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(54) **High corrosion-resistant, high-strength and non-magnetic stainless steel**

Hoch korrosionsbeständiger, hochfester und nichtmagnetischer Edelstahl

Acier inoxydable non magnétique à haute résistance à la corrosion

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(73) Proprietor: **Daido Tokushuko Kabushiki Kaisha**
Higashi-ku
Nagoya
Aichi (JP)

(72) Inventors:
• **Ishikawa, Koichi**
Nagoya-shi
Aichi 457-8545 (JP)
• **Ueta, Shigeki**
Nagoya-shi
Aichi 457-8545 (JP)

(74) Representative: **Diehl & Partner GbR**
Patentanwälte
Erika-Mann-Strasse 9
80636 München (DE)

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Description

FIELD OF THE INVENTION

[0001] The present invention relates to a high corrosion-resistant, high-strength and non-magnetic stainless steel, and makes reference upon a high-strength, high corrosion-resistant and non-magnetic stainless steel product and a method for producing the same. More particularly, the discussion therein relates to a technique for producing a non-magnetic stainless steel which is capable of blocking the influence of earth magnetism and is particularly suitable for the use in oil well excavation, without impairing its characteristics (high corrosion resistance and high strength).

BACKGROUND OF THE INVENTION

[0002] Conventionally, when an oil well is excavated using a drill, a position (for example, direction and inclination) of a tip of the drill from the earth's surface is identified by magnetic sensing to control the drill. Accordingly, a measuring instrument is mounted in a drill collar in the vicinity of a bit. In that case, for measuring the direction and inclination, the drill collar and the like are required to be made of a non-magnetic steel, in order to block the influence of earth magnetism. Conventionally, as steels for such a use, there have been used high Mn-based non-magnetic stainless steels such as 13Cr-18Mn-0.5Mo-2Ni-0.3N, 13Cr-21Mn-0.3N and 16.5Cr-16Mn-1Mo-1.3Ni-0.5Cu-0.4N.

[0003] Further, as well-known improved techniques of this kind, there have been proposed, for example, techniques described in the following patent documents.

Patent document 1 (JP-A-53-117618) discloses a high-strength austenitic stainless steel containing C: 0.15% or less, Si: 0.1 to 2.0%, Mn: 7.0 to 18%, Ni: 0.50 to 6.0%, Cr: 15.0 to less than 21.0%, Mo: 0.5 to 4.0%, N: 0.20 to 0.60% and the balance composed of Fe and impurities, which is for the use to a body of rotation of a centrifuge or the like.

[0004] Patent document 2 (JP-A-59-104455) discloses a ultra-low temperature high-strength steel excellent in rust resistance, which contains C: 0.01 to 0.20 wt%, Si: 0.05 to 1.5 wt%, Mn: 16 to 27 wt%, Cr: 10 to 20 wt%, Cu: 0.1 to 4 wt%, N: 0.10 to 0.50 wt%, Al: 0.003 to 0.20 wt% and the balance composed of Fe and unavoidable impurities, which is for the use to a holding material of a superconductive electromagnet or a superconductor, or the like.

[0005] Patent document 3 (JP-A-59-205452) discloses a high-strength member for an instrument loaded on an undersea research ship, which contains C: 0.15% or less, Si: 0.1 to 2.0%, Mn: 7.0 to 18.0%, Ni: 0.50 to 6.0%, Cr: 15.0 to 26.0%, Mo: 0.5 to 4.0%, N: 0.2 to 0.6% and the balance substantially composed of Fe, and is subjected to hot working at a rolling reduction of 50% or more, wherein the finishing temperature of the hot working is from 800 to 1,000°C.

[0006] Patent document 4 (JP-A-61-143563) discloses a rust-resistant, ultra-low temperature high manganese high-strength steel containing C: 0.20% or less, Si: 0.05 to 2.5%, Mn: 16 to 35%, Cr: 10 to 20%, Ni: 0.1 to 8.0%, N: 0.10 to 0.50%, Al: 0.001 to 0.20%, S: 0.003% or less and the balance composed of Fe and unavoidable impurities, which is for the use to a holding material of a superconductive electromagnet or a superconductor, or the like.

[0007] Patent document 5 (JP-A-61-170545) discloses an ultra-low temperature high manganese steel excellent in rust resistance, which contains C: 0.20% or less, Si: 0.05 to 2.5%, Mn: 9 to 35%, Cr: 10 to 20%, Ni: 0.1 to 8.0%, N: 0.001 to 0.50%, Al: 0.001 to 0.20%, Ca: 0.001 to 0.020% and the balance composed of Fe and unavoidable impurities, for the use to a structure used in a fusion experimental reactor using a superconductive electromagnet, or the like.

[0008] Patent document 6 (JP-A-61-238943) discloses a high-strength non-magnetic stainless steel excellent in rust resistance, which contains C: 0.01 to 0.15 wt%, Si: 0.05 to 0.60 wt%, Mn: 16 to 25 wt%, S: 0.010 wt% or less, Ni: 4.0 wt% or less, Cr: 14 to 20 wt%, N: 0.3 to 0.6 wt%, O: 0.01 wt% or less, Al: 0.001 to 0.20 wt% and the balance composed of Fe and unavoidable impurities, and contains non-metallic inclusions in an area ratio of 0.10% or less, which is for the use to a precision equipment part (a micromotor shaft, a magnetic tape guide, a shaft or the like) that is required to avoid magnetism.

[0009] Patent document 7 (JP-A-2004-052097) discloses an interdental brush wire containing, by mass, C: 0.07% or less, Si: 0.6% or less, Mn: 13 to 17%, Ni: 2.0 to 5.0%, Cr: 16.0 to 20.0%, Mo: 0.4 to 2.0%, N: 0.3 to 0.60% and Cu: 0.3 to 1.0%, which is for the use to the interdental brush wire.

[0010] Patent document 8 (JP-A-2004-156086) discloses a non-magnetic stainless steel containing C: 0.06% or less, Si: 0.40% or less, Mn: 15.5 to 17%, P: 0.040% or less, S: 0.010% or less, Cu: 0.35 to 2.00%, Ni: 2.50 to 4.00%, Cr: 17.0 to 21.0%, Mo+W: 0.5 to 1.5%, N: 0.42 to 0.65%, O: 0.01% or less, sol-Al: 0.05% or less, B: 0.001 to 0.010% and the balance substantially composed of Fe, which is for the use to a drill collar for oil well excavation.

[0011] As described above, a lot of stainless steels excellent in characteristics such as corrosion resistance and non-magnetism have been proposed.

[0012] However, the recent oil well excavation region is versatile, and further high-corrosion resistant and high-strength stainless steels based on the assumption of non-magnetism have been demanded by the industrial world. Furthermore, the various types of steels described in the above-mentioned patent documents 1 to 8 have many problems to be solved. For example, the high-strength austenitic stainless steel of patent document 1 and the high-strength member for an

instrument loaded on an undersea research ship of patent document 3 have a concern that workability and corrosion resistance are deteriorated by crystallization of coarse carbides due to their excessive C content.

The ultra-low temperature high-strength steel of patent document 2 and the rust-resistant, ultra-low temperature high manganese high-strength steel of patent document 4 have a concern that the required characteristics of non-magnetism, high strength and corrosion resistance are not satisfied due to their small N content. The ultra-low temperature high-strength steel of patent document 2 has a further concern that corrosion resistance is deteriorated due to its excessive Mn content.

[0013] The ultra-low temperature high manganese steel of patent document 5 has a concern that the required characteristics of non-magnetism, high strength and corrosion resistance are not satisfied, because the Cr content is rather small with respect to the Mn content, and the N content is also rather small.

In the high-strength non-magnetic stainless steel of patent document 6, the Ni and N contents are rather small. Further, in the interdental brush wire of patent document 7, Mn and Ni contents are excessively small. Moreover, in the non-magnetic stainless steel of patent document 8, the Ni and Mo contents are excessively small. Therefore, these alloys have a concern that the required characteristics of non-magnetism, high strength and corrosion resistance are not satisfied.

As described above, even according to patent documents 1 to 8, no stainless steel satisfying the required characteristics has been obtained.

[0014] International application WO 91/16469 A1 discloses an austenitic non-magnetic stainless steel wherein a relationship holds that $Ni+2xCu$ is at most $(Cr+Mo-14.6)/1.5$ and the content of Ni alone is at most 3.5% by weight.

SUMMARY OF THE INVENTION

[0015] The invention has been made in view of the above circumstances, and an object of the invention is to provide a high corrosion-resistant, high-strength and non-magnetic stainless steel having high corrosion resistance, high strength and non-magnetism. In particular, an object of the invention is to provide a high corrosion-resistant, high-strength and non-magnetic stainless steel which blocks the influence of earth magnetism at the time of oil well evacuation, and not only can be applied to oil well excavation products covering a wide range of regions, but also is suitable as raw materials for various parts (various spring products, VTR guide pins and motor shafts); a high corrosion-resistant, high-strength and non-magnetic stainless steel product and a method for producing the same.

[0016] In order to solve the above-mentioned problems, the present inventors have made intensive studies, centering on application of Cr and Mo as corrosion resistance-improving elements, for realizing high corrosion resistance. However, the inventors have encountered a problem that "non-magnetism which is capable of blocking the influence of earth magnetism" required for a drill collar and the like of oil well evacuation and the like cannot be achieved, because an increase in Cr content and Mo content causes magnetization. Then, the inventors have made further intensive studies. As a result, it has been found that when a composition balance is adjusted by making use of N and Ni, a stable non-magnetic austenite single-phase structure is obtained, even in the case where Cr and Mo are used to obtain high corrosion resistance.

The invention has been made based on such a finding.

[0017] Namely the present invention provides a high corrosion-resistant, high-strength and non-magnetic stainless steel containing: C: 0.01% to 0.05% by mass, Si: 0.05% to 0.50% by mass, Mn: more than 16.0% by mass but 19.0% by mass or less, P: 0.040% by mass or less, S: 0.010% by mass or less, Cu: 0.50% to 0.80% by mass, Ni: 3.5% to 5.0% by mass, Cr: 17.0% to 21.0% by mass, Mo: 1.80% to 3.50% by mass, B: 0.0010% to 0.0050% by mass, O: 0.010% by mass or less, and N: 0.45% to 0.65% by mass, with the balance substantially composed of Fe and unavoidable impurities, the steel satisfying the following equations (1) to (4):

$$[Cr] + 3.3 \times [Mo] + 16 \times [N] \geq 30 \quad (1)$$

$$[Cr]/[C] \geq 330 \quad (2)$$

$$[Cr]/[Mn] > 1.0 \quad (3)$$

$$([Ni] + 3 \times [Cu])/([Cr] + [Mo]) > 0.25 \quad (4)$$

wherein [Cr], [Mo], [N], [C], [Mn], [Ni] and [Cu] represent the content of Cr, the content of Mo, the content of N, the content of C, the content of Mn, the content of Ni, and the content of Cu in the steel in terms of mass %, respectively.

[0018] The high corrosion-resistant, high-strength and non-magnetic stainless steel according to the present invention may further contains at least one element selected from the group consisting of Ca, Mg and REM in a total content of 0.0001% to 0.0100% by mass.

The high corrosion-resistant, high-strength and non-magnetic stainless steel according to the present invention may further contains at least one element selected from the group consisting of Nb, V, Ta and Hf in a total content of 0.1 % to 2.0% by mass.

The high corrosion-resistant, high-strength and non-magnetic stainless steel according to the present invention may further contains A1 in a content of 0.001 % to 0.10% by mass.

The high corrosion-resistant, high-strength and non-magnetic stainless steel according to the present invention may further contains at least one member selected from the group consisting of W and Co in a total content of 0.1% to 3.0% by mass.

[0019] The present invention further discusses a method for producing a high corrosion-resistant, high-strength and non-magnetic stainless steel product, which includes subjecting the steel according to the present invention to working under a temperature condition of 300°C to 900°C at a reduction of area of 15% to 40%.

[0020] The present invention furthermore discusses a high corrosion-resistant, high-strength and non-magnetic stainless steel product obtained by subjecting the steel according to the present invention to working under a temperature condition of 300°C to 900°C at a reduction of area of 15% to 40%. Examples of the resulting steel product include oil well evacuation products, spring products, VTR guide pins, motor shafts and the like.

[0021] The high corrosion-resistant, high-strength and non-magnetic stainless steel according to the invention have the above-mentioned component composition and satisfies the above-mentioned equations (1) to (4), so that they have high corrosion resistance, high strength and non-magnetism. Accordingly, they has effects of being able to block the influence of earth magnetism at the time of oil well evacuation to be applied to oil well excavation products covering a wide range of regions, and moreover, being-suitable as raw materials for various parts (various spring products, VTR guide pins and motor shafts).

In accordance with the method for producing a high corrosion-resistant, high-strength and non-magnetic stainless steel product the resulting steel product can exhibit the same effects as described above.

BEST MODE FOR CARRYING OUT THE INVENTION

[0022] A high corrosion-resistant, high-strength and non-magnetic stainless steel according to one embodiment of the invention will be described below.

The high corrosion-resistant, high-strength and non-magnetic stainless steel according to this embodiment contains the following essential elements and selective elements and the balance substantially composed of Fe and unavoidable impurities, and satisfies relationship defined by equations (1) to (4) described later. Herein, in the present specification, all the percentages defined by mass are the same as those defined by weight, respectively.

(Component Composition of High-Corrosion Resistant, High-Strength and Non-Magnetic Stainless Steel, and Reason for Restriction Thereof)

[0023] The high corrosion-resistant, high-strength and non-magnetic stainless steel according to this embodiment contains C, Si, Mn, Cu, Ni, Cr, Mo, B and N as essential elements, and the balance is substantially composed of Fe and unavoidable impurities. The unavoidable impurities as mentioned herein include, for example, P, S and O.

(1) $0.01\% \leq C \leq 0.05\%$ by mass

C is an essential element which is indispensable as an austenite-forming element, and contributes to strength. Accordingly, 0.01 % by mass is specified as the lower limit of the content of C. Further, excessive addition of C causes coarse carbides to crystallize, thereby deteriorating workability and corrosion resistance. Accordingly, 0.05% by mass is specified as the upper limit of the content of C. The content of C is more preferably from 0.03% to 0.05% by mass.

(2) $0.05\% \leq Si \leq 0.50\%$ by mass

Si is an essential element added as a deoxidizer for the steel, so that 0.05% by mass is specified as the lower limit of the content of Si. However, an excessive content of Si causes a decrease in toughness to deteriorate hot workability, so that 0.50% by mass is specified as the upper limit of the content of Si. The content of Si is more preferably from 0.10% to 0.30% by mass.

(3) $16.0\% < Mn \leq 19.0\%$ by mass

Mn is an essential element acting as a deoxidizer for the steel. In order to secure the dissolved amount of N, Mn

should be contained in an amount of more than 16.0% by mass. On the other hand, Mn deteriorates corrosion resistance, so that 19.0% by mass is specified as the upper limit of the content of Mn. The content of Mn is more preferably more than 16.0% by mass but 17.0% by mass or less.

(4) $P \leq 0.040\%$ by mass

P is an unavoidable impurity, segregates in a grain boundary to heighten the corrosion susceptibility of the grain boundary and deteriorate the toughness. Accordingly, the content of P is preferably as low as possible. However, an excessive reduction thereof causes an increase in cost, so that the content of P is specified as 0.040% by mass or less. The content of P is more preferably 0.030% by mass or less.

(5) $S \leq 0.010\%$ by mass

S is an unavoidable impurity, and deteriorates hot workability, so that 0.010% by mass is specified as the upper limit of the content of S. From the viewpoint of a balance with production cost, the content of S is more preferably 0.005% by mass or less.

(6) $0.50\% \leq Cu \leq 0.80\%$ by mass

Cu is an essential element, effective for improving corrosion resistance, particularly corrosion resistance in a reducing acid environment, and effective for obtaining an austenite single-phase structure. Accordingly, 0.50% by mass is specified as the lower limit of the content of Cu. On the other hand, excessive addition of Cu deteriorates hot workability, so that 0.80% by mass is specified as the upper limit of the content of Cu.

(7) $3.5\% \leq Ni \leq 5.0\%$ by mass

Ni is an essential element, effective for improving corrosion resistance, particularly corrosion resistance in a reducing acid environment, and provides an austenite single-phase structure at the time of solution treatment. Accordingly, 3.5% by mass is specified as the lower limit of the content of Ni. On the other hand, excessive addition of Ni causes an increase in cost, so that 5.0% by mass is specified as the upper limit of the content of Ni. The content of Ni is more preferably from 3.5% to 4.5% by mass, from the viewpoint of a balance between characteristics and cost.

(8) $17.0\% \leq Cr \leq 21.0\%$ by mass

Cr is an essential element from the viewpoint of securing corrosion resistance, and in order to secure the dissolved amount of N, 17.0% by mass is specified as the lower limit of the content of Cr. On the other hand, excessive addition of Cr impairs hot workability and causes a decrease in toughness, so that 21.0% by mass is specified as the upper limit of the content of Cr. The content of Cr is more preferably from 18.0% to 19.5% by mass.

(9) $1.80\% \leq Mo \leq 3.50\%$ by mass

Mo is an essential element, which provides necessary corrosion resistance and is capable of further improving strength. Accordingly, 1.80% by mass is specified as the lower limit of the content of Mo. On the other hand, excessive addition of Mo impairs hot workability, and causes an increase in cost. Accordingly, 3.50% by mass is specified as the upper limit of the content of Mo. The content of Mo is more preferably from 2.00% to 2.50% by mass.

(10) $0.0010\% \leq B \leq 0.0050\%$ by mass

B is an essential element effective for improving hot workability of the steel, so that 0.0010% by mass is specified as the lower limit of the content of B. On the other hand, excessive addition of B forms nitrides such as BN to deteriorate workability, so that 0.0050% by mass is specified as the upper limit of the content of B. The content of B is more preferably 0.0030% by mass or less.

(11) $O \leq 0.010\%$ by mass

O is an unavoidable impurity, which forms harmful oxides which exert an adverse effect on cold workability, fatigue characteristics or the like. Accordingly, the O content should be restrained as low as possible, and 0.010% by mass is specified as the upper limit of the content of O. From the viewpoint of a balance with production cost, the content of O is more preferably 0.007% by mass or less, and still more preferably 0.005% by mass or less.

(12) $0.45\% \leq N \leq 0.65\%$ by mass

N is an essential element necessary for obtaining non-magnetism, high strength and good corrosion resistance, and 0.45% by mass is specified as the lower limit of the content of N. On the other hand, excessive addition of N causes N blow, so that 0.65% by mass is specified as the upper limit of the content of N. The content of N is more preferably from 0.50% to 0.60% by mass.

The high corrosion-resistant, high-strength and non-magnetic stainless steel according to this embodiment may further contain the following selective elements, that is to say, at least one element selected from the group consisting of Ca, Mg and REM; the group consisting of Nb, V, Ta and Hf; Al; and the group consisting of W and Co.

(13) At least one element selected from the group consisting of Ca, Mg and REM in a total content of 0.0001% to 0.0100% by mass

Ca, Mg and REM are selective elements, and elements effective for improving hot workability of the steel. Accordingly, they may be added in a total content of 0.0001 % by mass or less. However, excessive addition of these elements results in saturation of the effect, and conversely decreases hot workability. Accordingly, 0.0100% by mass is specified as the upper limit of the total content thereof. The total content thereof is more preferably 0.0050% by mass or less. Incidentally, in this embodiment, REM means one containing Ce, La or an alloy thereof.

(14) At least one element selected from the group consisting of Nb, V, Ta and Hf in a total content of 0.1% to 2.0% by mass

Nb, V, Ta and Hf are selective elements, and these have an effect of forming carbides or carbonitrides to miniaturize grains of the steel, thereby increasing toughness. Accordingly, 0.1 % by mass is specified as the lower limit of the total content of Nb, V, Ta and Hf. On the other hand, excessive addition of Nb, V, Ta and Hf causes an increase in cost, so that 2.0% by mass in total is specified as the upper limit. The content of Nb, V, Ta and Hf is more preferably 1.0% by mass or less.

(15) $0.001\% \leq \text{Al} \leq 0.10\%$ by mass

Al is a strong deoxidizing element, and is also a selective element which is added for decreasing O as much as possible, as needed. For the content of Al, 0.001 % by mass is specified as the lower limit, at which the effect thereof can be confirmed. On the other hand, excessive addition of Al deteriorates hot workability, so that 0.10% by mass is specified as the upper limit of the content of Al. The content of Al is more preferably 0.050% by mass, and still more preferably 0.010% by mass.

(16) At least one element selected from the group consisting of W and Co in a total content of 0.1 % to 3.0% by mass

W is a selective element, and has an effect of improving corrosion resistance and forming a carbide or a carbonitride to miniaturize grains, thereby increasing toughness. Accordingly, W may be added in an amount of 0.1% to 3.0% by mass. On the other hand, excessive addition of W causes an increase in cost, so that the content of W is more preferably 2.0% by mass or less.

[0024] Co is a selective element, and effective for obtaining an austenite single-phase structure to achieve high strength by solid solution strengthening. Accordingly, Co may be added as needed. However, excessive addition of Co causes a substantial increase in cost, so that 3.0% by mass is specified as the upper limit of the content of Co. The content of Co is more preferably 1.5% by mass or less.

(Component Relationship of High-Corrosion Resistant, High-Strength and Non-Magnetic Stainless Steel, and Reason for Restriction Thereof)

[0025] The high corrosion-resistant, high-strength and non-magnetic stainless steel according to this embodiment satisfies the following equations (1) to (4):

(17)

$$(17) \text{PI} = [\text{Cr}] + 3.3 \times [\text{Mo}] + 16 \times [\text{N}] \geq 30 \quad \text{equation (1)}$$

PI (Pitting Index) is a value indicating corrosion resistance, and defined by [Cr], [Mo] and [N]. The larger value shows the better corrosion resistance, so that PI is specified as 30 or more. In order to make it possible to use the steel under a severe corrosive environment, the value of equation (1) is more preferably 33 or more.

(18)

$$(18) [\text{Cr}]/[\text{C}] \geq 330 \quad \text{equation (2)}$$

C combines with Cr to form a carbide, thereby decreasing the content of Cr in the matrix and thus causing deterioration of corrosion resistance. For this reason, equation (2) becomes a relational expression which can be used as an index of corrosion resistance. Accordingly, the larger the Cr content to the C content is, the more the deterioration of corrosion resistance can be inhibited. The value of equation (2) is therefore specified as 330 or more.

(19)

$$(19) [\text{Cr}]/[\text{Mn}] > 1.0 \quad \text{equation (3)}$$

Both Cr and Mn are added in order to sufficiently dissolve N. However, Mn deteriorates corrosion resistance, so that it becomes necessary to balance with Cr as an element for improving corrosion resistance. Accordingly, in order to sufficiently maintain corrosion resistance by compensating for deterioration of corrosion resistance caused by addition of Mn, the value of equation (3) is specified as exceeding 1.0.

(20)

$$(20) ([Ni] + 3 \times [Cu]) / ([Cr] + [Mo]) > 0.25$$

equation (4)

Both Cr and Mo are added for sufficiently securing corrosion resistance. However, associated therewith, stability of an austenite single phase deteriorates. Accordingly, in order to stabilize the austenite phase, Ni and Cu as austenite-forming elements are allowed to be contained in predetermined amounts, thereby inhibiting deterioration of the stability of the austenite single phase. Further, an increase in weight of Cr and addition of Mo act toward a direction impairing non-magnetism, so that non-magnetism is maintained by Ni and Cu. In view of these circumstances, equation (4) defines a quantitative relation in which Ni and Cu should satisfy with respect to Cr and Mo. The value of equation (4) is specified as exceeding 0.25, but it is more preferably 0.30 or more.

[0026] In this regard, with regard to each element contained in the steel of the invention, according to an embodiment, the minimal amount thereof present in the steel is the smallest non-zero amount used in the inventive steels as summarized in Tables 1 and 2. According to a further embodiment, the maximum amount thereof present in the steel is the maximum amount used in the inventive steels as summarized in Tables 1 and 2.

(Method for Producing High-Corrosion Resistant, High-Strength and Non-Magnetic Stainless Steel and High-Corrosion Resistant, High-Strength and Non-Magnetic Stainless Steel Product Using the Same)

[0027] The high-corrosion resistant, high strength and non-magnetic stainless steel according to this embodiment is obtained by

(1) melting a steel ingot containing the above-mentioned specified components in specified amounts so as to satisfy the specified relations,

(2) processing it to an appropriate shape and size by hot working, and then,

(3) subjecting it to solution treatment (1050°C to 1150°C).

The high-corrosion resistant, high strength and non-magnetic stainless steel product according to this embodiment is obtained by, in addition to the above-mentioned steps,

(4) further subjecting the above-mentioned stainless steel to warm working (300°C to 900°C, reduction of area: 15% to 40%). Cutting or the like may be further performed as needed. The reason for specifying the lower limit temperature as 300°C is that the lower working temperature contributes to higher strength, whereas deteriorates elongation and drawing, resulting in difficulty in working.

Examples

(Preparation of Invention Steels and Comparative Steels)

[0028] A 50 kg steel ingot having each component composition (the balance is composed of Fe and unavoidable impurities) shown in Tables 1 and 2 was melted in a high-frequency induction furnace, and a rod stock having a diameter of 20 mm was prepared by hot forging processing, followed by solution treatment at 1050°C to 1150°C. The values of the above-mentioned equations (1) to (4) are shown together in Table 2. In the tables 1 and 2, "-" means that a corresponding element is not added or unavoidably contained even though it should not be added.

Table 1

Component Composition (unit: % by mass) and Values of Equations (1) to (4)																					
	C	Si	Mn	P	S	Cu	Ni	Cr	Mo	B	O	N	Ca, Mg, REM	Nb, V, Ta, Hf	Al	W, Co	PI	Cr/C	Cr/Mn	(Ni+3Cu) (Cr+Mo)	
Inventive steel	1	0.03	0.18	16.9	0.002	0.001	0.52	5.0	19.3	1.89	0.0038	0.005	0.48	Ca:0.0009	-	-	W:1.8	31.2	643	1.14	0.31
	2	0.02	0.48	16.1	0.018	0.002	0.65	3.6	18.8	1.94	0.0014	0.008	0.52	-	Nb:0.48	0.002	-	33.5	940	1.17	0.27
	3	0.04	0.13	18.7	0.028	0.002	0.53	4.5	18.9	2.11	0.0023	0.006	0.54	-	-	-	-	34.5	473	1.01	0.29
	4	0.03	0.31	18.9	0.037	0.003	0.55	4.4	19.3	1.96	0.0021	0.004	0.55	-	-	0.002	-	34.6	643	1.02	0.28
	5	0.04	0.21	16.1	0.011	0.003	0.62	3.6	18.7	2.05	0.0025	0.007	0.55	-	-	-	-	34.3	468	1.16	0.26
	6	0.02	0.49	16.2	0.009	0.004	0.59	4.9	20.1	2.77	0.0013	0.003	0.63	Ca:0.0020	-	-	-	39.3	1005	1.24	0.29
	7	0.03	0.25	16.3	0.025	0.002	0.61	3.5	18.8	1.95	0.0021	0.004	0.56	-	-	0.003	-	34.2	627	1.15	0.26
	8*	0.01	0.12	17.4	0.029	0.008	0.74	5.4	19.8	1.82	0.0028	0.007	0.64	-	V:0.78	-	Co:1.2	36.0	1980	1.14	0.35
	9	0.05	0.46	18.8	0.032	0.005	0.60	4.6	18.9	2.00	0.0032	0.008	0.54	Mg:0.0012	-	0.005	-	34.1	378	1.01	0.31
	10	0.03	0.28	16.0	0.027	0.003	0.58	3.6	18.5	2.16	0.0048	0.007	0.55	-	-	0.003	-	34.4	617	1.16	0.26
	11	0.05	0.29	17.4	0.023	0.003	0.79	3.8	17.6	2.54	0.0019	0.007	0.49	-	Nb:0.35	0.002	Co:0.6	33.8	352	1.01	0.31
	12	0.02	0.28	18.3	0.006	0.004	0.58	4.5	17.9	2.33	0.0024	0.005	0.65	Mg:0.0009	Ta:0.52	0.004	-	36.0	895	1.01	0.31
	13	0.04	0.29	18.6	0.027	0.002	0.64	4.9	19.2	2.76	0.0022	0.005	0.55	-	-	-	-	37.1	480	1.03	0.31
	14	0.03	0.39	18.9	0.029	0.001	0.61	4.5	19.1	1.94	0.0020	0.004	0.54	-	-	0.003	-	34.1	637	1.01	0.30
	15	0.04	0.22	18.8	0.020	0.004	0.57	5.0	18.8	2.01	0.0019	0.003	0.57	-	-	0.002	-	34.6	470	1.00	0.32
	16	0.05	0.38	17.7	0.017	0.001	0.55	4.6	18.0	1.85	0.0034	0.001	0.63	-	V:0.32	0.001	-	34.2	360	1.02	0.31
	17	0.05	0.24	18.5	0.032	0.002	0.52	5.0	19.0	2.84	0.0028	0.004	0.53	-	-	-	-	36.9	380	1.03	0.30
	18	0.03	0.29	18.8	0.030	0.001	0.63	4.6	19.2	2.11	0.0031	0.002	0.55	-	-	0.004	W:0.8	35.4	640	1.02	0.30
	19	0.04	0.27	18.5	0.028	0.003	0.50	4.4	18.6	2.22	0.0030	0.003	0.54	-	-	0.001	-	34.6	465	1.01	0.28
	20	0.02	0.11	16.6	0.025	0.002	0.68	4.1	19.6	2.03	0.0029	0.003	0.51	REM:0.0014	Hf:0.28	0.003	W:2.5	35.7	980	1.18	0.28
* not part of invention																					

Table 2

Component Composition (unit: % by mass) and Values of Equations (1) to (4)																					
		C	Si	Mn	P	S	Cu	Ni	Cr	Mo	B	O	N	Ca, Mg. REM	Nb, V, Ta, Hf	Al	W, Co	PI	Cr/C	Cr/Mn	(Ni+3Cu)/ (Cr+Mo)
Inventive steel	21	0.04	0.22	18.9	0.025	0.001	0.62	4.9	19.1	2.94	0.0033	0.006	0.56	-	-	0.002	-	37.8	478	1.01	0.31
	22	0.04	0.18	16.7	0.033	0.001	0.57	4.3	18.2	1.88	0.0041	0.004	0.49	Mg:0.017	-	-	-	32.2	455	1.09	0.30
	23	0.03	0.28	16.3	0.029	0.002	0.71	3.6	19.3	1.91	0.0025	0.005	0.54	-	-	0.001	-	34.2	643	1.18	0.27
	24	0.04	0.18	16.3	0.014	0.002	0.74	3.5	18.8	1.83	0.0016	0.006	0.55	-	-	-	-	33.6	470	1.15	0.28
	25*	0.01	0.47	16.9	0.027	0.003	0.61	5.5	19.1	2.32	0.0023	0.005	0.52	-	Hf:0.19	0.002	-	35.1	1910	1.13	0.34
Comparative Steel	26	0.04	0.30	17.7	0.032	0.001	0.58	3.9	17.8	2.10	0.0026	0.003	0.47	REM:0.0019	-	-	Co:0.8	32.3	445	1.01	0.28
	1	0.09	0.33	14.8	0.023	0.003	0.32	3.0	19.4	0.02	-	0.013	0.54	-	-	-	-	28.1	216	1.31	0.20
	2	0.05	0.43	1.5	0.019	0.004	0.26	8.5	18.2	0.23	-	0.009	0.04	-	-	-	-	19.6	364	12.13	0.50
	3	0.07	0.29	1.2	0.027	0.002	0.23	12.1	18.3	0.03	-	0.008	0.03	-	-	-	-	18.9	261	15.25	0.70
	4	0.05	0.33	21.0	0.031	0.003	0.23	4.1	16.8	0.43	-	0.007	0.46	-	-	-	-	25.6	336	0.80	0.28
	5	0.03	0.29	19.8	0.022	0.002	0.54	3.7	17.2	1.22	-	0.009	0.48	-	-	-	-	28.9	573	0.87	0.29
	6	0.04	0.32	16.2	0.028	0.004	0.11	3.6	18.4	2.41	-	0.006	0.51	-	-	-	-	34.5	460	1.14	0.19
	7	0.03	0.43	17.2	0.021	0.003	0.32	5.2	19.2	1.45	-	0.004	0.49	-	-	-	-	31.8	640	1.12	0.30
	8	0.04	0.32	16.3	0.026	0.002	0.25	3.9	17.3	0.90	-	0.006	0.55	-	-	-	-	29.1	433	1.06	0.26
	9	0.05	0.51	18.9	0.034	0.004	0.19	4.8	18.1	1.11	-	0.005	0.50	-	-	-	-	29.8	362	0.96	0.28
* not part of invention	10	0.03	0.29	16.8	0.039	0.003	0.34	3.4	16.3	0.33	-	0.003	0.58	-	-	-	-	26.7	543	0.97	0.27

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[0029] Thereafter, warm working was performed under temperature conditions and reductions of area shown in Tables 3 and 4 to prepare materials under test (working materials). The materials under test were processed to various test specimens.

The tensile strength, the 0.2% yield strength and the elongation (%) were determined by preparing a JIS No. 4 test specimen from each of the materials under test, and measuring the breaking stress at the time when the tensile load is applied to a leading edge of the specimen in accordance with JIS Z 2241.

The magnetic permeability was determined by performing measurement of the magnetic permeability according to the VSM method, taking the external magnetic field as 2,000 Oe.

The corrosion resistance was evaluated by the 6% ferric chloride test (JIS G 0578) and the 10% oxalic acid etching test (JIS G 0571).

The test results thereof are shown together in Tables 3 and 4.

Table 3

Test results 1		Working Method	Tensile Strength (MPa)	0.2% Yield Strength (MPa)	Elongation (%)	Magnetic Permeability	Ferric Chloride Corrosion (g/m ² ·h)	10% Oxalic Acid Etching
Inventive steel	1	300°C warm working-reduction of area 30%	1151	1053	41	1.004	0.14	step
	2	300°C warm working-reduction of area 30%	1250	1148	39	1.003	0.29	step
	3	300°C warm working-reduction of area 30%	1294	1179	38	1.002	0.25	step
	4	300°C warm working-reduction of area 30%	1321	1217	38	1.004	0.26	step
	5	300°C warm working-reduction of area 30%	1304	1201	38	1.006	0.29	step
	6	300°C warm working-reduction of area 30%	1512	1386	32	1.002	0.31	step
	7	300°C warm working-reduction of area 30%	1344	1232	37	1.007	0.29	step
	8	300°C warm working-reduction of area 30%	1536	1408	30	1.008	0.28	step
	9	300°C warm working-reduction of area 30%	1295	1191	38	1.003	0.25	step
	10	300°C warm working-reduction of area 30%	1318	1211	37	1.002	0.29	step
	11	300°C warm working-reduction of area 30%	1176	1078	41	1.004	0.25	step
	12	300°C warm working-reduction of area 30%	1560	1430	30	1.006	0.24	step
	13	300°C warm working-reduction of area 30%	1331	1217	38	1.003	0.26	step

(continued)

Test results 1									
		Working Method	Tensile Strength (MPa)	0.2% Yield Strength (MPa)	Elongation (%)	Magnetic Permeability	Ferric Chloride Corrosion (g/m ² ·h)	10% Oxalic Acid Etching	
	14	300°C warm working-reduction of area 30%	1298	1190	37	1.004	0.25	step	
	15	300°C warm working-reduction of area 30%	1368	1254	36	1.006	0.25	step	
	16	300°C warm working-reduction of area 30%	1523	1389	31	1.003	0.25	step	
	17	300°C warm working-reduction of area 30%	1272	1166	38	1.002	0.26	step	
	18	300°C warm working-reduction of area 30%	1322	1211	37	1.007	0.26	step	
	19	300°C warm working-reduction of area 30%	1296	1188	38	1.003	0.25	step	
	20	300°C warm working-reduction of area 30%	1224	1122	40	1.007	0.30	step	

(continued)

Test results 1 (Continued)								
		Working Method	Tensile Strength (MPa)	0.2% Yield Strength (MPa)	Elongation (%)	Magnetic Permeability	Ferric Chloride Corrosion (g/m ² ·h)	10% Oxalic Acid Etching
Inventive steel	21	300°C warm working-reduction of area 30%	1348	1236	36	1.007	0.25	step
	22	300°C warm working-reduction of area 30%	1176	1078	43	1.002	0.27	step
	23	300°C warm working-reduction of area 30%	1299	1182	39	1.002	0.30	step
	24	300°C warm working-reduction of area 30%	1320	1210	36	1.005	0.29	step
	25	300°C warm working-reduction of area 30%	1248	1144	38	1.002	0.28	step
	26	300°C warm working-reduction of area 30%	1128	1034	39	1.002	0.25	step

(continued)

Test results 1 (Continued)									
		Working Method	Tensile Strength (MPa)	0.2% Yield Strength (MPa)	Elongation (%)	Magnetic Permeability	Ferric Chloride Corrosion (g/m ² ·h)	10% Oxalic Acid Etching	
Comparative steel	1	300°C warm working-reduction of area 30%	1345	1233	35	1.015	1.3	step	
	2	300°C warm working-reduction of area 30%	877	768	51	1.135	15.0	step	
	3	300°C warm working-reduction of area 30%	943	892	49	1.007	1.5	step	
	4	300°C warm working-reduction of area 30%	1175	1087	41	1.004	4.3	step	
	5	300°C warm working-reduction of area 30%	1189	1101	40	1.005	3.9	step	
	6	300°C warm working-reduction of area 30%	1204	1108	39	1.022	2.1	step	
	7	Working temperature 250°C - reduction of area 30%	1401	1345	17	1.018	0.4	step	
	8	Working temperature 950°C - reduction of area 30%	1189	1008	41	1.027	1.4	ditch	
	9	Working temperature 300°C - reduction of area 10%	1064	971	43	1.035	0.5	step	
	10	Working temperature 300°C - reduction of area 50%	1389	1312	19	1.048	4.1	ditch	

Table 4

Test results 2		Working Method	Tensile Strength (MPa)	0.2% Yield Strength (MPa)	Elongation (%)	Magnetic Permeability	Ferric Chloride Corrosion (g/m ² ·h)	10% Oxalic Acid Etching
Inventive steel	1	900°C warm working-reduction of area 30%	1085	982	43	1.003	0.35	step
	2	900°C warm working-reduction of area 30%	1175	1059	41	1.008	0.32	step
	3	900°C warm working-reduction of area 30%	1213	1097	38	1.007	0.31	step
	4	900°C warm working-reduction of area 30%	1245	1120	39	1.002	0.30	step
	5	900°C warm working-reduction of area 30%	1235	1117	39	1.002	0.30	step
	6	900°C warm working-reduction of area 30%	1421	1287	36	1.003	0.26	step
	7	900°C warm working-reduction of area 30%	1263	1144	39	1.002	0.30	step
	8	900°C warm working-reduction of area 30%	1443	1307	35	1.002	0.26	step
	9	900°C warm working-reduction of area 30%	1222	1109	40	1.007	0.31	step
	10	900°C warm working-reduction of area 30%	1242	1121	38	1.002	0.30	step
	11	900°C warm working-reduction of area 30%	1105	1001	43	1.004	0.34	step
	12	900°C warm working-reduction of area 30%	1466	1328	35	1.003	0.26	step
	13	900°C warm working-reduction of area 30%	1247	1128	40	1.004	0.30	step
	14	900°C warm working-reduction of area 30%	1214	1099	40	1.003	0.31	step

(continued)

Test results 2								
		Working Method	Tensile Strength (MPa)	0.2% Yield Strength (MPa)	Elongation (%)	Magnetic Permeability	Ferric Chloride Corrosion (g/m ² ·h)	10% Oxalic Acid Etching
	15	900°C warm working-reduction of area 30%	1286	1164	39	1.002	0.29	step
	16	900°C warm working-reduction of area 30%	1422	1290	36	1.004	0.26	step
	17	900°C warm working-reduction of area 30%	1195	1083	40	1.003	0.31	step
	18	900°C warm working-reduction of area 30%	1250	1129	39	1.004	0.30	step
	19	900°C warm working-reduction of area 30%	1218	1103	41	1.002	0.31	step
	20	900°C warm working-reduction of area 30%	1150	1042	43	1.007	0.33	step
Test results 2 (Continued)								
		Working Method	Tensile Strength (MPa)	0.2% Yield Strength (MPa)	Elongation (%)	Magnetic Permeability	Ferric Chloride Corrosion (g/m ² ·h)	10% Oxalic Acid Etching
Inventive steel	21	900°C warm working-reduction of area 30%	1260	1143	38	1.002	0.30	step
	22	900°C wann working-reduction of area 30%	1105	1001	43	1.003	0.34	step
	23	900°C warm working-reduction of area 30%	1210	1101	40	1.004	0.31	step
	24	900°C warm working-reduction of area 30%	1240	1123	39	1.002	0.30	step
	25	900°C warm working-reduction of area 30%	1173	1062	42	1.007	0.32	step
	26	900°C warm working-reduction of area 30%	1060	970	45	1.002	0.35	step

(continued)

Test results 2 (Continued)									
		Working Method	Tensile Strength (MPa)	0.2% Yield Strength (MPa)	Elongation (%)	Magnetic Permeability	Ferric Chloride Corrosion (g/m ² ·h)	10% Oxalic Acid Etching	
Comparative steel	1	900°C warm working-reduction of area 30%	1243	1147	38	1.017	2.40	ditch	
	2	900°C warm working-reduction of area 30%	775	682	62	1.018	18.9	ditch	
	3	900°C warm working-reduction of area 30%	841	806	50	1.005	2.3	ditch	
	4	900°C warm working-reduction of area 30%	1017	962	48	1.003	5.8	ditch	
	5	900°C warm working-reduction of area 30%	1043	977	46	1.004	4.1	step	
	6	900°C warm working-reduction of area 30%	1023	982	47	1.014	2.8	step	
	7								
	8								
	9								
	10								

(Evaluation)

[0030] Inventive Steels 1 to 26 satisfied the required characteristics for all of strength (tensile strength ≥ 1050 MPa, 0.2% yield strength ≥ 968 MPa), workability (elongation ≥ 25), non-magnetism (magnetic permeability ≤ 1.010) and corrosion resistance (ferric chloride corrosion < 0.5 , 10% oxalic acid etching: step). Inventive Steels 1 to 26 contained the components defined in Tables 1 and 2 in predetermined amounts, and satisfied equations (1) to (4) defined in Tables 1 and 2. It is therefore conceivable that corrosion resistance, strength and non-magnetism could be achieved at the same time.

Accordingly, it has become clear that Inventive Steels 1 to 26 block the influence of earth magnetism at the time of oil well evacuation, and not only can be applied to oil well excavation products covering a wide range of regions, but also are suitable as raw materials for various parts (various spring products, VTR guide pins and motor shafts).

[0031] On the other hand, Comparative Steels 1 to 10 did not satisfy the required characteristic for any one of strength (tensile strength ≥ 1050 MPa, 0.2% yield strength ≥ 968 MPa), workability (elongation ≥ 25), non-magnetism (magnetic permeability ≤ 1.010) and corrosion resistance (ferric chloride corrosion < 0.5 , 10% oxalic acid etching: step). The reason for this is considered to be that Comparative Steels 1 to 10 did not contain the components defined in Table 2 in predetermined amounts, or did not satisfy any one of equations (1) to (4).

[0032] For example, Comparative Steel 1 did not satisfy equation 1 because of its small Mo content, and further did not satisfy equation 2 because of its excessive C content. Corrosion resistance is therefore considered to be impaired even when the Mn content is small. Incidentally, although Comparative Steel 1 did not satisfy equation 4, it satisfied the required characteristic for magnetic permeability.

Comparative Steel 2 contained Cr essential for securing corrosion resistance in a predetermined amount, but did not satisfy equation 1 because of its small Mo and N contents. Corrosion resistance is therefore considered to be impaired. Further, high magnetic permeability of Comparative Steel 2 is considered to be caused by the small N content.

[0033] Comparative Steel 3 contained Cr essential for securing corrosion resistance in a predetermined amount, but did not satisfy equation 1 because of its small Mo and N contents, and did not satisfy equation 2 because of its excessive C content. Corrosion resistance is therefore considered to be impaired.

Comparative Steels 4 and 5 did not satisfy equations (1) and (3) because of their excessively small Mo content, excessive Mn content and rather small Cr content. Corrosion resistance is therefore considered to be impaired.

Comparative Steel 6 did not satisfy equation (4) because of its excessively small Cu content. Corrosion resistance is therefore considered to be impaired.

[0034] Comparative Steel 7 satisfied equations (1) to (4), and satisfied the required characteristics of high corrosion resistance, non-magnetism and high strength, although the Cu, Ni and Mo contents were outside the predetermined ranges. However, it was revealed that Comparative Steel 7 was decreased in elongation to cause difficulty in working, which was unsuitable for actual production, because of its low working temperature.

Comparative Steel 8 did not satisfy equation (1), because of its excessively small Cu and Mo contents. Corrosion resistance is therefore considered to be impaired. Further, in Comparative Steel 8, the working temperature was increased to 950°C. However, it was confirmed that an increase in working temperature was not so much effective for an increase in strength.

[0035] Comparative Steels 9 and 10 did not satisfied equation (1) because of its excessively small Mo content, did not satisfy equation (3) in relation to the balance of the components, and was excessively small in Cu content. Corrosion resistance is therefore considered to be impaired. Further, both of these were high in magnetic permeability. Incidentally, in Comparative Steel 9, the reduction of area was as low as 10%, although the working temperature was low. It is therefore conceivable that deterioration of workability did not occur by high elongation and work hardening. On the other hand, in Comparative Steel 10, the working temperature was low, and moreover, the reduction of area was as high as 50%. It was therefore revealed that Comparative Steel 10 was increased in strength by work hardening, but decreased in elongation to cause difficulty in working, which was unsuitable for actual production.

[0036] Although one embodiment of the invention has been described above, the invention is not construed as being limited to the above-mentioned embodiment, and all modifications are possible based on the usual knowledge of those skilled in the art. Such modifications should be construed as being included in the scope of the invention.

[0037] The high corrosion-resistant, high-strength and non-magnetic stainless steel, according to the invention, has the predetermined component composition, and the predetermined mutual relationship of the components is adjusted. Accordingly, the industrial use value thereof is high for steel product manufacturers. The high corrosion-resistant, high-strength and non-magnetic stainless steel according to the invention is expected to be applied to oil well excavation products and steel products such as spring, shaft, bolt and screw products.

[0038] The present application is based on Japanese Application No. 2009-108189 filed April 27, 2009, Japanese Application No. 2009-123661 filed May 22, 2009 and Japanese Application No. 2010-015591 filed January 27, 2010.

Claims

1. A high corrosion-resistant, high-strength and non-magnetic stainless steel comprising, by mass:

C: 0.01% to 0.05%
Si: 0.05% to 0.50%
Mn: more than 16.0% but 19.0% or less
Cu: 0.50% to 0.80%
Ni: 3.5% to 5.0%
Cr: 17.0% to 21.0%
Mo: 1.80% to 3.50%
B: 0.0010% to 0.0050%
N: 0.45% to 0.65%

and optionally comprises

P: 0.040% or less
S: 0.010% or less
O: 0.010% or less
Ca, Mg and REM: 0.0001% to 0.0100% in total
Nb, V, Ta and Hf: 0.1% to 2.0 in total
Al: 0.001% to 0.10%
W and Co: 0.1% to 3.0% in total,

with the balance composed of Fe and unavoidable impurities, the steel satisfying the following equations (1) to (4):

$$[\text{Cr}] + 3.3x[\text{Mo}] + 16x[\text{N}] \geq 30 \quad (1)$$

$$[\text{Cr}]/[\text{C}] \geq 330 \quad (2)$$

$$[\text{Cr}]/[\text{Mn}] \geq 1.0 \quad (3)$$

$$([\text{Ni} + 3x[\text{Cu}])/([\text{Cr}] + [\text{Mo}]) > 0.25 \quad (4)$$

wherein [Cr], [Mo], [N], [C], [Mn], [Ni] and [Cu] represent the content of Cr, the content of Mo, the content of N, the content of C, the content of Mn, the content of Ni, and the content of Cu in the steel in terms of mass%, respectively.

Patentansprüche

1. Hochkorrosionsbeständiger, hochfester und nichtmagnetischer Rostfrei-Stahl, Folgendes nach Masse umfassend:

C: 0,01 % bis 0,05 %
Si: 0,05 % bis 0,50 %
Mn: mindestens 16,0 %, aber höchstens 19,0 %
Cu: 0,50 % bis 0,80 %
Ni: 3,5 % bis 5,0 %
Cr: 17,0 % bis 21,0 %
Mo: 1,80 % bis 3,50 %
B: 0,0010 % bis 0,0050 %
N: 0,45 % bis 0,65 %

und wahlweise Folgendes umfassend:

P: höchstens 0,040 %
 S: höchstens 0,010 %
 O: höchstens 0,010 %
 Ca, Mg und seltene Erdmetalle: 0,0001 % bis 0,0100 % insgesamt
 Nb, V, Ta und Hf: 0,1 % bis 2,0 % insgesamt
 Al: 0,001 % bis 0,10 %
 W und Co: 0,1 % bis 3,0 % insgesamt,

mit dem Rest bestehend aus Fe und unvermeidbaren Verunreinigungen, wobei der Stahl die folgenden Gleichungen (1) bis (4) erfüllt:

$$[\text{Cr}] + 3,3 \times [\text{Mo}] + 16 \times [\text{N}] \geq 30 \quad (1)$$

$$[\text{Cr}] / [\text{C}] \geq 330 \quad (2)$$

$$[\text{Cr}] / [\text{Mn}] \geq 1,0 \quad (3)$$

$$([\text{Ni}] + 3 \times [\text{Cu}]) / ([\text{Cr}] + [\text{Mo}]) > 0,25 \quad (4)$$

wobei [Cr], [Mo], [N], [C], [Mn], [Ni] und [Cu] den Gehalt von Cr, den Gehalt von Mo, den Gehalt von N, den Gehalt von C, den Gehalt von Mn, den Gehalt von Ni beziehungsweise den Gehalt von Cu in dem Stahl hinsichtlich Massenanteil darstellen.

Revendications

1. Acier inoxydable non-magnétique, à haute résistance, hautement résistant à la corrosion, comprenant, en masse :

C : 0,01 % à 0,05 %
 Si : 0,05 % à 0,50 %
 Mn : plus de 16,0 % mais 19,0 % ou moins
 Cu : 0,50 % à 0,80 %
 Ni : 3,5 % à 5,0 %
 Cr : 17,0 % à 21,0 %
 Mo : 1,80 % à 3,50 %
 B : 0,0010 % à 0,0050 %
 N : 0,45 % à 0,65 %

et comprenant éventuellement

P : 0,040 % ou moins
 S : 0,010 % ou moins
 O : 0,010 % ou moins
 Ca, Mg et REM : 0,0001 % à 0,0100 % au total
 Nb, V, Ta et Hf : 0,1 % à 2,0 au total
 Al : 0,001 % à 0,10 %
 W et Co : 0,1 % à 3,0 % au total,

le reste étant composé de Fe et d'impuretés inévitables, l'acier satisfaisant les équations (1) à (4) suivantes :

$$[\text{Cr}] + 3,3 \times [\text{Mo}] + 16 \times [\text{N}] \geq 30 \quad (1)$$

$$[\text{Cr}] / [\text{C}] \geq 330 \quad (2)$$

$$[\text{Cr}] / [\text{Mn}] \geq 1,0 \quad (3)$$

$$([\text{Ni} + 3 \times [\text{Cu}]) / ([\text{Cr}] + [\text{Mo}]) > 0,25 \quad (4)$$

dans lequel [Cr], [Mo], [N], [C], [Mn], [Ni] et [Cu] représentent la teneur en Cr, la teneur en Mo, la teneur en N, la teneur en C, la teneur en Mn, la teneur en Ni, et la teneur en Cu de l'acier en termes de % en masse, respectivement.

REFERENCES CITED IN THE DESCRIPTION

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