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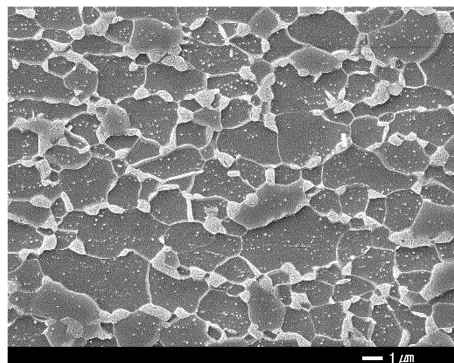
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(54) **ECO-FRIENDLY STEEL SHEET HAVING HIGH STRENGTH AND HIGH FORMABILITY, AND
METHOD FOR MANUFACTURING SAME**

(57) The present invention relates to a steel sheet used in automobiles, etc., and to a steel sheet that has high strength and high formability and is eco-friendly manufactured, and a manufacturing method therefor.

[FIG. 4]



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Description

[Technical Field]

5 **[0001]** The present disclosure relates to a steel sheet used in automobiles, etc., and to a steel sheet that has high strength and high formability and is eco-friendly manufactured, and a manufacturing method therefor.

[Background Art]

10 **[0002]** Improving fuel efficiency and durability is an important issue that automakers should address. To this end, by utilizing thin, high-strength steel, it may be possible to simultaneously improve various issues of the environment, fuel efficiency, impact resistance, and durability. For example, the Insurance Institute for Highway Safety in the United States has gradually strengthened crash safety regulations to protect occupants, and have required harsh collision components such as 25% small overlap since 2013. These solutions include reducing the weight of automobiles, and to reduce the weight thereof, high strength of a steel material is required and high formability is also required.

15 **[0003]** Specifically, as regulations on the impact safety of automobiles are expanding, steel with excellent strength is being used for structural members such as a member, a seat rail, and a pillar to improve the impact resistance of a vehicle body. These components have complex shapes depending on stability and design, and are mainly manufactured by forming in press molds, which may require high strength and a high level of formability.

20 **[0004]** However, as the strength of steel increases, it has advantageous characteristics in absorbing impact energy. However, in general, when the strength increases, there may be a problem in which elongation decreases and molding processability deteriorates. In addition, when the yield strength is excessively high, there may be a problem in which the inflow of a material from the mold is reduced during molding, resulting in poor formability. Accordingly, the automobile industry is requesting the steel industry to develop steel materials with excellent strength and formability, that is, excellent strength and elongation balance (TS*E1).

25 **[0005]** Steel companies have developed various products to meet these demands. For example, the products may include dual phase steel (DP steel), transformation induced plasticity steel (TRIP steel), complex phase steel (CP steel), and ferrite-bainite steel (FB steel), and the products are manufactured through iron making, steel making, casting, hot rolling, cold rolling, and annealing processes.

30 **[0006]** Meanwhile, demands for environmental protection are increasing around the world, and companies are concentrating their capabilities on Environmental, Social, Governance (ESG) factors by reducing carbon dioxide (CO₂) emissions. Several steel companies have announced plans to achieve zero carbon dioxide emissions, and a conventional method of coke reduction has the problem of high carbon dioxide emissions, so that there is high interest in eco-friendly technologies such as DRI technology that performs reduction using hydrogen.

35 **[0007]** Normally, the energy required for cold rolling and annealing uses by-product gas of an iron making process, but when eco-friendly technologies such as DRI are applied, by-product gas is reduced and energy costs increase, and thus, to save energy, technology to lower the heat treatment temperature is required. Furthermore, when the by-product gas is used to create a heat source, this may also generate CO₂, so that it may be necessary to minimize the amount used.

40 [Summary of Invention]

[Technical Problem]

45 **[0008]** An aspect of the present disclosure is to provide a steel sheet that has high strength and high formability and is eco-friendly manufactured by reducing the generation of carbon dioxide (CO₂), and a manufacturing method therefor.

[0009] The object of the present disclosure is not limited to the above-described matters. An additional object of the present disclosure is described throughout the specification, and, a person of ordinary skill in the art to which the present disclosure belongs will have no difficulty in understanding the additional object of the present disclosure from the contents described in the specification of the present disclosure.

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[Solution to Problem]

[0010] According to an aspect of the present disclosure, provided is an eco-friendly steel sheet having high strength and high formability, comprising: by wt%, C: 0.05 to 0.10%, Si: 0.3% or less (excluding 0%), Mn: 2.0 to 2.5%, Ti: 0.05% or less (excluding 0%), Nb: 0.1% or less (excluding 0%), Cr: 1.5% or less (excluding 0%), P: 0.1% or less, S: 0.01% or less, and a balance of Fe, and inevitable impurity elements,

wherein a microstructure comprises, in area fraction, 15 to 35% of a hard phase and 65 to 85% of a soft phase.

[0011] According to another aspect of the present disclosure, provided is a method for manufacturing an eco-friendly

steel sheet having high strength and high formability, the method comprising: manufacturing a hot-rolled steel sheet using a steel slab comprising, by wt%, C: 0.05 to 0.10%, Si: 0.3% or less (excluding 0%), Mn: 2.0 to 2.5%, Ti: 0.05% or less (excluding 0%), Nb: 0.1% or less (excluding 0%), Cr: 1.5% or less (excluding 0%), P: 0.1% or less, S: 0.01% or less, and a balance of Fe, and inevitable impurity elements;

manufacturing a cold-rolled steel sheet by cold-rolling the hot-rolled steel sheet at a reduction ratio of 70 to 90%; heating and maintaining the cold-rolled steel sheet to a temperature within a range of A_{c1} to $A_{c1}+50^{\circ}\text{C}$; and cooling the cold-rolled steel sheet slowly at an average cooling rate of 1 to 10°C/s to a temperature within a range of 650 to 700°C , and then rapidly cooling the cold-rolled steel sheet to a temperature within a range of 300 to 580°C at an average cooling rate of 5 to 50°C/s .

[Advantageous Effects of Invention]

[0012] According to the present disclosure, it may be possible to provide a steel sheet having high strength and formability, especially an excellent balance between strength and ductility ($TS*EI$), processing defects such as cracks or wrinkles may be prevented during press forming, so that the steel sheet may be suitably applied to components such as a structural structure that require processing into a complex shape. Furthermore, the present disclosure may be effective in manufacturing automobile components having excellent collision resistance in which cracks are not frequently formed, when a vehicle inevitably crashes.

[0013] Furthermore, the present disclosure may provide a steel sheet that is eco-friendly manufactured by reducing the generation of carbon dioxide (CO_2) by lowering an annealing heat treatment temperature during a manufacturing process, and a manufacturing method therefor.

[0014] Various useful advantages and effects of the present disclosure are not limited to the above and may be relatively easily understood in a process of describing embodiments of the present invention.

[Brief Description of Drawings]

[0015]

FIG. 1 is a graph illustrating a heat treatment stage of a continuous annealing process.

FIG. 2 is an arbitrary Fe-C state view illustrating a relationship between a component and an annealing temperature.

FIG. 3 is a schematic diagram illustrating an example of a method of measuring an aspect ratio of a hard phase.

FIG. 4 is an image obtained by observing a microstructure of Inventive Example 1 of embodiments.

FIG. 5 is an image obtained by observing a microstructure of Comparative Example 1 of embodiments.

FIG. 6 is an image obtained by observing a microstructure of Comparative Example 4 of embodiments.

[Best Mode for Invention]

[0016] The terms used in the present specification are intended to describe specific embodiments and are not intended to limit the present disclosure. In addition, singular forms used in the present specification include plural forms unless the relevant definition indicates the opposite meaning.

[0017] The meaning of "include" and "comprise" used in the specification specifies the configuration and does not exclude the existence or addition of other configurations.

[0018] Unless otherwise defined, all terms including technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which example embodiments of the present disclosure belong. It will be further understood that the terms, such as those defined in commonly used dictionaries, should be interpreted as having meanings consistent with the relevant technical literature and the currently disclosed content.

[0019] Representative high-strength steel used as automotive materials includes dual phase steel (DP steel), transformation induced plasticity steel (TRIP steel), complex phase steel (CP steel), and ferrite-bainite steel (FB steel).

[0020] Among these, DP steel includes a soft phase and a hard phase, and may include partial residual austenite. Such DP steel has low yield strength and high tensile strength, resulting in a low yield ratio (YR), and the DP steel has high work hardening rate, high ductility, excellent continuous yield behavior, excellent room temperature aging resistance, excellent bake hardenability, and in some cases, the DP steel has excellent hole expandability.

[0021] However, in order to secure ultra-high tensile strength of 780 MPa or more, a fraction of a hard phase such as martensite, which is advantageous for strength improvement, needs to be increased, and in this case, there may be a problem in that a yield strength may increase to cause defects such as cracks during press forming. Accordingly, it may be decisive to secure excellent properties in both strength and elongation.

[0022] Accordingly, the inventors of the present invention have increased a reduction ratio of cold rolling performed

at room temperature to finely disperse a structure and adjust a heat treatment temperature, and have increased recrystallization driving force to induce sufficient recrystallization of a soft phase which affects the ductility of steel. In addition, by ensuring the miniaturization and uniform distribution of a hard phase, which is advantageous for securing strength, the inventors have confirmed that an excellent balance of strength and elongation may be secured, and have completed the present invention.

[0023] On the other hand, in order to manufacture the DP steel, a steel slab is manufactured, and then this steel slab is manufactured through hot rolling, cold rolling, and annealing processes. The cold rolling process is a process mainly performed during the manufacture of a cold rolled steel sheet, which refer to rolling a hot rolled coil at a constant reduction ratio at room temperature. Typically, the cold rolling is performed in a Tandem Cold Rolling Mill (TCM). The TCM has the advantage of mass production at low manufacturing costs. On the other hand, in the annealing process, by heating and maintaining a steel sheet (cold rolled steel sheet) in a constant temperature section in a heating furnace, hardness may be lowered and workability may be improved through recrystallization and phase deformation. A steel sheet that has not undergone the annealing process has a high hardness, particularly a surface hardness, and have insufficient workability, while a steel sheet on which the annealing process has been performed has a recrystallization structure, thereby lowering hardness, yield point, and tensile strength.

[0024] The annealing process requires a large amount of energy because a steel sheet at room temperature is heated and needs to be heated to a high temperature, which may increase energy costs, and may incur costs for purification of gases generated after combustion and be not environmentally friendly due to an inevitable increase in the generation of pollutants such as carbon dioxide (CO₂). Accordingly, the inventors of the present disclosure have studied ways to lower a heating temperature of the annealing process, and have studied ways to minimize the generation of pollutants such as carbon dioxide (CO₂) during an energy production process and a post-combustion treatment process. Accordingly, to save energy in heat treatment processes with a high CO₂ generation rate and high energy costs, the present inventors have developed a technology of securing excellent materials even when a heat treatment temperature is lowered by increasing a cold reduction ratio during cold rolling after hot rolling, and have achieved the present invention.

[0025] That is, the present disclosure provides a steel sheet that is not only eco-friendly by applying the low annealing temperature to save energy and minimize pollutants, but also has an excellent balance of strength and elongation, and a manufacturing method therefor.

[0026] First, a steel sheet, which is an embodiment of the present disclosure, will be described in detail. An alloy composition of the steel sheet includes, by wt%, C: 0.05 to 0.10%, Si: 0.3% or less (excluding 0%), Mn: 2.0 to 2.5%, Ti: 0.05% or less (excluding 0%), Nb: 0.1% or less (excluding 0%), Cr: 1.5% or less (excluding 0%), P: 0.1% or less, S: 0.01% or less, and a balance of Fe, and inevitable impurity elements. The alloy composition is described in detail as follows. Unless otherwise specified in the present disclosure, the content of each element is based on wt%.

Carbon (C): 0.05 to 0.10%

[0027] Carbon (C) is an important element added for solid solution strengthening, and Carbon (C) is combined with precipitated elements to form fine precipitates, thereby contributing to improving the strength of steel. When the content of Carbon (C) exceeds 0.10%, hardenability increases and strength increases excessively as martensite is formed during cooling when manufacturing steel, which may result in a decrease in elongation. Furthermore, since weldability deteriorates, there may be a risk of welding defects occurring when processing into components. When the content of Carbon (C) is less than 0.05%, it may be difficult to secure a target level of strength. More advantageously, the content thereof may be 0.06 to 0.08%.

Silicon (Si): 0.3% or less (excluding 0%)

[0028] Silicon (Si) is a ferrite stabilizing element, and is advantageous to secure a target level of ferrite fraction by promoting ferrite transformation. Furthermore, Silicon (Si) is effective in increasing the strength of ferrite due to excellent solid solution strengthening ability, and is a useful element in securing strength without reducing the ductility of steel. When a content of Silicon (Si) exceeds 0.3%, a solid solution strengthening effect becomes excessive to reduce ductility, which may cause surface scale defects, may have a negative impact on plating surface quality, and may impair chemical treatment properties. More advantageously, the content thereof may be 0.1% or less.

Manganese (Mn): 2.0 to 2.5%

[0029] Manganese (Mn) is an element that prevents hot embrittlement caused by the formation of FeS by precipitating sulfur (S) in steel into MnS, and is advantageous for solid solution strengthening the steel. When a content of Manganese (Mn) is less than 2.0%, Manganese (Mn) may not obtain the above-described effect, and may find it difficult to secure a target level of strength. On the other hand, when the content of Manganese (Mn) exceeds 2.5%, problems such as

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weldability and hot rolling are likely to occur, and at the same time, there may be a risk that ductility will decrease as martensite is formed more easily due to an increase in hardenability. Furthermore, there may be a problem in that excessive formation of Mn oxide bands (Mn-bands) in a structure may increase the risk of defects such as processing cracks. Additionally, there may be a problem in that Mn oxide may be eluted to a surface thereof during annealing, greatly impairing plating properties. More advantageously, the content thereof may be 2.2 to 2.4%.

Titanium (Ti): 0.05% or less (excluding 0%)

[0030] Titanium (Ti) is an element that forms fine carbides and contributes to securing yield strength and tensile strength. Furthermore, Titanium (Ti) has the effect of precipitating N in steel into TiN and suppressing the formation of AlN in Al, which is inevitably present in the steel, thereby reducing the possibility of cracks occurring during continuous casting. When a content of Titanium (Ti) exceeds 0.05%, coarse carbides may precipitate, and there may be a risk of a decrease in strength and elongation due to a decrease in the amount of carbon in the steel. Furthermore, there may be a risk of nozzle clogging during continuous casting, and the manufacturing costs may increase. Accordingly, Titanium (Ti) may be, preferably, 0.05% or less, and may be, preferably, more than 0%.

Niobium (Nb): 0.1% or less (excluding 0%)

[0031] Niobium (Nb) is an element that segregates at austenite grain boundaries, suppresses coarsening of austenite grains during an annealing heat treatment, and forms fine carbides, contributing to strength improvement. When the content of Niobium (Nb) exceeds 0.1%, coarse carbides may be precipitated, the strength and elongation may be inferior due to the reduction of carbides in steel, and manufacturing costs may increase. Niobium (Nb) may be, preferably, 0.1% or less, and may be, preferably, more than 0%.

Chromium (Cr): 1.5% or less (excluding 0%)

[0032] Chromium (Cr) is an element that facilitates the formation of bainite, suppresses the formation of martensite during an annealing heat treatment, and forms fine carbides, contributing to strength improvement. When a content of Chromium (Cr) exceeds 1.5%, bainite may be excessively formed to reduce elongation, and when carbides are formed at grain boundaries, strength and elongation may deteriorate, and manufacturing costs may increase. Accordingly, Chromium (Cr) may be preferably included in an amount of 1.5% or less, and Chromium (Cr) may be, preferably, more than 0%.

Phosphorus (P): 0.1% or less

[0033] Phosphorus (P) is a substitutional element with the greatest solid solution strengthening effect, and is an element that improves in-plane anisotropy and is advantageous in securing strength without significantly reducing formability. However, when Phosphorus (P) is added excessively, the possibility of brittle fracture may occur significantly, increasing the possibility of sheet fracture of a slab during hot rolling, and plating surface characteristics may deteriorate. Accordingly, the content of Phosphorus (P) may be, preferably, 0.1% or less, and the amount of 0% may be excluded in consideration of a level of unavoidable inclusion.

Sulfur (S): 0.01% or less

[0034] Sulfur (S) is an element that is inevitably added as an impurity element in steel, and since Sulfur (S) reduces ductility, it may be desirable to keep the content of Sulfur (S) as low as possible. Specifically, since Sulfur (S) has the problem of increasing the possibility of causing red heat embrittlement, it may be desirable to control the content thereof to 0.01% or less. However, the amount of 0% may be excluded in consideration of a level of unavoidable inclusion.

[0035] As a remainder, Fe may be included, and unintended impurities may inevitably be introduced from raw materials or the surrounding environment during a normal manufacturing process, which may not be excluded. Since these impurities may be known to anyone skilled in the art during the manufacturing process, all of them are not specifically mentioned in this specification.

[0036] A high-strength steel sheet of the present disclosure has a microstructure including a hard phase and a soft phase, and specifically, by maximizing ferrite recrystallization through an optimized annealing process, ultimately, the steel sheet may include a structure in which bainite and martensite phases as hard phases are uniformly distributed in a recrystallized ferrite matrix. In the microstructure, the hard phase is mainly martensite, and refers to a mixed phase including a small amount of bainite, and the soft phase refers to a ferrite phase. In a structure comprised of a soft phase and a hard phase, the soft phase determines the formability, and the hard phase determines the strength.

[0037] The hard phase may include 15 to 35% of the area fraction. When the fraction of the hard phase is significantly high, the strength is high but the elongation is low, and when the fraction of the soft phase is high, the elongation is high but the strength is low. To secure the strength of 780 MPa or more provided by the present disclosure, the hard phase may include, preferably, 15% or more in area fraction, and to ensure formability, it is desirable that the hard phase does not exceed 35%.

[0038] To secure appropriate strength and formability at the same time, the soft phase may include, preferably, 65 to 85% in area fraction. The ferrite of the soft phase may be divided into recrystallized ferrite and non-recrystallized ferrite. As illustrated in Figure 3, a difference between the recrystallized ferrite and the non-recrystallized ferrite may be distinguished by an aspect ratio of the grain size to a rolling direction. As illustrated in FIG. 3B, the non-recrystallized ferrite has a large aspect ratio, and when the non-recrystallized ferrite is analyzed in detail, a linear deformation structure in the ferrite grains is observed. On the other hand, since the recrystallized ferrite is advantageous in securing formability, the recrystallized ferrite in the soft phase may be 60% or more, and the non-recrystallized ferrite is a soft phase, but when the fraction thereof is high, formability is reduced, and thus, the non-recrystallized ferrite may be 5% or less.

[0039] Meanwhile, an aspect ratio of the hard phase may be 1.2 or less. As illustrated in FIGS. 3 A and 3B, the aspect ratio refers to a ratio (b/a) of a major axis (b) and a minor axis (a) of a grain size with respect to the rolling direction, and an aspect ratio of the hard phase refers to an aspect ratio of a structure formed by stretching the hard phase in the rolling direction. As the aspect ratio of the hard phase increases, bending properties, which are important for resistance to deformation in the thickness direction, are adversely affected. Additionally, as the aspect ratio of the hard phase increases, hole expandability decreases. Accordingly, since it is decisive to keep the aspect ratio of the hard phase as low as possible, it is desirable that the aspect ratio does not exceed 1.2.

[0040] The steel sheet of the present disclosure has a high tensile strength TS of 780 MPa or more and an elongation of 18% or more, thereby ensuring excellent strength and formability.

[0041] Next, an embodiment of a method for manufacturing a steel sheet of the present disclosure will be described in detail. The steel sheet of the present disclosure may be manufactured by first preparing and heating a steel slab, performing hot rolling on the steel slab, and then coiling and cooling the steel slab, followed by cold rolling and continuous annealing. Hereinafter, each step will be described in detail.

Heating Steel Slab

[0042] A steel slab having the above-described alloy composition, that is, including, by wt%, C: 0.05 to 0.10%, Si: 0.3% or less (excluding 0%), Mn: 2.0 to 2.5%, Ti: 0.05% or less (excluding 0%), Nb: 0.1% or less (excluding 0%), Cr: 1.5% or less (excluding 0%), P: 0.1% or less, S: 0.01% or less, and a balance of Fe, and inevitable impurity elements, is prepared and then heated. This is to smoothly perform a subsequent hot rolling process and secure target physical properties of the steel sheet, and the heating process conditions are not particularly limited, and any method or condition commonly used in the technical field to which the present disclosure pertains may be used. As an example, the steel slab may be heated in a temperature within a range of 1100 to 1300°C.

Hot Rolling

[0043] The heated steel slab is hot rolled to manufacture a hot-rolled steel sheet. In this case, final hot rolling may be performed at an outlet temperature in a temperature within a range of, preferably, Ar3 to 1000°C. When the outlet temperature during the finishing hot rolling is less than Ar3, hot deformation resistance increases rapidly, the top, tail, and edge of a hot-rolled coil become single-phase regions, which may increase in-plane anisotropy, and deteriorate formability. On the other hand, when the temperature exceeds 1000°C, a rolling load is relatively reduced, which is advantageous for productivity, but there may be a risk of an occurrence of a thick oxidation scale. The final hot rolling may be performed at a temperature within a range of, more preferably, 760 to 940°C.

Coiling and Cooling

[0044] The hot-rolled steel sheet manufactured by hot rolling may be wound into a coil shape. The coiling may be performed in a temperature within a range of 400 to 700°C. When the coiling temperature is less than 400°C, the formation of excessive martensite or bainite causes excessive strength increase of the hot-rolled steel sheet, and accordingly, during subsequent cold rolling, problems such as shape defects due to load may occur. On the other hand, when the coiling temperature exceeds 700°C, a surface scale may increase and pickling properties may deteriorate.

[0045] Meanwhile, the wound hot-rolled steel sheet may be cooled to room temperature at an average cooling rate of 0.1°C/s or less (excluding 0°C/s). The wound hot-rolled steel sheet may be cooled after undergoing processes such as transport and stacking, and the process before cooling is not limited thereto. By cooling the wound hot-rolled steel sheet at a constant rate, a hot-rolled steel sheet in which carbides that serve as austenite nucleation sites are finely dispersed

may be obtained.

[0046] Then, an additional process of removing surface scale by pickling a surface of the hot-rolled steel sheet before performing subsequent cold rolling may be performed. The pickling method is not particularly limited, and it may be sufficient to use a method commonly used in the technical field to which the present disclosure pertains.

Cold Rolling

[0047] The hot-rolled steel sheet wound as above may be manufactured into a cold-rolled steel sheet by performing cold rolling at a constant reduction ratio at room temperature.

[0048] During the cold rolling, the cold rolling may be performed at a reduction ratio of 70 to 90%. When the reduction ratio of the cold rolling is less than 70%, recrystallization driving force is reduced to form ferrite coarsely, and the formation of austenite is also reduced, so that the temperature of a soaking section in an annealing furnace must be increased to ensure a sufficient austenite fraction. On the other hand, when the cold rolling reduction ratio exceeds 90%, there is a high possibility that cracks will occur at an edge of the steel sheet, and an initial thickness before rolling must be excessively thick and the number of rolling passes increases, which may result in lower productivity.

[0049] The method of performing the cold rolling is not particularly limited in the present disclosure, and any method used in the technical field to which the present disclosure pertains may be applied. For example, there is a Tandem Cold rolling mill (TCM) method and a Sendzimir rolling mill (ZRM) method. To briefly explain these, the TCM method is a reversible rolling method, which allows for low manufacturing costs and mass production and has the advantage of excellent productivity, but has the disadvantage of being somewhat limited in applying pressing force. The ZRM is a reversible batch method, which has the disadvantage of low productivity, but has the advantage of being somewhat easier to apply pressing force.

[0050] Since the reduction ratio of cold rolling is an important operating factor that improves various physical properties by improving phase transformation of steel, control of the reduction ratio is particularly decisive for ensuring quality. In the present disclosure, an appropriate method may be adopted in consideration of a product material, a size, an operating environment, and the like.

Continuous Annealing

[0051] A continuous annealing treatment may be performed on the manufactured cold-rolled steel sheet. The continuous annealing treatment may be performed, for example, in a continuous annealing furnace (CAL). An example of a heat treatment step of a continuous annealing process is graphically illustrated in FIG. 1. As illustrated in FIG. 1, a heat treatment step may be comprised of a Heating Section (HS), a Soaking Section (SS), a Slow Cooling Section (SCS), a Rapid Cooling Section (RCS), and an Over Aging Section (OAS) in the annealing furnace. Generally, since a temperature of each section is obtained by measuring a temperature attached to an end point of each section, the temperature refers to a temperature at an end of each section. For example, a Rapid Cooling Section (RCS) temperature is a temperature of a section in which the Rapid Cooling Section ends, and is indicated as 4 in FIG. 1.

[0052] In the Heating Section (HS), the steel sheet is heated at a constant temperature increase rate, and as the temperature of the steel sheet increases, recovery of dislocations, precipitation of cementite, recrystallization of ferrite, and dual-phase region reverse transformation occur. A line speed varies depending on the thickness and width of the steel sheet, and a change in microstructure for each temperature section may vary, depending on a hot rolling initial structure and a cold rolling reduction ratio.

[0053] When entering the Soaking Section (SS), the temperature is maintained constantly for a certain period of time, and in this case, depending on the annealing temperature, dual-phase region austenite or single phase region austenite reverse transformation is observed. The Soaking Section (SS) is known to be one of the sections that consumes the most energy in the annealing furnace. In the Slow Cooling Section (SCS), cooling occurs at a low cooling rate, and after the SCS, continuous cooling occurs at a high cooling rate in the Rapid Cooling Section (RCS), and some bainite may be generated during cooling depending on an RCS set temperature and degree of hardenability.

[0054] Meanwhile, FIG. 2 is an arbitrary Fe-C phase diagram, and when a temperature T1 is determined for an arbitrary component, a ratio of austenite and ferrite corresponding to the temperature may be determined by a lever rule. In other words, the temperature of the Soaking Section (SS) is closely related to phase transformation. Factors that affect phase transformation and change in a state of a substance may include a temperature, pressure, and a composition, and when the composition is determined, the phase transformation may be adjusted through the temperature and pressure. In particular, as the temperature and pressure increase, the phase transformation may proceed faster during heating in the annealing furnace. However, as the temperature increases, energy costs increases and carbon emissions such as carbon dioxide increase after combustion, making it unfriendly. In the steel manufacturing process, a variable compared to pressure is a cold reduction ratio. When the cold reduction ratio is increased at the same temperature, phase transformation progresses faster, and in an opposite concept, when the cold rolling reduction ratio is increased, the phase

transformation may be created even at low temperatures. Using this principle, in the present disclosure, the cold rolling reduction ratio is performed at 70 to 90%, which is higher than a conventional method.

[0055] A soaking section temperature in a typical annealing process is generally in the range of $Ac1+30^{\circ}C$ to $Ac3-30^{\circ}C$. However, as described above, the present disclosure enables ferrite recrystallization and austenite formation even when a heat treatment is performed at a low temperature by increasing the cold rolling reduction ratio, and an annealing process of the present disclosure may be heated and maintained to a temperature within a range of $Ac1$ to $Ac1+50^{\circ}C$. The present invention may reduce hardness and improve processability through recrystallization and phase transformation even in the above-described temperature range.

[0056] By cooling the cold-rolled steel sheet heat-treated in the above-described temperature range, a target structure may be formed, and at this time, cooling may be performed stepwise. In the present disclosure, the stepwise cooling may be performed in the Slow Cooling Section (SCS) and the Rapid Cooling Section (RCS), and for example, the cold-rolled steel sheet may be cooled slowly to a temperature within a range of 650 to $700^{\circ}C$ at an average cooling rate of 1 to $10^{\circ}C/s$, followed by rapid cooling at an average cooling rate of 5 to $50^{\circ}C/s$ to a temperature within a range of 300 to $580^{\circ}C$. By performing a slow cooling rate during slow cooling, sheet shape defects caused by a rapid temperature drop during subsequent rapid cooling may be suppressed.

[0057] When an end temperature of the slow cooling is less than $650^{\circ}C$, the diffusion activity of carbon is low due to a significantly low temperature to increase the carbon concentration in the ferrite, but as the carbon concentration in austenite decreases, the fraction of the hard phase becomes excessive, increasing the yield ratio, which increases the tendency for cracks to occur during processing. Furthermore, a temperature difference from the soaking section may significantly increase, causing a problem that a shape of the sheet becomes non-uniform. When an end temperature exceeds $700^{\circ}C$, there is a disadvantage that an excessively high cooling rate is required during subsequent cooling (rapid cooling). Furthermore, when the average cooling rate during the slow cooling exceeds $10^{\circ}C/s$, carbon diffusion may not sufficiently occur, and in consideration of productivity, the cooling may be performed at an average cooling rate of $1^{\circ}C/s$ or more.

[0058] After completing the above-described slow cooling, rapid cooling is performed. When a rapid cooling end temperature is less than $300^{\circ}C$, cooling deviations may occur in width and length directions of the steel sheet to deteriorate a sheet shape, and when the temperature exceeds $580^{\circ}C$, the hard phase may not be sufficiently secured and the strength may be lowered. On the other hand, when the average cooling rate during rapid cooling is less than $5^{\circ}C/s$, the fraction of the hard phase may increase excessively, and when the temperature exceeds $50^{\circ}C/s$, there may be a risk that the hard phase may become insufficient.

[0059] Meanwhile, in the annealing process, after cooling is completed, an over aging treatment (OAS) may be performed if necessary. The over aging treatment is a process of maintaining a rapid cooling end temperature for a certain period of time. The over aging treatment does not require any separate treatment and may be regarded as the same treatment as a type of air-cooling treatment. By performing the over aging treatment, a coil may be homogenized in the width and length directions of the coil, thereby improving shape quality. For this purpose, the over aging treatment may be performed for 200 to 800 seconds.

[Mode for Invention]

[0060] Hereinafter, embodiments of the present disclosure will be described. Various modifications to the following examples may be made by those skilled in the art without departing from the scope of the present disclosure. The following examples are for understanding of the present disclosure, and the scope of the present disclosure should not be limited to the following examples, but should be determined by the claims described below as well as their equivalents.

(Example)

[0061] After manufacturing a steel slab having the alloy composition shown in Table 1 below (unit is wt%, the remainder not illustrated in Table 1 is Fe and inevitable impurity elements), each steel slab was heated at $1200^{\circ}C$ for 1 hour, and then was subject to finish hot rolling at a finish rolling temperature of 800 to $920^{\circ}C$ to manufacture a hot-rolled steel sheet. The hot-rolled steel sheet was cooled at a cooling rate of $0.1^{\circ}C/s$ and wound at $650^{\circ}C$. Then, the wound hot-rolled steel sheet was cold-rolled at a reduction ratio of 40% and 80% to produce a cold-rolled steel sheet.

[0062] The manufactured cold-rolled steel sheet was heated to an annealing temperature within a range of 730 to $860^{\circ}C$, and a heat treatment was performed under an annealing temperature condition in Table 2. Table 2 shows the temperatures of each step of the annealing heat treatment in the Heating section (HS), the Soaking Section (SS), the Slow Cooling Section (SCS), the Rapid Cooling Section (RCS), and the Over aging Section (OAS) in FIG. 1. Meanwhile, the slow cooling (SCS section in Table 2) was performed at an average cooling rate of $3^{\circ}C/s$, and the rapid cooling (RCS section in Table 2) was performed at an average cooling rate of $20^{\circ}C/s$.

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Table 1:

Steel Type	C	Si	Mn	P	S	Cr	Ti	Nb	Ac1 (°C)
1	0.07	0.18	2.4	0.01	0.0052	0.98	0.015	0.08	719.1
2	0.092	0.27	2.41	0.011	0.004	1.02	0.042	0.04	722.3

Table 2:

Steel Type	Cold Rolling Reduction Ratio (%)	Temperature at Each Step Of Annealing Process (°C)					SS Temperature Range	Division
		HS	SS	SC S	RC S	OA S		
2	40	730	730	650	450	360	$Ac1 \leq SS \leq Ac1 + 50^\circ C$	Comparative Example 1
1	40	750	750	650	450	360	$Ac1 \leq SS \leq Ac1 + 50^\circ C$	Comparative Example 2
2	40	790	790	650	450	360	$Ac1 + 50^\circ C < SS$	Comparative Example 3
1	40	800	800	650	450	360	$Ac1 + 50^\circ C < SS$	Comparative Example 4
2	40	820	820	650	450	360	$Ac1 + 50^\circ C < SS$	Comparative Example 5
1	40	840	840	650	450	360	$Ac1 + 50^\circ C < SS$	Comparative Example 6
1	40	860	860	650	450	360	$Ac1 + 50^\circ C < SS$	Comparative Example 7
1	80	730	730	650	450	360	$Ac1 \leq SS \leq Ac1 + 50^\circ C$	Inventive Example 1
2	80	750	750	650	450	360	$Ac1 \leq SS \leq Ac1 + 50^\circ C$	Inventive Example 2
2	80	770	770	650	450	360	$Ac1 \leq SS \leq Ac1 + 50^\circ C$	Inventive Example 3
2	80	790	790	650	450	360	$Ac1 + 50^\circ C < SS$	Comparative Example 8
1	80	810	810	650	450	360	$Ac1 + 50^\circ C < SS$	Comparative Example 9
2	80	830	830	650	450	360	$Ac1 + 50^\circ C < SS$	Comparative Example 10
1	80	850	850	650	450	360	$Ac1 + 50^\circ C < SS$	Comparative Example 11

[0063] A microstructure of each steel sheet manufactured by the above-described method was observed, mechanical properties and plating properties were evaluated, and results thereof are shown in Table 3 below.

[0064] In this case, a tensile test for each specimen was performed at a strain rate of 0.01/s after collecting a tensile specimen of size JIS No. 5 in a vertical direction of a rolling direction.

[0065] Furthermore, non-crystallized ferrite in the structure phase was observed through the scanning electron microscope (SEM) of 5,000X magnification after nital etching. In this case, sub grains observed in normal non-crystallized ferrite from the observed grain shape on the ferrite or particles stretched in the rolling direction were analyzed with non-crystallized ferrite, and a fraction thereof was measured. For other phases, each fraction was measured using the SEM

and an image analyzer after nital etching. An aspect ratio of the hard phase was measured by measuring a ratio of a width (a) and a length (b) with respect to the rolling direction as illustrated in FIG. 3, which is a commonly used method. [0066]

Table 3:

Steel Type	Microstructure Area Fraction (%)			Hard Phase Aspect Ratio	Mechanical property				Division
	Recrystallized F	Non-recrystallized F	Hard Phase		YS (MPa)	TS (MPa)	Yield Ratio	elongation (%)	
2	7	65	28	3.1	611	1325	0.46	9.8	Comparative Example 1
1	16	49	35	2.8	602	1135	0.53	10.5	Comparative Example 2
2	26	26	48	2.5	683	1048	0.65	11.3	Comparative Example 3
1	28	18	54	2.1	736	1072	0.69	14	Comparative Example 4
2	26	9	65	1.9	779	1087	0.72	7.7	Comparative Example 5
1	12	3	85	1.2	804	1109	0.72	7.6	Comparative Example 6
1	5	1	94	1.19	809	1125	0.72	8.9	Comparative Example 7
1	71	5	24	1.1	577	782	0.74	22.7	Inventive Example 1
2	69	1	30	1.08	408	830	0.49	20.7	Inventive Example 2
2	65	0	35	1.05	543	965	0.56	18.1	Inventive Example 3
2	57	0	43	1.05	667	1055	0.63	13.1	Comparative Example 8
1	45	0	55	1.03	720	1078	0.67	12.7	Comparative Example 9
2	25	0	75	1.01	769	1089	0.71	8.3	Comparative Example 10
1	18	0	82	1.01	836	1128	0.74	7.3	Comparative Example 11

[0067] In Table 3, F refers to ferrite, YS refers to a yield strength, and TS refers to tensile strength.

[0068] As shown in Tables 1 to 3, in Inventive Examples 1 to 3, which satisfy the composition of the steel alloy and the manufacturing conditions, particularly, all of the suggestions of the present disclosure in the continuous annealing process, a microstructure required even at a low annealing temperature is obtained, and an eco-friendly manufacturing process due to good physical properties, high strength, excellent elongation, and low annealing temperature may be provided.

[0069] FIG. 4 is an SEM image of the microstructure of Inventive Example 1, in which ferrite is recrystallized by 60% or more and a hard phase has a round shape with an aspect ratio of 1.2 or less.

[0070] In Comparative Examples 1 to 2, since the reduction ratio is low, when the annealing temperature decreases, ferrite recrystallization may be insufficient, and austenite may be formed quickly during heating to ensure strength, but to cause a problem of low elongation. Specifically, Comparative Example 2 was subjected to the same heat treatment

as Invention Example 2, but due to the low reduction ration, recrystallization does not occur smoothly, and the fraction of recrystallization ferrite decreases, which may result in poor elongation. FIG. 5 is an SEM image of the microstructure of Comparative Example 1, and a plurality of recrystallized ferrite are observed.

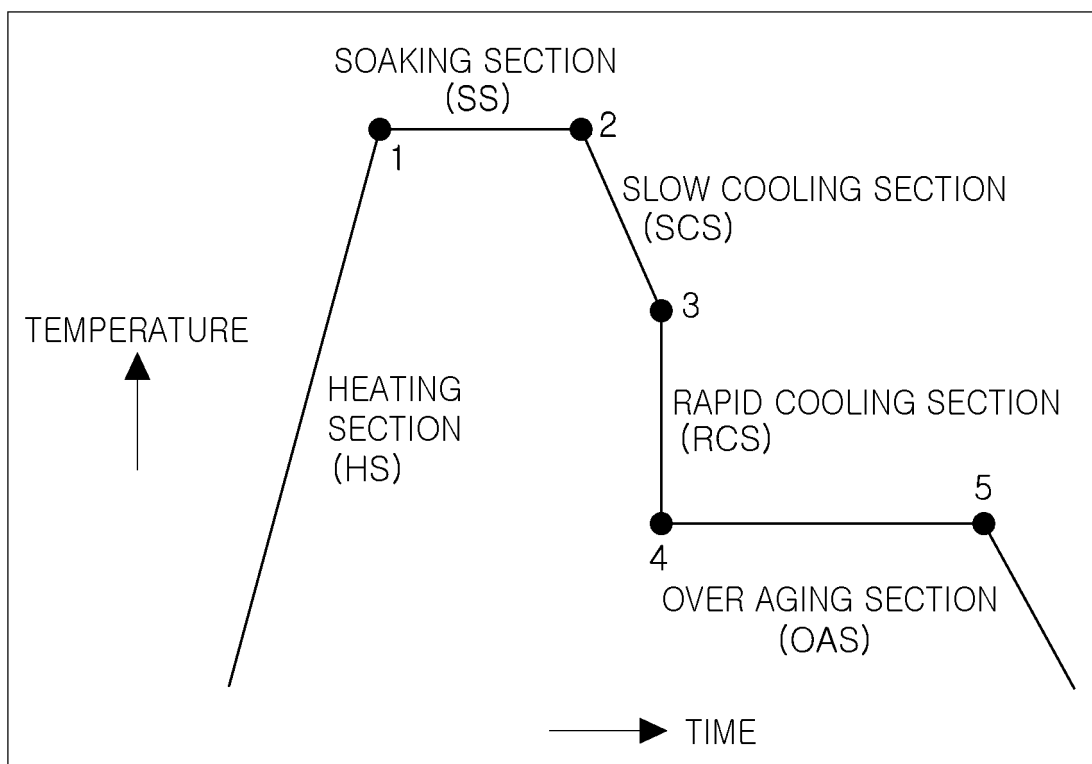
[0071] Comparative Examples 3 to 7 did not satisfy target physical properties of the elongation. Specifically, due to the low reduction ration, austenite may be formed coarsely, and thus the elongation decreases, and the annealing temperature increases, which may result in a problem of low energy efficiency. FIG. 6 is an SEM image of the microstructure of Comparative Example 4, from which it was confirmed that the fraction of the hard phase increased and the aspect ratio was high, and formability such as the elongation was deteriorated.

[0072] Comparative Examples 8 to 11 had problems of low energy efficiency due to a high annealing temperature, and low elongation due to a high secondary phase fraction.

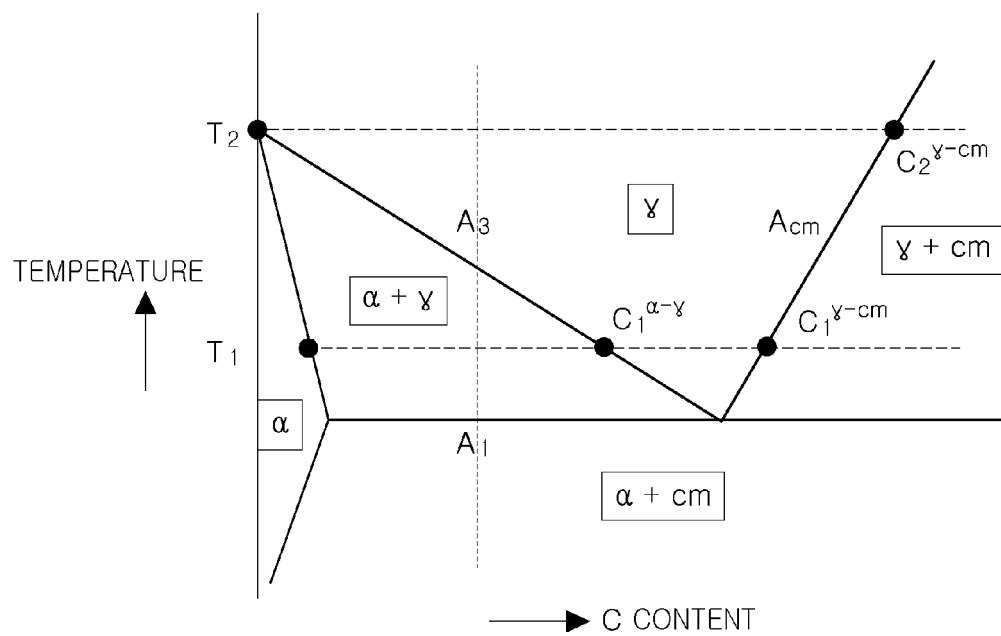
Claims

1. An eco-friendly steel sheet having high strength and high formability, comprising: by wt%, C: 0.05 to 0.10%, Si: 0.3% or less (excluding 0%), Mn: 2.0 to 2.5%, Ti: 0.05% or less (excluding 0%), Nb: 0.1% or less (excluding 0%), Cr: 1.5% or less (excluding 0%), P: 0.1% or less, S: 0.01% or less, and a balance of Fe, and inevitable impurity elements, wherein a microstructure comprises, in area fraction, 15 to 35% of a hard phase and 65 to 85% of a soft phase.
2. The eco-friendly steel sheet having high strength and high formability of claim 1, wherein the soft phase comprises, in area fraction, 60% or more of recrystallized ferrite and 5% or less of non-recrystallized ferrite.
3. The eco-friendly steel sheet having high strength and high formability of claim 1, wherein the hard phase comprises martensite or a mixed structure of martensite and a trace amount of bainite.
4. The eco-friendly steel sheet having high strength and high formability of claim 1, wherein an aspect ratio of the hard phase is 1.2 or less.
5. The eco-friendly steel sheet having high strength and high formability of claim 1, wherein the steel sheet has tensile strength TS of 780 MPa or more and an elongation EI of 18% or more.
6. A method for manufacturing an eco-friendly steel sheet having high strength and high formability, the method comprising:
 - manufacturing a hot-rolled steel sheet using a steel slab comprising, by wt%, C: 0.05 to 0.10%, Si: 0.3% or less (excluding 0%), Mn: 2.0 to 2.5%, Ti: 0.05% or less (excluding 0%), Nb: 0.1% or less (excluding 0%), Cr: 1.5% or less (excluding 0%), P: 0.1% or less, S: 0.01% or less, and a balance of Fe, and inevitable impurity elements; manufacturing a cold-rolled steel sheet by cold-rolling the hot-rolled steel sheet at a reduction ratio of 70 to 90%; heating and maintaining the cold-rolled steel sheet to a temperature within a range of Ac_1 to $Ac_1+50^{\circ}C$; and cooling the cold-rolled steel sheet slowly at an average cooling rate of 1 to $10^{\circ}C/s$ to a temperature within a range of 650 to $700^{\circ}C$, and then rapidly cooling the cold-rolled steel sheet to a temperature within a range of 300 to $580^{\circ}C$ at an average cooling rate of 5 to $50^{\circ}C/s$.
7. The method for manufacturing an eco-friendly steel sheet having high strength and high formability of claim 6, wherein the hot-rolled steel sheet comprises:
 - heating the steel slab to a temperature within a range of 1100 to $1300^{\circ}C$;
 - performing hot rolling the steel slab by performing finish rolling on the heated steel slab at a temperature within a range of Ar_3 to $1000^{\circ}C$; and
 - after the hot rolling, coiling a hot-rolled steel at a temperature within a range of 400 to $700^{\circ}C$ and cooling a wound hot-rolled steel at a cooling rate of $0.1^{\circ}C/s$ or less.
8. The method for manufacturing an eco-friendly steel sheet having high strength and high formability of claim 6, further comprising:
 - performing an over aging treatment for 200 to 800 seconds after the rapid cooling.

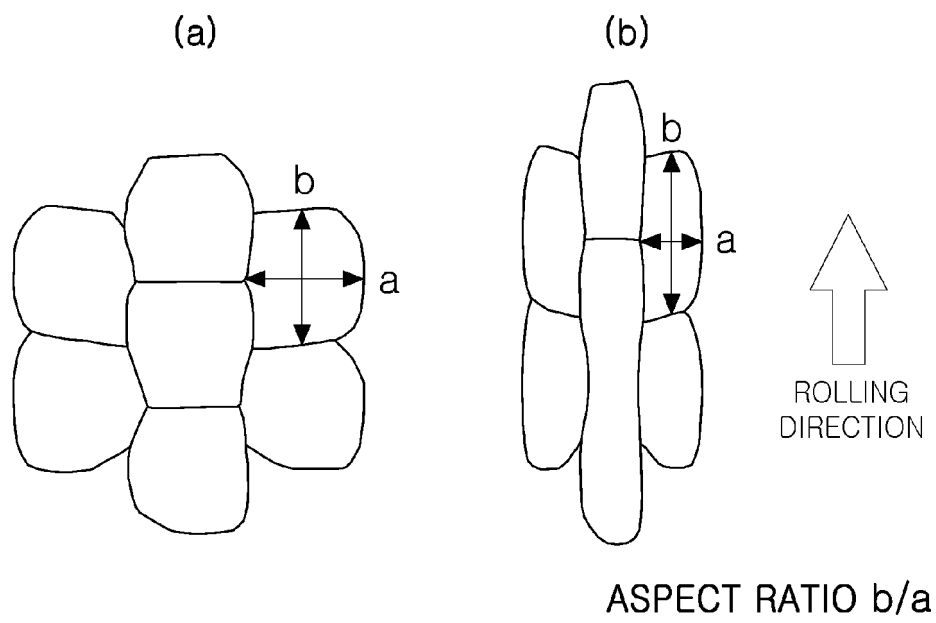
[FIG. 1]



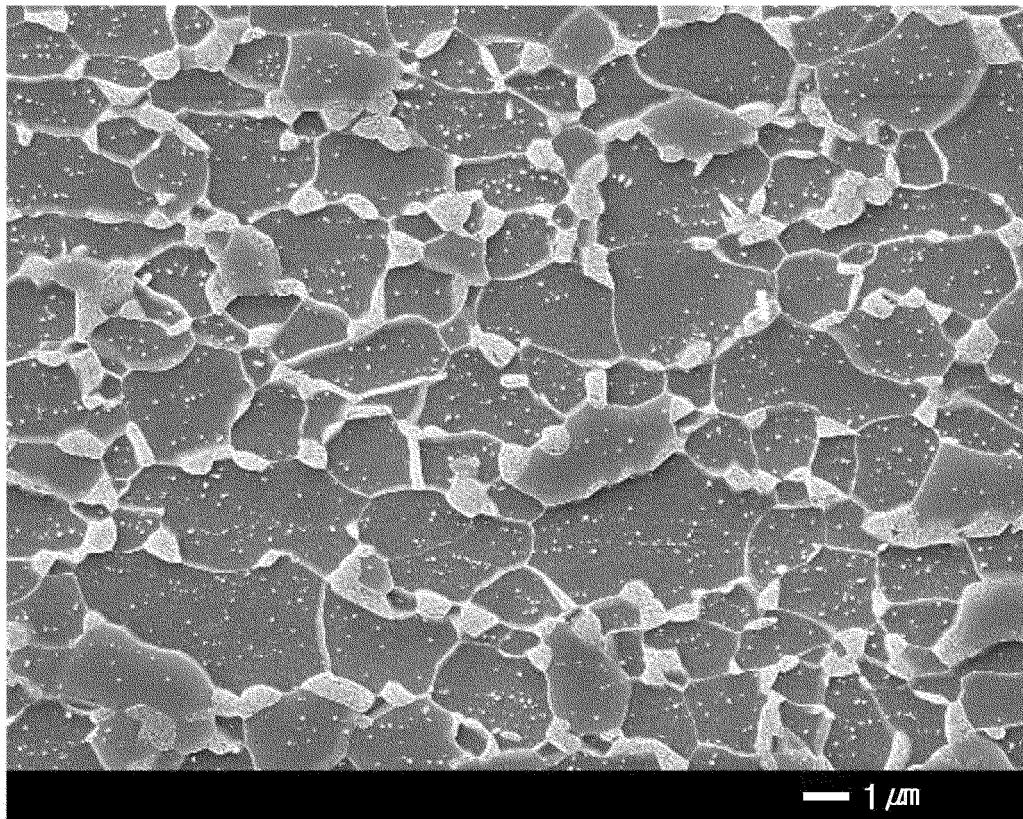
[FIG. 2]



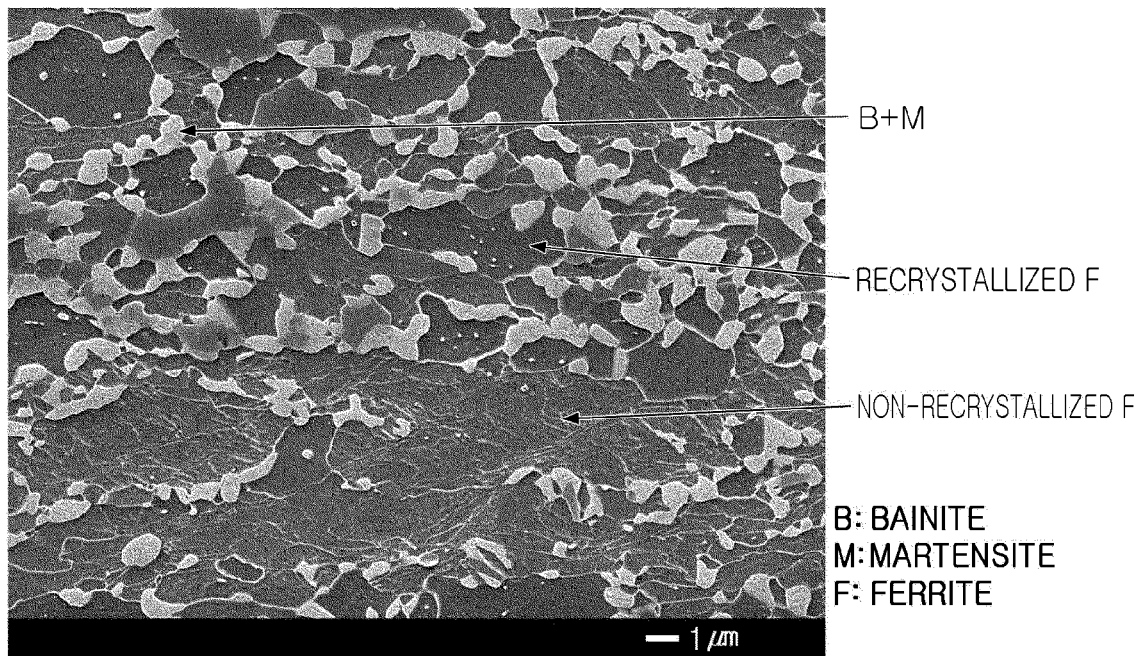
[FIG. 3]



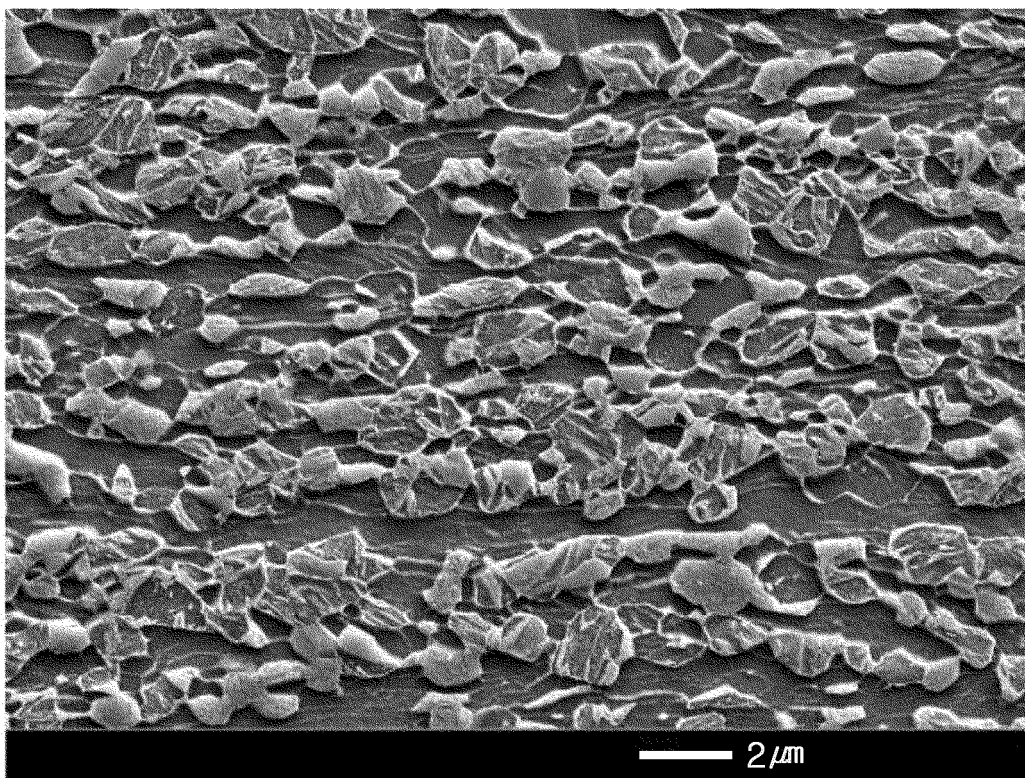
[FIG. 4]



[FIG. 5]



[FIG. 6]



INTERNATIONAL SEARCH REPORT

International application No.

PCT/KR2022/015870

A. CLASSIFICATION OF SUBJECT MATTER

C22C 38/38(2006.01)i; C22C 38/28(2006.01)i; C22C 38/26(2006.01)i; C21D 8/02(2006.01)i; C21D 9/46(2006.01)i;
B21C 47/02(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);
C22C 38/04(2006.01); C22C 38/14(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: 고강도(high strength), 고성형성(high formability), 강판(steel plate), 열연(hot rolling), 냉연(cold rolling), 냉각(cooling), 과시효(overaging)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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Y	KR 10-2255823 B1 (POSCO) 26 May 2021 (2021-05-26) See paragraphs [0103] and [0113]; and claims 3-4.	1-8
A	KR 10-2014-0041838 A (NIPPON STEEL & SUMITOMO METAL CORPORATION) 04 April 2014 (2014-04-04) See paragraphs [0142]-[0175].	1-8
A	JP 2014-196557 A (KOBE STEEL LTD.) 16 October 2014 (2014-10-16) See claims 1-5.	1-8
A	KR 10-2014-0047960 A (POSCO) 23 April 2014 (2014-04-23) See paragraph [0011].	1-8

☐ 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
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"E" earlier application or patent but published on or after the international filing date	"&" document member of the same patent family
"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 28 December 2022	Date of mailing of the international search report 29 December 2022
Name and mailing address of the ISA/KR Korean Intellectual Property Office Government Complex-Daejeon Building 4, 189 Cheongsaro, Seo-gu, Daejeon 35208 Facsimile No. +82-42-481-8578	Authorized officer Telephone No.

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

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Information on patent family members

International application No.

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