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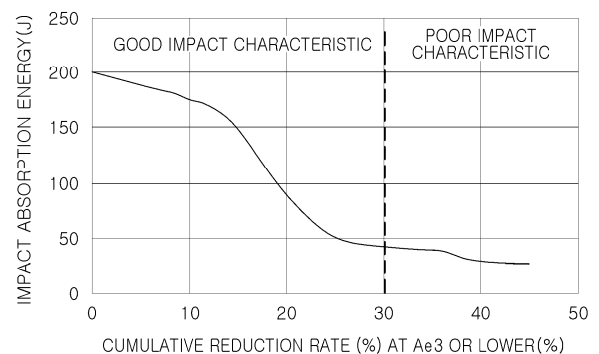
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(54) **HOT ROLLED STEEL SHEET, AND METHOD FOR MANUFACTURING SAME**

(57) A hot rolled steel sheet, and a method for manufacturing same are provided. The hot rolled steel sheet of the present invention comprises, by wt%, 0.02-0.09% of C, 1.0% or less of Si, 0.3-2.0% of Mn, 0.4-2.0% of Cr, 1.0% or less of Cu, 1.0% or less of Ni, 0.1% or less of Al, 0.02-0.1% of Nb, 0.01-0.1% of Ti, 0.03% or less of P, 0.02% or less of S, 0.015% or less of N and the balance of Fe and inevitable impurities, and satisfies $Nb+Ti \leq 0.12$, wherein the microstructure of the steel sheet comprises ferrite or bainite as a main phase and contains the balance (less than 20 area%) of other structures, the weathering index defined by the relation is 6.0 or more, the yield strength, at 30° with respect to the rolling direction, of the steel sheet is 450 MPa or more, and the -5°C impact absorption energy, at 120° with respect to the rolling direction, of the steel sheet, is 47 J or more.

[FIG. 1]



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Description

Technical Field

5 **[0001]** The present disclosure relates to a hot rolled steel sheet which may be used in various manners, such as for construction, bridges, and ground support, and a method for manufacturing the same, and more particularly, to a high-strength seawater-resistant hot rolled steel sheet having YS of 450 MPa or more with excellent impact characteristics and material uniformity, and a method for manufacturing the same.

10 Background Art

[0002] A steel material having excellent seawater resistance is a steel material which has a low corrosion reduction of about 60% or less as compared with a general steel when used for structures in fields such as architecture and civil engineering under an environment affected by seawater salinity, and extends a lifespan period of the structures, and thus, may increase safety of the structures under a seawater atmosphere.

15 **[0003]** A seawater-resistant steel for structures is mainly used as a steel pipe pile supporting offshore structures, and when it is used with a small caliber, a steel pipe is manufactured by manufacturing a tube in a width direction, but when it is used with a large caliber, a steel tube is manufactured by manufacturing a tube in a spiral form. Therefore, when the steel is used to support the weight of a structure such as a steel pipe pile, all physical properties required in all directions need to be satisfied, in the case of testing physical properties in various directions in a sheet material for stability of the structure.

[0004] As an example of the related art, the disclosure suggested in Patent Document 1 may be mentioned. Patent Document 1 suggests only a component system achieving the seawater resistance properties by formulating a Cu, Ni, and Cr component system, but mechanical properties are not specifically mentioned.

25 **[0005]** In addition, in the case of Patent Document 2, the main component system of Cu, Ni, and Cr is similar, but the strength level is as low as TS 520 MPa or less, and the range of the component is different. That is, most of the related art patents do not suggest a method of securing the material uniformity and the seawater resistance of a base material simultaneously.

30 [Related Art Document]

[Patent Document]

35 **[0006]**

(Patent Document 1) KR 2012-0083855A

(Patent Document 2) JP 2022-060949A

40 Summary of Invention

Technical Problem

[0007] An aspect of the present disclosure is to provide a high-strength seawater-resistant hot rolled steel sheet having YS of 450 MPa or more with excellent impact characteristics and material uniformity, and a method for manufacturing the same.

45 **[0008]** In addition, the technical objects to be achieved in the present disclosure are not limited to the above-mentioned technical objects, and other objects which are not mentioned may be clearly understood by those skilled in the art to which the present disclosure pertains from the following description.

50 Solution to Problem

[0009] According to an aspect of the present disclosure,

55 a hot rolled steel sheet includes, by weight: 0.02 to 0.09% of C, 1.0% or less of Si, 0.3 to 2.0% of Mn, 0.4 to 2.0% of Cr, 1.0% or less of Cu, 1.0% or less of Ni, 0.1% or less of Al, 0.02 to 0.1% of Nb, 0.01 to 0.1% of Ti, 0.03% or less of P, 0.02% or less of S, 0.015% or less of N, a balance of Fe, and inevitable impurities, wherein Nb+Ti≤0.12 is satisfied,

a steel sheet microstructure has ferrite or bainite as a main phase and contains a balance of less than 20% by

area of other structures,

a weathering index defined by the following Relation 1 is 6.0 or more,

a yield strength of the steel sheet oriented at 30° to a rolling direction is 450 MPa or more, and an impact absorption energy at -5°C of the steel sheet oriented at 120° to the rolling direction is 47 J or more:

$$\text{Weathering index (I)} = 26.01 (\% \text{ Cu}) + 3.88 (\% \text{ Ni}) + 1.20 (\% \text{ Cr}) + 1.49 (\% \text{ Si}) + 17.28 (\% \text{ P}) - 7.29 (\% \text{ Cu})(\% \text{ Ni}) - 9.1 (\% \text{ Ni})(\% \text{ P}) - 33.39 (\% \text{ Cu})^2 \quad [\text{Relation 1}]$$

[0010] According to another aspect of the present disclosure,

a method for manufacturing a hot rolled steel sheet includes: heating a steel slab including, by weight: 0.02 to 0.09% of C, 1.0% or less of Si, 0.3 to 2.0% of Mn, 0.4 to 2.0% of Cr, 1.0% or less of Cu, 1.0% or less of Ni, 0.1% or less of Al, 0.02 to 0.1% of Nb, 0.01 to 0.1% of Ti, 0.03% or less of P, 0.02% or less of S, 0.015% or less of N, a balance of Fe, and inevitable impurities, and satisfies $\text{Nb} + \text{Ti} \leq 0.12$ and a weathering index defined by the following Relation 1 of 6.0 or more, in a range of 1100 to 1300°C;

finish hot rolling the heated steel slab in a temperature range of an Ar3 temperature or higher to 920°C or lower;

cooling the hot rolled steel sheet after the finish hot rolling at a cooling rate of 10 to 50°C/s; and

coiling the cooled hot rolled steel sheet in a temperature range of 500 to 660°C,

wherein in the finish hot rolling, a cumulative rolling reduction rate in a temperature range of the Ar3 temperature or higher to an Ae3 temperature or lower is controlled to 30% or less:

$$\text{Weathering index (I)} = 26.01 (\% \text{ Cu}) + 3.88 (\% \text{ Ni}) + 1.20 (\% \text{ Cr}) + 1.49 (\% \text{ Si}) + 17.28 (\% \text{ P}) - 7.29 (\% \text{ Cu})(\% \text{ Ni}) - 9.1 (\% \text{ Ni})(\% \text{ P}) - 33.39 (\% \text{ Cu})^2 \quad [\text{Relation 1}]$$

Advantageous Effects of Invention

[0011] The present disclosure having the configuration as described above may provide a high-strength seawater-resistant hot rolled steel sheet having YS of 450 MPa or more with excellent impact characteristics and material uniformity.

[0012] Therefore, the present disclosure may be used in various forms such as sheet materials, H-beams, and steel pipes, which may be used in various manners for construction, bridges, ground support, and the like, and though the shape is not specified, when particularly used as a spiral steel pipe, a steel material having an excellent steel sheet tensile characteristic oriented at 30° to a rolling direction and an excellent steel sheet impact characteristic oriented at 120° to a rolling direction may be effectively provided.

Brief Description of Drawings

[0013] FIG. 1 is a graph illustrating changes in impact characteristics of a steel material with a cumulative rolling reduction rate in a temperature range from Ar3 to Ae3, in an example embodiment of the present disclosure.

Best Mode for Invention

[0014] Hereinafter, the present disclosure will be described.

[0015] The present disclosure may be used in various forms such as plate materials, H-beams, and steel pipes, and though its shape is not limited, particularly in the case of a spiral steel pipe, tensile performance of a steel sheet oriented at 30° to a rolling direction and an impact characteristic of a steel sheet oriented at 120° to a rolling direction are very important. That is, in a tensile characteristic of the steel sheet oriented at 30° and impact absorption energy of the steel sheet oriented at 120° to the rolling direction of the steel sheet (wherein a difference of 180° is regarded as being in the same direction), a steel sheet satisfying YS of 450 MPa or more and a Charpy impact energy of 47 J or more at -5°C in a tensile direction and in a vertical direction is needed. The reason is that a steel sheet material oriented at 30° to the steel material rolling direction and the impact characteristic of a steel sheet oriented at 120° are usually shown to be weak physical properties in the material. When the physical properties in the direction are satisfied, a steel sheet which satisfies an impact characteristic having an impact absorption energy of 47 J or more at -5°C in a Charpy V-notch test while satisfying a yield strength of 450 MPa or more in all directions may be manufactured. In addition, the steel sheet of the present disclosure may satisfy a weathering index of 6 or more, in order to secure seawater resistance simultaneously.

[0016] In this regard, the hot rolled steel sheet of the present disclosure includes, by weight: 0.02 to 0.09% of C,

1.0% or less of Si, 0.3 to 2.0% of Mn, 0.4 to 2.0% of Cr, 1.0% or less of Cu, 1.0% or less of Ni, 0.1% or less of Al, 0.02 to 0.1% of Nb, 0.01 to 0.1% of Ti, 0.03% or less of P, 0.02% or less of S, 0.015% or less of N, a balance of Fe, and inevitable impurities, wherein $Nb+Ti \leq 0.12$ is satisfied, a steel sheet microstructure has ferrite or bainite as a main phase and contains a balance of less than 20% by area of other structures, a weathering index defined by the following Relation 1 is 6.0 or more, a yield strength of the steel sheet oriented at 30° to a rolling direction satisfies 450 MPa or more, and an impact absorption energy at -5°C of the steel sheet oriented at 120° to the rolling direction satisfies 47 J or more.

[0017] First, the contents of the composition components forming the hot rolled steel sheet of the present disclosure and the reasons for limiting the contents will be described. Herein, "%" refers to "wt%", unless otherwise stated.

C: 0.02 to 0.09%

[0018] Carbon (C) is the most effective element for securing steel sheet strength, and may be added in an amount of 0.02% or more for securing strength. However, when the content is more than 0.09%, a soft casting characteristic is deteriorated, and the corrosion characteristic of a steel material may be deteriorated due to excessive production of cementite and pearlite structures. In this regard, it is preferred to control the C content to a range of 0.02 to 0.09% in the present disclosure. It is more preferred to control the C content to a range of 0.03 to 0.07%, and most preferably, to a range of 0.04 to 0.06%.

Si: 1.0% or less

[0019] Silicon (Si) is an element which improves a corrosion resistance characteristic by suppressing formation of a cementite or pearlite structure. When the content is more than 1.0%, impact characteristics and welding characteristics may be deteriorated. More preferably, Si is controlled to 0.6% or less.

Mn: 0.3 to 2.0%

[0020] Manganese (Mn) is an element which is the most commonly used for improving the strength of a steel sheet together with C, and the content may be controlled to a range of 0.3 to 2.0% in the present disclosure. When the content is less than 0.3%, the effect described above may not be obtained, and when the content is more than 2.0%, center segregation may be caused, and a carbon equivalent may be excessively increased to deteriorate weldability. More preferably, Mn is controlled to a range of 0.3 to 1.5%, and most preferably, to a range of 0.5 to 1.2%.

Cr: 0.4 to 2.0%

[0021] Chromium (Cr) is a fundamental alloy element improving seawater resistance and is concentrated on an interface of a corrosion product to stabilize a corrosion layer, thereby playing a role in improving a seawater resistance corrosion characteristic. In the present disclosure, the Cr content is limited to a range of 0.4 to 2.0%, and when the content is less than 0.4%, the effect described above may not be obtained, and when the content is more than 2.0%, an Ar3 temperature may be raised to coarsen a steel sheet structure. More preferably, Cr is controlled to a range of 0.5 to 1.5%, and most preferably, to a range of 0.5 to 1.3%.

Cu: 1.0% or less

[0022] Copper (Cu) is well known as an element to increase corrosion resistance, and its content is controlled to 1.0% or less in the present disclosure. When the content is more than 1.0%, a liquid phase is formed on a base material interface at a high temperature to cause high temperature brittleness, and in order to prevent this, a lot of expensive Ni is added, which is not preferred. More preferably, Cu is contained in a range of 0.5% or less.

Ni: 1.0% or less

[0023] Nickel (Ni) is an element added for preventing high temperature brittleness by Cu when Cu is added, and the content is controlled to 1.0% or less in the present disclosure. It is usually added at a ratio of 0.5 to 1 of Cu, and since it is an expensive element, it is preferred to minimize by adjusting the added amount to Cu. More preferably, Ni is controlled to a range of 0.4% or less.

Al: 0.1% or less

[0024] Aluminum (Al) is used as a deoxidation material and may be added in a certain amount for a solid solution strengthening effect with an amount included by deoxidation. However, when it is used too much, slab crack may be caused in a continuous casting, grain boundary oxidation may be caused in a final product, and thus, the content is controlled to 0.1% or less in the present disclosure. More preferably, Al is controlled to 0.05% or less.

Nb: 0.02 to 0.1%

[0025] Niobium (Nb) is used for precipitation strengthening and crystal grain refinement, but when the content is less than 0.02%, the effect described above may not be expected, and when the content is more than 0.1%, precipitates are coarsened, and the impact characteristics of a steel sheet may be worsened. Therefore, the Nb content is controlled to a range of 0.02 to 0.1% in the present disclosure. More preferably, Nb is controlled to the range of 0.03 to 0.07%.

Ti: 0.01 to 0.1%

[0026] Titanium (Ti) is used mainly for increasing steel material strength and suppressing structure coarsening during heating of a slab at a high temperature or in a heat affected zone of a welded part. In the present disclosure, the Ti content is controlled to a range of 0.01 to 0.1%, and when the Ti content is less than 0.01%, the effect described above may not be expected, and when the Ti content is more than 0.1%, steel sheet impact characteristics may be deteriorated. More preferably, the Ti content is controlled to a range of 0.02 to 0.09%.

Nb+Ti≤0.12

[0027] In the present disclosure, the sum of the added amounts of niobium and titanium is limited to 0.12% or less. When the sum is more than 0.12%, precipitates become coarsened, and the impact characteristics of a steel sheet may be worsened. More preferably, the content of Nb+Ti is controlled to a range of 0.10% or less.

P: 0.03% or less

[0028] In the present disclosure, P is contained in a range of 0.03% or less. The P is an impurity which is inevitably contained in steel making, and since it causes brittleness by segregation, it is preferred to include it in an as small amount as possible.

S: 0.02% or less

[0029] In the present disclosure, S is contained in a range of 0.02% or less. S is an impurity which is inevitably contained in steel making, and since it is an element which may cause grain boundary brittleness during hot rolling by forming an inclusion or forming a FeS compound having a low melting point, it is preferred to include it in an as small amount as possible.

N: 0.015% or less

[0030] In the present disclosure, a N content is controlled to a range of 0.015% or less which is a range controlled in a common steel.

Weathering index

[0031] In the present disclosure, a weathering index (I) by the following Relation 1 may be 6.0 or more.

[0032] The weathering index (I) is a warranty required in the KS standards, KSD3003, KSD3300, and the like, and in order to satisfy the standards, the weathering index (I) should satisfy 6.0 or more. When the weathering index (I) is less than 6.0, the corrosion resistance characteristic required in the corresponding standard may not be satisfied:

Weathering index (I) = $26.01 (\% \text{ Cu}) + 3.88 (\% \text{ Ni}) + 1.20 (\% \text{ Cr}) + 1.49 (\% \text{ Si}) + 17.28 (\% \text{ P}) - 7.29 (\% \text{ Cu})(\% \text{ Ni}) - 9.1 (\% \text{ Ni})(\% \text{ P}) - 33.39 (\% \text{ Cu})^2$. [Relation 1]

[0033] The remaining component of the present disclosure is iron (Fe). However, since in a common manufacturing process, unintended impurities may be unavoidably 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.

[0034] Meanwhile, the hot rolled steel sheet of the present disclosure has a steel sheet microstructure including ferrite or bainite as a main phase and a balance of less than 20% by area of other structures.

[0035] In the present disclosure, pearlite may be included as the other structure, when the area fraction thereof is more than 20%, a problem may arise in the corrosion resistance characteristic.

[0036] The hot rolled steel sheet of the present disclosure having the steel composition component and the microstructure as described above may satisfy a yield strength of the steel sheet oriented at 30° to a steel sheet rolling direction of 450 MPa or more and an impact absorption energy at -5°C of a steel sheet oriented at 120° to the rolling direction of 47 J or more.

[0037] Next, a method for manufacturing a hot rolled steel sheet according to an example embodiment of the present disclosure will be described.

[0038] The method for manufacturing a hot rolled steel sheet of the present disclosure includes: heating a steel slab including, by wt%: 0.02-0.09% of C, 1.0% or less of Si, 0.3-2.0% of Mn, 0.4 to 2.0% of Cr, 1.0% or less of Cu, 1.0% or less of Ni, 0.1% or less of Al, 0.02 to 0.1% of Nb, 0.01 to 0.1% of Ti, 0.03% or less of P, 0.02% or less of S, 0.015% or less of N, a balance of Fe, and inevitable impurities, and satisfies $Nb+Ti \leq 0.12$ and a weathering index defined by the following Relation 1 of 6.0 or more in a range of 1100 to 1300°C; finish hot rolling the heated steel slab in a temperature range of an Ar3 temperature or higher to 920°C or lower; cooling the hot rolled steel sheet after the finish hot rolling at a cooling rate of 10 to 50°C/s; and coiling the cooled hot rolled steel sheet in a temperature range of 500 to 660°C, wherein in the finish hot rolling, a cumulative rolling reduction rate in a temperature range of the Ar3 temperature or higher to an Ae3 temperature or lower is controlled to 30% or less.

[Heating]

[0039] First, in the present disclosure, a steel slab satisfying the steel component composition and the weathering index described above is heated to a temperature range of 1100 to 1300°C.

[0040] The heating process of the steel slab is performed in order to bring the alloy iron elements into a solid solution state so that they are used during rolling and secure surface quality of a material to be rolled.

[0041] In the present disclosure, the temperature range is controlled to a range of 1100 to 1300°C during the heating.

[0042] When the heating temperature is lower than 1100°C, the solid solution of the alloy iron element may not be formed, and the temperature in a width edge part of the material during rolling may be low to cause cracks. In addition, when the temperature is higher than 1300°C, a scale layer grown on the slab during the heating may not be detached by high pressure water, and the black skin of the roll may be peeled off, so that scale intrusion defects occur on the surface of a rolled material during rolling of the slab.

[Finish rolling]

[0043] Subsequently, in the present disclosure, the heated steel slab is finish hot rolled in a temperature range of an Ar3 temperature or higher to 920°C or lower.

[0044] The finish hot rolling is performed in order to secure material and impact characteristics.

[0045] In the present disclosure, the finish hot rolling temperature is controlled to a temperature range of the Ar3 temperature or higher to 920°C or lower during the finish hot rolling. When the finish hot rolling temperature is lower than the Ar3 temperature, a two-phase region rolling is performed to form a non-uniform structure and deteriorate impact characteristics, and when the temperature is higher than 920°C, the structure is coarsened to cause a problem in securing material and impact characteristics.

[0046] Meanwhile, at this time, in the present disclosure, during the finish hot rolling in the finish hot rolling process, it is required to perform finish hot rolling at a cumulative rolling reduction rate of 30% or less in a temperature range of the Ar3 temperature or higher to the Ae3 temperature or lower.

[0047] As such, the reason of controlling the cumulative rolling reduction rate in the temperature range is for guaranteeing the tensile characteristic at 30° to a rolling direction and the impact characteristic at 120° to a rolling direction, when the physical properties are guaranteed in a spiral steel pipe, by minimizing anisotropy of material physical properties.

[0048] In the present disclosure, the Ar3 temperature and the Ae3 temperature are terms well known in the art to which the present disclosure pertains, and may be easily determined by using JMatPro which is a commercially available software.

[Cooling]

[0049] Further, in the present disclosure, the hot rolled steel sheet after the finish hot rolling is cooled to a cooling rate of 10 to 50°C/s.

[0050] The cooling of the hot rolled sheet after the finish hot rolling is performed for the purpose of ferrite crystal grain refinement.

[0051] Herein, in the present disclosure, the cooling rate of the hot rolled sheet may be controlled to a range of 10 to 50°C/s. When the cooling rate is less than 10°C/S, ferrite transformation occurs at a high temperature to form a coarse structure and cause lack of the material property, and when the cooling rate is more than 50°C/s, problems such as poor shape caused by residual stress may arise. More preferably, the cooling rate is controlled to 20 to 45°C/s.

[0052] Meanwhile, in the present disclosure, the cooling rate is based on the temperature of the surface of the steel sheet.

[Coiling]

[0053] Finally, in the present disclosure, the cooled hot rolled steel sheet is coiled in a temperature range of 500 to 660°C.

[0054] When the coiling temperature is lower than 500°C, the impact characteristics are deteriorated due to formation of a hard phase such as martensite by deviation during cooling. However, when the coiling temperature is higher than 660°C, ferrite crystal grain and precipitates become coarsened, and the material property is not satisfied. More preferably, the coiling is performed at 550 to 650°C.

Mode for Invention

[0055] Hereinafter, the present disclosure will be described in detail through the following examples.

(Examples)

[0056]

[Table 1]

Steel type	C	Mn	Si	Al	P	S	Nb	Ti	Cu	Ni	Cr	N	Nb+Ti	I
1	0.05	0.7	0.5	0.03	0.01	0.003	0.05	0.02	0.3	0.1	1.3	0.006	0.07	7.6
2	0.05	0.7	0.5	0.03	0.01	0.003	0.05	0.02	0.2	0.05	0.5	0.006	0.07	5.6
3	0.05	0.7	0.5	0.03	0.01	0.003	0.04	0.09	0.3	0.1	1.3	0.006	0.13	7.6

[0057] * In Table 1, a content unit is wt%, and the balance is Fe and inevitable impurities. Further, I is a weathering index. Weathering index (I) = 26.01 (% Cu) + 3.88 (% Ni) + 1.20 (% Cr) + 1.49 (% Si) + 17.28 (% P) - 7.29 (% Cu)(% Ni) - 9.1 (% Ni)(% P) - 33.39 (% Cu)².

[Table 2]

No.	Steel type	Finish hot rolling temperature (°C)	Cooling rate (C/s)	Coiling temperature (°C)	Cumulative rolling reduction rate (%) at Ae3 or lower	Remarks
1	1	873	42	619	0	Experimental Example 1
2	1	866	35	616	5	Experimental Example 2
3	1	859	21	624	9	Experimental Example 3
4	1	852	46	623	14	Experimental Example 4
5	1	845	43	621	20	Experimental Example 5
6	1	838	50	622	25	Experimental Example 6
7	1	831	49	621	31	Comparative Example 1

(continued)

No.	Steel type	Finish hot rolling temperature (°C)	Cooling rate (C/s)	Coiling temperature (°C)	Cumulative rolling reduction rate (%) at Ae3 or lower	Remarks
8	1	824	37	620	36	Comparative Example 2
9	1	817	35	617	39	Comparative Example 3
10	1	810	39	622	45	Comparative Example 4
11	1	875	41	582	0	Experimental Example 7
12	1	872	41	522	0	Experimental Example 8
13	1	877	42	447	0	Comparative Example 5
14	1	921	38	619	0	Comparative Example 6
15	1	872	28	668	0	Comparative Example 7
16	2	876	32	620	0	Comparative Example 8
17	2	875	33	622	0	Comparative Example 9
18	2	877	31	680	0	Comparative Example 10
19	3	873	36	636	0	Comparative Example 11

[0058] Steel slabs having the steel composition components and the weathering indexes listed in Table 1 were prepared. Specifically, in Table 1, Steel Type 1 is an inventive steel, Steel Type 2 is a comparative steel having the weathering index outside of the range of the present disclosure, and Steel Type 3 is a comparative steel having the Nb+Ti content outside of the range of the present disclosure.

[0059] Subsequently, the thus-prepared steel slabs were heated to 1110°C, finish hot rolling, cooling, and coiling were performed under the conditions listed in Table 2, and then hot rolled steel sheets were manufactured. At this time, during the finish hot rolling, the cumulative rolling reduction rate at the Ae3 temperature or lower was controlled to the conditions of Table 2.

[0060] The mechanical properties and the microstructural properties of each hot rolled steel sheet manufactured above were evaluated, and the results are shown in the following Table 3. Specifically, the microstructure and its fraction of the hot rolled steel sheet are measured by using the results from analysis of a matrix structure at a 1/4t point of the sheet thickness of each hot rolled steel sheet. Specifically, the fractions of ferrite, bainite, and other structures were measured using FE-SEM and Image analyzer after Nital corrosion.

[0061] Further, the yield strength of a steel sheet oriented at 30° to the rolling direction of the hot rolled steel sheets was measured, and furthermore, the impact absorption energy at -5°C of the steel sheet oriented at 120° to the rolling direction of the hot rolled steel sheet was measured, and the results are shown in the following Table 3. Herein, the yield strength of each hot rolled steel sheet was measured by collecting a specimen at a 1/4t point of the steel sheet oriented at 30° to the rolling direction of the hot rolled steel sheets, and the tensile physical properties were evaluated by a tensile test using a method of measuring a sheet specimen having a size of a JIS No. 5 specimen using the JIS standards.

[0062] Further, the impact absorption energy of each hot rolled steel sheet was measured by collecting a specimen at a 1/4t point of the steel sheet oriented at 120° to the rolling direction of the hot rolled steel sheets, and the impact toughness of each specimen was measured using an average of absorption energy values measured 3 times at -5°C through the Charpy V-notch test.

[Table 3]

No.	Steel type	Microstructure		Yield strength (MPa) at 30° to rolling direction	Impact absorption energy (J) at 120° to rolling direction	Remarks
		Main structure	Other structures (type and fraction by area)			
1	1	Ferrite	Pearlite (3.2%)	503	201	Experimental Example 1

(continued)

No.	Steel type	Microstructure		Yield strength (MPa) at 30° to rolling direction	Impact absorption energy (J) at 120° to rolling direction	Remarks
		Main structure	Other structures (type and fraction by area)			
2	1	Ferrite	Pearlite (3.0%)	492	189	Experimental Example 2
3	1	Ferrite	Pearlite (2.8%)	491	179	Experimental Example 3
4	1	Ferrite	Pearlite (2.7%)	508	158	Experimental Example 4
5	1	Ferrite	Pearlite (2.8%)	504	89	Experimental Example 5
6	1	Ferrite	Pearlite (2.9%)	511	51	Experimental Example 6
7	1	Ferrite	Pearlite (2.9%)	507	42	Comparative Example 1
8	1	Ferrite	Pearlite (3.0%)	497	38	Comparative Example 2
9	1	Ferrite	Pearlite (3.2%)	492	31	Comparative Example 3
10	1	Ferrite	Pearlite (3.1%)	497	27	Comparative Example 4
11	1	Ferrite	Pearlite (4.2%) Bainite (3.2%)	481	223	Experimental Example 7
12	1	Bainite (100%)	-	499	228	Experimental Example 8
13	1	Bainite (55%)	Martensite (45%)	512	39	Comparative Example 5
14	1	Ferrite	Pearlite (3.1%)	476	44	Comparative Example 6
15	1	Ferrite	Pearlite (0.4%)	442	164	Comparative Example 7
16	2	Ferrite	Pearlite (3.0%)	386	223	Comparative Example 8
17	2	Ferrite	Pearlite (3.0%)	388	221	Comparative Example 9
18	2	Ferrite	Pearlite (0.2%)	352	126	Comparative Example 10
19	3	Ferrite	Pearlite (0.1%)	756	22	Comparative Example 11

[0063] As shown in Tables 1 to 3, in Experimental Examples 1 to 8 which satisfied the steel alloy composition components and the manufacturing process conditions of the present disclosure, the cumulative rolling reduction rate in the finish hot rolling at the Ae3 temperature or lower was controlled to 30% or less, and the material and impact characteristics were good. This is considered to be due to the fact that when the cumulative rolling reduction rate is increased at the Ae3 temperature or lower, the material anisotropy is increased to deteriorate the impact characteristic of the steel sheet at 120° to the rolling direction.

[0064] However, in Comparative Examples 1 to 4 in which the cumulative rolling reduction rate in the finish hot rolling at the Ae3 temperature or lower was 30% or more, the impact characteristic of the hot rolled steel sheet oriented at 120° to the rolling direction did not satisfy 47 J at -5°C.

[0065] In Comparative Example 5, since the coiling temperature (CT) was low, the impact characteristics were deteriorated by formation of a hard phase, and in Comparative Example 6, since the finish hot rolling temperature was too high, the structure was coarsened and the impact characteristics were not satisfied.

[0066] In addition, though Comparative Example 7 satisfied the impact characteristics, its yield strength of the steel sheet was poor due to the high-temperature CT.

[0067] Meanwhile, FIG. 1 is a graph illustrating changes in impact characteristics of a steel material with a cumulative rolling reduction rate in a temperature range from Ar3 to Ae3, in an example embodiment of the present disclosure. As shown in FIG. 1, when the cumulative rolling reduction rate in the finish hot rolling at the Ae3 temperature or lower was 30% or lower, the impact characteristics were confirmed to be improved.

[0068] As described above, the preferred example embodiments of the present disclosure have been described, various modifications are possible without departing from the scope of the present disclosure by a person skilled in the

art to which the present disclosure pertains, of course. Accordingly, the right scope of the present disclosure should not be limited to the example embodiments described and should be defined by the appended claims and equivalents thereto.

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Claims

1. A hot rolled steel sheet comprising, by weight: 0.02 to 0.09% of C, 1.0% or less of Si, 0.3 to 2.0% of Mn, 0.4 to 2.0% of Cr, 1.0% or less of Cu, 1.0% or less of Ni, 0.1% or less of Al, 0.02 to 0.1% of Nb, 0.01 to 0.1% of Ti, 0.03% or less of P, 0.02% or less of S, 0.015% or less of N, a balance of Fe, and inevitable impurities, wherein Nb+Ti≤0.12 is satisfied,

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a steel sheet microstructure has ferrite or bainite as a main phase and contains a balance of less than 20% by area of other structures,

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a weathering index defined by the following Relation 1 is 6.0 or more,

a yield strength of the steel sheet oriented at 30° to a rolling direction is 450 MPa or more, and an impact absorption energy at -5°C of the steel sheet oriented at 120° to the rolling direction is 47 J or more:

$$\text{Weathering index (I)} = 26.01 (\% \text{ Cu}) + 3.88 (\% \text{ Ni}) + 1.20 (\% \text{ Cr}) + 1.49 (\% \text{ Si}) + 17.28 (\% \text{ P}) - 7.29 (\% \text{ Cu})(\% \text{ Ni}) - 9.1 (\% \text{ Ni})(\% \text{ P}) - 33.39 (\% \text{ Cu})^2. \quad [\text{Relation 1}]$$

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2. The hot rolled steel sheet of claim 1, wherein the other structures are pearlite.

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3. A method for manufacturing a hot rolled steel sheet, the method comprising:

heating a steel slab including, by weight: 0.02 to 0.09% of C, 1.0% or less of Si, 0.3 to 2.0% of Mn, 0.4 to 2.0% of Cr, 1.0% or less of Cu, 1.0% or less of Ni, 0.1% or less of Al, 0.02 to 0.1% of Nb, 0.01 to 0.1% of Ti, 0.03% or less of P, 0.02% or less of S, 0.015% or less of N, a balance of Fe, and inevitable impurities, and satisfies Nb+Ti≤0.12 and a weathering index defined by the following Relation 1 of 6.0 or more, in a range of 1100 to 1300°C;

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finish hot rolling the heated steel slab in a temperature range of an Ar3 temperature or higher to 920°C or lower;

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cooling the hot rolled steel sheet after the finish hot rolling at a cooling rate of 10 to 50°C/s; and

coiling the cooled hot rolled steel sheet in a temperature range of 500 to 660°C,

wherein in the finish hot rolling, a cumulative rolling reduction rate in a temperature range of the Ar3 temperature or higher to an Ae3 temperature or lower is controlled to 30% or less:

$$\text{Weathering index (I)} = 26.01 (\% \text{ Cu}) + 3.88 (\% \text{ Ni}) + 1.20 (\% \text{ Cr}) + 1.49 (\% \text{ Si}) + 17.28 (\% \text{ P}) - 7.29 (\% \text{ Cu})(\% \text{ Ni}) - 9.1 (\% \text{ Ni})(\% \text{ P}) - 33.39 (\% \text{ Cu})^2. \quad [\text{Relation 1}]$$

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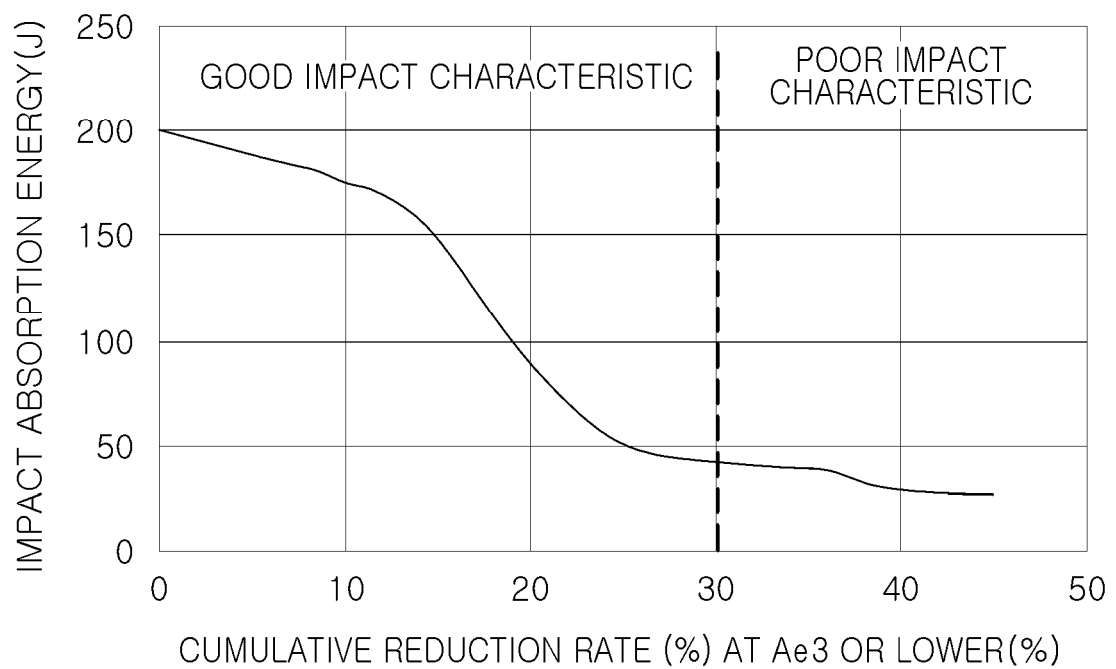
4. The method for manufacturing a hot rolled steel sheet of claim 3, wherein the coiled hot rolled steel sheet has ferrite and bainite as a main phase of a microstructure and contains a balance of less than 20% by area of other structures, a yield strength of the steel sheet oriented at 30° to a rolling direction is 450 MPa or more, and an impact absorption energy at -5°C of the steel sheet oriented at 120° to the rolling direction is 47J or more.

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[FIG. 1]



INTERNATIONAL SEARCH REPORT

International application No.

PCT/KR2024/019668

A. CLASSIFICATION OF SUBJECT MATTER

C22C 38/58(2006.01)i; C22C 38/48(2006.01)i; C22C 38/50(2006.01)i; C22C 38/06(2006.01)i; C22C 38/00(2006.01)i;
C21D 8/02(2006.01)i; C21D 9/46(2006.01)i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

C22C 38/58(2006.01); B21B 1/22(2006.01); C21D 8/02(2006.01); C21D 9/46(2006.01); C22C 38/00(2006.01);
C22C 38/38(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), 니오븀(niobium), 티타늄(titanium), 페라이트
(ferrite), 베이나이트(bainite), 펄라이트(pearlite), 가열(heating), 냉각(cooling)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 2019-196508 A (NIPPON STEEL CORP.) 14 November 2019 (2019-11-14) See paragraphs [0038], [0040], [0049] and [0057], claims 1-2 and 4 and tables 3-4.	1-4
A	WO 2023-214472 A1 (JFE STEEL CORPORATION) 09 November 2023 (2023-11-09) See claims 1-3.	1-4
A	KR 10-2019-0131086 A (NIPPON STEEL CORPORATION) 25 November 2019 (2019-11-25) See paragraph [0235] and claims 1 and 4.	1-4
A	KR 10-2014-0099321 A (JFE STEEL CORPORATION) 11 August 2014 (2014-08-11) See paragraphs [0090]-[0091] and claims 1-3 and 6.	1-4
A	JP 2015-214718 A (NIPPON STEEL & SUMITOMO METAL) 03 December 2015 (2015-12-03) See paragraph [0066] and claims 1-2 and 5-6.	1-4

☐ 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

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“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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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/KR2024/019668

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REFERENCES CITED IN THE DESCRIPTION

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