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(71) Applicant: **Hyundai Steel Company**
Incheon 22525 (KR)

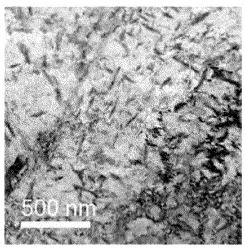
(72) Inventors:
- **PARK, Bong June**
  Incheon 22525 (KR)
- **NOH, Hyun Seong**
  Incheon 22525 (KR)
- **LA, Joung Hyun**
  Incheon 22525 (KR)
- **PARK, Min Suh**
  Incheon 22525 (KR)
- **JANG, Min Ho**
  Incheon 22525 (KR)
- **HAN, Seong Kyung**
  Incheon 22525 (KR)

(74) Representative: **Viering, Jentschura & Partner mbB**
Patent- und Rechtsanwälte
Am Brauhaus 8
01099 Dresden (DE)

(54) **COLD-ROLLED STEEL SHEET AND METHOD FOR MANUFACTURING SAME**

(57) Provided is a cold-rolled steel sheet consisting of carbon (C): 0.23 wt% to 0.35 wt%, silicon (Si): 0.05 wt% to 0.5 wt%, manganese (Mn): 0.3 wt% to 2.3 wt%, phosphorus (P): more than 0 wt% and not more than 0.02 wt%, sulfur (S): more than 0 wt% and not more than 0.005 wt%, aluminum (Al): 0.01 wt% to 0.05 wt%, chromium (Cr): more than 0 wt% and not more than 0.8 wt%, molybdenum (Mo): more than 0 wt% and not more than 0.4 wt%, titanium (Ti): 0.01 wt% to 0.1 wt%, boron (B): 0.001 wt% to 0.005 wt%, a balance of iron (Fe), and unavoidable impurities, wherein a final microstructure of the cold-rolled steel sheet includes cementite, a transition carbide, and a fine precipitate, the transition carbide including ε-carbide having an atomic ratio of a substitutional element selected from Fe, Mn, Cr, and Mo, to C of 2.5:1, or η-carbide having an atomic ratio of the substitutional element to C of 2:1, and the fine precipitate having an atomic ratio of an alloying element selected from Mo and Ti, to C of 1:1.

FIG. 1



(a)

Description

TECHNICAL FIELD

[0001] The present invention relates to a cold-rolled steel sheet and a method of manufacturing the same, and more particularly, to an ultra-high-strength cold-rolled steel sheet with high yield ratio and excellent bendability, and a method of manufacturing the same.

BACKGROUND ART

[0002] The demand for crashworthiness of the vehicle body has continuously increased in the automobile industry. Recently, although the number of vehicle parts has decreased due to the spread of electric vehicles, the weight of vehicles has increased due to the employment of batteries and thus the demand for crashworthiness is further expanding. As such, efforts are being continuously made to achieve ultra-high strength of collision-related parts such as front bumper beams, side sills, and door impact beams which contribute to crashworthiness. Particularly, the increased use of roll forming technique has expanded the application of martensite steel which has the highest strength among various types of cold-rolled steel, and the bendability of steel sheet serves as a very significant factor due to the characteristics of the above technique.

[0003] The related art includes Japanese Patent Publication No. 2005-105367.

DETAILED DESCRIPTION OF THE INVENTION

TECHNICAL PROBLEM

[0004] The present invention provides an ultra-high-strength cold-rolled steel sheet with high yield ratio and excellent bendability, and a method of manufacturing the same, and more particularly, provides a cold-rolled steel sheet capable of forming martensite steel with a tensile strength of 1400 MPa or more, and a method of manufacturing the same.

TECHNICAL SOLUTION

[0005] According to an aspect of the present invention, there is provided a cold-rolled steel sheet consisting of carbon (C): 0.23 wt% to 0.35 wt%, silicon (Si): 0.05 wt% to 0.5 wt%, manganese (Mn): 0.3 wt% to 2.3 wt%, phosphorus (P): more than 0 wt% and not more than 0.02 wt%, sulfur (S): more than 0 wt% and not more than 0.005 wt%, aluminum (Al): 0.01 wt% to 0.05 wt%, chromium (Cr): more than 0 wt% and not more than 0.8 wt%, molybdenum (Mo): more than 0 wt% and not more than 0.4 wt%, titanium (Ti): 0.01 wt% to 0.1 wt%, boron (B): 0.001 wt% to 0.005 wt%, a balance of iron (Fe), and unavoidable impurities, wherein a final microstructure of the cold-rolled steel sheet includes cementite, a transition carbide, and a fine precipitate, the transition carbide including ε-carbide having an atomic ratio of a substitutional element selected from Fe, Mn, Cr, and Mo, to C of 2.5:1, or η-carbide having an atomic ratio of the substitutional element to C of 2:1, and the fine precipitate having an atomic ratio of an alloying element selected from Mo and Ti, to C of 1:1, and wherein the cold-rolled steel sheet has a yield point (YP) of 1170 MPa or more, a tensile strength (TS) of 1400 MPa or more, an elongation (El) of 3.0% or more, a yield ratio of 70% or more, and a bendability (R/t) of 4.0 or less.

[0006] The cementite, the transition carbide, and the fine precipitate may each have an average size of 50 nm or less and an average aspect ratio of 4.0 or less.

[0007] The cementite, the transition carbide, and the fine precipitate may each have an area fraction of more than 0% and not more than 5%.

[0008] The final microstructure may consist of only tempered martensite.

[0009] The final microstructure may consist of tempered martensite, ferrite, and bainite, the tempered martensite having an area fraction of 80% or more and less than 100%, and the ferrite and bainite having an area fraction of more than 0% and not more than 20%.

[0010] According to another aspect of the present invention, there is provided a method of manufacturing a cold-rolled steel sheet, the method including (a) hot-rolling a steel material consisting of carbon (C): 0.23 wt% to 0.35 wt%, silicon (Si): 0.05 wt% to 0.5 wt%, manganese (Mn): 0.3 wt% to 2.3 wt%, phosphorus (P): more than 0 wt% and not more than 0.02 wt%, sulfur (S): more than 0 wt% and not more than 0.005 wt%, aluminum (Al): 0.01 wt% to 0.05 wt%, chromium (Cr): more than 0 wt% and not more than 0.8 wt%, molybdenum (Mo): more than 0 wt% and not more than 0.4 wt%, titanium (Ti): 0.01 wt% to 0.1 wt%, boron (B): 0.001 wt% to 0.005 wt%, and a balance of iron (Fe), (b) cold-rolling the hot-rolled steel material, and (c) sequentially performing annealing, first heat treatment, and second heat treatment processes on the cold-rolled steel material, wherein a final microstructure of the cold-rolled steel sheet obtained by performing steps (a) to (c) includes cementite, a transition carbide, and a fine precipitate, the transition carbide including ε-carbide having an atomic ratio of a substitutional element selected from Fe, Mn, Cr, and Mo, to C of 2.5:1, or η-carbide having an atomic ratio of the substitutional element to C of 2:1, and the fine precipitate having an atomic ratio of an alloying element selected from Mo and Ti, to C of 1:1, and wherein the cementite is formed during the first heat treatment process, the transition carbide is formed during the second heat treatment process, and the fine precipitate is formed during the hot-rolling.

[0011] Step (a) may be performed under conditions of a reheating temperature of 1150°C to 1300°C, a finishing delivery temperature of 800°C to 1000°C, and a coiling temperature of 500°C to 650°C, and step (c) may be performed under conditions of an annealing temperature of 800°C to 900°C, a first heat treatment temperature of 100°C to 300°C, and a second heat treatment temperature of 100°C to 210°C.

[0012] Step (a) may be performed under conditions of a reheating temperature of 1150°C to 1300°C, a finishing delivery temperature of 800°C to 1000°C, and a coiling temperature of 500°C to 650°C, and step (c) may include performing plating and be performed under conditions of an annealing temperature of 800°C to 900°C, a first heat treatment temperature of 450°C to 600°C, and a second heat treatment temperature of 100°C to 210°C.

[0013] In step (c), cooling may be performed to a first heat treatment temperature after the annealing process, and then the first heat treatment process may be performed.

[0014] In step (c), cooling may be performed to room temperature after the first heat treatment process, and then the second heat treatment process may be performed by performing heating.

[0015] The second heat treatment process may include a process of maintaining the second heat treatment temperature for 3 hours to 20 hours.

ADVANTAGEOUS EFFECTS

[0016] According to an embodiment of the present invention, an ultra-high-strength cold-rolled steel sheet with high yield ratio and excellent bendability, and a method of manufacturing the same may be implemented. For example, according to the present invention, a high-strength cold-rolled steel sheet with a high tensile strength, a high yield ratio (YP/TS) of more than 70%, and an excellent bendability (R/t) of 4.0 or less may be implemented. As such, it is expected that the application of a material with excellent impact absorbability and excellent formability for forming complex shaped parts may contribute to an increase in vehicle passenger safety and an increase in fuel efficiency through vehicle body weight reduction. However, the scope of the present invention is not limited to the above-described effects.

DESCRIPTION OF THE DRAWINGS

[0017]

FIG. 1 includes microscopic images showing a result of analyzing cementite (Fe_3C) among carbides in a final microstructure of a cold-rolled steel sheet according to an embodiment of the present invention.
FIG. 2 includes microscopic images showing a result of analyzing ε-carbide ($Fe_{2.5}C$) among carbides in a final microstructure of a cold-rolled steel sheet according to an embodiment of the present invention.
FIG. 3 is a schematic view for describing a method of measuring the size of carbides in a final microstructure of a cold-rolled steel sheet according to an embodiment of the present invention.
FIG. 4 is a graph showing the distribution of sizes of carbides in a final microstructure of a cold-rolled steel sheet according to an embodiment of the present invention.
FIG. 5 is a graph showing the distribution of aspect ratios of carbides in a final microstructure of a cold-rolled steel sheet according to an embodiment of the present invention.
FIG. 6 is a graph showing a step of sequentially performing annealing, first heat treatment, and second heat treatment processes in a method of manufacturing a cold-rolled steel sheet, according to an embodiment of the present invention.
FIG. 7 is a microscopic image of a final microstructure according to Test Example 1 of the present invention.
FIG. 8 is a microscopic image of a final microstructure according to Test Example 2 of the present invention.
FIG. 9 is a microscopic image of a final microstructure according to Test Example 3 of the present invention.
FIG. 10 is a microscopic image of a final microstructure according to Test Example 4 of the present invention.

MODE OF THE INVENTION

[0018] A cold-rolled steel sheet and a method of manufacturing the same, according to an embodiment of the present invention, will now be described in detail. The terms used herein are appropriately selected in consideration of their functions in the present invention, and definitions of these terms should be made based on the whole content of the present specification. A detailed description of an ultra-high-strength cold-rolled steel sheet with high yield ratio and excellent bendability, and a method of manufacturing the same will be provided below.

[0019] A cold-rolled steel sheet according to an embodiment of the present invention consists of carbon (C): 0.23 wt% to 0.35 wt%, silicon (Si): 0.05 wt% to 0.5 wt%, manganese (Mn): 0.3 wt% to 2.3 wt%, phosphorus (P): more than 0 wt% and not more than 0.02 wt%, sulfur (S): more than 0 wt% and not more than 0.005 wt%, aluminum (Al): 0.01 wt% to 0.05 wt%, chromium (Cr): more than 0 wt% and not more than 0.8 wt%, molybdenum (Mo): more than 0 wt% and not more than 0.4 wt%, titanium (Ti): 0.01 wt% to 0.1 wt%, boron (B): 0.001 wt% to 0.005 wt%, a balance of iron (Fe), and unavoidable impurities.

[0020] The functions and contents of the components included in the cold-rolled steel sheet will now be described.

Carbon (C)

[0021] C is the most effective and significant element for increasing the strength of steel. In addition, C is added and dissolved in austenite to form a martensite structure when quenched. Furthermore, C combines with elements such as Fe, Cr, and Mo to form carbides and increase strength and hardness. C may be added at a content ratio of 0.23 wt% to 0.35 wt% of a total weight in a base steel sheet for forming the cold-rolled steel sheet according to an embodiment of the present invention. When the content of C is less than 0.23 wt% of the total weight, the above-described effect may not be achieved and a sufficient strength may not be ensured. On the other hand, when the content of C is greater than 0.35 wt% of the total weight, weldability and workability may be reduced.

Silicon (Si)

[0022] Si is an element added to ensure bendability and hydrogen embrittlement resistance by suppressing the formation of cementite. Si is also an element added to increase strength due to the solid solution strengthening effect in ferrite, and suppress the formation of carbides. Si is well-known as a ferrite stabilizing element and thus may increase ductility by increasing a fraction of ferrite during cooling. Si is also known as an element capable of ensuring strength by promoting the formation of martensite by increasing the concentration of C in austenitic. Meanwhile, Si may be added together with Al as a deoxidizer for removing oxygen from steel in a steelmaking process, and also have the solid solution strengthening effect. Si may be added at a content ratio of 0.05 wt% to 0.5 wt% of the total weight in the base steel sheet for forming the cold-rolled steel sheet according to an embodiment of the present invention. When the content of Si is less than 0.05 wt% of the total weight, ductility may not be ensured and the above-described effect of adding Si may not be properly achieved. On the other hand, when the content of Si is greater than 0.5 wt% of the total weight, ferrite may be excessively formed to reduce strength, oxide may be formed on the surface of the steel sheet to reduce the platability of the steel sheet, red scale may be formed during reheating and hot-rolling to cause a problem in surface quality, and toughness and plasticity may be reduced and the weldability of steel may also be reduced.

Manganese (Mn)

[0023] Mn is an element that contributes to an increase in strength by increasing solid solution strengthening and quenchability. For example, Mn is an element that facilitates the formation of a low-temperature transformation phase and provides the effect of increasing strength through solid solution strengthening. Some of Mn is dissolved in steel and the other combines with S contained in the steel to form non-metallic MnS inclusions. MnS has ductility and thus elongates in the direction of plastic working. However, due to the formation of MnS, the content of S in the steel is reduced to make the grains susceptible and suppress the formation of FeS, a low-melting-point compound. Although the acid resistance and oxidation resistance of the steel are hindered, a yield point is increased by refining perlite and solid-solution-strengthening ferrite. Mn may be added at a content ratio of 0.3 wt% to 2.3 wt% of the total weight in the base steel sheet for forming the cold-rolled steel sheet according to an embodiment of the present invention. When the content of Mn is less than 0.3 wt%, the above-described strength ensuring effect may not be sufficiently achieved. When the content of Mn is greater than 2.3 wt%, bendability and hydrogen embrittlement resistance may be reduced due to the formation of Mn bands and MnS. For example, bendability may be reduced by forming internal and external segregation zones of a continuous casting slab and the steel sheet and causing the formation and propagation of cracks. That is, slab quality and weldability may be reduced, and center segregation may occur to reduce the ductility and workability of the base steel sheet.

Phosphorus (P)

[0024] P may serve to increase the strength of steel through solid solution strengthening and suppress the formation of carbides. P may be added at a content ratio of more than 0 wt% and not more than 0.02 wt% of the total weight in the base steel sheet for forming the cold-rolled steel sheet according to an embodiment of the present invention. When the content of P is greater than 0.02 wt%, welded joints may become brittle, embrittlement may be caused by grain boundary segregation, press formability may be reduced, and impact resistance may also be reduced.

Sulfur (S)

[0025] S is an element that combines with Mn, Ti, or the like to increase the machinability of steel and forms a fine MnS precipitate to increase workability, but generally hinders ductility and weldability. S may be added at a content ratio of more than 0 wt% and not more than 0.005 wt% of the total weight in the base steel sheet for forming the cold-rolled steel sheet according to an embodiment of the present invention. When the content of S is greater than 0.005 wt%, the number of MnS inclusions may be increased to reduce bendability and hydrogen embrittlement resistance, and segregation may occur during continuous casting solidification to cause high-temperature cracks.

Aluminum (Al)

[0026] Al is an element mostly used as a deoxidizer and prevents slab cracks during the formation of nitrides, promotes the formation of ferrite, increases elongation, suppresses the formation of carbides, and stabilizes austenite by increasing the concentration of C in the austenite. Al is also an element served as a layer between Fe and a zinc (Zn) plating layer to increase platability, and may effectively suppress the formation of Mn bands in a hot-rolled coil. Al may be preferably added at a content ratio of 0.01 wt% to 0.05 wt% of the total weight in the base steel sheet for forming the cold-rolled steel sheet according to an embodiment of the present invention. When the content of Al is less than 0.01 wt%, the above-described effect of adding Al may not be properly achieved. On the other hand, when the content of Al is greater than 0.05 wt%, strength may be reduced due to the formation of ferrite, Al inclusions may be increased to reduce continuous castability, Al may be concentrated on the surface of the steel sheet to reduce platability, AlN may be formed in the slab to cause hot-rolling cracks.

Chromium (Cr)

[0027] Cr is an element capable of increasing hardenability and ensuring high strength, and may increase quenchability as an austenite stabilizing element. In addition, Cr increases elongation by forming a Cr-based precipitate in the grains during annealing. Cr may be preferably added at a content ratio of more than 0 wt% and not more than 0.8 wt% of the total weight in the base steel sheet for forming the cold-rolled steel sheet according to an embodiment of the present invention. When the content of Cr is greater than 0.8 wt%, the saturation effect may occur, laser weldability and ductility may be reduced, and platability may be hindered.

Molybdenum (Mo)

[0028] Mo is an element added to increase quenchability and ensure strength and toughness, and is also an element capable of increasing hydrogen embrittlement resistance due to the grain refinement and precipitation effect. Mo may be preferably added at a content ratio of more than 0 wt% and not more than 0.4 wt% of the total weight in the base steel sheet for forming the cold-rolled steel sheet according to an embodiment of the present invention. When the content of Mo is greater than 0.4 wt%, manufacturing costs may be increased and weldability may be reduced.

Titanium (Ti)

[0029] Ti contributes to grain refinement and BN formation suppression. Ti may be preferably added at a content ratio of 0.01 wt% to 0.1 wt% of the total weight in the base steel sheet for forming the cold-rolled steel sheet according to an embodiment of the present invention. When the content of Ti is less than 0.01 wt%, a reduction in ductility of the casting slab due to excessive formation of a BN precipitate may reduce slab quality and strength. Meanwhile, when the content of Ti is greater than 0.1 wt%, bendability and hydrogen embrittlement resistance may be reduced due to the coarsening of a TiN precipitate, and recrystallization temperature may be excessively increased to cause a non-uniform structure.

Boron (B)

[0030] B is an element added to increase the hardenability of steel by suppressing the formation of ferrite. B is also a strong quenching element and serves to increase strength by preventing the segregation of P. Because secondary work embrittlement may be caused when the segregation of P occurs, B may be added to prevent the segregation of P and increase resistance to work embrittlement. B may be preferably added at a content ratio of 0.001 wt% to 0.005 wt% of the total weight in the base steel sheet for forming the cold-rolled steel sheet according to an embodiment of the present invention. When the content of B is less than 0.001 wt%, strength may not be ensured due to low quenchability. When the content of B is greater than 0.005 wt%, grain boundary embrittlement may be increased due to the formation of BN, weldability may be reduced, and the surface quality of the steel may be hindered due to the formation of B oxide.

[0031] FIG. 1 includes microscopic images showing a result of analyzing cementite (Fe_3C) among carbides in a final microstructure of a cold-rolled steel sheet according to an embodiment of the present invention, and FIG. 2 includes microscopic images showing a result of analyzing ε-carbide ($Fe_{2.5}C$) among carbides in a final microstructure of a cold-rolled steel sheet according to an embodiment of the present invention. FIG. 3 is a schematic view for describing a method of measuring the size of carbides in a final microstructure of a cold-rolled steel sheet according to an embodiment of the present invention, FIG. 4 is a graph showing the distribution of sizes of carbides in a final microstructure of a cold-rolled steel sheet according to an embodiment of the present invention, and FIG. 5 is a graph showing the distribution of aspect ratios of carbides in a final microstructure of a cold-rolled steel sheet according to an embodiment of the present invention.

[0032] Referring to FIGS. 1 to 5, the final microstructure of the cold-rolled steel sheet according to an embodiment of the present invention includes cementite, a transition carbide, and a fine precipitate. In the cementite (Fe_3C), an atomic ratio of Fe to C is 3:1. The transition carbide includes ε-carbide having an atomic ratio of a substitutional element selected from Fe, Mn, Cr, and Mo, to C of 2.5:1, or η-carbide having an atomic ratio of the substitutional element to C of 2:1. The fine precipitate is characterized by having an atomic ratio of an alloying element selected from Mo and Ti, to C of 1:1. The carbides and the fine precipitate may partially include nitrogen.

[0033] In the cold-rolled steel sheet according to an embodiment of the present invention, to ensure bendability and hydrogen embrittlement resistance, the cementite, the transition carbide, and the fine precipitate may each have an average size of 50 nm or less and an average aspect ratio of 4.0 or less. Referring to FIG. 3, the average size refers to an average size including the major and minor axes of oval or acicular carbide particles 10, and more specifically, to an average size including a minor axis length a and a major axis length b. The average aspect ratio refers to a ratio of the major axis length to the minor axis length, b/a. In the cold-rolled steel sheet according to an embodiment of the present invention, the cementite, the transition carbide, and the fine precipitate may each have an area fraction of more than 0% and not more than 5%. The area fractions of the cementite, the transition carbide, and the fine precipitate were measured through replica analysis using at least five microscopic images of a scanning electron microscope.

[0034] The final microstructure of the cold-rolled steel sheet according to an embodiment of the present invention may consist of only tempered martensite. Alternatively, a final microstructure of a cold-rolled steel sheet according to another embodiment of the present invention may consist of tempered martensite, ferrite, and bainite, and the tempered martensite may have an area fraction of 80% or more and less than 100% while the ferrite and bainite may have an area fraction of more than 0% and not more than 20%. The above-described microstructure is based on a result of analyzing a 1/4 point of a thickness direction from a direction perpendicular to a rolling direction with the scanning electron microscope. In the present invention, when the area fraction of the tempered martensite is less than 80%, a target strength may not be achieved. Furthermore, in the present invention, because the ferrite and bainite are unavoidably formed due to an insufficient cooling rate and serve as a main factor for reducing strength, smaller area fractions thereof are preferable and the sum of area fractions of the two phases of ferrite and bainite is required not to exceed 20%.

[0035] The cold-rolled steel sheet according to an embodiment of the present invention, which has the above-described alloying element composition and microstructure, includes cementite-type carbide but may achieve properties of a yield point (YP) of 1170 MPa or more, a tensile strength (TS) of 1400 MPa or more, an elongation (El) of 3.0% or more, a yield ratio of 70% or more, and a bendability (R/t) of 4.0 or less. For example, the cold-rolled steel sheet according to an embodiment of the present invention may have a yield point (YP) of 1170 MPa to 1400 MPa, a tensile strength (TS) of 1400 MPa to 1700 MPa, an elongation (El) of 3.0% to 9.0%, a yield ratio of 70% to 90%, and a bendability (R/t) of 2.0 to 4.0. In the bendability (R/t), R denotes a minimum bend radius, and t denotes a thickness.

[0036] A method of manufacturing the cold-rolled steel sheet according to an embodiment of the present invention, which has the above-described composition and microstructure, will now be described.

[0037] The method of manufacturing the steel sheet, according to an embodiment of the present invention, includes (a) hot-rolling a steel material consisting of C: 0.23 wt% to 0.35 wt%, Si: 0.05 wt% to 0.5 wt%, Mn: 0.3 wt% to 2.3 wt%, P: more than 0 wt% and not more than 0.02 wt%, S: more than 0 wt% and not more than 0.005 wt%, Al: 0.01 wt% to 0.05 wt%, Cr: more than 0 wt% and not more than 0.8 wt%, Mo: more than 0 wt% and not more than 0.4 wt%, Ti: 0.01 wt% to 0.1 wt%, B: 0.001 wt% to 0.005 wt%, and a balance of Fe, (b) cold-rolling the hot-rolled steel material, and (c) sequentially performing annealing, first heat treatment, and second heat treatment processes on the cold-rolled steel material.

[0038] The hot-rolling step (a) may be performed under conditions of a reheating temperature of 1150°C to 1300°C, a finishing delivery temperature of 800°C to 1000°C, and a coiling temperature of 500°C to 650°C.

[0039] When the steel material is reheated to the above-mentioned temperature of 1150°C to 1300°C, components segregated during continuous casting may be redissolved. To increase strength through precipitation and solid solution strengthening, a strengthening element needs to be sufficiently dissolved in austenite before hot-rolling and thus the steel material needs to be heated to 1150°C or above. When the reheating temperature is lower than 1150°C, various carbides may not be sufficiently dissolved and the components segregated during continuous casting may not be dispersed evenly enough. However, at a reheating temperature exceeding 1300°C, an adverse effect such as austenite coarsening or decarburization may occur and a target strength may not be obtained. That is, when the reheating temperature is higher than 1300°C, very coarse austenite grains may be formed and thus strength may not be easily ensured. Furthermore, when the reheating temperature is higher than 1300°C, heating costs and a process time may be increased and thus an increase in manufacturing costs and a reduction in productivity may be resulted.

[0040] The finishing delivery temperature (FDT) of the hot-rolling is a very significant factor which affects final material quality, and the rolling at 800°C to 1000°C may refine austenite. However, when the finishing delivery temperature is lower than 800°C, a hot-rolling load may be increased and a mixed grain structure may occur at the edge. Furthermore, when the hot-rolling is performed at a temperature high than 1000°C, target mechanical properties may not be obtained due to coarse grains. After the hot-rolling, cooling may be performed at a cooling rate of 1 °C/s to 100 °C/s, and an average grain size may be reduced when the cooling rate is increased.

[0041] Meanwhile, when the coiling temperature is lower than 500°C, the hot-rolled coil may have a non-uniform shape and a cold-rolling load may be increased. When the coiling temperature is higher than 650°C, a non-uniform microstructure may be caused by the difference in cooling rate between the center and edge of the steel sheet, and the inside of the grain boundaries may be oxidized.

[0042] Meanwhile, the hot-rolling may be performed under a condition of a reduction ratio of 35% to 65%. The microstructure of the steel material after the hot-rolling may include bainite, martensite, and ferrite.

[0043] The cold-rolling step (b) may include performing pickling and then performing cold-rolling at a reduction ratio of 35% to 65%. The higher the reduction ratio, the greater the increase in formability due to the microstructural refinement effect. When the cold-rolling is performed at a reduction ratio lower than 35%, a uniform microstructure may not be easily obtained, and when the cold-rolling is performed at a reduction ratio higher than 65%, roll force may be increased and thus a process load may also be increased.

[0044] FIG. 6 is a graph showing a step of sequentially performing annealing, first heat treatment, and second heat treatment processes in a method of manufacturing a cold-rolled steel sheet, according to an embodiment of the present invention.

[0045] Referring to FIG. 6, the cold-rolled steel material is heated to a temperature of Ac3 or more at a heating rate of 1 °C/s to 10 °C/s. The temperature Ac3 may be calculated as shown below.

[0046]

$$Ac3(℃) = 910 - 203\,[C]^{0.5} - 30[Mn] + 44.7[Si] + 31.5[Mo] - 15.2[Ni],$$

where [C], [Mn], [Si], [Mo], and [Ni] denote wt% values of C, Mn, Si, Mo, and Ni in the steel material.

[0047] Based on the method of manufacturing the cold-rolled steel sheet, according to an embodiment of the present invention, an annealing process for maintaining the temperature of Ac3 or more, and more specifically, an annealing temperature of 800°C to 900°C, for 60 sec. to 600 sec. is performed.

[0048] Subsequently, cooling is performed to 500°C to 700°C at a cooling rate of 1 °C/s to 20 °C/s, and then to a martensite transformation end temperature (or cooling end temperature) at a cooling rate of 5 °C/s to 50 °C/s. Herein, the martensite transformation end temperature is 100°C to 350°C.

[0049] After that, for a non-plated cold-rolled steel sheet, a first heat treatment process for maintaining a first heat treatment temperature of 100°C to 300°C for 10 sec. to 100 sec. and then performing cooling to room temperature at a cooling rate of 20 °C/s or less is performed.

[0050] Meanwhile, for a plated cold-rolled steel sheet, a first heat treatment process for maintaining a first heat treatment temperature of 450°C to 600°C for 5 sec. to 60 sec. and then performing cooling to room temperature at a cooling rate of 20 °C/s or less is performed. When the cooling ends at a temperature of 300 °C or below and then primary heat treatment is performed, transformation heat due to the formation of bainite may cause material degradation. Meanwhile, when the cooling ends at a temperature of 450°C or above, martensite transformation may occur during the cooling due to bainite transformation delay (up to 60 sec.) and thus material quality may be ensured.

[0051] To completely end the transformation of martensite, the lower the first heat treatment temperature in the above-mentioned temperature range, the more preferable.

[0052] The method of manufacturing the cold-rolled steel sheet, according to an embodiment of the present invention, is characterized in that the cooling after the annealing process and before the first heat treatment process is performed only to the first heat treatment temperature rather than being performed rapidly to room temperature. When the cooling is performed rapidly to room temperature after the annealing process and before the first heat treatment process, although the first heat treatment process is performed, the final microstructure of the cold-rolled steel sheet does not include cementite. However, as in the present invention, when the cooling is performed only to the first heat treatment temperature rather than being performed rapidly to room temperature after the annealing process and before the first heat treatment process, cementite may be formed during the first heat treatment process. In general, a steel material including cementite has poor workability.

[0053] However, the cooling performed rapidly to room temperature after the annealing process and before the first heat treatment process to fundamentally prevent the formation of cementite increases manufacturing costs because an additional system or the like is required.

[0054] In the cold-rolled steel sheet according to an embodiment of the present invention, although the final microstructure includes cementite because the cooling is not performed rapidly to room temperature after the annealing process and before the first heat treatment process, properties of a yield point (YP) of 1170 MPa or more, a tensile strength (TS) of 1400 MPa or more, an elongation (El) of 3.0% or more, a yield ratio of 70% or more, and a bendability (R/t) of 4.0 or less may be ensured by precisely controlling subsequent processes, and thus an ultra-high-strength cold-rolled steel sheet with high yield ratio and excellent bendability may be implemented.

[0055] Cooling may be performed to room temperature after the first heat treatment process, and then the second heat treatment process may be performed by performing heating. The second heat treatment process includes a process of performing heating to a second heat treatment temperature of 100°C to 210°C at a heating rate of 10 °C/s or less and then maintaining the second heat treatment temperature for 3 hours to 20 hours. When the second heat treatment temperature is lower than 100°C, a target yield point may not be easily achieved during the heat treatment, and when the second heat treatment temperature is higher than 210°C, bendability may be reduced. Furthermore, when the heat treatment time is excessively long, because a reduction in bendability occurs even within the above-mentioned range of second heat treatment temperature, the time for maintaining the second heat treatment temperature is controlled to 3 hours to 20 hours.

[0056] The final microstructure of the cold-rolled steel sheet according to an embodiment of the present invention, which is formed by applying the above-described process conditions, is characterized by including cementite, a transition carbide, and a fine precipitate, the transition carbide including ε-carbide having an atomic ratio of a substitutional element selected from Fe, Mn, Cr, and Mo, to C of 2.5:1, or η-carbide having an atomic ratio of the substitutional element to C of 2:1, and the fine precipitate having an atomic ratio of an alloying element selected from Mo and Ti, to C of 1:1.

[0057] The cementite is formed during the first heat treatment process after the annealing and cooling. When the first heat treatment temperature is 100°C to 300°C, the cementite is present in martensite. When the first heat treatment temperature is 450°C to 600°C, the cementite is not formed in martensite and is present in bainite when the bainite is present. The cementite is present at a ratio of 0% to 5% of a total area fraction, and the lower the ratio, the more preferable.

[0058] The transition carbide is formed during the second heat treatment process. In the method of manufacturing the cold-rolled steel sheet, according to an embodiment of the present invention, when the second heat treatment process is not performed, no transition carbide is present. The transition carbide is required to increase a yield point, and may be present at a ratio of 0% to 5% of the total area fraction.

[0059] The fine precipitate is formed during the hot-rolling or during the coiling after the hot-rolling, and does not include Fe unlike the cementite and the transition carbide. The fine precipitate may be present at a ratio of 0% to 5% of the total area fraction.

Test Examples

[0060] Test examples will now be described for better understanding of the present invention. However, the following test examples are merely to promote understanding of the present invention, and the present invention is not limited to thereto.

1. Compositions of Specimens

[0061] In the test examples, specimens with alloying element compositions (unit: wt%) of Table 1 are provided.

[Table 1]

Steel Type	C	Si	Mn	Cr	Mo	Ti	B	Fe
A	0.25	0.1	2.0	0.4	0.2	0.03	0.0025	Bal.
B	0.24	0.1	1.9	0.3	0.2	0.06	0.0025	Bal.
C	0.22	0.2	2.2	0.3	0.2	0.03	0.0022	Bal.
D	0.26	0.7	1.8	0.4	0.2	0.03	0.0020	Bal.

[0062] In Table 1, steel types A and B satisfy the composition of the cold-rolled steel sheet according to an embodiment of the present invention, i.e., C: 0.23 wt% to 0.35 wt%, Si: 0.05 wt% to 0.5 wt%, Mn: 0.3 wt% to 2.3 wt%, P: more than 0 wt% and not more than 0.02 wt%, S: more than 0 wt% and not more than 0.005 wt%, Al: 0.01 wt% to 0.05 wt%, Cr: more than 0 wt% and not more than 0.8 wt%, Mo: more than 0 wt% and not more than 0.4 wt%, Ti: 0.01 wt% to 0.1 wt%, B: 0.001 wt% to 0.005 wt%, and a balance of Fe. However, steel type C falls below and does not satisfy the composition range of C of 0.23 wt% to 0.35 wt%, and steel type D exceeds and does not satisfy the composition range of Si of 0.05 wt% to 0.5 wt%.

2. Process Conditions and Property Evaluation

[0063] Table 2 shows various heat treatment process conditions for specimens with the compositions shown in Table 1, and Table 3 shows a result of evaluating properties after the compositions and heat treatment process conditions shown in Tables 1 and 2 are applied.

[0064] In Table 2, 'Steel Type' indicates the compositions shown in Table 1, and in Table 3, 'YP (MPa)', 'TS (MPa)', and 'EL (%)' indicate a yield point, a tensile strength, and an elongation of the specimens, respectively.

[Table 2]

Test Example	Steel Type	Annealing Temp. (°C)	Cooling End Temp. (°C)	First Heat Treatment Temp. (°C)	Second Heat Treatment Temp. (°C)	Second Heat Treatment Time (hr)
1	A	840	250	250	150	6
2	B	840	250	250	150	6
3	C	840	250	250	150	6
4	D	840	250	250	150	6
5	B	780	250	250	150	6
6	B	800	250	250	150	6
7	B	820	250	250	150	6
8	A	840	150	150	150	6
9	A	840	200	200	150	6
10	A	840	300	300	150	6
11	A	840	350	350	150	6
12	A	840	450	450	150	6
13	A	840	250	250	25	6
14	A	840	250	250	50	6
15	A	840	250	250	100	6
16	A	840	250	250	130	6
17	A	840	250	250	150	6
18	A	840	250	250	180	6
19	A	840	250	250	200	6
20	A	840	250	250	250	6
21	A	840	250	250	280	6
22	A	840	250	250	300	6
23	A	840	250	250	200	24
24	A	840	250	250	150	20
25	A	840	250	250	120	20

[Table 3]

Test Example	YP (MPa)	TS (MPa)	EL (%)	Yield Ratio (%)	Bendability (R/t)	Fine Precipitate Fraction (%)	Cementite Fraction (%)	Transition Carbide Fraction (%)	Carbide Size (nm)	Carbide Average Aspect Ratio
1	1247	1624	7.2	76.8	2.6	0.08	0.91	2.91	30.5	3.44
2	1184	1533	6.9	77.2	2.4	0.12	0.51	1.12	26.1	2.52

(continued)

Test Example	YP (MPa)	TS (MPa)	EL (%)	Yield Ratio (%)	Bendability (R/t)	Fine Precipitate Fraction (%)	Cementite Fraction (%)	Transition Carbide Fraction (%)	Carbide Size (nm)	Carbide Average Aspect Ratio
3	1093	1417	6.5	91.0	3.4	0.08	0.67	0.99	21.0	2.33
4	1077	1543	7.9	69.8	2.7	0.08	0.31	0.28	25.6	2.82
5	1165	1522	7.0	76.6	3.4	0.08	0.51	2.87	49.5	3.88
6	1196	1576	7.6	75.9	3.6	0.07	0.49	2.33	41.8	3.69
7	1205	1580	7.9	76.3	3.6	0.07	0.55	3.76	29.4	3.88
8	1320	1655	8.0	79.8	3.1	0.08	0.30	3.01	24.0	2.38
9	1196	1628	8.5	73.5	3.0	0.08	0.38	2.97	33.5	3.12
10	1226	1527	7.0	80.3	3.8	0.08	1.18	2.66	42.3	3.61
11	1130	1360	8.0	83.1	2.6	0.07	2.22	2.98	57.9	5.87
12	1218	1651	6.8	73.8	2.8	0.08	0.02	2.22	29.4	2.44
13	1121	1635	6.8	68.6	3.8	0.08	0.44	-	-	-
14	1140	1626	7.4	70.1	3.4	0.08	0.42	-	-	-
15	1200	1625	7.3	73.8	2.8	0.08	0.61	2.13	22.9	3.67
16	1236	1626	6.7	76.0	2.8	0.08	0.66	2.31	21.1	3.01
17	1247	1624	7.2	76.8	2.6	0.07	0.51	3.35	30.5	3.44
18	1279	1616	7.2	79.1	2.6	0.08	0.43	3.22	33.8	2.83
19	1348	1609	6.0	83.8	2.8	0.08	0.75	3.38	32.9	2.96
20	1336	1548	6.9	86.3	4.1	0.08	1.91	2.28	34.6	4.02
21	1320	1504	7.0	87.8	4.2	0.07	2.39	1.05	34.8	4.06
22	1361	1425	7.1	95.5	4.2	0.07	3.39	1.66	35.0	4.12
23	1271	1573	7.4	80.8	4.1	0.08	1.01	3.88	62.8	5.33
24	1229	1573	8.1	78.1	3.3	0.08	0.90	2.89	33.0	3.54
25	1206	1574	7.6	76.6	3.2	0.07	0.60	2.11	29.2	3.12

[0065] Referring to Tables 1 to 3, Test Examples 1 to 4 exhibit differences in properties depending on the alloy composition. Specifically, Test Examples 1 and 2, which are cold-rolled steel sheets implemented according to an embodiment of the present invention and satisfying the composition range of C: 0.23 wt% to 0.35 wt%, Si: 0.05 wt% to 0.5 wt%, Mn: 0.3 wt% to 2.3 wt%, P: more than 0 wt% and not more than 0.02 wt%, S: more than 0 wt% and not more than 0.005 wt%, Al: 0.01 wt% to 0.05 wt%, Cr: more than 0 wt% and not more than 0.8 wt%, Mo: more than 0 wt% and not more than 0.4 wt%, Ti: 0.01 wt% to 0.1 wt%, B: 0.001 wt% to 0.005 wt%, and a balance of Fe, may satisfy the properties of a yield point (YP) of 1170 MPa or more, a tensile strength (TS) of 1400 MPa or more, an elongation (El) of 3.0% or more, a yield ratio of 70% or more, and a bendability (R/t) of 4.0 or less, and include, in final microstructures thereof, cementite, a transition carbide, and a fine precipitate each having an average size of 50 nm or less, an average aspect ratio of 4.0 or less, and an area fraction of more than 0% and not more than 5%. On the contrary, Test Example 3, which falls below and does not satisfy the composition range of C of 0.23 wt% to 0.35 wt%, may not achieve the target properties of a yield point (YP) of 1170 MPa or more. Test Example 4, which exceeds and does not satisfy the composition range of Si of 0.05 wt% to 0.5 wt%, may not achieve the target property of a yield point (YP) of 1170 MPa or more due to the formation of intermediate phases such as ferrite and bainite. Particularly, Test Example 4 may ensure the bendability because the carbide size and the carbide aspect ratio are satisfied, but may not achieve the yield point because ferrite is formed more than 10%.

[0066] Referring to Tables 1 to 3, Test Examples 5 to 7 exhibit differences in properties depending on the annealing temperature. Test Examples 6 and 7, which are cold-rolled steel sheets implemented according to an embodiment of the present invention and satisfying the annealing temperature range of 800°C to 900°C, may satisfy the properties of a yield point (YP) of 1170 MPa or more, a tensile strength (TS) of 1400 MPa or more, an elongation (El) of 3.0% or more, a yield ratio of 70% or more, and a bendability (R/t) of 4.0 or less, and include, in final microstructures thereof, cementite, a transition carbide, and a fine precipitate each having an average size of 50 nm or less, an average aspect ratio of 4.0 or less, and an area fraction of more than 0% and not more than 5%.

[0067] On the contrary, Test Example 5, which falls below and does not satisfy the annealing temperature range of 800°C to 900°C, may not achieve the target property of a yield point (YP) of 1170 MPa or more.

[0068] Referring to Tables 1 to 3, Test Examples 8 to 12 exhibit differences in properties depending on the first heat treatment temperature. Test Examples 8 to 10, which are non-plated cold-rolled steel sheets implemented according to an embodiment of the present invention and satisfying the first heat treatment temperature range of 100°C to 300°C, may satisfy the properties of a yield point (YP) of 1170 MPa or more, a tensile strength (TS) of 1400 MPa or more, an elongation (El) of 3.0% or more, a yield ratio of 70% or more, and a bendability (R/t) of 4.0 or less, and include, in final microstructures thereof, cementite, a transition carbide, and a fine precipitate each having an average size of 50 nm or less, an average aspect ratio of 4.0 or less, and an area fraction of more than 0% and not more than 5%.

[0069] Test Example 12, which is a plated cold-rolled steel sheet implemented according to an embodiment of the present invention and satisfying the first heat treatment temperature range of 450°C to 600°C, may satisfy the properties of a yield point (YP) of 1170 MPa or more, a tensile strength (TS) of 1400 MPa or more, an elongation (El) of 3.0% or more, a yield ratio of 70% or more, and a bendability (R/t) of 4.0 or less, and include, in a final microstructure thereof, cementite, a transition carbide, and a fine precipitate each having an average size of 50 nm or less, an average aspect ratio of 4.0 or less, and an area fraction of more than 0% and not more than 5%.

[0070] On the contrary, Test Example 11 annealed at an annealing temperature of 350°C may not achieve the target properties of a yield point (YP) of 1170 MPa or more and a tensile strength (TS) of 1400 MPa or more, and not satisfy the carbide average size range of 50 nm or less and the carbide average aspect ratio range of 4.0 or less. When the first heat treatment temperature is maintained in a range of more than 300°C and less than 450°C, a reduction in strength occurs due to transformation heat. However, when the first heat treatment temperature ranging from 450°C to 600°C is satisfied as in Test Example 12, transformation may be suppressed and thus material quality may be ensured.

[0071] Referring to Tables 1 to 3, Test Examples 13 to 22 exhibit differences in properties depending on the second heat treatment temperature. Test Examples 15 to 19, which are cold-rolled steel sheets implemented according to an embodiment of the present invention and satisfying the second heat treatment temperature range of 100°C to 210°C, may satisfy the properties of a yield point (YP) of 1170 MPa or more, a tensile strength (TS) of 1400 MPa or more, an elongation (El) of 3.0% or more, a yield ratio of 70% or more, and a bendability (R/t) of 4.0 or less, and include, in final microstructures thereof, cementite, a transition carbide, and a fine precipitate each having an average size of 50 nm or less, an average aspect ratio of 4.0 or less, and an area fraction of more than 0% and not more than 5%.

[0072] On the contrary, Test Examples 13 and 14, which fall below and do not satisfy the second heat treatment temperature range of 100°C to 210°C, may not achieve the target property of a yield point (YP) of 1170 MPa or more because a transition carbide is not formed.

[0073] Test Examples 20 to 22, which exceed and do not satisfy the second heat treatment temperature range of 100°C to 210°C, may not achieve the target property of a bendability (R/t) of 4.0 or less and not satisfy the carbide average aspect ratio range of 4.0 or less. That is, the target property of a bendability (R/t) of 4.0 or less may not be satisfied due to carbide shape defects.

[0074] Referring to Tables 1 to 3, Test Examples 23 to 25 exhibit differences in properties depending on the second heat treatment time. Test Examples 24 and 25, which are cold-rolled steel sheets implemented according to an embodiment of the present invention and satisfying the second heat treatment temperature range of 100°C to 210°C and the second heat treatment time of 3 hours to 20 hours, may satisfy the properties of a yield point (YP) of 1170 MPa or more, a tensile strength (TS) of 1400 MPa or more, an elongation (El) of 3.0% or more, a yield ratio of 70% or more, and a bendability (R/t) of 4.0 or less, and include, in final microstructures thereof, cementite, a transition carbide, and a fine precipitate each having an average size of 50 nm or less, an average aspect ratio of 4.0 or less, and an area fraction of more than 0% and not more than 5%.

[0075] On the contrary, Test Example 23, which exceeds and does not satisfy the second heat treatment time of 3 hours to 20 hours, may not achieve the target property of a bendability (R/t) of 4.0 or less, and not satisfy the carbide average size range of 50 nm or less and the carbide average aspect ratio range of 4.0 or less. That is, when an excessively long second heat treatment time of 24 hours is applied, the aspect ratio is increased due to the growth of carbide and the target property of a bendability (R/t) of 4.0 or less may not be satisfied.

[0076] A cold-rolled steel sheet and a method of manufacturing the same, according to embodiments of the present invention, have been described above. According to the present invention, a high-strength cold-rolled steel sheet with a high tensile strength, a high yield ratio (YP/TS) of more than 70%, and an excellent bendability (R/t) of 4.0 or less may be implemented. As such, it is expected that the application of a material with excellent impact absorbability and excellent formability for forming complex shaped parts may contribute to an increase in vehicle passenger safety and an increase in fuel efficiency through vehicle body weight reduction.

[0077] While the present invention has been particularly shown and described with reference to embodiments thereof, it will be understood by one of ordinary skill in the art that various changes in form and details may be made therein without departing from the scope of the present invention as defined by the following claims.

Claims

1. A cold-rolled steel sheet consisting of carbon (C): 0.23 wt% to 0.35 wt%, silicon (Si): 0.05 wt% to 0.5 wt%, manganese (Mn): 0.3 wt% to 2.3 wt%, phosphorus (P): more than 0 wt% and not more than 0.02 wt%, sulfur (S): more than 0 wt% and not more than 0.005 wt%, aluminum (Al): 0.01 wt% to 0.05 wt%, chromium (Cr): more than 0 wt% and not more than 0.8 wt%, molybdenum (Mo): more than 0 wt% and not more than 0.4 wt%, titanium (Ti): 0.01 wt% to 0.1 wt%, boron (B): 0.001 wt% to 0.005 wt%, a balance of iron (Fe), and unavoidable impurities,

   wherein a final microstructure of the cold-rolled steel sheet comprises cementite, a transition carbide, and a fine precipitate, the transition carbide comprising ε-carbide having an atomic ratio of a substitutional element selected from Fe, Mn, Cr, and Mo, to C of 2.5:1, or η-carbide having an atomic ratio of the substitutional element to C of 2:1, and the fine precipitate having an atomic ratio of an alloying element selected from Mo and Ti, to C of 1:1, and wherein the cold-rolled steel sheet has a yield point (YP) of 1170 MPa or more, a tensile strength (TS) of 1400 MPa or more, an elongation (El) of 3.0% or more, a yield ratio of 70% or more, and a bendability (R/t) of 4.0 or less.

2. The cold-rolled steel sheet of claim 1, wherein the cementite, the transition carbide, and the fine precipitate each has an average size of 50 nm or less and an average aspect ratio of 4.0 or less.

3. The cold-rolled steel sheet of claim 1, wherein the cementite, the transition carbide, and the fine precipitate each has an area fraction of more than 0% and not more than 5%.

4. The cold-rolled steel sheet of claim 1, wherein the final microstructure consists of only tempered martensite.

5. The cold-rolled steel sheet of claim 1, wherein the final microstructure consists of tempered martensite, ferrite, and bainite, the tempered martensite having an area fraction of 80% or more and less than 100%, and the ferrite and bainite having an area fraction of more than 0% and not more than 20%.

6. A method of manufacturing a cold-rolled steel sheet, the method comprising (a) hot-rolling a steel material consisting of carbon (C): 0.23 wt% to 0.35 wt%, silicon (Si): 0.05 wt% to 0.5 wt%, manganese (Mn): 0.3 wt% to 2.3 wt%, phosphorus (P): more than 0 wt% and not more than 0.02 wt%, sulfur (S): more than 0 wt% and not more than 0.005 wt%, aluminum (Al): 0.01 wt% to 0.05 wt%, chromium (Cr): more than 0 wt% and not more than 0.8 wt%, molybdenum (Mo): more than 0 wt% and not more than 0.4 wt%, titanium (Ti): 0.01 wt% to 0.1 wt%, boron (B): 0.001 wt% to 0.005 wt%, and a balance of iron (Fe); (b) cold-rolling the hot-rolled steel material; and (c) sequentially performing annealing, first heat treatment, and second heat treatment processes on the cold-rolled steel material,

   wherein a final microstructure of the cold-rolled steel sheet obtained by performing steps (a) to (c) comprises cementite, a transition carbide, and a fine precipitate, the transition carbide comprising ε-carbide having an atomic ratio of a substitutional element selected from Fe, Mn, Cr, and Mo, to C of 2.5:1, or η-carbide having an atomic ratio of the substitutional element to C of 2:1, and the fine precipitate having an atomic ratio of an alloying element selected from Mo and Ti, to C of 1:1, and
   wherein the cementite is formed during the first heat treatment process, the transition carbide is formed during the second heat treatment process, and the fine precipitate is formed during the hot-rolling.

7. The method of claim 6, wherein step (a) is performed under conditions of a reheating temperature of 1150°C to 1300°C, a finishing delivery temperature of 800°C to 1000°C, and a coiling temperature of 500°C to 650°C, and wherein step (c) is performed under conditions of an annealing temperature of 800°C to 900°C, a first heat treatment temperature of 100°C to 300°C, and a second heat treatment temperature of 100°C to 210°C.

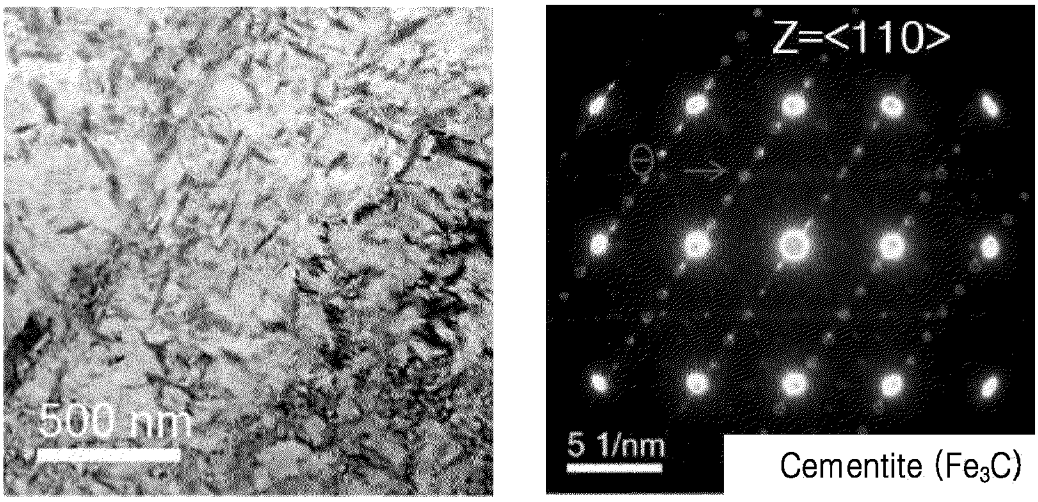
8. The method of claim 6, wherein step (a) is performed under conditions of a reheating temperature of 1150°C to 1300°C, a finishing delivery temperature of 800°C to 1000°C, and a coiling temperature of 500°C to 650°C, and wherein step (c) comprises performing plating and is performed under conditions of an annealing temperature of 800°C to 900°C, a first heat treatment temperature of 450°C to 600°C, and a second heat treatment temperature of 100°C to 210°C.

9. The method of claim 6, wherein, in step (c), cooling is performed to a first heat treatment temperature after the annealing process, and then the first heat treatment process is performed.

10. The method of claim 6, wherein, in step (c), cooling is performed to room temperature after the first heat treatment process, and then the second heat treatment process is performed by performing heating.

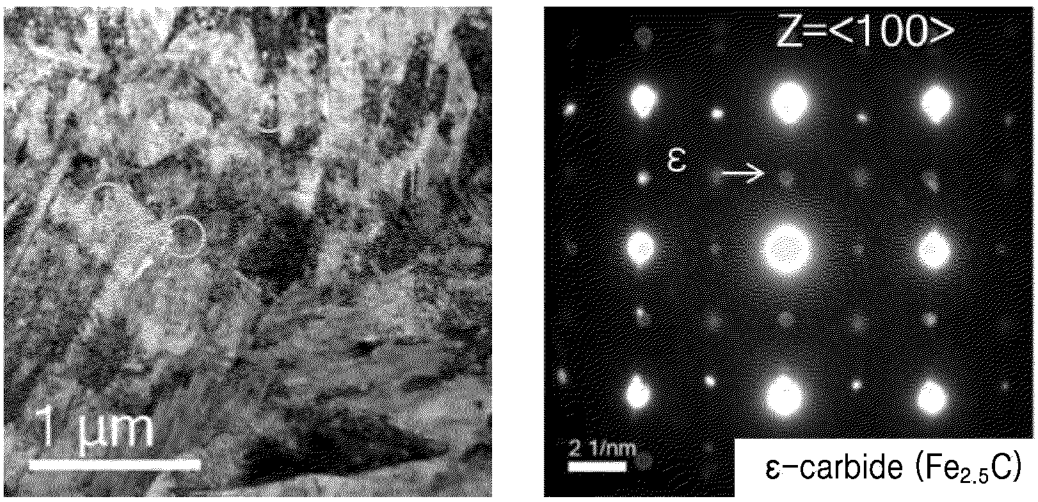
11. The method of claim 7 or 8, wherein the second heat treatment process comprises a process of maintaining the second heat treatment temperature for 3 hours to 20 hours.

FIG. 1



(a) (b)

FIG. 2



(a) (b)

FIG. 3

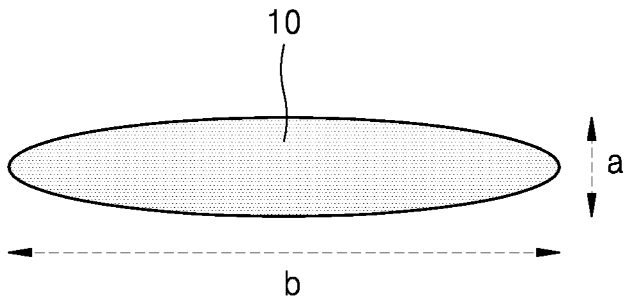

10
a
b

FIG. 4

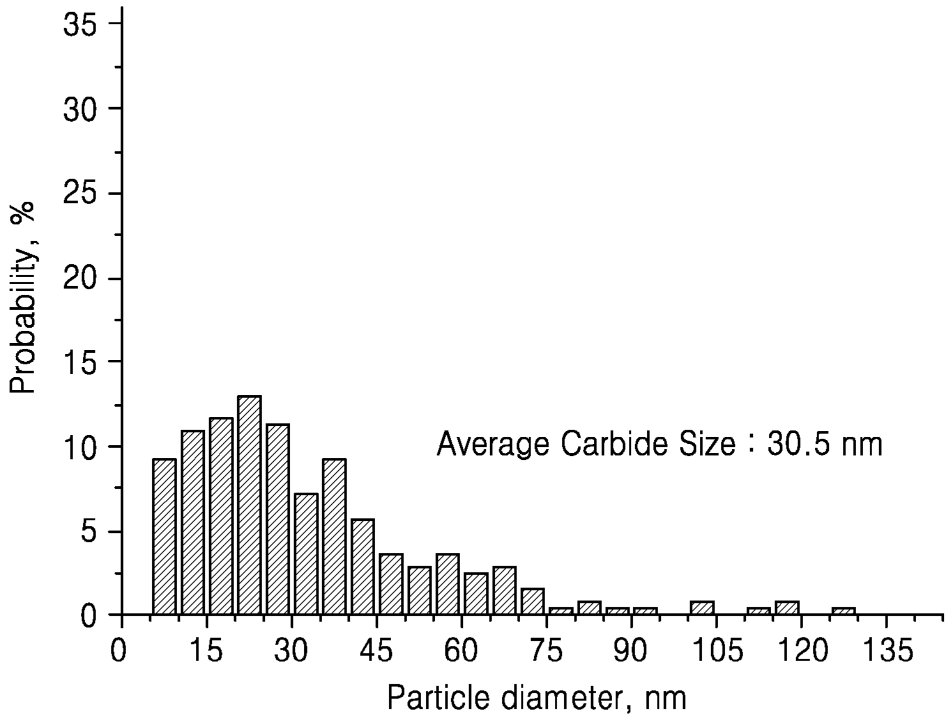

Probability, %
35
30
25
20
15
10
5
0
Average Carbide Size : 30.5 nm
0
15
30
45
60
75
90
105
120
135
Particle diameter, nm

FIG. 5

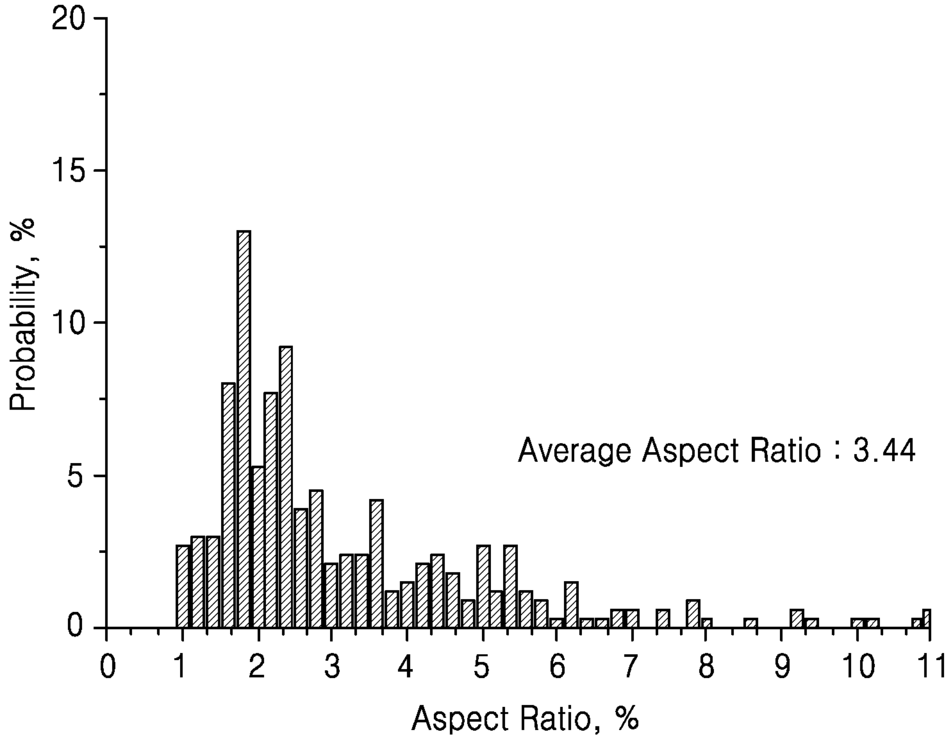

20
15
10
5
0
Probability, %
Average Aspect Ratio : 3.44
0
1
2
3
4
5
6
7
8
9
10
11
Aspect Ratio, %

FIG. 6

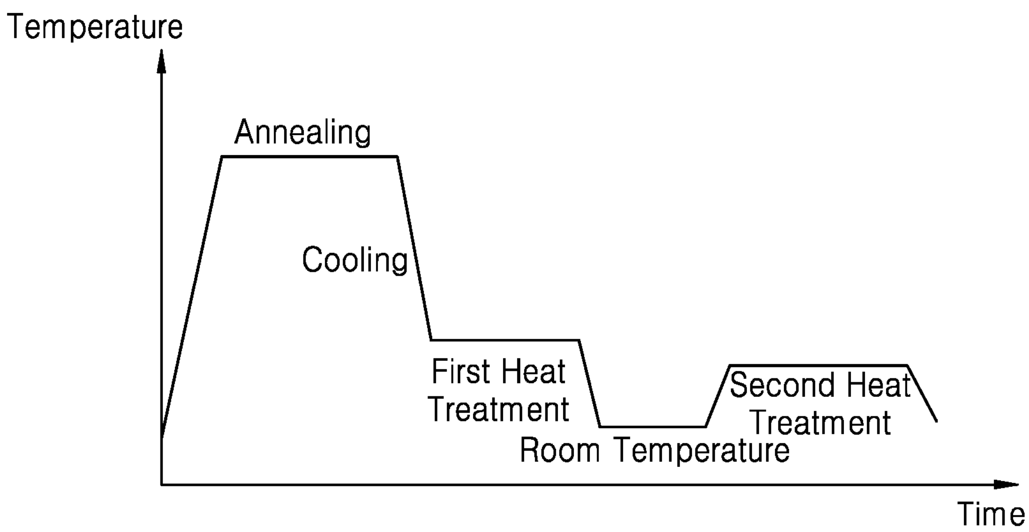

Temperature
Annealing
Cooling
First Heat
Treatment
Second Heat
Treatment
Room Temperature
Time

FIG. 7

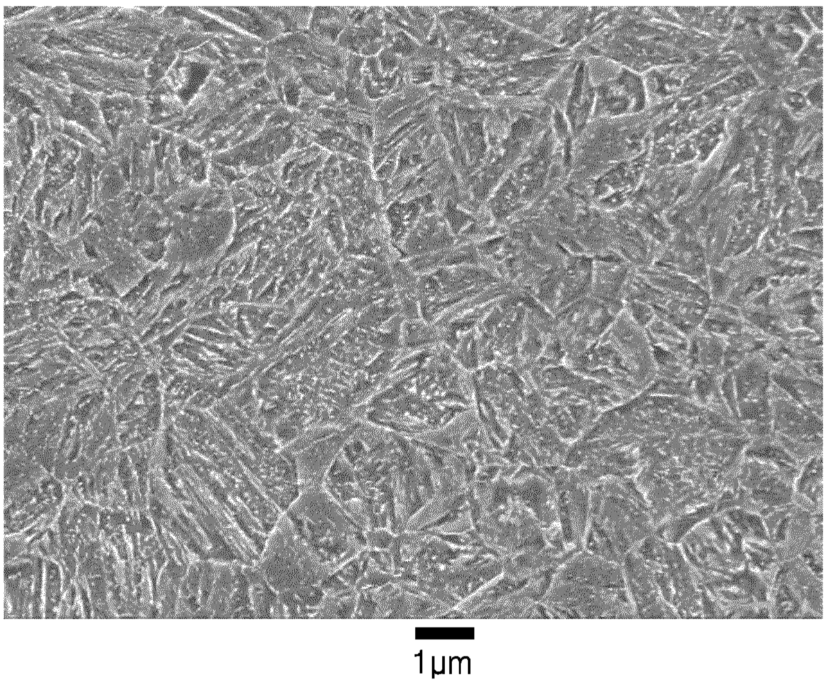


FIG. 8

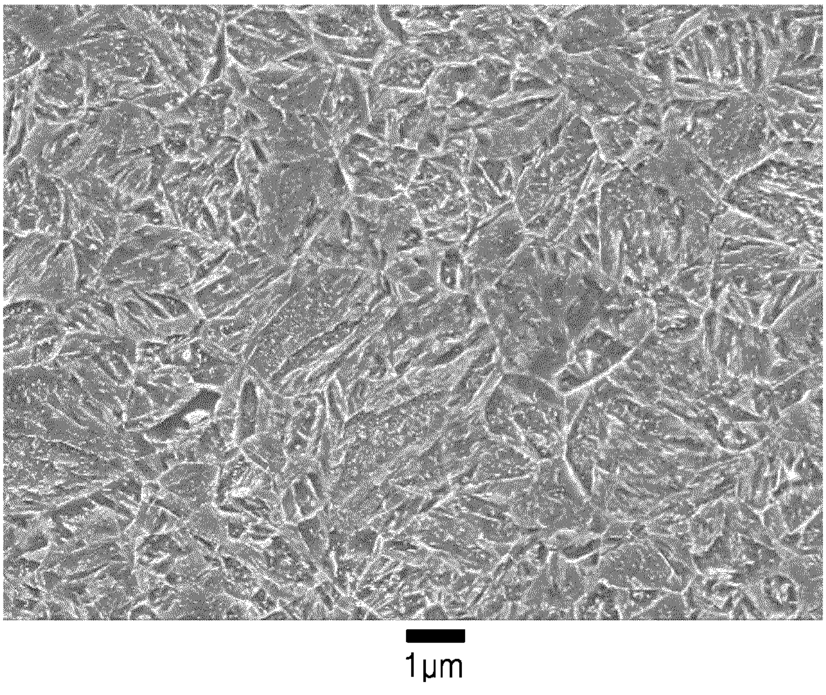


FIG. 9

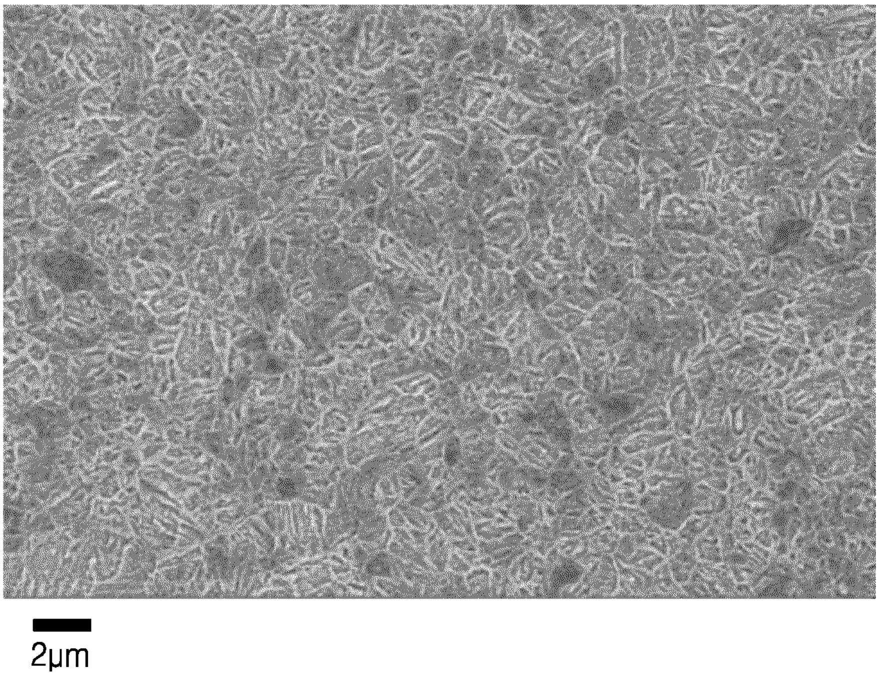
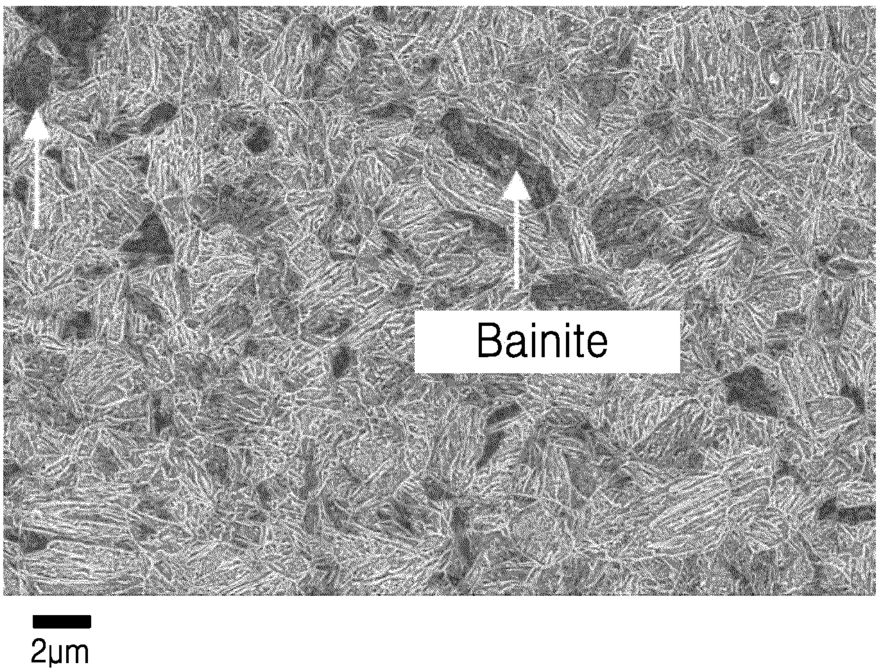


FIG. 10



INTERNATIONAL SEARCH REPORT

International application No.
PCT/KR2022/019583

A. CLASSIFICATION OF SUBJECT MATTER

C22C 38/38(2006.01)i; **C22C 38/06**(2006.01)i; **C22C 38/22**(2006.01)i; **C22C 38/28**(2006.01)i; **C22C 38/32**(2006.01)i; **C21D 8/02**(2006.01)i; **C21D 9/46**(2006.01)i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

C22C 38/38(2006.01); C21D 8/02(2006.01); C21D 8/04(2006.01); C21D 9/46(2006.01); C22C 38/00(2006.01)

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

Korean utility models and applications for utility models: IPC as above
Japanese utility models and applications for utility models: IPC as above

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

eKOMPASS (KIPO internal) & keywords: 냉연 강판(cold rolling steel plate), 열간압연(hot rolling), 냉간압연(cold rolling), 소둔(annealing), 제1열처리(first heat treatment), 제2열처리(second heat treatment), 탄소(C), 규소(Si), 망간(Mn), 인(P), 황(S), 알루미늄(Al), 크롬(Cr), 몰리브덴(Mo), 티타늄(Ti), 붕소(B)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	KR 10-2020-0134397 A (HYUNDAI STEEL COMPANY) 02 December 2020 (2020-12-02) See paragraph [0052]; claims 1-6; and figure 2.	1-11
A	KR 10-2011-0042369 A (JFE STEEL CORPORATION) 26 April 2011 (2011-04-26) See paragraphs [0106]-[0122].	1-11
A	JP 2007-254887 A (KOBE STEEL LTD.) 04 October 2007 (2007-10-04) See paragraphs [0049]-[0063].	1-11
A	KR 10-2012-0032326 A (POSCO) 05 April 2012 (2012-04-05) See paragraphs [0021]-[0029].	1-11
A	KR 10-2012-0113588 A (HYUNDAI HYSCO CO., LTD.) 15 October 2012 (2012-10-15) See claims 1-7.	1-11

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

* Special categories of cited documents:
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- "D" document cited by the applicant in the international application
- "E" earlier application or patent but published on or after the international filing date
- "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
- "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
- "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
- "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
- "&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
23 March 2023	**24 March 2023**

Name and mailing address of the ISA/KR	Authorized officer
Korean Intellectual Property Office **Government Complex-Daejeon Building 4, 189 Cheongsa-ro, Seo-gu, Daejeon 35208**	
Facsimile No. **+82-42-481-8578**	Telephone No.

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/KR2022/019583

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KR 10-2012-0113588 A	15 October 2012	None	

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REFERENCES CITED IN THE DESCRIPTION

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