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(54) **COLD-ROLLED IF STEEL, HOT-DIP GALVANIZED STEEL SHEET AND MANUFACTURING METHOD THEREFOR**

(57) Disclosed in the present invention are a cold-rolled IF steel and a hot-dip galvanized steel sheet, further comprising following chemical elements in mass percentage: 0.004-0.007% of C, 0.50-0.80% of Mn, 0.025-0.040% of P, 0.04-0.08% of Nb, 0.05-0.2% of Cr and 0.01-0.1% of Al, and further satisfying $1.2 \leq (\text{Nb} \times 12)/(\text{C} \times 93) \leq 2.0$, wherein each chemical element in the formula is substituted by the numerical value before the percent sign of the mass percentage content there-

of. Further disclosed in the present invention is a manufacturing method for the steel sheet, the manufacturing method comprising the following steps: slab preparation; hot rolling; cold rolling; and annealing. The cold-rolled IF steel and the hot-dip galvanized steel sheet of the present invention have good stamping performance stability, excellent surface morphology and better resistance to deformation.

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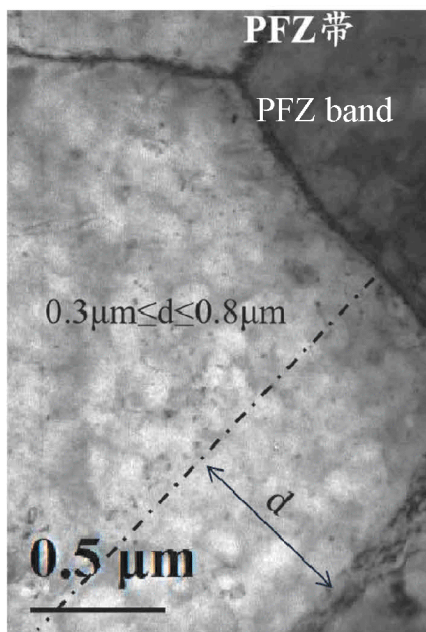


Figure 1

Description

Technical Field

- 5 [0001] The present disclosure relates to a steel plate and a manufacturing method therefor, in particular to a high-strength steel and a manufacturing method therefor.

Background Art

- 10 [0002] At present, the coating process of automotive outer panels can effectively reduce energy consumption and VOC emissions due to the reduction of one coating layer and one baking step. However, due to the reduction of coating and baking passes, the new coating process has a decreased ability to cover the surface morphology of the substrate, and has higher requirements on surface morphology of the material, especially surface waviness. Furthermore, automobile light-weighting is an inevitable path for the automotive industry. By improving the strength of the steel plate, the thickness of the automotive panels can be reduced, thereby effectively reducing vehicle weight, fuel consumption and emissions.

- 15 [0003] IF steel is a common raw material for automotive panels. Ti/Nb elements are adopted to fix C and N atoms in the crystal gaps, and Mn, Si, and P elements are added to achieve solid solution strengthening in the IF steel. The matrix of the steel is free of interstitial atoms in solid solution and has a low yield strength, while the addition of solid solution elements effectively improves the tensile strength of the material. Therefore, IF steel has the characteristics of low yield ratio, good deep drawing performance and free of aging phenomenon, and is widely used in the production of automotive outer panels.

- 20 [0004] However, in the actual application process, a stamped automotive outer panel made from thinned IF steel is prone to deformation during transportation. When a high-strength steel is used for manufacturing automotive stamping parts, it is found that the yield ratio is often greater than 0.65, the uniform plastic deformation range is significantly shortened, the material is difficult to deform, and it is detrimental to the stamping formability of automotive panels. Therefore, it is necessary to improve the deformation resistance after stamping while maintaining the excellent stamping formability of IF steel.

- 25 [0005] Therefore, in order to meet user requirements for stamping, transportation, light-weighting and coating, in addition to ensuring that the material's mechanical properties of the steel plate meet the standards, its yield ratio, waviness after stamping, and deformation resistance after stamping should also be controlled.

- 30 [0006] For example: A Chinese Patent document with Publication No. CN109023050B, published on December 18, 2018, and titled "A 390MPa grade high-strength IF steel and a manufacturing method therefor," discloses a high-strength IF steel and a production method therefor. It consists of the following composition in mass percentage: C: 0.0-0.004%, Si: 0.0-0.030%, Mn: 0.4%-0.6%, P: 0.06%-0.085%, S: 0.0-0.010%, Al: 0.03%-0.1%, Nb: 0.01%-0.1%, B: 0.00050%-0.0012%, with a balance of iron and unavoidable impurities. In this invention, the diameter of precipitation phases is greater than 50 nm, and the main precipitation phases are FeNbP and FeTiP. It changes the texture of material by changing the content of precipitation phases, increases the plastic strain ratio, and improves the stamping performance of the material, but fails to consider the coating quality of the material.

- 35 [0007] Another example: A Chinese Patent document with Publication No. CN114196882B, published on October 28, 2022, titled "A high surface quality high-strength steel strip coil for automotive panels and a manufacturing method therefor," discloses a method for manufacturing automotive outer panels. It consists of the following composition in mass percentage: $0.002\% \leq C \leq 0.01\%$, $Si \leq 0.01\%$, $Mn \leq 0.8\%$, $P \leq 0.05\%$, $S \leq 0.01\%$, $0.01\% \leq Al \leq 0.06\%$, $N \leq 0.004\%$, $0.02\% \leq Nb \leq 0.09\%$, $B \leq 0.0003\%$, with a balance of Fe and unavoidable impurities. In this invention, the composition and process of Nb-IF steel are mainly controlled to prepare a material with relatively high strength and excellent formability, but the impact of surface morphology and deformation resistance of the material on the coating and transportation of automotive outer panels is not considered.

Summary

- 40 [0008] One of the objects of the present disclosure is to provide a cold-rolled IF steel. The cold-rolled IF steel has good stability of stamping performance, excellent surface morphology and better resistance to deformation, and may ensure that the deformation of stamping parts during transportation is avoided and the surface of the material after electrophoretic coating has low waviness, and there is no obvious orange peel phenomenon during use by the user.
- 45 The cold-rolled IF steel may effectively improve the deformation resistance and production stability of stamping parts, improve the coating surface quality of automotive outer panels, and it is suitable for producing automotive covering parts, and has broad application prospects and value.

- [0009] To achieve the above object, the present disclosure provides a cold-rolled IF steel, comprising Fe and

unavoidable impurities, and further comprising the following chemical elements in mass percentages:

C: 0.0040-0.0070%, Mn: 0.50-0.80%, P: 0.025-0.040%, Nb: 0.040-0.080%, Cr: 0.05-0.20%, and Al: 0.010-0.100%;

It also satisfies: $1.20 \leq (\text{Nb} \times 12) / (\text{C} \times 93) \leq 2.00$, wherein each chemical element in the formula is substituted with the numerical value before the percent sign of its mass percentage content.

[0010] Furthermore, the cold-rolled IF steel of the present disclosure consists of the following chemical elements in mass percentages:

C: 0.004-0.0070%, Mn: 0.50-0.80%, P: 0.025-0.040%, Nb: 0.040-0.080%, Cr: 0.05-0.20%, Al: 0.010-0.100%; with a balance of Fe and unavoidable impurities.

[0011] The design principles of the various chemical elements in the cold-rolled IF steel of the present disclosure will be described in detail as follows:

C: In the cold-rolled IF steel of the present disclosure, C element in the steel may affect the content of NbC precipitation phase, and NbC particles may play a role in fine grain strengthening and second-phase strengthening. When the content of C is greater than 0.007%, C atoms tends to exist in the form of solid solution, leading to the formation of {111} texture which is not conducive to the stamping performance of the material, especially the r value of the material. When the content of C is less than 0.004%, the quantity of NbC particles precipitated is relatively small, the grain size of the material may be decreased, the effect of the second-phase strengthening may be weakened, and the strength of the material will be reduced. Therefore, the mass percentage of C is controlled at 0.004-0.0070% in the cold-rolled IF steel of the present disclosure.

Mn: In the cold-rolled IF steel of the present disclosure, Mn is a solid solution element commonly used in steel, and may effectively improve the strength of the material and reduce the yield ratio. When the content of Mn is greater than 0.50%, it may combine with S to form MnS precipitates, thereby avoiding hot cracking of the steel slab and improving the bonding performance of the coating layer. When the content of Mn is increased, although the yield strength of the material is increased significantly, considering the difference in the effect of Mn and P on the Fe-based lattice distortion state, its content should not be too high. Therefore, the mass percentage of Mn is controlled at 0.50-0.80% in the cold-rolled IF steel of the present disclosure.

P: In the cold-rolled IF steel of the present disclosure, P is a solid solution strengthening element and one of the elements with the strongest effect on strengthening ferrite, and may effectively improve the strength of the material. When the content of P is too low, the strengthening effect of P is not significant. When the content of P is too high, it is prone to segregation, the brittleness of the steel is increased, the welding performance is affected, and it has adverse effect on the alloying treatment of the zinc layer. Therefore, the mass percentage of P is controlled at 0.025-0.040% in the cold-rolled IF steel of the present disclosure.

Nb: In the cold-rolled IF steel of the present disclosure, Nb mainly forms carbide precipitates with C, with the surplus existing as a solid solution element. The fine and dispersed carbides precipitated may effectively refine grains, and may be formed as a precipitate-free zone (PFZ) during the process of nucleation and growth, and may effectively improve the strength of the material and reduce the yield ratio. When the content of Nb is too low, free C atoms fail to be fixed completely, and the yield strength is reduced. Therefore, the mass percentage of Nb is controlled at 0.040-0.080% in the cold-rolled IF steel of the present disclosure.

Cr: In the cold-rolled IF steel of the present disclosure, Cr acts as a solid solution strengthening element. Its characteristics are: the carbide-forming ability of Cr is lower than that of Nb; Cr has a strong affinity for carbon, and may effectively reduce the diffusion coefficient of C in the matrix of iron; the atomic radius of Cr is larger than that of Mn, and the degree of lattice distortion caused is higher; the solid solubility of Cr in the matrix of iron is greater than that of Nb, and the degree of lattice distortion caused is smaller than that of Nb. When the mass percentage of Cr is $\leq 0.05\%$, it is insufficient to significantly increase the lattice resistance to dislocation slip during deformation, refine the NbC precipitation phase and improve the work hardening value. When the mass percentage of Cr is $\geq 0.2\%$, due to its opposite effect of the lattice distortion caused by P on the matrix of Fe, the solid solution strengthening effects of P and Cr are reduced. Adding Cr with a mass percentage of 0.05-0.20% may reduce the diffusion rate of carbon atoms, promote the precipitation of the NbC phase, slow down the growth of the NbC phase, and refine grains, thereby improving the work hardening value and deformation resistance of the material. As such, the mass percentage of Cr is controlled at 0.05-0.20% in the cold-rolled IF steel of the present disclosure.

Al: In the cold-rolled IF steel of the present disclosure, Al acts as an impurity element of a deoxidizer, and may fix free N atoms. When the content of Al is relatively low, the effects of nitrogen fixation and deoxidation fail to be guaranteed; when the content of Al is too high, it tends to dissolve in the matrix, the plasticity of material is reduced and more inclusions are generated. Therefore, the mass percentage of Al is controlled at 0.010-0.100%

in the cold-rolled IF steel of the present disclosure.

[0012] It should be noted that, while the mass percentage of a single element is controlled in the present disclosure, the range of $(Nb \times 12) / (C \times 93)$ is also controlled at 1.20 -2.00. This is a key factor in ensuring that the steel coil of the present disclosure has a low yield ratio and high deformation resistance, and is also an important factor in ensuring that the steel coil has low waviness. When the mass percentage of Nb and C is less than the lower limit of the range of $(Nb \times 12) / (C \times 93)$, the effect of grain refinement strengthening and second-phase strengthening may be weakened. When the mass percentage of Nb and C is higher than the upper limit of the range of $(Nb \times 12) / (C \times 93)$, the annealing recrystallization temperature may rise, the yield strength of material is improved, and it is detrimental to the formation of favorable textures and cost control.

[0013] Furthermore, in the cold-rolled IF steel according to the present disclosure, among the unavoidable impurities: $S \leq 0.010\%$, $B \leq 0.0006\%$, $N \leq 0.004\%$, and $Si \leq 0.0010\%$.

[0014] In the cold-rolled IF steel of the present disclosure, S, B, N, and Si are all unavoidable impurities. To ensure that the cold-rolled IF steel of the present disclosure has good performance, it is expected that their contents are as low as possible if conditions permit. Among them:

S: In the cold-rolled IF steel of the present disclosure, S is controlled as a harmful impurity element in steel. It forms as a low-melting-point precipitation phase in the steel, causes material to be hot brittle and is not conducive to the welding performance of the material. As such, the mass percentage of S is controlled at 0.010% or less in the cold-rolled IF steel of the present disclosure.

B: In the cold-rolled IF steel of the present disclosure, B may reduce the plasticity of the material. If its content is too high, it tends to hinder recrystallization and the formation of the PFZ band is inhibited. Therefore, the mass percentage of B is controlled at 0.0006% or less in the cold-rolled IF steel of the present disclosure.

N: In the cold-rolled IF steel of the present disclosure, N atom in solid solution may cause a decrease in the r-value of material and induce aging phenomena, and it is not conducive to the aging resistance and stamping performance of the material. Therefore, the mass percentage of N is controlled at 0.004% or less in the cold-rolled IF steel of the present disclosure.

Si: In the cold-rolled IF steel of the present disclosure, Si is an impurity element in the steelmaking process, and is prone to segregate at the grain boundaries, and form a hot brittle phase. When the content of Si is high, it may have an adverse effect on the anisotropy and plasticity of the material. If technical conditions permit, its content in the steel should be reduced. Therefore, the mass percentage of Si is controlled at 0.0010% or less in the cold-rolled IF steel of the present disclosure.

[0015] Furthermore, the microstructure of the cold-rolled IF steel of the present disclosure has a grain size of grade 10 or more.

[0016] In the present disclosure, by controlling the grain size of grade 10 or more, it may ensure the material has sufficient strength, the waviness of the stamping part after forming is reduced, and the material has high coating quality.

[0017] Furthermore, the cold-rolled IF steel of the present disclosure has an atom-free precipitation zone, and the width of the atom-free precipitation zone is $0.30\mu\text{m} - 0.80\mu\text{m}$.

[0018] In the present disclosure, the PFZ band refers to an atom-free precipitation zone (PFZ) formed around the grain boundaries of the material. The width of the PFZ band has a significant impact on the yield ratio of the material. When the width of the PFZ band is $\leq 0.30\mu\text{m}$, the accumulated dislocations are not conducive to the formation of larger dislocation pile-up groups, and higher local stresses are formed, and they also are not conducive to the occurrence of cross-slip, and fail to effectively reduce the yield strength of the material and the difficulty of stamping. When the width of the PFZ band is $\geq 0.80\mu\text{m}$, a significant increase in holding time of annealing is required, and it is not conducive to cost control. Therefore, the average width of the atom-free precipitation zone is controlled at $0.30\mu\text{m} - 0.80\mu\text{m}$ in the cold-rolled IF steel of the present disclosure.

[0019] Furthermore, in the cold-rolled IF steel according to the present disclosure, the microstructure has NbC precipitated in the grains and at the grain boundaries, wherein the size of NbC precipitated in the grains is $\leq 30.0\text{nm}$, and the number is 600-1000 per square micrometer. In some embodiments, the size of NbC precipitated in the grains is 19.0-30.0nm, such as 19.0-25.0nm.

[0020] In the present disclosure, the main precipitation phases in the grains and at the grain boundaries both are NbC. When the density of the precipitation phase of the cold-rolled IF steel is relatively low, it is insufficient to effectively refine grains, hinder dislocation slip, and make the material has relatively high tensile strength and yield strength. When the density of the precipitation phase of the cold-rolled IF steel is relatively high, the content of Nb is required to be increased inevitably, the economic cost is increased inevitably, the yield strength is increased, and it is not conducive to stamping. At the same time, when the diameter of the precipitation phase at the grain boundaries of

the cold-rolled IF steel is $\geq 60\text{nm}$, it is conducive to the formation of PFZ band; when the diameter of the precipitation phase is less than 60 nm , it is not conducive to grain growth and the formation of the PFZ band. In some embodiments, the diameter of the precipitation phase at the grain boundaries is $60\text{-}85\text{nm}$. When the size of the precipitation phase in the grains is $\geq 30\text{ nm}$, the NbC phase formed in the material during the heat treatment process undergoes excessive Ostwald ripening, the density of the precipitation phase is reduced, so that the obstruction of dislocation movement is reduced and grains are prone to grow, and it is not conducive to improving the tensile strength of the material. As such, in the cold-rolled IF steel of the present disclosure, the microstructure is controlled to have NbC precipitated in the grains and at the grain boundaries, wherein the size of NbC precipitated in the grains is $\leq 30.0\text{nm}$, and the number is $600\text{-}1000$ per square micrometer.

[0021] Furthermore, in the cold-rolled IF steel according to the present disclosure, the performance satisfies at least one of the following items:

A yield strength is $235\text{-}270\text{MPa}$, a tensile strength is $385\text{-}430\text{MPa}$, and a yield ratio is ≤ 0.630 ;

A work hardening value under 2% deformation is $\geq 45.0\text{MPa}$;

A waviness W_{sa} before deformation is $\leq 0.180\mu\text{m}$, and a waviness W_{sa} after deformation is $\leq 0.220\mu\text{m}$.

[0022] In the present disclosure, the reason for limiting the yield strength within the range of $235\text{-}270\text{MPa}$ is that: excessively high yield strength is not conducive to the stamping of the material, while excessively low yield strength is not conducive to the resistance to dent and resistance to deformation of the material. At the same time, the tensile strength is limited at $385\text{-}430\text{ MPa}$, which is mainly subject to the process and material composition. When the tensile strength of the material is relatively high, its alloy composition or microstructure also changes accordingly, and the yield strength of the material will also increase accordingly, which is not conducive to the stamping of the material. When the tensile strength is relatively low, it tends to lead to insufficient strength of material and reduction of deformation resistance. In some embodiments, the IF cold-rolled steel of the present disclosure has a yield strength of $250\text{-}270\text{MPa}$. In some embodiments, the IF cold-rolled steel of the present disclosure has a tensile strength of $400\text{-}430\text{MPa}$. In some embodiments, the IF cold-rolled steel of the present disclosure has a yield ratio of $0.600\text{-}0.630$.

[0023] In addition, a work hardening value is used to characterize the ability of the part to resist deformation after forming in the present disclosure, that is, the increase in the yield strength of the material after being stretched and deformed by a certain amount of deformation. Traditional IF steel has a low yield strength, the increase in its yield strength after stamping is small, and the manufactured parts are prone to deformation during transportation. For steel for automotive, a strain hardening rate (n) is usually used to measure the ability of the material to resist deformation during the stamping deformation process. This value is often measured in the uniform plastic deformation segment, that is, a strain hardening rate within a large deformation range (typically a strain range of $10\%\text{-}20\%$), and it fails to measure the deformation resistance of low yield strength materials after deformation. A deformation rate of the automotive outer panel is usually $3\%\text{-}7\%$. Increasing the work hardening value within this strain range may effectively improve the deformation resistance of the stamping parts, and avoid deformation of the stamping parts during transportation. Therefore, a work hardening value (WH) under a small deformation rate (for example, the work hardening value in the present disclosure may correspond to a deformation rate of 2%) is limited as $\geq 45.0\text{MPa}$, which is beneficial for the stamping parts to maintain the stability of shape during transportation. In some embodiments, a work hardening value under 2% deformation of the IF cold-rolled steel of the present disclosure is $45\text{-}66.0\text{MPa}$, such as $48.0\text{-}66.0\text{MPa}$.

[0024] In the present disclosure, a cup test under 5% deformation may be used to simulate the stamping process of an automotive outer panel, and may control the waviness value after deformation to be $0.220\mu\text{m}$ or less, and may ensure that the orange peel R value of the material is at a low level after subsequent electrophoretic coating, and improve the coating quality. In some embodiments, the waviness W_{sa} before deformation of the IF cold-rolled steel of the present disclosure is $0.155\text{-}0.180\mu\text{m}$, and the waviness after deformation is $0.180\text{-}0.220\mu\text{m}$.

[0025] Another object of the present disclosure is to provide a hot-dip galvanized steel plate that has good stamping, coating, and deformation resistance performance, meets user requirements for stamping formability of material, application of mid-coating-free process, and maintaining the stability of shape and size during the transportation of automobile stamping parts.

[0026] To achieve the above object, the present disclosure also provides a hot-dip galvanized steel plate, the substrate of which is the cold-rolled IF steel described above in the present disclosure, and the substrate is coated with a hot-dip galvanized layer.

[0027] Another object of the present disclosure is to provide a method for manufacturing a cold-rolled IF steel. By controlling the production process and the element composition of the steel plate, this method may improve the work hardening value of the steel, enable the stamping parts to have high deformation resistance, while also making the material to achieve a low yield ratio and low waviness, thereby ensuring the steel plate has good stamping performance and coating effect, and at the same time maintains the shape stability of the stamping parts during transporta-

tion.

[0028] In order to achieve the above object, the present disclosure also provides a method for manufacturing a cold-rolled IF steel, comprising the following steps:

Obtaining a slab;

Hot rolling: A temperature of the hot-rolled slab discharged from a furnace is 1150°C-1200°C, a finish rolling temperature is 890°C-920°C, and a coiling temperature is 600°C-650°C;

Cold rolling;

Annealing: An annealing temperature is controlled at 800°C-840°C with a holding time of 80s-110s, and a cooling rate is 180°C/min-230°C/min.

[0029] In the above hot rolling step of the present disclosure, when a temperature of the hot-rolled slab discharged from a furnace is too low, it is not conducive to uniform heating of the slab and complete completion of the austenitizing process; when a temperature of the hot-rolled slab discharged from a furnace is too high, it tends to cause an increase in iron scale and serious coarsening of the original austenite grains, and it has an adverse effect on grain refinement, the surface quality of steel plate, and the descaling process. As such, a temperature of the hot-rolled slab discharged from a furnace is controlled at 1150°C-1200°C.

[0030] In the above hot rolling step of the present disclosure, when a finish rolling temperature is too high, the size of grain is prone to increase; when a finish rolling temperature is too low, more serious work hardening tends to occur, the difficulty of rolling is increased and the yield strength of the finished product is increased. As such, a finish rolling temperature of the hot-rolled slab is controlled at 890°C-920°C.

[0031] In the above hot rolling step of the present disclosure, a coiling temperature of the steel coil should be controlled at 600°C-650°C. This is because: when a coiling temperature is too low, it tends to cause deterioration of workability and it is not conducive to coiling; when a coiling temperature is too high, it tends to cause the growth of grains and NbC precipitation phase, and it is not conducive to the control of its grain size in subsequent steps.

[0032] In the above annealing step of the present disclosure, an annealing temperature is controlled at 800°C-840°C with a holding time of 80s-110s, and a cooling rate is controlled at 180°C/min-230°C/min. This is because: when an annealing temperature is too low, recrystallization is insufficient, the width of the PFZ band formed is relatively small, and it is detrimental to reducing the yield ratio of material; when an annealing temperature is too high, grains tend to coarsen, the pancake-shaped ferrite is disappeared, and it has an adverse effect on the strength of material and the surface of material after stamping. When a holding time is too short, annealing is incomplete, and it is not conducive to the deep drawing performance; when a holding time is too long, the grains will coarsen, and the strength of material will be decreased. When a cooling rate is too slow, production efficiency is reduced; when a cooling rate is too fast, it is not conducive to the formation of a wider low-vacancy concentration region, and Ostwald ripening is insufficient, and the formation width of the PFZ band is reduced.

[0033] Furthermore, in the cold rolling step of the manufacturing method for the cold-rolled IF steel of the present disclosure, a cold rolling deformation rate is controlled at 75%-85%.

[0034] In the cold rolling step of the manufacturing method for the cold-rolled IF steel of the present disclosure, when a cold rolling deformation rate is too low, the grains obtained by rolling are coarse, the deformation energy storage is relatively low, it is detrimental to annealing recrystallization and is insufficient to form pancake-shaped ferrite grains, and it is not conducive to the stamping performance of the material. When a cold rolling deformation rate is too high, abnormally grown grains are prone to occur, it leads to uneven grain size, and it is not conducive to the elongation of the material and the surface morphology after stamping. As such, a cold rolling deformation rate is controlled at 75%-85%.

[0035] In some embodiments, the manufacturing method for the cold-rolled IF steel of the present disclosure further comprises temper rolling step after annealing. In some embodiments, in the step of temper rolling, a rolling force per unit width is controlled at 2.7 kN/mm-4.0 kN/mm, and a unit rolling tension is ≤ 40 MPa, for example 30-40 MPa.

[0036] Another object of the present disclosure is to provide a method for manufacturing a hot-dip galvanized steel plate. By controlling the element composition and the production process of the steel plate, the work hardening value of the steel is improved so that the stamping parts have a higher deformation resistance, and at the same time the material achieves a lower yield ratio and waviness, thereby ensuring the steel plate has good stamping performance and coating effect, and at the same time maintains the shape stability of the stamping parts during transportation.

[0037] To achieve the above object, the present disclosure also provides a method for manufacturing a hot-dip galvanized steel plate, comprising the following steps:

Obtaining a slab;

Hot rolling: A temperature of the hot-rolled slab discharged from a furnace is 1150°C-1200°C, a finish rolling temperature is 890°C-920°C, and a coiling temperature is 600°C-650°C;

Cold rolling;

Annealing: An annealing temperature is controlled at 800°C- 840°C with a holding time of 80s-110s, a cooling rate is 180°C/min-230°C/min, and the cold-rolled IF steel is obtained;

Hot-dip galvanizing;

Temper rolling.

[0038] Furthermore, in the cold rolling step of the manufacturing method for the hot-dip galvanized steel plate of the present disclosure, a cold rolling deformation rate is controlled at 75%-85%.

[0039] Furthermore, in the temper rolling step of the manufacturing method for the hot-dip galvanized steel plate of the present disclosure, a rolling force per unit width is controlled at 2.7kN/mm-4.0kN/mm, and a unit rolling tension is $\leq$ 40MPa, for example 30-40MPa.

[0040] In the temper rolling step of the manufacturing method for the hot-dip galvanized steel plate of the present disclosure, the rolling force per unit width and the unit rolling tension have a strong improvement effect on the plate quality, surface morphology and mechanical performance of the material. By controlling the elongation of temper rolling, the mechanical performance of the strip steel meets the use requirements. The combination of high rolling force and low tension can better optimize the surface morphology of the material after temper rolling, so that the material obtained also has a lower waviness in the cup test. However, when the rolling force is too high, roll marks tend to generate. When the tension is too low, the shape of the plate is prone to be controlled difficulty, an increase of rolling force is significant, and it is not conducive to production; when the tension is too high, the deformation degree and dislocation density of various textures within the material along the rolling direction show significant differences, and it is not conducive to the surface quality of the material after forming. As such, a rolling force per unit width is controlled at 2.7 kN/mm-4.0 kN/mm, and a unit rolling tension is $\leq$ 40 MPa in the present disclosure.

[0041] The cold-rolled IF steel, hot-dip galvanized steel plate, and manufacturing method therefor according to the present disclosure have the following advantages and beneficial effects:

The cold-rolled IF steel and hot-dip galvanized steel plate of the present disclosure have good stamping, coating and deformation resistance, and can meet user requirements for material stamping formability, application of mid-coating-free process and maintaining the stability of shape and size during the transportation of automobile stamping parts. They can be used to produce automotive outer panels, such as engine hoods and door outer panels.

[0042] By controlling the element composition and production process of the steel plate, the manufacturing method for the cold-rolled IF steel and hot-dip galvanized steel plate of the present disclosure improve the work hardening value of the steel to make stamping parts have a higher deformation resistance, and at the same time enable the material to obtain a lower yield ratio and waviness, thereby ensuring that the steel has good stamping performance and coating effect, and at the same time maintains the shape stability of the stamping parts during transportation.

Description of the Drawings

[0043]

Figure 1 shows a transmission electron microscope photograph of the PFZ band of Example 1 in the present disclosure.

Figure 2 shows a transmission electron microscope photograph of the intragranular precipitates of Example 1 in the present disclosure.

Detailed Description

[0044] The cold-rolled IF steel, hot-dip galvanized steel plate, and manufacturing methods therefor according to the present disclosure will be further explained and illustrated below with reference to specific examples. However, such explanation and illustration are not intended to unduly limit the technical solution of the present disclosure.

Examples 1-9 and Comparative Examples 1-9

[0045] The cold-rolled IF steels of Examples 1-5 and the hot-dip galvanized steel plates of Examples 6-9 of the present disclosure were all made using the following steps:

- (1) Obtaining a slab according to the chemical composition shown in Table 1-1 and Table 1-2;
- (2) Hot rolling: A temperature of the hot-rolled slab discharged from a furnace was 1150°C-1200°C, a finish rolling temperature was 890°C-920°C, and a coiling temperature was 600°C-650°C;
- (3) Cold rolling: a cold rolling deformation rate was controlled at 75%-85%;

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(4) Annealing: An annealing temperature was controlled at 800°C-840°C with a holding time of 80s-110s, and a cooling rate was 180°C/min-230°C/min, and a cold-rolled IF steel was obtained;

(5) Hot-dip galvanizing;

(6) Temper rolling: a rolling force per unit width was controlled at 2.7kN/mm- 4.0kN/mm, and a unit rolling tension was controlled at ≤ 40 MPa, and a hot-dip galvanized steel plate was obtained.

[0046] Examples 1-5 failed to comprise step (5), while Examples 6-9 comprised step (5).

[0047] The steels of Comparative Examples 1-5 and Comparative Examples 6-9 were also made using the above steps, but their specific composition ratios and process parameters failed to meet the design requirements of the present disclosure. Similarly, Comparative Examples 1-5 failed to comprise the hot-dip galvanizing step, while Comparative Examples 6-9 comprised the hot-dip galvanizing step.

Table 1-1 (with a balance of Fe and other unavoidable impurities except S, B, N and Si)

No.	C	Mn	P	Nb	Cr	Al
Ex.1	0.004	0.65	0.035	0.04	0.15	0.07
Ex.2	0.0052	0.7	0.04	0.08	0.2	0.012
Ex.3	0.0051	0.6	0.028	0.048	0.05	0.03
Ex.4	0.0055	0.65	0.035	0.064	0.15	0.025
Ex.5	0.0061	0.6	0.03	0.064	0.1	0.049
Ex.6	0.005	0.5	0.035	0.064	0.16	0.05
Ex.7	0.0065	0.5	0.025	0.07	0.09	0.024
Ex.8	0.007	0.8	0.034	0.08	0.14	0.06
Ex.9	0.0051	0.6	0.035	0.064	0.15	0.1
Com.Ex.1	0.005	0.6	0.034	0.063	<u>0.008</u>	0.009
Com.Ex.2	0.0051	0.6	0.034	0.063	<u>0.3</u>	0.014
Com.Ex.3	0.0051	0.6	0.034	<u>0.039</u>	0.15	0.03
Com.Ex.4	0.0035	<u>0.47</u>	0.02	0.055	0.14	0.12
Com.Ex.5	0.0051	0.6	0.035	0.064	0.14	0.09
Com.Ex.6	<u>0.008</u>	<u>0.9</u>	0.043	<u>0.09</u>	0.15	0.026
Com.Ex.7	0.0051	0.6	0.035	0.064	0.16	0.03
Com.Ex.8	<u>0.0073</u>	0.65	0.034	0.064	0.14	0.07
Com.Ex.9	0.0051	0.65	0.035	0.064	0.14	0.04

Table 1-2 (with a balance of Fe and other unavoidable impurities except S, B, N and Si)

No.	S	B	N	Si	(Nb×12)/(C×93)
Ex.1	0.005	0.0003	0.002	0.001	1.29
Ex.2	0.01	0.0003	0.002	0.0008	1.98
Ex.3	0.006	0.0004	0.003	0.0008	1.21
Ex.4	0.006	0.0003	0.004	0.001	1.5
Ex.5	0.01	0.0004	0.003	0.0009	1.35
Ex.6	0.007	0.0004	0.003	0.0009	1.65
Ex.7	0.007	0.0004	0.004	0.001	1.39
Ex.8	0.01	0.0004	0.003	0.0006	1.47
Ex.9	0.009	0.0003	0.004	0.0005	1.62
Com.Ex.1	0.01	0.0003	0.004	0.002	1.59

(continued)

No.	S	B	N	Si	(Nb×12)/(C×93)
Com.Ex.2	0.01	0.0004	0.002	0.001	1.59
Com.Ex.3	0.008	0.0003	0.003	0.001	<u>0.99</u>
Com.Ex.4	0.007	0.0004	0.004	0.0015	<u>2.02</u>
Com.Ex.5	0.012	0.0004	0.003	0.001	1.62
Com.Ex.6	0.01	0.0004	0.003	0.001	1.45
Com.Ex.7	0.009	0.0007	0.003	0.002	1.62
Com.Ex.8	0.008	0.0003	0.003	0.001	1.13
Com.Ex.9	0.013	0.0003	0.004	0.001	1.62

[0048] Table 2 lists the specific process parameters of the above process steps for the cold-rolled IF steels of Examples 1-5, the hot-dip galvanized steel plates of Examples 6-9, the comparative steels of Comparative Examples 1-5, and the steel plates of Comparative Examples 6-9 of the present disclosure.

Table 2.

No.	Temperature discharged from a furnace (°C)	Finish rolling temperature (°C)	Coiling temperature (°C)	Cold rolling deformation rate (%)	Annealing temperature (°C)	Holding time of annealing (s)	Cooling rate of annealing (°C/min)	Rolling force per unit width (kN/mm)	Unit rolling tension (MPa)
Ex.1	1160	910	630	81	830	105	220	3.8	38
Ex.2	1190	900	620	83	810	95	190	3.5	33
Ex.3	1170	915	600	79	820	100	210	3.6	35
Ex.4	1150	890	630	80	825	90	230	3.8	35
Ex.5	1200	920	630	80	820	95	210	3.8	35
Ex.6	1170	910	600	85	800	80	230	3.7	33
Ex.7	1180	910	650	75	840	110	180	3	35
Ex.8	1170	910	610	78	820	100	210	4	30
Ex.9	1170	920	630	80	820	90	210	2.7	40
Com.Ex.1	1210	910	630	80	820	100	210	3.8	35
Com.Ex.2	1170	910	610	81	820	100	210	3.5	35
Com.Ex.3	1145	900	620	80	820	105	220	3.5	35
Com.Ex.4	1220	910	630	73	810	105	220	3.8	42
Com.Ex.5	1170	930	630	80	810	100	190	3.8	41
Com.Ex.6	1170	910	590	86	840	75	210	4.2	35
Com.Ex.7	1170	910	660	80	850	100	170	2.6	35
Com.Ex.8	1210	910	630	78	790	90	210	3.8	47
Com.Ex.9	1170	910	630	79	820	90	250	3.8	35

[0049] Samples were taken from the obtained cold-rolled IF steels of Examples 1-5, hot-dip galvanized steel plates of Examples 6-9, and the comparative steel /steel plates of Comparative Examples 1-9. They were subjected to prepare Metallographic specimens by etching with 4% nitric acid and were subjected to prepare transmission electron microscopy specimens by electrolytic double-jet polishing. The width of PFZ band, size of precipitation phases, and the quantity of precipitation phases were statistically observed and recorded in Table 3. Wherein:

The quantity and diameter of precipitation phases were the results of statistics per square micrometer of area on the cross-section of the IF steels of the examples and comparative examples under a JEM-2100F transmission electron microscope.

[0050] The width values of PFZ band were the average values obtained from statistics of three observed fields of view for the IF steels of the examples and comparative examples.

[0051] Furthermore, the grades of grain size of the obtained cold-rolled IF steels of Examples 1-5, hot-dip galvanized steel plates of Examples 6-9, and the comparative steels /steel plates of Comparative Examples 1-9 were observed and recorded in Table 3. Wherein:

The grade of grain size was measured by preparing metallographic samples for each example and comparative example according to GB/T 6394-2002 "Determination of the Average Grain Size of Metals" and taking measurements from three selected fields of view.

[0052] Additionally, it should be noted that the microstructure of the hot-dip galvanized steel obtained in Examples 6-9 is the same as the microstructure of the cold-rolled IF steel obtained before the hot-dip galvanizing step. Therefore, the microstructure of the hot-dip galvanized steel can equally represent the microstructure of the cold-rolled IF steel for the corresponding examples or comparative examples.

Table 3.

No.	Grain size of the microstructure (grade)	Width of PFZ band (μm)	Size of NbC precipitated in the grains (nm)	Quantity of NbC precipitated in the grains (number/ nm^2)	Size of NbC precipitated at the grain boundaries (nm)
Ex.1	10	0.71	21.5	620	81
Ex.2	10.5	0.71	22	951	62
Ex.3	10	0.62	19.5	724	77
Ex.4	10	0.38	21.4	710	69
Ex.5	10	0.78	22.1	700	62
Ex.6	10.5	0.55	19	825	60
Ex.7	10	0.7	26	840	71
Ex.8	10	0.72	23	912	75
Ex.9	10	0.7	22.5	810	85
Com.Ex.1	<u>9.5</u>	0.6	28.3	813	54
Com.Ex.2	10	<u>0.28</u>	20.5	797	46
Com.Ex.3	<u>9</u>	0.45	17.5	590	60
Com.Ex.4	<u>9</u>	0.45	21	810	58
Com.Ex.5	<u>9.5</u>	0.35	25	730	49
Com.Ex.6	<u>10</u>	<u>0.25</u>	15	950	53
Com.Ex.7	<u>9</u>	<u>0.85</u>	<u>36</u>	<u>598</u>	<u>46</u>
Com.Ex.8	10	<u>0.25</u>	17	783	58
Com.Ex.9	10	<u>0.25</u>	23.5	824	43

[0053] As can be seen from Table 3, through reasonable chemical element composition design combined with optimized process parameters, the cold-rolled IF steels of Examples 1-5 and the hot-dip galvanized steel plates of Examples 6-9 of the present disclosure achieve ideal microstructural characteristics. The grades of grain size of their microstructures are all greater than or equal to 10, the width of the atom-free precipitation zone is $0.3\mu\text{m}$ - $0.8\mu\text{m}$, the intragranular precipitates are all NbC with size of less than 30nm, and the number per square micrometer is 600-1000.

[0054] Furthermore, Figure 1 shows a transmission electron microscope photograph of the PFZ band of Example 1 in the present disclosure. Figure 2 shows transmission electron microscope photograph of the intragranular precipitates of Example 1 in the present disclosure.

[0055] As shown in Figures 1 and 2, through reasonable chemical element composition design combined with optimized process parameters, Example 1 of the present disclosure achieves ideal microstructural characteristics.

[0056] Additionally, samples were taken from the obtained cold-rolled IF steels of Examples 1-5, hot-dip galvanized steel plates of Examples 6-9, and the comparative steels/steel plates of Comparative Examples 1-9. The mechanical properties and work hardening values of the samples were measured with reference to GB/T 228.1-2021 "Metallic materials - Tensile testing", and the test results are recorded in Table 4. The waviness before deformation and waviness after cup test under 5% deformation were measured with reference to standard PV1054. The test results are recorded in Table 4.

[0057] It should also be noted that the mechanical properties and deformation resistance properties of the hot-dip galvanized steel obtained in Examples 6-9 are the same as those of the cold-rolled IF steel obtained before the hot-dip galvanizing step. Therefore, the relevant properties of the hot-dip galvanized steel can equally represent the properties of the cold-rolled IF steel for the corresponding examples or comparative examples.

Table 4.

No.	Yield strength (MPa)	Tensile strength (MPa)	Yield ratio	Work hardening value under 2% deformation (MPa)	Waviness Wsa before deformation (μm)	Waviness Wsa after cup test under 5% deformation (μm)
Ex.1	258	413	0.625	60.4	0.167	0.198
Ex.2	262	427	0.619	65.2	0.165	0.194
Ex.3	252	401	0.628	48.1	0.174	0.196
Ex.4	262	421	0.622	61.1	0.165	0.195
Ex.5	249	409	0.609	59.4	0.17	0.21
Ex.6	269	428	0.629	61.3	0.159	0.193
Ex.7	258	420	0.614	60.4	0.173	0.205
Ex.8	265	430	0.616	61	0.165	0.188
Ex.9	261	415	0.629	60.3	0.174	0.203
Com.Ex.1	245	<u>382</u>	<u>0.641</u>	<u>42.2</u>	0.17	0.189
Com.Ex.2	265	404	<u>0.656</u>	53.3	0.172	0.196
Com.Ex.3	250	<u>376</u>	<u>0.665</u>	52.5	<u>0.213</u>	<u>0.238</u>
Com.Ex.4	245	<u>375</u>	<u>0.653</u>	51.2	<u>0.219</u>	<u>0.245</u>
Com.Ex.5	252	391	<u>0.645</u>	54.1	<u>0.21</u>	<u>0.231</u>
Com.Ex.6	286	441	<u>0.649</u>	64.3	0.172	0.21
Com.Ex.7	248	392	<u>0.633</u>	58.4	<u>0.212</u>	<u>0.234</u>
Com.Ex.8	280	406	<u>0.689</u>	60.4	<u>0.208</u>	<u>0.225</u>
Com.Ex.9	270	418	<u>0.646</u>	62.4	<u>0.183</u>	0.217

[0058] As can be seen from Table 4, through reasonable chemical element composition design combined with optimized process parameters, the cold-rolled IF steels of Examples 1-5 and the hot-dip galvanized steel plates of Examples 6-9 of the present disclosure achieve good properties. The yield strength is 235MPa-270MPa, the tensile strength is 385 MPa-430MPa, the yield ratios is less than 0.63, and the work hardening value under 2% deformation is greater than 45.0 MPa. Their waviness Wsa is less than 0.18 μm , and Wsa after cup test under 5% deformation is less than 0.22 μm .

[0059] Meanwhile, combining Tables 1, 2, 3 and 4, it can be seen that the chemical element composition design of Comparative Examples 1-3 fails to meet the design specification requirements of the present disclosure, resulting in their work hardening values (corresponding to the deformation resistance of the steel after processing and deformation) and yield ratio not simultaneously satisfying the indicators of the present disclosure.

[0060] For Comparative Example 4, a temperature discharged from a furnace was greater than the upper limit of the indicator requirement of the present disclosure, leading to the formation of coarse grains during the rough rolling stage, thereby reducing the effect of grain refinement strengthening in the present disclosure, lowering the tensile strength of the steel, and resulting in relatively coarse grains in the final product.

[0061] For Comparative Example 5, a finish rolling temperature exceeded the upper limit of the indicator requirement of the present disclosure, resulting in the grade of grain size of the finished steel fails to meet the standard, and the waviness Wsa after stamping and deformation exceeds the upper limit of the indicator requirement.

[0062] For Comparative Example 6, a holding time of annealing was lower than the design specification requirement of the present disclosure, resulting in a yield ratio of 0.668, far exceeding the upper limit of the indicator requirement.

[0063] For Comparative Example 7, a coiling temperature was higher than the upper limit of the design specification requirement of the present disclosure, resulting in the waviness Wsa of the finished product before and after stamping exceeding the upper limits of the indicator requirements.

[0064] For Comparative Example 8, an annealing temperature was lower than the design specification requirement of the present disclosure, resulting in insufficient thermal activation energy during the recrystallization process, ultimately causing the width of PFZ band of the steel to be below the lower limit of the indicator, and the yield ratio and waviness Wsa before and after stamping to be higher than the upper limits of the indicators.

[0065] For Comparative Example 9, a cooling rate in the annealing section was higher than the design specification requirement of the present disclosure, resulting in a narrowing of the width of the low vacancy concentration, ultimately causing the width of PFZ band of the steel to be below the indicator requirement and the yield ratio to be higher than the indicator requirement.

[0066] The hot-dip galvanized steel plates corresponding to cold-rolled IF steels of Examples 1-5 of the present disclosure, and the cold-rolled IF steels corresponding to the hot-dip galvanized steel plates of Examples 6-9, all achieve the properties described in the present disclosure.

[0067] In summary, it can be seen that the cold-rolled IF steels and hot-dip galvanized steel plates of the present disclosure all have good stamping, coating, and deformation resistance performance, and can meet user requirements for material stamping formability, application of mid-coating-free process, and maintaining the stability of shape and size during the transportation of automobile stamping parts. They can be used to produce automotive outer panels, such as engine hoods and door outer panels, and have broad application prospects and use value.

[0068] It should be noted that, the ways in which the various technical features of the present disclosure are combined are not limited to the ways recited in the claims of the present disclosure or the ways described in the specific examples. All the technical features recited in the present disclosure may be combined or integrated freely in any manner, unless contradictions are resulted.

[0069] It should also be noted that the Examples set forth above are only specific examples according to the present disclosure. Obviously, the present disclosure is not limited to the above Examples. Similar variations or modifications made thereto can be directly derived or easily contemplated from the present disclosure by those skilled in the art. They all fall in the protection scope of the present disclosure.

Claims

1. A cold-rolled IF steel, comprising Fe and unavoidable impurities, wherein the cold-rolled IF steel further comprises the following chemical elements in mass percentages:

C: 0.0040-0.0070%, Mn: 0.50-0.80%, P: 0.025-0.040%, Nb: 0.040-0.080%, Cr: 0.05-0.20%, and Al: 0.010-0.100%;

it also satisfies: $1.20 \leq (\text{Nb} \times 12) / (\text{C} \times 93) \leq 2.00$, wherein each chemical element in the formula is substituted with its numerical value before the percent sign of its mass percentage content.

2. The cold-rolled IF steel according to claim 1, wherein the cold-rolled IF steel consists of the following chemical elements in mass percentages:

C: 0.0040-0.0070%, Mn: 0.50-0.80%, P: 0.025-0.040%, Nb: 0.040-0.080%, Cr: 0.05-0.20%, Al: 0.010-0.100%; with a balance of Fe and unavoidable impurities.

3. The cold-rolled IF steel according to claim 1 or 2, wherein among the unavoidable impurities: S $\leq$ 0.01%, B $\leq$ 0.0006%, N $\leq$ 0.004%, and Si $\leq$ 0.0010%.

4. The cold-rolled IF steel according to claim 1 or 2, wherein a microstructure of the cold-rolled IF steel has a grain size of grade 10 or more.

5. The cold-rolled IF steel according to claim 1 or 2, wherein the cold-rolled IF steel has an atom-free precipitation zone, and a width of the precipitate-free zone is 0.30 μ m- 0.80 μ m.
6. The cold-rolled IF steel according to claim 1 or 2, wherein its microstructure has NbC precipitated in grains and at grain boundaries, wherein: a diameter of NbC precipitated at grain boundaries is ≥ 60 nm; and/or, a size of NbC precipitated in grains is ≤ 30 nm, and a number is 600-1000 per square micrometer.
7. The cold-rolled IF steel according to claim 6, wherein the diameter of NbC precipitated at grain boundaries is 60-85nm, and the size of NbC precipitated in grains is 19.0-30.0nm.
8. The cold-rolled IF steel according to claim 1 or 2, wherein its performance satisfies at least one of the following items:
 - a yield strength is 235-270MPa, a tensile strength is 385-430MPa, and a yield ratio is ≤ 0.630 ;
 - a work hardening value under 2% deformation is ≥ 45.0 MPa;
 - a waviness Wsa before deformation is $\leq 0.180\mu$ m, and a waviness Wsa after deformation is $\leq 0.220\mu$ m.
9. A hot-dip galvanized steel plate, wherein a substrate of the hot-dip galvanized steel plate is the cold-rolled IF steel according to any one of claims 1-8, and the substrate is coated with a hot-dip galvanized layer.
10. A method for manufacturing the cold-rolled IF steel according to any one of claims 1-8, comprising the following steps:
 - obtaining a slab;
 - hot rolling: a temperature of a hot-rolled slab discharged from a furnace is 1150°C-1200°C, a finish rolling temperature is 890°C-920°C, and a coiling temperature is 600°C-650°C;
 - cold rolling;
 - annealing: an annealing temperature is controlled at 800°C-840°C with a holding time of 80s-110s, and a cooling rate is 180°C/min-230°C/min.
11. The manufacturing method according to claim 10, wherein in the cold rolling step, a cold rolling deformation rate is controlled at 75%-85%.
12. The manufacturing method according to claim 10, wherein after the annealing step, the method further comprises temper rolling step; preferably, in the temper rolling step, a rolling force per unit width is controlled at 2.7 kN/mm-4.0 kN/mm, and a unit rolling tension is ≤ 40 MPa.
13. A method for manufacturing the hot-dip galvanized steel plate according to claim 9, comprising the following steps:
 - obtaining a slab;
 - hot rolling: a temperature of a hot-rolled slab discharged from a furnace is 1150°C-1200°C, a finish rolling temperature is 890°C-920°C, and a coiling temperature is 600°C-650°C;
 - cold rolling;
 - annealing: an annealing temperature is controlled at 800°C- 840°C with a holding time of 80s-110s, a cooling rate is 180°C/min-230°C/min, and a cold-rolled IF steel is obtained;
 - hot-dip galvanizing;
 - temper rolling.
14. The manufacturing method according to claim 13, wherein in the cold rolling step, a cold rolling deformation rate is controlled at 75%-85%.
15. The manufacturing method according to claim 13, wherein in the temper rolling step, a rolling force per unit width is controlled at 2.7kN/mm- 4.0kN/mm, and a unit rolling tension is ≤ 40 MPa.

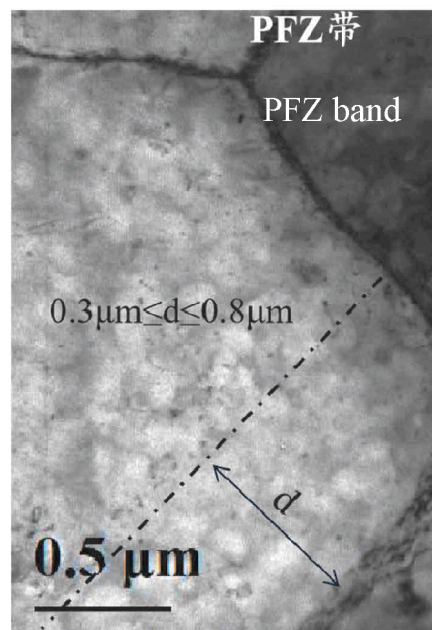


Figure 1

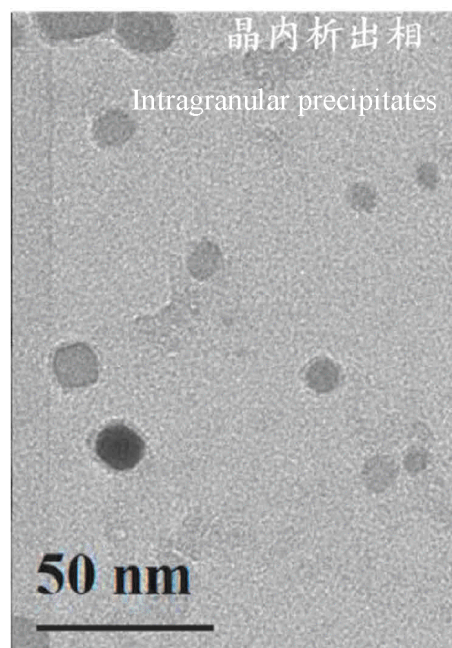


Figure 2

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2024/138730

A. CLASSIFICATION OF SUBJECT MATTER

C22C38/02(2006.01)i; C22C38/04(2006.01)i; C22C38/06(2006.01)i; C22C38/12(2006.01)i; C22C38/18(2006.01)i;
C21D1/26(2006.01)i; C21D7/04(2006.01)i; C21D7/13(2006.01)i; C21D9/46(2006.01)i; C23C2/06(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 C23C

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)

CNXTX, DWPI, CNKI, EPOCOD: 钢, 铬, 硅, 铝, 锰, 碳, 碳化铌, 铌, Steel, chromium, silicon, aluminum, manganese, carbon, niobium carbide, niobium

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	CN 109715838 A (THYSSENKRUPP STEEL EUROPE AG et al.) 03 May 2019 (2019-05-03) description, paragraphs 11, 16-41, 92, 119, and 164	1-15
A	JP 2006328443 A (SUMITOMO METAL INDUSTRIES, LTD.) 07 December 2006 (2006-12-07) entire document	1-15
A	JP 2012077384 A (SUMITOMO METAL INDUSTRIES, LTD.) 19 April 2012 (2012-04-19) entire document	1-15
A	JP 2004232051 A (JFE STEEL K.K.) 19 August 2004 (2004-08-19) entire document	1-15

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

☒ See patent family annex.

* Special categories of cited documents:	"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
"A" document defining the general state of the art which is not considered to be of particular relevance	"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"D" document cited by the applicant in the international application	"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
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"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	
"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	

Date of the actual completion of the international search 18 March 2025	Date of mailing of the international search report 26 March 2025
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
Information on patent family members

International application No.

PCT/CN2024/138730

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Patent document cited in search report			Publication date (day/month/year)	Patent family member(s)			Publication date (day/month/year)
CN	109715838	A	03 May 2019	MX	2019002942	A	12 June 2019
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