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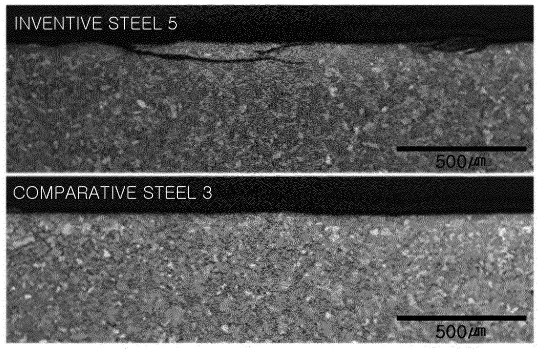
(54) AUSTENITE STEEL MATERIAL HAVING SUPERB SURFACE CHARACTERISTIC, AND METHOD FOR PRODUCING SAME

(57) The present invention relates to abrasion-resistant austenite steel material having superb surface characteristic, and a method for producing the abrasion-resistant austenite steel material. Provided are austenite steel material having superb surface characteristic, and a method for producing same, the austenite steel material according to the present invention comprising, in weight %: 0.6-1.3% carbon (C); 14-22% manganese (Mn); 5% or lower (excluding 0%) copper (Cu); 5% or lower (excluding 0%) chromium (Cr); 1.0% or lower (excluding 0%) silicon (Si); 0.5% or lower (excluding 0%) aluminum (Al); 0.1% or lower (including 0%) phosphorous (P); 0.02% or lower (including 0%) sulfur (S); and remainder in iron (Fe) and other unavoidable impurities, and having the microstructure comprising, by surface area %, 5% or lower carbide and the rest in austenite structure, and surface flaw size of 0.3mm or lower.

【FIG. 1】



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Description

[Technical Field]

[0001] The present disclosure relates to an austenitic steel having excellent surface characteristics, and a method of manufacturing the same.

[Background Art]

[0002] The present disclosure relates to an austenitic steel material, excellent in terms of wear resistance, used in the mining, transportation and storage fields in oil and gas industries such as for industrial machinery, structural materials, a steel material for slurry pipes, a steel material in sour service, and a method for producing the same, and more particularly to an austenite steel material, having excellent surface characteristic, and excellent in wear resistance, toughness, and corrosion resistance, and the like, as well as ductility, and a method for producing the same.

[0003] The austenitic steel may be used for various purposes due to characteristics thereof such as process hardenability, non-magnetic properties, and the like. Particularly, as carbon steel having ferrite and martensite as a main structure has a limitation in properties thereof, an austenitic steel has been increasingly used as a substitutable material which may overcome disadvantages of the carbon steel.

[0004] In particular, due to the growth of the mining industry as well as the oil and gas industries, wear of a steel material used in mining, transportation, refining, and storage processes, is becoming a significant problem. Particularly, as the development of oil sands as a source of fossil fuel to replace petroleum has been regularized, wear of a steel material, caused by a slurry including oil, gravel, sand, and the like, is a main cause of an increase in production costs. Therefore, demand for the development and application of a steel material excellent in terms of wear resistance and toughness has significantly increased.

[0005] Hadfield steel has been used extensively as a wear-resistant component for various industries due to its excellent wear resistance. It has continuously and steadily tried to increase austenite structure and wear resistance by containing a high content of carbon and a large amount of manganese in order to increase the wear resistance of the steel material.

[0006] However, the high content of carbon the Hadfield steel may cause network-type carbides to form at high temperatures along the austenite grain boundaries, thereby drastically lowering the properties of the steel material, particularly ductility. In order to suppress the precipitation of the network-type carbides, a method of making high manganese steel by a quenching or a solution treatment at a high temperature and then cooling it rapidly to room temperature after hot processing has been proposed.

[0007] However, the Hadfield steel has excellent wear resistance in a general mechanical wear environment, but it is difficult to exhibit excellent wear resistance in an environment where corrosion wear is accompanied, so that it is difficult to apply to a harsh environment in which complex wear occurs.

[0008] Recently, austenitic wear resistant steel has been developed to ensure corrosion resistance in consideration of the above-described problems. However, deterioration of toughness due to precipitation of carbides may be a problem in austenitic wear resistant steel having a very high content of carbon. Further, segregation due to alloying elements such as manganese, carbon, and the like, in solidification may be inevitably generated in the case of an ingot or casting piece of the high manganese steel. In this case, the occurrence of the segregation may be further exacerbated in post-processing such as hot-rolling, or the like. As a result, partial precipitation of carbides may occur in the form of a network along a segregation zone, deepened in a final product. As a result, non-uniformity of a microstructure may be promoted, and properties thereof may be deteriorated. Therefore, studies have mainly been made to prevent deterioration of the properties due to precipitation of carbides, mainly in austenitic wear resistant steel.

[0009] Another problem may be non-uniform oxidation occurring on the surface. Such non-uniform oxidation may especially occur along the grain boundaries, causing cracks in the slab reheating process, and propagating the cracks during the rolling process in which stress occurs, to deteriorate the surface characteristics of the final product. Cracks on the surface may cause premature failure in product bending or tensioning process, and may reduce wear resistance thereof.

(Prior art document)

[0010] (Patent Document 1) Korean Patent Publication No. 2010-0106649

[Disclosure]

[Technical Problem]

[0011] An aspect of the present disclosure is to provide an austenitic steel having excellent surface characteristics with improved surface quality by suppressing non-uniform oxidation.

[0012] Another aspect of the present disclosure is to provide a method for producing an austenitic steel having superb surface characteristics with improved surface quality by suppressing non-uniform oxidation.

[Technical Solution]

[0013] According to an aspect of the present disclosure, an austenitic steel having excellent surface characteristics, includes, by weight, carbon (C) : 0.6% to 1.3%, manganese (Mn): 14% to 22%, copper (Cu): 5% or less (excluding 0%), chromium (Cr): 5% or less (excluding 0%), silicon (Si): 1.0% or less (excluding 0%), aluminum (Al): 0.5% or less (excluding 0%), phosphorus (P): 0.1% or less (including 0%), sulfur (S): 0.02% or less (including 0%), a remainder of iron (Fe), and inevitable impurities, wherein a microstructure of the austenitic steel comprises, by area, 5% or less of carbide and a remaining austenite structure, and a surface defect size of the austenitic steel is 0.3 mm or less.

[0014] According to another aspect of the present disclosure, a method for producing an austenitic steel having excellent surface characteristic, includes: reheating a slab to a temperature of 1000°C or higher to 1150°C or lower, the slab comprising, by weight, carbon (C) : 0.6% to 1.3%, manganese (Mn) : 14% to 22%, copper (Cu): 5% or less (excluding 0%), chromium (Cr): 5% or less (excluding 0%), silicon (Si): 1.0% or less (excluding 0%), aluminum (Al): 0.5% or less (excluding 0%), phosphorus (P) : 0.1% or less (including 0%), sulfur (S) : 0.02% or less (including 0%), a remainder of iron (Fe), and inevitable impurities; hot-rolling the reheated slab at a finishing rolling temperature of 850°C to 950°C to obtain a hot-rolled steel; and cooling the hot-rolled steel to a temperature of 600°C or lower at a cooling rate of 5°C/s or higher.

[Advantageous Effects]

[0015] According to an aspect of the present disclosure, an austenitic steel having excellent surface characteristics may be provided.

[0016] Through the above, it may be applied to fields requiring wear resistance in mining, transportation, storage, or industrial machinery fields in the oil and gas industry, in which wear is generated in a large amount and wear resistance is thus required, due to excellent wear resistance. In particular, the application range to a field requiring an excellent surface quality may be expanded. In addition, productivity and efficiency may be expected to increase due to reduced surface repair of products in the light of the production of steel material.

[Description of Drawings]

[0017] FIG. 1 is a photograph of structures of Inventive Steel 3 and Comparative Steel 5.

[Best Mode for Invention]

[0018] The inventors of the present disclosure have been studying steels having excellent strength and wear resistance as compared with conventional steel materials used in technical fields requiring wear resistance. In this connection, it is recognized that, in the case of high manganese steels, excellent strength and elongation specific to an austenitic steel material may be secured; and, when the process hardening rate is improved, the hardness may be increased due to the process hardening of the material itself in the wear environment, and excellent wear resistance may be ensured. On the basis of this recognition, the present disclosure is completed.

[0019] Further, it is recognized that, in order to improve the poor surface characteristics, which is a problem of conventional austenitic wear-resistant steels, by deriving the reheating conditions of the slab before hot-rolling to suppress the non-uniform oxidation, wear resistant steel having excellent wear resistance and superb surface characteristics may be produced.

[0020] Hereinafter, an austenitic steel having excellent surface characteristics according to a preferred aspect of the present disclosure will be described.

[0021] The austenitic steel having excellent surface characteristics according to a preferred aspect of the present disclosure may include, by weight, carbon (C): 0.6% to 1.3%, manganese (Mn): 14% to 22%, copper (Cu) : 5% or less (excluding 0%), chromium (Cr): 5% or less (excluding 0%), silicon (Si): 1.0% or less (excluding 0%), aluminum (Al) : 0.5% or less (excluding 0%), phosphorus (P): 0.1% or less (including 0%), sulfur (S): 0.02% or less (including 0%), a remainder of iron (Fe), and inevitable impurities, wherein a microstructure of the austenitic steel comprises, by area, 5% or less of carbide and a remaining austenite structure, and a surface defect size of the austenitic steel is 0.3 mm or less.

[0022] First, steel components and component ranges will be described.

C: 0.6wt% to 1.3wt% (hereinafter, referred to as "%")

[0023] Carbon (C) may be an austenite stabilizing element which may improve a uniform elongation rate, and may be advantageous to improving strength and process hardenability. When the content of carbon is less than 0.6%, it may be difficult to form stable austenite at room temperature such that there may be the problem in which it may be difficult to secure sufficient strength and process hardenability. When the content thereof exceeds 1.3%, a large amount of carbides may be precipitated such that a uniform elongation rate may decrease, and it may thus be difficult to secure an excellent elongation rate, resulting in a decrease in wear resistance and occurrence of early breakage. To improve wear resistance, it is preferable to increase a content of carbon to the maximum, but there is a limit to the carbon solubility and there is a concern about deterioration of the properties. Therefore, an upper limit thereof is preferably limited to 1.3%.

[0024] Therefore, the C content is preferably limited to 0.6 to 1.3%.

[0025] A more preferable content of C may be 0.6 to 1.25%.

Mn: 14% to 22%

[0026] Manganese (Mn) may be a very important element that stabilizes austenite and improves the uniform elongation. To obtain austenite as the main structure in the present disclosure, Mn is preferably contained in an amount of 14% or more.

[0027] When the content of Mn is less than 14%, the stability of the austenite may decrease, and a martensitic structure may be formed. As a result, when the austenite structure is not sufficiently secured, it may be difficult to secure a sufficient uniform elongation rate. When the content thereof exceeds 22%, not only production costs may increase, but there may also be problems of deterioration of corrosion resistance, difficulty in the manufacturing process, and the like, due to the addition of manganese.

[0028] Therefore, the Mn content is preferably limited to 14 to 22%.

Cu: 5% or less (excluding 0%)

[0029] Copper (Cu) may have a significantly low solid solution degree in carbides, and may slowly disperse in austenite such that copper may be concentrated on a carbide interfacial surface nucleated with austenite. Therefore, copper may interfere with dispersion of carbon such that copper may effectively slow down the growth of carbides, and may thus have an effect of preventing the formation of carbides. Further, copper may help to improve corrosion resistance. When the content of Cu exceeds 5%, there may be a problem of deteriorating the hot workability of the steel. Therefore, an upper limit thereof is preferably limited to 5%. The content of copper for obtaining the above-described carbide-suppressing effect is more preferably 0.05% or more.

[0030] More preferably, the content of Cu may be 0.05% to 3.0%.

Cr: 5% or less (excluding 0%)

[0031] Chromium may be dissolved in the austenite to increase the strength of the steel material up to the proper amount of addition. Chromium may be also an element that improves the corrosion resistance of steel material. Chromium may be a carbide element, and may be also an element that reduces toughness by forming carbides in the austenite grain boundary. Therefore, it is preferable to determine the content of chromium added in the present disclosure in consideration of relationships with carbon and other elements to be added together. In order to prevent the formation of carbide, an upper limit of Cr content is preferably limited to 5%. When the Cr content exceeds 5%, it may be difficult to effectively inhibit the formation of chromium-based carbides in the austenite grain boundary, and thus the impact toughness may be reduced. Therefore, the chromium content is preferably limited to 5% or less.

Silicon (Si): 1.0% or less (excluding 0%), aluminum (Al): 0.5% or less (excluding 0%)

[0032] Aluminum (Al) and silicon (Si) may be components which may be contained as deoxidizers during a steelmaking process. The steel material of the present disclosure may include aluminum (Al) and silicon (Si) within the above defined range.

Phosphorus (P) : 0.1% or less (including 0%), sulfur (S) : 0.02% or less (including 0%)

[0033] Phosphorus (P) and sulfur (S) may be representative impurities, which may cause deterioration in quality when added in excess. Therefore, it is preferable that phosphorus (P) is limited to 0.1% or less, and sulfur (S) is limited to 0.02% or less.

[0034] The remainder of the invention may be iron (Fe) and other inevitable impurities. In a general steel manufacturing process, inevitable impurities may be inevitably added from raw materials or a surrounding environment, and thus, impurities may not be excluded.

[0035] A person skilled in the art may be aware of the impurities, and thus, the descriptions of the impurities may not be provided in the present disclosure.

[0036] An austenite steel material according to one preferred aspect of the present disclosure may have a microstructure comprising 5% or less of carbide and the remainder austenite structure, and the surface defect size may be 0.3 mm or less. More preferably, the surface defect size may be 0.2 mm or less.

[0037] When the content of the carbide exceeds 5%, the carbide may surround the grain boundaries, and there may be a possibility that the elongation and the impact toughness may be drastically reduced.

[0038] When the surface defect size exceeds 0.3 mm, the generated surface cracks may propagate during further processing to cause early breakage, or there is a problem in guaranteeing the target final product thickness.

[0039] The proposed surface defect size may be defined, for example, as a distance from a point in which the crack starts to a point in which the crack stops.

[0040] Hereinafter, a method for producing an austenitic steel having excellent surface characteristics according to another preferred embodiment of the present disclosure will be described.

[0041] According to another aspect of the present disclosure, there is provided a method of manufacturing an austenitic steel having excellent surface characteristics, may include: reheating a slab to a temperature of 1000°C or higher to 1150°C or lower, the slab comprising, by weight, carbon (C): 0.6% to 1.3%, manganese (Mn): 14% to 22%, copper (Cu): 5% or less (excluding 0%), chromium (Cr): 5% or less (excluding 0%), silicon (Si) : 1.0% or less (excluding 0%), aluminum (Al) : 0.5% or less (excluding 0%), phosphorus (P) : 0.1% or less (including 0%), sulfur (S) : 0.02% or less (including 0%), a remainder of iron (Fe), and inevitable impurities; hot-rolling the reheated slab at a finishing rolling temperature of 850°C to 950°C to obtain a hot-rolled steel; and cooling the hot-rolled steel to a temperature of 600°C or lower at a cooling rate of 5°C/s or higher.

Reheating Slab

[0042] Before hot-rolling, a slab may be reheated at a temperature of 1000°C or higher to 1150°C or lower. Reheating at 1000°C or higher is necessary to ensure a sufficient temperature in hot-rolling, and it is essential to reheat at 1150°C or lower to suppress surface uneven oxidation of the high Mn steel slab.

Hot-Rolling

[0043] As described above, the reheated slab may be hot-rolled to obtain a hot-rolled steel plate having a finish rolling temperature of 850°C to 950°C.

[0044] When the finish rolling temperature is lower than 850°C, carbide may precipitate and the uniform elongation may be lowered, and the microstructure may be pancaked to cause non-uniform stretching due to anisotropy of structure. When the finishing rolling temperature exceeds 950°C, the rolling finishing temperature may be too high and it may be difficult to hit the target temperature in the actual process.

Cooling

[0045] The hot-rolled steel obtained through the hot-rolling may be cooled to a temperature of 600°C or lower at a cooling rate of 5°C/s or higher.

[0046] When the cooling rate is less than 5°C/s, or the cooling stop temperature is more than 600°C, carbides may precipitate and elongation may decrease . The rapid cooling process may also help to ensure high employment of C and N elements in the matrix. Therefore, it is preferable that the cooling is carried out to a temperature of 600°C or lower at a cooling rate of 5°C/s or higher. The cooling rate is more preferably 10°C/s or higher, and more preferably 15°C/s or higher.

[Mode for Invention]

[0047] In the description below, an example embodiment of the present disclosure will be described in greater detail.

It should be noted that the exemplary embodiments are provided to describe the present disclosure in greater detail, and to not limit the scope of rights of the present disclosure. The scope of rights of the present disclosure may be determined on the basis of the subject matters recited in the claims and the matters reasonably inferred from the subject matters.

(Example)

[0048] Slabs satisfying the composition and composition ranges as shown in Table 1 below were prepared as hot-rolled steel plates having a thickness of 12 mm through reheating and rolling conditions shown in Table 2 below.

[0049] Then, the microstructure, yield strength, uniform elongation, and impact toughness of each of the manufactured hot-rolled steel sheets were measured, and the results are shown in Table 3 below. The surface defect size of the hot-rolled steel plate was measured and shown in Table 3 below.

[0050] Inventive Steel 3 and Comparative Steel 5 were observed for their structure, and the results are shown in FIG. 1.

[Table 1]

	Component Composition (wt%)							
	C	Mn	Si	Al	Cr	Cu	P	S
[1]IS1	0.64	16.9	0.08	0.057	4.7	1.5	0.022	0.009
IS2	0.81	18.1	0.014	0.119	2.5	1.3	0.023	0.006
IS3	1.09	21.5	0.31	0.041	3.3	0.06	0.016	0.004
IS4	1.22	14.7	0.091	0.262	0.09	0.35	0.012	0.016
[2]CS1	0.33	15.2	0.017	0.08	0.023	0.025	0.013	0.007
CS2	1.35	15.8	0.098	0.044	0.11	0.1	0.017	0.005
CS3	0.65	12.2	0.046	0.041	0.22	0.15	0.013	0.003
CS4	1.11	18.6	0.16	0.076	5.8	0.09	0.018	0.009
CS5	1.23	19.1	0.15	0.08	1.1	0.09	0.015	0.006
CS6	0.64	16.4	0.11	0.041	1.8	0.9	0.017	0.008
CS7	0.61	18.3	0.11	0.045	1.8	0.9	0.014	0.005
CS8	0.75	17.6	0.11	0.041	1.8	0.9	0.017	0.008
[1]IS: Inventive Steel, [2]CS: Comparative Steel								

[Table 2]

	Reheating & Rolling Conditions			
	Reheating Temp. (°C)	Finish Rolling Temp.(°C)	Cooling Rate (°C/s)	Cooling Stop Temp.(°C)
[1]IS1	1145	940	26	385
IS2	1108	915	16	200
IS3	1056	901	32	475
IS4	1023	869	41	275
[2]CS1	1110	876	22	495
CS2	1125	899	19	425
CS3	1130	920	27	355
CS4	1134	925	19	375
CS5	1231	925	19	375
CS6	1105	825	25	390

(continued)

	Reheating & Rolling Conditions			
	Reheating Temp. (°C)	Finish Rolling Temp.(°C)	Cooling Rate (°C/s)	Cooling Stop Temp.(°C)
CS7	1140	912	3.5	435
CS8	1125	947	23	670
[1]IS: Inventive Steel, [2]CS: Comparative Steel				

[Table 3]

	Microstructure (γ: austenite)	Surface Defect Size (mm)	Yield Strength (MPa)	Elongat ion (%)	Impact Toughness (J@-40°C)
[1]IS1	γ+carbide 5% or less	0.24mm or less	453	50	199
IS2	γ+carbide 5% or less	0.11mm or less	411	60	227
IS3	γ+carbide 5% or less	0.05mm or less	500	53	208
IS4	γ+carbide 5% or less	0.13mm or less	523	47	116
[2]CS1	γ+carbide 5% or less	-	270	48	87
CS2	γ+carbide 9.1%	-	581	19	27
CS3	γ+martensite	-	380	33	19
CS4	γ+carbide 11.8%	-	607	17	22
CS5	γ+carbide 5% or less	More than 0.3mm	564	31	121
CS6	γ+carbide 6.1%	-	420	36	42
CS7	γ+carbide 6.9%	-	431	53	33
CS8	γ+carbide 7.2%	-	520	43	29
[1]IS: Inventive Steel, [2]CS: Comparative Steel					

[0051] As shown in Tables 1 to 3, Inventive Steels 1 to 4 satisfied both the composition range and the manufacturing conditions, and Inventive Steels 1 to 4 showed good surface characteristics.

[0052] Comparative Steel 1 showed that sufficient strength did not be secured because C was very low.

[0053] Comparative Steel 2 showed that formation of carbide increased, due to excessive addition of C, and values for elongation and impact toughness rapidly decreased.

[0054] In Comparative Steel 3, a stable austenite phase was not formed due to the insufficient Mn content, and martensite was formed, and a value for impact toughness rapidly decreased.

[0055] Comparative Steel 4 showed that elongation and impact toughness rapidly decreased, due to excessive carbide formation when the Cr content was exceeded.

[0056] Comparative Steel 5 showed that the reheating temperature exceeded the reference value, and a relatively large defect occurred on the surface of the product.

[0057] Comparative Steels 6 to 8 showed that the conditions such as the rolling finishing temperature, the cooling rate, and the cooling stop temperature failed to fall within the scope of the present disclosure, and the impact toughness rapidly decreased, due to excessive precipitation of carbide.

[0058] As shown in FIG. 1, Comparative Steel 5 having a relatively high reheating temperature had large cracks formed on the surface thereof. In Inventive Steel 3 having a relatively low temperature reheating temperature, it can be seen that the surface layer was uniform, and no relatively large defect occurred.

[0059] While example embodiments have been shown and described above, the scope of the present disclosure is not limited thereto, and 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 invention as defined by the appended claims.

Claims

1. An austenitic steel having excellent surface characteristics, comprising, by weight, carbon (C): 0.6% to 1.3%, manganese (Mn): 14% to 22%, copper (Cu): 5% or less (excluding 0%), chromium (Cr): 5% or less (excluding 0%), silicon (Si): 1.0% or less (excluding 0%), aluminum (Al): 0.5% or less (excluding 0%), phosphorus (P): 0.1% or less (including 0%), sulfur (S): 0.02% or less (including 0%), a remainder of iron (Fe), and inevitable impurities,
   wherein a microstructure of the austenitic steel comprises, by area, 5% or less of carbide and a remaining austenite structure, and
   a surface defect size of the austenitic steel is 0.3 mm or less.

2. The austenitic steel according to claim 1, wherein the surface defect size of 0.2 mm or less.

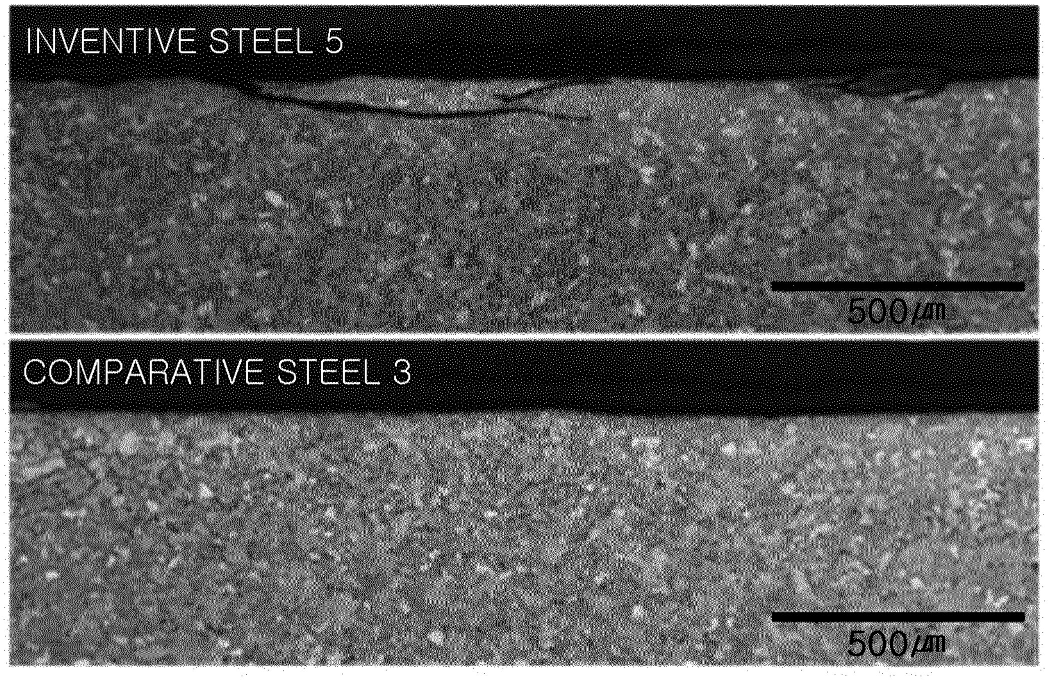
3. A method of manufacturing an austenitic steel having excellent surface characteristics, comprising:

   reheating a slab to a temperature of 1000°C or higher to 1150°C or lower, the slab comprising, by weight, carbon (C): 0.6% to 1.3%, manganese (Mn): 14% to 22%, copper (Cu): 5% or less (excluding 0%), chromium (Cr): 5% or less (excluding 0%), silicon (Si): 1.0% or less (excluding 0%), aluminum (Al): 0.5% or less (excluding 0%), phosphorus (P): 0.1% or less (including 0%), sulfur (S): 0.02% or less (including 0%), a remainder of iron (Fe), and inevitable impurities;
   hot-rolling the reheated slab at a finishing rolling temperature of 850°C to 950°C to obtain a hot-rolled steel; and
   cooling the hot-rolled steel to a temperature of 600°C or lower at a cooling rate of 5°C/s or higher.

4. The method according to claim 3, wherein the cooling rate in the cooling is 15°C/s or higher.

5. The method according to claim 3, wherein a microstructure of the austenitic steel comprises, by area, 5% or less of carbide and a remaining austenite structure, and
   a surface defect size of the austenitic steel is 0.3 mm or less.

【FIG. 1】



INTERNATIONAL SEARCH REPORT

International application No.
PCT/KR2017/015215

A. CLASSIFICATION OF SUBJECT MATTER

C22C 38/38(2006.01)i, C22C 38/20(2006.01)i, C22C 38/02(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 38/38; C21D 9/46; C21D 8/02; C22C 38/00; C22C 38/02; C22C 38/04; B21B 3/00; C22C 38/20; 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: austenite, carbide, manganese, copper, chrome, carbon, silicon, aluminum

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	KR 10-2007-0091300 A (ARCELOR FRANCE) 10 September 2007 See paragraphs [0045], [0066], [0067] and claims 1, 9.	1-5
A	KR 10-2015-0075305 A (POSCO) 03 July 2015 See paragraphs [0059]-[0061] and claims 1, 4-6.	1-5
A	JP 2016-196703 A (NIPPON STEEL & SUMITOMO METAL) 24 November 2016 See paragraphs [0039]-[0041] and claims 1, 2.	1-5
A	US 2002-0048529 A1 (KUCHARCZYK et al.) 25 April 2002 See paragraphs [0034]-[0040] and claim 2.	1-5
A	US 2014-0261918 A1 (JIN et al.) 18 September 2014 See paragraphs [0157]-[0163] and claim 1.	1-5

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

* Special categories of cited documents:	"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
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Date of the actual completion of the international search 21 MARCH 2018 (21.03.2018)	Date of mailing of the international search report **21 MARCH 2018 (21.03.2018)**
Name and mailing address of the ISA/KR Korean Intellectual Property Office Government Complex-Daejeon, 189 Seonsa-ro, Daejeon 302-701, Republic of Korea Facsimile No. +82-42-481-8578	Authorized officer Telephone No.

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