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(54) **HIGH STRENGTH HOT-ROLLED STEEL SHEET HAVING EXCELLENT HOLE EXPANSION RATIO AND MANUFACTURING METHOD FOR SAME**

(57) A high strength hot-rolled steel sheet having an excellent hole expansion ratio according to an aspect of the present invention comprises, by weight %, 0.12% or more and less than 0.30% of carbon (C), 0.1-2.5% of manganese (Mn), 0.5% or less of silicon (Si) (not including 0%), 0.0005-0.005% of boron (B), 0.02% or less of

phosphorus (P), 0.01% or less of sulfur (S), and the balance being iron (Fe) and unavoidable impurities, and comprises 95 volume% or more of martensite as a microstructure. And the product of the tensile strength (TS) and hole expansion ratio (HER) can be 30,000MPa% or greater.

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Description

[Technical Field]

[0001] The present disclosure relates to a hot-rolled steel sheet used as a material such as a component for an automobile collision member and a structural support, and more particularly, to a hot-rolled steel sheet having high strength characteristics and an excellent hole expansion ratio, and a manufacturing method including the same.

[Background Art]

[0002] Steel materials not only require high-strength characteristics to secure safety, but also require workability such as a hole expansion ratio (HER) in order to be processed to have various shapes in accordance with the designer's requirements. However, since the strength and workability of steel materials are difficult to be compatible with each other, various studies are being conducted to secure the strength and workability of steel materials at the same time.

[0003] The following patent documents are known as a method for simultaneously securing high strength and high formability of a hot-rolled steel sheet.

[0004] Patent Document 1 proposes a technique for securing strength by precipitation hardening by the addition of an alloying element. That is, Patent Document 1. That is, Patent Document 1 seeks to secure high strength characteristics by adding alloying elements such as Ti, Nb, V, and Mo, but these alloying elements are expensive elements and are not preferable in terms of economic efficiency due to an excessive increase in manufacturing costs.

[0005] Patent Documents 2 to 4 propose a technique for securing strength and ductility by using a dual structure of ferrite and martensite, or by retaining austenite and utilizing a composite structure of ferrite, bainite, and martensite. However, such ferrite or residual austenite has a technical difficulty in not sufficiently securing high-strength characteristics due to its excellent ductility and inferior strength.

(Prior art Documents)

[0006]

(Patent Document 1) Republic of Korea Patent Publication No. 10-2005-113247 (published on December 1, 2005)

(Patent Document 2) Japanese Unexamined Patent Application Publication No. 2005-298967 (published on October 27, 2005)

(Patent Document 3) US Patent Publication No. 2005-0155673 (published on July 21, 2005)

(Patent Document 4) European Patent Publication No. 1396549 (published on Mar. 10, 2004)

[Disclosure]

[Technical Problem]

[0007] An aspect of the present disclosure is to provide a high-strength hot-rolled steel sheet having an excellent hole expansion ratio and a method of manufacturing the same can be provided.

[0008] The subject of the present disclosure is not limited to the above. Those of ordinary skill in the art will have no difficulty in understanding the additional subject of the present disclosure from the general contents of the present specification.

[Technical Solution]

[0009] According to an aspect of the present disclosure, a high strength hot-rolled steel sheet having an excellent hole expansion ratio includes, by weight %, 0.12% or more and less than 0.30% of carbon (C), 0.1 to 2.5% of manganese (Mn), 0.5% or less of silicon (Si) (not including 0%), 0.0005 to 0.005% of boron (B), 0.02% or less of phosphorous (P), 0.01% or less of sulfur (S), and a balance of iron (Fe) and unavoidable impurities, and 95 volume% or more of martensite as a microstructure, wherein a product of tensile strength (TS) and hole expansion ratio (HER) can be 30,000MPa% or greater.

[0010] The hot-rolled steel sheet may further include, by weight %, one or more elements of 0.5% or less of chromium (Cr), and 0.005 to 0.2 % of titanium (Ti).

[0011] The microstructure may include a total of 5 vol% or less of one or more of ferrite, bainite, carbide and residual austenite.

[0012] The hot-rolled steel sheet may have tensile strength (TS) of 1,250 MPa or more.

[0013] The hot-rolled steel sheet may have a hole expansion ratio (HER) of 20% or more.

[0014] The hot-rolled steel sheet may have a thickness of 1.8 mm or less.

[0015] According to an aspect of the present disclosure, a method of manufacturing a high strength hot-rolled steel sheet having an excellent hole expansion ratio comprises operations of:

reheating a slab, including by weight %, 0.12% or more and less than 0.30% of carbon (C), 0.1 to 2.5% of manganese (Mn), 0.5% or less of silicon (Si) (not including 0%), 0.0005 to 0.005% of boron (B), 0.02% or less of phosphorous (P), 0.01% or less of sulfur (S), and a balance of iron (Fe) and unavoidable impurities; hot-rolling the reheated slab to provide a hot-rolled steel sheet; initiating cooling of the hot-rolled steel sheet within 5 seconds of an end point of the hot-rolled steel sheet, and cooling the hot-rolled steel sheet to a cooling end temperature of 350°C or lower at a cooling rate of 50 to 1,000°C/s; and winding the cooled hot-rolled steel sheet.

[0016] The slab may further include, by wt%, one or more elements of 0.5% or less of chromium (Cr), and 0.005 to 0.2% of titanium (Ti).

[0017] The means for solving the above problems do not list all of the features of the present invention, and various features of the present invention and advantages and effects thereof will be understood in greater detail with reference to the specific embodiments as below.

[Advantageous Effects]

[0018] According to an aspect of the present disclosure, a hot-rolled steel sheet having high strength and a remarkably improved hole expansion ratio (HER), and a method of manufacturing the same may be provided.

[Best Mode for Invention]

[0019] The present disclosure relates to a cryogenic austenitic high-manganese steel material having excellent corrosion resistance and a method of manufacturing the same, and hereinafter, preferable embodiments of the present disclosure will be described. Embodiments of the present disclosure may be modified in various forms, and the scope of the present disclosure should not be construed as being limited to the embodiments described below. The embodiments are provided to further describe the present disclosure to a person skilled in the art to which the present disclosure pertains.

[0020] Hereinafter, a steel composition in the present disclosure will be described in greater detail. Hereinafter, "%" indicating a content of each element may be based on weight unless otherwise indicated.

[0021] The high strength hot-rolled steel sheet having an excellent hole expansion ratio includes, by weight %, 0.12% or more and less than 0.30% of carbon (C), 0.1 to 2.5% of manganese (Mn), 0.5% or less of silicon (Si) (not including 0%), 0.0005 to 0.005% of boron (B), 0.02% or less of phosphorous (P), 0.01% or less of sulfur (S), and a balance of iron (Fe) and unavoidable impurities. In addition, the high strength hot-rolled steel sheet having an excellent hole expansion ratio according to an aspect of the present disclosure may further include, by wt%, one or more elements of 0.5% or less of chromium (Cr), and 0.005 to 0.2% of titanium (Ti).

Carbon (C): 0.12% or more and less than 0.30%

[0022] Since carbon(C) is an element effectively contributing to improvement of strength of steel, the present disclosure may include a certain level or more of carbon (C) to secure the strength of the hot-rolled steel sheet. In addition, when the carbon content (C) is less than a certain level, since a large amount of low-temperature structure may be formed during cooling after hot rolling, in the present disclosure, a problem in which a desired microstructure cannot be obtained, may occur, in the present disclosure, 0.12% or more of carbon (C) may be included. A preferred carbon (C) content may be 0.125% or more, and a more preferable carbon (C) content may be 0.13% or more. On the other hand, when carbon (C) is excessively added, a problem in which strength is improved, but a hole expansion ratio (HER) and weldability are deteriorated may occur, such that in the present disclosure, a carbon(C) content may be limited to be less than 0.30%. A preferable carbon(C) content may be 0.29% or less, and a more preferable carbon(C) content may be 0.28% or less.

Manganese (Mn): 0.1 to 2.5%

[0023] Manganese (Mn) is an element effectively contributing to improving strength and hardenability of steel. In addition, manganese (Mn) is also an element capable of effectively preventing occurrence of cracks due to sulfur (S) since manganese (Mn) combines with sulfur (S) that is inevitably introduced during a steel manufacturing process to form MnS. Therefore, in the present disclosure, 0.1 % or more of manganese (Mn) may be included to achieve this effect. A preferable manganese (Mn) content may be 0.3% or more, and a more preferable manganese (Mn) content may be 0.5% or more. However, when manganese (Mn) is excessively added, there is a concern about lowering of tensile strength due to residual austenite, and since it is not preferable in terms of weldability and economy, in the present

disclosure, an upper limit of the manganese (Mn) content may be limited to 2.5%. A preferable manganese (Mn) content may be 2.3% or less, and a more preferable manganese (Mn) content may be 2.1% or less.

Silicon (Si): 0.5% or less (excluding 0%)

[0024] Since silicon (Si) is an element having a strong affinity with oxygen, when a large amount of Si is added, it may cause a decrease in surface quality due to surface scale, and is not preferable in terms of weldability. Accordingly, in the present disclosure, an upper limit of a silicon (Si) content may be limited to 0.5%. A preferable silicon (Si) content may be 0.4 % or less, and a more preferable silicon (Si) content may be 0.3 % or less. However, since silicon (Si) acts as a deoxidizing agent and is an element contributing to improving the strength of steel, in the present disclosure, 0% may be excluded from a lower limit of the silicon (Si) content.

Boron (B): 0.0005 to 0.005%

[0025] Boron (B) is an element effectively contributing improving the hardenability of steel, and is an element capable of effectively suppressing transformation into a low-temperature structure such as ferrite and pearlite, during cooling after hot rolling even by adding a small amount thereof. Accordingly, in the present disclosure, 0.0005% or more of boron (B) may be included to achieve such an effect. A preferable boron (B) content may be 0.0007% or more, and a more preferable boron (B) content may be 0.0009% or more. On the other hand, when boron (B) is added excessively, since boron (B) reacts with iron (Fe) to cause grain boundary brittleness, in the present disclosure, an upper limit of boron (B) may be limited to 0.005%. A preferable boron (B) content may be 0.003% or less, and a more preferable boron (B) content may be 0.002% or less.

Phosphorus (P): 0.02% or less

[0026] Phosphorus (P) is a major element that segregates at grain boundaries and causes a decrease in toughness of steel. Therefore, it is desirable to control a phosphorus (P) content as low as possible. Therefore, it is theoretically most advantageous to limit the phosphorus (P) content to 0%. However, since phosphorus (P) is an impurity that is unavoidably introduced into steel during a steelmaking process, and an excessive process load may be caused to control the phosphorus (P) content to 0%. Accordingly, in the present disclosure, in consideration of this point, an upper limit of the phosphorus (P) content may be limited to 0.02%.

Sulfur (S): 0.01 % or less

[0027] Sulfur (S) is a major element forming MnS, increasing an amount of precipitates, and embrittling steel. Therefore, it is desirable to control a sulfur (S) content as low as possible. Therefore, it is theoretically most advantageous to limit the sulfur (S) content to 0%. However, sulfur (S) is also an impurity that is unavoidably introduced into steel during a steelmaking process, and an excessive process load may be caused to control the sulfur (S) content to 0%. Accordingly, in the present disclosure, an upper limit of the sulfur (S) content may be limited to 0.01% in consideration of this point.

Chromium (Cr): 0.5 % or less

[0028] Since chromium (Cr) is an element contributing to the hardenability of steel, in the present disclosure, chromium (Cr) may be included to achieve this effect. However, excessive addition of chromium (Cr), which is an expensive element, is not desirable from an economic point of view, and when chromium (Cr) is excessively added, weldability may be deteriorated, such that in the present disclosure, an upper limit of the chromium (Cr) content may be limited to 0.5%. A preferable chromium (Cr) content may be 0.4% or less, and a more preferable chromium (Cr) content may be 0.3% or less.

Titanium (Ti): 0.005 to 0.2%

[0029] In general, titanium (Ti) is an element known to form carbides and nitrides by combining with carbon (C) and nitrogen (N). In the present disclosure, boron (B) is essentially added to steel in order to secure hardenability, but when nitrogen (N) and boron (B) contained in the steel are combined, a desired effect may not be achieved by adding boron (B) in the present disclosure. On the other hand, when titanium (Ti) is added, since nitrogen (N) before being combined with boron (B) is combined with titanium (Ti) to form a nitride, an effect of adding boron (B) can be more effectively improved. Therefore, in the present disclosure, 0.005% or more of titanium (Ti) may be added to achieve this effect. A preferable titanium (Ti) content may be 0.01% or more, and a more preferable titanium (Ti) content may be 0.015% or more. However, when titanium (Ti) is excessively added, a problem of lowering continuous casting in a slab manufacturing

step occurs, such that in the present disclosure, an upper limit of the titanium (Ti) content may be limited to 0.2%. A preferable titanium (Ti) content may be 0.17% or less, and a more preferable titanium (Ti) content may be 0.15% or less.

[0030] In the present disclosure, in addition to the above-described steel composition, a remainder thereof may include Fe and unavoidable impurities. In a general manufacturing process, inevitable impurities may be inevitably added from raw materials or an ambient environment, and thus, impurities may not be excluded. A person skilled in the art of a general manufacturing process may be aware of the impurities, and thus, the descriptions of the impurities may not be provided in the present disclosure. Also, addition of effective elements other than the above composition may not be excluded.

[0031] Hereinafter, the microstructure of the present disclosure will be described in more detail.

[0032] The present inventors of the present disclosure have conducted a research on the conditions in which the strength of the steel and the hole expansion ratio (HER) can be secured at the same time. Although the strength and workability of conventional steels were widely recognized as incompatible physical properties, the present inventors of the present disclosure could derive, after in-depth research, that not only the type of unfinished structure of the steel but also a fraction of a specific microstructure had a significant effect on the compatibility between the strength and hole expansion ratio (HER) of the steel.

[0033] The hot-rolled steel sheet according to an aspect of the present disclosure includes martensite as a matrix structure, and a fraction of martensite may be 95% by volume or more, with respect to a volume of the total hot-rolled steel sheet. Since in the present disclosure, 95 % or more of martensite, which is a hard tissue, is included, high strength can be effectively secured and at the same time, a hole expansion ratio (HER) may be effectively secured.

[0034] The hot-rolled steel sheet according to an aspect of the present disclosure does not entirely exclude inclusion of structures other than martensite. However, since ferrite, bainite, carbide and residual austenite are not desirable for securing strength, the total fraction thereof may be limited to 5 vol% or less, and more preferably, the total fraction thereof must be strictly limited to 3 vol% or less.

[0035] In addition, the hot-rolled steel sheet according to an aspect of the present disclosure may further include cementite precipitates, and the like, in addition to the above-described structure as a balance structure.

[0036] Therefore, the hot-rolled steel sheet according to an aspect of the present disclosure may satisfy 1,250 MPa or more of tensile strength (TS) and 20% or more hole expansion ratio (HER). In particular, in the hot-rolled steel sheet according to an aspect of the present disclosure, a product of tensile strength (TS) and hole expansion ratio (HER) may be effectively compatible with strength and workability at a level of 30,000 MPa% or more.

[0037] In addition, the thickness of the hot-rolled steel sheet according to an aspect of the present disclosure is not particularly limited.

[0038] However, since the hot-rolled steel sheet according to an aspect of the present disclosure has excellent strength and workability, it can effectively contribute to securing the economy and light weight of a final product through thinning. Accordingly, the thickness of the hot-rolled steel sheet according to an aspect of the present disclosure may be 1.8 mm or less, and a more preferable thickness may be 1.5 mm or less.

[0039] Hereinafter, a manufacturing method in the present disclosure will be described in greater detail.

[0040] A method of manufacturing a high strength hot-rolled steel sheet having an excellent hole expansion ratio according to an aspect of the present disclosure may include operations of: reheating a slab, including by weight %, 0.12% or more and less than 0.30% of carbon (C), 0.1 to 2.5% of manganese (Mn), 0.5% or less of silicon (Si) (not including 0%), 0.0005 to 0.005% of boron (B), 0.02% or less of phosphorous (P), 0.01% or less of sulfur (S), and a balance of iron (Fe) and unavoidable impurities; hot-rolling the reheated slab to provide a hot-rolled steel sheet; initiating cooling of the hot-rolled steel sheet within 5 seconds of an end point of the hot-rolled steel sheet, and cooling the hot-rolled steel sheet to a cooling end temperature of 350°C or lower at a cooling rate of 50 to 1,000°C/s; and winding the cooled hot-rolled steel sheet.

Reheating slab and hot rolling

[0041] Since a slab steel composition of the present disclosure corresponds to the steel composition of the hot-rolled steel sheet described above, the description of the slab steel composition of the present disclosure is replaced by the description of the hot-rolled steel sheet steel composition described above.

[0042] Slabs manufactured by a conventional slab manufacturing process may be reheated in a certain temperature range. For sufficient homogenization treatment, a lower limit of a reheating temperature may be limited to 1,050°C, and an upper limit of the reheating temperature may be limited to 1,350°C in consideration of economy and surface quality.

[0043] The reheated slab may be finish-rolled to a thickness of 1.8 mm or less, preferably 1.5 mm or less, by hot rolling. In the present disclosure, hot rolling may be performed under conventional conditions, but a finish rolling temperature for controlling a rolling load and reducing a surface scale may be in a range of 800 to 950°C. In addition, since in the present disclosure, a hot-rolled steel sheet having a thin thickness is intended to be manufactured, continuous rolling in which a preceding material and a following material are not separated and continuously rolled is more preferable

in terms of securing the thickness of the hot-rolled steel sheet.

Cooling

[0044] The hot-rolled steel sheet immediately after hot-rolling may be cooled under rapid cooling conditions.

[0045] In the present disclosure, since a microstructure of the hot-rolled steel sheet intends to be strictly controlled, cooling of the present disclosure is preferably initiated within 5 seconds immediately after hot-rolling. This is because ferrite, pearlite and bainite, which are not intended by the present disclosure, may be formed by air cooling in an atmosphere when a time from the hot rolling to a start of cooling exceeds 5 seconds. A more preferable time from the hot rolling to the start of cooling may be within 3 seconds.

[0046] In addition, the hot-rolled steel sheet immediately after hot rolling may be cooled to a cooling end temperature of 350°C or lower at a cooling rate of 50 to 1,000°C/s. When the cooling rate is less than 50° C/s, transformation into ferrite, pearlite, and bainite occurs during cooling, and thus there is a problem in that the desired microstructure of the present disclosure cannot be secured. In the present disclosure, an upper limit of the cooling rate is not particularly limited in order to secure the desired microstructure, but the upper limit of the cooling rate may be limited to 1,000°C/s in consideration of facility limitations and economics. In addition, when the cooling end temperature exceeds 350°C, transformation into ferrite, pearlite and bainite is inevitable, and thus there is a problem in that the desired microstructure of the present disclosure cannot be secured.

[0047] The hot-rolled steel sheet manufactured by the above manufacturing method secures 1,250 MPa or more of tensile strength (TS) and 20% or more of hole expandability (HER), and the strength and workability can be effectively compatible to a level that a product of the tensile strength (TS) and hole expandability (HER) is 30,000 MPa% or more.

[Mode for Invention]

[0048] Hereinafter, the present disclosure will be described in more detail through examples. However, it is necessary to note that the following examples are only intended to illustrate the present disclosure in more detail and are not intended to limit the scope of the present disclosure. This is because the scope of the present disclosure is determined by matters described in the claims and able to be reasonably inferred therefrom.

(Example)

[0049] After a slab having the composition as in Table 1 below was prepared, a hot-rolled steel sheet specimen was prepared using the conditions of Table 2 below. Each slab was manufactured by a conventional manufacturing method, and was reheated in a temperature range of 1,050 to 1,350° C. and subjected to homogenization.

[Table 1]

Steel type	C	Mn	Si	P	S	Cr	Ti	B
A	0.216	1.01	0.04	0.007	0.003	0.02	0.0180	0.0020
B	0.135	1.22	0.06	0.012	0.003	0.04	0.0200	0.0022
C	0.151	0.99	0.03	0.016	0.001	0.05	0.0180	0.0021
D	0.244	1.06	0.07	0.013	0.002	0.04	0.0190	0.0020
E	0.221	2.01	0.03	0.015	0.001	0.03	0.0200	0.0019
F	0.211	1.09	0.05	0.007	0.010	0.05	0.1100	0.0021
G	0.218	0.96	0.04	0.006	0.009	0.02	0.0200	0.0020
H	0.090	0.98	0.04	0.007	0.007	0.02	0.0210	0.0018
I	0.221	1.01	0.07	0.012	0.001	0.03	0.0200	0.0003
J	0.164	3.14	0.08	0.011	0.004	0.04	0.0210	0.0019
K	0.226	0.96	0.65	0.009	0.004	0.04	0.0190	0.0018
L	0.219	0.99	0.07	0.022	0.005	0.02	0.0220	0.0018
M	0.216	1.02	0.06	0.013	0.014	0.05	0.0220	0.0022

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[Table 2]

Classifi- cation	Steel type	Finish rolling end temperat ure (°C)	Thicknes s of hot- rolled steel sheet (mm)	Cooling initiati on time after rolling ends(sec)	Cooling rate (°C/sec)	Cooling end temperat ure (°C)
1	A	860	1.4	1.2	100	236
2	A	874	1.4	1.5	200	208
3	A	893	1.4	0.9	300	204
4	A	919	1.4	0.8	100	289
5	A	885	1.2	2.6	100	140
6	B	916	1.4	1.2	100	246
7	C	860	1.4	1.1	100	181
8	D	861	1.4	0.5	100	135
9	E	880	1.4	0.8	100	155
10	F	897	1.4	1.1	100	245
11	G	897	1.4	1.7	100	118
12	A	884	1.4	5.7	100	129
13	A	873	1.4	1.0	30	202
14	A	882	1.4	1.4	100	413
15	H	903	1.4	0.5	100	220
16	I	908	1.4	1.6	100	148
17	J	899	1.4	1.6	100	106
18	K	903	1.4	1.8	100	225
19	L	903	1.4	1.9	100	218
20	M	903	1.4	1.4	100	165

[0050] For each specimen prepared under the conditions of Table 2, a microstructure and mechanical properties were measured and shown in Table 3. The microstructure was measured using an optical microscope and a scanning electron microscope, and then evaluated through an image analysis. Among the mechanical properties, tensile strength was evaluated by conducting a tensile test in a C direction using a DIN standard. Among the mechanical properties, a hole expansion ratio(HER) was evaluated according to a JFST 1001-1996 standard, and the hole expansion ratio until fracture was measured by pushing up with a punch after processing a hole in each specimen.

[Table 3]

Clas sifi- cati on	Stee 1 type	Martensite fraction (volume%)	Tensile strength (TS , MPa)	Hole expansion ratio (HER, %)	Tensile strength* Hole expansion ratio (MPa%)
1	A	98	1610	32	51520
2	A	97	1619	25	40475
3	A	98	1520	40	60800
4	A	96	1621	35	56735
5	A	97	1624	27	43848
6	B	96	1287	33	42471
7	C	96	1383	30	41490

(continued)

Classi- fication	Steel type	Martensite fraction (volume%)	Tensile strength (TS, MPa)	Hole expansion ratio (HER, %)	Tensile strength* Hole expansion ratio (MPa%)
8	D	96	1674	26	43524
9	E	97	1622	26	42172
10	F	98	1648	35	57680
11	G	96	1557	38	59166
12	A	62	1211	20	24220
13	A	71	1184	33	39072
14	A	66	1296	19	24624
15	H	42	949	40	37960
16	I	48	1131	38	42978
17	J	88	1315	22	28930
18	K	97	1602	17	27234
19	L	98	1543	19	29317
20	M	96	1569	18	28242

[0051] In the case of specimens 1 to 11 satisfying both the alloy composition and manufacturing conditions of the present disclosure, it can be confirmed that both the fraction of martensite of 95% by volume or more and a product of tensile strength (TS) and hole expansion ratio (HER) of 30,000 MPa% or more are satisfied. In addition, it can be seen that specimens 1 to 11 satisfy both tensile strength of 1,250 MPa or more and hole expansion ratio (HER) of 20% or more.

[0052] On the other hand, in the case of specimens 12 to 20 not satisfying any one or more of the alloy composition and manufacturing conditions of the present disclosure, it can be confirmed that the fraction of martensite is less than 95% by volume, or the product of tensile strength (TS) and hole expansion ratio (HER) is less than 30,000 MPa%.

[0053] Specifically, in the specimen 12, a time from an end of rolling to initiation of cooling exceeds 5 seconds, it can be confirmed that the martensite fraction desired by the present disclosure is not secured, and the tensile strength is deteriorated.

[0054] Specimen 13 shows a case in which a cooling rate was low, and Specimen 14 shows a case in which a cooling end temperature was high, and it can be confirmed that transformation to martensite did not occur sufficiently, and the tensile strength or hole expansion ratio (HER) for the purpose of the present disclosure was not secured.

[0055] Specimen 15 shows a case in which the carbon (C) content was low, and Specimen 16 shows a case in which the boron (B) content was low, and it can be seen that the martensite fraction was less than 50% by volume, and the tensile strength was deteriorated.

[0056] Specimen 17 shows a case in which the content of manganese (Mn) was high, and it can be confirmed that the transformation to martensite did not occur sufficiently, so that residual austenite was formed and the tensile strength was excellent, while the hole expansion ratio (HER) was deteriorated.

[0057] Specimens 18 to 20 show a case in which the content of silicon (Si), phosphorus (P), and sulfur (S) is high, respectively, and it can be seen that while the tensile strength was high, the hole expansion ratio (HER) was deteriorated.

[0058] Therefore, the hot-rolled steel sheet according to an aspect of the present disclosure satisfies tensile strength (TS) of 1,250 MPa or more and a hole expansion ratio (HER) of 20% or more, and in particular, it can be confirmed that the product of the tensile strength (TS) and the hole expansion ratio (HER) is at least 30,000 MPa%, so that the strength and workability are effectively compatible.

[0059] While the example embodiments have been illustrated and described above, it will be apparent to those skilled in the art that modifications and variations could be made without departing from the scope of the present disclosure as defined by the appended claims.

Claims

1. A high strength hot-rolled steel sheet having an excellent hole expansion ratio, comprising:

by weight %, 0.12% or more and less than 0.30% of carbon (C), 0.1 to 2.5% of manganese (Mn), 0.5% or less of silicon (Si) (not including 0%), 0.0005 to 0.005% of boron (B), 0.02% or less of phosphorous (P), 0.01% or less of sulfur (S), and a balance of iron (Fe) and unavoidable impurities, and 95 volume % or more of martensite as a microstructure,

wherein a product of tensile strength (TS) and hole expansion ratio (HER) is 30,000MPa% or greater.

2. The high strength hot-rolled steel sheet having an excellent hole expansion ratio of claim 1, wherein the hot-rolled steel sheet further comprises, by weight%, one or more elements of 0.5% or less of chromium (Cr) and 0.005 to 0.2% of titanium (Ti).

3. The high strength hot-rolled steel sheet having an excellent hole expansion ratio of claim 1, wherein the microstructure comprises a total of 5 vol% or less of one or more ferrite, bainite, carbide, and residual austenite.

4. The high strength hot-rolled steel sheet having an excellent hole expansion ratio of claim 1, wherein the hot-rolled steel sheet has tensile strength (TS) of 1,250 MPa or more.

5. The high strength hot-rolled steel sheet having an excellent hole expansion ratio of claim 1, wherein the hot-rolled steel sheet has a hole expansion ratio (HER) of 20% or more.

6. The high strength hot-rolled steel sheet having an excellent hole expansion ratio of claim 1, wherein the hot-rolled steel sheet has a thickness of 1.5mm or less.

7. A method of manufacturing a high strength hot-rolled steel sheet having an excellent hole expansion ratio, comprising operations of:

reheating a slab, including by weight %, 0.12% or more and less than 0.30% of carbon (C), 0.1 to 2.5% of manganese (Mn), 0.5% or less of silicon (Si) (not including 0%), 0.0005 to 0.005% of boron (B), 0.02% or less of phosphorous (P), 0.01% or less of sulfur (S), and a balance of iron (Fe) and unavoidable impurities;

hot-rolling the reheated slab to provide a hot-rolled steel sheet;

initiating cooling of the hot-rolled steel sheet within 5 seconds of an end point of the hot-rolled steel sheet, and cooling the hot-rolled steel sheet to a cooling end temperature of 350°C or lower at a cooling rate of 50 to 1,000°C/s; and

winding the cooled hot-rolled steel sheet.

8. The method of manufacturing a high strength hot-rolled steel sheet having an excellent hole expansion ratio of claim 7, wherein the slab further comprises, by weight%, one or more elements of 0.5% or less of chromium (Cr) and 0.005 to 0.2% of titanium (Ti).

REFERENCES CITED IN THE DESCRIPTION

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