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

(72) Inventors:
- **ZHANG, Hanlong**
  Shanghai 201900 (CN)
- **ZHANG, Yulong**
  Shanghai 201900 (CN)
- **ZHONG, Yong**
  Shanghai 201900 (CN)

(74) Representative: **Kuhnen & Wacker**
Patent- und Rechtsanwaltsbüro PartG mbB
Prinz-Ludwig-Straße 40A
85354 Freising (DE)

(54) AUTOMOTIVE STRUCTURAL STEEL HAVING A YIELD STRENGTH OF>=1000 MPA AND MANUFACTURING METHOD THEREFOR

(57) An automotive structural steel having a yield strength of ≥1000 MPa and a manufacturing method therefor. The steel comprises, in percentage by weight, the components of: 0.15-0.23% of C, 0.12-0.5% of Si, 1.6-2.4% of Mn, 0.001-0.004% of B, 0.01-0.04% of Al, 0.05-0.5% of Cr, 0.15-0.5% of Mo, P≤0.015%, S≤0.005%, and the balance comprising Fe and other inevitable impurities, and needs to satisfy the following relations: the characteristic value Bs of the formation rate of lower bainite is 0.6-1.4, Bs=(Mo+B*100-Mn/5)/C; and the lower bainite in the microstructure thereof is ≥ 95% . The automotive structural steel has a yield strength of ≥1000 MPa, a tensile strength of ≥1180MPa, an elongation of ≥7%, the 180° bending property d of ≤3.5T. The automotive structural steel of the present invention has ultra-high strength, and further has excellent formability, especially bending formability, thus being specifically suitable for manufacturing parts of an automotive chassis system.

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Description

Technical Field

[0001] The present disclosure relates to automotive steel, and in particular to automotive structural steel with a yield strength of ≥1000MPa and a manufacturing method thereof.

Background Art

[0002] Under the development concept of "green and safety" for the new generation of automobiles, the strength requirement for the automotive structural parts is getting higher and higher as it can greatly reduce the thickness of automotive structural parts and achieve a significant reduction in the weight of the complete vehicle. This not only achieves the green development goal of "reducing carbon emissions", but also improves the maneuverability of the complete vehicle, reduces the braking distance, and thus improves the safety of the vehicle.

[0003] The strength of the hot-rolled or pickled steel plate or steel strip used in the automotive structural part of the prior art is not high, and the tensile strength thereof is generally around 800MPa, hence there is an urgent need to further improve the strength of the steel. Of course, the strength of the hot-rolled or pickled steel plate can be further improved by subjecting the steel to cold rolling and annealing. However, on the one hand, there are still a large number of the automotive structural parts that require the use of thicker hot-rolled or pickled materials, and on the other hand, the production process of cold rolling and re-annealing will increase the cost and carbon emissions for manufacturing the steel plate or steel strip. Therefore, the present disclosure mainly focuses on the invention design for improving the strength of hot-rolled or pickled material for automobiles.

[0004] Presently there are two means for improving the strength of hot-rolled and pickled steel plates or strips:

1. Introducing a large amount of martensite into the steel plate microstructure, or introducing retained (metastable) austenite into the steel plate microstructure and then incurring the transition of the retained (metastable) austenite into martensite via the deformation generated during the forming of steel.
For example, both of Chinese patent applications CN200610025065.7 and CN201210461655.X disclose a hot-rolled high-strength steel with a matrix comprising martensite structure and the manufacture method thereof, wherein the steel exhibits a tensile strength of up to 1150MPa, and even 1400MPa or higher. The introduction of a large amount of martensite can significantly improve the strength of the steel plate or steel strip, but the martensite has lower plasticity and toughness. Although the overall average plasticity and toughness of the steel material can be improved by tempering or the introduction of other soft phases (such as ferrite), some local areas, especially at the interface between the martensite phase and other phases, exhibit inferior local plasticity and toughness due to the excessive strength/hardness difference between the martensite phase and the surrounding phases, which in turn result in a steel plate or steel strip having weak bending property and hole expansion and flanging properties, and tending to incur cracks at the interface between the martensite and the surrounding phases. Besides, carbon, manganese and silicon elements are often added into the steel plate or steel strip at high contents in order to obtain a sufficient amount of martensite or retained austenite, and such an addition further deteriorates the weldability, surface paintability and surface tint of the steel plate.
2. Inducing the precipitation of a large amount of micro-alloy carbide or carbonitride so as to improve the strength of hot-rolled or pickled steel plate or strip.

[0005] For example, Chinese patent application CN201610268167.5 discloses a method for producing a hot-rolled steel plate or steel strip with a tensile strength of 1180 MPa or higher by the precipitation of micro-alloy carbide or carbonitride. However, this method also has two disadvantages. Firstly, the substantial precipitation of micro-alloy carbide or carbonitride needs the incorporation of large amounts of micro-alloying elements such as Ti, V, Nb, etc., which are extremely expensive and increase the massive production cost. On the other hand, the substantial precipitation of micro-alloy carbide or carbonitride is disadvantaged for the bending property of the steel plate. The bending of steel material tends to incur cracks in the positions where the micro-alloy carbide or carbonitride aggregates, or at the interface between the precipitation and the matrix. Furthermore, the above indicated elements will also react with the nitrogen to form coarse and sharp-edged nitrides (such as TiN), which tend to bring about the bending and cracking of the steel plate and steel strip.

Summary of the Disclosure

[0006] The object of the present disclosure is to provide an automotive structural steel with a yield strength of ≥1000MPa and a method for manufacturing the same. The automotive structural steel has a tensile strength of ≥1180MPa and also has good bending and flanging properties. The automotive structural steel has a yield strength of ≥1000MPa, a tensile

strength of ≥1180MPa, an elongation of ≥7%, and a 180° bending property of d≤3.5T, and is particularly suitable for automotive chassis structural parts.

[0007] In order to achieve the above object, the technical solution of the present disclosure is:

the automotive structural steel described in the present disclosure is a bainite steel, in which neither martensite has been introduced, nor a substantial amount of carbide precipitation has been introduced. Instead, the steel plate or steel strip has a microstructure which is controlled to be basically pure lower bainite (with the microstructure comprising ≥95% by area proportion of lower bainite), thus it has a tensile strength of ≥1180MPa while having good bending and flanging properties.

[0008] In order to impart the steel plate or steel strip with a yield strength of ≥ 1000 MPa and a tensile strength of ≥ 1180 MPa, it is necessary to increase the proportion of the lower bainite on the one hand and to increase the strength or hardness of the lower bainite on the other hand. However, due to the limitations of hot rolling production processes and equipment (such as, the layer cooling roller table is short, the rolling production rate is fast, etc.), the time for the transition of lower bainite is rather short. Therefore, when designing the present disclosure, it is necessary to consider accelerating the transition rate of the lower bainite, shortening the formation time of the lower bainite, and expanding the bainite phase zone, so as to form the lower bainite as fast and as much as possible.

[0009] Specifically, the automotive structural steel with a yield strength of ≥1000 MPa as described in the present disclosure comprises the following chemical elements in percentage by weight:

C: 0.15-0.23%;
Si: 0.12-0.5%;
Mn: 1.6-2.4%;
B: 0.001-0.004%;
Al: 0.01-0.04%;
Cr: 0.05-0.5%;
Mo: 0.15-0.5%;
P: ≤0.015%;
S: ≤0.005%; and
the balance amount of Fe and other unavoidable impurities, and the steel satisfies the relation of Bs= 0.6-1.4, wherein Bs represents the characteristic value of lower bainite formation rate and is determined by the equation of Bs = (Mo + B*100-Mn/5)/C;
the area proportion of lower bainite in the microstructure of the automotive structural steel is ≥95%.

[0010] Furthermore, the automotive structural steel of the present disclosure further comprises at least one of Ti, V and Nb, and Ti+Nb+V ≤0.03 wt%, preferably Ti+Nb+V ≤0.006 wt%.

[0011] Preferably, in the microstructure of the automotive structural steel of the present disclosure, the area proportion of the lower bainite is ≥95%, the combined area proportion of retained austenite + martensite + tempered martensite + upper bainite is ≤0.2%.

[0012] Preferably, in the microstructure of the automotive structural steel of the present disclosure, the area proportion of lower bainite is ≥95%, the combined area proportion of ferrite + carbonitride precipitation + granular bainite is ≤5%, and the combined area proportion of retained austenite + martensite + tempered martensite + upper bainite is ≤0.01%.

[0013] The automotive structural steel has a yield strength of ≥1000 MPa, a tensile strength of ≥1180 MPa, an elongation of ≥7%, and a 180° bending property of d≤3.5T, preferably d≤3T.

[0014] The automotive structural steel of the present disclosure has the following composition design:

C: the C element is mainly used for controlling the microstructure phase transition, the lower bainite hardness/strength, the time required for lower bainite formation, the martensite formation temperature (Ms) and the substantial precipitation of micro-alloy carbide or carbonitride in the steel, thereby affecting the mechanical properties of the steel material. When the C content in the steel is less than 0.15%, the strength of the steel will not meet the target requirement, or martensite will be formed due to excessively high Ms. Under such a circumstance, although high strength can be achieved, the bending property will be substantially deteriorated. If the steel has a C content of greater than 0.23%, it tends to have excessively high strength or an excessive amount of carbides, which will degrade the plasticity and bending property of the steel plate. In view of the above, the C content is controlled in the range of 0.15-0.23% in the present disclosure, such as 0.16%, 0.17%, 0.18%, 0.19%, 0.20%, 0.21%, 0.22%, and preferably 0.18-0.21%.

[0015] Si: Si has a certain solid solution strengthening effect, but it will influence the surface quality of the steel plate. When the steel has a Si content of less than 0.12%, it is difficult for the steel plate to exhibit a sufficient strengthening effect. When the Si content in the steel is greater than 0.5%, iron oxide scale or tiger-skin stripe color difference tends to generate on the surface of the steel plate after pickling, which is disadvantageous to the surface quality of automotive steel plates. Therefore, the Si content is controlled to be between 0.12% and 0.5% in the present disclosure, such as 0.15%, 0.2%, 0.25%, 0.3%, 0.35%, 0.4% and 0.45%.

[0016] Mn: Mn element influences the hardenability of the steel plate as well as the formation of martensite and lower

bainite. Higher Mn content will result in lower Ms point. However, Mn has a dragging effect on the diffusion of C atoms, so it will prolong the time needed for the formation of lower bainite. Therefore, the steel shall not have an excessively high Mn content, otherwise it cannot have pure lower bainite microstructure. However, when the Mn content is low, the Ms point temperature increases, which is disadvantageous to the formation of pure lower bainite structure. In view of the above, the Mn content is controlled in the range of 1.6% to 2.4% in the present disclosure, such as 1.7%, 1.8%, 1.9%, 2.0%, 2.1%, 2.2%, 2.3%, and preferably in the range of 1.8% to 2.2%.

[0017] B: The B element can enhance the hardness of the lower bainite and function, in synergy with the Mo element, to shorten the formation time of lower bainite. However, when the B content is too high, brittle boride tends to be formed, thereby influencing the plasticity and bending properties of the steel plate. In view of the above, the content of B is controlled in the range of 0.001% to 0.004% in the present disclosure, such as 0.0015%, 0.002%, 0.0025%, 0.003% and 0.0035%.

[0018] Al: Al element is merely added into the steel as a deoxidizing element, which can remove the O element from the steel to ensure the performance and quality of the steel. When the Al content is too high, it will incur an increase in cost and a significant increase in the difficulty of continuous casting production. Therefore, the Al content is controlled in the range of 0.01% to 0.04% in the present disclosure, such as, 0.015%, 0.02%, 0.025%, 0.03% and 0.035%.

[0019] Cr: Cr is mainly used for expanding the bainite phase zone, making it easier to obtain lower bainite in the steel. Meanwhile, the strength of the steel plate can be further improved through solid solution strengthening. However, Cr can react with C to form carbide. When the Cr content is too high, it is disadvantageous to the plasticity and bending properties of the steel plate. In view of the above, the Cr content is controlled in the range of 0.05% to 0.50% in the present disclosure, such as 0.10%, 0.15%, 0.20%, 0.25%, 0.30%, 0.35%, 0.40%, 0.45%, and preferably in the range of 0.15% to 0.35%.

[0020] Mo: Mo can be used for expanding the bainite phase zone, making it easier to obtain lower bainite in the steel. Meanwhile, Mo can function, in synergy with the B element, to shorten the formation time of lower bainite. In addition, Mo can further improve the strength of the steel plate through solid solution strengthening or forming precipitation of carbide or carbonitride. However, if the Mo content is too high, the carbides in the steel will become coarse, which is disadvantageous to the bending property of the steel plate. In view of the above, the content of Mo is controlled in the range of 0.15% to 0.50% in the present disclosure, such as 0.20%, 0.25%, 0.30%, 0.35%, 0.40%, 0.45%, and preferably in the range of 0.15% to 0.38%.

[0021] Among the above indicated elements, Mo, B and Mn will influence the formation rate (or time) of the lower bainite. In order to ensure that the area proportion of lower bainite is ≥95%, it is necessary to further control the weight percentages of Mo, B, Mn and C to satisfy the relation of $0.6 \leq Bs \leq 1.4$, wherein Bs represents the characteristic value of the formation rate of lower bainite and is determined by formula of $Bs = (Mo + B*100-Mn/5)/C$. When Mo and B elements are added synergistically, the bainite transition C curve can be significantly shifted to the left, thus these two elements provide a positive contribution in accelerating the formation rate of lower bainite. Besides, the formation of lower bainite is also influenced by the diffusion rate of carbon element. Generally speaking, faster diffusion rate of carbon atoms will result in faster formation of lower bainite. Therefore, the Mn element has a dragging-effect on the diffusion of carbon atoms, thus it provides a negative contribution in accelerating the formation rate of lower bainite. Similarly, since the diffusion rate of carbon atoms is positively correlated with the bainite formation rate, the above formula also needs to be divided by the carbon content. If Bs is less than 0.6, the formation rate of lower bainite is too low and the formation time is too long, thus it is impossible to effectively ensure that ≥95% of lower bainite can be obtained within the controlled cooling time. If Bs is >1.4, although the formation rate of lower bainite is sufficient, since the degradation or decomposition of lower bainite and the precipitation of carbide are also positively correlated with the diffusion rate of atoms such as carbon atoms, an excessively high Bs value also means that the lower bainite tends to degenerate into granular bainite, and the precipitation rate of carbonitride is too fast, which leads to excessive formation, aggregation of carbides or growth of coarse carbides in the steel plate or the steel strip, and ultimately results in deterioration of bending property. In some embodiments, Bs is 0.6, 0.7, 0.8, 0.9, 1.0, 1.1, 1.2, 1.3, 1.4, or within the range of any two of the above values.

[0022] Ti, Nb and V: although Ti, Nb and V are optional alloying elements and can be added into the steel, it is still not recommended to add them. Ti, Nb and V can form micro-alloy carbides or carbonitrides which substantially precipitate as a second phase for further improving the strength of the steel plate. However, the substantial precipitation of an excessive amount or oversized micro-alloy carbides or carbonitrides will deteriorate the bending performance. Since nitrogen is inevitably included in steel, the above said alloying elements will also react with N element to produce nitrides (such as TiN) in the form of sharp-edged blocks, which will further deteriorate the bending property of the steel plate or strip. Additionally, the addition of the above said alloy elements will increase the cost of the material, and performance and cost control must be taken into comprehensive consideration. In view of the above, the mass percentages of Nb, Ti and V have to be controlled to meet $Ti+Nb+V \leq 0.03\%$ in the present disclosure, such as in the range of 0.001% to 0.03%, preferably $Ti+Nb+V \leq 0.006\%$, such as in the range of 0.001% to 0.006%.

[0023] In some embodiments, the unavoidable impurities include N in an amount of ≤ 0.005% by mass.

[0024] In the microstructure of the automotive structural steel of the present disclosure, the area proportion of lower bainite is ≥95%, such as ≥96%, ≥97%, ≥98%, ≥99%.

[0025] Preferably, in the microstructure of the automotive structural steel of the present disclosure, the combined area proportion of ferrite + carbonitride precipitation + granular bainite is ≤5%, such as ≤4%, ≤3%, ≤2%, ≤1%.

[0026] Preferably, in the microstructure of the automotive structural steel of the present disclosure, the combined area proportion of retained austenite + martensite + tempered martensite + upper bainite is ≤0.2%, such as ≤0.1%, ≤0.05%, ≤0.02%, ≤0.01%.

[0027] Preferably, in the microstructure of the automotive structural steel of the present disclosure, the combined area proportion of all the phases other than the lower bainite, ferrite, carbide precipitation and granular bainite is ≤0.2%, such as ≤0.1%, ≤0.05%, ≤0.02%, ≤0.01%. In some embodiments, in the microstructure of the automotive structural steel described in the present disclosure, said phases other than the lower bainite, ferrite, carbide precipitation, and granular bainite are one or more phases selected from retained austenite, martensite, tempered martensite, and upper bainite.

[0028] Preferably, in the microstructure of the automotive structural steel of the present disclosure, the area proportion of lower bainite is ≥95%, and the combined area proportion of retained austenite + martensite + tempered martensite + upper bainite is ≤0.2%. Preferably, the area proportion of lower bainite is ≥95%, the combined area proportion of ferrite + carbonitride precipitation + granular bainite is ≤5%, and the combined area proportion of retained austenite + martensite + tempered martensite + upper bainite is ≤0.01%.

[0029] In some embodiments, the automotive structural steel of the present disclosure has a yield strength of ≥1000 MPa, such as ≥1020 MPa, ≥1050 MPa, ≥1100 MPa, ≥1150 MPa.

[0030] In some embodiments, the automotive structural steel of the present disclosure has a tensile strength of ≥1180MPa, such as ≥1200MPa, ≥1250MPa, ≥1300MPa, ≥1320MPa.

[0031] In some embodiments, the automotive structural steel of the present disclosure has an elongation of ≥7%, such as ≥7.5%, ≥8%, ≥8.5%, ≥9%, ≥9.5%, ≥10%, ≥10.5%.

[0032] In some embodiments, the automotive structural steel of the present disclosure has a 180° bending property of d≤3.5T, such as d≤3T, d≤2.5T.

[0033] The method for manufacturing the automotive structural steel with a yield strength of ≥1000 MPa as described in the present disclosure comprises the following steps:

1) smelting and continuous casting,
wherein the components described above are smelted and subjected to the continuous casting to produce an ingot, wherein the slab cooling rate during the continuous casting is ≥5K/s;

2) hot rolling,

wherein the ingot is heated with the heating temperature at the center point of the slab width being from 1150 °C to 1220 °C;
the total reduction rate of the rolling is ≥98%, wherein the reduction rates of both of the first pass and the second pass are ≥60%; and the finishing rolling outlet temperature is 920-980°C; and the slab rolling rate is controlled so that after rolling, the time tp for transmitting any position of the steel plate or steel strip from the temperature measuring point at the finishing rolling outlet to the coiling temperature measuring point is tp≥(5/Bs)+4 seconds;

3) layer cooling and coiling,

after rolling, the strip is cooled to a temperature of ≤530°C at a cooling rate of ≥150°C/s, and then is further cooled to the coiling temperature at a cooling rate of ≥10°C/s, wherein the coiling temperature is from (Ms+10°C) to 400°C; wherein the martensite transition temperature of the strip steel is Ms = 498.9-333.3*(C) -33.3*(Mn) -27.8*(Cr) -16.7*(Ni)-11.1*(Si+Mo+W) in the unit of °C;
for a steel plate or steel strip with Bs < 0.9, after coiling, the steel coil is held on the coiler for a duration of ≥(10/Bs) + 5 seconds before it is unloaded; and

4) heap cooling.

[0034] In some embodiments, the slab cooling rate during the continuous casting in step 1) is ≥5K/s, such as ≥6K/s, ≥7K/s, ≥8K/s, ≥9K/s, ≥10K/s, ≥11K/s, ≥12K/s, ≥13K/s, ≥14K/s, ≥15K/s, ≥16K/s.

[0035] In some embodiments, in step 2), the heating temperature at the center point of the slab width is 1150°C, 1160°C, 1170°C, 1180°C, 1190°C, 1200°C, 1210°C, 1220°C or within the range obtained by combining any two of the above values.

[0036] In some embodiments, in step 2), the reduction rate of the first pass is ≥60%, such as ≥65%, ≥70%, ≥75%, and the reduction rate of the second pass is ≥60%, such as ≥65%, ≥70%, ≥75%.

[0037] In some embodiments, in step 2), the finishing rolling outlet temperature is 920°C, 930°C, 940°C, 950°C, 960°C, 970°C, 980°C or within the range obtained by combining any two of the above values.

[0038] Furthermore, the method for manufacturing the automotive structural steel with a yield strength of ≥ 1000 MPa of

the present disclosure may further include step 5), wherein the hot-rolled steel plate or strip is pickled to produce a pickled plate.

[0039] Preferably, in step 3), the steel strip is rapidly cooled to a temperature of ≤530 °C at a cooling rate of ≥180 °C/s after rolling.

[0040] In some embodiments, in step 3), the cooling rate for cooling the steel strip to a temperature of ≤530 °C after rolling is 150 °C/s, 160 °C/s, 170 °C/s, 180 °C/s, 190 °C/s, 200 °C/s or within the range obtained by combining any two of the above values.

[0041] In some embodiments, the cooling rate of the second cooling stage in step 3) is 10°C/s, 12°C/s, 14°C/s, 16°C/s, 18°C/s, 20°C/s or within the range obtained by of any two of the foregoing values.

[0042] Preferably, for a steel plate or steel strip with Bs ≥ 0.9, after coiling, the coil is held on the coiler for a duration of ≥(10/Bs) + 5 seconds before it is unloaded.

[0043] Preferably, the heap cooling of step 4) is performed by heaping the unloaded coil in a heat preservation pit under an ambient temperature of ≥280 °C for 2 to 6 hours. Preferably, the coil is heaped with one side laying flat.

[0044] Preferably, after rolling the steel strip has a thickness of ≤4 mm.

[0045] In the method for manufacturing automotive structural steel having a yield strength of 1000 MPa or more according to the present disclosure:

In the step 1), the cooling rate of the slab adopted during the continuous casting will influence the grain size in the final structure of the steel plate and steel strip, and the grain size will consequently influence the formation speed and formation time of the lower bainite. Smaller grain size will bring about faster lower bainite formation rate and shorter time needed for the lower bainite formation. If the cooling rate is less than 5K/s, coarse grains will be formed in the ingot structure, which is disadvantageous for obtaining fine-grained structure during the subsequent rolling. Furthermore, it tends to incur the formation of central segregation or banded structure in the subsequent finished product structure, both of which tend to induce the formation of martensite and substantially increase the ratio of martensite in the final steel plate or steel strip, thus deteriorate the bending property of the steel plate or steel strip.

In the step 2), if the heating temperature is too high, the grain size in the steel will be coarse, thereby slowing down the formation rate of the final lower bainite and consequently a steel plate or steel strip with an insufficient amount of lower bainite will be produced. If the heating temperature is too low, the slab will have insufficient austenitization degree, and the content of the lower bainite in the steel plate or steel strip will also be insufficient. When the final rolling temperature of the finishing rolling is lower than 920°C, ferrite will precipitate before the finishing rolling, thereby resulting in a low content of lower bainite in the final structure of the steel. However, while considering the slab heating temperature, the final rolling temperature of the finish rolling is controlled to be ≤980°C. In order to ensure that the rolled steel plate or steel strip has a microstructure with smaller grain, the total reduction rate of the rolling must be ≥98%, and each of the first and second pass must have a reduction rate of ≥60%. When the reduction rate is insufficient, a fine and uniform structure cannot be obtained, the time for forming the final lower bainite is rather long, and it is unable to produce ≥95% lower bainite. Similarly, in order to finish the transition of lower bainite before unloading of the coil, it is necessary to control the slab rolling rate so that after rolling, the steel plate or steel strip has a tp_{min} of tp_{min}≥ (5/Bs) + 4 seconds, wherein the tp_{min} represents the minimal time for transmitting any position of the rolled steel plate or steel strip from the finish rolling outlet temperature measuring point to the coiling temperature measuring point. The specific time may vary due to the differences in the slab size and the production line equipment, but in any case it is necessary to ensure that the steel plate and steel strip undergo lower bainite transition as fully as possible before they enter the coiler. Therefore, this time is highly related with the characteristic value of the bainite transition rate Bs. If the time is insufficient, then it is impossible to achieve ≥95% lower bainite.

In the step 3), in order to avoid the ferrite phase zone and the pearlite phase zone, the first cooling stage needs a cooling rate of ≥150 °C/s, preferably ≥180 °C/s, and is cooled to a temperature of ≤530 °C. If the cooling temperature is too high, it will promote the production of upper bainite, granular bainite, and even pearlite, ferrite and other phases, making it impossible to achieve a lower bainite content of ≥95%. When the steel has been cooled to ≤530 °C, the cooling rate in the second cooling stage is reduced to ≥10 °C/s until the coiling temperature is reached. However, the cooling rate should not be too low so as to avoid the formation of granular bainite and upper bainite. The coiling temperature needs to be controlled in the range of (Ms+10 °C) to 400 °C, which also aims to ensure the formation of ≥95% lower bainite. If the coiling temperature is too low, martensite will be formed, while if the coiling temperature is too high, granular bainite, upper bainite and carbides or carbonitrides will be precipitated. In some embodiments, the coiling temperature is from (Ms+20 °C) to 400 °C. Meanwhile, for a steel plate or steel strip having a Bs of < 0.9, the steel coil needs to be held on the coiler for a duration of ≥ (10/Bs) + 5 seconds before it is unloaded, in order to ensure the fully formation of lower bainite and avoid the formation of martensite or retained austenite.

[0046] Preferably, the steel plate or steel strip with a Bs of ≥ 0.9, which has been coiled, can be directly unloaded for heap cooling without being held on the coiler, alternatively, the steel coil can be held on the coiler for a duration of ≥ (10/Bs) + 5

seconds before it is unloaded; preferably, the steel coil is held on the coiler for a duration of ≥ (10/Bs) + 5 seconds before unloading so as to ensure that the lower bainite is fully formed and to further avoid the formation of martensite or retained austenite.

[0047] Preferably, the rolled steel strip has a thickness of ≤4 mm. If the thickness of the steel strip is too thick, the uniformity of the structure in the thickness direction is inferior, which is disadvantageous to obtaining ≥95% lower bainite.

[0048] In the step 4), it is further preferable that the steel coil is uploaded and heaped with one side flat (vertically) in a heat preservation pit under an ambient temperature of ≥280 °C for 2 to 6 hours to further avoid the formation of martensite. However, if the temperature of the heat preservation heaping is too high or the heaping time is too long, on the one hand the precipitation of carbides or carbonitrides will be induced, and on the other hand the lower bainite will decompose to form granular bainite, which is disadvantageous to the bending property. In some embodiments, the steel coil is heaped in a heat preservation pit under an ambient temperature of 280 to 340 °C for 2 to 6 hours.

[0049] The present disclosure has the following advantages and beneficial effects over the prior art:
The present disclosure aims to provide a steel plate having both high strength and high bending property by forming almost pure high-strength lower bainite in the steel plate and steel strip.

[0050] The martensitic high-strength steel of the prior art has a microstructure mainly comprising martensite or tempered martensite, sometimes the microstructure may be supplemented with a small number of other microstructures such as ferrite, bainite or carbide precipitation. However, this kind of martensitic high-strength steel has poor bending property. On the contrary, the high-strength steel of the present disclosure has almost pure lower bainite structure, has a strength comparable to said martensitic high-strength steel, and also has better bending property. Additionally, according to a reference (Wear Resistance of Medium Carbon Steel with Different Microstructures-PMC (nih.gov)), the steel plates mainly comprising bainite also have a fracture toughness higher than that of martensite steel plates or tempered martensite steel plates.

[0051] On the other hand, the precipitation-strengthened ultra-high strength hot-rolled steel sheets or strips have large amounts of micro-alloying elements such as Nb, Ti, and V for improving the strength of the steel plates or strips through the precipitation of large amounts of micro-alloy carbides or carbonitrides.

[0052] On the contrary, the present disclosure avoids the addition of large amounts of expensive alloying elements to form microalloy carbide or carbonitride precipitations, while also avoids the negative impact of large amounts of microalloy carbide or carbonitride precipitations on the bending property, so that the steel plate or steel strip obtained by the present disclosure has more excellent bending formability while keeping a comparable strength.

[0053] How to make the hot-rolled or pickled steel plate or strip form a nearly pure lower bainite micro-structure which has ultra-high strength or hardness is a key problem that needs to be solved by the present disclosure. Due to the short production time and fast pace of the hot rolling, the duration of the temperature control and controlled cooling stage of laminar cooling is extremely short, and the accuracy of the temperature control and controlled cooling is also weak. However, due to the narrow temperature window for lower bainite formation and the low formation temperature, the lower bainite formation rate is slow, thus result in contradictions among the lower bainite formation temperature, formation rate, and hot rolling production time, and consequently making the design and manufacturing extremely difficult.

[0054] Therefore, when designing the composition, on the one hand, it is necessary to expand the transition range of the lower bainite as much as possible so that the lower bainite can be formed at a transition temperature as low as possible, as a lower formation temperature will result in higher strength or hardness of the lower bainite. However, since the transition of lower bainite involves the diffusion kinetics of related atoms such as carbon atoms, a lower phase transition temperature will incur slower lower bainite transition. Therefore, when designing the composition, it is also necessary to reasonably design the ratio of related elements which influence the diffusion and rate, and optimize the transition rate of the lower bainite, namely, corresponding to the Bs value described in the present disclosure, so that as much lower bainite as possible can be formed in a shorter time of the hot rolling process.

[0055] Of course, in addition to the composition design, the present disclosure also needs to consider the problems about the formation zone and formation time in the manufacturing process. On the one hand, it is formed at a temperature as low as possible so as to improve the product strength, and on the other hand, it is formed as much as possible so as to improve the bending property. Therefore, on the one hand, a manufacturing process that can refine the grains, such as increasing the slab cooling rate during the continuous casting and increasing the reduction rate during the hot rolling, is designed to accelerate atomic diffusion and lower bainite transition through grain refinement. On the other hand, temperature control is optimized so that the lower bainite is formed at a temperature as low as possible without generating other structures, such as martensite, upper bainite, etc. More importantly, the present disclosure also pays special attention to the problem of matching between the hot rolling process time and the lower bainite formation rate. The corresponding time is designed in each process linked with the hot rolling process to ensure that ≥95% of the lower bainite is formed in the final structure.

[0056] Through the above-mentioned design of composition and manufacturing process, the automotive structural steel obtained by the present disclosure not only has ultra-high strength, but also has excellent forming property, especially bending formability. The automotive structural steel has a yield strength of ≥1000MPa, a tensile strength of ≥1180MPa, an

elongation of ≥7%, and a 180° bending property of d≤3.5T, thus it can satisfy the lightweight requirements of future automotive structures and is particularly suitable for use in components of chassis systems.

BRIEF DESCRIPTION OF THE DRAWINGS

[0057] Figure 1 shows a photograph of the steel microstructure according to Example D1 of the present disclosure.

DETAILED DESCRIPTION

[0058] The present invention will be further described below with reference to the embodiments and drawings.

Example and Comparative Example

[0059] The automotive structural steels of the examples of the present disclosure and the comparative examples were prepared by the following steps:

1) smelting and continuous casting,
wherein the components of Table 1 were smelted and subjected to the continuous casting to produce an ingot, wherein the slab cooling rate during the continuous casting is ≥5K/s;
2) hot rolling,

wherein the ingot was heated with the heating temperature at the center point of the slab width being from 1150 °C to 1220 °C;
the total reduction rate of the rolling was ≥98%, wherein both of the reduction rates of the first pass and the second pass were ≥60%; and the finishing rolling outlet temperature was 920-980°C; and the slab rolling rate was controlled so that after rolling, the time tp for transmitting any position of the steel plate or steel strip from the temperature measuring point at the finishing rolling outlet to the coiling temperature measuring point is tp≥(5/Bs) +4 seconds; after rolling the steel strip had a thickness of ≤4 mm;

3) layer cooling and coiling,

after rolling, the strip was rapidly cooled by water cooling to a temperature of ≤530°C at a cooling rate of ≥150°C/s, and then was further cooled to the coiling temperature at a cooling rate of ≥10°C/s, wherein the coiling temperature was from (Ms+10°C) to 400°C; wherein the martensite transition temperature of the strip steel Ms = 498.9-333.3*(C) -33.3*(Mn) -27.8*(Cr) -16.7*(Ni)-11.1*(Si+Mo+W) in the unit of °C;
the extra holding time on the coiler adopted for each example and comparative example was summarized in table 2.

4) heap cooling,

[0060] The heap cooling was conducted by heaping the uploaded steel with one side laying flat in a heat preservation pit under an ambient temperature of ≥280 °C for 2 to 6 hours.

[0061] The compositions of the steel of the examples of the present disclosure and the steel of the comparative examples are shown in Table 1, with the balance being Fe and other unavoidable impurities. Table 2 shows the process parameters of the steel of the examples of the present disclosure and the steel of the comparative examples. The data of the comparative examples which do not conform to the present disclosure are marked with underlines.

[0062] In the present disclosure, the yield strength, tensile strength and elongation are characterized according to GB/T228.1-2021 "Tensile Test of Metal Materials Part 1: Room Temperature Test Method". The 180° bending property d/T is characterized as follows: the 180° bending test is performed using the bending performance determination method as described in the GB/T232-2010 standard (bending diameter d=1a). The test method for the microstructure content comprises: using the surface of a metallographic sample etch polished with a 4% nitric acid solution in ethanol, and then characterizing it with SEM electron microscope.

[0063] Table 3 shows the properties and structures of the steel plates or steel strips corresponding to the steel of the examples of the present disclosure and the steel of the comparative examples. All the indexes of the examples meet the design of the present disclosure, and all the hot-rolled steel plates or steel strips have a yield strength of ≥ 1000 MPa, a tensile strength of ≥ 1180 MPa; an elongation of ≥ 7%; and a 180° bending performance of d ≤ 3.5T.

[0064] Example E1 and E2 comprise high content of Mn, Cr and Mo, hence they exhibit a tensile strength of up to 1300 MPa, but the elongation at break is relatively low, and the 180° bending performance is d=3.5T.

[0065] In Examples D1 and H1, the granular bainite transition and the precipitation of carbonitrides are promoted by slow heap cooling after the coiling, but the bending property does not reach the optimal level, and the 180° bending property is d=3.5T. Examples B1 and F1 also exhibit a 180° bending property of d=3.5T. Example F1 has relatively high strength, and on the other hand, due to the relatively low Bs value, the lower bainite formation rate is relatively slow, which tends to induce the formation of martensite after unloading the coil and during heap cooling. Therefore, the formation of lower bainite is ensured by holding the coil on the coiler for an additional 33 seconds after coiling, but finally about 0.1% of martensite is still formed, resulting in relatively low bending property. Example B1 also has similar problems. Example B1 has a moderate Bs of ≥0.9, and Example B1 does not comprise holding the coil on the coiler for an additional time after coiling, so that finally about 0.15% of martensite is formed, resulting in relatively low bending property. The 180° bending properties of Examples A1, B2, C1, D2, G1, and I1 reached the preferable level of d≤3.0T. Except Example D2, the bainite contents in the remaining five examples were >99%, which resulted in higher bending properties. Among them, since Examples A1 and C1 had relatively low strength, their 180° bending property reached the level of d≤2.5T.

[0066] Among the comparative examples, the difference between Comparative Example H2 and Comparative Example H1 is that the coiling temperature is too high, thus Comparative Example H2 comprises excessive carbonitride precipitation, granular bainite formation, and insufficient lower bainite content. Although the strength of Comparative Example H2 is increased, its bending property is significantly deteriorated.

[0067] In Comparative Example C2, since the coiling temperature is too low, almost pure martensite structure is generated, which greatly increases the strength, but significantly deteriorates the plasticity and bending property.

[0068] As compared with Example D1, the Comparative Example J1 comprises similar contents of single elements in the composition design, but the Bs value of J1 is too large. Although the manufacturing process of J1 is similar to that of Example D1, the excessively large Bs value still leads to the precipitation of carbonitride and an excessive amount of granular bainite, and consequently resulting in poor bending property.

[0069] As compared with Example G1, the Comparative Example K1 comprises similar contents of single elements in the composition design, but the Bs value of K1 is too small, and the time configured for the formation of lower bainite in the manufacturing process is very short, and the coil is not held on the coiler, all of which consequently result in insufficient lower bainite formation and the generation of more martensite and retained austenite. Although the Comparative Example K1 exhibits strength and elongation which meet the related standards, it has extremely poor bending property.

[0070] The Comparative Example G2 mainly differs from Example G1 in that the tp time is insufficient and there is no extra holding on the coiler after coiling. Since the components of Example G have a relatively low Bs value, the lower bainite formation rate is slow. The excessively short tp time and the lack of extra holding after coiling lead to insufficient formation time of the lower bainite. Consequently, the Comparative Example G2 comprises insufficient lower bainite, and martensite and retained austenite are also generated. Although the Comparative Example G2 exhibits strength and elongation which meet the related standards, it has inferior bending property.

[0071] As can be seen from Figure 1, in the structure produced in Example D1 of the present disclosure, the area proportion of the lower bainite is ≥95%, the combined area proportion of ferrite + carbide + granular bainite is <5%, and the combined area proportion of martensite + tempered martensite + upper bainite is ≤0.01.

[0072] Summing up the above, the automotive structural steel prepared by the present disclosure not only has ultra-high strength, but also has superior formability, especially bending formability, which can fulfill the lightweight requirements of future automotive structures and is particularly suitable for use in chassis system components.

Table 1 (percentage in weight)

	C	Si	Mn	P	S	N	Al	Cr	Mo	B	Nb	Ti	V	Bs	Ms temperature, °C
Example A	0.19	0.34	1.7	0.013	0.003	0.004	0.010	0.35	0.30	0.0030	0.001	0.002	0.002	1.37	362
Example B	0.20	0.50	2	0.005	0.001	0.001	0.025	0.20	0.23	0.0035	0.002	0.001	0.001	0.90	352
Example C	0.23	0.18	1.8	0.008	0.002	0.003	0.035	0.05	0.15	0.0040	0.001	0.003	0.001	0.83	357
Example D	0.16	0.40	1.6	0.01	0.005	0.005	0.040	0.45	0.38	0.0015	0.015	0.007	0.003	1.31	371
Example E	0.17	0.27	2.4	0.004	0.003	0.002	0.0020	0.50	0.50	0.0010	0.009	0.005	0.006	0.71	340
Example F	0.22	0.30	2.2	0.006	0.004	0.003	0.030	0.15	0.45	0.0018	0.004	0.001	0.001	0.86	340
Example G	0.18	0.45	1.9	0.007	0.001	0.001	0.037	0.3	0.27	0.0022	0.001	0.002	0.002	0.61	359
Example H	0.15	0.12	2.3	0.011	0.004	0.002	0.015	0.42	0.36	0.0028	0.012	0.010	0.008	1.00	355
Example I	0.21	0.23	2.1	0.006	0.004	0.003	0.018	0.10	0.40	0.0025	0.003	0.001	0.001	1.10	349
Comparative Example J	0.18	0.30	1.8	0.012	0.003	0.004	0.020	0.38	0.40	0.0030	0.016	0.006	0.04	1.89	361
Comparative Example K	0.17	0.40	2	0.007	0.001	0.004	0.0020	0.28	0.25	0.002	0.002	0.003	0.00	0.29	361

Table 2

	Steel no.	Slab cooling rate °C/s	Heating temperature of the hot rolling °C	Reduction rate of the first/second rolling %	Finishing rolling outlet temperature °C	Cooling rate °C /s	tp_{min} s	Water cooling temperature °C	Cooling rate in the Second cooling stageC /s	Coiling temperature °C	The extra holding time on the coiler s	The temperature of the heat preservation pit/the heat preservation time
Example A1	A	5	1200	75/70	925	155	16	530	10	395	0	-
Example B1	B	10	1160	60/60	965	200	13	505	12	380	0	-
Example B2	B	9	1150	60/60	920	190	12	515	15	370	45	-
Example C1	C	8	1210	65/60	970	185	11	490	14	375	37	-
Example D1	D	11	1220	75/75	980	170	10	500	14	400	0	320°C/4h
Example D2	D	14	1180	70/65	935	160	14	520	11	390	0	300°C/3h
Example E1	E	13	1215	65/65	960	165	12	480	14	350	42	-
Example E2	E	7	1195	70/70	955	155	16	490	10	355	40	280°C/6h
Example F1	F	12	1170	70/60	930	180	10	495	17	365	33	-
Example G1	G	15	1205	75/60	940	195	15	525	11	385	25	-
Example H1	H	16	1210	75/65	950	150	15	485	10	365	0	340°C/2h
Example I1	I	6	1190	75/65	975	175	10	510	20	360	30	
Comparative Example C2	C	9	1210	65/65	930	150	12	510	28	250	0	-
Comparative Example H2	H	6	1220	70/70	980	200	10	530	10	450	0	-
Comparative Example G2	G	15	1205	75/60	940	195	11	520	15	390	0	
Comparative Example J1	J	11	1200	65/60	950	180	9	520	20	390	0	-
Comparative Example K1	K	13	1180	60/60	960	160	11	500	15	380	0	-

Table 3

	Yield Strength Pa	Tensile Strength MPa	Elongation %	d/T	the area proportion of lower bainite %	the area proportion of ferrite+carbide+granular bainite %	the area proportion of other phases%
Example A1	1015	1194	9.5	2.5	>99	<1	<0.01
Example B1	1031	1228	10.5	3.5	>99	<1	<0.2
Example B2	1045	1220	9	3	>99	<1	<0.01
Example C1	1005	1181	10	2.5	>99	<1	<0.01
Example D1	1049	1206	9	3.5	95	<5	<0.01
Example D2	1011	1191	9.5	3	97	<3	<0.01
Example E1	1116	1321	7	3.5	98	<2	<0.2
Example E2	1151	1323	7	3.5	96	<4	<0.01
Example F1	1076	1274	7.5	3.5	>99	<1	<0.2
Example G1	1025	1207	9	3	>99	<1	<0.01
Example H1	1067	1240	8	3.5	95	<5	<0.01
Example I1	1051	1233	8.5	3	>99	<1	<0.01
Comparative Example C2	1094	1295	5.5	5.5	<1	<1	>98
Comparative Example H2	1082	1245	7	4.5	<85	>10	<0.01
Comparative Example G2	1023	1237	9	4	<94	<1	6
Comparative Example J1	1079	1233	7.5	4	<93	7	<0.01
Comparative Example K1	1045	1261	8.5	5	>85	<1	15

Claims

1. An automotive structural steel with a yield strength of ≥1000 MPa, comprising the following chemical elements in percentage by weight:

   C: 0.15-0.23%;
   Si: 0.12-0.5%;
   Mn: 1.6-2.4%;
   B: 0.001-0.004%;
   Al: 0.01-0.04%;
   Cr: 0.05-0.5%;
   Mo: 0.15-0.5%;
   P: ≤0.015%;
   S: ≤0.005%; and
   the balance amount of Fe and other unavoidable impurities, and the steel satisfies the relation of Bs= 0.6-1.4, wherein Bs represents the characteristic value of lower bainite formation rate and is determined by the equation of Bs = (Mo + B*100-Mn/5)/C;
   the area proportion of lower bainite in the microstructure of the automotive structural steel is ≥95%.

2. The automotive structural steel with a yield strength of ≥1000 MPa according to claim 1, **characterized in that** the automotive structural steel further comprises at least one of Ti, V and Nb, and Ti+Nb+V

≤0.03 wt%, preferably Ti+Nb+V ≤0.006 wt%.

3. The automotive structural steel with a yield strength of ≥1000 MPa according to claim 1, **characterized in that** the content of C is 0.18-0.21 wt%.

4. The automotive structural steel with a yield strength of ≥1000 MPa according to claim 1, **characterized in that** the content of Mn is 1.8-2.2 wt%.

5. The automotive structural steel with a yield strength of ≥1000 MPa according to claim 1, **characterized in that** the content of Cr is 0.15-0.35 wt%.

6. The automotive structural steel with a yield strength of ≥1000 MPa according to claim 1, **characterized in that** the content of Mo is 0.15-0.38 wt%.

7. The automotive structural steel with a yield strength of ≥1000 MPa according to claim 1, **characterized in that** in the microstructure of the automotive structural steel, the area proportion of the lower bainite is ≥95%, the combined area proportion of retained austenite + martensite + tempered martensite + upper bainite is ≤0.2%.

8. The automotive structural steel with a yield strength of ≥1000 MPa according to claim 1, **characterized in that** in the microstructure of the automotive structural steel, the area proportion of lower bainite is ≥95%, the combined area proportion of ferrite + carbonitride precipitation + granular bainite is ≤5%, and the combined area proportion of retained austenite + martensite + tempered martensite + upper bainite is ≤0.01%.

9. The automotive structural steel with a yield strength of ≥1000 MPa according to claim 1, **characterized in that** the automotive structural steel has a yield strength of ≥1000 MPa, a tensile strength of ≥1180 MPa, an elongation of ≥7%, and a 180° bending property of d≤3.5T, preferably d≤3T.

10. A method for manufacturing the automotive structural steel with a yield strength of ≥1000 MPa according to any one of claims 1 to 9, **characterized in that** the method comprises the following steps:

1) smelting and continuous casting, wherein the components according to any one of claims 1 to 6 are smelted and subjected to the continuous casting to produce an ingot, wherein the slab cooling rate during the continuous casting is ≥5K/s;
2) hot rolling, wherein the ingot is heated under a temperature of 1150-1220°C;
the total reduction rate of the rolling is ≥98%, wherein both of the reduction rates of the first pass and the second pass are ≥60%; and the finishing rolling outlet temperature is 920-980°C;
3) layer cooling and coiling,

after rolling, the strip is cooled to a temperature of ≤530°C at a cooling rate of ≥150°C/s, and then is further cooled to the coiling temperature at a cooling rate of ≥10°C/s, wherein the coiling temperature is from (Ms+10°C) to 400°C; after the hot rolling, the time tp for transmitting any position of the steel plate or steel strip from the temperature measuring point at the finishing rolling outlet to the coiling temperature measuring point is tp≥(5/Bs)+4 seconds; wherein
the martensite transition temperature of the strip steel Ms = 498.9-333.3*(C) -33.3*(Mn) -27.8*(Cr) -16.7*(Ni)-11.1*(Si+Mo+W) in the unit of °C;
for a steel plate or steel strip with Bs < 0.9, after coiling, the steel coil is held on the coiler for a duration of ≥(10/Bs) + 5 seconds before it is unloaded; and

4) heap cooling.

11. The method for manufacturing the automotive structural steel with a yield strength of ≥1000 MPa according to claim 10, **characterized in that** the method further comprises step 5), in which the hot-rolled steel plate or steel strip is pickled to form a pickled plate.

12. The method for manufacturing the automotive structural steel with a yield strength of ≥1000 MPa according to claim 10, **characterized in that** in step 3), after rolling, the steel strip is rapidly cooled to a temperature of ≤530°C at a cooling rate of ≥180°C/s.

13. The method for manufacturing the automotive structural steel with a yield strength of ≥1000 MPa according to claim 10, **characterized in that** for a steel plate or steel strip with Bs < 0.9, after coiling, the coil is held on the coiler for a duration of ≥(10/Bs) + 5 seconds before it is unloaded.

14. The method for manufacturing the automotive structural steel with a yield strength of ≥1000 MPa according to claim 10, **characterized in that** the heap cooling of step 4) is performed by heaping the unloaded steel coil in a heat preservation pit under an ambient temperature of ≥280 °C for 2 to 6 hours.

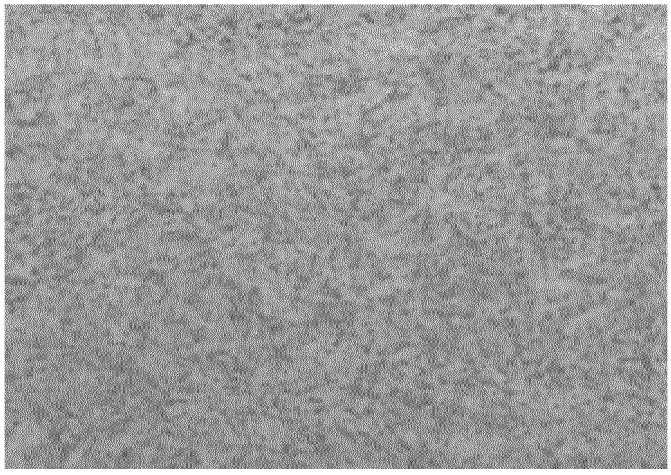

Fig. 1

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2023/102180

A. CLASSIFICATION OF SUBJECT MATTER

C22C38/02(2006.01)i; C22C38/06(2006.01)i; C22C38/18(2006.01)i; C22C38/38(2006.01)i; C22C38/44(2006.01)i; C22C38/54(2006.01)i; C21D9/46(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)

CNTXT, DWPI, ENTXT, WPABS, CNKI, ISI WEB OF SCIENCE: 钢板, 下贝氏体, 屈服强度, 碳, C, Mn, 锰, Si, 硅, Al, 铝, 铬, Cr, Mo, 钼, B, 硼, steel sheet, steel plate, lower bainite, yield strength, carbon, manganese, silicon, aluminum, chromium, molybdenum, boron

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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A	CN 1840723 A (BAOSHAN IRON & STEEL CO., LTD.) 04 October 2006 (2006-10-04) entire document	1-14
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☐ Further documents are listed in the continuation of Box C. ☑ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
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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
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"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	Date of mailing of the international search report
18 September 2023	**22 September 2023**

Name and mailing address of the ISA/CN	Authorized officer
China National Intellectual Property Administration (ISA/CN) **China No. 6, Xitucheng Road, Jimenqiao, Haidian District, Beijing 100088**	Telephone No.

Form PCT/ISA/210 (second sheet) (July 2022)

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
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