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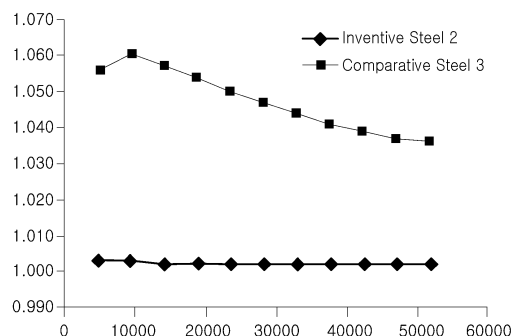
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(54) **HIGH-STRENGTH AND HIGH-DUCTILITY NONMAGNETIC STEEL HAVING EXCELLENT WELDABILITY, AND MANUFACTURING METHOD THEREFOR**

(57) The present invention relates to nonmagnetic steel that can be suitably used for components in which an eddy current occurs, such as a distribution board and a transformer, and, more specifically, to nonmagnetic steel having excellent strength, ductility and weldability, and a manufacturing method therefor.

[FIG. 1]



Description

[Technical Field]

5 **[0001]** The present disclosure relates to a nonmagnetic steel that can be suitably used for components in which an eddy current occurs, such as a distribution board and a transformer, and more particularly, to a nonmagnetic steel that is excellent in not only terms of weldability but also in strength and ductility, and a manufacturing method therefor.

[Background Art]

10 **[0002]** In general, a material for a distribution board, a transformer, or the like requires excellent nonmagnetic properties together with high strength. In order to satisfy such requirements, stainless steel, to which nickel (Ni) and chromium (Cr) are added in large amounts, has conventionally been used. However, stainless steel is disadvantageous, in that the strength may be low and the price may be high.

15 **[0003]** In order to increase the strength of the nonmagnetic steel, ferritic or martensitic stainless steel may be used. However, the ferritic or martensitic stainless steel is disadvantageous in that high magnetism thereof causes an eddy current, resulting in power loss, and the price is significantly high.

20 **[0004]** Thus, steel having an austenite phase has been developed by controlling a manganese (Mn) content and a carbon (C) content in the steel so that the steel may have nonmagnetic properties, together with high strength, at a low price.

[0005] The austenite-type steel is advantageous in that the austenite phase can be stably maintained at room temperature and even at an extremely low temperature by controlling the amounts of the two aforementioned elements, and thereby, the nonmagnetic properties can be well maintained.

25 **[0006]** Meanwhile, it is necessary to prevent a deterioration in physical properties that is caused by welding when manufacturing steel having high strength and excellent nonmagnetic properties as an intended part. To do so, there has increasingly been a need for securing the weldability of the nonmagnetic steel.

[0007] Accordingly, it has been required to develop a nonmagnetic steel that is excellent in not only nonmagnetic properties but also weldability together with high strength.

[Disclosure]

[Technical Problem]

35 **[0008]** An aspect of the present disclosure is to provide a nonmagnetic steel that is excellent in weldability while having high strength and high ductility at low manufacturing costs by optimizing an alloy composition.

[0009] Another aspect of the present disclosure is to provide a method for manufacturing the above-described nonmagnetic steel.

40 **[0010]** The objects of the present disclosure are not limited to those described above. Additional objects of the present disclosure are described overall in the specification, and those skilled in the art to which the present disclosure pertains will have no difficulty in understanding additional objects of the present disclosure from the description in the specification of the present disclosure.

[Technical Solution]

45 **[0011]** According to an aspect of the present disclosure, a high-strength and high-ductility nonmagnetic steel having excellent weldability contains, by wt%, 0.03 to 0.50% of carbon (C), 0.3% or less of silicon (Si), 15 to 30% of manganese (Mn), more than 0% to 2.0% or less of chromium (Cr), more than 0% to 0.5% or less of molybdenum (Mo), 0.01 to 0.1% of titanium (Ti), 0.01 to 0.5% of vanadium (V), 0.2 to 1.0% of aluminum (Al), 0.1% or less of phosphorus (P), 0.01% or less of sulfur (S), and 0.03% or less of nitrogen (N), with a balance of Fe and other inevitable impurities, wherein the nonmagnetic steel has a single-phase austenite structure.

50 **[0012]** According to another aspect of the present disclosure, a method for manufacturing a high-strength and high-ductility nonmagnetic steel having excellent weldability includes: reheating a steel slab having the above-described alloy composition to a temperature of 1100 to 1250°C; finish-hot rolling the reheated steel slab at a temperature of 800 to 1000°C to manufacture a thick steel sheet; and cooling the thick steel sheet at a cooling rate of 10°C/s or higher.

[Advantageous Effects]

[0013] According to the present disclosure, it is possible to provide steel having excellent nonmagnetic properties at

low cost. In addition, the steel according to the present disclosure has excellent weldability as well as excellent strength and ductility.

[Description of Drawings]

[0014] FIG. 1 is a graph illustrating a comparison of results of measuring permeabilities of inventive steel according to an exemplary embodiment in the present disclosure and comparative steel.

[Best Mode]

[0015] The inventors of the present disclosure have conducted in-depth research to provide a nonmagnetic steel having not only excellent nonmagnetic properties but also excellent weldability together with high strength and high ductility. As a result, they have found that an optimal component system capable of greatly improving the phase stability of the nonmagnetic steel can be provided.

[0016] In particular, the technical significance of the present disclosure is that Al is added in a certain amount, as well as C, Mn, etc. as alloy elements, to prevent carbon from forming carbides, and Cr and Mo are further added to further improve strength, ductility, and weldability.

[0017] Hereinafter, the present disclosure will be described in detail.

[0018] According to an aspect of the present disclosure, a high-strength and high-ductility nonmagnetic steel having excellent weldability may contain, by wt%, 0.03 to 0.50% of carbon (C), 0.3% or less of silicon (Si), 15 to 30% of manganese (Mn), more than 0% to 2.0% or less of chromium (Cr), more than 0% to 0.5% or less of molybdenum (Mo), 0.01 to 0.1% of titanium (Ti), 0.01 to 0.5% of vanadium (V), 0.2 to 1.0% of aluminum (Al), 0.1% or less of phosphorus (P), 0.01% or less of sulfur (S), and 0.03% or less of nitrogen (N).

[0019] Hereinafter, the reason for controlling alloy components for the nonmagnetic steel provided in the present disclosure as described above will be described in detail. Here, unless specifically mentioned otherwise, an amount of each component refers to wt%, and a ratio of a structure is based on an area.

Carbon (C): 0.03 to 0.50%

[0020] Carbon (C) is an element important in securing an austenite structure in the steel, and C may be contained in a predetermined amount or more to sufficiently secure the stability of the austenite. In the present disclosure, 0.03% or more of C may be contained for the above-described effect. In a case in which a C content exceeds 0.30%, the non-magnetic properties deteriorate because carbides are precipitated when C is exposed to a high temperature for a long period of time, for example on a continuous-casting roll. In the present disclosure, however, C may be contained in an amount of up to 0.50% because a predetermined amount of aluminum (Al) is added to reduce formation of carbides.

[0021] Therefore, in the present disclosure, C may be contained in an amount of 0.03 to 0.50%.

Silicon (Si): 0.3% or less

[0022] Silicon (Si) does not greatly affect the stacking fault energy of the steel, and is usually used as a deoxidizer. If a Si content exceeds 0.3%, manufacturing costs increase, and there is a concern that oxides may be excessively formed, causing a deterioration in surface quality of a product.

[0023] Therefore, Si may be contained in an amount of 0.3% or less, excluding 0%, taking into account that it is unavoidably added in a steel manufacturing process.

Manganese (Mn): 15 to 30%

[0024] Manganese (Mn) is an important element serving to stabilize the austenite structure, and needs to be contained in an amount of 15% or more for the steel to obtain a low permeability. In particular, when a C content is low, if Mn is added in an amount of less than 15%, an α' -martensite phase is formed, resulting in a deterioration in nonmagnetic properties. On the other hand, if an Mn content exceeds 30%, manufacturing costs increase significantly, and there is a problem in that oxidation occurs internally or processing cracks and the like are formed during heating in a hot processing step, resulting in a deterioration in surface quality.

[0025] Therefore, in the present disclosure, Mn may be contained in an amount of 15 to 30%.

Chromium (Cr): 2.0% or less (excluding 0%)

[0026] Chromium (Cr) is an element that is effective in suppressing high temperature oxidation to reduce surface

defects and improving strength through solid solution strengthening. If Cr is added in a large amount, manufacturing costs increase, and coarse carbides are formed, resulting in a decrease in strength. Taking this into account, Cr may therefore be contained in an amount of 2.0% or less, excluding 0%.

5 Molybdenum (Mo): 0.5% or less (excluding 0%)

[0027] Molybdenum (Mo) is an element that is effective in making a precipitate phase fine to increase a precipitation enhancing effect. If Mo is added in a large amount, the alloying cost increases and the precipitate phase is coarsened, and accordingly, the above-described effect cannot be sufficiently obtained. Taking this into account, Mo may therefore
10 be contained in an amount of 0.5% or less, excluding 0%.

Titanium (Ti): 0.01 to 0.1%

[0028] Titanium (Ti) is an element reacting with nitrogen (N) in the steel to precipitate nitrides and forming twins, and may be added to secure the strength and formability of the steel. In addition, Ti improves yield strength by forming a precipitate phase. This effect can be obtained by adding Ti even in a small amount, and thus, Ti may be added in an amount of 0.01% or more. However, if a Ti content exceeds 0.1%, there are concerns that precipitates may be excessively
15 formed, thereby causing cracks during rolling or forging, and formability and weldability may deteriorate.

[0029] Therefore, in the present disclosure, Ti may be contained in an amount of 0.01 to 0.1%.
20

Vanadium (V): 0.01 to 0.5%

[0030] Vanadium (V) is useful in improving strength by reacting with carbon, nitrogen, and the like in the steel and forming carbides, nitrides, and the like. Particularly, in austenitic high-manganese steel having high solid solubility at a high temperature of 900°C or more and low solid solubility at a temperature of 600 to 800°C, V is an element having a great precipitation enhancing effect. In order to sufficiently obtain the precipitation enhancing effect, V is preferably
25 contained in an amount of 0.01% or more. However, if a V content exceeds 0.5%, there is a concern that precipitates may be excessively formed, resulting in a deterioration in high-temperature workability during hot processing such as rolling or forging, thereby causing cracks.

[0031] Therefore, in the present disclosure, V may be contained in an amount of 0.01 to 0.5%.
30

Aluminum (Al): 0.2 to 1.0%

[0032] Aluminum (Al) is added as a deoxidizer and is an element that is effective in preventing formation of carbides in the steel. In addition, Al has an effect in controlling a twin fraction to improve formability. In order to sufficiently obtain the above-described effect, Al is preferably contained in an amount of 0.2% or more. However, if an Al content exceeds 1.0%, Al highly tends to form oxides, resulting in poor penetration of a molten pool during arc welding, thereby causing
35 poor welding, and the formation of oxides causes an inferior surface quality of a product.

[0033] Therefore, in the present disclosure, Al may be contained in an amount of 0.2 to 1.0%, more advantageously
40 in an amount of 0.2 to 0.8%.

Phosphorus (P): 0.1% or less

[0034] Phosphorus (P) is an element promoting segregation and causing cracks during casting, and is preferably contained as low as possible. If a P content exceeds 0.1%, castability may deteriorate. Therefore, P may be contained
45 in an amount of 0.1% or less.

Sulfur (S): 0.01% or less

[0035] Sulfur (S) is an element forming an inclusion such as MnS to hinder the physical properties of the steel. Thus, S is preferably contained as low as possible. If an S content exceeds 0.01%, there is a problem of hot embrittlement. Therefore, S may be contained in an amount of 0.01% or less.
50

Nitrogen (N): 0.03% or less

[0036] Nitrogen (N) is bonded to titanium (Ti) to form Ti nitrides, but if an N content exceeds 0.03%, free nitrogen (free N) remaining after being bonded to Ti causes problems such as age hardening, which greatly deteriorates a toughness of a base material, and cracks in surfaces of a slab and a steel plate, which deteriorate a surface quality. Therefore, N
55

may be contained in an amount of 0.03% or less.

[0037] In the present disclosure, the other component is iron (Fe). Meanwhile, unintended impurities may be inevitably mixed from raw materials or surrounding environments in a general manufacturing process, and the impurities cannot be excluded. Such impurities are known to those of ordinary skill in manufacturing industries, and thus, all descriptions thereof will not be particularly provided in the present specification.

[0038] The nonmagnetic steel having the above-described alloy composition according to the present disclosure preferably has a single-phase austenite structure as a microstructure. The single-phase austenite structure makes it possible to keep the steel nonmagnetic even though the steel is subjected to external energy.

[0039] In particular, the nonmagnetic steel according to the present disclosure has a highly stable austenite phase by optimizing an alloy composition, and accordingly, has a relative permeability of 1.01 or less in a magnetic field of 50 kA/m as a characteristic thereof.

[0040] Loss caused by an eddy current in a material exposed to an electromagnetic field is closely related to the magnetism of the material. The greater the magnetism is, the greater the eddy current generated, resulting in an increase in loss. In general, the magnetism is proportional to permeability (μ). That is, the greater the permeability, the greater the magnetism. The permeability is defined as a ratio of an induced magnetic field (B) to a magnetic field (H) for magnetization, that is, the equation $\mu=B/H$. In other words, a reduction in permeability decreases the magnetism of the material, thereby preventing eddy current loss on a surface when exposed to an electric field, resulting in an increase in energy efficiency. Thus, it is advantageous in preventing energy loss to use a nonmagnetic steel sheet having no magnetism as a material for a distribution board, a transformer, or the like.

[0041] In addition, the steel according to the present disclosure may be a thick steel sheet having a thickness of 10 to 40 mm with excellent strength and ductility. Specifically, the steel according to the present disclosure may secure a tensile strength of 450 MPa or more and an elongation of 55% or more.

[0042] Hereinafter, a method for manufacturing a high-strength and high-ductility nonmagnetic steel according to another aspect of the present disclosure will be described in detail.

[0043] First, after preparing a steel slab satisfying the above-described alloy composition, the steel slab is reheated at a temperature of 1100 to 1250°C.

[0044] If the temperature for reheating the steel slab is less than 1100°C, a rolling load may be excessively applied during subsequent hot rolling. On the other hand, if the temperature exceeds 1250°C, severe oxidation may occur internally, resulting in a deterioration in surface quality.

[0045] Therefore, the reheating of the steel slab may be performed at a temperature of 1100 to 1250°C.

[0046] The steel slab reheated as described above may be hot rolled to manufacture a thick steel sheet. At this time, it is preferable to perform finish-hot rolling at a temperature of 800 to 1000°C.

[0047] If the temperature for the finish-hot rolling is less than 800°C, there is a problem in that a load increases during rolling. Meanwhile, the higher the temperature for the finish-hot rolling, the lower the deformation resistance, making the rolling easier, while coarsening the structure and thereby making it impossible to secure target strength. Therefore, the temperature for the finish-hot rolling is preferably limited to 1000°C or less.

[0048] Thereafter, the thick steel sheet manufactured as described above may be cooled.

[0049] The cooling is preferably performed at a cooling rate sufficient to suppress formation of carbides in grain boundaries, more preferably at a cooling rate of 10°C/s or higher.

[0050] If the cooling rate during cooling is less than 10°C/s, it is difficult to avoid the formation of carbides, and thus, carbides are precipitated in grain boundaries during cooling, resulting in premature fracturing of the steel, thereby causing a problem in that strength deteriorates together with a reduction in ductility.

[0051] In the present disclosure, a higher cooling rate is more advantageous, and thus, there is no need to particularly limit an upper limit for the cooling rate as long as the cooling rate is within an accelerated cooling rate range. However, taking into account that it is difficult for the cooling rate to exceed 80°C/s during normal accelerated cooling, the upper limit may be limited to 80°C/s or less.

[0052] Meanwhile, the cooling of the thick steel sheet may be stopped at a temperature of 500°C or less. Although the accelerated cooling is performed as described above, if the cooling is stopped at an excessively high temperature, there is a concern that carbides may be generated and grown. When the carbides are generated in a large amount, there may be a problem in that the stability of the austenite decreases and the permeability properties deteriorate.

[0053] Even though the cooling is performed until room temperature is reached, there is no problem in securing intended physical properties. Thus, a lower limit for the temperature at which the cooling is terminated is not particularly limited.

[0054] The final steel (thick steel sheet) obtained by completing the hot rolling and the cooling according to the present disclosure has a highly stable austenite phase with a microstructure, and accordingly has excellent weldability and nonmagnetic properties as well as high strength and high ductility.

[0055] Hereinafter, the present disclosure will be described in more detail by way of examples. It should be noted, however, that the following examples are merely intended to illustratively describe the present disclosure in more detail,

not to limit the scope of the present disclosure. This is because the scope of the present disclosure is defined by the matters set forth in the claims and which can be reasonably inferred therefrom.

[Best Mode]

(Examples)

[0056] After preparing steel slabs each having an alloy composition shown in Table 1 below, the steel slabs were reheated at 1200°C and then finish-hot rolled at 950°C to manufacture respective thick steel sheets. Thereafter, the manufactured thick steel sheets were cooled at 20°C/s, and the cooling was terminated at 400°C.

[0057] Thereafter, mechanical properties (a yield strength (YS), a tensile strength (TS), and an elongation (EI)) and a permeability were measured for each of the thick steel sheets manufactured as described above. The results are shown in Table 2 below. Here, the yield strength (YS) is expressed as a 0.2% offset value.

[0058] The permeability refers to a relative permeability which is a ratio of permeability in specific atmosphere to permeability in vacuum. In the present disclosure, the relative permeability (μ), i.e. a ratio between the permeability in the vacuum and the permeability in the atmosphere, was measured using paramagnetic measurement equipment.

[0059] Meanwhile, the mechanical properties were evaluated by a one-way tensile tester after the thick steel sheet is processed into a plate-shaped specimen according to ASTM E8/E8M, which is a standard tensile test method.

[0060] In addition, weldability was evaluated by observing a surface of a welded portion with the naked eye after performing flux cored arc welding (FCAW) at a heat input of 1.5 KJ/cm with respect to each specimen.

[Table 1]

Steel No.	Alloy composition (wt%)												Classification
	C	Si	Mn	P	S	Al	Cr	Mo	Ti	Ni	V	N	
1	0.05	0.3	0	0.02	0.003	0.2	15	1.1	2.1	25	0.3	0.005	Conventional Steel
2	0.20	0.3	30	0.02	0.003	0.2	2	0.3	0.06	0	0.3	0.005	Inventive Steel 1
3	0.10	0.3	30	0.02	0.003	0.2	2	0.3	0.06	0	0.3	0.005	Inventive Steel 2
4	0.03	0.3	30	0.02	0.003	0.2	2	0.3	0.06	0	0.3	0.005	Inventive Steel 3
5	0.10	0.3	27	0.02	0.003	0.2	2	0.3	0.06	0	0.3	0.005	Inventive Steel 4
6	0.45	0.01	18.3	0.08	0.003	0.95	0	0	0.085	0	0.01	0.0087	Comparative Steel 1
7	0.05	0.3	25	0.02	0.003	0.2	15	0.3	0.06	0	0.3	0.005	Comparative Steel 2
8	0.51	0.01	18	0.09	0.004	0.01	0	0	0.046	0	0	0.010	Comparative Steel 3
9	0.61	0.01	18.5	0.09	0.002	2.68	0	0	0.073	0	0.015	0.0065	Comparative Steel 4

[Table 2]

Classification	Relative permeability	Mechanical properties			Weldability
		YS (MPa)	TS (MPa)	EI (%)	
Conventional Steel	1.004	203	624	35	-
Inventive Steel 1	1.002	160	591	67	Good
Inventive Steel 2	1.001	159	532	78	Good
Inventive Steel 3	1.000	159	492	64	Good
Inventive Steel 4	1.001	159	650	58	Good
Comparative Steel 1	1.010	538	960	59	Poor
Comparative Steel 2	1.050	157	398	26	Good
Comparative Steel 3	1.070	484	1106	60.4	Good
Comparative Steel 4	1.010	529	849	50	Poor

[0061] As shown in Tables 1 and 2, it can be seen that all of Inventive Steels 1 to 4 satisfying both the alloy composition and the manufacturing conditions according to the present disclosure have a relative permeability of less than 1.01 as a result of measurement, and it can also be seen that not only strength and ductility but also weldability is good.

[0062] In contrast, Conventional Steel, that is, stainless steel containing Cr and Ni in a large amount, had a low relative permeability, but it was difficult to secure ductility, and manufacturing costs may be greatly increased because expensive elements were added in a large amount thereto.

[0063] On the other hand, it can be seen that Comparative Steel 2 containing Cr in a large amount and Comparative Steel 3 containing C in a large amount with a low Al content have a very inferior permeability of 1.01 or more.

[0064] In addition, it can be seen that Comparative Steel 1 having a relatively high Al content without containing Cr and Mo and Comparative Steel 4 having an excessive Al content while containing C in a large amount have a permeability of 1.01 with inferior weldability. Based thereon, it is considered that the strong deoxidation effect of Al in the steel deteriorates arc stability, resulting in surface bead defects, thereby causing welding defects. In addition, it was seen that the strong deoxidation effect of Al in the steel improved recovery rates of other elements such as Ti and precipitate phases such as Al_2O_3 and Ti (Al) (C.N) were formed, resulting in a deterioration in impact toughness, material quality, or the like.

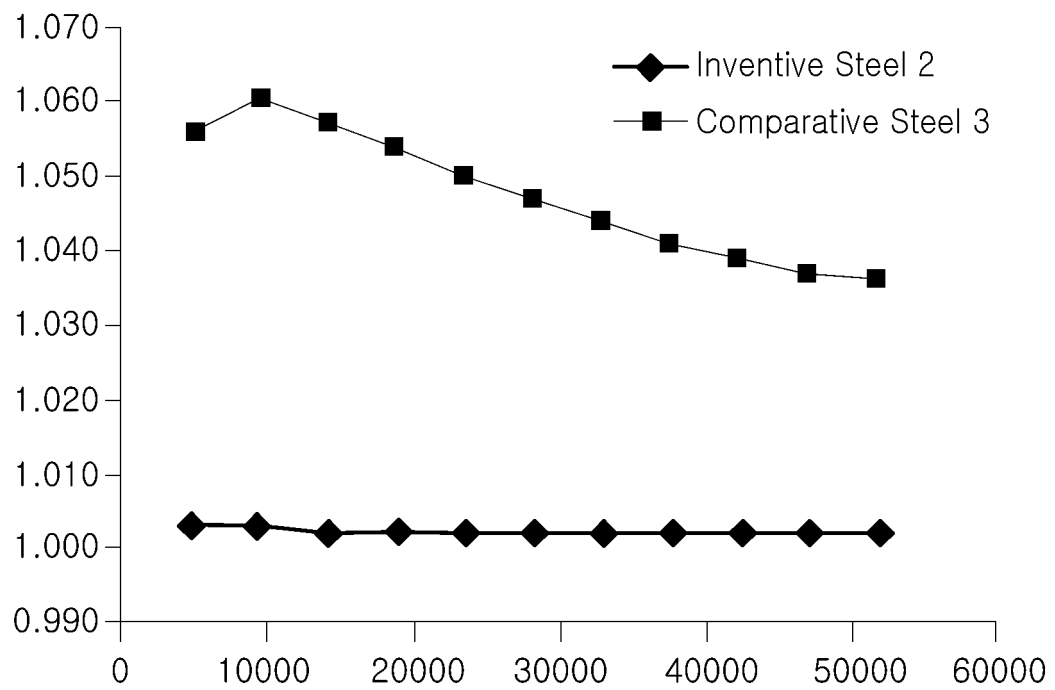
[0065] FIG. 1 shows a comparison of results of measuring permeability values of Inventive Steel 2 and Comparative Steel 3, and it can be seen therefrom that Inventive Steel 2 keeps a low permeability overall, whereas Comparative Steel 3 keeps a high permeability.

[0066] As described above, when compared to the conventional steel containing Cr and Ni in a large amount, the nonmagnetic steel satisfying the alloy composition proposed in the present disclosure can be obtained at a lower cost. In addition, the nonmagnetic steel according to the present disclosure is excellent in weldability as well as strength and ductility, and thus, it is expected that application thereof can be expanded.

Claims

1. A high-strength and high-ductility nonmagnetic steel having excellent weldability, the nonmagnetic steel comprising, by wt%, 0.03 to 0.50% of carbon (C), 0.3% or less of silicon (Si), 15 to 30% of manganese (Mn), more than 0% to 2.0% or less of chromium (Cr), more than 0% to 0.5% or less of molybdenum (Mo), 0.01 to 0.1% of titanium (Ti), 0.01 to 0.5% of vanadium (V), 0.2 to 1.0% of aluminum (Al), 0.1% or less of phosphorus (P), 0.01% or less of sulfur (S), and 0.03% or less of nitrogen (N), with a balance of Fe and other inevitable impurities, wherein the nonmagnetic steel has a single-phase austenite structure.
2. The nonmagnetic steel of claim 1, wherein the steel has a relative permeability of 1.01 or less in a magnetic field of 50 kA/m.
3. The nonmagnetic steel of claim 1, wherein the steel has a tensile strength of 450 MPa or more and an elongation of 55% or more.
4. A method for manufacturing a high-strength and high-ductility nonmagnetic steel having excellent weldability, the method comprising:
 - reheating a steel slab at a temperature of 1100 to 1250°C, the steel slab containing, by wt%, 0.03 to 0.50% of carbon (C), 0.3% or less of silicon (Si), 15 to 30% of manganese (Mn), more than 0% to 2.0% or less of chromium (Cr), more than 0% to 0.5% or less of molybdenum (Mo), 0.01 to 0.1% of titanium (Ti), 0.01 to 0.5% of vanadium (V), 0.2 to 1.0% of aluminum (Al), 0.1% or less of phosphorus (P), 0.01% or less of sulfur (S), and 0.03% or less of nitrogen (N), with a balance of Fe and other inevitable impurities;
 - finish-hot rolling the reheated steel slab at a temperature of 800 to 1000°C to manufacture a thick steel sheet; and
 - cooling the thick steel sheet at a cooling rate of 10°C/s or higher.
5. The method of claim 4, wherein the cooling is performed at a cooling rate of 10 to 80°C/s.
6. The method of claim 4, wherein the cooling is terminated at a temperature of 500°C or less.

[FIG. 1]



INTERNATIONAL SEARCH REPORT

International application No.

PCT/KR2019/014166

A. CLASSIFICATION OF SUBJECT MATTER

C22C 38/38(2006.01)i, C22C 38/22(2006.01)i, C22C 38/28(2006.01)i, C22C 38/24(2006.01)i, C22C 38/00(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 9/52; C22C 38/00; C22C 38/04; C22C 38/06; C22C 38/60; C22C 38/22; C22C 38/28; C22C 38/24; C22C 38/02; C21D 8/02

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: high manganese, weldability, non-magnetic, austenite

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 62-001823 A (KOBELITE LTD.) 07 January 1987 See pages 4-5, claim 2 and table 1.	1-6
A	JP 02-104633 A (DAIDO STEEL CO., LTD.) 17 April 1990 See claim 1.	1-6
A	JP 2016-196703 A (NIPPON STEEL & SUMITOMO METAL) 24 November 2016 See paragraphs [0038]-[0042] and claim 1.	1-6
A	JP 07-126809 A (KOBELITE LTD.) 16 May 1995 See claims 1-2.	1-6
A	JP 04-141557 A (NIPPON STEEL CORP.) 15 May 1992 See page 4 and claim 1.	1-6

☐ 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

"E" earlier application or patent but published on or after the international filing date

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