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(54) **HIGH MANGANESE NITROGEN-CONTAINING STEEL SHEET HAVING HIGH STRENGTH AND HIGH DUCTILITY, AND METHOD FOR MANUFACTURING SAME**

STAHLBLECH MIT HOHEM MANGAN- UND STICKSTOFFANTEIL SOWIE HOHER FESTIGKEIT UND LEITFÄHIGKEIT UND HERSTELLUNGSVERFAHREN DAFÜR

TÔLE D'ACIER CONTENANT DE L'AZOTE À HAUTE TENEUR EN MANGANÈSE PRÉSENTANT UNE RÉSISTANCE ET UNE DUCTILITÉ ÉLEVÉES, ET SON PROCÉDÉ DE FABRICATION

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(73) Proprietor: **Hyundai Steel Company**
Incheon 401-040 (KR)

(72) Inventors:
• **LEE, Young Kook**
Seoul 137-759 (KR)
• **JUNG, Yeon Seung**
Seoul 133-725 (KR)
• **KANG, Sin Gon**
Seoul 130-763 (KR)
• **MIN, Dong Joon**
Seoul 135-863 (KR)

(74) Representative: **Michalski Hüttermann & Partner**
Patentanwälte mbB
Speditionstraße 21
40221 Düsseldorf (DE)

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• **LIEVEN BRACKE ET AL: 'The Influence of Cr and N Additions on the Mechanical Properties of FeMnC Steels' METALLURGICAL AND MATERIALS TRANSACTIONS A vol. 38, no. 3, March 2007, pages 520 - 528, XP019695750**

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Description

[Technical Field]

5 **[0001]** The present invention relates to high manganese-nitrogen containing TWIP steel sheets having high strength and high ductility, and a method of manufacturing the same, which may be used as steel sheets for automobiles requiring high workability and impact absorbing materials such as bumper reinforcing materials for automobiles.

[Background Art]

10 **[0002]** Generally, steel sheets for an automobile body require high workability. To satisfy such requirements, ultra-low carbon steel having a low tensile strength of about 200 to 300 MPa and good workability has generally been used for automobiles steel sheets. Recently, various attempts have been made to improve fuel efficiency of automobiles in order to solve environmental problems such as air pollution. Particularly, as weight reduction of automobiles becomes
15 essential for improvement of fuel efficiency, it is necessary for automobile steel sheets to have not only high workability but also high strength.

20 **[0003]** US 2008/035248 A1 refers to a hot-rolled austenitic iron/carbon/manganese steel sheet, the strength of which is greater than 1200 MPa, the product P (strength (in MPa) * elongation at break (in %)) of which is greater than 65 000 MPa % and the nominal chemical composition of which comprises, the contents being expressed by weight: 0.85% ≤ C ≤ 1.05%; 16% ≤ Mn ≤ 19%; Si ≤ 2%; Al ≤ 0.050%; S ≤ 0.030%; P ≤ 0.050%; N ≤ 0.1%, and, optionally,
25 one or more elements chosen from: Cr ≤ 1%; Mo ≤ 0.40%; Ni ≤ 1%; Cu ≤ 5%; Ti ≤ 0.50%; Nb ≤ 0.50%; V ≤ 0.50%, the rest of the composition consisting of iron and inevitable impurities resulting from the smelting, the recrystallized surface fraction of said steel being equal to 100%, the surface fraction of precipitated carbides of said steel being equal to 0% and the mean grain size of said steel being less than or equal to 10 microns.

30 **[0004]** US 4 855 105 A refers to a wear-resistant steel containing carbon, manganese, silicon, sulphur, phosphorus, nitrogen, titanium and iron in the following ratio of the components in % by weight: carbon: 0.4-1.3; manganese: 3-11.5; sulphur: up to 0.05; phosphorus: up to 0.1; titanium: 0.01-0.15; nitrogen: 0.02-0.9; iron: the balance, and a method for making it which provides for saturation of the melted alloying addition with the nitrogen by treating said addition with the low-temperature plasma produced from a nitrogen-containing gas mixture at a partial pressure of the nitrogen in the
35 latter of approximately from 0.08 to 0.3 MPa. While mixing the melts, first the melted non-alloyed steel base representing up to 0.7 of the total weight of the melt is taken and the whole of the melted alloying addition saturated with the nitrogen is added to it, after which the rest of the melted non-alloyed steel base is introduced.

40 **[0005]** GB 2 024 862 A refers to a high-manganese, non-magnetic steel having excellent weldability and machinability and suitable for use in the structural parts of electrical equipment or nuclear fusion equipment consisting essentially of (% by weight): -carbon 0.55-0.80 -silicon 0.1-1.2 -manganese 10.0-14.5 -nickel 0.3-3.0 -chromium 0.5-3.6 -nitrogen 0.01-0.2 -balance iron and inevitable impurities. The steel may further contain at least one element of 0.01 to 1.0% of molybdenum, 0.01 to 0.5% of vanadium, 0.01 to 0.5% of niobium, 0.005 to 0.5% of titanium, 0.01 to 1.0% of zirconium, 0.0007 to 0.005% of calcium, 0.01 to 0.15% of sulfur, 0.03 to 0.2% of selenium, 0.03 to 0.2% of lead, and 0.01 to 0.8% of tin.

45 **[0006]** GB 2 040 999 A refers to a steel containing less than 0.5% C, less than 2% Si, 20 to 30% mn, and 0.005 to 0.04 N, the balance being iron and impurities, wherein the following relationships are simultaneously satisfied: Mn (%) > 16 x C (%) + 18 Mn (%) ≥ 12 x C (%) + 21.5.

50 **[0007]** JP H0657379 A refers to a cast double-layered slab in which high Mn non-magnetic steel containing 0.01 to 0.80% C, 0.01 to 2.50% Si, 9 to 32% Mn, 0.1 to 14.5% Cr, 0.10 to 8.0% Ni, 0.001 to 0.50% N and 0.001 to 0.20% Al, containing, as necessary, one or two or more kinds from among Mo, W, Co, Cu, Nb, Ti and V so as to satisfy Mo+W+Co+Cu=0.01 to 4.0% and moreover containing 0.001 to 0.02% Ca, and the balance inevitable impurities is used as an internal layer and austenitic stainless steel is used as a surface layer, is subjected to hot rolling.

55 **[0008]** JP H03 13544 A refers to the preparation of a slab of a steel having a composition consisting of, by weight, 0.55-0.80% C, <+0.5% Si, 11-17% Mn, 0.02-0.06% Al, 0.02-0.06% N, <+0.02% P, and the balance iron with inevitable impurities. The steel bar is produced by heating the above steel slab up to 1050-1250 °C, performing finish rolling at
60 >=20% rolling reduction, and regulating the final rolling temperature to 710-980 °C.

65 **[0009]** Further, since automobile components such as bumper reinforcing materials for automobiles or impact absorbing materials in a car door are directly related to passenger safety, there is an urgent need for commercialization of ultra high-strength steel which generally has a tensile strength of 780 MPa or more and high elongation.

70 **[0010]** Examples of such high strength steel for automobiles include dual phase (DP) steel, transformation induced plasticity (TRIP) steel, twin induced plasticity (TWIP) steel, and the like.

75 **[0011]** First, DP steel has a dual phase of ferrite and martensite transformed from austenite at room temperature and is manufactured by setting a cooling finish temperature below a martensite start temperature (Ms) to transform part of the austenite into martensite when cooling a hot rolled steel sheet to room temperature. Such DP steel may have various

mechanical properties through regulation of mole fraction of martensite and ferrite.

[0012] TRIP steel exhibits good workability and is obtained by partially forming retained austenite, followed by transformation of the austenite into martensite during component machining. TRIP steel has high strength resulting from significant work hardening based on martensite transformation, but has a drawback of excessively low elongation.

[0013] In other words, both DP steel and TRIP steel have a work hardening mechanism mainly based on a martensite structure, which is a hard phase and exhibits a highly increasing rate in the degree of work hardening during plastic deformation, thereby enabling manufacture of high strength hot-rolled steel sheets. In this case, however, the steel sheets have significantly low ductility, thereby making it difficult to guarantee an elongation of 30% or more.

[0014] On the other hand, TWIP steel contains a large amount of manganese and has a single austenite phase, which is stable at room temperature and allows formation of mechanical twins in the austenite structure during component machining, thereby increasing the degree of work hardening. Namely, TWIP steel has an austenite structure instead of a ferrite structure as a matrix structure and has improved elongation through additional work hardening by continuously generating mechanical twins in austenite grains to obstruct movement of dislocations during plastic deformation. Further, TWIP steel may have high elongation and high tensile strength due to the mechanical twins causing a high degree of work hardening. In particular, TWIP steel has elongation 50% higher than that of conventional DP steel or TRIP steel and is thus preferably applied to steel sheets for automobiles.

[0015] However, current TWIP steel has a high manganese content in the range of about 18 to 30% in order to guarantee austenite stability and adjust stacking fault energy, and requires addition of large amounts of aluminum or silicon together with manganese, causing a significant increase in material and manufacturing costs. Moreover, there is a need for development of TWIP steel which has a low Mn content in order to avoid additional increase in manufacturing costs caused by volatilization of Mn or temperature decrease during a steel manufacturing process or continuous casting process. Further, in terms of mechanical properties, since currently developed TWIP steel has a low yield strength of about 300 MPa and a tensile strength of 1 GPa or less, there is a need for steel sheets which have higher strength without deteriorating elongation.

[Disclosure]

[Technical Problem]

[0016] The present invention provides a steel sheet capable of solving problems of DP steel, TRIP steel and TWIP steel in the related art.

[0017] Specifically, the present invention provides a steel sheet which has both high strength and high ductility with reduced amounts of manganese.

[0018] In addition, the present invention provides a steel sheet which contains inexpensive elements instead of manganese while guaranteeing higher strength and ductility and easier working than steel sheets having a high manganese content.

[0019] Further, the present invention provides a method of manufacturing a high manganese-nitrogen containing steel sheet, which allows an increase in nitrogen content of the steel sheet.

[Technical Solution]

[0020] In accordance with an aspect of the present invention, a high manganese-nitrogen containing TWIP steel sheet consisting of:

0.5 to 1.0 wt% of carbon; 10 to 20 wt% of manganese; 0.02 to 0.3 wt% of nitrogen;
optionally 4.0 wt% or less of chromium;
optionally at least one of less than 4 wt% of silicon, less than 3 wt% of aluminum, less than 0.30 wt% of niobium, less than 0.30 wt% of titanium and less than 0.30 wt% of vanadium;
and the balance of Fe and unavoidable impurities; wherein at least part of the nitrogen is contained in the steel sheet through arc-melting; wherein the steel sheet has a product of tensile strength to total elongation (TS×EI) of 50,000 MPa% or more.

[0021] In accordance with another aspect of the present invention, a high manganese-nitrogen containing steel sheet includes: 0.5 to 1.0 wt% of carbon, 10 to 20 wt% of manganese, 4.0 wt% or less of chromium, 0.02 to 0.3 wt% of nitrogen, and the balance of Fe and unavoidable impurities.

[0022] In accordance with a further aspect of the present invention, a high manganese-nitrogen containing steel sheet includes: 0.5 to 1.0 wt% of carbon, 10 to 20 wt% of manganese, 4.0 wt% or less of chromium, 0.02 to 0.3 wt% of nitrogen, at least one of less than 4 wt% of silicon, less than 3 wt% of aluminum, less than 0.30 wt% of niobium, less than 0.30

wt% of titanium and less than 0.30 wt% of vanadium, and the balance of Fe and unavoidable impurities.

[0023] At least part of the nitrogen is contained in the steel sheet through arc-melting.

[0024] The steel sheet has a tensile strength and total elongation (TS×EI) of 50,000 MPa% or more.

[0025] Manganese may be present in an amount of 15 to 18 wt%.

[0026] Nitrogen may be present in an amount of 0.10 to 0.3 wt%.

[0027] The steel sheet may be a hot-rolled steel sheet.

[0028] The steel sheet may be a cold-rolled annealed steel sheet.

[0029] In accordance with yet another aspect of the present invention, a method of manufacturing a high manganese-nitrogen containing steel sheet according to claim 6 includes: placing electrolytic iron, electrolytic manganese and carbon powder in a chamber; filling the chamber with an argon-nitrogen atmosphere; and arc-melting the electrolytic iron, electrolytic manganese and carbon powder.

[0030] The arc-melting may be repeated plural times.

[0031] The nitrogen-argon atmosphere may have a nitrogen fraction of 0.2 to 0.8.

[0032] The method may further include: hot rolling the high nitrogen-containing steel sheet at 900 °C or more; and air cooling or forced air cooling the hot rolled steel sheet.

[0033] The method may further include: cold rolling the cooled steel sheet at a reduction rate of 50% or more at room temperature; annealing the cold rolled steel sheet at 800 °C or more; and air cooling or forced air cooling the annealed steel sheet.

[0034] The manufactured steel sheet may consist of: 0.5 to 1.0 wt% of carbon, 10 to 20 wt% of manganese, 0.02 to 0.2 wt% of nitrogen, and the balance of Fe and unavoidable impurities.

[0035] In the method, a raw material for chromium may be further placed in the chamber.

[0036] In this case, the manufactured steel sheet may consist of 0.5 to 1.0 wt% of carbon, 10 to 20 wt% of manganese, 4.0 wt% or less of chromium, 0.02 to 0.2 wt% of nitrogen, and the balance of Fe and unavoidable impurities.

[0037] Further, raw materials for chromium and at least one of silicon, aluminum, niobium, titanium and vanadium may be placed in the chamber.

[0038] In this case, the manufactured steel sheet may consist of: 0.5 to 1.0 wt% of carbon, 10 to 20 wt% of manganese, 4.0 wt% or less of chrome, 0.02 to 0.3 wt% of nitrogen, at least one of less than 4 wt% of silicon, less than 3 wt% of aluminum, less than 0.30 wt% of niobium, less than 0.30 wt% of titanium and less than 0.30 wt% of vanadium, and the balance of Fe and unavoidable impurities.

[Advantageous Effects]

[0039] According to exemplary embodiments of the invention, high manganese-nitrogen containing TWIP steel sheets have an austenite structure formed at room temperature and allow effective regulation of stacking fault energy through addition of chrome and nitrogen. Thus, the steel sheets allow a high degree of work hardening, and have high tensile strength and excellent workability by mechanical twins formed during plastic deformation of the steel sheets. Namely, the high manganese-nitrogen containing steel sheets according to the exemplary embodiments have a very high product of tensile strength to total elongation (TS×EI) of 50,000 MPa% or more, which is much higher than that of conventional TWIP steel, thereby guaranteeing a significantly high product of tensile strength to total elongation while reducing manufacturing costs.

[0040] Further, the high manganese-nitrogen containing steel sheets according to the exemplary embodiments may be used in various ways such as hot rolled steel sheets, cold-rolled annealed steel sheets, and the like.

[Description of Drawing]

[0041]

Fig. 1 is an electron micrograph of a high manganese-nitrogen containing steel sheet according to one example of the present invention; and

Fig. 2 is a tensile strength curve of steel according to Example 9.

[Mode for Invention]

[0042] Exemplary embodiments of the present invention will now be described in detail with reference to the accompanying drawings.

[0043] In high manganese-nitrogen containing steel sheets according to exemplary embodiments, carbon and nitrogen are added while lowering the manganese content to be in the range of 10~20 wt% to have a single austenite phase structure at room temperature, as compared with conventional twin induced plasticity (TWIP) steel containing 20 wt%

of manganese. Particularly, nitrogen induces not only solid solution strengthening effects, but also mechanical twins by affecting the stacking fault energy.

[0044] Thus, the high manganese-nitrogen containing steel sheets according to the exemplary embodiments include the aforementioned alloy elements, thereby achieving an elongation of 50% or more and higher yield strength and tensile strength than conventional TWIP steel while reducing the amounts of expensive alloy elements such as manganese or aluminum below those of the conventional TWIP steel.

[0045] First, according to a first exemplary embodiment, a high manganese-nitrogen containing steel sheet consists of 0.5 to 1.0 wt% of carbon, 10 to 20 wt% of manganese, 0.02 to 0.3 wt% of nitrogen, and the balance of Fe and unavoidable impurities.

[0046] Specifically, the high manganese-nitrogen containing steel sheet according to the first exemplary embodiment includes 10 to 20 wt% of manganese. Namely, since TWIP steel has mechanical twins formed in an austenite matrix at room temperature during plastic deformation, it is important to expand an austenite region of high temperature to an austenite region at room temperature on a Fe-carbon phase diagram. In this embodiment, manganese is used as an austenite stabilizing element.

[0047] More preferably, manganese is present in an amount of 15 to 18 wt% in the steel sheet. If the Mn content reaches 15 wt%, austenite stability can be secured and stacking fault energy can be effectively lowered to promote formation of mechanical twins during plastic deformation, thereby providing a very high product of tensile strength to elongation.

[0048] If the Mn content is less than 10 wt%, austenite stability is significantly deteriorated, causing formation of ferrite or martensite in the austenite region during cooling after hot rolling. Further, if the Mn content is less than 10 wt%, stacking fault energy of the austenite phase excessively increases, thereby making it difficult to form mechanical twins.

[0049] If the Mn content exceeds 20 wt%, the stacking fault energy excessively increases, so that the twins are not formed and plastic deformation of austenite occurs, thereby causing deterioration of mechanical properties.

[0050] Further, the high manganese-nitrogen containing steel sheet according to this embodiment includes 0.5 to 1.0 wt% of carbon. Namely, Fe-Mn binary alloys containing 20 wt% or less of Mn have ϵ -martensite or α -martensite partially formed therein instead of a single austenite phase microstructure at room temperature. Thus, according to this embodiment, in order to form a single austenite phase microstructure at room temperature, carbon is added as an austenite stabilizing element which is inexpensive and highly effective.

[0051] If the carbon content is less than 0.5 wt%, it is difficult to obtain a single austenite phase during cooling after hot rolling due to insufficient austenite stability, or, even in the case where the single austenite phase is obtained at room temperature, phase transformation occurs from austenite to martensite during plastic deformation to form TRIP steel, and thus desired TWIP steel cannot be obtained.

[0052] If the carbon content exceeds 1.0 wt%, stable austenite can be obtained at room temperature, but cementite precipitation occurs, causing deterioration in elongation or weldability. Further, if the carbon content exceeds 1.0 wt%, the stacking fault energy excessively increases thereby making it difficult to form the mechanical twins during deformation.

[0053] Further, the high manganese-nitrogen containing steel sheet according to the first exemplary embodiment contains 0.02 to 0.3 wt% of nitrogen. Specifically, nitrogen acts as an interstitial element which stabilizes the austenite structure, and as in carbon, austenite stability increases and strength resulting from solid solution strengthening increases with increasing amount of nitrogen. Further, although the nitrogen content increases, the stacking fault energy does not increase, thereby facilitating formation of the mechanical twins.

[0054] According to this embodiment, when the nitrogen content is 0.10 wt% or more, the degree of solid solution hardening increases, thereby providing advantageous effects of significantly increased yield strength of the steel sheet.

[0055] The nitrogen content less than 0.02 wt% is an amount of nitrogen added as an impurity in manufacture of typical steel sheets and makes it difficult to obtain austenite stability. Thus, ferrite or martensite is not formed at room temperature after hot rolling, and it is difficult to obtain a function of regulating the stacking fault energy. On the other hand, although it is very difficult to increase the nitrogen content without adding elements such as chrome, the present invention enables an increase of the nitrogen content to 0.1 wt% or more, more preferably 0.2 wt% or more, through an arc-melting process described below.

[0056] Next, according to a second exemplary embodiment, a high manganese-nitrogen containing steel sheet consists of 0.5 to 1.0 wt% of carbon, 10 to 20 wt% of manganese, 0.02 to 0.3 wt% of nitrogen, 4 wt% or less of chromium, and the balance of Fe and unavoidable impurities.

[0057] First, chromium improves not only corrosion resistance but also nitrogen solubility of steel. Further, chromium reduces the stacking fault energy, which increases due to addition of carbon, thereby promoting formation of the mechanical twins. However, since chromium is a ferrite stabilizing element, the chromium content exceeding 4.0 wt% can cause partial formation of ferrite during hot rolling. Further, since chromium is expensive, use of large amounts of chromium increases manufacturing costs. Thus, the content of chromium is set to 4 wt% or less.

[0058] Further, if the nitrogen content exceeds 0.3 wt%, it is necessary to increase the Cr content added in order to allow nitrogen to be dissolved in a large amount in the steel sheet, which results in an undesirable increase of manu-

facturing costs.

[0059] Further, the amounts of other elements added to the steel sheet according to the second embodiment are the same as those of the steel sheet according to the first embodiment, and a detailed description thereof will thus be omitted herein.

[0060] Next, a high manganese-nitrogen containing steel sheet according to a third exemplary embodiment of the invention consists of 0.5 to 1.0 wt% of carbon, 10 to 20 wt% of manganese, 4.0 wt% or less of chromium, 0.02 to 0.3 wt% of nitrogen, at least one of less than 4 wt% of silicon, less than 3 wt% of aluminum, less than 0.30 wt% of niobium, less than 0.30 wt% of titanium and less than 0.30 wt% of vanadium, and the balance of Fe and unavoidable impurities.

[0061] Specifically, if the silicon content is 4 wt% or less, solid solution hardening obtained by silicon results in reduction of grain size, thereby improving strength through increase of yield strength. Further, addition of silicon reduces the stacking fault energy of steel, thereby facilitating formation of mechanical twins during plastic deformation.

[0062] However, if the added amount of silicon exceeds 4 wt%, a silicon oxide layer is formed on the steel sheet, thereby deteriorating wettability. Further, the stacking fault energy of the steel is excessively lowered to decrease austenite stability, thereby promoting formation of ϵ -martensite. Thus, the silicon content of silicon is set to 4 wt% or less.

[0063] Further, if the aluminum content is 3 wt% or less, deoxidation effects cannot be obtained. Further, aluminum suppresses formation of ϵ -martensite through increase in stacking fault energy at a slip plane, thereby improving ductility. In addition, aluminum may suppress formation of ϵ -martensite even with a low amount of manganese, thereby enabling minimization of manganese content in manufacture of steel while improving workability.

[0064] However, if the aluminum content exceeds 3 wt%, formation of twins is suppressed due to excessive increase in stacking fault energy, thereby deteriorating ductility and casting properties upon continuous casting. Moreover, surface oxidation severely occurs upon hot rolling, thereby deteriorating surface quality of finished products.

[0065] Further, niobium, titanium and vanadium are strong carbide forming elements coupling with carbon to form carbide, which effectively prevents grain growth to form fine grains while providing precipitation hardening effects by formation of precipitate phases. However, if the amount of niobium, titanium or vanadium exceeds 0.30 wt%, segregation of niobium, titanium or vanadium can occur in grain boundaries causing grain boundary brittleness, or the precipitate phases can become excessively coarse, thereby deteriorating grain growth effects. Thus, niobium, titanium or vanadium may be added in an amount of 0.30 wt% or less.

[0066] Further, the amounts of other elements added to the steel sheet according to the third embodiment are the same as those of the steel sheets according to the first and second embodiments, and a detailed description thereof will thus be omitted herein.

[0067] Next, a method of manufacturing a high manganese-nitrogen containing steel sheet according to an exemplary embodiment of the invention will be described.

[0068] The method of manufacturing a high manganese-nitrogen containing steel sheet according to the exemplary embodiment is as follows. First, electrolytic iron, electrolytic manganese, and carbon powder are placed in a chamber. Here, the composition of a final steel sheet may be controlled by controlling the amounts of such raw materials supplied to the chamber. Then, the chamber is evacuated and is filled with argon and nitrogen to create an argon-nitrogen atmosphere therein. Here, the argon-nitrogen atmosphere has a total pressure of 1 atm., and nitrogen has a partial pressure in the range of 0.2 to 0.8 atm. If the ratio of nitrogen is less than 20 wt%, the amount of nitrogen added becomes too low in the steel during arc-melting, thereby deteriorating arc-melting efficiency. If the ratio of nitrogen exceeds 80 wt%, the pressure of inert gas, that is, the pressure of argon, is excessively reduced, causing severe generation of manganese fumes, by which the interior of the chamber is severely contaminated. Further, if the ratio of nitrogen is too high, scattering of the raw materials severely occurs due to melting of a tungsten electrode rod, causing a very rough surface of the steel sheet after arc-melting. Next, the raw materials are subjected to arc-melting using an electrode rod within the chamber, followed by cooling for an appropriate period of time, thereby providing desired steel. Here, although arc-melting and cooling may be performed once, arc-melting and cooling are desirably repeated plural times. In addition, the nitrogen content increases with increasing the number of times of repeating the processes of arc-melting and cooling.

[0069] Particularly, since the nitrogen content is limited to 0.02 to 0.1 wt% in a typical method of manufacturing TWIP steel, it is very difficult to form a high manganese-nitrogen containing steel sheet having the composition according to the first exemplary embodiment without adding an element for promoting dissolution of nitrogen in the steel sheet, such as chrome. However, when the steel is formed by arc-melting in the argon-nitrogen atmosphere as described above, it is possible to add a larger amount of nitrogen without adding an expensive element such as chromium than in the case of forming the steel sheet using a typical method, and, particularly, the high manganese-nitrogen containing steel sheet having the composition according to the first embodiment may be obtained. However, the method of manufacturing a steel sheet using arc-melting may be applied not only to the steel sheet having the composition according to the first embodiment but also to steel sheets having various compositions.

[0070] After manufacturing the high manganese-nitrogen containing steel sheet using the arc-melting, the steel sheet is subjected to hot rolling at 900°C or more, followed by air cooling or forced air cooling.

[0071] Further, more preferably, the hot rolled and cooled steel sheet is subjected to cold rolling at a reduction rate of

50% at room temperature, followed by annealing at 800°C or more and air cooling or forced air cooling.

[0072] Alternatively, the high manganese-nitrogen containing steel sheets according to the embodiments of the invention may be manufactured by a typical method.

[0073] Specifically, the typical method of manufacturing the steel sheet includes heating a steel slab having a desired composition to 1100°C or more, hot rolling the heated steel slab at 900°C or more to provide a steel sheet, and air cooling or forced air cooling the hot rolled steel sheet. Then, the method may further include cold rolling the cooled steel sheet at a reduction rate of 50% or more, annealing the cold rolled steel sheet at 800°C or more, and air cooling or forced air cooling the annealed steel sheet.

[Mode for Invention]

[0074] Samples of Examples 1 to 6 and Comparative Examples 1 to 6 were each produced in accordance with the method of the invention by heating steel slabs having compositions listed in Table 1 to 1100°C or more, hot rolling at 900°C or more to provide steel sheets with a thickness of 3mm, and air cooling the hot rolled steel sheet. In particular, the sample of Example 4 is a cold rolled steel sheet sample which was produced by cold rolling the hot rolled steel sheet sample of Example 3 from a thickness of 3mm to a thickness of 1.5 mm, followed by annealing at 800°C for 10 minutes.

Table 1

Sample No.	Composition (wt%)						Note
	C	Mn	Cr	N	Al	Si	
Example 1	0.594	14.96	1.83	0.068		-	hot-rolled steel sheet
Example 2	0.618	15.03	1.82	0.086	-	-	hot-rolled steel sheet
Example 3	0.560	14.90	2.51	0.210	-	-	hot-rolled steel sheet
Example 4	0.560	14.90	2.51	0.210	-		cold-rolled annealed steel sheet
Example 5	0.580	17.05	0.209	0.023	0.005	1.59	hot-rolled steel sheet
Example 6	0.610	19.01	0.302	0.020	0.96	-	hot-rolled steel sheet
Comparative Example 1	0.607	9.00	1.73	0.060	-	-	hot-rolled steel sheet
Comparative Example 2	0.0006	23.8	-	-	2.70	3.0	hot-rolled steel sheet
Comparative Example 3	0.580	17.49	-	-	1.50	-	hot-rolled steel sheet
Comparative Example 4	0.933	12.76	-	--	-	0.010	hot-rolled steel sheet
Comparative Example 5	1.16	9.87	-	-	-	0.066	hot-rolled steel sheet
Comparative Example 6	1.19	8.08	-	-	-	0.067	hot-rolled steel sheet

[0075] Next, strength and elongation of the samples were measured, and results are shown in the following table 2.

Table 2

Sample No.	Yield strength (YS) (MPa)	Tensile strength (TS) (MPa)	Total elongation EI (%)	TS×EI (MPa%)	Note
Example 1	361.4	900.9	60.0	54054	hot-rolled steel sheet
Example 2	366.3	880.1	62.4	54918	hot-rolled steel sheet
Example 3	653.1	1050.6	59.6	62616	hot-rolled steel sheet
Example 4	607.7	1155.3	61.3	70820	cold-rolled annealed steel sheet
Example 5	343.2	803.2	68.2	53413	hot-rolled steel sheet
Example 6	358.4	818.3	66.5	54417	hot-rolled steel sheet

(continued)

Sample No.	Yield strength (YS) (MPa)	Tensile strength (TS) (MPa)	Total elongation El (%)	TS×EI (MPa%)	Note
Comparative Example 1	650.1	928.7	15.5	14395	hot-rolled steel sheet
Comparative Example 2	339.0	666.0	67.0	44622	hot-rolled steel sheet
Comparative Example 3	313.3	711.4	61.4	43680	hot-rolled steel sheet
Comparative Example 4	387.0	1021.2	33.9	34619	hot-rolled steel sheet
Comparative Example 5	461.2	908.8	7.61	6916	hot-rolled steel sheet
Comparative Example 6	470.5	937.3	5.04	4724	hot-rolled steel sheet

[0076] As seen from the Table, each of the steel sheets according to Examples 1 to 4 has a yield strength (YS) exceeding 300 MPa and a tensile strength (TS) exceeding 880Mpa. Further, each of the steel sheets according to Examples 1 to 4 has a total elongation (EL) of about 60%, and a very high product of tensile strength to elongation (TS×EL) of 50,000 MPa%. In other words, it can be seen that each of the steel sheets according to the examples has higher yield strength and higher tensile strength than conventional TWIP steel (Comparative Examples 2 and 3), and similar elongation to the conventional TWIP steel. Particularly, as can be seen from Example 3, when the nitrogen content exceeds 0.2 wt%, the steel sheet sample have very high yield strength and tensile strength provided by solid solution hardening effects of nitrogen. Namely, the steel sheet according to Example 3 has a tensile strength exceeding 1 GPa and an elongation approaching 60%, thereby providing a product of tensile strength and elongation (TS×EL) exceeding 60,000 MPa%. Further, Example 4 is a steel sheet produced by cold rolling and annealing the hot rolled steel sheet of Example 3, and it was confirmed that Example 4 had improved tensile strength and elongation.

[0077] Formation of mechanical twins can be confirmed from Fig. 1. Specifically, Fig. 1 is an electron micrograph of a high manganese-nitrogen containing steel sheet according to one example of the present invention, and as seen from Fig.1, the steel sheet according to Example 3 has mechanical twins.

[0078] Further, as compared with the steel sheets according to Examples 1 to 4, the steel sheet of Example 5 further including aluminum and silicon and the steel sheet of Example 6 further including aluminum have large amounts of nitrogen despite a significant decrease in Cr content, thereby exhibiting excellent yield strength and tensile strength.

[0079] On the other hand, the steel sheets of the comparative examples were produced by a conventional method and had lower tensile strength or elongation than those of the examples. First, the steel sheet according to Comparative Example 1 was a TRIP steel sheet and had a high tensile strength of 928.7 MPa and a low total elongation of 15.5%. Other TWIP steel sheets (Comparative Examples 2 and 3), which did not contain nitrogen and were produced by a conventional method, have high total elongation of 60% or more, but have a relatively low tensile strength of about 700 MPa, thereby providing a product of tensile strength to elongation (TS×EL) of about 40,000 MPa%. Further, it could be seen that the steel sheets according to Comparative Examples 4 to 6 rapidly reduced in elongation with increasing carbon content.

[0080] Next, the steel sheets according to Examples 8 to 9 were produced using arc-melting. Specifically, electrolytic iron, electrolytic manganese, and carbon powder were placed in a predetermined ratio in a chamber, which in turn was evacuated and filled with argon and nitrogen to create an argon-nitrogen atmosphere in the chamber. Here, advantageously, the argon-nitrogen atmosphere had a total pressure of 1 atm., and nitrogen had a partial pressure in the range of 0.2 to 0.8 atm. Then, the raw materials were subjected to arc-melting using an arc electrode rod at an electric current of 400A for 30 minutes while advancing the arc electrode rod in a state of being separated a distance of 2 to 5 cm from each of the samples, followed by cooling for 30 minutes. The process of arc-melting and cooling was repeated three times.

[0081] Next, the steel sheet according to Comparative Example 7 was produced by melting the raw materials in a nitrogen atmosphere without arc-melting.

[0082] Detailed compositions of the high Mn steel sheets according to Example 8, 9 and Comparative Example 7 are as follows. Example 8 is a reference example only.

Table 3

Sample No.	Composition (wt%)				Note
	C	Mn	Cr	N	
Example 8	0.760	14.27	-	0.109	Arc-melting
Example 9	0.570	16.47	-	0.090	Arc-melting
Comparative Example 7	0.618	15.03	1.82	0.086	Melting in nitrogen atmosphere

[0083] As in Examples 8 to 9, it was possible to produce a high-Mn steel sheet by arc-melting Cr-free steel in an argon-nitrogen atmosphere. Further, as in Example 4, it was possible to form higher-nitrogen steel by arc-melting Cr-containing steel in an argon-nitrogen atmosphere.

[0084] On the other hand, the steel according to the comparative example included chromium and was produced by a typical steel manufacturing method in a nitrogen atmosphere. It could be confirmed that, even in the case where Cr-containing steel was subjected to melting in a nitrogen atmosphere as in the comparative example, the nitrogen content of the steel was less than that of the steel sheets according to the examples 8, 9. Namely, as in the comparative example, when steel containing 1.73 wt% of Cr is produced by melting, the steel contained 0.086 wt% of nitrogen.

[0085] Fig. 2 is a tensile strength curve of steel according to Example 9. As shown in Fig. 2, advantageously, the steel according to Example 9 has excellent strength and elongation, that is, 985 MPa and 56%, and has a product of tensile strength to elongation of about 55,000 MPa%, which is much higher than high Mn steel containing 20 wt% or less of Mn without containing Cr, and which is similar to high Mn steel containing more than 20% Mn and an expensive metal element such as Cr or the like.

Claims

1. A high manganese-nitrogen containing twin induced plasticity TWIP steel sheet consisting of:

0.5 to 1.0 wt% of carbon; 10 to 20 wt% of manganese; 0.02 to 0.3 wt% of nitrogen; optionally 4.0 wt% or less of chromium;
optionally at least one of less than 4 wt% of silicon, less than 3 wt% of aluminum, less than 0.30 wt% of niobium, less than 0.30 wt% of titanium and less than 0.30 wt% of vanadium;
and the balance of Fe and unavoidable impurities; wherein at least part of the nitrogen is contained in the steel sheet through arc-melting; wherein the steel sheet has a product of tensile strength to total elongation (TS×EI) of 50,000 MPa% or more.

2. The high manganese-nitrogen containing steel sheet of claim 1, wherein manganese is present in an amount of 15 to 18 wt%.

3. The high manganese-nitrogen containing steel sheet of any one of claim 1 or 2, wherein nitrogen is present in an amount of 0.10 to 0.3 wt%.

4. The high manganese-nitrogen containing steel sheet of any one of claims 1 to 3, wherein the steel sheet is a hot rolled steel sheet.

5. The high manganese-nitrogen containing steel sheet of any one of claims 1 to 4, wherein the steel sheet is a cold rolled annealed steel sheet.

6. A method of manufacturing a high manganese-nitrogen containing steel sheet of claims 1 to 5, comprising:

placing the components of claims 1 to 3, wherein iron is in the form of electrolytic iron, manganese is in the form of electrolytic manganese and carbon is in the form of carbon powder in a chamber;
the chamber is evacuated and the chamber is filled with an argon-nitrogen atmosphere having a total pressure of 1 atm with nitrogen having a partial pressure in the range of 0.2-0.8 atm; and
arc-melting said components followed by cooling, heating the steel slab to 1100° C; hot rolling the heated steel slab at 900° C or more to provide a steel sheet and air cooling or forced air cooling the hot rolled steel sheet;

optionally the hot rolled and cooled steel sheet is subjected to cold rolling at a reduction rate of 50% at room temperature, followed by annealing at 800°C or more and air cooling or forced air cooling.

7. The method of any one of claim 6, wherein the arc-melting is repeated plural times.
8. The method of any one of claim 6 or 7, wherein the nitrogen-argon atmosphere has a nitrogen fraction of 0.2 to 0.8.

Patentansprüche

1. Manganreiches stickstoffhaltiges TWIP-Stahlblech (TWIP = Twin Induced Plasticity; zwillingsinduzierte Plastizität), bestehend aus:

0,5 bis 1,0 Gew.% Kohlenstoff;
10 bis 20 Gew.% Mangan;
0,02 bis 0,3 Gew.% Stickstoff;

gegebenenfalls 4 Gew.% oder weniger Chrom; gegebenenfalls mindestens einem von weniger als 4 Gew.% Silicium, weniger als 3 Gew.% Aluminium, weniger als 0,30 Gew.% Niob, weniger als 0,30 Gew.% Titan und weniger als 0,30 Gew.% Vanadium;

und Fe und unvermeidbaren Verunreinigungen als restlichen Bestandteilen;

wobei mindestens ein Teil des Stickstoff durch Lichtbogenschmelzen in das Stahlblech aufgenommen ist, wobei das Stahlblech ein Produkt aus Zugfestigkeit mal Gesamtdehnung (TS x EI) von 50000 MPa% oder mehr aufweist.

2. Manganreiches stickstoffhaltiges Stahlblech nach Anspruch 1, wobei Mangan in einer Menge von 15 bis 18 Gew.% vorhanden ist.
3. Manganreiches stickstoffhaltiges Stahlblech nach einem der Ansprüche 1 oder 2, wobei Stickstoff in einer Menge von 0,10 bis 0,3 Gew.% vorhanden ist.
4. Manganreiches stickstoffhaltiges Stahlblech nach einem der Ansprüche 1 bis 3, wobei das Stahlblech ein heißgewalztes Stahlblech ist.
5. Manganreiches stickstoffhaltiges Stahlblech nach einem der Ansprüche 1 bis 4, wobei das Stahlblech ein kaltgewalztes Stahlgelbtes Stahlblech ist.
6. Verfahren zur Herstellung eines manganreichen stickstoffhaltigen Stahlblechs nach den Ansprüchen 1 bis 5, umfassend:

Platzieren der Komponenten der Ansprüche 1 bis 3, wobei Eisen in Form von Elektrolyteisen vorliegt, Mangan in Form von Elektrolytmangan vorliegt und Kohlenstoff in Form von Kohlenstoffpulver vorliegt, in einer Kammer; die Kammer evakuiert wird und die Kammer mit einer Argon-Stickstoff-Atmosphäre mit einem Gesamtdruck von 1 atm mit Stickstoff mit einem Partialdruck im Bereich von 0,2-0,8 atm gefüllt wird; und die Komponenten lichtbogengeschmolzen werden, gefolgt von Kühlen, Erhitzen der Stahlbramme auf 1100°C; Heißwalzen der erhitzten Stahlbramme bei 900 °C oder mehr, um ein Stahlblech bereitzustellen, und Luftkühlen oder Zwangsluftkühlen des heißgewalzten Stahlblechs: wobei das heißgewalzte und gekühlte Stahlblech gegebenenfalls Kaltwalzen mit einer Reduktionsrate von 50 % bei Raumtemperatur unterzogen wird, gefolgt von Glühen bei 800 °C oder mehr und Luftkühlen oder Zwangsluftkühlen.

7. Verfahren nach Anspruch 6, wobei das Lichtbogenschmelzen mehrmals wiederholt wird.
8. Verfahren nach einem der Ansprüche 6 oder 7, wobei die Stickstoff-Argon-Atmosphäre eine Stickstofffraktion von 0,2 bis 0,8 hat.

Revendications

1. Tôle d'acier TWIP à plasticité induite par maclage contenant de l'azote à haute teneur en manganèse, contenant de 0,5 % en poids à 1,0 % en poids de carbone; de 10 % en poids à 20 % en poids de manganèse; de 0,02 % en poids à 0,3 % en poids d'azote, optionnellement 4,0 % en poids ou moins de chrome, optionnellement d'au moins parmi moins de 4 % en poids de silicium, moins de 3 % en poids d'aluminium, moins de 0,30 % en poids de niobium, moins de 0,30% en poids de titane et moins de 0,30 % en poids de vanadium; le reste étant du fer et des impuretés inévitables,
dans laquelle au moins une partie de l'azote est contenue dans la tôle d'acier par l'entremise d'une fusion à l'arc, et dans laquelle la tôle d'acier présente un produit de la résistance à la traction avec l'allongement total (TS x EI) de 50000 MPa%, ou plus.
2. Tôle d'acier contenant de l'azote à haute teneur en manganèse selon la revendication 1, dans laquelle le manganèse est présent en une quantité de 15 % en poids à 18 % en poids.
3. Tôle d'acier contenant de l'azote à haute teneur en manganèse selon l'une quelconque des revendications 1 ou 2, dans laquelle l'azote est présent en une quantité de 0,10 % en poids à 0,3 % en poids.
4. Tôle d'acier contenant de l'azote à haute teneur en manganèse selon l'une quelconque des revendications 1 à 3, dans laquelle la tôle d'acier est une tôle d'acier laminée à chaud.
5. Tôle d'acier contenant de l'azote à haute teneur en manganèse selon l'une quelconque des revendications 1 à 4, dans laquelle la tôle d'acier est une tôle d'acier recuite laminée à froid.
6. Procédé de fabrication d'une tôle d'acier contenant de l'azote à haute teneur en manganèse selon les revendications 1 à 5, comprenant les étapes suivantes:

 placer les composants des revendications 1 à 3, dans lesquels le fer se présente sous la forme de fer électrolytique, le manganèse se présente sous la forme de manganèse électrolytique et le carbone se présente sous la forme poudre de carbone, dans une chambre;
 évacuer la chambre et remplir la chambre avec une atmosphère d'azote-argon qui présente une pression totale de 1 atm, où l'azote présente une pression partielle comprise dans la gamme de 0,2 atm à 0,8 atm; et
 faire fondre à l'arc lesdits composants, ensuite les refroidir, chauffer la brame d'acier à 1100°C; laminier à chaud la brame d'acier chauffée à 900°C ou plus pour former une tôle d'acier, et refroidir à l'air ou refroidir à l'air forcé la tôle d'acier laminée à chaud;
 soumettre optionnellement la tôle d'acier laminée à chaud et refroidie à un laminage à froid à une vitesse de réduction de 50 % à la température ambiante, et ensuite recuire à 800°C ou plus et refroidir à l'air ou refroidir à l'air forcé.
7. Procédé selon la revendication 6, dans lequel la fusion à l'arc est répétée plusieurs fois.
8. Procédé selon l'une quelconque des revendications 6 ou 7, dans lequel l'atmosphère d'azote-argon présente une fraction d'azote comprise entre 0,2 et 0,8.

Fig. 1

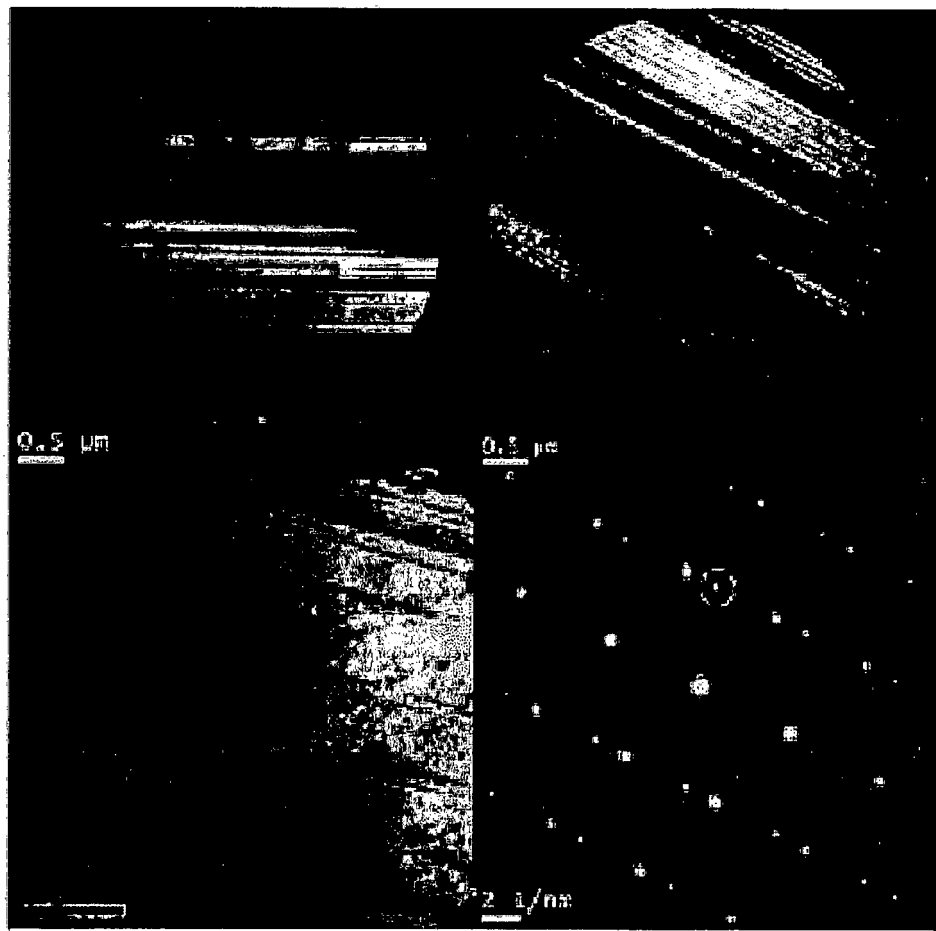
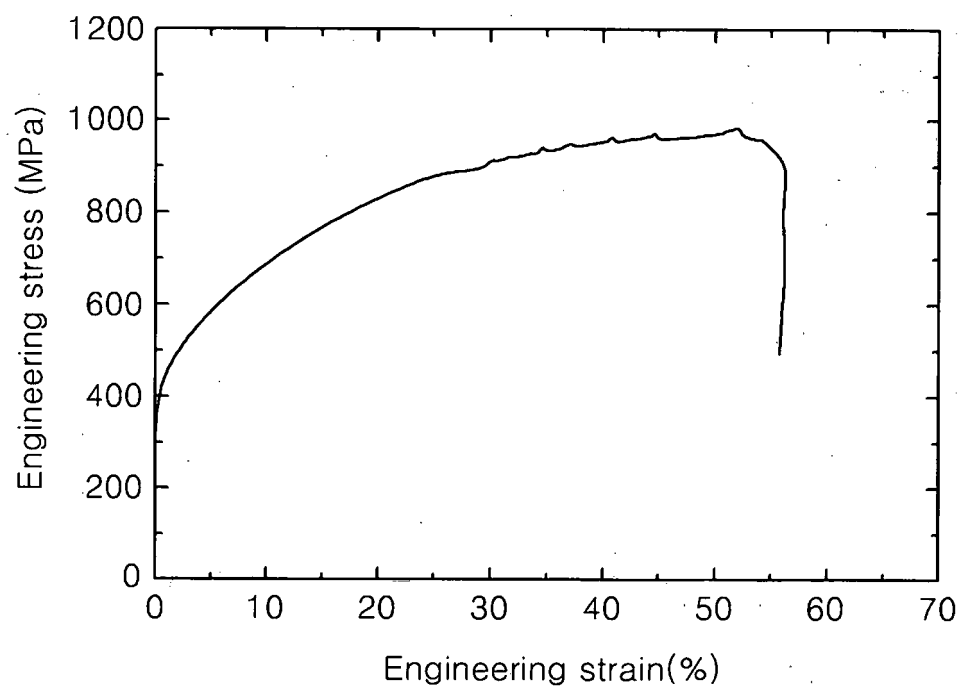


Fig. 2

REFERENCES CITED IN THE DESCRIPTION

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