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

(72) Inventors:
- **LIU, Hao**
  Shanghai 201900 (CN)
- **TAN, Ning**
  Shanghai 201900 (CN)
- **JIN, Xinyan**
  Shanghai 201900 (CN)

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

(54) HOT STAMPED PART HAVING EXCELLENT LOW-TEMPERATURE BRITTLENESS RESISTANCE AND MANUFACTURING METHOD THEREFOR

(57) A hot stamped part having excellent low-temperature brittleness resistance, comprising Fe and inevitable impurities, and also comprising the following chemical elements in percentage by mass: C: 0.26-0.40%, Si: 0.1-1.5%, Mn+Cr: 0.5-3.0%, Al: 0.01-0.50%, Nb+Ti: 0.04-0.25%, Mo+Ni: 0.1-1.0%, and B: 0.001-0.005%. The matrix of the microstructure of the hot stamped part comprises a lathstrip-shaped tempered martensite having a volume ratio of more than 85%, and the microstructure of the hot stamped part also comprises precipitated phases, wherein the precipitation amounts of elements Nb and Ti account for more than 50% of the total mass fraction of the two elements, and the precipitated phases of Nb and Ti are dispersed and distributed in the matrix in the form of particles. Also disclosed is a manufacturing method for the hot stamped part.

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Description

Technical field

[0001] The present disclosure relates to a hot stamped part and a manufacturing method therefor, and in particular relates to a hot stamped part having low-temperature brittleness resistance, and a manufacturing method therefor.

Background Art

[0002] In recent years, with the gradual increase of global car ownership, the environmental pollution and energy consumption caused thereby have become increasingly serious. The lightweight technology of automobiles can effectively alleviate such problems, so the current automobile manufacturers have carried out a lot of research on the lightweight of automobiles.

[0003] It is found that when ultra-high-strength steel is used to prepare automobile structures, it can achieve the purpose of reducing the weight of automobiles under the premise of ensuring safety. However, when the ultra-high-strength steel products having a tensile strength of higher than 1180MPa is prepared in practice, it is extremely difficult for cold forming, and the resilience control ability is insufficient. The parts prepared by hot stamping have the characteristics of ultra-high strength, easy forming, and high dimensional accuracy, so the hot stamped ultra-high strength steel product has gradually become one of the important technical solutions for car body lightweight.

[0004] At present, with the gradual upgrading of crash safety regulations, the market demand for hot stamping steel with a tensile strength of more than 1700MPa is also increasing. However, it is found that the performance of hot stamping steel products with a tensile strength of more than 1700MPa is very insufficient in terms of bending and impact performance, especially poor in low temperature state of -60°C, which leads to the risk of brittle cracking of hot stamped parts in service in an extremely cold area, which will cause immeasurable losses to the safety of users' lives and property.

[0005] Therefore, in order to ensure the service life of hot stamped parts in an extremely low temperature environment, it is also necessary to consider the low temperature brittleness resistance of the material when ultra-high strength hot stamped parts are prepared. The current VDA238-100 bending performance test is close to the actual crash failure mode of the parts, so the evaluation of low-temperature VDA (bending angle) is particularly important.

[0006] However, there are many shortcomings for hot stamping steels with a strength grade of 1700MPa while the toughness is obtained, and the low-temperature brittleness under plane deformation has not been paid attention to and explained in related studies.

[0007] For example, the Chinese publication CN110423953A, published on November 8, 2019, and titled with "A hot-stamped member with excellent bending performance having a tensile strength of 1800MPa or higher and preparation method thereof", discloses a hot-stamped member with excellent bending performance having a tensile strength of 1800MPa or higher comprising the following chemical composition in weight percentage: C: 0.29-0.35%, Si≤0.5%, Mn: 0.5-1.5%, P≤0.020%, S≤0.010%, Cr≤0.50%, Al: 0.01-0.06%, Nb: 0.01-0.06%, V: 0.01-0.06%, Mo≤0.5%, with a balance of Fe and unavoidable impurities. The hot stamped member has a surface layer of ferritic structure as a soft phase, and an inner layer of martensitic structure. In this technical solution, the bending performance of the material is improved with the help of the surface layer of soft phase, but the surface layer softening will inevitably lead to the reduction of collision deformation resistance of the part, and the bending performance under low temperature conditions is not mentioned in the technical solution.

[0008] For another example, the Chinese publication CN106460115A, published on February 22, 2017, and titled with "A heat treated steel and its manufacturing method", discloses a heat-treated steel with a tensile strength of 1.8GPa or more and excellent toughness and weldability, and its chemical composition is designed as: C: 0.05~0.30%, Mn: 2.0% ~10.0%, Cr: 0.01%~1.0%, Ti: 0.01%~0.1%, B: 0.001%~0.01%, Si: 0.08% or less, P: 0.05% or less, S: 0.05% or less, N: 0.01% or less, Ni: 0%~2.0%, Cu, Mo and V: 0%~1.0% respectively, with a balance of Fe and unavoidable impurities. When the C equivalent is [C] and the Mn equivalent is [Mn], it satisfies "$4612\times[C]+102\times[Mn]+605\geq1800$". The microstructure of the heat-treated steel has a martensitic structure with a volume ratio of 90% or more, and its dislocation density in martensite is not less than $9.0\times10^{15}m^{-2}$. In this technical solution, the high strength of parts is achieved with the help of low carbon and high manganese. But the high manganese design makes steelmaking difficult, and it is prone to segregation defects, leading to toughness deterioration.

[0009] In summary, the existing hot stamping steel with a tensile strength of 1700MPa or more is mainly used to obtain ultra-high strength and room temperature toughness, which is not involved or related to the resistance to low-temperature bending brittle cracking. Therefore, in order to solve the current problem of brittle cracking of ultra-high-strength hot-stamped parts existing in extremely cold areas, the inventors expect to provide a new hot-stamped part with excellent low-temperature brittleness resistance and its manufacturing method, so as to effectively meet the market demand.

Summary

[0010] One object of the present disclosure is to provide a hot-stamped part with excellent resistance to low-temperature brittleness. The hot-stamped part has excellent resistance to low-temperature brittleness cracking while having ultra-high strength. It has a tensile strength at room temperature of greater than 1700MPa (such as 1700~2200MPa), a ratio of bending performance at a low temperature of -60 °C to that at room temperature (20 °C) (i.e., the ratio of bending angle at -60°C to that at 20°C) is greater than 0.85 (such as 0.86~0.93), and at the same time a product of strength and toughness at a low temperature of -60 °C (the tensile strength at room temperature ×bending angle at -60°C) is not less than 8×10^4 (such as 8.8×10^4-11.3×10^4). The use of this hot stamped parts can effectively solve the current problem of brittle cracking of ultra-high strength hot stamped parts existing in extremely cold areas, and it has a good application prospect and can be widely used in automobile, shipbuilding, machinery and other industries.

[0011] To achieve the above purposes, the present disclosure proposes a hot stamped part having excellent low-temperature brittleness resistance, which comprises Fe and unavoidable impurities, and also comprises the following chemical elements with the following mass percentages:

C: 0.26~0.40%, Si: 0.1~1.5%, Mn+Cr: 0.5~3.0%, Al: 0.01~0.50%, Nb+Ti: 0.04~0.25%, Mo+Ni: 0.1~1.0%, B: 0.001~0.005%;

wherein the matrix of the microstructure of the hot-stamped part has lath tempered martensite with a volume fraction of higher than 85%;

wherein the microstructure of the hot-stamped part also has a precipitated phase, wherein the precipitated amount of Nb and Ti elements accounts for more than 50% of the total mass fraction of these two elements, and the precipitated phase of Nb and Ti is diffusely distributed in the matrix in a granular form.

[0012] Further, in the hot stamped part having excellent low-temperature brittleness resistance according to the present disclosure, the mass percentage of each chemical element is as follows:
C: 0.26~0.40%, Si: 0.1~1.5%, Mn+Cr: 0.5~3.0%, Al: 0.01~0.50%, Nb+Ti: 0.04~0.25%, Mo+Ni: 0.1~1.0%, B: 0.001~0.005%; with a balance of Fe and other unavoidable impurities.

[0013] Further, in the hot stamped part having excellent low-temperature brittleness resistance according to the present disclosure, the mass percentage of each chemical element is as follows: C: 0.26~0.40%; Si: 0.1~1.5%; Mn: ≤2.5%, Cr≤2%, and Mn+Cr: 0.5~3.0%; Al: 0.01~0.50%; Nb: 0.01~0.1%, Ti: 0.02~0.15%, and Nb+Ti: 0.04~0.25%; Mo: ≤0.6%, Ni: ≤0.8%, and Mo+Ni: 0.1~1.0%; B: 0.001~0.005%; with a balance of Fe and other unavoidable impurities.

[0014] In the hot stamped part having excellent low-temperature brittleness resistance according to the present disclosure, the design principles of each chemical element are as follows:

C: In the hot-stamped parts with excellent low-temperature brittleness resistance described in the present disclosure, C is the key element for realizing ultra-high strength of the hot-stamped steel. When the content of C element in the steel is less than 0.26%, it is difficult to achieve the strength target of 1700MPa of hot-stamped parts. However, it should be noted that the content of C element in steel should not be too high. With the increase of C content in steel, the low-temperature bending performance and welding performance of hot stamped parts will deteriorate significantly. Therefore, considering the influence of the content of C element on the performance of hot-stamped parts, in the hot-stamped parts with excellent low temperature brittleness resistance described in the present disclosure, the mass percentage of C element is specifically controlled in the range of 0.26~0.40%.

Si: In the hot-stamped parts with excellent low-temperature brittleness resistance described in the present disclosure, adding a certain amount of Si element can effectively improve the strength of the hot-stamped parts, and contribute to the deoxidation of steel. It is found that when the Si content in hot stamping steel is less than 0.1%, the deoxidation effect is not good. However, when the Si content in hot stamping steel exceeds 1.5%, it will affect the plating ability of the steel plate. Therefore, in order to exert the beneficial effect of Si element, in the hot-stamped parts with excellent low temperature brittleness resistance described in the present disclosure, the mass percentage of Si element is specifically controlled in the range of 0.1~1.5%. In some embodiments, the mass percentage of Si is controlled in the range of 0.2~0.8%.

Mn, Cr: In the hot-stamped parts with excellent low-temperature brittleness resistance described in the present disclosure, adding a certain amount of Mn and Cr can effectively improve the hardenability of the hot-stamped steel, improve the strength and hardness of the steel, and the effects of Mn and Cr are similar. It is found that when the Mn+Cr in the hot stamping steel is less than 0.5%, the contribution of Mn and Cr elements to the strength of the steel is low, and the purpose of the present disclosure cannot be achieved. When the Mn+Cr in hot stamping steel is higher than 3.0%, it will deteriorate the manufacturability and weldability of the steel. Therefore, in the hot-stamped parts with excellent low temperature brittleness resistance described in the present disclosure, the sum of the mass percentages of Mn and Cr elements "Mn+Cr" is specifically controlled at 0.5~3.0%. In some embodiments, the Mn content is ≤ 2.5%. In some embodiments, the Cr content is ≤ 2%. In some embodiments, the content of Mn is 0.2~2.5%, the content of Cr is 0.2~2%, and the content of Mn+Cr is 0.5~3.0%. In some embodiments, the content of Mn is 0.3~1.5%, the content of Cr is 0.2~1.2%, and the content of Mn+Cr is 0.5~2.7%.

Al: In the hot stamped parts with excellent low temperature brittleness resistance described in the present disclosure, Al is used as a deoxidizing element, which can play the role of deoxidation. Therefore, in order to ensure that Al exerts its own deoxidation effect, it is required to add no less than 0.01% of Al in the hot stamping steel. However, it should be noted that the content of Al in hot stamping steel should not be too high. When the steel comprises more Al, it will cause the formation of coarse inclusions in the steel, and will lead to poor manufacturability. Therefore, in the hot-stamped parts with excellent low temperature brittleness resistance described in the present disclosure, the mass percentage of Al element is controlled in the range of 0.01~0.50%. In some embodiments, the mass percentage of Al is controlled in the range of 0.01~0.10%.

Nb, Ti: In the hot-stamped parts with excellent low-temperature brittleness resistance described in the present disclosure, Nb and Ti are important microalloying elements in steel. Part of Nb and Ti can play a role in solution strengthening, and Nb, Ti elements have strong binding force with C and N, which can combine and precipitate stable carbides, nitrides and carbonitrides, thereby inhibiting the growth of austenite grains in heating of hot stamping, so as to play a role in grain refinement. In addition, the precipitated phase formed by the combination can also be used as a hydrogen trap, which can reduce the susceptibility of hydrogen-induced delayed cracking of hot stamping steel and significantly improve the low-temperature toughness of steel. Moreover, Ti is also a good effective element for deoxidation and nitrogen fixation, which can not only reduce the oxide inclusion in steel, but also avoid the combination of B and N to form BN. Therefore, in order to give full play to the beneficial effects of Nb and Ti, in the hot stamped parts described in the present disclosure, the sum of the mass percentages of Nb and Ti, i.e."Nb+Ti", is specifically controlled at 0.04~0.25%. When the content of Nb+Ti is less than 0.04%, the number of precipitated phases formed is insufficient, and the beneficial effect is limited. When the content of Nb+Ti is higher than 0.25%, it will lead to saturation of the effect, and it is easy to form massive nitrides, which will deteriorate the low-temperature bending performance of the product. In some embodiments, the content of Nb is 0.01~0.1%. In some embodiments, the content of Ti is 0.02~0.15%.

Mo, Ni: In the hot-stamped parts with excellent low-temperature brittleness resistance described in the present disclosure, both Mo and Ni can significantly improve the bending performance of the hot-stamped parts, especially the low-temperature brittleness resistance. Ni can reduce the tough-brittle transition temperature of hot stamping steel, which is of great significance for improving the bending toughness of steel. The Mo element can significantly improve the hardenability of steel, and its carbide can not only refine austenite grains, but also inhibit tempered martensitic brittleness, so as to comprehensively improve the strength and toughness of the hot-stamped parts. Therefore, adding a certain amount of Mo and Ni can impart the hot-stamped parts excellent low-temperature cracking resistance. But considering the alloy cost of steel and the saturation of the elemental effect, in the present disclosure, the sum of the mass percentages of Mo, Ni elements, i.e. "Mo+Ni", is controlled at 0.1~1.0%. In some embodiments, the content of Mo is ≤ 0.6%. In some embodiments, the Ni content is ≤ 0.8%. In some embodiments, the content of Mo is 0.1 ~0.6%, the content of Ni is 0.1 ~0.8%, and the sum of the mass percentages of Mo and Ni, "Mo+Ni", is controlled at 0.1~1.0%.

B: In the hot-stamped parts with excellent low-temperature brittleness resistance described in the present disclosure, adding a certain amount of B element can greatly increase the hardenability of steel. However, it should be noted that the content of B element in steel has an optimal range. When the content of B element in steel is higher than a certain amount, the effect of increasing hardenability is not obvious. Therefore, in the present disclosure, the mass percentage of B element is specifically controlled at 0.001~0.005%.

[0015] It should be noted that the hot stamped parts obtained by quenching medium and high carbon hot stamped steel have high dislocation density and phase transformation internal stress, and are easy to form twin martensite, which is hard and brittle, and the bending performance of which is significantly lower than those of lath martensite. Although the initial martensite formed from hot stamping and quenching to the high temperature zonewill partly self-temper to form tempered martensite and precipitated carbides, the overall performance of the part is still poor. Therefore, the present disclosure studies to inhibit the formation of twin martensite in the matrix through composition and process control, and finds that the matrix has a lath tempered martensite with a volume fraction of higher than 85%. In some embodiments, the matrix of the microstructure of the hot stamped part of the present disclosure has a lath tempered martensite with a volume fraction of 88~98%.

[0016] The results show that in the present disclosure, the size of the precipitated phase of Nb, Ti, Mo and other elements has a significant impact on the bending performance of the hot stamped parts, so it is necessary to optimize the whole process to promote the precipitated amount of Nb+Ti to account for no less than 50% of its total mass fraction (such as 55~75%), and reduce the size of the precipitated phase, which is diffusely distributed. In particular, for the detection method of the precipitated amount of Nb and Ti, the precipitated carbides, nitrides and carbonitride residues are obtained by chemical electrolytic extraction, and then the precipitated mass fractions of Nb+Ti were determined by inductively coupled plasma test method.

[0017] Further, in the hot stamped part having excellent low-temperature brittleness resistance according to the present disclosure, among unavoidable impurities, P is ≤0.03%, S is ≤0.01%, N is ≤0.004%, O is ≤0.004%.

[0018] In the above technical solution, P element, S element, N element, O element and H element are all impurity elements in steel. If the technical conditions permit, in order to obtain the steel with better performance and better quality, the content of impurity elements in the material should be reduced as much as possible.

[0019] P, S: In the present disclosure, P and S are both harmful elements, and the segregation of P element will cause cold brittleness in steel. However, S segregation and sulfides such as MnS will reduce the toughness of steel, which will lead to hot embrittlement at high temperatures. The purpose of the present disclosure is to improve the low temperature brittleness resistance of hot stamped parts. Therefore, the mass percentage of P, S elements in steel must be strictly controlled, and specifically controlled at P≤0.03%, S≤0.01%.

[0020] N: In the present disclosure, N is an impurity element in hot stamping steel, which has a strong affinity with Ti, Al, B and other elements, and the resulting TiN, AlN, BN are hard phase inclusions, and these hard phase inclusions are the source of brittle cracking. Therefore, it is necessary to strictly control the N content in hot stamping steel, and ensure that the N content meets N≤0.004%, and preferably it can be further controlled to be N≤0.003%.

[0021] O: In the present disclosure, the O element is very easy to form oxide inclusions with non-metals in the steel, which will significantly deteriorate the bending performance of the steel. Thus, the steelmaking deoxidation process must be strictly controlled, and the mass percentage of the O element must be controlled to satisfy O≤0.004%. Of course, in some preferred embodiments, it can be further controlled to be O≤0.0025%.

[0022] Further, in the hot stamped part having excellent low-temperature brittleness resistance according to the present disclosure, N is ≤0.003% and/or O is ≤0.0025%.

[0023] Further, in the hot stamped part having excellent low-temperature brittleness resistance according to the present disclosure, it further comprises at least one of the following chemical elements: Cu: 0.01~1.0%, W: 0.01 ~0.5%, V: 0.01~0.5%.

[0024] In the above-mentioned technical solution of the present disclosure, in order to further optimize the performance of the prepared hot-stamped part, the hot-stamped part can be further preferably added with Cu, W, V elements when the chemical composition is designed.

[0025] Cu, W, V: In the hot-stamped parts with excellent low-temperature brittleness resistance described in the present disclosure, a trace amount of Cu element can effectively refine the grain and improve the strength and toughness of the hot stamping steel, and Cu has the effect of improving the corrosion resistance of the material. The W and V elements in steel refine grains through precipitation of fine carbonitrides, which can effectively improve the toughness of hot stamping steels. However, considering the alloy cost of steel and the saturation of elemental effect, in the present disclosure, one or more of Cu, W and V are preferably added, and the content is specifically controlled to satisfy: Cu: 0.01~1.0%, W: 0.01 ~0.5%, V: 0.01 ~0.5%.

[0026] Further, in the hot stamped part having excellent low-temperature brittleness resistance according to the present disclosure, the precipitate phase of Ti includes TiN with a ratio of long axis to short axis of less than 6 (e.g., 2.8~5.8), and a density of TiN with the long axis greater than 2 μm of less than 50 pieces/mm^2 (e.g., 15~50 pieces/mm^2), based on the area ratio.

[0027] In the present disclosure, it is shown that the content of N elements in hot-stamped parts will affect the shape, size and quantity of TiN. The lath-like TiN, especially the string-like TiN inclusions with the long axis greater than 2 μm, will significantly deteriorate the low-temperature bending performance, so it is necessary to control its quantity to be less than 50 pieces/mm^2.

[0028] Further, in the hot stamped part having excellent low-temperature brittleness resistance according to the present disclosure, the particle diameters of TiC, Nb(C,N) and MoC in the precipitated phase are less than 80nm.

[0029] Further, in the hot stamped part having excellent low-temperature brittleness resistance according to the present disclosure, the matrix of the microstructure also has one or more of ferrite, pearlites, bainite, martensite, and residual austenite.

[0030] Further, in the hot stamped part having excellent low-temperature brittleness resistance according to the present disclosure, the tensile strength is greater than 1700MPa, the ratio of bending performance at a low temperature of -60°C to that at room temperature is greater than 0.85, and the product of strength and toughness at a low temperature of -60°C is not less than 8×10^4.

[0031] It should be noted that, in the present disclosure, the bending performance at a low temperature of - 60 °C and the bending performance at room temperature (20 °C) of the hot stamped parts described in the present disclosure are tested according to VDA238-100 test method. When the bending performance at a low temperature of -60 °C is tested, the sample is put into an alcohol cooling tank and cooled to the target temperature, and after holding for 20 min, the sample is quickly transferred to a VDA bending equipment, and the bending test is guaranteed to be completed within 1 min to obtain the corresponding bending performance at a low temperature of -60°C.

[0032] Further, in the hot stamped part having excellent low-temperature brittleness resistance according to the present disclosure, the hot stamped part has a diffusible hydrogen content of less than 0.15ppm, such as 0.04-0.15ppm.

[0033] Correspondingly, another object of the present disclosure is to provide a manufacturing method of the above-mentioned hot stamped parts with excellent low temperature brittleness resistance. The manufacturing method is simple for production and has reasonable process design. The obtained hot stamped parts have excellent low temperature brittle cracking resistance characteristics while having ultra-high strength. It has good application prospects, and can be widely used in automobile, shipbuilding, machinery and other industries.

[0034] In order to achieve the above purpose, the present disclosure proposes a manufacturing method for the above-mentioned hot stamped part with excellent low temperature brittleness resistance, which comprises the following steps:

(1) smelting and casting;
(2) hot rolling, coiling, pickling: wherein the slab temperature when it exists the heating furnace is controlled to be 1220~1280 °C, the final rolling temperature is 880~940 °C; the coiling temperature is controlled at 580~680°C, and after coiling, the steel plate is cooled to 300°C or lower (such as 200~300°C) at a rate of 0.3~1°C/s;
(3) cold rolling, annealing: wherein the total reduction rate of cold rolling is controlled to be 30~60%; the annealing temperature is controlled to be 680~750°C, and after annealing the steel plate is cooled to room temperature at an average rate of 1~15°C/s;
(4) hot stamping: wherein the reheating temperature of the steel plate is controlled to be 850~950 °C, and the reheating time is 2~10min, and then the steel plate is quickly transferred to a mold to complete hot stamping; then it is cooled to 100~200°C at an average rate of 10~100°C/s, followed by air cooling to room temperature;
(5) low temperature tempering: the steel plate is held in a baking oven at 150~250°C for 10~40min, and then taken out and air cooled to room temperature.

[0035] In the above-mentioned technical solution of the present disclosure, in the smelting process of step (1), it is necessary to smelt according to the chemical composition designed by the present disclosure, and after denitrification by converter, refining and deoxidation, it is further casted into a slab.

[0036] It should be noted that, in the present disclosure, a part of the nitrogen can be taken away in the process of oxygen blowing and decarburization in smelting, and the argon blowing time can be extended in the later stage, which can effectively ensure that the N content in steel is less than 0.004%, and preferably less than 0.003%. Correspondingly, the subsequent refining and deoxidation can promote the vacuum reaction between C and O, and the addition of Al for settling can reduce the O content in steel to be O≤0.004%, and preferably O≤0.0025%.

[0037] Correspondingly, in step (2) of the manufacturing method of the present disclosure, the temperature of the hot-rolled slab when it exits the furnace should be relatively high to ensure the full dissolution of microalloying elements, so as to facilitate the full precipitation in the subsequent hot-rolling and coiling process. Considering the precipitation quantity and avoiding the roughening of the precipitated phase, in the present disclosure, the slab temperature when it exits the heating furnace is specifically controlled at 1220~1280 °C, and the final rolling temperature is controlled at 880~940 °C. In addition, the inventors' research shows that in the coiling process, the range of coiling temperature T is controlled at 580~680°C, which is beneficial to the formation of the precipitated phase. In addition, the reduced cooling rate is used for cooling at a speed of 0.3~1°C/s after coiling, which can ensure that the coil can be kept in the range of from the coiling temperature T to 300°C for a long time, so as to further promote the precipitation of carbides, nitrides and carbonitrides of microalloying elements such as Nb and Ti.

[0038] In addition, in step (3) of the manufacturing method of the present disclosure, the total cold rolling reduction rate is required to be controlled at 30%~60%. If the total cold rolling reduction rate of the steel plate is less than 30%, the grain refinement effect of the steel plate is not obvious. If the total cold rolling reduction rate of the steel plate is greater than 60%, the steel plate will have large internal residual stress and many strip-like structures, which is not conducive to the subsequent production, and the strip structure will significantly deteriorate the toughness of the subsequent hot-stamped parts.

[0039] In addition, in step (3), annealing has the effect of improving the non-equilibrium microstructure of the rolled steel plate, which can reduce the segregation of elements such as C, Mn and the like in the strip structure. In the present disclosure, the annealing temperature is controlled at 680~750 °C, which is conducive to optimizing the microstructure uniformity of the steel plate components. After annealing, the steel plate is cooled to room temperature at an average cooling rate of 1~15°C/s, which can promote the precipitation of some microalloying elements on one hand, and on the other hand, it can avoid the formation of strip-like structure and the component segregation by rapid cooling.

[0040] In this technical solution designed by the present disclosure, the steel plate after annealing needs to be processed by hot stamping of step (4). In the present disclosure, the steel plate is reheated to 850~950 °C, and the heating time is controlled to be 2~10min, and the above range can not only ensure the full austenitization of the steel plate, but also avoid the coarsening of austenite grains.

[0041] Correspondingly, after heating, the steel plate needs to be quickly transferred to a mold to complete the hot stamping, and then cooled to 100~200°C at an average rate of 10~100°C/s. When the average cooling rate is lower than 10°C/s, the strength of the prepared hot stamped parts cannot be guaranteed. When the average cooling rate is higher than 100°C/s, there will be the following problems: first, rapid cooling leads to the formation of twin martensite; second, the martensitic dislocation density is high and the internal stress is large; third, it is not conducive to the formation of precipitated phases. The above three points will deteriorate the low-temperature bending performance of the prepared hot stamped parts. In addition, when the prepared hot stamped part is cooled to 200°C or lower, it is already below the end point of low-carbon martensite phase transformation, and if the final cooling temperature is 100°C or lower, it will be conducive to the formation of medium- and high-carbon twin martensite. Therefore, in the present disclosure, the hot stamped part is specifically controlled to be cooled to 100~200 °C.

[0042] In the present disclosure, the hot stamped part prepared after hot stamping treatment also needs to be tempered at a low temperature in a low-temperature baking oven at 150~250 °C, and the holding time for tempering needs to be controlled at 10~40min. The main purpose is to reduce the proportion of martensite having high dislocation density, so as to ensure that the proportion of lath tempered martensite of the final hot-stamped part is higher than 85%.

[0043] It should be noted that in the tempering process, the discharge of supersaturated carbon from martensite will promote the precipitation of carbides. The carbides include but not limited to the precipitation phase of microalloy carbides. In addition, the H element of the present disclosure is a harmful element, and the free diffusible hydrogen aggregation in the hot stamped part will deteriorate the toughness and cause the increased risk of cracking. Diffusible hydrogen in hot-stamped part is discharged by low-temperature tempering treatment, so that the diffusible hydrogen content of the final hot-stamped part is $\leq$ 0.15ppm, which helps to reduce the risk of brittle cracking, thereby further improving the low-temperature bending performance of the hot-stamped part.

[0044] Of course, when it is implemented, this low-temperature tempering process designed by the present disclosure is not only limited to being completed in the baking oven offline, but also can be completed online by mold induction heating or by heat treatment with online heating furnace. In addition, the present disclosure specifically controls the holding time for tempering in the range of 10~40min. That is because when the low-temperature tempering time is too short (less than 10min), the short-time tempering cannot achieve the above effect. When the low-temperature tempering time is too long (higher than 40min), the high-temperature and long-term tempering may not only reduce the strength but also enter the tempering brittleness range, which will lead to the weakening of the strength and low-temperature bending performance of the final hot-stamped part.

[0045] Further, the manufacturing method described in the present disclosure further comprises a step of plating or coating the steel plate after the annealing step of step (3).

[0046] In this technical solution designed by the present disclosure, the hot-stamped steel plate obtained after annealing may be an uncoated bare plate, and the steel plate can also be further plated or coated, so as to reduce oxide scale due to the heating of the steel plate and improve the corrosion resistance of the steel plate.

[0047] Compared with the prior art, the hot-stamped part with excellent low-temperature brittleness resistance and the manufacturing method thereof of the present disclosure have the advantages and beneficial effects described below:
The present disclosure has developed a hot-stamped part with excellent low temperature brittleness resistance by reasonably designed chemical composition combined with optimized process. The hot-stamped part has excellent resistance to low-temperature brittleness cracking while having ultra-high strength. It has a tensile strength of greater than 1700MPa, a ratio of bending performance at a low temperature of -60 °C to that at room temperature (20 °C) of greater than 0.85, and at the same time a product of strength and toughness at a low temperature of -60 °C (the tensile strength at room temperature $\times$bending angle at -60°C) of not less than 8×10^4. The use of this hot stamped parts can effectively solve the current problem of brittle cracking of ultra-high strength hot stamped parts existing in extremely cold areas, and it has a good application prospect and can be widely used in automobile, shipbuilding, machinery and other industries.

[0048] In order to achieve the above beneficial effects, the inventors have made the following improvements:

1. The inventors have improved the chemical composition and process design of the hot stamped parts, and have strictly controlled the N and O content in steel to inhibit the formation of large-scale nitride inclusions of TiN, AlN and BN, thereby reducing the non-metallic oxidative inclusions in the steel. The above-mentioned nitride and oxide hard phase inclusions are the fracture sources of brittle cracking, which can significantly deteriorate the low temperature bending performance. However, the precipitation of hard inclusions such as TiN is unavoidable. Therefore, the present disclosure needs to reduce the content per unit area and adopt technological measures to inhibit its growth, so that the ratio of the long axis to short axis of TiN is controlled to be less than 6, and the density of TiN with the long axis greater than 2 μm is controlled to be less than 50 pieces/mm^2 calculated by the area ratio.
2. The inventors can effectively promote the precipitation of Nb+Ti by controlling the hot rolling and annealing process, so that the precipitated amount of Nb and Ti elements accounts for more than 50% of the total mass fraction of these two elements, and the precipitated phase of Nb and Ti elements can inhibit the growth of austenite grains due to hot stamping and reheating, thereby refining the grains and effectively improving the low-temperature bending performance. In addition, the precipitated phase of Nb and Ti can also reduce the risk of hydrogen embrittlement. Therefore,

the present disclosure effectively controls the size of Nb and Ti precipitated phase while satisfying the precipitate quantity, so that the particle diameters of TiC, Nb(C,N) and MoC in the precipitated phase are less than 80nm, so as to form a diffusely distributed nanoscale precipitated phase, which further improves the low-temperature bending performance.

3. The present disclosure can inhibit the formation of twin martensite by promoting the precipitation of microalloy carbides, reducing the C content in matrix, and controlling the quenching cooling rate and end temperature of cooling. In the tempering process, the hot-stamped part is also tempered at a low temperature to ensure that the volume fraction of lath tempered martensite in the final microstructure is higher than 85%, so as to reduce the martensitic dislocation density and improve the low-temperature bending performance.

4. By adding trace amounts of Mo and Ni, the present disclosure can prevent the above-mentioned low-temperature tempering brittleness and inhibit low-temperature crack propagation, and effectively improve the low-temperature bending performance of the hot-stamped parts.

Description of the drawings

[0049] Fig. 1 is a microstructure photograph of the hot-stamped part of Example 6 under the scanning electron microscope.

Detailed Description

[0050] The hot stamped part having excellent low-temperature brittleness resistance and its manufacturing method described in the present disclosure 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 1-10

[0051] The hot stamped parts of Examples 1-10 were prepared according to the following steps:

(1) Smelting and casting were performed according to the chemical composition shown in Table 1: in actual operation, smelting was carried out according to the chemical composition designed in Table 1, and subjected to denitrification by converter, refining and deoxidation, and then casted into slabs.

(2) Hot rolling, coiling, pickling: the slab obtained by casting was hot rolled, and the temperature of the slab when it exited the heating furnace was controlled to be 1220~1280 °C, and the final rolling temperature was controlled to be 880~940 °C; it was coiled after hot rolling, wherein the coiling temperature was controlled to be 580~680°C, and it was cooled to 300°C or less at a rate of 0.3~1°C/s after coiling; after pickling, the hot-rolled slab was obtained.

(3) Cold rolling, annealing: the hot-rolled slab was cold rolled, wherein the total cold rolling reduction rate was controlled at 30~60%; the cold-rolled steel plate needed to be further annealed, wherein the annealing temperature was specifically controlled to be 680~750°C, and it was cooled to room temperature at an average rate of 1~15°C/s after annealing, wherein after the annealing, the steps of plating or coating the steel plate could also be carried out to obtain the steel plate having a plating layer or coating.

(4) Hot stamping: the reheating temperature of the steel plate was controlled to be 850~950 °C, and the reheating time was controlled to be 2~10min, and then the steel plate was quickly transferred to a mold to complete the hot stamping; then the steel plate was cooled to 100~200°C at an average rate of 10~100°C/s, followed by air cooling to room temperature to obtain the corresponding hot stamped part.

(5) Low temperature tempering: the prepared hot stamped part was delivered to a baking oven at 150~250 °C and held for 10~40min, and then taken out and air cooled to room temperature to obtain the final hot stamped part with a final thickness of 1.4mm.

[0052] In this technical solution designed by the present disclosure, the chemical composition design and related process of the prepared hot stamped parts of Examples 1-10 of the present disclosure all meet the requirements of the design specification of the present disclosure.

[0053] Table 1 lists the mass percentage of each chemical element of the hot-stamped parts of Examples 1-10.

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

	Ex. 1	Ex. 2	Ex. 3	Ex. 4	Ex. 5	Ex. 6	Ex. 7	Ex. 8	Ex. 9	Ex. 10
C	0.26	0.28	0.3	0.31	0.32	0.33	0.35	0.36	0.38	0.4

(continued)

	Ex. 1	Ex. 2	Ex. 3	Ex. 4	Ex. 5	Ex. 6	Ex. 7	Ex. 8	Ex. 9	Ex. 10
Si	0.3	1.5	0.5	0.3	0.4	0.2	0.8	0.1	0.4	0.3
Mn	2.5	-	1	0.5	0.2	1.1	0.8	1	0.5	0.4
Cr	0.5	1.2	0.5	2	0.8	0.3	0.4	0.2	-	0.4
P	0.008	0.03	0.007	0.005	0.008	0.008	0.007	0.01	0.008	0.005
S	0.002	0.004	0.01	1E-3	0.002	0.002	0.004	0.005	0.003	0.001
Al	0.04	0.06	0.2	0.01	0.05	0.06	0.04	0.05	0.5	0.04
Nb	0.04	0.01	0.06	0.04	0.03	0.05	0.02	0.1	0.1	0.08
Ti	0.08	0.03	0.02	0.11	0.06	0.05	0.09	0.06	0.15	0.05
Mo	0.1	0.2	-	0.2	-	0.2	0.2	0.3	0.2	0.6
Ni	-	0.8	0.4	0.4	0.3	0.2	0.1	0.3	0.3	0.2
B	0.0035	0.005	0.0026	0.0027	0.0035	0.002	0.0024	0.0028	0.0025	0.001
N	0.004	0.0032	0.0028	0.0025	0.0027	0.0026	0.0025	0.0028	0.0027	0.0022
O	0.004	0.0036	0.0023	0.002	0.0025	0.0022	0.002	0.0024	0.0023	0.0024
Cu	-	1	-	-	-	-	-	-	0.02	0.3
W	-	0.5	-	0.1	-	-	-	-	-	0.05
V	-	-	-	0.05	0.2	-	-	-	0.5	-
Mn+Cr	3	1.2	1.5	2.5	1	1.4	1.2	1.2	0.5	0.8
Nb+Ti	0.12	0.04	0.08	0.15	0.09	0.1	0.11	0.16	0.25	0.13
Mo+Ni	0.1	1	0.4	0.6	0.3	0.4	0.3	0.6	0.5	0.8

[0054] Correspondingly, Table 2-1 and Table 2-2 list the specific process parameters in the above process steps (1)-(5) of the hot-stamped parts of Examples 1-10.

Table 2-1

No.	Step (2)					Step (3)		
	The slab temperature when the slab exits the heating furnace (°C)	Final rolling temperature (°C)	Coiling temperature (°C)	Cooling rate after coiling (°C/s)	Final cooling temperature after coiling (°C)	Total reduction rate of cold rolling (%)	Annealing temperature (°C)	Average cooling rate to room temperature after annealing (°C/s)
Ex. 1	1260	890	590	0.8	280	37	730	9
Ex. 2	1220	880	600	1.0	300	48	720	4
Ex. 3	1240	900	580	0.5	240	52	750	8
Ex. 4	1230	880	620	0.6	200	60	740	6
Ex. 5	1270	900	640	0.9	260	43	690	10
Ex. 6	1280	940	600	0.7	280	58	730	7
Ex. 7	1260	920	680	0.8	270	46	700	8
Ex. 8	1250	900	660	0.5	230	55	690	14
Ex. 9	1220	900	620	0.5	290	48	680	8
Ex. 10	1270	940	630	0.4	220	30	690	3

Table 2-2

No.	Step (4)				Step (5)	
	Steel plate reheating temperature (°C)	Reheating time (min)	Average cooling rate after hot stamping (°C/s)	End temperature of cooling for hot stamping (°C)	Tempering temperature (°C)	Holding time for tempering (min)
Ex. 1	920	5	100	112	150	30
Ex. 2	910	6	58	125	170	20
Ex. 3	940	4	45	102	190	10
Ex. 4	950	2	54	125	160	30
Ex. 5	850	10	25	105	180	20
Ex. 6	940	4	43	128	170	25
Ex. 7	930	6	32	136	210	15
Ex. 8	880	8	35	168	200	20
Ex. 9	890	6	20	152	240	40
Ex. 10	930	5	10	194	250	30

[0055] In the present disclosure, after completing the above manufacturing process, the obtained final hot-stamped parts of Examples 1-10 were sampled separately, and the microstructure of the hot-stamped part samples of Examples 1-10 was observed, and it was found that the matrix of the microstructure of the hot-stamped part samples of Examples 1-10 had a lath tempered martensite with a volume fraction of higher than 85%; at the same time, the microstructure of the hot stamped part of each Example also had one or more of ferrite, pearlite, bainite, martensite, and residual austenite. The specific observation and analysis results are listed in Table 3 below.

[0056] Correspondingly, in observation of the microstructure of the hot-stamped part samples in Examples 1-10, it was not difficult to find that the microstructure of the hot-stamped parts also had precipitated phases, in which the precipitated amount of Nb and **Ti** accounts for 50% or more of the total mass fraction of these two elements, and the precipitated phases of Nb and **Ti** were diffusively distributed in the matrix in a granular form.

[0057] Further analysis of these precipitated phases showed that in Examples 1-10, the particle diameters of TiC, Nb(C,N) and MoC in the precipitated phases were less than 80 nm. In addition, the precipitated phases of **Ti** could include TiN. The ratio of the long axis to the short axis of TiN was less than 6, and the density of TiN with a long axis of greater than 2μm was less than 50 pieces/mm^2 based on the area ratio.

[0058] Table 3 lists the observation and analysis results of the microstructure of the hot-stamped parts of Examples 1-10.

Table 3

No.	Volume fraction of the lath tempered martensite in the matrix of the microstructure (%)	The precipitated amount of Nb and Ti accounting for the total mass fraction of these two elements (%)	The maximum ratio of the long axis to the short axis of TiN precipitated phase	The density of TiN with a long axis of greater than 2μm (pieces/mm^2)
Ex. 1	88	58	4.5	47
Ex. 2	90	72	3.8	18
Ex. 3	89	63	4.2	41
Ex. 4	92	65	5.3	25
Ex. 5	94	75	2.8	26
Ex. 6	89	70	5.2	30
Ex. 7	95	55	3.5	15
Ex. 8	98	63	5.8	36
Ex. 9	95	74	3.2	30

(continued)

No.	Volume fraction of the lath tempered martensite in the matrix of the microstructure (%)	The precipitated amount of Nb and Ti accounting for the total mass fraction of these two elements (%)	The maximum ratio of the long axis to the short axis of TiN precipitated phase	The density of TiN with a long axis of greater than 2μm (pieces/mm^2)
Ex. 10	90	68	5.1	35

[0059] Correspondingly, after completing the above observation and analysis of the microstructure, in order to further illustrate that the hot stamped parts prepared by the present disclosure had very excellent mechanical properties, the inventors sampled the obtained hot-stamped parts of Examples 1-10 again, and tested the strength and low-temperature brittleness resistance of the hot-stamped parts of these examples, and the relevant test results are listed in Table 4 below.

[0060] In the present disclosure, the testing methods adopted in Examples 1-10 were as follows:

Tensile test: according to the requirements of GB/T 228 Metallic materials-Tensile testing-Method of test at room temperature, the tensile strength at room temperature was tested to measure the tensile strength at room temperature of the hot stamped parts of Examples 1-10.

[0061] Bending performance test: The bending performances of the hot stamped parts of Examples 1-10 at a low temperature of -60 °C and at room temperature (20 °C) were tested according to VDA238-100 detection method. When the bending performance at -60 °C was detected by the low temperature test, the sample was put into an alcohol cooling tank and cooled to the target temperature. After holding for 20min, the sample was quickly transferred to VDA bending equipment, and the bending test was guaranteed to be completed within 1 min to obtain the corresponding bending performance at a low temperature of -60 °C. For the measured bending performances of the hot-stamped parts of Examples 1-10 at a low temperature of -60 °C and at room temperature (20 °C), the ratio of bending performance (i.e., the ratio of bending angle at -60 °C to bending angle at 20 °C) can be further obtained.

[0062] Correspondingly, based on the above tests, the product of strength and toughness at a low temperature of -60 °C (tensile strength at room temperature ×bending angle at -60 °C) of the hot-stamped parts of Examples 1-10 can be further obtained.

[0063] In addition, for the prepared hot-stamped parts of Examples 1-10, the diffusible hydrogen content of the parts was measured by using Bruker G4 diffusible hydrogen analyzer, and the diffusible hydrogen content of the hot-stamped parts of each Example was further measured.

[0064] Table 4 lists the test results of the mechanical performance of the hot-stamped parts of Examples 1-10.

Table 4

No.	Tensile strength (MPa)	Bending angle ratio	Product of strength and toughness at a low temperature of -60°C (MPa×°)	The diffusible hydrogen content (ppm)
Ex. 1	1729	0.92	10.7×10^4	0.08
Ex. 2	1739	0.93	11.3×10^4	0.15
Ex. 3	1812	0.88	10.5×10^4	0.12
Ex. 4	1950	0.87	9.6×10^4	0.04
Ex. 5	1848	0.90	10.2×10^4	0.07
Ex. 6	1925	0.89	10.0×10^4	0.08
Ex. 7	2027	0.86	9.1×10^4	0.04
Ex. 8	2043	0.88	9.2×10^4	0.06
Ex. 9	2074	0.87	8.7×10^4	0.05
Ex. 10	2191	0.86	8.8×10^4	0.06

[0065] As can be seen from Table 4, the hot-stamped parts of Examples 1-10 prepared by adopting this technical solution designed by the present disclosure have ultra-high strength and excellent low temperature brittleness resistance. In particular, the tensile strength is in the range of 1729-2191MPa, the ratio of bending performance at a low temperature of -60 °C to that at room temperature (20 °C) is in the range of 0.86-0.93, and the product of strength and toughness at a low temperature of -60 °C is in the range of 8.8×10^4-11.3×10^4.

[0066] Moreover, the final diffusible hydrogen content of the final hot-stamped parts prepared in Examples 1-10 by adopting the technical solution of the present disclosure is ≤ 0.15ppm, particularly in the range of 0.04-0.15ppm.

[0067] Based on the above, the hot stamped parts produced according to the present disclosure have excellent low temperature brittleness resistance while having ultra-high strength. Using this hot stamped part can effectively solve the current problem of brittle cracking of the ultra-high strength hot stamped part existing in extremely cold areas. It has a good application prospect and can be widely used in automobile, shipbuilding, machinery and other industries.

[0068] Fig. 1 is a microstructure photograph of the hot-stamped part of Example 6 under the scanning electron microscope.

[0069] As shown in Fig.1, Fig.1 shows the microstructure of the hot-stamped part of Example 6. It is not difficult to see from Fig.1 that the fraction of lath tempered martensite is higher than 85%.

[0070] 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.

[0071] 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 hot stamped part having excellent low-temperature brittleness resistance, which comprises Fe and unavoidable impurities, wherein it further comprises the following chemical elements in mass percentage as follows:

C: 0.26~0.40%, Si: 0.1~1.5%, Mn+Cr: 0.5~3.0%, Al: 0.01~0.50%, Nb+Ti: 0.04~0.25%, Mo+Ni: 0.1~1.0%, B: 0.001~0.005%;
wherein the matrix of the microstructure of the hot-stamped part has lath tempered martensite with a volume fraction of higher than 85%;
wherein the microstructure of the hot-stamped part also has a precipitated phase, wherein the precipitated amount of Nb and Ti elements accounts for more than 50% of the total mass fraction of these two elements, and the precipitated phase of Nb and Ti is diffusely distributed in the matrix in a granular form.

2. The hot stamped part having excellent low-temperature brittleness resistance according to claim 1, wherein the mass percentage of each chemical element is as follows:
C: 0.26~0.40%, Si: 0.1~1.5%, Mn+Cr: 0.5~3.0%, Al: 0.01~0.50%, Nb+Ti: 0.04~0.25%, Mo+Ni: 0.1~1.0%, B: 0.001~0.005%; with a balance of Fe and other unavoidable impurities.

3. The hot stamped part having excellent low-temperature brittleness resistance according to claim 1, wherein the mass percentage of each chemical element is as follows: C: 0.26~0.40%; Si: 0.1~1.5%; Mn: ≤2.5%, Cr≤2%, and Mn+Cr: 0.5~3.0%; Al: 0.01~0.50%; Nb: 0.01~0.1%, Ti: 0.02~0.15%, and Nb+Ti: 0.04~0.25%; Mo: ≤0.6%, Ni: ≤0.8%, and Mo+Ni: 0.1~1.0%; B: 0.001~0.005%; with a balance of Fe and other unavoidable impurities.

4. The hot stamped part having excellent low-temperature brittleness resistance according to any one of claims 1-3, wherein among the unavoidable impurities, P is ≤0.03%, S is ≤0.01%, N is ≤0.004%, O is ≤0.004%.

5. The hot stamped part having excellent low-temperature brittleness resistance according to claim 4, wherein N is ≤0.003% and/or O is ≤0.0025%.

6. The hot stamped part having excellent low-temperature brittleness resistance according to any one of claims 1-3, wherein it further comprises at least one of the following chemical elements:
Cu: 0.01~1.0%, W: 0.01~0.5%, V: 0.01~0.5%.

7. The hot stamped part having excellent low-temperature brittleness resistance according to any one of claims 1-3, wherein the precipitated phase of Ti includes TiN with a ratio of long axis to short axis of less than 6, and a density of TiN with the long axis greater than 2 μm of less than 50 pieces/mm^2 based on the area ratio.

8. The hot stamped part having excellent low-temperature brittleness resistance according to any one of claims 1-3, wherein the particle diameters of TiC, Nb(C,N) and MoC in the precipitated phase are less than 80nm.

9. The hot stamped part having excellent low-temperature brittleness resistance according to any one of claims 1-3, wherein the matrix of the microstructure also has one or more of ferrite, pearlites, bainite, and residual austenite.

10. The hot stamped part having excellent low-temperature brittleness resistance according to any one of claims 1-3, wherein the tensile strength is greater than 1700MPa, the ratio of bending performance at a low temperature of -60°C to that at room temperature is greater than 0.85, and the product of strength and toughness at a low temperature of -60°C is not less than 8×10^4.

11. The hot stamped part having excellent low-temperature brittleness resistance according to claim 10, wherein the tensile strength is 1700~2200MPa, the ratio of bend angle at -60°C to that at room temperature is 0.86~0.93, and the product of strength and toughness at a low temperature of - 60°C is 8.8×10^4-11.3×10^4.

12. The hot stamped part having excellent low-temperature brittleness resistance according to any one of claims 1-3, wherein the hot stamped part has a diffusible hydrogen content of less than 0.15ppm.

13. The manufacturing method of the hot stamped part having excellent low-temperature brittleness resistance according to any one of claims 1-13, which comprises the steps of:

(1) smelting and casting;
(2) hot rolling, coiling, pickling: wherein the slab temperature when the slab exits the heating furnace is controlled to be 1220~1280°C, and the final rolling temperature is controlled to be 880~940°C; the coiling temperature is controlled to be 580~680°C, and the slab is cooled to 300°C or less at a rate of 0.3~1°C/s after coiling;
(3) cold rolling and annealing: wherein the total reduction rate of cold rolling is controlled to be 30~60%; the annealing temperature is controlled to be 680~750°C, and the steel is cooled to room temperature at an average rate of 1~15°C/s after annealing;
(4) hot stamping forming: wherein the reheating temperature of the steel plate is controlled to be 850~950°C, the reheating time is controlled to be 2~10min, and then the steel plate is quickly transferred to a mold to complete the hot stamping; then it is cooled to 100~200°C at an average rate of 10~100°C/s, followed by air cooling to room temperature;
(5) low temperature tempering: wherein the steel plate is held in a baking oven at 150~250°C for 10~40min, and then taken out and cooled to room temperature by air cooling.

14. The manufacturing method according to claim 13, wherein it further comprises a step of plating or coating the steel plate after the annealing step in step (3).

15. The manufacturing method according to claim 13, wherein the steel plate is cooled to 200~300°C at a rate of 0.3~1°C/s after coiling.

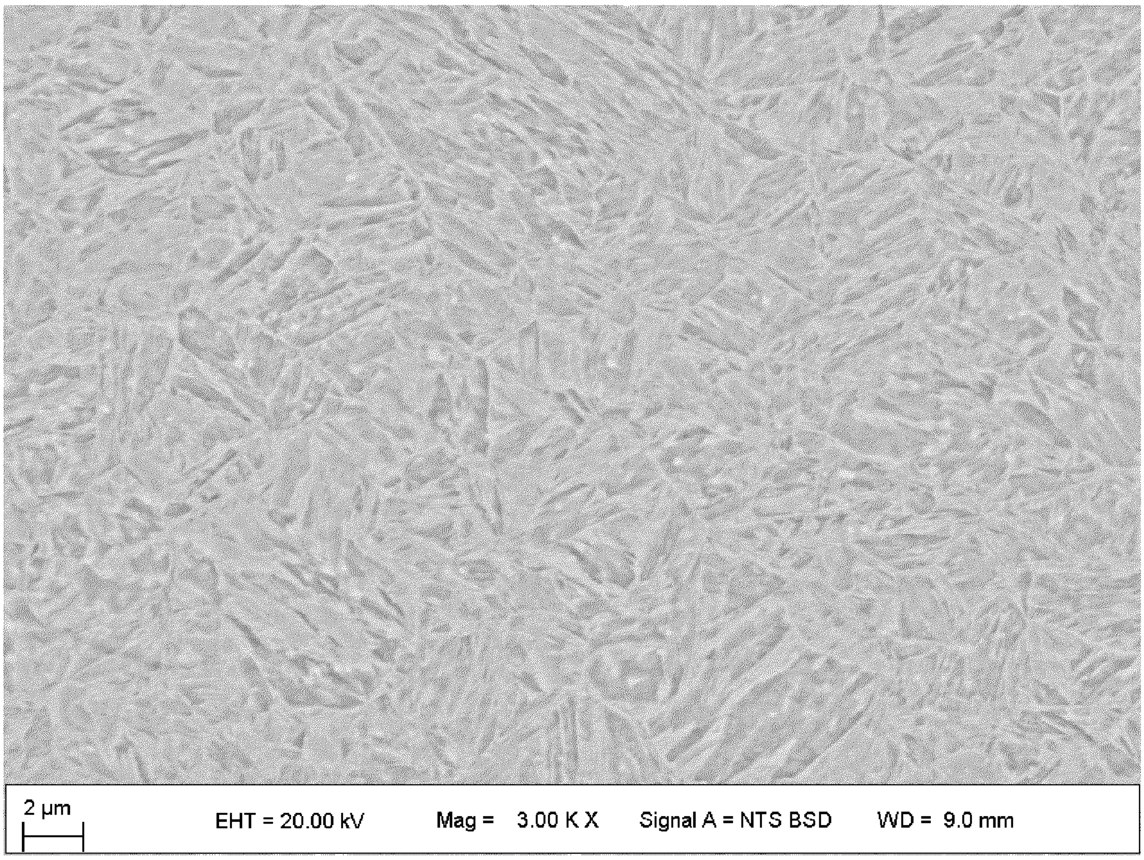

Fig. 1

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2023/111404

A. CLASSIFICATION OF SUBJECT MATTER

C22C38/00(2006.01)i; C22C38/02(2006.01)i; C22C38/04(2006.01)i; C22C38/06(2006.01)i; C22C38/08(2006.01)i; C22C38/12(2006.01)i; C22C38/14(2006.01)i; C22C38/18(2006.01)i; C22C38/40(2006.01)i; C22C38/58(2006.01)i; C21D8/02(2006.01)i; C21D8/00(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)

CNKI, CNABS, CNTXT, DWPI, SIPOABS, ISI WEB OF SCIENCE: 热冲压, 回火, 马氏体, 析出, 铁, 碳, 炭, 硅, 锰, 铬, 铝, 铌, 钛, 镍, 钼, 硼, hot, stamp+, temper+, martensite, precipit+, iron, fe, carbon, c, silicon, si, manganese, mn, chromium, cr, aluminium, al, niobium, nb, titanium, ti, nickel, ni, molybdenum, mo, boron, b

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	CN 105506494 A (BAOSHAN IRON & STEEL CO., LTD.) 20 April 2016 (2016-04-20) description, paragraphs [0006]-[0044]	1-15
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A	CN 112840046 A (NIPPON STEEL CORP.) 25 May 2021 (2021-05-25) entire document	1-15
A	CN 114107795 A (BAOSHAN IRON & STEEL CO., LTD.) 01 March 2022 (2022-03-01) entire document	1-15
A	JP 2009030092 A (JFE STEEL K. K.) 12 February 2009 (2009-02-12) entire document	1-15
A	JP 2010150612 A (NIPPON STEEL CORP.) 08 July 2010 (2010-07-08) entire document	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 **12 October 2023**	Date of mailing of the international search report **26 October 2023**
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 Telephone No.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2023/111404

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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Information on patent family members

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