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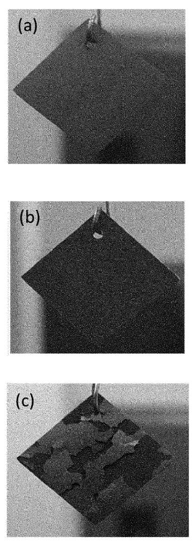
(54) CRYOGENIC AUSTENITIC HIGH-MANGANESE STEEL HAVING EXCELLENT SCALE PEELING PROPERTIES, AND MANUFACTURING METHOD THEREFOR

(57) The cryogenic austenitic high-manganese steel having excellent scale peeling properties, according to one aspect of the present invention, comprises 0.2-0.5 wt% of C, 23-28 wt% of Mn, 0.05-0.5 wt% of Si, 0.03 wt% or less of P, 0.005 wt% or less of S, 0.5 wt% or less of Al, and 3-4 wt% of Cr, with the remainder being Fe and other unavoidable impurities, and also comprises at least 95 area% of austenite as a microstructure, wherein the fraction of the unpeeled scale at the surface of the steel prior to descaling may be 30 area% or less (including 0 area%).

【Fig. 2】



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Description

[Technical Field]

[0001] The present disclosure relates to an austenitic high-manganese steel and a manufacturing method therefor, and more particularly, to an austenitic high-manganese steel having excellent surface quality due to excellent cryogenic toughness and uniform surface scale peeling properties, and a manufacturing method therefor.

[Background Art]

[0002] An austenitic high-manganese steel has high toughness as austenite is stable even at room temperature or in a cryogenic environment by adjusting contents of manganese (Mn) and carbon (C) which are elements increasing stability of the austenite.

[0003] The austenitic high-manganese steel includes more than a certain amount of manganese (Mn) having high oxidizability, and therefore, exhibits a tendency to easily cause surface scale. In the typical manufacturing of the austenitic high-manganese steel, primary scale formed during reheating of slab is mostly removed by spraying high-pressure water prior to hot rolling, so the effect of the primary scale on the subsequent processes is insignificant. However, even though secondary scale formed during hot rolling is not completely removed even by a descaling process after the hot rolling, the scale may not be completely removed, which affects the subsequent processes. In particular, when the secondary scale is formed to be thick, or when the secondary scale is not uniformly peeled off during the descaling, there may be a problem of reduction work efficiency when transferring steel. In addition, since non-uniform scale peeling is not preferable in terms of the appearance of the steel, additional processes such as grinding are necessarily accompanied, which is not preferable in terms of productivity and economy. Therefore, there is a need to develop an austenitic high-manganese steel having excellent surface quality due to excellent cryogenic toughness and uniform scale peeling properties.

(Related Art Document)

[0004] (Patent Document 1) Korean Patent Laid-Open Publication No. 10-2015-0075324 (published on July 3, 2015)

[Disclosure]

[Technical Problem]

[0005] An aspect of the present disclosure is to provide a cryogenic austenitic high-manganese steel having excellent scale peeling properties, and a manufacturing method therefor.

[0006] An object of the present disclosure is not limited to the abovementioned contents. Those skilled in the art will have no difficulty in understanding an additional object of the present disclosure from the general contents of present specification.

[Technical Solution]

[0007] According to an aspect of the present disclosure, a cryogenic austenitic high-manganese steel having excellent scale peeling properties includes: 0.2 to 0.5 wt% of C, 23 to 28 wt% of Mn, 0.05 to 0.5 wt% of Si, 0.03 wt% or less of P, 0.005 wt% or less of S, 0.5 wt% or less of Al, 3 to 4 wt% of Cr, a balance of Fe, and other unavoidable impurities, and 95 area% or more of austenite in a microstructure, in which a fraction of the unpeeled scale from a surface of the steel prior to descaling may be 30 area% or less (including 0 area%).

[0008] The cryogenic austenitic high-manganese steel may further include at least one selected from 1 wt% or less of Cu (excluding 0 wt%) and 0.0005 to 0.01 wt% of B.

[0009] The fraction of the unpeeled scale from the surface of the steel prior to the descaling may be 10 area% or less (including 0 area%).

[0010] An average grain size of the austenite may be 5 to 150 μm.

[0011] Charpy impact toughness of the steel at -196°C may be 90J or more (based on a specimen having a thickness of 10 mm) .

[0012] The steel may have a yield strength of 400 MPa or more, a tensile strength of 800 MPa or more, and an elongation of 40% or more.

[0013] According to another aspect of the present disclosure, a manufacturing method of a cryogenic austenitic high-manganese steel having excellent scale peeling properties includes: reheating a slab including 0.2 to 0.5 wt% of C, 23 to 28 wt% of Mn, 0.05 to 0.5 wt% of Si, 0.03 wt% or less of P, 0.005 wt% or less of S, 0.5 wt% or less of Al, 3 to 4 wt% of Cr, a balance of Fe, and other unavoidable impurities, in a temperature range of 1050 to 1300°C; providing an intermediate material by hot rolling the reheated slab at a finish rolling temperature of 900 to 950°C; cooling the intermediate material to a temperature range of 600°C or lower at a cooling rate of 1 to 100°C/s; and providing a final material by descaling the surface scale of the cooled intermediate material by shot blasting.

[0014] The slab may further include at least one selected from 1 wt% or less of Cu (excluding 0 wt%) and 0.0005 to 0.01 wt% of B.

[0015] An area fraction of an unpeeled scale area from a surface of the final material immediately prior to the descaling after cooling may be 30 area% or less (including 0 area%).

[0016] The technical solution does not enumerate all of the features of the present description, and various features of the present disclosure and advantages and effects according to the various features will be understood in more detail with reference to the following specific exemplary embodiments.

[Advantageous Effects]

[0017] As set forth above, according to an exemplary embodiment in the present disclosure, it is possible to provide an austenitic high-manganese steel having excellent surface quality due to excellent cryogenic toughness and uniform surface scale peeling properties, and a manufacturing method therefor.

[Description of Drawings]

[0018]

FIG. 1 is a diagram illustrating results of measuring a weight of a specimen while heating the specimen of chromium (Cr)-added steel and chromium (Cr)-free steel, respectively, up to 1100°C.
FIG. 2 (a), (b) and (c) are photographs of surfaces of Specimen 2, Specimen 4, and Specimen 9, respectively.

[Best Mode for Invention]

[0019] The present disclosure relates to a cryogenic austenitic high-manganese steel having excellent scale peeling properties, and a manufacturing method therefor, and exemplary embodiments in the present disclosure will hereinafter be described. Exemplary embodiments in the present disclosure may be modified into several forms, and it is not to be interpreted that the scope of the present disclosure is limited to exemplary embodiments described below. Exemplary embodiments in the present disclosure are provided in order to further describe the present disclosure in detail to those skilled in the art to which the present disclosure pertains.

[0020] Hereinafter, compositions of steel according to the present disclosure will be described in more detail. Hereinafter, unless otherwise indicated, % indicating a content of each element is based on weight.

[0021] A cryogenic austenitic high-manganese steel according to an exemplary embodiment in the present disclosure may include 0.2 to 0.5 wt% of C, 23 to 28 wt% of Mn, 0.05 to 0.5 wt% of Si, 0.03 wt% or less of P, 0.005 wt% or less of S, 0.5 wt% or less of Al, 3 to 4 wt% of Cr, a balance of Fe, and other unavoidable impurities.

Carbon (C): 0.2 to 0.5%

[0022] Carbon (C) is an element that is effective in stabilizing austenite in steel and securing strength by solid solution strengthening. Therefore, in the present disclosure, a lower limit of a content of carbon (C) may be limited to 0.2% in order to secure low-temperature toughness and strength. That is, the reason is that when the content of carbon (C) is less than 0.2%, stability of austenite is insufficient, such that stable austenite may not be obtained at a cryogenic temperature, and stain induced transformation into ε-martensite and α'-martensite is easily caused by external stress, such that toughness and strength of the steel may be decreased. On the other hand, when the content of carbon (C) exceeds a certain range, the toughness of the steel may rapidly be deteriorated due to precipitation of carbides, and the strength of the steel may be too high to significantly reduce the workability of the steel, such that an upper limit of the content of carbon (C) may be limited to 0.5%. Therefore, the content of carbon (C) of the present disclosure may be 0.2 to 0.5%. The content of the carbon (C) may be preferably 0.3 to 0.5%, and may more preferably be 0.35 to 0.5%.

Manganese (Mn): 23 to 28%

[0023] Manganese (Mn) is an important element that serves to stabilize austenite. Thus, in the present disclosure, a lower limit of a content of manganese (Mn) may be limited to 23% in order to achieve such an effect. That is, the cryogenic austenitic high-manganese steel having an excellent surface quality and resistance to stress corrosion cracking according to an exemplary embodiment in the present disclosure includes 23% or more of manganese (Mn), and austenite stability may thus be effectively increased. Therefore, formation of ferrite, ε-martensite, and α'-martensite may be suppressed to effectively secure low-temperature toughness of the steel. On the other hand, when the content of manganese (Mn) exceeds a predetermined level, an austenite stability increase effect is saturated, while a manufacturing cost is significantly increased, and internal oxidation is excessively generated during hot rolling, such that a surface quality may become inferior. Thus, in the present disclosure, an upper limit of the content of manganese (Mn) may be limited to 28%. Accordingly, the upper limit of the content of manganese (Mn) may be preferably 23 to 28%, and may more preferably be 23 to 25%.

Silicon (Si): 0.05 to 0.5%

[0024] Silicon (Si) is a deoxidizing agent like aluminum (Al), and is an element that is indispensably added in a trace amount. However, when silicon (Si) is excessively added, oxide may be formed at a grain boundary to reduce high-temperature ductility and cause a crack or the like, thereby deteriorating the surface quality. Therefore, in the present disclosure, an upper limit of a content of silicon (Si) may be limited to 0.5%. On the other hand, an excessive cost is required in order to reduce the content of silicon (Si) in the steel. Thus, in the present disclosure, a lower limit of the content of silicon (Si) may be limited to 0.05%. Therefore, the content of silicon (Si) of the present disclosure may be 0.05 to 0.5%.

Phosphorus (P): 0.03% or less

[0025] Phosphorus (P) is an element that is easily segregated and is an element that causes cracking at the time of casting or deteriorates weldability. Therefore, in the present disclosure, an upper limit of a content of phosphorus (P) may be limited to 0.03% in order to prevent castability deterioration and weldability deterioration. In addition, in the present disclosure, a lower limit of a content of phosphorus (P) is not particularly limited, but may be limited to 0.001% in consideration of a steelmaking burden.

Sulfur (S): 0.005% or less

[0026] Sulfur (S) is an element that causes a hot shortness defect due to formation of inclusions. Therefore, in the present disclosure, an upper limit of a content of sulfur (S) may be limited to 0.005% in order to suppress occurrence of hot shortness. In addition, in the present disclosure, a lower limit of the content of sulfur (S) is not particularly limited, but may be limited to 0.0005% in consideration of a steelmaking burden.

Aluminum (Al): 0.05% or less

[0027] Aluminum (Al) is a representative element that is added as a deoxidizing agent. Therefore, in the present disclosure, a lower limit of a content of aluminum (Al) may be limited to 0.001%, and more preferably 0.005%, in order to achieve such an effect. However, aluminum (Al) may react with carbon (C) and nitrogen (N) to form precipitates, and hot workability may be deteriorated due to these precipitates. Thus, in the present disclosure, an upper limit of the content of aluminum (Al) may be limited to 0.05%. The upper limit of the content of aluminum (Al) may be preferably 0.045%.

Chromium (Cr): 3 to 4%

[0028] Chromium (Cr) is an element that contributes to improvement of impact toughness at a low temperature by stabilizing austenite up to a range of an appropriate addition amount, and is solid-dissolved in austenite to strength of the steel. In addition, chromium is also an element that improves corrosion resistance of the steel. Therefore, in the present disclosure, 3% or more of chromium (Cr) may be added to achieve the above-described effect. In addition, the chromium (Cr)-added steel may have Cr thickened on a surface side of a base material, exhibit a different surface scale behavior than the Cr-free steel, and secure the scale peeling uniformity due to the thickening of the surface of the chromium (Cr). According to the exemplary embodiment in the present disclosure, since 3% or more of chromium (Cr) is included, chromium (Cr) may be uniformly distributed on the surface layer part of the steel, and thus, the uniform scale peeling properties may be secured. However, chromium (Cr) is a carbide-forming element and is an element that decreases low-temperature impact by forming carbide at the austenite grain boundary, and thus, in the present disclosure, an upper limit of a content of chromium (Cr) may be limited to 4% in consideration of a content relationship between carbon (C) and other elements added together. Accordingly, the upper limit of the content of chromium (Cr) may be 3 to 4%, and may more preferably be 3 to 3.8%.

[0029] The cryogenic austenitic high-manganese steel having the excellent scale peeling properties according to an aspect of the present disclosure may further include at least one selected from 1 wt% or less of Cu (excluding 0 wt%) and 0.0005 to 0.01 wt% of B.

Copper (Cu): 1% or less (excluding 0%)

[0030] Copper (Cu) is an austenite stabilizing element, is an element that stabilizes austenite along with manganese (Mn) and carbon (C), and is an element that contributes to improvement of low-temperature toughness of the steel. In addition, copper (Cu) is an element that has a very low solubility in carbide and has a slow diffusion in austenite, and therefore, is concentrated at the interface between the austenite and the carbide to surround a nucleus of fine carbide, thereby effectively suppressing the formation and growth of the carbide due to the additional diffusion of carbon (C). Accordingly, according to the present disclosure, copper (Cu) is added to secure low-temperature toughness, and a lower limit of a content of copper (Cu) may be preferably 0.3%. A lower limit of the content of copper (Cu) may more preferably be 0.4%. On the other hand, when the content of copper (Cu) exceeds 1%, hot workability of the steel may be deteriorated. As a result, in the present disclosure, an upper limit of the content of copper (Cu) may be limited to 1%. Accordingly, in the present disclosure, the content of copper (Cu) may be 1% or less (excluding 0%), and the upper limit of the content of copper (Cu) may more preferably be 0.7%.

Boron (B): 0.0005 to 0.01%

[0031] Boron (B) is a grain boundary strengthening element that strengthens an austenite grain boundary, and is an element that may effectively lower high-temperature cracking sensitivity of the steel by strengthening the austenite grain boundary even when it is added in a small amount. Therefore, in order to achieve such an effect, in the present disclosure, 0.0005% or more of boron (B) may be added. A lower limit of a content of boron (B) may be preferably 0.001%, and an upper limit of the content of boron (B) may more preferably be 0.002%. On the other hand, when the content of boron (B) exceeds a certain range, segregation occurs at the austenite grain boundary to increase the high-temperature cracking sensitivity of the steel, and therefore, the surface quality of the steel may be deteriorated. As a result, the upper limit of the content of boron (B) may be limited to 0.01%. The upper limit of the content of boron (B) may be preferably 0.008%, and the lower limit of the content of boron (B) may more preferably be 0.006%.

[0032] The cryogenic austenitic high-manganese steel having excellent scale peeling properties according to an exemplary embodiment in the present disclosure may include a balance of Fe and other unavoidable impurities in addition to the components described above. However, in a general manufacturing process, unintended impurities may inevitably be mixed from a raw material or the surrounding environment, and thus, these impurities may not be completely excluded. Since these impurities are known to those skilled in the art, all the contents are not specifically mentioned in the present specification. In addition, addition of effective components other than the compositions described above is not excluded.

[0033] The cryogenic austenitic high-manganese steel having scale peeling properties according to an aspect of the present disclosure includes 95 area% or more of austenite as a microstructure, thereby effectively securing the cryogenic toughness of the steel. An average grain size of austenite may be 5 to 150 μm. The average grain size of austenite that may be implemented in a manufacturing process is 5 μm or more, and when the average grain size of austenite significantly increases, strength of the steel may be decreased. Thus, a grain size of austenite may be limited to 150 μm or less.

[0034] The cryogenic austenitic high-manganese steel having excellent scale peeling properties according to an exemplary embodiment in the present disclosure may include carbide and/or ε-martensite as a structure that may exist in addition to austenite. When a fraction of carbide and/or ε-martensite exceeds a predetermined level, toughness and ductility of the steel may be rapidly deteriorated. Thus, in the present disclosure, the fraction of carbide and/or ε-martensite may be limited to 5 area% or less.

[0035] In the cryogenic austenitic high-manganese steel having excellent scale peeling properties according to an aspect of the present disclosure, a fraction of an area in which the scale is not peeled off the surface of the steel after hot rolling and cooling may be 30 area% or less (including 0 area%). Preferably, the fraction of the area in which the scale is not peeled off the steel surface after the hot rolling and cooling may be 10 area% or less (including 0 area%). Therefore, the cryogenic austenitic high-manganese steel having excellent scale peeling properties according to an aspect of the present disclosure may secure uniform scale peeling properties during the descaling, and may secure the excellent surface quality without separate subsequent processes. This scale peeling behavior is expected to be a technical effect realized by adding a certain amount of chromium (Cr) to the steel.

[0036] The cryogenic austenitic high-manganese steel having excellent scale peeling properties according to an aspect of the present disclosure has a yield strength of 400 MPa or more, a tensile strength of 800 MPa or more, an elongation of 40% or more, and Charpy impact toughness at -196°C of 90 J or more (based on a specimen having a thickness of 10 mm), thereby providing a structural steel that is particularly suitable for the cryogenic environment.

[0037] A manufacturing method according to the present disclosure will hereinafter be described in more detail.

[0038] The cryogenic austenitic high-manganese steel having excellent scale peeling properties of the present disclosure may be manufactured by reheating a slab including 0.2 to 0.5 wt% of C, 23 to 28 wt% of Mn, 0.05 to 0.5 wt% of Si, 0.03 wt% or less of P, 0.005 wt% or less of S, 0.5 wt% or less of Al, 3 to 4 wt% of Cr, a balance of Fe, and other unavoidable impurities at a temperature range of 1050 to 1300°C, providing an intermediate material by hot rolling the reheated slab at a finish rolling temperature of 900 to 950°C, cooling the intermediate material to a temperature range of 600°C or lower at a cooling rate of 1 to 100°C/s, and providing a final material by descaling the surface scale of the cooled intermediate material by shot blasting.

Reheating a slab

[0039] A slab used for the manufacturing method according to the exemplary embodiment in the present disclosure corresponds to the steel composition of the austenitic high-manganese steel described above, and a description for the steel composition of the slab is thus replaced by the description for the steel composition of the austenitic high-manganese steel described above.

[0040] The slab having the steel composition described above may be heated in a temperature range of 1050 to 1300°C. When the reheating temperature is lower than a certain range, there may be a problem in which an excessive rolling load is applied during the hot rolling, or there may be a problem in that an alloy component is not sufficiently solid-dissolved. Accordingly, the present disclosure may limit the lower limit of the reheating temperature range of the slab to 1050°C. On the other hand, when the reheating temperature exceeds a certain range, there is a concern that the strength of the steel is deteriorated due to the excessive growth of crystal grains, or as the steel is reheated beyond the solidus temperature of the steel material, there is a concern that the hot-rolling property of the steel may be deteriorated, such that the present disclosure may limit the upper limit of the reheating temperature range to 1300°C.

Hot Rolling

[0041] A hot rolling process includes a rough rolling process and a finish rolling process, and the reheated slab may be hot-rolled and provided as an intermediate material. In this case, hot finish rolling is preferably performed in a temperature range of 900 to 950°C.

[0042] FIG. 1 is a diagram illustrating results of measuring a weight of a specimen while heating the specimen of chromium (Cr)-added steel and chromium (Cr)-free steel, respectively, up to 1100°C. The chromium (Cr)-added steel is a specimen of steel to which 3.4% of chromium (Cr) is added, and the chromium (Cr)-free steel is a specimen of steel to which chromium (Cr) is not artificially added (i.e., the content of the chromium (Cr) converges to 0%). As illustrated in FIG. 1, a degree of oxidation may be divided into A stage in which an increase in weight is 2% or less, B stage in which the increase in weight exceeds 2% and is 5% or less, and C stage in which the increase in weight exceeds 5%.

[0043] In the case of the chromium (Cr)-free steel, it may be seen that the B stage starts around 850°C, and the C stage starts around 920°C, whereas in the case of the chromium (Cr)-added steel, the B stage starts around 900°C and the stage C starts around 980°C. That is, it may be confirmed that the surface oxidation of the chromium (Cr)-added steel and the chromium (Cr)-free steel does not occur at a certain temperature range or less, but the chromium (Cr)-added steel exhibits the tendency of the surface oxidation lower than that of the chromium (Cr)-free steel after the certain temperature range.

[0044] On the other hand, in order to prevent the surface oxidation during the hot rolling, it is preferable to perform the hot rolling in a temperature range as low as possible, but when the hot finish rolling temperature is less than a certain range, there may be problem of the excessive rolling load due to the increase in the rolling load and there may be a problem of not securing low-temperature properties. In addition, when the hot finish rolling temperature exceeds a certain range, there may be a problem in that the crystal grains grow coarse and the target strength may not be secured. Accordingly, the present disclosure may limit the finish hot rolling to a range of 900 to 950°C in consideration of the content of chromium (Cr) added to the steel, the targeted tensile strength, the low temperature properties, and the like.

Cooling

[0045] The hot rolled material may be cooled to a cooling stop temperature of 600°C or lower at a cooling rate of 1 to 100°C/s. When the cooling rate is lower than a predetermined range, a decrease in ductility of the steel by carbide deposited at a grain boundary during cooling and deterioration of wear resistance due to the decrease in the ductility of the steel may be problematic. Thus, in the present disclosure, the cooling rate of the hot rolled material may be limited to 10°C/s or higher. However, the faster the cooling rate, the more advantageous it is to inhibit carbide precipitation. However, in general cooling, it is difficult to implement a cooling rate exceeding 100°C/s due to characteristics of a facility. Thus, in the present disclosure, an upper limit of the cooling rate may be limited to 100°C/s. As the cooling of the present disclosure, accelerated cooling may be applied.

[0046] In addition, even though the intermediate material is cooled at the cooling rate of 10°C/s or more, when the cooling is stopped at a high temperature, it is highly likely that carbides will be generated and grown. Thus, in the present disclosure, a cooling stop temperature may be limited to 600°C.

Descaling

[0047] A descaling process of removing the scale formed on the surface of the intermediate material during or after cooling may be performed. Shot blasting may be used for the descaling, and shot blasting conditions applied when manufacturing the general high-manganese steel may be applied.

[0048] The austenitic high-manganese steel manufactured as described above includes 95 area% or more of austenite, has a yield strength of 400 MPa or more, a tensile strength of 800 MPa or more, an elongation of 40% or more, and Charpy impact toughness of 90 J or more at -196°C (based on a specimen having a thickness of 10 mm).

[0049] In addition, in the austenitic high-manganese steel manufactured as described above, the fraction of the area in which the scale is not peeled off the steel surface prior to the descaling after the cooling may be 30 area% or less (including 0 area%), and preferably, the fraction of the area in which the scale is not peeled off the steel surface prior to the descaling may be 10 area% or less (including 0 area%) .

[Mode for Invention]

[0050] Hereinafter, the present disclosure will be described in more detail through the Inventive Example. However, it is to be noted that Inventive Example to be described later is for illustrating and embodying the present disclosure and is not intended to limit the scope of the present disclosure.

(Inventive Example)

[0051] A slab having an alloy composition of Table 1 was prepared, and each specimen was manufactured by applying a manufacturing process of Table 2.

[Table 1]

Divi sion	Alloy Composition (wt%)							
	C	Si	Mn	Cr	P	S	Al	Cu
Steel Type 1	0.46	0.33	24.0	3.42	0.013	0.002	0.024	0.50
Steel Type 2	0.45	0.28	24.1	3.21	0.014	0.001	0.024	0.44
Steel Type 3	0.42	0.26	23.9	-	0.018	0.002	0.028	0.38

[Table 2]

Specimen No.	Division	Slab Heating		Hot Rolling		Cooling Rate (°C/s)
		Heating Furnace Temperature (°C)	Extraction Temperature (°C)	Finish Rolling Temperature (°C)	Final Thickness (mm)	
1	Steel Type 1	1218	1169	900	25	25
2	Steel Type 2	1225	1172	910	24	21
3	Steel Type 1	1218	1165	925	38	26
4	Steel Type 2	1225	1160	942	24	19
5	Steel Type 2	1225	1162	918	22	21

(continued)

Specimen No.	Division	Slab Heating		Hot Rolling		Cooling Rate (°C/s)
		Heating Furnace Temperature (°C)	Extraction Temperature (°C)	Finish Rolling Temperature (°C)	Final Thickness (mm)	
6	Steel Type 3	1220	1158	890	25	23
7	Steel Type 3	1221	1160	932	25	22
8	Steel Type 3	1220	1160	959	22	22
9	Steel Type 2	1211	1154	969	40	20
10	Steel Type 2	1215	1161	852	40	21

[0052] Tensile properties, and impact toughness of each specimen were evaluated, and evaluation results were shown in Table 3. The tensile properties of each specimen were tested at room temperature according to American Society for Testing Materials (ASTM) A370, and the impact toughness was also measured at -196°C by processing into impact specimens having a thickness of 10 mm, processed according to a condition of the same standard. In addition, a peeled scale area and an unpeeled scale area were divided based on surface photographs of each specimen taken after hot rolling and cooling, and the fraction of the unpeeled surface scale was measured, and the results were also described in Table 3. In this case, the case where the fraction of the unpeeled surface scale is 10 area% or less was classified as scale type I, the case where the fraction of the unpeeled surface scale is more than 10 area% and 30 area% or less was classified as scale type II, and the case where the fraction of the unpeeled surface scale exceeds 30 area% was classified as scale type III.

[Table 3]

Specimen No.	Division	Tensile Property			C Direction Impact Toughness (J, @-196°C)	Scale Type
		Yield Strength (MPa)	Tensile Strength (MPa)	Elongation (%) (%)		
1	Steel Type 1	485	868	57	105	I
2	Steel Type 2	454	867	56	106	I
3	Steel Type 1	483	872	59	108	II
4	Steel Type 2	446	852	54	103	II
5	Steel Type 2	471	878	57	98	II
6	Steel Type 3	441	858	55	96	III
7	Steel Type 3	425	851	56	101	III
8	Steel Type 3	325	782	60	112	III

(continued)

Specimen No.	Division	Tensile Property			C Direction Impact Toughness (J, @-196°C)	Scale Type
		Yield Strength (MPa)	Tensile Strength (MPa)	Elongation (%) (%)		
9	Steel Type 2	351	792	66	125	III
10	Steel Type 2	590	945	39	82	I

[0053] As shown in Tables 1 to 3, it may be seen that in the case of specimens 1 to 5 that satisfy the alloy composition and process conditions of the present disclosure, a yield strength of 400 MPa or more, a tensile strength of 800 MPa or more, an elongation of 40% or more, and Charpy impact toughness of 90 J or more at -196°C (based on a specimen having a thickness of 10 mm) were satisfied and the fraction of the unpeeled scale of the surface of the specimen is 30 area% or less, whereas in the case of specimens 6 to 10 that do not satisfy the alloy composition and process conditions of the present disclosure, these physical properties and the surface characteristics are not satisfied at the same time.

[0054] FIG. 2 (a), (b) and (c) are photographs of the surfaces of Specimen 2, Specimen 4, and Specimen 9, respectively. Accordingly, it may be seen that the peeled scale area and the unpeeled scale area on the surface of each specimen are clearly distinguished.

[0055] While the present disclosure has been described in detail through exemplary embodiment, other types of exemplary embodiments are also possible. Therefore, the technical spirit and scope of the claims set forth below are not limited to exemplary embodiments.

Claims

1. A cryogenic austenitic high-manganese steel having excellent scale peeling properties, comprising:

   0.2 to 0.5 wt% of C, 23 to 28 wt% of Mn, 0.05 to 0.5 wt% of Si, 0.03 wt% or less of P, 0.005 wt% or less of S, 0.5 wt% or less of Al, 3 to 4 wt% of Cr, a balance of Fe, and other unavoidable impurities, and
   95 area% or more of austenite in a microstructure,
   wherein a fraction of the unpeeled scale from a surface of the steel prior to descaling is 30 area% or less (including 0 area%).

2. The cryogenic austenitic high-manganese steel of claim 1, further comprising at least one selected from 1 wt% or less of Cu (excluding 0 wt%) and 0.0005 to 0.01 wt% of B.

3. The cryogenic austenitic high-manganese steel of claim 1, wherein the fraction of the unpeeled scale from the surface of the steel prior to the descaling is 10 area% or less (including 0 area%).

4. The cryogenic austenitic high-manganese steel of claim 1, wherein an average grain size of the austenite is 5 to 150 μm.

5. The cryogenic austenitic high-manganese steel of claim 1, wherein Charpy impact toughness of the steel at -196°C is 90 J or more (based on a specimen having a thickness of 10 mm) .

6. The cryogenic austenitic high-manganese steel of claim 1, wherein the steel has a yield strength of 400 MPa or more, a tensile strength of 800 MPa or more, and an elongation of 40% or more.

7. A manufacturing method of a cryogenic austenitic high-manganese steel having excellent scale peeling properties, comprising:

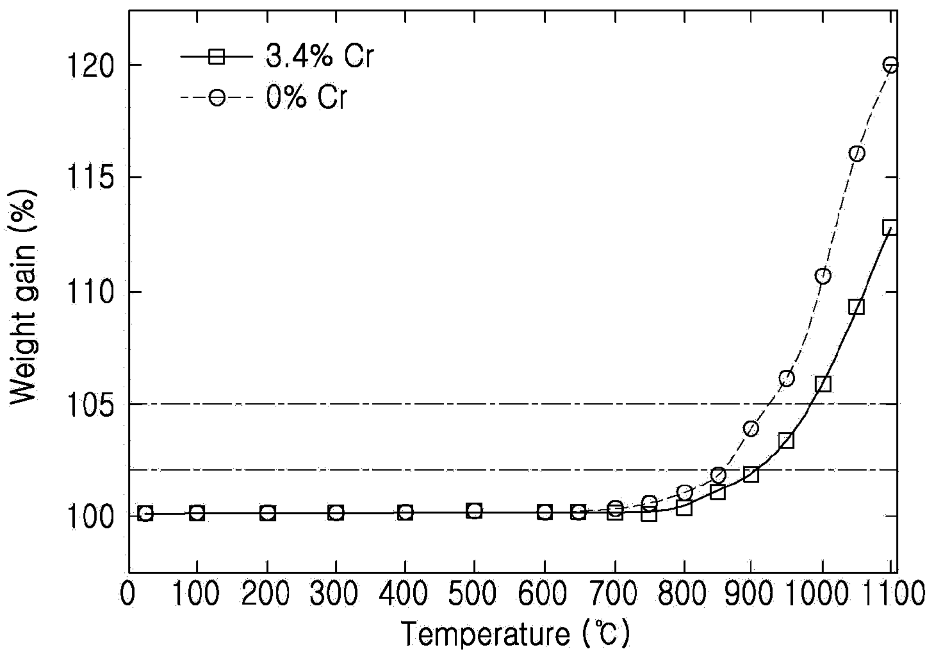
   reheating a slab including 0.2 to 0.5 wt% of C, 23 to 28 wt% of Mn, 0.05 to 0.5 wt% of Si, 0.03 wt% or less of P, 0.005 wt% or less of S, 0.5 wt% or less of Al, 3 to 4 wt% of Cr, a balance of Fe, and other unavoidable impurities, in a temperature range of 1050 to 1300°C;

providing an intermediate material by hot rolling the reheated slab at a finish rolling temperature of 900 to 950°C; cooling the intermediate material to a temperature range of 600°C or lower at a cooling rate of 1 to 100°C/s; and providing a final material by descaling the surface scale of the cooled intermediate material by shot blasting.

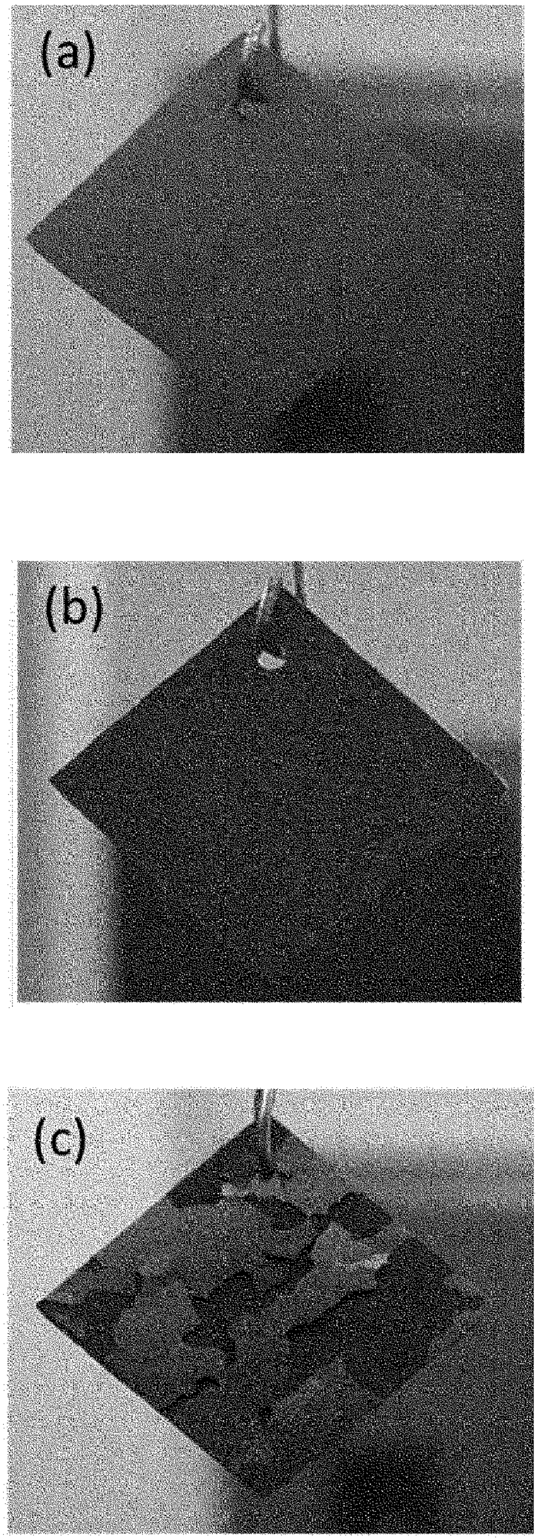
8. The manufacturing method of claim 7, wherein the slab further includes at least one selected from 1 wt% or less of Cu (excluding 0 wt%) and 0.0005 to 0.01 wt% of B.

9. The manufacturing method of claim 7, wherein an area fraction of an unpeeled scale area from a surface of the final material immediately prior to the descaling after cooling is 30 area% or less (including 0 area%).

【Fig. 1】


3.4% Cr
0% Cr
Weight gain (%)
120
115
110
105
100
0
100
200
300
400
500
600
700
800
900
1000
1100
Temperature (℃)

【Fig. 2】



INTERNATIONAL SEARCH REPORT

International application No.
PCT/KR2019/014194

A. CLASSIFICATION OF SUBJECT MATTER

C22C 38/38(2006.01)i, C22C 38/20(2006.01)i, C22C 38/32(2006.01)i, C22C 38/02(2006.01)i, C22C 38/06(2006.01)i, C21D 8/02(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; C21D 8/02; C22C 38/00; C22C 38/04; C23C 5/00; C22C 38/20; C22C 38/32; C22C 38/02; C22C 38/06

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: descaling, low temperature, high manganese, shot blasting, austenitic steel, scale peeling

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	KR 10-2017-0075657 A (POSCO) 03 July 2017 See claims 1-6 and table 2.	1-6 7-9
Y	JP 56-163258 A (MITSUBISHI HEAVY IND., LTD.) 15 December 1981 See page 2 and claim 1.	7-9
A	JP 2016-196703 A (NIPPON STEEL & SUMITOMO METAL) 24 November 2016 See paragraphs [0035], [0038]-[0042] and claims 1, 3, 4.	1-9
A	KR 10-2018-0074450 A (POSCO) 03 July 2018 See claims 1-3.	1-9
A	JP 60-077962 A (UBE IND., LTD.) 02 May 1985 See page 2 and claim 1.	1-9

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

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
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"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	Date of mailing of the international search report
07 FEBRUARY 2020 (07.02.2020)	**07 FEBRUARY 2020 (07.02.2020)**

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/KR2019/014194

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REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

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