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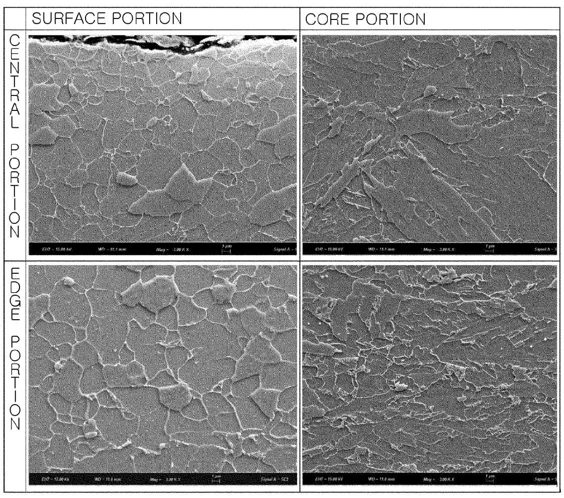
(54) **HIGH-YIELD RATIO HIGH-STRENGTH STEEL PLATE HAVING EXCELLENT IMPACT RESISTANCE AFTER COLD FORMING AND MANUFACTURING METHOD THEREFOR**

(57) The present invention relates to a high-strength steel plate and a manufacturing method therefor and, more specifically, to a high-strength steel plate having excellent impact resistance after cold forming and having a high-yield ratio, and a manufacturing method therefor.

FIG. 1



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Description

Technical Field

[0001] The present disclosure relates to high-strength steel and a manufacturing method therefor and, more specifically, to high-strength steel having excellent impact resistance after cold forming and having a high yield ratio, and a manufacturing method therefor.

Background Art

[0002] Conventional chassis components of a commercial vehicle may be mainly formed of a steel material having a thickness of 8 mm or more due to characteristics of the vehicle. High-strength hot-rolled steel plates having a tensile strength of about 600 MPa may be used for members, and hot-rolled steel plates having a tensile strength of about 440 MPa may be used for wheel disks. However, recently, in order to reduce weight, there may be a trend to apply high-strength hot-rolled steel plates having a tensile strength of 700 MPa or more to the members, apply high-strength hot-rolled steel plates having a tensile strength of 590 MPa or more to the wheel disks, and reduce thicknesses of the steel plates, or change designs of the components. In addition, a wheel has been manufactured using a press molding process in the past, but recently there may be a trend to manufacture the same by a spinning process and a flow forming process. The forming process requires a hot-rolled steel plate having superior elongation because a greater amount of deformation is given to the hot-rolled steel plate, and formed components are required to secure durability and impact resistance during use.

[0003] However, when conventional high-strength steel is applied to the spinning and flow forming processes, durability of components should be equal or better than that of an existing one, but when the components are formed, there are difficulties in application, e.g., fine cracks occur in a shear surface, durability is inferior in regions in which forming volume is high, or the like.

[0004] Conventional high-strength steel may undergo hot-rolling in a normal austenite zone, may be then coiled at a high temperature to use ferrite as a matrix structure, and may form fine precipitates, as in Patent Documents 1 and 2, and a technique in which a coiling temperature is cooled to a temperature at which a bainite matrix structure is formed, to prevent formation of coarse pearlite from forming, and is then coiled, may be applied, as in Patent Document 3. In addition, as in Patent Document 4, a technique for refining austenite grains by pressure reduction ratio of 40% or more in a non-recrystallized region during hot-rolling using Ti, Nb, or the like has also been proposed. Recently, as in Patent Document 5, a technique for improving uniformity of a microstructure between an external portion and an internal portion in a steel plate and suppressing formation of coarse carbides has been proposed, and as in Patent Document 6, a technique for simultaneously suppressing formation of pearlite and a martensite-austenite (MA) phase, and formation of martensite, adversely affecting durability, has been proposed.

[0005] However, Patent Documents 1 to 4 do not take into account occurrence of cracks on and around a shear surface during shear forming of high-strength thick materials, and configure cooling rate conditions and pressure reduction ratio conditions, difficult to be secured in manufacturing for thick materials having a thickness of 8 mm or more. When precipitate-forming elements such as Ti, Nb, V, or the like, are used to refine crystal grains of thick materials and secure strength at the same time, and coiling is performed at a high temperature of 500 to 700°C, in which precipitates are easily formed, there may be problems in that ferrite is excessively grown to decrease yield strength, and coarse pearlite is formed. In addition, even when manufacturing at a low coiling temperature to utilize a bainite matrix structure, and when a cooling rate in a width direction of a steel plate is not uniformly controlled during cooling after hot-rolling, a non-uniform microstructure may be formed in a hot-rolled steel plate, making it difficult to obtain a high elongation rate, and making it difficult to secure stable high yield ratio characteristics, and sensitivity to molding cracks such as cracks in a shear surface during molding or the like may also increase. Moreover, these technologies target hot-rolled steel plates less than 5 mm thick, which may be used for passenger cars, and the required cooling rate may be too high, making them unsuitable for manufacturing thick materials. In addition, applying high pressure reduction ratio of 40% in the non-recrystallization zone may deteriorate a shape quality of a rolled plate and may cause load on the equipment, making it difficult to apply to thick materials having a thickness of 8 mm or more. Patent Documents 5 and 6 may be inventions targeting thick materials. First, in order to improve durability of thick high-strength steel, Patent Document 5 discloses a manufacturing technology to ensure that a grain shape in an internal portion (1/4t to 1/2t) is equiaxed and has fine grains, and to suppress formation of MA phase and martensite. Patent Document 6 proposes a technique for manufacturing a hot-rolled coil by dividing it into three parts in a longitudinal direction through a relational formula derived for a specific component, cooling a head portion, an intermediate portion, and a tail portion under constant cooling rate conditions to different cooling end temperatures, and then coiling them. These technologies may be technologies for producing a uniform microstructure by controlling the cooling rate after hot-rolling through a relationship derived for a specific component in consideration of the quality of the cross-section of the part, may include a large number of punching holes, and may be subjected to continuous load. Although it may be effective in improving durability of commercial vehicle wheels, impact resistance after molding was not considered. In addition, it may be difficult to control cooling of the steel plate uniformly across an entire width after hot-rolling, and when the hot-rolled steel plate is thicker than 8 mm, it may be difficult to control the actual cooling rate.

[0006] A cooling process after hot-rolling may be usually carried out within tens of seconds at a run-out table (ROT) having a length of 100 to 120 m, but may be difficult to manufacture hot-rolled steel by cooling it to a cooling end temperature or a coiling temperature while satisfying a proposed range for a cooling rate of an internal portion. Therefore, in the prior art, hot-rolled steel plates having a thickness of 8 mm or more have problems in that it may be difficult to achieve an effect of suppressing formation of coarse carbides and it may be insufficient to secure a high level of impact resistance.

[Prior art literature]

[0007]

(Patent Document 1) Korean Patent Publication No. 10-2010-0029138 (published on March 15, 2010)
(Patent Document 2) Japanese Patent Publication No. 2007-262487 (published on October 11, 2007)
(Patent Document 3) Korean Patent Publication No. 10-1528084 (published on June 10, 2015)
(Patent Document 4) Japanese Patent Publication Hei 9-143570 (published on June 3, 1997)
(Patent Document 5) Korean Patent Publication No. 10-2020-0062422 (published on June 4, 2020)
(Patent Document 6) Korean Patent Publication No. 10-2021-0068808 (published on June 10, 2021)

Summary of Invention

Technical Problem

[0008] According to an aspect of the present disclosure, an object of the present disclosure is to provide high-strength steel having excellent impact resistance after cold forming and having a high yield ratio, and a manufacturing method therefor.

[0009] An object of the present disclosure is not limited to those described above. A person skilled in the art will have no difficulty in understanding the additional problems of the present disclosure from the overall content of the present specification.

Solution to Problem

[0010] An aspect of the present disclosure may provide a steel plate including, by weight, C: 0.05 to 0.15%, Si: 0.01 to 0.5%, Mn: 1.0 to 2.0%, Al: 0.01 to 0.1%, Cr: 0.001 to 1.0%, P: 0.001 to 0.05%, S: 0.001 to 0.01%, N: 0.001 to 0.01%, Ti: 0.03 to 0.08%, Nb: 0.01 to 0.05%, a remainder of Fe and inevitable impurities, and Nb+Ti: 0.04 to 0.1%,

[0011] wherein a microstructure of a surface portion ranging from a surface to a 50 um thickness includes, by area, 95% or more equiaxed ferrite and 3% or less pearlite, and includes, by area, 5% or less one or more of bainitic ferrite, bainite, a martensite-austenite constituent (MA) phase, or martensite, in total,

[0012] a microstructure of a core portion ranging from a 1/4 thickness to a 3/4 thickness includes, by area, 80 to 95% bainitic ferrite, 10% or less bainite, 3% or less pearlite, 5 to 10% one or two of a martensite-austenite constituent (MA) phase or martensite, and a remainder including equiaxed ferrite.

[0013] The steel plate may have a thickness of 8 to 25 mm.

[0014] The steel plate may have a tensile strength of 590 MPa or more, a fracture elongation of 25% or more, a yield ratio of 0.75 to 0.9, and an impact toughness of 70 J or more at -20°C after cold forming.

[0015] In the steel plate, a ratio (E/YS) of impact toughness (E) at -20°C after cold forming and yield strength (YS) before cold forming may be 0.15 or more.

[0016] The steel plate may include edge portions corresponding to 30% regions from both ends, and a central portion of a central 40% region corresponding to a region excluding both of the edge portions, in a width direction, wherein, in the edge portions and the central portion, a difference in tensile strength is 10 MPa or less, a difference in elongation at break is 8% or less, and a difference in impact toughness at -20°C after cold forming is 20 J or less.

[0017] Another aspect of the present disclosure may provide a method of manufacturing a steel plate, including, reheating a steel slab including, by weight, C: 0.05 to 0.15%, Si: 0.01 to 0.5%, Mn: 1.0 to 2.0%, Al: 0.01 to 0.1%, Cr: 0.001 to 1.0%, P: 0.001 to 0.05%, S: 0.001 to 0.01%, N: 0.001 to 0.01%, Ti: 0.03 to 0.08%, Nb: 0.01 to 0.05%, a remainder of Fe and inevitable impurities, and Nb+Ti: 0.04 to 0.1%, hot-rolling the reheated steel slab; and

cooling and coiling the hot-rolled steel plate to a temperature range of 500 to 650°C at an average cooling rate greater than or equal to a CR value defined in the following relationship 1 within a range of 1 to 30°C/s,

wherein, in the cooling and coiling, edge portions corresponding to 30% regions from both ends in a width direction of a coil are cooled to a temperature (TE) of 550 to 650°C, and a central portion of a central 40% region corresponding to a region excluding both of the edge portions in the width direction is cooled to a temperature (TC) of 500 to 550°C, a difference in average temperature between the edge portions and the central portion is 50 to 150°C:

$$CR = 45 - 16.3 \times [C] - 5.6 \times [Si] - 16.3 \times [Mn] - 2.9 \times [Cr] + 15 \times [Ti] + 23 \times [Nb] - 0.9 \times (t - 8) \quad \text{[Relationship 1]}$$

where [C], [Si], [Mn], [Cr], [Ti], and [Nb] are weight percentages of the elements, and t is a thickness (mm) of the steel plate.

[0018] A temperature of the reheating may be 1100 to 1350°C, and
a temperature of the hot-rolling may be 800 to 1150°C.

[0019] The method may further include air-cooling the coiled coil to a temperature range of 200°C or lower.

[0020] The steel plate may have a thickness of 8 to 25 mm.

Advantageous Effects of Invention

[0021] According to an aspect of the present disclosure, high-strength steel having excellent impact resistance after cold forming and having a high yield ratio, and a manufacturing method therefor may be provided.

[0022] According to an aspect of the present disclosure, high-strength steel that can be applied as a steel material used in chassis members, wheels, or the like of medium-to-large commercial vehicles, and a manufacturing method therefor may be provided.

Brief Description of Drawings

[0023]

FIG. 1 is a photograph illustrating a microstructure of Inventive Example 2 according to an embodiment of the present disclosure observed with a scanning electron microscope (X3,000).

FIG. 2 is a photograph illustrating a microstructure of Comparative Example 2 according to an embodiment of the present disclosure observed with a scanning electron microscope (X3,000).

Best Mode for Invention

[0024] Hereinafter, preferred embodiments of the present disclosure will be described. Embodiments of the present disclosure may be modified in various forms, and the scope of the present disclosure should not be construed as limited to embodiments described below. The present embodiments may be provided to explain the present disclosure in more detail to those skilled in the art.

[0025] In order to solve the above-described conventional problems and ensure excellent formability and impact resistance, the present inventor researched a change in impact resistance after cold forming according to characteristics of a microstructure of a steel plate. Therefore, it was confirmed that desired properties could be secured by controlling the microstructure in thickness and width directions of the steel plate by optimizing an alloy composition and manufacturing conditions, to complete the present disclosure.

[0026] In a hot-rolled steel plate, which may be usually manufactured in the form of a coil, coarse carbides and pearlite may be likely to be formed, when maintained for a long time at a high temperature range of about 500 to 700 °C In particular, when ferrite phase transformation that begins during a cooling process after completion of hot-rolling progresses slowly, a solid content of carbon increases in an untransformed phase, creating conditions in which coarse carbides or pearlite is easy to be formed. Moreover, since a central portion of the coil in a width direction has a slower cooling rate, as compared to an edge portion thereof, this type of tissue may develop further. Therefore, in order to suppress formation of such coarse carbides and pearlite in the central portion of the coil in a width direction, it may be necessary to cool a coiled coil to room temperature by forced cooling such as water cooling, but in this case, in the edge portion in which the cooling rate is fast, a martensite phase or a martensite and austenite (MA) phase may be formed excessively, making the microstructure non-uniform, making it difficult to secure high elongation, and cracks in a shear surface may also increase, which may be undesirable. Therefore, the present disclosure proposes a method for suppressing formation of coarse carbides and pearlite without forcibly cooling the coil.

[0027] Hereinafter, the present disclosure will be described in detail.

[0028] Hereinafter, a steel composition of the present disclosure will be described in detail.

[0029] In the present disclosure, unless otherwise specified, % indicating a content of each element is based on weight.

[0030] Steel according to an aspect of the present disclosure includes, by weight, C: 0.05 to 0.15%, Si: 0.01 to 0.5%, Mn: 1.0 to 2.0%, Al: 0.01 to 0.1%, Cr: 0.001 to 1.0%, P: 0.001 to 0.05%, S: 0.001 to 0.01%, N: 0.001 to 0.01%, Ti: 0.03 to 0.08%, Nb: 0.01 to 0.05%, a remainder of Fe and inevitable impurities, and Nb+Ti: 0.04 to 0.1%.

Carbon (C): 0.05 to 0.15%

[0031] Carbon (C) may be the most economical and effective element in strengthening steel, and as an addition amount increases, a precipitation strengthening effect or a bainite phase fraction may increase, making it easier to secure strength. However, as a thickness of a hot-rolled steel plate increases, since a cooling rate in a core portion in a thickness direction may slow down during cooling after hot-rolling, coarse carbides or pearlite may be likely to be formed when an amount of the carbon (C) is large high. Therefore, when an amount of the carbon (C) is less than 0.05%, it may be difficult to obtain a sufficient strengthening effect, and when an amount thereof exceeds 0.15%, there may be a problem that impact resistance may be reduced due to formation of pearlite or coarse carbides in the core portion in the thickness direction, and weldability may be also inferior. A more preferred lower limit may be 0.055%, and a more preferred upper limit may be 0.12%.

Silicon (Si): 0.01 to 0.5%

[0032] Silicon (Si) may be an element that may be effective in deoxidizing molten steel and solid-solution strengthening steel, and may be also effective in improving formability by delaying formation of coarse carbides. However, when an amount thereof is less than 0.01%, an effect of delaying solid solution strengthening and carbide formation may not be maximized, and when an amount thereof exceeds 0.5%, red scale may be formed on a surface of the steel plate during hot-rolling, which not only deteriorates the quality. In addition, there may be problems with decreased ductility and weldability. More preferably, it may be included in an amount of 0.05% or more, and more preferably, it may be included in an amount of 0.3% or less.

Manganese (Mn): 1.0 to 2.0%

[0033] Manganese (Mn), like Si, may be an effective element in solid solution strengthening steel, and may increase hardenability of steel, facilitating formation of bainite during cooling after hot-rolling. However, when an amount thereof is less than 1.0%, the above effect due to addition may not be obtained, and when an amount thereof exceeds 2.0%, hardenability may increase significantly, martensite phase transformation may be likely to occur, and a segregation zone may develop significantly in the core portion in the thickness direction when casting slabs in the casting process. More preferably, it may be included in an amount of 1.3% or more, and more preferably, it may be included in an amount of 1.8% or less.

Aluminum (Al): 0.01 to 0.1%

[0034] Aluminum (Al) may be an ingredient mainly added for deoxidation, and when an amount thereof is less than 0.01%, the effect of addition may be insufficient. On the other hand, when an amount thereof exceeds 0.1%, AlN may be formed by combining with nitrogen, which easily causes corner cracks in a slab during continuous casting and defects due to formation of inclusions. More preferably, it may be included in an amount of 0.015% or more, more preferably, it may be included in an amount of 0.06% or less.

Chromium (Cr): 0.001 to 1.0%

[0035] Chromium (Cr), similar to Mn, may play a role in solid-solution strengthening steel and delaying ferrite phase transformation upon cooling to aid bainite formation. However, when an amount thereof is less than 0.001%, the above effect due to addition may not be obtained, and when an amount thereof exceeds 1.0%, ferrite transformation may be excessively delayed and elongation may be inferior due to excessive formation of martensite. In addition, excessive addition of Cr may cause a segregation zone in the core portion in the thickness direction to develop significantly and make the microstructure in the thickness direction non-uniform, resulting in poor impact resistance. A more preferable lower limit may be 0.01%, and a more preferable upper limit may be 0.5%.

Phosphorus (P): 0.001 to 0.05%

[0036] Phosphorus (P), like Si, may have both solid solution strengthening and ferrite transformation promotion effects. However, to manufacture in an amount of phosphorus (P) of less than 0.001%, excessive manufacturing costs may be required, which may be economically disadvantageous and may be insufficient to obtain strength. On the other hand, when an amount thereof exceeds 0.05%, brittleness may occur due to grain boundary segregation, and fine cracks may be likely to occur during molding, which may greatly deteriorate impact resistance.

Sulfur (S): 0.001 to 0.01%

[0037] S may be an impurity present in steel, and when an amount thereof exceeds 0.01%, it may combine with Mn or the like to form non-metallic inclusions. Therefore, there may be a problem in that fine cracks may be likely to occur during forming, greatly reducing impact resistance. However, to manufacture in an amount of at less than 0.001%, a lot of time may be required during steelmaking, which reduces productivity.

Nitrogen (N): 0.001 to 0.01%

[0038] Nitrogen (N) may be a representative solid solution strengthening element along with C, and may form coarse precipitates together with Ti, Al, or the like. In general, the solid solution strengthening effect of nitrogen (N) may be better than that of C, but there may be a problem in that toughness decreases significantly as an amount of nitrogen (N) in steel increases. Therefore, an upper limit thereof is limited to 0.01%. On the other hand, to manufacture in an amount of less than 0.001%, a lot of time may be required during steelmaking operations, resulting in lower productivity.

Titanium (Ti): 0.03-0.08%

[0039] Titanium (Ti) may be a representative precipitation strengthening element, and may form coarse TiN in steel due to its strong affinity with N. TiN may have an effect of suppressing grain growth during a heating process for hot-rolling. In addition, titanium (Ti) remaining after reacting with N may be dissolved in steel, and may combine with C to form TiC precipitates, which may be a useful ingredient in improving the strength of steel. When an amount of titanium (Ti) is less than 0.03%, the above effect may not be obtained, and when an amount thereof exceeds 0.08%, there may be a problem of poor collision resistance during molding due to generation of coarse TiN and coarsening of precipitates. More preferably, it may be included in an amount of 0.04% or more, and more preferably, it may be included in an amount of 0.075% or less.

Niobium (Nb): 0.01 to 0.05%

[0040] Niobium (Nb) may be a representative precipitation strengthening element along with Ti, and may be effective in improving strength and impact toughness of steel through an effect of grain refinement by precipitating during hot-rolling and delaying recrystallization. When an amount of niobium (Nb) is less than 0.01%, the above effect may not be obtained, and when an amount thereof exceeds 0.05%, formability may be inferior due to formation of elongated grains and coarse composite precipitates due to excessive recrystallization delay during hot-rolling. More preferably, a lower limit thereof may be 0.015%, and more preferably, an upper limit thereof may be 0.04%.

[0041] The steel of the present disclosure may contain remaining iron (Fe) and inevitable impurities, in addition to the composition described above. Since unavoidable impurities may be unintentionally introduced during the normal manufacturing process, and, thus, may not be excluded. Since these impurities may be known to anyone skilled in the field of steel manufacturing, all of them may not be specifically mentioned in this specification.

[0042] Steel according to an aspect of the present disclosure may have a sum of niobium (Nb) and titanium (Ti) of 0.04 to 0.1%.

[0043] Niobium (Nb) and titanium (Ti) may be precipitated as (Ti,Nb) (C,N)-based composite precipitates, and when they precipitate during hot-rolling, an effect of grain refinement due to delayed recrystallization may greatly increase. However, when formation of composite precipitates may be excessive, there may be a problem in that coarse composite precipitates increase, which reduces the effect of improving strength and deteriorates formability. When the sum of niobium (Nb) and titanium (Ti) is less than 0.04%, effects of grain refinement and strength improvement may be small. On the other hand, when the sum exceeds 0.1%, moldability becomes inferior and it may be economically disadvantageous. A more preferred lower limit may be 0.045%, and a more preferred upper limit may be 0.09%.

[0044] Hereinafter, a steel microstructure of the present disclosure will be described in detail.

[0045] In the present disclosure, unless specifically stated otherwise, % indicating a fraction of microstructure is based on area.

[0046] In steel according to an aspect of the present disclosure, a microstructure of a surface portion ranging from a surface to a 50 um thickness may include, by area, 95% or more equiaxed ferrite and 3% or less pearlite, and may include, by area, 5% or less one or more of bainitic ferrite, bainite, a martensite-austenite constituent (MA) phase, or martensite, in total, and a microstructure of a core portion ranging from a 1/4 thickness to a 3/4 thickness may include, by area, 80 to 95% bainitic ferrite, 10% or less bainite, 3% or less pearlite, 5 to 10% one or two of a martensite-austenite constituent (MA) phase or martensite, and a remainder including equiaxed ferrite.

[0047] In the present disclosure, when the equiaxed ferrite in the surface portion is less than 95%, ductility may be insufficient during spinning and flow forming molding applied, in manufacturing commercial vehicle wheels, and work hardening in the surface portion becomes severe to have a risk of fine cracks occurring during forming. In particular, when 3% or more of highly brittle pearlite is formed, or more than 5% one or more of the bainitic ferrite, the bainite, the MA phase, or the martensite, having high hardness, is included, there may be problems in that cracks easily propagate along an interface with a matrix phase. Therefore, to suppress occurrence of fine cracks formed in the surface portion during molding and prevent propagation of cracks, 5% or less of one or more of the bainitic ferrite, the bainite, the MA phase, or the martensite, in total, may be included. In the present disclosure, as the microstructure of the surface portion, the equiaxed ferrite may be 100%, and the sum of the pearlite, the bainitic ferrite, the bainite, the MA phase, and the martensite may be 0%.

[0048] In addition, when an amount of the bainitic ferrite in the core portion is less than 80%, there may be a problem that cracks easily occur on a shear surface during a punching and shear forming process in manufacturing the wheel, and there may be a problem that impact resistance deteriorates after forming. In addition, when manufacturing a steel plate, in a core portion of a rolled sheet in a thickness direction during a cooling process of the steel plate after hot-rolling, bainitic ferrite, which is a matrix structure, may be formed, and then a high concentration of residual C may remain in an untransformed austenite, making it easy to form pearlite. In this case, when pearlite is formed in excess of 3%, cracks may occur in a shear surface during a molding process and impact resistance after molding may be poor. When the pearlite fraction is 3% or less, there may be no cracking caused by molding such as shear, and impact resistance at low temperatures may be excellent. In the present disclosure, carbides and nitrides, having a diameter of 1 um or more, may be included as pearlite.

[0049] In comparison, when the MA phase or the martensite is included in an amount of 5 to 10%, it may not affect occurrence of cracks and may be advantageous in securing impact resistance and high strength after forming. The MA phase may have an advantage of securing high strength by forming a dislocation density therearound, and when formed together with a matrix structure including ferrite and bainite, it may have excellent impact resistance even though a dislocation density increases after cold forming. However, when the MA phase or the martensite is less than 5%, yield strength and tensile strength may be insufficient, and when the MA phase or the martensite is included in excess of 10%, ductility may be insufficient and formability may be poor. When the bainite also exceeds 10%, there may be a problem of insufficient ductility.

[0050] In the present disclosure, the microstructure of the core portion may include 0% each of the bainite and the pearlite, and may inevitably include the equiaxed ferrite in addition to the bainitic ferrite, the bainite, the pearlite, the MA phase, and the martensite.

[0051] In the present disclosure, an area fraction of the microstructure may be analyzed using an optical microscope and a scanning electron microscope (SEM), and an area fraction of the phase may be measured from an image observed at 3,000 times at a location corresponding to the core portion of the rolled cross-section in the thickness direction.

[0052] Hereinafter, a method of manufacturing steel of the present disclosure will be described in detail.

[0053] Steel according to an aspect of the present disclosure may be manufactured by reheating, rolling, cooling, and coiling a steel slab satisfying the above-described alloy composition.

Reheating

[0054] A steel slab satisfying an alloy composition of the present disclosure may be reheated to a temperature range of 1100 to 1350°C.

[0055] When a temperature of the reheating is less than 1100°C, since a precipitate may not be sufficiently redissolved, formation of the precipitate may be reduced in a process after hot-rolling, and coarse TiN may remain. On the other hand, when the temperature exceeds 1350°C, strength may decrease due to abnormal grain growth of austenite grains.

Hot-rolling

[0056] The reheated steel slab may be hot-rolled at a temperature range of 800 to 1150°C.

[0057] When a temperature of the hot-rolling exceeds 1150°C, a temperature of a hot-rolled steel plate increases, a grain size may become coarse, and surface quality of the hot-rolled steel plate may deteriorate. On the other hand, when the temperature is less than 800°C, stretched grains may develop due to delayed recrystallization, which may worsen anisotropy and may deteriorate formability. When the rolling is performed at a temperature of an austenite temperature range or less, an uneven microstructure may develop more severely.

Cooling and Coiling

[0058] The hot-rolled steel plate may be cooled and coiled to a temperature range of 500 to 650°C at an average cooling rate greater than or equal to a CR value defined in the following relationship 1 within a range of 1 to 30°C/s. When cooling, edge portions corresponding to 30% regions from both ends in a width direction of a coil may be cooled to a temperature (TE) of 550 to 650°C, and a central portion of a central 40% region corresponding to a region excluding both of the edge portions in the width direction may be cooled to a temperature (TC) of 500 to 550°C. In this case, a difference in average temperature between the edge portions and the central portion may be 50 to 150°C.

[0059] In the present disclosure, relationship 1 was derived to induce an appropriate level of ferrite phase transformation when cooling the steel plate, to form a fine and uniform MA phase, and to suppress excessive formation of pearlite. When the cooling rate is less than the CR value of relationship 1, ferrite in the core portion in the thickness direction may be coarse, pearlite may be excessively formed, occurrence of cracks in a shear surface may be more severe, and impact resistance characteristics after molding may be inferior. In addition, when the cooling rate exceeds 30°C/s, there may be a problem in that bainite, an MA phase, and martensite are excessively formed, resulting in insufficient ductility and poor shear surface quality.

$$CR = 45 - 16.3 \times [C] - 5.6 \times [Si] - 16.3 \times [Mn] - 2.9 \times [Cr] + 15 \times [Ti] + 23 \times [Nb] - 0.9 \times (t - 8) \qquad \text{[Relationship 1]}$$

[0060] (Where [C], [Si], [Mn], [Cr], [Ti], and [Nb] are weight percentages of the elements, and t is a thickness (mm) of the steel plate.)

[0061] To suppress excessive formation of carbides and pearlite, a cooling end temperature should be lowered when cooling after hot-rolling. However, there may be concerns that it is difficult to secure a target elongation due to reduction of the ferrite due to excessive formation of the bainite or excessive formation of the MA phase and the martensite.

[0062] Therefore, in the present disclosure, to increase the cooling rate in the central portion in the width direction of the coil and reduce a time period that the coil is maintained at a high temperature after coiling, the cooling end temperature of the central portion in the width direction and the edge portions may be set differently when cooling after hot-rolling. However, in this case, a difference in average temperature between the edge portions and the central portion may be 50 to 150°C. When the difference in average temperature is less than 50°C, it may be difficult to obtain the above effect. On the other hand, when the difference in average temperature exceeds 150°C, the above effect may not increase further, but it may become difficult to control a temperature of each section of the coil.

[0063] The present disclosure does not specifically limit a method of controlling the cooling end temperature of the edge portions and the central portion differently during coiling, but as an example, when cooling the hot-rolled steel plate, a method of blocking cooling water injected into the edge portions before reaching the steel plate, or a method of controlling an amount of the cooling water injected differently may be applied. Alternatively, the two methods may be used in parallel.

[0064] In the present disclosure, it may be desirable to satisfy both the above relationship 1 and the cooling end temperature conditions to secure desired strength, formability, and impact resistance. When all of the above cooling conditions are satisfied, bainitic ferrite may be used as a matrix structure in the core portion in the thickness direction to have a uniform and fine microstructure, and the coarse carbides or pearlite may be reduced in an internal coiling portion of the coil and the core portion in the thickness direction in which the cooling rate is slow, to resolve an uneven structure of the hot-rolled steel plate. In addition, non-uniform formation of the MA phase and formation of coarse martensite may be suppressed in an external coiling portion and the edge portions of the coil in which the cooling rate is relatively fast.

Cooling

[0065] The coiled coil may be air-cooled to a temperature range of 200°C or lower.

[0066] In the present disclosure, the coiled coil may be air-cooled to a temperature range of 200°C or lower. The air-cooling of the coil means cooling it in a room temperature atmosphere at a cooling rate of 0.001 to 10°C/h. In this case, when the cooling rate exceeds 10°C/h, some of an untransformed phase of the steel in the external coiling portion of the coil may be likely to transform into the MA phase, which may deteriorate shear formability, punch formability, and durability of the steel. On the other hand, controlling the cooling rate to less than 0.001°C/h requires separate heating, heat retention equipment, or the like, which may be economically disadvantageous. A more preferable lower limit may be 0.01°C/h, and a more preferable upper limit may be 1°C/h.

[0067] In steel of the present disclosure manufactured in this manner, since a thickness may be 8 to 25 mm, a tensile strength may be 590 MPa or more, an fracture elongation may be 25% or more, a yield ratio may be 0.75 to 0.9, an impact toughness may be 70 J or more at -20°C after cold forming, and a ratio (E/YS) of impact toughness (E) at -20°C after cold forming and yield strength (YS) before cold forming may be 0.15 or more, the steel may have a high yield ratio and excellent impact toughness. In addition, the steel may include edge portions corresponding to 30% regions from both ends, and a central portion of a central 40% region corresponding to a region excluding both of the edge portions, in a width direction, and in the edge portions and the central portion, a difference in tensile strength may be 10 MPa or less, a difference in fracture elongation may be 8% or less, and a difference in impact toughness at -20°C after cold forming may be 20 J or less.

[0068] Hereinafter, the present disclosure will be described in more detail through examples. However, it should be noted that the examples below are only for illustrating and explaining the present disclosure in more detail, and are not intended to limit the scope of the present disclosure.

Mode for Invention

(Example)

[0069] Hot-rolled steel plates were manufactured from steel slabs having alloy compositions illustrated in Table 1 below under conditions illustrated in Table 2 below. In this case, the steel slabs were reheated to a temperature of 1100 to 1350°C and then hot-rolled. Table 2 illustrates, during manufacturing, cooling rates applied, and CR values of relationship 1, and cooling end temperatures may be a temperature (TC) in the 40% range of the central portion in the width direction and a temperature (TE) in the range of 30% of each of the edge portions in the width direction, respectively. In addition, differences between temperatures of the central portion and temperatures of the edge portions may be illustrated.

[Table 1]

Steel	Alloy Composition (wt%)										
	C	Si	Mn	Cr	Al	P	S	N	Ti	Nb	Ti+Nb
A	0.11	0.11	1.2	0.5	0.03	0.01	0.003	0.004	0.05	0.03	0.08
B	0.06	0.21	1.2	0.9	0.03	0.01	0.003	0.005	0.04	0.04	0.08
C	0.08	0.18	1.7	0.5	0.03	0.01	0.003	0.005	0.05	0.04	0.09
D	0.07	0.08	1.6	0.7	0.03	0.008	0.003	0.005	0.05	0.02	0.07
E	0.06	0.25	1.7	0.5	0.03	0.005	0.002	0.004	0.07	0.04	0.11
F	0.07	0.08	1.6	0.7	0.03	0.008	0.003	0.005	0.05	0.02	0.07
G	0.07	0.08	1.6	0.7	0.03	0.008	0.003	0.005	0.05	0.02	0.07
H	0.11	0.11	1.2	0.5	0.03	0.01	0.003	0.004	0.05	0.03	0.08
I	0.06	0.21	1.2	0.9	0.03	0.01	0.003	0.005	0.04	0.04	0.08
J	0.08	0.18	1.7	0.5	0.03	0.01	0.003	0.005	0.05	0.04	0.09
K	0.06	0.11	1.7	0.5	0.03	0.01	0.003	0.004	0.02	0.015	0.035

[Table 2]

Sample No.	Steel	Thickness (mm)	Hot-Rolling	Cooling				
			Temp. (°C)	Rate (°C/s)	Relationship 1 (CR)	End Temp.		
						TE(°C)	TC(°C)	|TE-TC|
1	A	10	900	30	21	605	520	85
2	B	12	870	25	19	590	515	75
3	C	20	830	15	4	610	535	75

(continued)

Sample No.	Steel	Thickness (mm)	Hot-Rolling	Cooling				
			Temp. (°C)	Rate (°C/s)	Relationship 1 (CR)	End Temp.		
						TE(°C)	TC(°C)	|TE-TC|
4	D	15	850	25	10	580	525	55
5	E	18	840	15	6	600	520	80
6	F	11	880	5	14	560	510	50
7	G	20	840	15	6	580	700	120
8	H	21	840	15	11	700	520	180
9	I	11	850	25	19	600	400	200
10	J	18	850	15	6	300	510	210
11	D	6	870	25	18	590	520	70
12	K	18	885	8	6	570	510	60
13	F	11	890	40	14	580	510	70

$$CR = 45 - 16.3 \times [C] - 5.6 \times [Si] - 16.3 \times [Mn] - 2.9 \times [Cr] + 15 \times [Ti] + 23 \times [Nb] - 0.9 \times (t - 8) \qquad \text{[Relationship 1]}$$

(Where [C], [Si], [Mn], [Cr], [Ti], and [Nb] are weight percentages of the elements, and t is a thickness (mm) of the steel plate.)

[0070] Table 3 below illustrates measured microstructures of the manufactured steel plate. The microstructures were expressed by measuring surface portions and core portions in a thickness direction, respectively, and measuring fractions of edge portions and central portions in a width direction, respectively. The microstructures in the surface portion were observed from a surface to a 50 um thickness, and the microstructures in the core portion were observed from a 1/4 t to a 3/4 t (25 to 75% range, t is a thickness (mm)) of the steel plate in the thickness direction. In addition, the microstructures in the edge portions were observed from portions corresponding to 30% regions from both ends in the width direction, and the microstructures in the central portion were observed from a central 40% region corresponding to a region excluding both of the edge portions in the width direction. After etching using a Lepera etching method, area fractions of MA phase and martensite were measured using an optical microscope and an image analyzer, and results therefrom were analyzed at 1,000x magnification. In addition, fractions of equiaxed ferrite (PF), bainitic ferrite (BF), bainite (B), and pearlite (P) were measured from the results of analysis at 3,000x and 5,000x magnification using a scanning electron microscope (SEM). In this case, PF may be a polygonal ferrite having an equiaxed crystal shape, and BF may include ferrite observed in low temperature regions, such as needle-shaped ferrite, bainitic ferrite, or the like. In addition, P included pearlite, and coarse carbides and nitrides, having a diameter of 1 um or more.

[Table 3]

Sample No.	Steel	Microstructure (area%)												
		Position	Surface Layer						Core Portion					
			PF	BF	B	P	MA	Mart	PF	BF	B	P	MA	Mart
1	A	Central Portion	98	0	0	1	1	0	6	82	7	0	5	0
		Edge Portion	99	0	0	1	0	0	4	85	5	0	6	0
2	B	Central Portion	98	0	0	1	1	0	4	81	7	2	6	0
		Edge Portion	99	0	0	1	0	0	5	82	8	0	5	0
3	C	Central Portion	98	0	0	1	1	0	7	83	3	0	7	0
		Edge Portion	98	0	0	2	0	0	5	85	4	0	6	0
4	D	Central Portion	97	0	1	1	1	0	5	83	4	1	7	0
		Edge Portion	98	0	0	1	1	0	7	84	3	0	6	0
5	E	Central Portion	97	0	0	2	1	0	7	81	4	2	6	0
		Edge Portion	98	0	0	1	1	0	6	82	5	2	5	0
6	F	Central Portion	92	0	0	8	0	0	13	75	2	7	3	0
		Edge Portion	93	0	0	7	0	0	12	79	2	5	2	0
7	G	Central Portion	93	0	0	5	2	0	15	72	0	11	2	0
		Edge Portion	95	0	0	3	2	0	23	68	0	6	3	0
8	H	Central Portion	98	0	0	2	0	0	5	83	4	1	7	0
		Edge Portion	90	3	0	5	2	0	15	68	8	8	1	0
9	I	Central Portion	12	69	0	6	8	5	18	61	12	0	7	2
		Edge Portion	6	82	5	2	5	0	12	82	0	0	5	1
10	J	Central Portion	5	86	8	0	1	0	9	78	5	1	7	0
		Edge Portion	10	65	5	2	8	10	12	62	19	1	6	0
11	D	Central Portion	75	23	0	2	0	0	12	70	5	5	8	0
		Edge Portion	87	12	0	1	0	0	8	83	2	5	2	0

(continued)

Sample No.	Steel	Microstructure (area%)												
		Position	Surface Layer						Core Portion					
			PF	BF	B	P	MA	Mart	PF	BF	B	P	MA	Mart
12	K	Central Portion	97	2	0	1	0	0	10	82	0	2	6	0
		Edge Portion	95	3	0	2	0	0	11	83	2	2	2	0
13	F	Central Portion	85	12	0	0	3	0	5	77	13	2	3	0
		Edge Portion	82	10	5	0	3	0	8	82	7	1	2	0

[0071] Table 4 below illustrates property values for each manufactured sample measured in the central and edge portions in the width direction. Yield strength (YS), tensile strength (TS), yield ratio (YR), and fracture elongation (T-El) were evaluated by performing a tensile test by collecting JIS 5 standard test samples in a direction perpendicular to the rolling direction. In addition, impact absorption energy (E) at -20°C after cold forming was measured, and a ratio (E/YS) of impact absorption energy at -20°C after cold forming and yield strength was illustrated. The impact absorption energy was tested using Charpy V-notch samples manufactured in accordance with ASTM standards (ASTM A370), and were sampled in a direction, perpendicular to a rolling direction.

[Table 4]

Sampl e No.	Stee l	Properties														Example
		Central Portion in width direction							Edge Portion in width direction							
		YS (MPa)	TS (MPa)	YR	U-El (%)	T-El (%)	E (J)	E/Y S	YS (MPa)	TS (MPa)	YR	U-El (%)	T-El (%)	E (J)	E/Y S	
1	A	557	655	0.8 5	8	27	10 2	0.1 8	552	648	0.8 5	8	27	10 9	0.2 0	Inventive Ex. 1
2	B	524	624	0.8 4	8	28	10 7	0.2 0	527	630	0.8 4	8	28	11 5	0.2 2	Inventive Ex. 2
3	C	496	605	0.8 2	9	35	11 3	0.2 3	491	608	0.8 1	9	34	12 5	0.2 5	Inventive Ex. 3
4	D	536	631	0.8 5	8	30	10 8	0.2 0	528	637	0.8 3	8	31	11 2	0.2 1	Inventive Ex. 4
5	E	541	615	0.8 8	8	34	67	0.1 2	532	603	0.8 8	8	33	72	0.1 3	Comparati ve Ex. 1
6	F	525	632	0.8 3	8	27	58	0.1 1	520	636	0.8 2	8	26	65	0.1 3	Comparati ve Ex. 2
7	G	503	609	0.8 3	7	31	54	0.1 1	518	613	0.8 4	7	29	62	0.1 2	Comparati ve Ex. 3
8	H	489	598	0.8 2	8	32	85	0.1 7	507	611	0.8 3	8	33	56	0.1 1	Comparati ve Ex. 4
9	I	544	635	0.8 6	7	is	11 8	0.2 2	530	623	0.8 5	8	25	10 8	0.2 0	Comparati ve Ex. 5
10	J	515	621	0.8 3	7	27	72	0.1 4	516	653	0.7 9	6	24	11 1	0.2 2	Comparati ve Ex. 6
11	D	552	645	0.8 6	7	18	11 5	0.2 1	542	640	0.8 5	7	18	12 8	0.2 4	Comparati ve Ex. 7
12	K	493	572	0.8 3	9	36	45	0.0 9	490	577	0.8 5	8	35	59	0.1 2	Comparati ve Ex. 8
13	F	534	643	0.8 3	7	24	12 5	0.2 3	536	649	0.8 3	7	23	13 0	0.2 4	Comparati ve Ex. 9

[0072] As illustrated in Tables 3 and 4, in Inventive Examples satisfying an alloy composition and manufacturing conditions of the present disclosure, microstructure characteristics proposed in the present disclosure were satisfied, and properties desired in the present disclosure were secured. FIG. 1 is a photograph illustrating a microstructure of Inventive Example 2 according to an embodiment of the present disclosure observed with a scanning electron microscope (X3,000).

[0073] In Comparative Example 1, a sum of Ti and Nb amounts exceeded the range of the present disclosure, and impact resistance was inferior due to formation of coarse precipitates and TiN by excessive precipitates in ferrite grains.

[0074] In Comparative Example 2, a cooling rate was below the cooling rate standard proposed in relationship 1, and as illustrated in FIG. 2, excessive pearlite was formed in a microstructure.

[0075] As illustrated in FIG. 2, as a result, strength did not decrease significantly, but target impact resistance characteristics could not be secured.

[0076] In Comparative Example 3, a coiling temperature of a central portion in a width direction exceeded the range proposed in the present disclosure. In particular, excessive pearlite was formed in a core portion in a thickness direction for both the central portion and the edge portion, and target impact resistance characteristics were not secured.

[0077] In Comparative Example 4, a coiling temperature of an edge portion in a width direction exceeds the range proposed in the present disclosure. Therefore, impact resistance was found to be inferior due to excessive formation of pearlite in a core portion of the edge portion in the thickness direction. This may be because heat transfer of the coiling coil progressed slowly at the edge due to the high edge temperature.

[0078] In Comparative Example 5, a coiling temperature of a central portion in a width direction was below the range of the present disclosure, and bainite was excessively formed in a core portion of a central portion in a thickness direction, and pearlite, an MA phase, and martensite were formed excessively in a surface portion at the level proposed in the present disclosure, and elongation was inferior. An edge portion satisfied a coiling temperature range, and had relatively good elongation and impact resistance, but ferrite in the surface portion fell below the range proposed in the present disclosure. This may be believed to be because a temperature of the edge portion of the coil also decreased rapidly after coiling due to a low cooling end temperature of the central portion in the width direction.

[0079] In Comparative Example 6, a coiling temperature of an edge portion in a width direction was below the range of the present disclosure, and it was confirmed that bainite was excessively formed in a core portion in a thickness direction, resulting in poor elongation. In addition, a surface portion in a central portion lacked ferrite, and the central portion lacked bainitic ferrite, and as a result, a ratio of impact resistance and yield strength did not satisfy the level proposed in the present disclosure.

[0080] In Comparative Example 7, a thickness of steel was less than 8 mm. Since a cooling rate was excessively applied for a given steel composition, ferrite was insufficient in a surface portion, and bainitic ferrite was reduced in a central portion in a thickness direction while pearlite was excessively formed. This may be believed to be because an untransformed phase increased during an initial cooling process, and pearlite was formed in regions with a relatively high amount of C. As a result, a desired level of elongation could not be secured.

[0081] In Comparative Example 8, a sum of Ti and Nb amounts falls below the range of the present disclosure, and a phase fraction of each microstructure measured at each location satisfied the range proposed by the present disclosure, but due to a decrease in precipitate during hot-rolling, as a result, the microstructure became coarse and fine precipitates decreased after cooling and coiling, resulting in insufficient strength and greatly reduced impact resistance.

[0082] In Comparative Example 9, a cooling rate satisfied the range proposed in the present disclosure by exceeding a CR value of relationship 1, but exceeds 30°C/s. As a result, polygonal ferrite in a surface portion was insufficient, and bainite was excessively formed in a core portion in a thickness direction, making it impossible to secure a desired level of elongation.

[0083] Although the present disclosure has been described in detail through examples above, other forms of embodiments are also possible. Therefore, the technical spirit and scope of the claims set forth below are not limited to the embodiments.

Claims

1. A steel plate comprising:

by weight, C: 0.05 to 0.15%, Si: 0.01 to 0.5%, Mn: 1.0 to 2.0%, Al: 0.01 to 0.1%, Cr: 0.001 to 1.0%, P: 0.001 to 0.05%, S: 0.001 to 0.01%, N: 0.001 to 0.01%, Ti: 0.03 to 0.08%, Nb: 0.01 to 0.05%, a remainder of Fe and inevitable impurities, and Nb+Ti: 0.04 to 0.1%,
wherein a microstructure of a surface portion ranging from a surface to a 50 um thickness includes, by area, 95% or more equiaxed ferrite and 3% or less pearlite, and includes, by area, 5% or less one or more of bainitic ferrite, bainite, a martensite-austenite constituent (MA) phase, or martensite, in total,

a microstructure of a core portion ranging from a 1/4 thickness to a 3/4 thickness includes, by area, 80 to 95% bainitic ferrite, 10% or less bainite, 3% or less pearlite, 5 to 10% one or two of a martensite-austenite constituent (MA) phase or martensite, and a remainder including equiaxed ferrite.

2. The steel plate of claim 1, having a thickness of 8 to 25 mm.

3. The steel plate of claim 1, having a tensile strength of 590 MPa or more, a fracture elongation of 25% or more, a yield ratio of 0.75 to 0.9, and an impact toughness of 70 J or more at -20°C after cold forming.

4. The steel plate of claim 1, wherein a ratio (E/YS) of impact toughness (E) at -20°C after cold forming and yield strength (YS) before cold forming is 0.15 or more.

5. The steel plate of claim 1, wherein the steel plate comprises edge portions corresponding to 30% regions from both ends, and a central portion of a central 40% region corresponding to a region excluding both of the edge portions, in a width direction,
wherein, in the edge portions and the central portion, a difference in tensile strength is 10 MPa or less, a difference in fracture elongation is 8% or less, and a difference in impact toughness at -20°C after cold forming is 20 J or less.

6. A method of manufacturing a steel plate, comprising:

reheating a steel slab including, by weight, C: 0.05 to 0.15%, Si: 0.01 to 0.5%, Mn: 1.0 to 2.0%, Al: 0.01 to 0.1%, Cr: 0.001 to 1.0%, P: 0.001 to 0.05%, S: 0.001 to 0.01%, N: 0.001 to 0.01%, Ti: 0.03 to 0.08%, Nb: 0.01 to 0.05%, a remainder of Fe and inevitable impurities, and Nb+Ti: 0.04 to 0.1%,
hot-rolling the reheated steel slab; and
cooling and coiling the hot-rolled steel plate to a temperature range of 500 to 650°C at an average cooling rate greater than or equal to a CR value defined in the following relationship 1 within a range of 1 to 30°C/s,
wherein, in the cooling and coiling, edge portions corresponding to 30% regions from both ends in a width direction of a coil are cooled to a temperature (TE) of 550 to 650°C, and a central portion of a central 40% region corresponding to a region excluding both of the edge portions in the width direction is cooled to a temperature (TC) of 500 to 550°C,
a difference in average temperature between the edge portions and the central portion is 50 to 150°C:

$$CR = 45 - 16.3 \times [C] - 5.6 \times [Si] - 16.3 \times [Mn] - 2.9 \times [Cr] + 15 \times [Ti] + 23 \times [Nb] - 0.9 \times (t - 8) \quad \text{[Relationship 1]}$$

Where [C], [Si], [Mn], [Cr], [Ti], and [Nb] are weight percentages of the elements, and t is a thickness (mm) of the steel plate.

7. The method of claim 6, wherein a temperature of the reheating is 1100 to 1350°C, and
a temperature of the hot-rolling is 800 to 1150°C.

8. The method of claim 6, further comprising air-cooling the coiled coil to a temperature range of 200°C or lower.

9. The method of claim 6, wherein the steel plate has a thickness of 8 to 25 mm.

FIG. 1

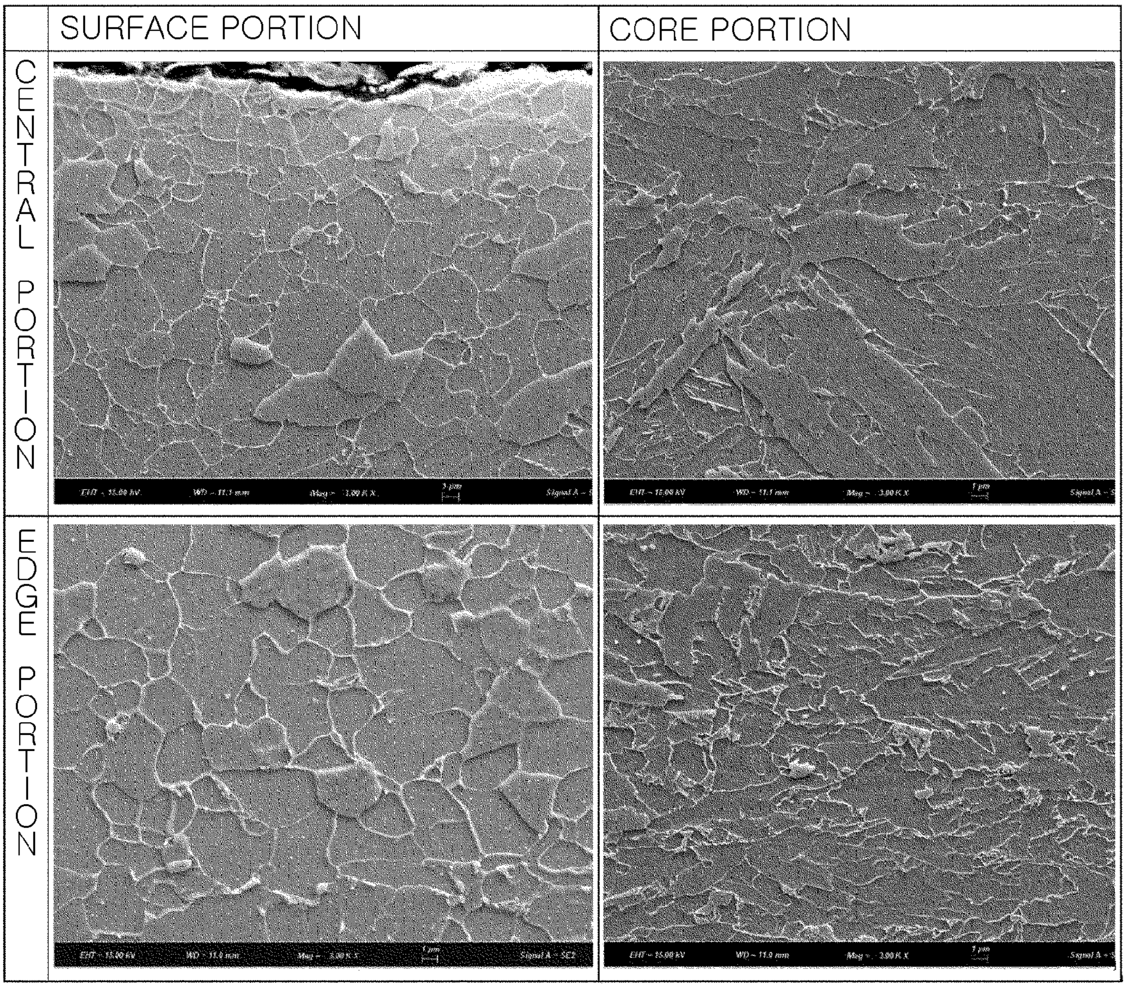
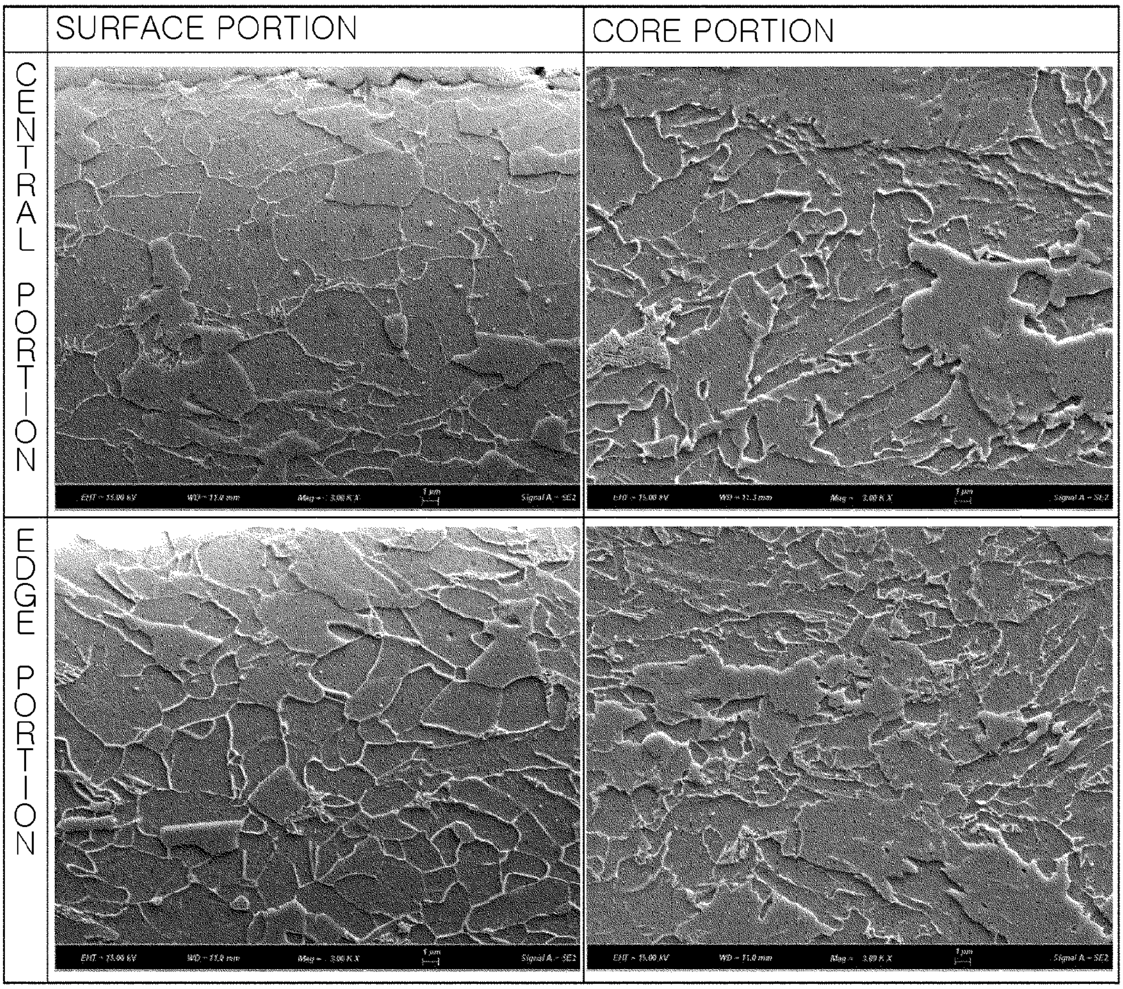

SURFACE PORTION
CORE PORTION
CENTRAL PORTION
EDGE PORTION

FIG. 2


SURFACE PORTION
CORE PORTION
CENTRAL PORTION
EDGE PORTION

INTERNATIONAL SEARCH REPORT

International application No.
PCT/KR2022/017540

A. CLASSIFICATION OF SUBJECT MATTER

C22C 38/38(2006.01)i; **C22C 38/28**(2006.01)i; **C22C 38/26**(2006.01)i; **C22C 38/00**(2006.01)i; **C21D 9/46**(2006.01)i; **C21D 8/02**(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); B21B 1/26(2006.01); B21B 3/02(2006.01); C21D 8/02(2006.01); C21D 9/46(2006.01); C22C 38/00(2006.01); C22C 38/06(2006.01); C22C 38/34(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: 페라이트(ferrite), 베이니틱 페라이트(bainitic ferrite), 펄라이트(pearlite), 마르텐사이트(martensite), 권취(coiling), 두께(thickness), 온도(temperature)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	KR 10-1304859 B1 (POSCO) 05 September 2013 (2013-09-05) See paragraph [0069], clams 1 and 4 and table 4.	1-9
A	JP 2016-060955 A (KOBE STEEL LTD.) 25 April 2016 (2016-04-25) See paragraphs [0060]-[0061] and [0065] and claims 1-2 and 4.	1-9
A	KR 10-1333854 B1 (JFE STEEL CORPORATION) 27 November 2013 (2013-11-27) See claims 4-5 and 7.	1-9
A	US 2014-0205855 A1 (KAWATA et al.) 24 July 2014 (2014-07-24) See claims 1-2 and 8.	1-9
A	KR 10-2019-0077829 A (POSCO) 04 July 2019 (2019-07-04) See claims 1 and 5.	1-9

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

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"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
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Date of the actual completion of the international search	Date of mailing of the international search report
13 February 2023	**14 February 2023**

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