30-150 s, followed by cooling to 730-780 °C at a cooling rate of 5-15 °C/s, and then further cooling to a continuous tempering temperature at a rate of 50-700 °C/s.
13. The method of claim 11, wherein in step (4), the annealing soaking temperature is controlled to be 850-860 °C.
14. The method of claim 11, wherein in step (5), preferably, the cooling rate is 30-50 °C/s.

15. The method of claim 8, wherein in step (6), a temper rolling elongation is controlled to be 0-0.3%.

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INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2023/101256

A. CLASSIFICATION OF SUBJECT MATTER

C22C 38/02(2006.01)i; C22C 38/04(2006.01)i; C22C 38/06(2006.01)i; C22C 38/12(2006.01)i; C22C 38/14(2006.01)i;
C21D8/02(2006.01)i; C21D6/00(2006.01)i; C21D1/26(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, 冷轧, 退火, 回火, 碳, 硅, 锰, 铝, 硼, 钛, cold roll, anneal, temper, C, carbon, Si, silicon, Mn, manganese, Al, aluminum, B, boron, Ti, titanium

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	CN 111647732 A (SHOUGANG GROUP CO., LTD.) 11 September 2020 (2020-09-11) description, paragraph 49, embodiment 2, and paragraph 12	1-15
A	CN 113737087 A (BAOSHAN IRON & STEEL CO., LTD.) 03 December 2021 (2021-12-03) claims 1-12	1-15
A	CN 113122783 A (TANGSHAN QUANFENG THIN PLATE CO., LTD.) 16 July 2021 (2021-07-16) claims 1-4	1-15
A	CN 109207847 A (BAOSHAN IRON & STEEL CO., LTD.) 15 January 2019 (2019-01-15) claims 1-11	1-15

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

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Date of the actual completion of the international search

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Name and mailing address of the ISA/CN

China National Intellectual Property Administration (ISA/
CN)
China No. 6, Xitucheng Road, Jimenqiao, Haidian District,
Beijing 100088

Authorized officer

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/CN2023/101256

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		WO 2021238916 A1	02 December 2021
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CN 113122783 A	16 July 2021	None	
CN 109207847 A	15 January 2019	CN 109207847 B	12 March 2021

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REFERENCES CITED IN THE DESCRIPTION

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