



(11) **EP 4 438 761 A1**

(12) **EUROPEAN PATENT APPLICATION**
published in accordance with Art. 153(4) EPC

(43) Date of publication:
02.10.2024 Bulletin 2024/40

(21) Application number: **22895942.5**

(22) Date of filing: **07.11.2022**

(51) International Patent Classification (IPC):
C22C 38/38 ^(2006.01) **C22C 38/22** ^(2006.01)
C22C 38/26 ^(2006.01) **C22C 38/28** ^(2006.01)
C22C 38/32 ^(2006.01) **C22C 38/00** ^(2006.01)
C22C 38/58 ^(2006.01) **C21D 8/02** ^(2006.01)
B21C 47/02 ^(2006.01)

(52) Cooperative Patent Classification (CPC):
B21C 47/02; C21D 8/02; C22C 38/00; C22C 38/22;
C22C 38/26; C22C 38/28; C22C 38/32;
C22C 38/38; C22C 38/58

(86) International application number:
PCT/KR2022/017335

(87) International publication number:
WO 2023/090735 (25.05.2023 Gazette 2023/21)

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB
GR HR HU IE IS IT LI LT LU LV MC ME MK MT NL
NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA
Designated Validation States:
KH MA MD TN

(30) Priority: **22.11.2021 KR 20210161314**

(71) Applicant: **POSCO Co., Ltd**
Pohang-si, Gyeongsangbuk-do 37859 (KR)

(72) Inventors:
• **YI, Il-Cheol**
Gwangyang-si, Jeollanam-do 57807 (KR)
• **KIM, Sung-Il**
Gwangyang-si, Jeollanam-do 57807 (KR)

(74) Representative: **Meissner Bolte Partnerschaft**
mbB
Patentanwälte Rechtsanwälte
Postfach 86 06 24
81633 München (DE)

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

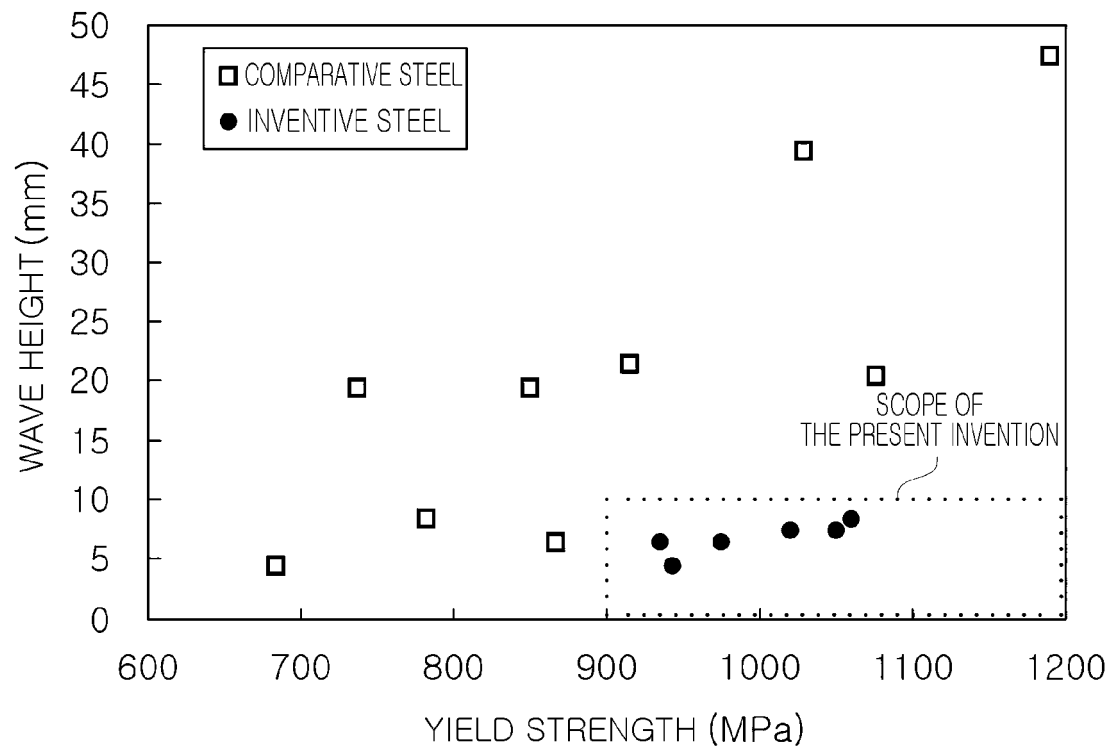
(57) An embodiment of the present invention provides a hot-rolled steel sheet comprising, by wt%, 0.06-0.12% of C, 0.004-0.4% of Si, 0.8-2.0% of Mn, 0.01-0.05% of Al, 0.05-1.0% of Cr, 0.001-0.3% of Mo, 0.001-0.05% of P, 0.001-0.005% of S, 0.001-0.01% of N, 0.001-0.05% of Nb, 0.001-0.05% of Ti, 0.001-0.005% of B, and the remainder of Fe and other inevitable impurities, satisfying relational formula 1 below, and having a microstructure including, by area%, at least one from among 5-15% of austenite, 80% or more of auto-tempered martensite, and the remainder of bainite and ferrite.

[Relational formula 1]

$$(10[C] + [Si] + 2.5[Mn]) / (1.5[Cr] + 2.0[Mo] - 3.2[Nb]) \leq 20$$

EP 4 438 761 A1

[FIG. 1]



Description

Technical Field

5 **[0001]** The present disclosure relates to a hot-rolled steel sheet and a method for manufacturing the same.

Background Art

10 **[0002]** A high-strength hot-rolled steel sheet may be applied in various uses, including a boom arm for a special purpose vehicle such as a crane, a concrete pumping truck, and the like, a truck, and a frame of a trailer. A thickness of the steel sheet used for this purpose is generally about 3 to 10 mm, and a high-strength hot-rolled steel sheet, which is thicker than a general steel sheet for automobiles requires not only high yield strength to support a design load, but also excellent shape quality for part processing and stability. In particular, when the shape quality of the high-strength hot-rolled steel sheet is excellent, the quality remains sound even after being processed, which has the advantage of

15 increasing the stability of large structures.
[0003] Patent Document 1 is a technology which is intended to secure the shape quality by minimizing residual stress by controlling alloy composition and annealing and cooling conditions. Patent Document 2 is a technology which is intended to secure the shape quality by controlling the alloy composition and annealing and cooling conditions and simultaneously, further performing a heat-treatment process.

20 **[0004]** However, the Patent Documents 1 and 2 disclose an annealing process that can apply various cooling conditions as a method for manufacturing a cold-rolled steel sheet, but in the case of a hot-rolled steel sheet, unlike the cold-rolled steel sheet, the hot-rolled steel sheet is manufactured without additional processes after hot rolling, so that due to rapid phase transformation and high yield strength during cooling, the shape quality of the steel sheet may deteriorate significantly even after shape correction. In addition, in the case of a general high-strength hot-rolled steel sheet, the hot-rolled steel sheet may be manufactured to obtain actual target physical properties, but in the case of a high-strength hot-rolled steel sheet with a yield strength of 900 MPa or more, it is actually difficult to improve the shape quality through shape correction which is commonly used.

25 **[0005]** Accordingly, there is a demand for the development of technology that can increase shape correction properties for the high-strength hot-rolled steel sheet with high yield strength.

30 [Prior art document]

[0006]

35 (Patent Document 1) Korean Patent Publication No. 10-1228753
 (Patent Document 2) Korean Patent Publication No. 10-1568495

Summary of Invention

40 Technical Problem

[0007] An aspect of the present disclosure is to provide a hot-rolled steel sheet having excellent shape correction properties and a method for manufacturing the same.

45 Solution to Problem

[0008] According to an aspect of the present disclosure, a hot-rolled steel sheet is provided, the hot-rolled steel sheet including, by weight: 0.06 to 0.12% of C, 0.004 to 0.4% of Si, 0.8 to 2.0% of Mn, 0.01 to 0.05% of Al, 0.05 to 1.0% of Cr, 0.001 to 0.3% of Mo, 0.001 to 0.05% of P, 0.001 to 0.005% of S, 0.001 to 0.01% of N, 0.001 to 0.05% of Nb, 0.001 to 0.05% of Ti, 0.001 to 0.005% of B, with a remainder of Fe and other inevitable impurities, satisfying Relational Expression 1 below, and having a microstructure including, by area, 5 to 15% of austenite, 80% or more of auto-tempered martensite, and a remainder of at least one of bainite and ferrite.

55 [Relational Formula 1]

$$(10[C] + [Si] + 2.5[Mn]) / (1.5[Cr] + 2.0[Mo] - 3.2[Nb]) \leq 20$$

[0009] According to another aspect of the present disclosure, a hot-rolled steel sheet is provided, the hot-rolled steel sheet including, by weight: 0.06 to 0.12% of C, 0.004 to 0.4% of Si, 0.8 to 2.0% of Mn, 0.01 to 0.05% of Al, 0.05 to 1.0% of Cr, 0.001 to 0.3% of Mo, 0.001 to 0.05% of P, 0.001 to 0.005% of S, 0.001 to 0.01% of N, 0.001 to 0.05% of Nb, 0.001 to 0.05% of Ti, 0.001 to 0.005% of B, with a remainder of Fe and other inevitable impurities, satisfying Relational Expression 1 below, and having a microstructure including, by area, 80% or more of auto-tempered martensite, and a remainder of at least one of fresh martensite, bainite, and ferrite, wherein a wave height of the steel sheet in a longitudinal direction is 10 nm or less.

[Relational Expression 1]

$$(10[C] + [Si] + 2.5[Mn]) / (1.5[Cr] + 2.0[Mo] - 3.2[Nb]) \leq 20$$

[0010] According to another aspect of the present disclosure, a method for manufacturing a hot-rolled steel sheet is provided, the manufacturing method including: reheating a slab including by weight: 0.06 to 0.12% of C, 0.004 to 0.4% of Si, 0.8 to 2.0% of Mn, 0.01 to 0.05% of Al, 0.05 to 1.0% of Cr, 0.001 to 0.3% of Mo, 0.001 to 0.05% of P, 0.001 to 0.005% of S, 0.001 to 0.01% of N, 0.001 to 0.05% of Nb, 0.001 to 0.05% of Ti, 0.001 to 0.005% of B, with a remainder of Fe and other inevitable impurities, the slab satisfying Relational Expression 1 below, at a temperature within a range of 1200 to 1350°C; hot rolling the reheated slab at a temperature within a range of 800 to 1200°C to satisfy Relational Expression 2 below to obtain a hot-rolled steel sheet; and primarily cooling, secondarily cooling, and coiling the hot-rolled steel sheet to satisfy Relational Expressions 3 to 6.

[Relational Expression 1]

$$(10[C] + [Si] + 2.5[Mn]) / (1.5[Cr] + 2.0[Mo] - 3.2[Nb]) \leq 20$$

$$FDT \geq 896 - 251[C] + 37.5[Si] - 31.6[Mn] - 7.16[Cr] + 29.5[Mo] + 129[Ti] - 107[Nb] \quad [\text{Relational Expression 2}]$$

$$[\text{Relational Expression 3}] \quad MTL \leq MT \leq MTU$$

$$[\text{Relational Expression 4}] \quad CRL \leq ICR$$

$$[\text{Relational Expression 5}] \quad TCR \leq 80^\circ\text{C/sec}$$

$$[\text{Relational Expression 6}] \quad MTL - 100 \leq CT$$

in the above Relational Expressions 2 to 6, where FDT refers to a surface temperature of the hot-rolled steel sheet at the end of hot rolling, MT refers to a surface temperature of the hot-rolled steel sheet at the end of primary cooling and the start of secondary cooling, MTL refers to $430 - 380[C] - 13.4[Si] - 47.3[Mn] - 16.0[Cr] - 24.2[Mo]$, MTU refers to $481 - 358[C] - 16.6[Si] - 45.6[Mn] - 15.2[Cr] - 24.1[Mo]$, ICR refers to a primary cooling rate of the surface of hot-rolled steel sheet from FDT to MT, CRL refers to $10^{[2.9 - (0.1[C] + 0.9[Mn] + 0.5[Cr] + 1.2[Mo])]} + 10$, TCR refers to an average cooling rate of the surface of the hot-rolled steel sheet from FDT to CT, and CT refers to a coiling temperature.

[0011] According to another aspect of the present disclosure, a method for manufacturing a hot-rolled steel sheet is provided, the manufacturing method including: reheating a slab including by weight: 0.06 to 0.12% of C, 0.004 to 0.4% of Si, 0.8 to 2.0% of Mn, 0.01 to 0.05% of Al, 0.05 to 1.0% of Cr, 0.001 to 0.3% of Mo, 0.001 to 0.05% of P, 0.001 to 0.005% of S, 0.001 to 0.01% of N, 0.001 to 0.05% of Nb, 0.001 to 0.05% of Ti, 0.001 to 0.005% of B, with a remainder of Fe and other inevitable impurities, the slab satisfying Relational Expression 1 below, at a temperature within a range of 1200 to 1350°C; hot rolling the reheated slab at a temperature within a range of 800 to 1200°C to satisfy Relational Expression 2 below to obtain a hot-rolled steel sheet; primarily cooling, secondarily cooling, and coiling the hot-rolled steel sheet to satisfy Relational Expressions 3 to 6; and leveling the coiled hot-rolled steel sheet.

[Relational Expression 1]

$$(10[C] + [Si] + 2.5[Mn]) / (1.5[Cr] + 2.0[Mo] - 3.2[Nb]) \leq 20$$

$$FDT \geq 896 - 251[C] + 37.5[Si] - 31.6[Mn] - 7.16[Cr] + 29.5[Mo] + 129[Ti] - 107[Nb] \quad [\text{Relational Expression 2}]$$

$$[\text{Relational Expression 3}] \quad MTL \leq MT \leq MTU$$

$$[\text{Relational Expression 4}] \quad CRL \leq ICR$$

$$[\text{Relational Expression 5}] \quad TCR \leq 80^{\circ}\text{C/sec}$$

$$[\text{Relational Expression 6}] \quad MTL - 100 \leq CT$$

in the above Relational Expressions 2 to 6, where FDT refers to a surface temperature of the hot-rolled steel sheet at the end of hot rolling, MT refers to a surface temperature of the hot-rolled steel sheet at the end of primary cooling and the start of secondary cooling, MTL refers to $430 - 380[C] - 13.4[Si] - 47.3[Mn] - 16.0[Cr] - 24.2[Mo]$, MTU refers to $481 - 358[C] - 16.6[Si] - 45.6[Mn] - 15.2[Cr] - 24.1[Mo]$, ICR refers to a primary cooling rate of the surface of hot-rolled steel sheet from FDT to MT, CRL refers to $10[2.9 - (0.1[C] + 0.9[Mn] + 0.5[Cr] + 1.2[Mo])] + 10$, TCR refers to an average cooling rate of the surface of the hot-rolled steel sheet from FDT to CT, and CT refers to a coiling temperature.

Advantageous Effects of Invention

[0012] As set forth above, according to an aspect of the present disclosure, a high-strength hot-rolled steel sheet having excellent shape correction properties and a method for manufacturing the same can be provided.

Brief description of drawings

[0013]

FIG. 1 is a graph illustrating a relationship between yield strength and a wave height after leveling for Inventive Examples 1 to 6 and Comparative Examples 1 to 10.

FIG. 2 is a photograph of a microstructure before (left) and after (right) leveling for Inventive Example 16 observed using EBSD and an electron microscope, respectively.

Best Mode for Invention

[0014] In order to manufacture a hot-rolled steel sheet having high strength and excellent shape correction properties, the above-described properties should be simultaneously secured within a hot-rolling process without performing an additional heat treatment process. In general, in the case of a steel material having high strength, the steel material should include a low-temperature transformation phase such as martensite or bainite to secure the strength, and in order to secure such a low-temperature transformation phase, cooling should be performed at a high cooling rate and a low cooling stop temperature during the cooling process in the hot rolling process. However, in this case, a wave height of the hot-rolled steel sheet is significantly increased and yield strength also increases, so that it may be difficult to perform shape correction.

[0015] The present inventors had the insight that a hot-rolled steel sheet with high yield strength and excellent shape correction properties may be manufactured by precisely controlling alloy composition and manufacturing conditions, thereby completing the present invention.

[0016] Hereinafter, the present disclosure will be described. First, an alloy composition of the present disclosure will be described. A content of the alloy composition described below refers to % by weight.

Carbon (C): 0.06 to 0.12%

[0017] Carbon (C) is the most economical and effective element in strengthening steel, and as an addition amount of C increases, a fraction of martensite or bainite increases, thereby increasing tensile strength and yield strength. In particular, the strength of tempered martensite or martensite is absolutely affected by the C content. If the C content is less than 0.06%, it is difficult to obtain a sufficient strengthening effect compared to the yield strength to be obtained by the present disclosure, and if the C content exceeds 0.12%, martensite becomes too hard, so that there is a problem of an increase in brittleness and a decrease in shape correction and in addition, there is a disadvantage in that weldability and material uniformity are also inferior. Therefore, the C content is preferably in the range of 0.06 to 0.12%. A lower limit of the C content is more preferably 0.065% and even more preferably 0.07%. An upper limit of the C content is more preferably 0.115%, and even more preferably 0.110%.

Silicon (Si): 0.004 to 0.4%

[0018] Silicon (Si) is an element which deoxidizes molten steel, exerts a solid solution strengthening effect within a matrix, and is advantageous in delaying formation of coarse carbides, concentrating C, and allowing austenite to remain even after cooling when certain cooling conditions are met. If the Si content is less than 0.004%, the effect of delaying the formation of carbides is not sufficient, so that not only is it difficult to retain austenite, but a process cost for controlling the Si content is also excessively required. If the Si content exceeds 0.4%, a red scale due to Si is formed on a surface of the steel sheet during hot rolling, which not only significantly deteriorates the surface quality of the steel sheet, but also deteriorates bendability and material uniformity, which ultimately leads to poor shape correction properties. Therefore, the Si content is preferably in the range of 0.004 to 0.4%. A lower limit of the Si content is more preferably 0.01%, even more preferably 0.03%, and most preferably 0.05%. An upper limit of the Si content is more preferably 0.25%, even more preferably 0.18%, and most preferably 0.15%.

Manganese (Mn): 0.8 to 2.0%

[0019] Manganese (Mn), like Si, is an effective element in solid solution strengthening steel, and increases hardenability of steel to facilitate formation of a low-temperature transformation structure such as martensite and bainite during cooling. However, if the Mn content is less than 0.8%, the above-described effect is too low, and the burden of increasing alloy costs increases as the insufficient hardenability of steel is compensated for with other elements. On the other hand, if the Mn content exceeds 2.0%, a segregation zone is developed significantly in a thickness central portion during casting of a slab in a continuous casting process, and during cooling, the microstructure in a thickness direction is formed to be non-uniform, resulting in poor shape correction properties. In addition, grain boundaries may be weakened, thereby excessively increasing brittleness of steel. Therefore, the Mn content is preferably in the range of 0.8 to 2.0%. A lower limit of the Mn content is more preferably 0.9%. An upper limit of the Mn content is more preferably 1.8%, and even more preferably 1.7%.

Aluminum (Al): 0.01 to 0.05%

[0020] Aluminum (Al) is an element mainly added for deoxidation of a steel material, and if the Al content is less than 0.01%, the above-described effect is insufficient. On the other hand, if the Al content exceeds 0.05%, Al combines with nitrogen (N) to form AlN, so that it is likely to cause corner cracks in a slab during continuous casting, and defects due to formation of inclusions, and which may have an adverse effect on shape correction. Therefore, the Al content is preferably in the range of 0.01 to 0.05%. A lower limit of the Al content is more preferably 0.015% and even more preferably 0.02%. An upper limit of the Al content is more preferably 0.045% and even more preferably 0.45%.

Chromium (Cr): 0.05 to 1.0%

[0021] Chromium (Cr) strengthens steel by solid solution and increases hardenability of steel during cooling, to suppress formation of ferrite, and simultaneously, serves to help formation of a low-temperature transformation structure such as martensite or bainite. If the Cr content is less than 0.05%, the above-described effect cannot be achieved or becomes excessively small. On the other hand, when the content of Cr exceeds 1.0%, similarly to Mn, a segregation zone in a thickness central portion starts to be developed significantly, and the microstructure in a thickness direction becomes non-uniform, resulting in poor material uniformity and shape correction properties. In addition, the formation of bainite is promoted more than the formation of tempered martensite targeted by the present disclosure, making it difficult to secure strength. Therefore, the Cr content is preferably in the range of 0.05 to 1.0%. A lower limit of the Cr content is more preferably 0.07% and even more preferably 0.1%. An upper limit of the Cr content is more preferably 0.9%.

Molybdenum (Mo): 0.001 to 0.3%

[0022] Molybdenum (Mo) increases hardenability of steel to facilitate formation of a low-temperature transformation structure such as martensite and bainite, which is known to be strong to be similar to that of Mn. However, unlike Mn, Mo strengthens grain boundaries and suppresses brittleness and serves to increase strength. If the Mo content is less than 0.001%, the above-described effect cannot be sufficiently obtained, and if the Mo content exceeds 0.3%, Mo combines with C formed during coiling after hot rolling to grow the precipitates coarsely, so that areas in which material uniformity and shape correction properties are partially deteriorated may occur. In addition, since Mo is an expensive element, it is disadvantageous in terms of manufacturing costs and is also harmful to weldability. Therefore, the Mo content is preferably in the range of 0.001 to 0.3%. A lower limit of the Mo content is more preferably 0.03%, more preferably 0.05%, and most preferably 0.07%.

Phosphorus (P): 0.001 to 0.05%

[0023] Phosphorus (P) is an element having a high solid solution strengthening effect, but causing brittleness due to grain boundary segregation to deteriorate material uniformity and shape correction properties. If the P content exceeds 0.05%, as described above, sudden breakage, or the like may occur during shape correction due to the brittleness due to grain boundary segregation, which may result in poor shape correction properties. It is advantageous to control the P content as low as possible. However, if the P content is less than 0.001%, a lot of manufacturing costs are required, which is economically disadvantageous. Therefore, the P content is preferably in the range of 0.001 to 0.05%. A lower limit of the P content is more preferably 0.002%, more preferably 0.003%, and most preferably 0.005%. An upper limit of the P content is more preferably 0.03%, more preferably 0.02%, and most preferably 0.015%.

Sulfur (S): 0.001 to 0.005%

[0024] Sulfur (S) is an impurity which exists in steel, and when the S content exceeds 0.005%, S combines with Mn to form non-metallic inclusions, which may cause a problem in that microcracks easily occur and impact resistance is greatly reduced during bending steel, and material uniformity and shape correction properties are deteriorated. On the other hand, it is advantageous to control the S content to be as low as possible, but if the S content is less than 0.001%, a lot of time and energy are required during steelmaking, which reduces productivity. Therefore, the S content is preferably in the range of 0.001 to 0.005%. A lower limit of the S content is more preferably 0.002%. An upper limit of the S content is more preferably 0.0004%.

Nitrogen (N): 0.001 to 0.01%

[0025] Nitrogen (N), together with C, is a representative solid solution strengthening element, and also forms coarse precipitates together with Ti, Al, or the like. In general, it is known that the solid solution strengthening effect of N is superior to that of carbon. However, if the N content exceeds 0.01%, there is a problem in that toughness is greatly reduced. On the other hand, if the N content is less than 0.001%, a lot of time is required during steelmaking operation, which reduces productivity. Therefore, the N content is preferably in the range of 0.001 to 0.01%. A lower limit of the N content is more preferably 0.002%, even more preferably 0.003%, and most preferably 0.004%. An upper limit of the N content is more preferably 0.009% and even more preferably 0.008%.

Niobium (Nb): 0.001 to 0.05%

[0026] Niobium (Nb) is a representative precipitation strengthening element together with Ti and V, effective in improving strength and impact toughness through a grain refinement effect due to delayed recrystallization by precipitation during hot rolling. In addition, it is advantageous to retain austenite under specific cooling conditions. As these physical properties increase, shape correction properties can be improved. If the Nb content is less than 0.001%, the above-described effect cannot be obtained. On the other hand, if the Nb content exceeds 0.05%, Nb is grown into coarse composite precipitates, which has the problem of deteriorating material uniformity. Therefore, the Nb content is preferably in the range of 0.001 to 0.05%. An upper limit of the Nb content is more preferably 0.03%, even more preferably 0.02%, and most preferably 0.01%.

Titanium (Ti): 0.001 to 0.05%

[0027] Titanium (Ti) is a representative precipitation strengthening element along with Nb and V, and forms TiN due to the strong affinity with N. TiN has the effect of suppressing growth of grains during a heating process for hot rolling,

which is advantageous in utilizing B added to improve hardenability through stabilization of dissolved N. In addition, Ti remaining after reacting with nitrogen is dissolved in steel and combined with carbon to form TiC precipitates, which is a useful ingredient in additionally improving the strength of steel. If the Ti content is less than 0.001%, the above-described effect cannot be obtained. On the other hand, if the Ti content exceeds 0.05%, there is a problem of poor material uniformity due to the generation of coarse TiN and coarsening of precipitates during a heat treatment. Therefore, the Ti content is preferably in the range of 0.001 to 0.05%. A lower limit of the Ti content is more preferably 0.005%, even more preferably 0.01%, and most preferably 0.02%. An upper limit of the Ti content is more preferably 0.04% and even more preferably 0.03%.

Boron (B): 0.001 to 0.005%

[0028] Boron (B) has the effect of improving hardenability when exists in a solid solution state in steel, has the effect of improving brittleness of steel in low-temperature areas by stabilizing grain boundaries, and has the effect of strengthening grain boundaries even in a trace amount thereof. If the B content is less than 0.001%, it is difficult to obtain the above-described effect. On the other hand, if B content exceeds 0.005%, the hardenability increases significantly, resulting in poor formability, and the formation of precipitates such as coarse BN occurs, which actually increases the brittleness of steel. Therefore, the B content is preferably in the range of 0.001 to 0.005%. An upper limit of the B content is more preferably 0.004%, and even more preferably 0.003%.

[0029] Meanwhile, it is preferable that the hot-rolled steel sheet of the present disclosure satisfies the above-described alloy composition, and simultaneously satisfies the following Relational Expression 1 (hereinafter, a left side thereof in the following Relational Expression 1 is also referred to as 'T'). In this case, a content of each alloy element in the following Relational Expression 1 is % by weight.

$$[\text{Relational Expression 1}]$$

$$(10[C] + [Si] + 2.5[Mn]) / (1.5[Cr] + 2.0[Mo] - 3.2[Nb]) \leq 20$$

[0030] The above Relational Expression 1 is a component Relational Expression for controlling a microstructure. When the T value exceeds 20, a sufficient low-temperature structure is obtained, but non-uniform distribution of a Mn segregation zone and retained austenite increases, making it impossible to obtain uniform physical properties, which cannot obtain a sufficient shape correction effect. Therefore, the T value is preferably 20 or less. The T value is more preferably 19 or less, even more preferably 17 or less, and most preferably 16 or less. Meanwhile, the smaller the T value, the more advantageous it is to secure a uniform microstructure and physical properties, so in the present disclosure, a lower limit of the T value is not particularly limited.

[0031] The remaining component of the present disclosure is iron (Fe). However, since in the common manufacturing process, unintended impurities may be inevitably incorporated from raw materials or the surrounding environment, the component may not be excluded. Since these impurities are known to any person skilled in the common manufacturing process, the entire contents thereof are not particularly mentioned in the present specification.

[0032] In this case, the inevitable impurities may include 0.01% or less of Ni. Ni is an expensive element, and in the present disclosure, excellent shape correction properties may be secured without adding Ni, so it has the advantage of excellent economic efficiency. The Ni content is more preferably 0.008% or less, even more preferably 0.006% or less, and most preferably 0.005% or less.

[0033] It is preferable that the hot-rolled steel sheet of the present disclosure includes a microstructure before shape correction through leveling, by area, at least one of 5 to 15% of austenite, 80% or more of auto-tempered martensite, and a remainder of at least one of bainite and ferrite. Austenite lowers a yield strength and improves shape correction, and simultaneously, is transformed into martensite after leveling, thereby improving strength. When the austenite fraction is less than 5%, it is difficult to sufficiently obtain the above-described effect, and when the austenite fraction exceeds 15%, a sufficient low-temperature structure may not be secured, which has the disadvantage of lowering the strength of the finally obtained steel sheet. A lower limit of the austenite fraction is more preferably 6%, and even more preferably 7%. An upper of the austenite fraction is more preferably 13%, even more preferably 11%, and most preferably 10%. Auto-tempered martensite has ductility which is advantageous for localized and limited transformation, such as shape correction, and has the effect of having high strength. When the auto-tempered martensite fraction is less than 80%, there is a disadvantage in that the strength of the finally obtained steel sheet is excessively low. The auto-tempered martensite fraction is more preferably 82% or more. Auto-tempered martensite is more advantageous in securing strength if auto-tempered martensite is formed in as large a quantity as possible, but at least one of bainite and ferrite may inevitably be formed during the manufacturing process. Meanwhile, auto-tempered martensite has almost the same structure as tempered martensite, which is formed through short-term tempering at a low temperature without performing separate

tempering, and has fine epsilon carbides formed within a lath.

[0034] It is preferable that the hot-rolled steel sheet of the present disclosure includes a microstructure after shape correction through leveling, by area: at least one of 80% or more of auto-tempered martensite, and a remainder of at least one of fresh martensite, bainite, and ferrite. Austenite before leveling is transformed into martensite after leveling, not only shape correction but also superior strength can be secured.

[0035] In addition, the hot-rolled steel sheet of the present disclosure after leveling has excellent shape correction properties as a wave height of the steel sheet in a longitudinal direction is 10 mm or less. In this case, the wave height refers to a height from the valley to the crest when the steel sheet has a wave shape in the longitudinal direction.

[0036] The hot-rolled steel sheet before and after leveling, provided as described above preferably has an average grain size of prior austenite of 10 to 30 μm . When the average grain size of the prior austenite is less than 10 μm , there is a disadvantage in that quenchability is reduced and a sufficient low-temperature structure cannot be secured. When the average grain size of the prior austenite exceeds 30 μm , there is a disadvantage in that retained austenite cannot be formed in the steel sheet due to excessively increased quenchability and ductility is greatly reduced. A lower limit of the average grain size of prior austenite is more preferably 12 μm , even more preferably 15 μm , and most preferably 17 μm . An upper limit of the average grain size of prior austenite is more preferably 28 μm and even more preferably 26 μm .

[0037] In addition, the hot-rolled steel sheet after leveling may have excellent strength with a yield strength of 900 MPa or more.

[0038] Hereinafter, a method for manufacturing a hot-rolled steel sheet according to an embodiment of the present disclosure will be described. Meanwhile, the method for manufacturing a hot-rolled steel sheet according to an embodiment of the present disclosure may also be performed using a process in which continuous casting and hot rolling processes are directly connected.

[0039] First, a slab satisfying the above-described alloy composition and Relational Expression 1 is reheated at a temperature within a range of 1200 to 1350°C. When the reheating is lower than 1200°C, precipitates are not sufficiently re-dissolved, so the formation of is reduced in processes after hot rolling, coarse TiN remains, and it is difficult to eliminate segregation generated during continuous casting by diffusion. On the other hand, when the reheating is higher than 1350°C, the strength decreases and tissue non-uniformity occurs due to abnormal grain growth of austenite grains, so the reheating temperature is preferably in the range of 1200 to 1350°C. A lower limit of the reheating temperature is more preferably 1220°C, even more preferably 1230°C, and most preferably 1250°C. An upper limit of the reheating temperature is more preferably 1330°C, even more preferably 1310°C, and most preferably 1300°C.

[0040] Thereafter, the reheated slab is hot rolled at a temperature within a range of 800 to 1200°C satisfy the following Relational Expression 2 to obtain a hot-rolled steel sheet. When the hot rolling temperature is higher than 1200°C, a temperature of the hot-rolled steel sheet increases, the grain size becomes coarse, and surface quality of the hot-rolled steel sheet deteriorates. On the other hand, when the hot rolling temperature is lower than 800°C, stretched crystal grains are developed due to excessive recrystallization delay, which worsens anisotropy and deteriorates formability, ultimately deteriorating material uniformity and shape correction properties. A lower limit of the hot rolling temperature is more preferably 810°C, even more preferably 820°C, and most preferably 830°C. An upper limit of the hot rolling temperature is more preferably 1180°C.

[0041] Meanwhile, in the present disclosure, it is preferable to satisfy the conditions of the following Relational Expression 2 (hereinafter, a right side thereof in the following Relational Expression 2 is also referred to as 'FDTL') during hot rolling. In the following Relational Expression 2, FDT refers to a surface temperature of the hot-rolled steel sheet at the end of hot rolling.

$$\text{FDT} \geq 896 - 251[\text{C}] + 37.5[\text{Si}] - 31.6[\text{Mn}] - 7.16[\text{Cr}] + 29.5[\text{Mo}] + 129[\text{Ti}] - 107[\text{Nb}] \quad [\text{Relational Expression 2}]$$

[0042] When the FDT is lower than FDTL, ferrite is partially formed on a surface of a steel sheet of which the temperature is lower than that of a thickness central portion of the steel sheet, so a sufficient fraction of martensite is not formed after cooling, resulting in material deviation between the central portion and the surface portion, thereby causing a problem in that shape correction properties are also inferior. In other words, if Relational Expression 2 is satisfied, high strength and excellent shape correction properties can be obtained simultaneously.

[0043] Thereafter, the hot rolled steel sheet is primarily cooled, secondarily cooled, and coiled to satisfy the following Relational Expressions 3 to 6. In this case, in the following Relational Expressions 3 to 6, MT a surface temperature of the hot-rolled steel sheet at the end of primary cooling and at the start of secondary cooling, MTL refers to 430-380[C]-13.4[Si]-47.3[Mn]-16.0[Cr]-24.2[Mo], MTU refers to 481-358[C]-16.6[Si]-45.6[Mn]-15.2[Cr]-24.1[Mo], ICR refers to a primary cooling rate on a surface of the hot-rolled steel sheet from FDT to MT, CRL refers to $10[2.9 - (0.1[\text{C}] + 0.9[\text{Mn}] + 0.5[\text{Cr}] + 1.2[\text{Mo}])] + 10$, TCR refers to an average cooling rate of the surface of the hot-rolled steel sheet from FDT to CT, and CT refers to a coiling temperature.

[0044] When the MT exceeds MTU, martensite cannot be formed, and when the MT is less than the MTL, fine and

evenly distributed austenite cannot be formed. When the ICR is lower than the CRL, sufficient martensite cannot be formed, and a large amount of ferrite or bainite is formed unintentionally, making it impossible to obtain high strength, thereby suppressing the formation of austenite, which also deteriorates shape correction properties. Meanwhile, in the present disclosure, even if the value of ICR is very high, there is no significant change in the strength of martensite, so an upper limit thereof is not particularly limited. If the TCR exceeds 80°C/sec, a problem occurs in which austenite is exposed to low temperatures and disappears before being stabilized. If the CT is lower than MTL-100, a temperature of a coil becomes too low, causing a difficulty in coiling during the process. In addition, as fine residual austenite formed in a process of generating a large amount of martensite phases, which is excessively hard and poorly brittle, disappears, the material of the rolled sheet becomes non-uniform and the shape deteriorates. Meanwhile, in the present disclosure, an upper limit of the coiling temperature is not particularly limited, but in terms of securing strength, the upper limit thereof may be 350°C. In other words, the fine and evenly distributed austenite formed by appropriately controlling the cooling and coiling processes makes correction easier during shape correction through leveling, and simultaneously, all the austenite after correction disappears. The hot-rolled steel sheet manufactured through the above-described process control may have excellent shape correction properties and high yield strength.

[Relational Expression 3] $MTL \leq MT \leq MTU$

[Relational Expression 4] $CRL \leq ICR$

[Relational Equation 5] $TCR \leq 80^{\circ}\text{C/sec}$

[Relational Expression 6] $MTL-100 \leq CT$

[0045] Thereafter, leveling the coiled hot-rolled steel sheet may be included. The leveling is performed for shape correction, and in the present disclosure, the leveling process is not particularly limited, and all conventional techniques used in the art may be used. Meanwhile, the leveling is a shape correction method in which reduction is not applied to a steel sheet, and thus, it can be distinguished from skin pass rolling in which a rolling reduction of 0.1 to 2.0% is applied.

Mode for Invention

[0046] Hereinafter, the present disclosure will be specifically described through the following Examples. However, it should be noted that the following examples are only for describing the present disclosure by illustration, and not intended to limit the right scope of the present disclosure. The reason is that the right scope of the present disclosure is determined by the matters described in the claims and reasonably inferred therefrom.

(Example)

[0047] A slab having the alloy composition shown in Table 1 below was reheated under the conditions shown in Table 2 below to manufacture a hot-rolled steel sheet. In this case, a reheating temperature of the slab was 1250°C, and a thickness of the hot-rolled steel sheet immediately after hot rolling was 4 mm. Thereafter, leveling was performed using a tension leveler. A microstructure, average particles size of prior austenite, wave height, and mechanical properties for a hot-rolled steel sheet before and after levelling, and the results thereof were shown in Table 3 and 4 below, respectively. Meanwhile, in this example, a trace amount of impurities was detected even though Ni was not added.

[0048] The microstructure was measured using an Electron Back-Scattered Diffraction (EBSD) test equipment of an electron microscope.

[0049] The average particle size of prior austenite was measured by mixing 200 ml of supersaturated aqueous picric acid solution and 10 ml of 10% aqueous sodium dodecylbenzene sulfonate solution, and corroding a specimen collected from the hot-rolled steel sheet manufactured above for 10 minutes in a mixed solution obtained by adding 10 ml of 10% aqueous ferric chloride solution with an optical microscope.

[0050] The wave height was expressed as the largest difference from a valley to a crest for a steel sheet length of 2m after unwinding the hot-rolled coil.

[0051] Yield strength (YS), tensile strength (TS), and elongation at break (EI) were measured by collecting JIS 5 standard test specimens from the hot-rolled coil in a direction parallel to a rolling direction.

EP 4 438 761 A1

[Table 1]

Steel type No.	Alloy composition(weight%)													
	C	Si	Mn	Cr	Al	P	S	N	Mo	Ti	Nb	B	Ni	T
1	0.18 0	0.10 0	1.30 0	0.08 0	0.03 0	0.01 0	0.00 3	0.00 5	0.02 0	0.02 0	0.01 0	0.002 5	0.00 2	40.2
2	0.05 0	0.02 0	1.20 0	0.50 0	0.03 0	0.01 0	0.00 3	0.00 5	0.10 0	0.02 0	0.00 2	0.002 5	0.00 2	3.7
3	0.09 5	0.10 0	2.20 0	0.07 0	0.03 0	0.01 0	0.00 3	0.00 5	0.10 0	0.02 0	0.00 2	0.001 5	0.00 5	21.9
4	0.05 0	0.10 0	1.55 0	0.01 0	0.02 0	0.01 0	0.00 3	0.00 4	0.02 0	0.02 0	0.00 2	0.002 5	0.00 5	92.1
5	0.08 0	0.20 0	1.95 0	0.15 0	0.03 0	0.01 0	0.00 3	0.00 5	0.07 0	0.02 0	0.00 2	0.002 5	0.00 2	16.4
6	0.13 0	0.05 0	1.30 0	0.05 0	0.03 0	0.01 0	0.00 3	0.00 5	0.25 0	0.02 0	0.00 2	0.002 0	0.00 5	8.1
7	0.11 0	0.10 0	0.95 0	0.30 0	0.02 0	0.01 0	0.00 4	0.00 4	0.10 0	0.01 0	0.00 1	0.002 5	0.00 2	5.5
8	0.09 0	0.02 0	1.00 0	0.10 0	0.02 0	0.01 0	0.00 4	0.00 4	0.10 0	0.02 5	0.00 4	0.002 5	0.00 2	10.1
9	0.10 0	0.02 0	1.50 0	0.10 0	0.02 0	0.01 0	0.00 4	0.00 4	0.15 0	0.02 5	0.00 4	0.002 5	0.00 5	10.9
10	0.11 0	0.02 0	1.40 0	0.10 0	0.03 0	0.01 0	0.00 3	0.00 4	0.01 0	0.02 0	0.00 2	0.002 0	0.00 5	28.2
11	0.11 0	0.15 0	1.35 0	0.10 0	0.02 0	0.01 0	0.00 3	0.00 5	0.12 0	0.02 0	0.00 2	0.001 5	0.00 2	12.1
12	0.07 5	0.10 0	1.25 0	0.90 0	0.02 0	0.00 5	0.00 2	0.00 5	0.07 0	0.02 5	0.00 2	0.001 5	0.00 2	2.7
13	0.09 0	0.05 0	1.70 0	0.10 0	0.02 0	0.01 0	0.00 3	0.00 7	0.10 0	0.03 0	0.00 2	0.002 5	0.00 2	15.1
14	0.07 5	0.09 0	1.50 0	0.80 0	0.03 0	0.01 0	0.00 3	0.00 4	0.12 0	0.02 0	0.01 0	0.002 0	0.00 2	3.3
15	0.10 0	0.08 0	1.40 0	0.10 0	0.04 0	0.01 5	0.00 2	0.00 8	0.30 0	0.02 5	0.00 1	0.001 5	0.00 2	6.1
16	0.08 0	0.10 0	0.90 0	0.70 0	0.03 0	0.01 2	0.00 4	0.00 4	0.25 0	0.02 5	0.00 1	0.001 2	0.00 2	2.0
$T = (10[C] + [Si] + 2.5[Mn]) / (1.5[Cr] + 2.0[Mo] - 3.2[Nb])$														

[Table 2]

Divisi on	Steel type No.	FDT (°C)	FDTL (°C)	MTL (°C)	MT (°C)	MTU (°C)	ICR (°C/s)	CRL (°C/s)	TCR (°C/s)	Total coolin g time (s)	CT (°C)
Compar ative Examl e 1	1	890	815	297	350	354	90	54	59	11	240
Compar ative Examl e 2	2	890	848	344	350	398	68	38	53	12	250
Compar ative Examl e 3	3	890	811	285	320	342	95	16	58	12	190
Compar ative Examl e 4	4	890	841	336	350	390	90	40	58	11	250
Compar ative Example 5	5	850	825	301	400	356	32	20	32	14	400
Compar ative Examl e 6	6	810	834	312	350	368	46	35	41	13	280

EP 4 438 761 A1

(continued)

Divisi on	Stee l type No.	FDT (°C)	FDTL (°C)	MTL (°C)	MT (°C)	MTU (°C)	ICR (°C/ s)	CRL (°C/s)	TCR (°C/ s)	Total coolin g time (s)	CT (°C)
Compar ative Examl e 7	7	930	844	335	350	390	83	68	72	12	70
Compar ative Examl e 8	8	890	848	344	360	399	53	76	37	17	260
Compar ative Examl e 9	9	830	831	316	350	371	193	30	101	7	220
Compar ative Examl e 10	10	950	827	320	350	376	71	47	56	11	230
Invent ive Examl e 1	11	890	837	318	360	373	88	40	54	12	240
Invent ive Examl e 2	12	870	840	325	365	380	84	27	48	13	240
Invent ive Examl e3	13	870	827	311	350	367	74	26	49	13	230
Invent ive Examl e 4	14	880	832	314	355	369	66	20	46	14	230
Invent ive Examl e 5	15	860	841	316	360	371	71	27	48	13	230
Invent ive Examl e 6	16	880	857	338	380	393	83	37	44	14	270
FDT refers to a surface temperature of the hot-rolled steel sheet at the end of hot rolling, MT refers to a surface of the hot-rolled steel sheet at the end of primary cooling and the start of secondary cooling, MTL refers to 430-380[C]-13.4[Si]-47.3[Mn]-16.0[Cr]-24.2[Mo], MTU refers to 481-358[C]-16.6[Si]-45.6[Mn]-15.2[Cr]-24.1[Mo], ICR refers to a primary cooling rate of the surface of the hot-rolled steel sheet from FDT to MT, CRL refers to $10^{[2.9 - (0.1[C] + 0.9[Mn] + 0.5[Cr] + 1.2[Mo])]} + 10$, TCR refers to an average cooling rate of the surface of hot-rolled steel sheet from FDT to CT, and CT refers to a coiling temperature.											

[Table 3]

Divisi on	Microstructure (area %)			Average particle size of prior austenite (μm)	Mechanical properties YS (MPa)	Wave height (mm)
	F.M	A	at least one of B and F			
Compara tive Example 1	83	9	8	19	1188	33
Compara tive Example 2	86	7	7	21	738	31
Compara tive Example 3	80	6	14	23	817	28
Compara tive Example 4	78	2	20	21	705	22
Compara tive Example 5	65	0	35	21	654	8
Compara tive Example 6	75	7	18	21	730	24
Compara tive Example 7	88	2	10	21	1003	43

(continued)

Divisio n	Microstructure (area %)			Average particle size of prior austenite (μm)	Mechanical properties		Wave height (mm)
	F.M	A	at least one of B and F		YS (MPa)		
Compara tive Example 8	83	5	12	22	778		20
Compara tive Example 9	86	3	11	23	1103		53
Compara tive Example 10	87	3	10	22	993		22
Inventi ve Example 1	86	8	6	26	917		34
Inventive Example 2	83	7	10	25	866		23
Inventi ve Example 3	82	8	10	23	850		29
Inventi ve Example 4	86	7	7	19	836		18
Inventi ve Example 5	86	8	6	20	867		27
Inventi ve Example 6	86	9	5	18	815		24
F.M: Auto-tempered martensite, A: Austenite, B: Bainite, F: Ferrite							

[Table 4]

Divisio n	Microstructure (area %)		Average particle size of prior austenite (μm)	Mechanical properties			Wave height (mm)
	F.M	at least one of M, B, and F		YS (MPa)	TS (MPa)	El (%)	
Compara tive Example 1	83	17	19	1344	1585	8	31
Compara tive Example 2	86	14	21	782	954	14	8
Comparative Example 3	80	20	23	915	1042	13	21
Compara tive Example 4	78	22	21	737	990	12	19
Compara tive Example 5	65	35	21	684	875	17	4
Compara tive Example 6	75	25	21	850	1175	12	19
Compara tive Example 7	88	12	21	1029	1285	12	39
Compara tive Example 8	83	17	22	867	1024	14	6
Compara tive Example 9	86	14	23	1190	1445	11	47
Compara tive Example 10	87	13	22	1076	1331	11	20
Inventi ve Example 1	86	14	26	1060	1294	12	8
Inventi ve Example 2	83	17	25	975	1128	11	6
Inventi ve Example 3	82	18	23	1050	1207	12	7
Inventi ve Example 4	86	14	19	943	1147	12	4
Inventi ve Example 5	86	14	20	1020	1241	11	7
Inventi ve Example 6	86	14	18	935	1145	12	6
F.M: Auto-tempered martensite, M: Martensite, B: Bainite, F: Ferrite							

[0052] As can be seen from Tables 1 to 4 above, in Inventive Examples 1 to 6 satisfying all of the alloy composition, relational expressions, and manufacturing conditions proposed by the present disclosure, it can be seen that the mechanical properties and shape quality targeted by the disclosure are secured.

[0053] In Comparative Example 1, the manufacturing conditions of the present disclosure are satisfied, but the range of the C content of the present disclosure is exceeded and Relational Expression 1 is not satisfied, so it can be seen that the wave height after leveling is high due to high strength and low shape correction properties.

[0054] In Comparative Example 2, the manufacturing conditions of the present disclosure are satisfied, but the range of the C content of the present disclosure is felt below, so it can be seen that the yield strength is low.

[0055] In Comparative Example 3, the manufacturing conditions of the present disclosure are satisfied, but the range of the Mn content of the present disclosure is exceeded and Relational Expression 1 is not satisfied, which leads to a deterioration in shape correction properties due to increased segregation and embrittlement, so it can be seen that the wave height after leveling is high.

[0056] In Comparative Example 4, the manufacturing conditions of the present disclosure are satisfied, but the range of the C and Cr contents of the present disclosure is felt below and Relational Expression 1 is not satisfied, so it can be seen that the yield strength is low and the wave height after leveling is high.

[0057] In Comparative Example 5, the alloy composition of the present disclosure is satisfied, but not only is the existing hot rolling process using one-stage cooling adopted, but MT does not satisfy the conditions of the present disclosure, so it can be seen that an appropriate fraction of austenite before leveling may not be secured, and the yield strength is also low.

[0058] In Comparative Example 6, the C content range of the present disclosure is exceeded and FDT is lower than FDTL, so it can be seen that anisotropy increases due to ferrite formed during rolling, the yield strength is low due to material non-uniformity, and the wave height after leveling is high.

[0059] In Comparative Example 7, the alloy composition of the present disclosure is satisfied, but CT does not satisfy the conditions of the present disclosure, so it can be seen that an appropriate fraction of austenite cannot be secured before leveling, and a wave height after leveling is high.

[0060] In Comparative Example 8, the alloy composition of the present disclosure is satisfied, but it can be seen that the yield strength is low as ICR is lower than CRL.

[0061] In Comparative Example 9, the alloy composition of the present disclosure is satisfied, but as TCR exceeds the conditions of the present disclosure, so it can be seen that an appropriate fraction of austenite cannot be secured before leveling, and a wave height after leveling is high.

[0062] In Comparative Example 10, the manufacturing conditions of the present disclosure are satisfied, but Relational Expression 1 is not satisfied, so it can be seen that a wave height after leveling is high.

[0063] FIG. 1 is a graph illustrating a relationship between yield strength and a wave height after leveling for Inventive Examples 1 to 6 and Comparative Examples 1 to 10. As can be seen from FIG. 1, it can be confirmed that a yield strength of 900 MPa or more and a wave height of 10 mm or less are simultaneously secured in Inventive Examples 1 to 6.

[0064] FIG. 2 is a photograph of the microstructure before (left) and after (right) leveling for Inventive Example 16 observed using EBSD and an electron microscope, respectively. As can be seen from FIG. 2, in the case of Invention Example 16, it can be seen that austenite formed before leveling disappeared after leveling, thereby forming the microstructure desired by the present disclosure.

Claims

1. A hot-rolled steel sheet comprising, by weight:

0.06 to 0.12% of C, 0.004 to 0.4% of Si, 0.8 to 2.0% of Mn, 0.01 to 0.05% of Al, 0.05 to 1.0% of Cr, 0.001 to 0.3% of Mo, 0.001 to 0.05% of P, 0.001 to 0.005% of S, 0.001 to 0.01% of N, 0.001 to 0.05% of Nb, 0.001 to 0.05% of Ti, 0.001 to 0.005% of B, with a remainder of Fe and other inevitable impurities, satisfying Relational Expression 1 below, and having a microstructure including, by area, 5 to 15% of austenite, 80% or more of auto-tempered martensite, and a remainder of at least one of bainite and ferrite,

[Relational Expression 1]

$$(10[C] + [Si] + 2.5[Mn]) / (1.5[Cr] + 2.0[Mo] - 3.2[Nb]) \leq 20.$$

2. A hot-rolled steel sheet comprising, by weight:

0.06 to 0.12% of C, 0.004 to 0.4% of Si, 0.8 to 2.0% of Mn, 0.01 to 0.05% of Al, 0.05 to 1.0% of Cr, 0.001 to 0.3% of Mo, 0.001 to 0.05% of P, 0.001 to 0.005% of S, 0.001 to 0.01% of N, 0.001 to 0.05% of Nb, 0.001 to 0.05% of Ti, 0.001 to 0.005% of B, with a remainder of Fe and other inevitable impurities, satisfying Relational Expression 1 below, and having a microstructure including, by area, 80% or more of auto-tempered martensite,

and a remainder of at least one of fresh martensite, bainite, and ferrite,
wherein a wave height of the steel sheet in a longitudinal direction is 10 nm or less,

5 [Relational Expression 1]

$$(10[C] + [Si] + 2.5[Mn]) / (1.5[Cr] + 2.0[Mo] - 3.2[Nb]) \leq 20.$$

10 3. The hot-rolled steel sheet of claim 1 or 2, wherein the inevitable impurities include 0.01% or less of Ni.

4. The hot-rolled steel sheet of claim 1 or 2, wherein the hot-rolled steel sheet has an average grain size of prior austenite of 10 to 30 μ m.

15 5. The hot-rolled steel sheet of claim 2, wherein the hot-rolled steel sheet has a yield strength of 900 MPa or more.

6. A method for manufacturing a hot-rolled steel sheet, comprising:

20 reheating a slab including by weight: 0.06 to 0.12% of C, 0.004 to 0.4% of Si, 0.8 to 2.0% of Mn, 0.01 to 0.05% of Al, 0.05 to 1.0% of Cr, 0.001 to 0.3% of Mo, 0.001 to 0.05% of P, 0.001 to 0.005% of S, 0.001 to 0.01% of N, 0.001 to 0.05% of Nb, 0.001 to 0.05% of Ti, 0.001 to 0.005% of B, with a remainder of Fe and other inevitable impurities, the slab satisfying Relational Expression 1 below, at a temperature within a range of 1200 to 1350°C; hot rolling the reheated slab at a temperature within a range of 800 to 1200°C to satisfy Relational Expression 2 below to obtain a hot-rolled steel sheet; and
25 primarily cooling, secondarily cooling, and coiling the hot-rolled steel sheet to satisfy Relational Expressions 3 to 6,

[Relational Expression 1]

$$(10[C] + [Si] + 2.5[Mn]) / (1.5[Cr] + 2.0[Mo] - 3.2[Nb]) \leq 20$$

$$FDT \geq 896 - 251[C] + 37.5[Si] - 31.6[Mn] - 7.16[Cr] + 29.5[Mo] + 129[Ti] - 107[Nb] \quad [\text{Relational Expression 2}]$$

35

$$[\text{Relational Expression 3}] \quad MTL \leq MT \leq MTU$$

40

$$[\text{Relational Expression 4}] \quad CRL \leq ICR$$

$$[\text{Relational Expression 5}] \quad TCR \leq 80^\circ\text{C/sec}$$

45

$$[\text{Relational Expression 6}] \quad MTL - 100 \leq CT$$

50

in the above Relational Expressions 2 to 6, where FDT refers to a surface temperature of the hot-rolled steel sheet at the end of hot rolling, MT refers to a surface temperature of the hot-rolled steel sheet at the end of primary cooling and the start of secondary cooling, MTL refers to $430 - 380[C] - 13.4[Si] - 47.3[Mn] - 16.0[Cr] - 24.2[Mo]$, MTU refers to $481 - 358[C] - 16.6[Si] - 45.6[Mn] - 15.2[Cr] - 24.1[Mo]$, ICR refers to a primary cooling rate of the surface of hot-rolled steel sheet from FDT to MT, CRL refers to $10^{[2.9 - (0.1[C] + 0.9[Mn] + 0.5[Cr] + 1.2[Mo])]}$ + 10, TCR refers to an average cooling rate of the surface of the hot-rolled steel sheet from FDT to CT, and CT refers to a coiling temperature.

55

7. A method for manufacturing a hot-rolled steel sheet, comprising:

reheating a slab including by weight: 0.06 to 0.12% of C, 0.004 to 0.4% of Si, 0.8 to 2.0% of Mn, 0.01 to 0.05% of Al, 0.05 to 1.0% of Cr, 0.001 to 0.3% of Mo, 0.001 to 0.05% of P, 0.001 to 0.005% of S, 0.001 to 0.01% of N, 0.001 to 0.05% of Nb, 0.001 to 0.05% of Ti, 0.001 to 0.005% of B, with a remainder of Fe and other inevitable impurities, the slab satisfying Relational Expression 1 below, at a temperature within a range of 1200 to 1350°C; hot rolling the reheated slab at a temperature within a range of 800 to 1200°C to satisfy Relational Expression 2 below to obtain a hot-rolled steel sheet; primarily cooling, secondarily cooling, and coiling the hot-rolled steel sheet to satisfy Relational Expressions 3 to 6; and leveling the coiled hot-rolled steel sheet,

[Relational Expression 1]

$$(10[C] + [Si] + 2.5[Mn]) / (1.5[Cr] + 2.0[Mo] - 3.2[Nb]) \leq 20$$

$$FDT \geq 896 - 251[C] + 37.5[Si] - 31.6[Mn] - 7.16[Cr] + 29.5[Mo] + 129[Ti] - 107[Nb] \quad [\text{Relational Expression 2}]$$

$$[\text{Relational Expression 3}] \quad MTL \leq MT \leq MTU$$

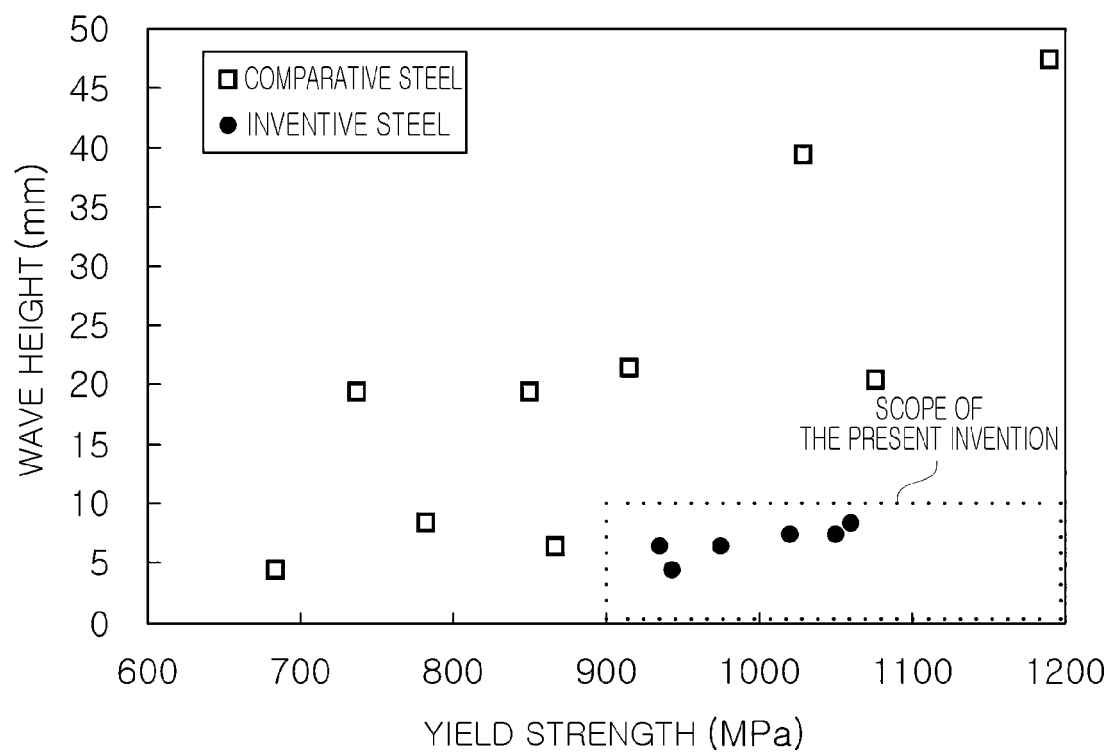
$$[\text{Relational Expression 4}] \quad CRL \leq ICR$$

$$[\text{Relational Expression 5}] \quad TCR \leq 80^\circ\text{C/sec}$$

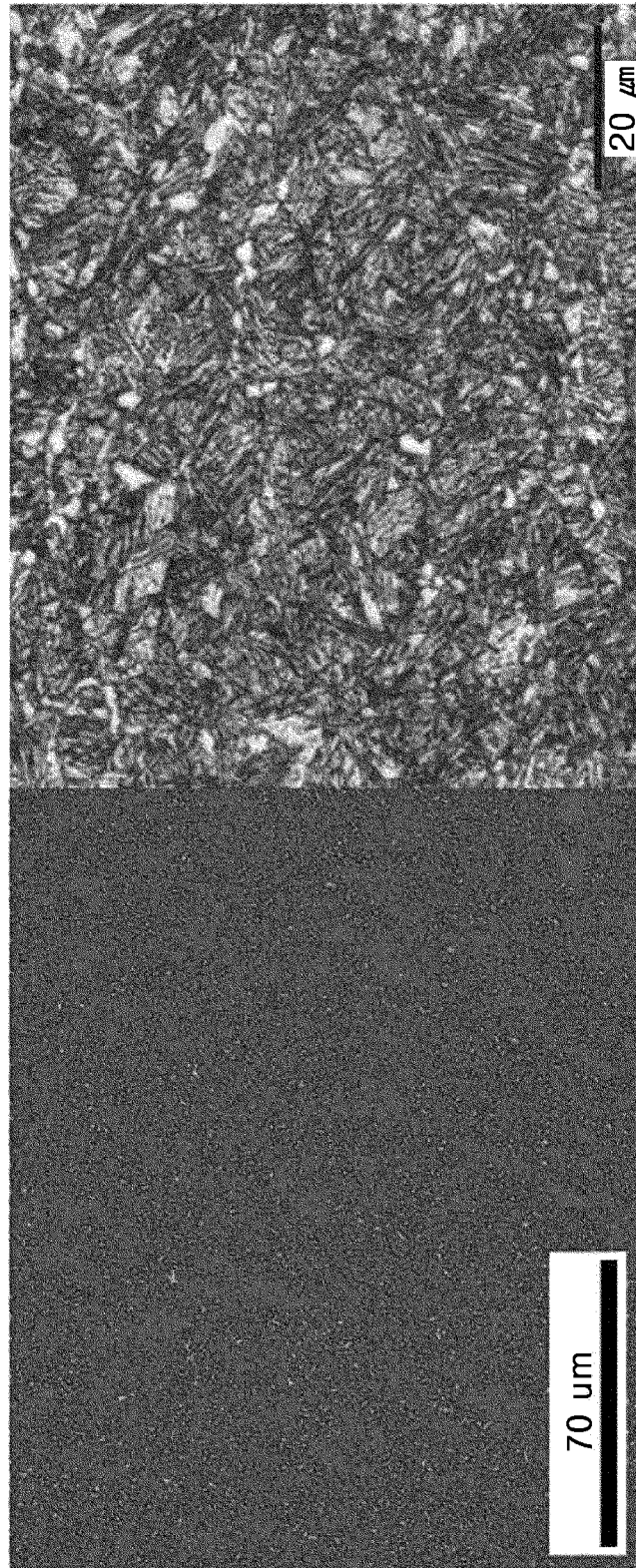
$$[\text{Relational Expression 6}] \quad MTL - 100 \leq CT$$

in the above Relational Expressions 2 to 6, where FDT refers to a surface temperature of the hot-rolled steel sheet at the end of hot rolling, MT refers to a surface temperature of the hot-rolled steel sheet at the end of primary cooling and the start of secondary cooling, MTL refers to $430 - 380[C] - 13.4[Si] - 47.3[Mn] - 16.0[Cr] - 24.2[Mo]$, MTU refers to $481 - 358[C] - 16.6[Si] - 45.6[Mn] - 15.2[Cr] - 24.1[Mo]$, ICR refers to a primary cooling rate of the surface of hot-rolled steel sheet from FDT to MT, CRL refers to $10[2.9 - (0.1[C] + 0.9[Mn] + 0.5[Cr] + 1.2[Mo])] + 10$, TCR refers to an average cooling rate of the surface of the hot-rolled steel sheet from FDT to CT, and CT refers to a coiling temperature.

[FIG. 1]



[FIG. 2]



INTERNATIONAL SEARCH REPORT

International application No.

PCT/KR2022/017335

A. CLASSIFICATION OF SUBJECT MATTER

C22C 38/38(2006.01)i; C22C 38/22(2006.01)i; C22C 38/26(2006.01)i; C22C 38/28(2006.01)i; C22C 38/32(2006.01)i;
C22C 38/00(2006.01)i; C22C 38/58(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); C21D 8/02(2006.01); C22C 38/00(2006.01); C22C 38/04(2006.01); C22C 38/06(2006.01);
C22C 38/34(2006.01); C22C 38/58(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: 열연강판(hot rolled steel sheet), 오스테나이트(austenite), 오토텐퍼드 마르텐사이트(autotempered martensite), 냉각(cooling), 항복강도(yield strength)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	KR 10-2014-0072180 A (JFE STEEL CORPORATION) 12 June 2014 (2014-06-12) See paragraphs [0025], [0066] and [0081], claims 1, 4-5 and 7 and tables 1 and 2.	1-5
A		6-7
A	JP 6787532 B2 (NIPPON STEEL CORPORATION) 18 November 2020 (2020-11-18) See paragraphs [0083]-[0085], claim 1 and table 2A.	1-7
A	KR 10-1617115 B1 (NIPPON STEEL & SUMITOMO METAL CORPORATION) 29 April 2016 (2016-04-29) See paragraph [0107] and claims 1-2, 4 and 9.	1-7
A	KR 10-2020-0075959 A (POSCO) 29 June 2020 (2020-06-29) See paragraphs [0131] and [0133], claims 1, 7 and 9-10 and table 2.	1-7

☒ 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

“&” document member of the same patent family

Date of the actual completion of the international search

09 February 2023

Date of mailing of the international search report

09 February 2023

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)

INTERNATIONAL SEARCH REPORT

International application No.

PCT/KR2022/017335

5

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2015-190015 A (JFE STEEL CORP.) 02 November 2015 (2015-11-02) See claims 1-3.	1-7

10

15

20

25

30

35

40

45

50

55

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

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/KR2022/017335

Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
KR 10-2014-0072180 A	12 June 2014	CA 2851325 A1	10 May 2013
		CA 2851325 C	25 April 2017
		CN 103917682 A	09 July 2014
		CN 103917682 B	09 November 2016
		EP 2759615 A1	30 July 2014
		EP 2759615 B1	15 July 2020
		JP 2013-117068 A	13 June 2013
		JP 5594344 B2	24 September 2014
		US 2014-0251513 A1	11 September 2014
		US 9752216 B2	05 September 2017
JP 6787532 B2	18 November 2020	WO 2013-065298 A1	10 May 2013
		WO 2013-065346 A1	10 May 2013
		CN 112840045 A	25 May 2021
		EP 3868904 A1	25 August 2021
		KR 10-2021-0056410 A	18 May 2021
		TW 202024351 A	01 July 2020
		US 11492679 B2	08 November 2022
		US 2021-0395852 A1	23 December 2021
		WO 2020-080552 A1	23 April 2020
KR 10-1617115 B1	29 April 2016	BR 112014016420 A2	13 June 2017
		BR 112014016420 A8	04 July 2017
		CA 2860165 A1	11 July 2013
		CA 2860165 C	06 December 2016
		CN 104040009 A	10 September 2014
		CN 104040009 B	18 May 2016
		EP 2801637 A1	12 November 2014
		EP 2801637 B1	07 February 2018
		ES 2663747 T3	16 April 2018
		ES 2663747 T9	20 September 2018
		JP 5621942 B2	12 November 2014
		JP WO2013-103125 A1	11 May 2015
		KR 10-2014-0098841 A	08 August 2014
		MX 2014008124 A	15 September 2014
		MX 359273 B	21 September 2018
		PL 2801637 T3	31 July 2018
		RU 2014132066 A	27 February 2016
		RU 2587003 C2	10 June 2016
		TW 201335383 A	01 September 2013
		TW I488977 B	21 June 2015
KR 10-2020-0075959 A	29 June 2020	US 10087499 B2	02 October 2018
		US 2015-0017471 A1	15 January 2015
		WO 2013-103125 A1	11 July 2013
		CN 113195771 A	30 July 2021
		EP 3901312 A1	27 October 2021
JP 2015-190015 A	02 November 2015	JP 2022-511066 A	28 January 2022
		KR 10-2164078 B1	13 October 2020
		US 2022-0064750 A1	03 March 2022
		WO 2020-130329 A1	25 June 2020
		JP 6135577 B2	31 May 2017

Form PCT/ISA/210 (patent family annex) (July 2022)

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- KR 101228753 [0006]
- KR 101568495 [0006]