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(54) **FERRITIC STAINLESS STEEL HAVING EXCELLENT DUCTILITY AND METHOD FOR  
MANUFACTURING SAME**

FERRITISCHER EDELSTAHL MIT HERVORRAGENDER DUKTILITÄT UND VERFAHREN ZUR  
HERSTELLUNG DAVON

MATÉRIAU D'ACIER INOXYDABLE FERRITIQUE PRÉSENTANT UNE EXCELLENTE DUCTILITÉ  
ET SON PROCÉDÉ DE PRODUCTION

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**Description**

[Technical Field]

5 **[0001]** The present disclosure relates to ferritic stainless steel having a high degree of ductility and a method for manufacturing the ferritic stainless steel, and more particularly, to a new kind of ferritic stainless steel provided by improving ferritic stainless steel having poor ductility compared to austenitic stainless steel for use in applications requiring high ductility, and a method for manufacturing the ferritic stainless steel.

10 [Background Art]

**[0002]** Ferritic stainless steels have a high degree of corrosion resistance even though the contents of expensive alloying elements in the ferritic stainless steels are low. That is, ferritic stainless steels are more competitive in price than austenitic stainless steels. Ferritic stainless steels are used in applications such as construction materials, transportation vehicles, or kitchen utensils. However, ferrite stainless steels have poor ductility and thus it is difficult to use ferritic stainless steels instead of austenitic stainless steels in many applications. Therefore, many efforts have been made to improve the ductility of ferritic stainless steels and thus to increase the applications of ferritic stainless steels.

**[0003]** To this end, attempts to improve the ductility of ferritic stainless steels by limiting the total amount or number of precipitates in ferritic stainless steels have been made. However, meaningful results have not yet been reported.

20 **[0004]** JP H09 287021 A relates to a high purity ferritic stainless hot rolled steel strip with good workability obtained without executing cold rolling and annealing.

**[0005]** JP 2000 144342 A relates to a ferritic stainless steel with good formability, that is capable of working a continuously cast slab into a prescribed shape without causing surface defects, cracking or fracture. Al inclusions and Ti inclusions are dispersed in the steel.

25 **[0006]** EP 1 514 949 A1 relates to a Ti-containing ferritic stainless steel sheet and a manufacturing method thereof. The ferritic stainless steel has a ferrite grain size number of 6.0 or more and an average diameter of Ti base precipitates of 0.05-1.0 $\mu$ m. The manufacturing method comprises hot-rolling and recrystallisation annealing.

[Disclosure]

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[Technical Problem]

**[0007]** An aspect of the present disclosure provides ferritic stainless steel having a high degree of ductility and a method of manufacturing the ferritic stainless steel.

35 **[0008]** The present disclosure is not limited to the above-mentioned aspect. Other aspects of the present disclosure are stated in the following description, and the aspects of the present disclosure will be clearly understood by those of ordinary skill in the art through the following description.

[Technical Solution]

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**[0009]** According to an aspect of the present disclosure, ferritic stainless steel includes, by wt%, C: 0.005% to 0.1%, Si: 0.01% to 2.0%, Mn: 0.01% to 1.5%, P: 0.05% or less, S: 0.005% or less, Cr: 10% to 30%, Ti: 0.005% to 0.5%, Al: 0.01% to 0.15%, N: 0.005% to 0.03%, and the balance of Fe and inevitable impurities, wherein the ferritic stainless steel comprises an independent Ti(CN) precipitate and a dependent Ti(CN) precipitate formed using a TiN inclusion as precipitation nuclei, and the ferritic stainless steel has a P within a range of 60% or less, the P being defined by Formula 1 below:

[Formula 1]

50

$$P(\%) = \{N_s / (N_s + N_c)\} \times 100$$

where  $N_s$  refers to the number of independent Ti(CN) precipitate particles per unit area ( $\text{mm}^2$ ), and  $N_c$  refers to the number of dependent Ti(CN) precipitate particles per unit area ( $\text{mm}^2$ ), and wherein the ferritic stainless steel may include  $3.5 \times 10^6$  or fewer particles of the independent Ti(CN) precipitate per square millimeter ( $\text{mm}^2$ ) of ferrite matrix, wherein the independent Ti(CN) precipitate has a particle diameter of 0.01  $\mu\text{m}$  or greater, and wherein the particle diameter of the independent Ti(CN) precipitate is measured by Transmission Electron Microscopy (TEM).

**[0010]** The ferritic stainless steel may preferably have a P of 58% or less.

**[0011]** The independent Ti(CN) precipitate may have an average particle diameter of 0.15  $\mu\text{m}$  or less, wherein the average particle diameter of the independent Ti(CN) precipitate is measured by Transmission Electron Microscopy (TEM).

**[0012]** The TiN inclusion may have an average particle diameter of 2  $\mu\text{m}$  or greater, wherein the average particle diameter of the TiN inclusion is measured by Transmission Electron Microscopy (TEM).

**[0013]** The ferritic stainless steel may have an elongation of 34% or greater.

**[0014]** According to another aspect of the present disclosure, a method for manufacturing ferritic stainless steel in accordance with the invention as defined herein includes casting molten steel as a slab, the molten steel including, by wt%, C: 0.005% to 0.1%, Si: 0.01% to 2.0%, Mn: 0.01% to 1.5%, P: 0.05% or less, S: 0.005% or less, Cr: 10% to 30%, Ti: 0.005% to 0.5%, Al: 0.01% to 0.15%, N: 0.005% to 0.03%, and the balance of Fe and inevitable impurities, wherein in the casting of the molten steel, the slab is cooled at an average cooling rate of 5°C/sec or less and excluding 0°C/sec within a temperature range of 1000°C to 1250°C based on a surface temperature of the slab.

**[0015]** In the casting of the molten steel, the slab may be cooled at an average cooling rate of 5°C/sec or less and excluding 0°C/sec within a temperature range of 1100°C to 1200°C based on the surface temperature of the slab.

**[0016]** After the casting of the molten steel, the method may further include: obtaining a hot-rolled sheet by performing a hot rolling process on the slab; and performing a hot band annealing process on the hot-rolled sheet within a temperature range of 450°C to 1080°C for 60 minutes or less.

[Advantageous Effects]

**[0017]** The ferritic stainless steel of the present disclosure has a high degree of ductility.

[Description of Drawings]

**[0018]**

FIG. 1 is a scanning electron microscope (SEM) image illustrating the microstructure of a hot-rolled sheet of Inventive Example 1.

FIG. 2 is a high magnification SEM image illustrating region A in FIG. 1.

[Best Mode]

**[0019]** The inventors have reviewed various factors to improve the ductility of ferritic stainless steel and have acquired the following knowledge.

(1) In general, a small amount of titanium (Ti) is added to ferritic stainless steel to improve the corrosion resistance of the ferritic stainless steel. In this case, however, a large amount of Ti(CN) inevitably precipitates in the ferrite matrix of Ti-containing ferritic stainless steel, and the Ti(CN) precipitate becomes the main cause of ductility deterioration.

(2) The Ti(CN) precipitate includes a Ti(CN) precipitate independently formed in the ferrite matrix (hereinafter referred to as an "independent Ti(CN) precipitate") and a Ti(CN) precipitate formed with the help of particles of a TiN inclusion that are crystallized during a steel making process and function as precipitation nuclei (hereinafter referred to as a "dependent Ti(CN) precipitate"). The dependent Ti(CN) precipitate does not have a significant effect on ductility deterioration when compared to the independent Ti(CN) precipitate.

(3) Therefore, if a large amount of Ti(CN) precipitates in the form of a dependent Ti(CN) precipitate with the help of TiN inclusion particles functioning as precipitation nuclei, the amount of independent Ti(CN) precipitate particles may decrease. In this manner, the ductility of Ti-containing ferritic stainless steel may be improved.

**[0020]** Hereinafter, ferritic stainless steel having a high degree of ductility will be described in detail according to an aspect of the present disclosure.

**[0021]** First, the composition of the ferritic stainless steel of the present disclosure will be described in detail. In the following description, the contents of elements are given in wt% unless otherwise mentioned.

Carbon (C): 0.005% to 0.1%

**[0022]** Since carbon (C) markedly affects the strength of steel, if the content of carbon (C) in steel is excessively high, the strength of the steel may increase to an excessive degree, and the ductility of the steel may decrease. Therefore, the content of carbon (C) is limited to 0.1% or less. However, if the content of carbon (C) is excessively low, the strength of steel decreases too much. Therefore, the lower limit of the content of carbon (C) is limited to 0.005%.

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Silicon (Si): 0.01% to 2.0%

**[0023]** Silicon (Si) is an element added to molten steel during a steel making process to remove oxygen and stabilize ferrite. In the present disclosure, silicon (Si) is added in an amount of 0.01% or greater. However, if the content of silicon (Si) in steel is excessively high, the ductility of the steel may decrease due to hardening. Therefore, the content of silicon (Si) is limited to 2.0% or less.

Mn (Manganese): 0.01% to 1.5%

**[0024]** Manganese (Mn) is an element effective in improving the corrosion resistance of steel. In the present disclosure, manganese (Mn) is added in an amount of 0.01% or greater, more preferably, 0.5% or greater. However, if the content of manganese (Mn) in steel is excessively high, the generation of Mn-containing fumes markedly increases during a welding process, and thus the weldability of the steel decreases. In addition, an MnS precipitate may be excessively formed to result in a decrease in the ductility of the steel. Therefore, the content of manganese (Mn) is limited to 1.5% or less, more preferably 1.0% or less.

Phosphorus (P): 0.05% or less

**[0025]** Phosphorus (P) is an impurity inevitably included in steel, causing grain boundary corrosion during a pickling process and deteriorating the hot formability of the steel. Therefore, the content of phosphorus (P) is adjusted as low as possible. In the present disclosure, the upper limit of the content of phosphorus (P) is set to 0.05%.

Sulfur (S): 0.005% or less

**[0026]** Sulfur (S), an impurity inevitably included in steel, segregates along grain boundaries of the steel and deteriorates the hot formability of the steel. Therefore, the content of sulfur (S) is adjusted as low as possible. In the present disclosure, the upper limit of the content of sulfur (S) is set to be 0.005%.

Chromium (Cr): 10% to 30%

**[0027]** Chromium (Cr) is effective in increasing the corrosion resistance of steel. In the present disclosure, chromium (Cr) is added in an amount of 10% or greater. However, if the content of chromium (Cr) is excessively high, manufacturing costs increase markedly, and grain boundary corrosion occurs. Therefore, the content of chromium (Cr) is limited to 30% or less.

Titanium (Ti): 0.05% to 0.50%

**[0028]** Titanium (Ti) fixes carbon (C) and nitrogen (N), thereby decreasing the amounts of carbon (C) and nitrogen (N) dissolved in steel. In addition, titanium (Ti) is effective in improving the corrosion resistance of steel. In the present disclosure, titanium (Ti) is added in an amount of 0.05% or greater, more preferably 0.1% or greater. However, if the content of titanium (Ti) is excessively high, manufacturing costs increase markedly, and Ti-containing inclusions are formed causing surface defects. Therefore, the content of titanium (Ti) is limited to 0.50% or less, more preferably 0.30% or less.

Aluminum (Al): 0.01% to 0.15%

**[0029]** Aluminum (Al) is a powerful deoxidizer used to decrease the oxygen content of molten steel. In the present disclosure, aluminum (Al) is added in an amount of 0.01% or greater. However, if the content of aluminum (Al) is excessively high, nonmetallic inclusions increase, causing defects in sleeves of cold-rolled strips and deteriorating the weldability of steel. Therefore, the content of aluminum (Al) is limited to 0.15% or less, more preferably 0.1% or less.

Nitrogen (N): 0.005% to 0.03%

**[0030]** Nitrogen (N) is an element facilitating recrystallization by precipitating austenite during a hot rolling process. In the present disclosure, nitrogen (N) is added in an amount of 0.005% or greater. However, if the content of nitrogen (N) in steel is excessively high, the ductility of the steel decreases. Therefore, the content of nitrogen (N) is limited to 0.03% or less.

**[0031]** The ferritic stainless steel of the present disclosure includes  $3.5 \times 10^6$  or fewer independent Ti(CN) precipitate

particles per square millimeter ( $\text{mm}^2$ ) of ferrite matrix. As described above, the Ti(CN) precipitate includes an independent Ti(CN) precipitate and a dependent Ti(CN) precipitate formed using TiN inclusion particles as precipitation nuclei. The dependent Ti(CN) precipitate does not have a significant effect on ductility deterioration when compared to the independent Ti(CN) precipitate. Therefore, only the number of independent Ti(CN) precipitate particles is controlled in the present disclosure. If the number of independent Ti(CN) precipitate particles is outside the above-mentioned range, it is difficult to obtain a desired degree of ductility.

**[0032]** As described above, a method of reducing the number of independent Ti(CN) precipitate particles is to increase the amount of Ti(CN) precipitating using TiN inclusion particles as precipitation nuclei. According to the present disclosure, a desired degree of ductility is obtained by adjusting P defined by Formula 1 below within the range of 60% or less.

[Formula 1]

$$P(\%) = \{N_S / (N_S + N_C)\} \times 100$$

where  $N_S$  refers to the number of independent Ti(CN) precipitate particles per unit area ( $\text{mm}^2$ ), and  $N_C$  refers to the number of dependent Ti(CN) precipitate particles per unit area ( $\text{mm}^2$ ).

**[0033]** In the present disclosure, the independent Ti(CN) precipitate being the subject of control is limited to having a particle diameter of  $0.01 \mu\text{m}$  or greater. Since there is a limit to analyzing and quantifying independent Ti(CN) precipitate having a particle diameter of less than  $0.01 \mu\text{m}$ , special consideration may not be given thereto. The upper limit of the particle diameter of the independent Ti(CN) precipitate may not be specifically set. However, since it is difficult to form an independent Ti(CN) precipitate having a particle diameter of  $2 \mu\text{m}$  or greater, the upper limit of the particle diameter of the independent Ti(CN) precipitate may be set to be  $2 \mu\text{m}$ .

**[0034]** It may be preferable that the independent Ti(CN) precipitate have an average particle diameter of  $0.15 \mu\text{m}$  or less. If the average particle diameter of the independent Ti(CN) precipitate is greater than  $0.15 \mu\text{m}$ , surface defects may be formed even though the number of independent Ti(CN) precipitate particles is small. The term "average particle diameter" refers to the average of equivalent circular diameters of particles measured by observing a cross-section of steel.

**[0035]** In addition, it may be preferable that the average particle diameter of a TiN inclusion be within the range of  $2 \mu\text{m}$  or greater. The reason for this is that a relatively coarse TiN inclusion having an average particle diameter of  $2 \mu\text{m}$  or greater forms nucleus forming sites more efficiently, and thus facilitates the precipitation of Ti(CN). The upper limit of the average particle diameter of the TiN inclusion is not limited. However, if the TiN inclusion is excessively coarse, the total surface area of the TiN inclusion may be excessively small, and thus it may be difficult to increase the number of dependent Ti(CN) precipitate particles. Therefore, the upper limit of the average particle diameter of the TiN inclusion may be set to be  $20 \mu\text{m}$ .

**[0036]** The ferritic stainless steel of the present disclosure has a high degree of ductility. According to an exemplary embodiment of the present disclosure, the ferritic stainless steel may have an elongation of 34% or greater.

**[0037]** The ferritic stainless steel of the present disclosure is manufactured as follows.

**[0038]** Hereinafter, a method for manufacturing ferritic stainless steel having a high degree of ductility will be described in detail according to an aspect of the present disclosure.

**[0039]** According to the aspect of the present disclosure, the method for manufacturing ferritic stainless steel includes casting molten steel having the above-described composition as a slab. One of the technical features of the method is to maximally restrict the formation of an independent Ti(CN) precipitate by facilitating the diffusion of titanium (Ti), carbon (C), and nitrogen (N), and thus inducing the formation of a dependent Ti(CN) precipitate with the help of TiN inclusion particles functioning as precipitation nuclei.

**[0040]** In general, a slab produced by casting molten steel is subjected to a cooling process to improve productivity. However, according to the research conducted by the inventors, if a slab is cooled at a normal cooling rate, relatively fine TiN inclusion particles are formed in the slab, and Ti(CN) precipitates randomly in the slab, thereby markedly increasing the number of independent Ti(CN) precipitate particles. The reason for this is speculated as follows: relatively rapid cooling of the slab limits the diffusion of alloying elements in the slab, and sufficient nucleus forming energy facilitates the formation of nuclei of a TiN inclusion and a Ti(CN) precipitate simultaneously across the slab.

**[0041]** However, according to the present disclosure, after the molten steel is cast as a slab, the slab is cooled within the temperature range of  $1100^\circ\text{C}$  to  $1200^\circ\text{C}$  based on the surface temperature of the slab at an average cooling rate of  $5^\circ\text{C}/\text{sec}$  or less (excluding  $0^\circ\text{C}/\text{sec}$ ), preferably  $3^\circ\text{C}/\text{sec}$  or less (excluding  $0^\circ\text{C}/\text{sec}$ ), more preferably  $2^\circ\text{C}/\text{sec}$  (excluding  $0^\circ\text{C}/\text{sec}$ ). That is, the inventors have tried to precipitate as much Ti(CN) as possible using TiN inclusion particles as precipitation nuclei by properly controlling the average cooling rate of a slab within the temperature range of  $1100^\circ\text{C}$  to  $1200^\circ\text{C}$ , and thus to decrease the number of independent Ti(CN) precipitate particles. The inventors have found that if a slab is cooled under the conditions described above, the number of independent Ti(CN) precipitate particles is reduced to a target value or less. The reason for this may be that since slow cooling guarantees a sufficient time period for alloying

elements to move, large amounts of Ti, C, and N diffuse toward TiN inclusion particles and precipitate in the form of Ti(CN) using the TiN inclusion particles as precipitation nuclei. In the present disclosure, the average cooling rate of the slab may be controlled using any method or apparatus. For example, a heat insulating material may be disposed around a cast strand.

**[0042]** As described above, the method of controlling the average cooling rate of the slab is not limited. For example, the slab may be cooled slowly at a constant cooling rate within the above-mentioned temperature range, or the slab may be cooled at a relatively high cooling rate after the slab is constantly maintained at a particular temperature within the temperature range.

**[0043]** The temperature range within which the slab is slowly cooled is widened to a range of 1000°C to 1250°C to induce the formation of a coarse TiN inclusion and enable the coarse TiN inclusion to function as nucleus forming sites more effectively for the precipitation of Ti(CN).

**[0044]** According to an exemplary embodiment of the present disclosure, the method may further include: forming a hot-rolled sheet by performing a finish hot rolling process on the slab; and performing a hot band annealing process on the hot-rolled sheet. These processes will now be described in detail.

**[0045]** Hot band annealing process: perform within the range of 450°C to 1080°C for 60 minutes or less.

**[0046]** The hot band annealing process is performed to improve the ductility of the hot-rolled sheet. Owing to the hot band annealing process, the independent Ti(CN) precipitate may be dissolved again, and dissolved alloying elements may be diffused, thereby further decreasing the number of independent Ti(CN) precipitate particles. To this end, the hot band annealing process may be performed at a temperature of 450°C or higher. However, if the temperature of the hot band annealing process is higher than 1080°C, or the duration of the band annealing process is longer than 60 minutes, the dependent Ti(CN) precipitate may be dissolved again, and thus the above-mentioned effects may be decreased. The lower limit of the duration of the band annealing process is not limited. For example, it may be preferable that the band annealing process be performed for 1 minute or longer to obtain sufficient effects.

**[0047]** As long as the above-mentioned manufacturing conditions for the ferritic stainless steel are controlled as described above, other conditions may be controlled according to manufacturing conditions for normal ferritic stainless steel. In addition, the annealed hot-rolled sheet may be subjected to a cold rolling process and a cold rolled sheet annealing process to produce a cold-rolled steel sheet.

**[0048]** Hereinafter, aspects of the present disclosure will be described more specifically according to examples. However, the following examples should be considered in a descriptive sense only and not for purpose of limitation. The scope of the present invention is defined by the appended claims, and modifications and variations reasonably made therefrom.

[Mode for Invention]

**[0049]** Molten steels having the compositions shown in Table 1 were prepared and were cast at a constant speed under the conditions shown in Table 2 in order to produce slabs. The slabs were subjected to a hot rolling process and a hot band annealing process to obtain hot-rolled sheets. In Table 1, the contents of elements are given in wt%, and in Table 2, the slab cooling rate is an average cooling rate measured based on the surface temperature of a slab within the temperature range of 1100°C to 1200°C.

[Table 1]

| Steel | C     | Si   | Mn   | P     | S     | Cr   | Ti   | Al    | N     |
|-------|-------|------|------|-------|-------|------|------|-------|-------|
| A     | 0.012 | 0.25 | 0.16 | 0.031 | 0.003 | 11.0 | 0.15 | 0.040 | 0.012 |
| B     | 0.015 | 0.35 | 0.8  | 0.025 | 0.002 | 12.0 | 0.21 | 0.032 | 0.015 |

[Table 2]

| Steel | Slab Cooling Rate (°C/sec) within the Temperature Range of 1100°C to 1200°C | Hot Band Annealing Temperature (°C) | Hot Band Annealing Time (min) | Notes               |
|-------|-----------------------------------------------------------------------------|-------------------------------------|-------------------------------|---------------------|
| A     | 2                                                                           | 600                                 | 30                            | Inventive Example 1 |
| A     | 2                                                                           | 800                                 | 15                            | Inventive Example 2 |

(continued)

| Steel | Slab Cooling Rate (°C/sec) within the Temperature Range of 1100°C to 1200°C | Hot Band Annealing Temperature (°C) | Hot Band Annealing Time (min) | Notes                 |
|-------|-----------------------------------------------------------------------------|-------------------------------------|-------------------------------|-----------------------|
| A     | 6                                                                           | 800                                 | 15                            | Comparative Example 1 |
| B     | 1                                                                           | 900                                 | 15                            | Inventive Example 3   |
| B     | 6                                                                           | 900                                 | 15                            | Comparative Example 2 |

Thereafter, the hot-rolled sheets were photographed using a transmission electron microscope (TEM), and the number and ratio (P) of independent Ti(CN) precipitate particles having a particle diameter of 0.01  $\mu\text{m}$  or greater were measured using an image analyzer. In addition, samples were taken from the hot-rolled sheets based on a direction making an angle of 90° with the rolling direction of the hot-rolled sheets according to JIS 13B, and the elongation of the samples was measured. Results of the measurements are shown in Table 3.

[Table 3]

| Steel | Number of Independent Ti(CN) Precipitate Particles per Millimeters ( $\text{mm}^2$ ) | P (%) | Elongation (%) | Notes                 |
|-------|--------------------------------------------------------------------------------------|-------|----------------|-----------------------|
| A     | $3.1 \times 10^6$                                                                    | 56    | 37             | Inventive Example 1   |
| A     | $2.9 \times 10^6$                                                                    | 42    | 37             | Inventive Example 2   |
| A     | $8.9 \times 10^6$                                                                    | 88    | 30             | Comparative Example 1 |
| B     | $2.2 \times 10^6$                                                                    | 58    | 39             | Inventive Example 3   |
| B     | $6.5 \times 10^6$                                                                    | 79    | 32             | Comparative Example 2 |

Referring to Table 3, Samples of Inventive Examples 1 to 3 satisfying the conditions proposed in the present disclosure had  $3.5 \times 10^6$  or fewer independent Ti(CN) precipitate particles per square millimeter ( $\text{mm}^2$ ) and thus had an elongation of 34% or greater. However, each sample of Comparative Examples 1 and 2 had an excessive number of independent Ti(CN) precipitate particles because the slab cooling rate was relatively high, and thus the ductility of the samples of Comparative Examples 1 and 2 were poor.

FIG. 1 is a scanning electron microscope (SEM) image illustrating the microstructure of a hot-rolled sheet of Inventive Example 1, and FIG. 2 is a higher magnification SEM image illustrating region A in FIG. 1. A particle shown in the center of region A in FIG. 1 corresponds to a TiN inclusion particle crystallized during a steel making process. Referring to FIG. 2 illustrating region A on an enlarged scale, a large amount of Ti(CN) has precipitated on the TiN inclusion particle functioning as a precipitation nucleus.

## Claims

- Ferritic stainless steel comprising, by wt%, C: 0.005% to 0.1%, Si: 0.01% to 2.0%, Mn: 0.01% to 1.5%, P: 0.05% or less, S: 0.005% or less, Cr: 10% to 30%, Ti: 0.005% to 0.5%, Al: 0.01% to 0.15%, N: 0.005% to 0.03%, and the balance of Fe and inevitable impurities, wherein the ferritic stainless steel comprises an independent Ti(CN) precipitate and a dependent Ti(CN) precipitate formed using a TiN inclusion as precipitation nuclei, and the ferritic stainless steel has a P within a range of 60% or less, the P being defined by Formula 1 below:

[Formula 1]

$$P(\%) = \{N_s / (N_s + N_c)\} \times 100$$

where  $N_s$  refers to the number of independent Ti(CN) precipitate particles per unit area ( $\text{mm}^2$ ), and  $N_c$  refers to the number of dependent Ti(CN) precipitate particles per unit area ( $\text{mm}^2$ ), and wherein the ferritic stainless steel comprises  $3.5 \times 10^6$  or fewer particles of the independent Ti(CN) precipitate per square millimeter ( $\text{mm}^2$ ) of ferrite matrix, wherein the independent Ti(CN) precipitate has a particle diameter of  $0.01 \mu\text{m}$  or greater, and wherein the particle diameter of the independent Ti(CN) precipitate is measured by Transmission Electron Microscopy (TEM).

2. The ferritic stainless steel of claim 1, wherein the P is 58% or less.

3. The ferritic stainless steel of claim 1, wherein the independent Ti(CN) precipitate has an average particle diameter of  $0.15 \mu\text{m}$  or less, and wherein the average particle diameter of the independent Ti(CN) precipitate is measured by Transmission Electron Microscopy (TEM).

4. The ferritic stainless steel of claim 1, wherein the TiN inclusion has an average particle diameter of  $2 \mu\text{m}$  or greater, and wherein the average particle diameter of the TiN inclusion is measured by Transmission Electron Microscopy (TEM).

5. The ferritic stainless steel of claim 1, wherein the ferritic stainless steel has an elongation of 34% or greater.

6. A method for manufacturing ferritic stainless steel according to Claim 1, the method comprising casting molten steel as a slab, the molten steel comprising, by wt%, C: 0.005% to 0.1%, Si: 0.01% to 2.0%, Mn: 0.01% to 1.5%, P: 0.05% or less, S: 0.005% or less, Cr: 10% to 30%, Ti: 0.005% to 0.5%, Al: 0.01% to 0.15%, N: 0.005% to 0.03%, and the balance of Fe and inevitable impurities, wherein in the casting of the molten steel, the slab is cooled at an average cooling rate of  $5^\circ\text{C}/\text{sec}$  or less and excluding  $0^\circ\text{C}/\text{sec}$  within a temperature range of  $1000^\circ\text{C}$  to  $1250^\circ\text{C}$  based on a surface temperature of the slab.

7. The method of claim 6, wherein in the casting of the molten steel, the slab is cooled at an average cooling rate of  $5^\circ\text{C}/\text{sec}$  or less and excluding  $0^\circ\text{C}/\text{sec}$  within a temperature range of  $1100^\circ\text{C}$  to  $1200^\circ\text{C}$  based on the surface temperature of the slab.

8. The method of claim 6, wherein after the casting of the molten steel, the method further comprises:

reheating the slab;  
obtaining hot-rolled steel by performing a hot rolling process on the reheated slab; and  
performing a hot band annealing process on the hot-rolled steel within a temperature range of  $450^\circ\text{C}$  to  $1080^\circ\text{C}$  for 60 minutes or less.

## Patentansprüche

1. Ferritischer rostfreier Stahl, umfassend in Gew.-%: C: 0,005 % bis 0,1 %, Si: 0,01 % bis 2,0 %, Mn: 0,01 % bis 1,5 %, P: höchstens 0,05 %, S: höchstens 0,005 %, Cr: 10 % bis 30 %, Ti: 0,005 % bis 0,5 %, Al: 0,01 % bis 0,15 %, N: 0,005 % bis 0,03 % und den Rest aus Fe und unvermeidlichen Verunreinigungen, wobei der ferritische rostfreie Stahl einen unabhängigen Ti(CN)-Niederschlag und einen abhängigen Ti(CN)-Niederschlag, der unter Verwendung eines TiN-Einschlusses als Fällungskerne ausgebildet wird, umfasst und der ferritische rostfreie Stahl einen P-Wert innerhalb eines Bereichs von höchstens 60 % aufweist, wobei der P-Wert durch die nachstehende Formel 1 definiert ist:

[Formel 1]

$$P(\%) = \{N_s / (N_s + N_c)\} \times 100$$

wobei  $N_s$  sich auf die Anzahl unabhängiger Ti(CN)-Niederschlagsteilchen pro Flächeneinheit ( $\text{mm}^2$ ) bezieht und  $N_c$  sich auf die Anzahl abhängiger Ti(CN)-Niederschlagsteilchen pro Flächeneinheit ( $\text{mm}^2$ ) bezieht und wobei der ferritische rostfreie Stahl  $3,5 \times 10^6$  oder weniger Teilchen des unabhängigen Ti(CN)-Niederschlags pro Quadratmillimeter ( $\text{mm}^2$ ) Ferritmatrix umfasst, wobei der unabhängige Ti(CN)-Niederschlag einen Teilchendurchmesser von  $0,01 \mu\text{m}$  oder größer aufweist und wobei der Teilchendurchmesser des unabhängigen Ti(CN)-Niederschlags durch

Transmissionselektronenmikroskopie (TEM) gemessen wird.

2. Ferritischer rostfreier Stahl nach Anspruch 1, wobei der P-Wert bei höchstens 58 % liegt.

3. Ferritischer rostfreier Stahl nach Anspruch 1, wobei der unabhängige Ti(CN)-Niederschlag einen durchschnittlichen Teilchendurchmesser von höchstens 0,15 µm aufweist, und wobei der durchschnittliche Teilchendurchmesser des unabhängigen Ti(CN)-Niederschlags durch Transmissionselektronenmikroskopie (TEM) gemessen wird.

4. Ferritischer rostfreier Stahl nach Anspruch 1, wobei der TiN-Einschluss einen durchschnittlichen Teilchendurchmesser von 2 µm oder größer aufweist und wobei der durchschnittliche Teilchendurchmesser des TiN-Einschlusses durch Transmissionselektronenmikroskopie (TEM) gemessen wird.

5. Ferritischer rostfreier Stahl nach Anspruch 1, wobei der ferritische rostfreie Stahl eine Ausdehnung von 34 % oder mehr aufweist.

6. Verfahren zum Herstellen ferritischen rostfreien Stahls nach Anspruch 1, wobei das Verfahren ein Gießen von geschmolzenem Stahl als eine Bramme umfasst, wobei der geschmolzene Stahl in Gew.-% Folgendes umfasst: C: 0,005 % bis 0,1 %, Si: 0,01 % bis 2,0 %, Mn: 0,01 % bis 1,5 %, P: höchstens 0,05 %, S: höchstens 0,005 %, Cr: 10 % bis 30 %, Ti: 0,005 % bis 0,5 %, Al: 0,01 % bis 0,15 %, N: 0,005 % bis 0,03 % und den Rest aus Fe und unvermeidbaren Verunreinigungen, wobei bei dem Gießen des geschmolzenen Stahls, die Bramme mit einer mittleren Abkühlungsgeschwindigkeit von höchstens 5 °C/Sek. und ausschließlich 0 °C/Sek. innerhalb eines Temperaturbereichs von 1000 °C bis 1250 °C basierend auf einer Oberflächentemperatur der Bramme abgekühlt wird.

7. Verfahren nach Anspruch 6, wobei bei dem Gießen des geschmolzenen Stahls die Bramme mit einer durchschnittlichen Abkühlungsgeschwindigkeit von höchstens 5 °C und ausschließlich 0 °C/Sek. innerhalb eines Temperaturbereichs von 1100 °C bis 1200 °C basierend auf der Oberflächentemperatur der Bramme abgekühlt wird.

8. Verfahren nach Anspruch 6, wobei nach dem Gießen des geschmolzenen Stahls das Verfahren ferner Folgendes umfasst:

Anlassen der Bramme;

Erhalten von warmgewalztem Stahl durch Durchführen eines Warmwalzenvorgangs auf der angelassenen Bramme; und

Durchführen eines Warmbandglühungsvorgangs auf dem warmgewalzten Stahl innerhalb eines Temperaturbereichs von 450 °C bis 1080 °C für höchstens 60 Minuten.

## Revendications

1. Acier inoxydable ferritique comprenant, en % en poids, C : 0,005 % à 0,1 %, Si : 0,01 % à 2,0 %, Mn : 0,01 % à 1,5 %, P : 0,05 % ou inférieur, S : 0,005 % ou inférieur, Cr : 10% à 30 %, Ti : 0,005 % à 0,5 %, Al : 0,01 % à 0,15 %, N : 0,005 % à 0,03 %, et le reste en Fe et impuretés inévitables, l'acier inoxydable ferritique comprenant un précipité indépendant Ti(CN) et un précipité dépendant Ti(CN) formés à l'aide d'une inclusion TiN en tant que noyaux de précipitation, et un acier inoxydable ferritique ayant un P dans une plage de 60 % ou moins, le P étant défini par la formule 1 ci-dessous :

[Formule 1]

$$P(\%) = \{Ns / (Ns + Nc)\} \times 100$$

où Ns désigne le nombre de particules de précipité Ti(CN) indépendantes par unité de surface (mm<sup>2</sup>) et Nc désigne le nombre de particules de précipité Ti(CN) dépendantes par unité de surface (mm<sup>2</sup>), et l'acier inoxydable ferritique comprenant 3,5 x 10<sup>6</sup> particules, ou inférieur, du précipité Ti(CN) indépendant par millimètre carré (mm<sup>2</sup>) de matrice de ferrite, le précipité Ti(CN) indépendant ayant un diamètre de particules de 0,01 µm ou supérieur, et le diamètre de particule du précipité Ti(CN) indépendant étant mesuré par microscopie électronique à transmission (TEM).

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2. Acier inoxydable ferritique selon la revendication 1, dans lequel le P est de 58 % ou inférieur.
3. Acier inoxydable ferritique selon la revendication 1, dans lequel le précipité indépendant de Ti(CN) a un diamètre de particule moyen de 0,15  $\mu\text{m}$  ou supérieur, et le diamètre de particule moyen du précipité indépendant de Ti(CN) establt mesuré par microscopie électronique à transmission (TEM).
4. Acier inoxydable ferritique selon la revendication 1, dans lequel l'inclusion TiN a un diamètre de particule moyen de 2  $\mu\text{m}$  ou supérieur, et le diamètre de particule moyen de l'inclusion TiN étant mesuré par microscopie électronique à transmission (TEM).
5. Acier inoxydable ferritique selon la revendication 1, dans lequel l'acier inoxydable ferritique a un allongement de 34 % ou supérieur.
6. Procédé de fabrication d'acier inoxydable ferritique selon la revendication 1, le procédé comprenant le moulage d'acier en fusion sous forme de brame, l'acier en fusion comprenant, en % en poids, C : 0,005 % à 0,1 %, Si : 0,01 % à 2,0 %, Mn : 0,01 % à 1,5 %, P : 0,05 % ou inférieur, S : 0,005 % ou inférieur, Cr : 10 % à 30 %, Ti : 0,005 % à 0,5 %, Al : 0,01 % à 0,15 %, N : 0,005 % à 0,03 %, et le reste en Fe et impuretés inévitables, au cours du moulage de l'acier en fusion, la brame étant refroidie à une vitesse de refroidissement moyenne égale ou inférieure à 5 °C/sec, et excluant 0 °C/sec dans une plage de température de 1 000 °C à 1 250 °C sur la base de la température de surface de la brame.
7. Procédé selon la revendication 6, dans lequel au cours du moulage de l'acier en fusion, la brame est refroidie à une vitesse de refroidissement moyenne égale ou inférieure à 5 °C, en excluant 0 °C/sec dans une plage de température de 1 100 °C à 1 200 °C sur la base de la température de surface de la brame.
8. Procédé selon la revendication 6, dans lequel après le moulage de l'acier en fusion, le procédé comprenant en outre :
  - le réchauffement de la brame ;
  - l'obtention de l'acier laminé à chaud par laminage à chaud sur la brame réchauffée ; et
  - l'exécution d'un processus de recuit à bande chaude sur l'acier laminé à chaud dans une plage de température de 450 °C à 1 080 °C pendant 60 minutes ou moins.

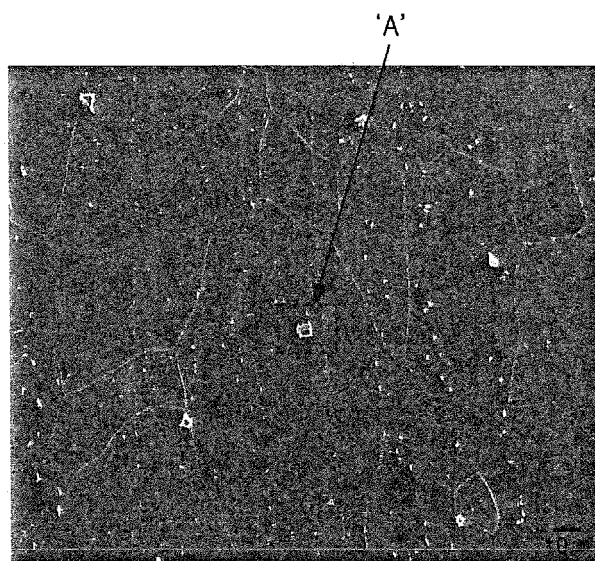
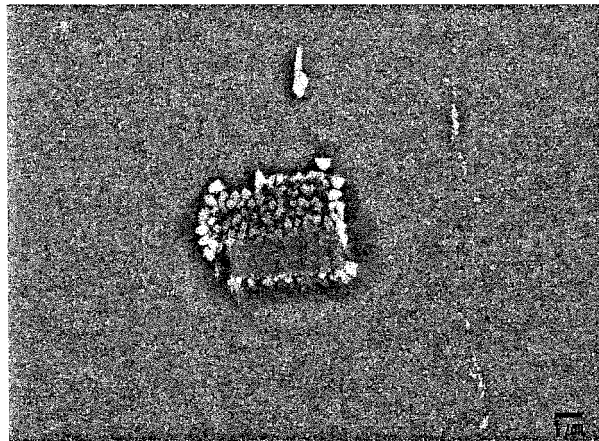


FIG. 1



'A'

FIG. 2

**REFERENCES CITED IN THE DESCRIPTION**

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