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(54) **LOW-COST AUSTENITIC STAINLESS STEEL HAVING HIGH STRENGTH AND HIGH FORMABILITY, AND METHOD FOR MANUFACTURING SAME**

(57) Disclosed are a low-cost austenitic stainless steel having high strength and high formability and a method for manufacturing same. The low-cost austenitic stainless steel having high strength and high formability according to an embodiment includes, greater than 0% and at most 0.08% of C, 0.2 to 0.25% of N, 0.8 to 1.5% of Si, 8.0 to 9.5% of Mn, 15.0 to 16.5% of Cr, greater than 0% and at most 1.0% of Ni, 0.8 to 1.8% of Cu, and the remainder of Fe and other unavoidable impurities and satisfies Expressions (1) to (4) below.

(1) $Ni+0.47Mn+15N \geq 7.5$

(2) $23(C+N)+1.3Si+0.24(Cr+Ni+Cu)+0.1Mn \geq 12$

(3) $551-462(C+N)-9.2Si-8.1Mn-13.7Cr-29(Ni+Cu) \leq 70$

(4) $11 \leq 1+45C-5Si+0.09Mn+2.2Ni-0.28Cr-0.67Cu+88.6N \leq 17$

Here, C, N, Si, Mn, Cr, Ni, and Cu represent contents (wt%) of the elements, respectively.

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Description

[Technical Field]

[0001] The present disclosure relates to an austenitic stainless steel and a method for manufacturing same, and more particularly, to a low-cost austenitic stainless steel having high strength and high formability and a method for manufacturing same.

[Background Art]

[0002] Vehicle market trends are changing from conventional internal combustion engine-based automotive industry toward battery-based eco-friendly vehicle markets. That is, conventional internal combustion engine vehicle markets which are of high interest in middle-sized or large-sized vehicles are changing toward battery-based vehicle markets which prefer small-sized or lightweight vehicles.

[0003] Structural materials protecting batteries are required to have high strength in order to protect the batteries from the risk of safety accidents such as explosions or from external impact and for the safety of passengers, and the structural materials are also required to be lightweight to prevent weight of small-sized or lightweight vehicles from increasing. As well as structural materials for protecting batteries, general structural materials have become smaller in size and higher in strength to comply with environmental regulations. Accordingly, there is a need to develop materials with high productivity, excellent stability, high strength, and excellent formability applicable throughout the industry.

[0004] Stainless steels are materials applicable throughout the industry due to excellent corrosion resistance. Particularly, austenitic stainless steels with excellent elongation have no problem in forming complex shapes to meet various needs of customers and are advantageous in terms of aesthetic appearance.

[0005] However, austenitic stainless steels have lower yield strength compared to common carbon steels and are economically disadvantageous because expensive alloying elements are used therein. Therefore, there is a need to develop stainless steels for structural materials having high levels of yield strength and proper tensile strength with excellent formability maintained.

[0006] In addition, there is a problem in that alloying elements constituting austenitic stainless steels are expensive compared to elements constituting most carbon steels. Particularly, Ni included in austenitic stainless steels may cause problems in terms of price competitiveness because it is expensive and difficult to stably supply Ni due to unstable supply and demand thereof due to a wide fluctuation in prices. Therefore, there is a need to develop low-cost austenitic stainless steels in which the contents of expensive elements such as Ni are reduced.

[Disclosure]

[Technical Problem]

[0007] To solve the above-described problems, provided is a low-cost austenitic stainless steel having high strength and high formability.

[Technical Solution]

[0008] In accordance with an aspect of the present disclosure to achieve the above-described objects, a low-cost austenitic stainless steel having high strength and high formability includes, in percent by weight (wt%), greater than 0% and at most 0.08% of C, 0.2 to 0.25% of N, 0.8 to 1.5% of Si, 8.0 to 9.5% of Mn, 15.0 to 16.5% of Cr, greater than 0% and at most 1.0% of Ni, 0.8 to 1.8% of Cu, and the remainder of Fe and other unavoidable impurities and satisfies Expressions (1) to (4) below:

$$\text{Ni}+0.47\text{Mn}+15\text{N} \geq 7.5 \quad (1)$$

$$23(\text{C}+\text{N})+1.3\text{Si}+0.24(\text{Cr}+\text{Ni}+\text{Cu})+0.1\text{Mn} \geq 12 \quad (2)$$

$$551-462(\text{C}+\text{N})-9.2\text{Si}-8.1\text{Mn}-13.7\text{Cr}-29(\text{Ni}+\text{Cu}) \leq 70 \quad (3)$$

$$11 \leq 1+45\text{C}-5\text{Si}+0.09\text{Mn}+2.2\text{Ni}-0.28\text{Cr}-0.67\text{Cu}+88.6\text{N} \leq 17 \quad (4)$$

wherein C, N, Si, Mn, Cr, Ni, and Cu represent contents (wt%) of the elements, respectively.

[0009] In each low-cost austenitic stainless steel having high strength and high formability of the present disclosure, a yield strength of a cold-rolled, annealed steel sheet may be 400 MPa or more.

[0010] In each low-cost austenitic stainless steel having high strength and high formability of the present disclosure, an elongation of a cold-rolled, annealed steel sheet may be 55% or more.

[0011] In each low-cost austenitic stainless steel having high strength and high formability of the present disclosure, a yield strength of a skin pass-rolled steel sheet may be 800 MPa or more..

[0012] In each low-cost austenitic stainless steel having high strength and high formability of the present disclosure, an elongation of the skin pass-rolled steel sheet may be 25% or more.

[0013] Also, in accordance with an aspect of the present disclosure to achieve the above-described objects, a method for manufacturing a low-cost austenitic stainless steel having high strength and high formability includes: preparing a slab including, in percent by weight (wt%), greater than 0% and at most 0.08% of C, 0.2 to 0.25% of N, 0.8 to 1.5% of Si, 8.0 to 9.5% of Mn, 15.0 to 16.5% of Cr, greater than 0% and at most 1.0% of Ni, 0.8 to 1.8% of Cu, and the remainder of Fe and other unavoidable impurities and satisfying Expressions (1) to (4) below; hot rolling the slab to prepare a hot-rolled steel sheet and hot annealing the hot-rolled steel sheet to prepare a hot-rolled, annealed steel sheet; cold rolling the hot-rolled, annealed steel sheet to prepare a cold-rolled steel sheet and cold annealing the cold-rolled steel sheet at a temperature of 1050°C or higher to prepare a cold-rolled, annealed steel sheet; and skin pass rolling the cold-rolled, annealed steel sheet to prepare a skin pass-rolled steel sheet:

$$\text{(1)} \quad Ni+0.47Mn+15N \geq 7.5$$

$$\text{(2)} \quad 23(C+N)+1.3Si+0.24(Cr+Ni+Cu)+0.1Mn \geq 12$$

$$\text{(3)} \quad 551-462(C+N)-9.2Si-8.1Mn-13.7Cr-29(Ni+Cu) \leq 70$$

$$\text{(4)} \quad 11 \leq 1+45C-5Si+0.09Mn+2.2Ni-0.28Cr-0.67Cu+88.6N \leq 17$$

wherein C, N, Si, Mn, Cr, Ni, and Cu represent contents (wt%) of the elements, respectively.

[0014] In the method for manufacturing each low-cost austenitic stainless steel having high strength and high formability, the skin pass rolling may be performed at a reduction ratio of 20% or more.

[0015] In the method for manufacturing each low-cost austenitic stainless steel having high strength and high formability, the slab may have a reduction of area of 50% or more at a high temperature of 800°C or higher.

[Advantageous Effects]

[0016] According to an embodiment of the present disclosure, provided is an austenitic stainless steels having excellent yield strength, in which a cold-rolled, annealed steel sheet prepared by cold annealing at a temperature of 1050°C or higher after cold rolling has excellent yield strength and excellent elongation sufficient for forming may be obtained after skin pass rolling performed to further increase strength. Also, a low-cost austenitic stainless steel having high strength and high formability with high productivity even using reduced amounts of expensive alloying elements may be provided.

[Best Mode]

[0017] A low-cost austenitic stainless steel having high strength and high formability according to an embodiment of the present disclosure includes, in percent by weight (wt%), greater than 0% and at most 0.08% of C, 0.2 to 0.25% of N, 0.8 to 1.5% of Si, 8.0 to 9.5% of Mn, 15.0 to 16.5% of Cr, greater than 0% and at most 1.0% of Ni, 0.8 to 1.8% of Cu, and the remainder of Fe and other unavoidable impurities and satisfies Expressions (1) to (4) below.

$$\text{(1)} \quad Ni+0.47Mn+15N \geq 7.5$$

$$\text{(2)} \quad 23(C+N)+1.3Si+0.24(Cr+Ni+Cu)+0.1Mn \geq 12$$

$$\text{(3)} \quad 551-462(C+N)-9.2Si-8.1Mn-13.7Cr-29(Ni+Cu) \leq 70$$

$$\text{(4)} \quad 11 \leq 1+45C-5Si+0.09Mn+2.2Ni-0.28Cr-0.67Cu+88.6N \leq 17$$

wherein C, N, Si, Mn, Cr, Ni, and Cu represent contents (wt%) of the elements, respectively.

[Modes of the Invention]

[0018] Hereinafter, embodiments of the present disclosure will be described in detail with reference to the accompanying drawings. The embodiments of the present disclosure may, however, be embodied in many different forms and should not be construed as being limited to the embodiments set forth herein. Rather, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey the concept of the invention to those skilled in the art.

[0019] Also, the terms used herein are merely used to describe particular embodiments. An expression used in the singular encompasses the expression of the plural, unless otherwise indicated. Throughout the specification, the terms such as "including" or "having" are intended to indicate the existence of features, operations, functions, components, or combinations thereof disclosed in the specification, and are not intended to preclude the possibility that one or more other features, operations, functions, components, or combinations thereof may exist or may be added.

[0020] Meanwhile, unless otherwise defined, all terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this disclosure belongs. Thus, these terms should not be interpreted in an idealized or overly formal sense unless expressly so defined herein. As used herein, the singular forms are intended to include the plural forms as well, unless the context clearly indicates otherwise.

[0021] The terms "about", "substantially", etc. used throughout the specification means that when a natural manufacturing and a substance allowable error are suggested, such an allowable error corresponds the value or is similar to the value, and such values are intended for the sake of clear understanding of the present invention or to prevent an unconscious infringer from illegally using the disclosure of the present invention.

[0022] A low-cost austenitic stainless steel having high strength and high formability according to an embodiment of the present disclosure includes, in percent by weight (wt%), greater than 0% and at most 0.08% of C, 0.2 to 0.25% of N, 0.8 to 1.5% of Si, 8.0 to 9.5% of Mn, 15.0 to 16.5% of Cr, greater than 0% and at most 1.0% of Ni, 0.8 to 1.8% of Cu, and the remainder of Fe and other unavoidable impurities.

[0023] Hereinafter, reasons for numerical limitations on the contents of alloying elements in the embodiment of the present disclosure will be described.

<u>Carbon (C): greater than 0 wt% and at most 0.08 wt%</u>

[0024] Carbon (C), as an element effective on stabilizing an austenite phase, is added to obtain a yield strength of an austenitic stainless steel. However, an excess of C may not only deteriorate cold workability due to solid strengthening effect but also may induce grain boundary precipitation of a Cr carbide thereby adversely affecting ductility, toughness, corrosion resistance, and the like and deteriorating welding properties among the elements. Therefore, an upper limit thereof may be set to 0.08 wt%.

<u>Nitrogen (N): 0.2 to 0.25 wt%</u>

[0025] Nitrogen (N) is the most important element in the present disclosure. Nitrogen is a strong austenite-stabilizing element effective on enhancing corrosion resistance and yield strength of an austenitic stainless steel. However, an excess of N may cause occurrence of defects such as nitrogen pores while a slab is made and deteriorate cold workability due to solid solution strengthening effect. Therefore, an upper limit thereof may be set to 0.25 wt%.

<u>Silicon (Si): 0.8 to 1.5 wt%</u>

[0026] Silicon (Si), acting as a deoxidizer during a steelmaking process, is an element effective for improving corrosion resistance. Also, Si is an effective element for increasing yield strength of steel materials among substitutional elements. In consideration of these effects, Si may be added in an amount of 0.8 wt% or more in the present disclosure. However, an excess of Si, as a ferrite phase-stabilizing element, may promote formation of delta (δ) ferrite in a cast slab, thereby not only deteriorating hot workability but also deteriorating ductility and impact characteristics of steel materials. Therefore, an upper limit of the Si content may be set to 1.5 wt%.

<u>Manganese (Mn): 8.0 to 9.5 wt%</u>

[0027] Manganese (Mn), as an austenite phase-stabilizing element added as a Ni substitute, may be added in an amount of 8.0 wt% or more to enhance cold workability by inhibiting formation of strain-induced martensite. However, an excess of Mn causes an increase in formation of S-based inclusions (MnS) leading to deterioration of ductility and toughness austenitic stainless steels and may cause formation of Mn fumes during a steelmaking process resulting in increased manufacturing risks. Also, an excess of Mn rapidly deteriorates corrosion resistance of products. Therefore, an upper limit of the Mn content may be set to 9.5 wt%.

Chromium (Cr): 15.0 to 16.5 wt%

[0028] Chromium (Cr) is a ferrite-stabilizing element but effective on suppressing formation of a martensite phase. As a basic element for obtaining corrosion resistance required in stainless steels, Cr may be added in an amount of 15% or more. However, an excess of Cr, as a ferrite-stabilizing element, may promote formation of delta (δ) ferrite in a slab in large quantity resulting in deterioration of hot workability and adverse effects on material characteristics. Therefore, an upper limit thereof may be set to 16.5 wt%.

Nickel (Ni): greater than 0 wt% and at most 1.0 wt%

[0029] Nickel (Ni), as a strong austenite phase-stabilizing element, is added to improve hot workability and cold workability. However, because Ni is an expensive element, costs of raw materials may increase in the case of adding a large amount of Ni. Therefore, an upper limit of the Ni content may be set to 1.0% in consideration of both costs and efficiency of steel materials.

Copper (Cu): 0.8 to 1.8 wt%

[0030] Copper (Cu), as an austenite phase-stabilizing element added instead of nickel (Ni) in the present disclosure. Also, Cu, as an element improving corrosion resistance of steel materials under a reducing environment, may be added in an amount of 0.8 wt% or more. However, an excess of Cu not only increases costs of steel materials but also causes liquefaction and embrittlement at a low temperature. Also, an excess of Cu may be segregated in edges of a slab, thereby deteriorating hot workability of steel materials. Thus, an upper limit of the Cu content may be set to 1.8 wt% in consideration of costs, efficiency, and properties of steel materials.

[0031] The remaining component of the composition of the present disclosure is iron (Fe). However, the composition may include unintended impurities inevitably incorporated from raw materials or surrounding environments. In the present disclosure, addition of other unintended alloying elements in addition to the above-described alloying elements is not excluded. The impurities are not specifically mentioned in the present disclosure, as they are known to any person skilled in the art.

[0032] Examples of the unavoidable impurities include phosphorus (P) and sulfur (S), and at least one of P (at most 0.035 wt%) and S (at most 0.01 wt%) may be contained according to an embodiment of the present disclosure.

Phosphorus (P): at most 0.035 wt%

[0033] Phosphorus (P), as an impurity that is inevitably contained in steels, is a major causative element of grain boundary corrosion of steel materials or deterioration of hot workability, and therefore, it is preferable to control the P content as low as possible. In the present disclosure, an upper limit of the P content may be set to 0.035 wt%.

Sulfur (S): at most 0.01 wt%

[0034] Sulfur (S), as an impurity that is inevitably contained in steels, is a major causative element of deterioration of hot workability as being segregated in grain boundaries, and therefore, it is preferable to control the S content as low as possible. In the present disclosure, an upper limit of S may be set to 0.01 wt%.

[0035] It is important to improve yield strength of steel materials to decrease weight of the steel materials and enhance stability. In addition, sufficient elongation should be obtained to manufacture structural materials having various shape including battery module cases. In addition, in order to obtain price competitiveness of austenitic stainless steels, the amounts of expensive austenite-stabilizing elements such as Ni need to be reduced and the amounts of elements replacing the expensive elements such as Mn, N, and Cu should be appropriately adjusted.

[0036] However, in the case where the Ni content is reduced and Mn, N, and Cu are added, work hardening is rapidly increased to deteriorate elongation of a steel material and induce reduction in resistance to hot deformation, thereby deteriorating productivity, and thus harmony of the respective alloying elements should be considered. In consideration of the yield strength, elongation, and price competitiveness of steel materials as described above, the composition of alloying elements may further be limited to satisfy Expressions (1) to (4) in addition to the above-described composition.

[0037] In the present disclosure, in order to obtain excellent elongation of a cold-rolled, annealed steel sheet prepared by cold rolling and annealing the steel material, Expression (1) regarding a fraction of an austenite phase has been derived.

(1) $Ni+0.47Mn+15N \geq 7.5$

[0038] Here, Mn, Ni, and N denote contents (wt%) of the elements, respectively.

[0039] As the value of Expression (1) decreases, the fraction of the austenite phase decreases. When the value of Expression (1) is less than 7.5, the austenitic stainless steel may include delta ferrite in an amount of 5% or more or phase transformation into martensite phase occurs during cold rolling. As a result, elongation of the austenitic stainless steel may deteriorate, and thus a lower limit of the value of Expression (1) may be set to 7.5 in the present disclosure to obtain a sufficient elongation.

[0040] In addition, in order to obtain a high yield strength of the austenitic stainless steel, Expression (2) has been derived in the present disclosure in consideration that the yield strength is improved by a stress field of a steel material.

(2) $23(C+N)+1.3Si+0.24(Cr+Ni+Cu)+0.1Mn \geq 12$

[0041] Here, C, N, Si, Mn, Cr, Ni, and Cu represent contents (wt%) of the elements, respectively.

[0042] As the value of Expression (2) increases, a stress field between lattices increases due to size difference among the alloying elements so that a limit to withstand plastic deformation against external stress increases. When the value of Expression (2) is less than 12, it is difficult to obtain a yield strength required in the present disclosure. Therefore, a lower limit of the value of Expression (2) may be set to 12 in the present disclosure to obtain high strength characteristics.

[0043] In addition, in consideration of phase transformation caused by deformation of the austenitic stainless steel, Expression (3) has been derived in the present disclosure.

(3) $551-462(C+N)-9.2Si-8.1Mn-13.7Cr-29(Ni+Cu) \leq 70$

[0044] Here, C, N, Si, Mn, Cr, Ni, and Cu represent contents (wt%) of the elements, respectively.

[0045] As the value of Expression (3) increases, the austenite phase is easily transformed by an external stress. Specifically, when the value of Expression (3) exceeds 70, the austenitic stainless steel exhibits a rapid strain-induced martensite transformation behavior, causing non-uniform plastic processing. As a result, a problem of deteriorating elongation of the austenitic stainless steel may occur, and thus a lower limit of the value of Expression (3) may be set to 70.

[0046] In addition, in consideration of dislocation slip behavior of steel materials due to deformation of the austenitic stainless steel, Expression (4) has been derived.

(4) $11 \leq 1+45C-5Si+0.09Mn+2.2Ni-0.28Cr-0.67Cu+88.6N \leq 17$

[0047] Here, C, N, Si, Mn, Cr, Ni, and Cu represent contents (wt%) of the elements, respectively.

[0048] As the value of Expression (4) decreases, expression of cross slip of an austenite phase by an external stress becomes difficult. When the value of Expression (4) is less than 11, the austenitic stainless steel exhibits only a planar slip behavior with respect to deformation and dislocation is rapidly piled up by an external stress. As a result, problems of non-uniform plastic processing and high work hardening may occur. Accordingly, the elongation of the austenitic stainless steel may deteriorate, it may be difficult to perform the skin pass rolling, and hot rolling defects such as edge cracks may occur during deformation at a high temperature, thereby causing a problem of decreasing productivity. In consideration thereof, a lower limit of Expression (4) may be set to 11.

[0049] On the contrary, when the value of Expression (4) is too high, cross slip frequently occurs causing a problem of increasing plastic non-uniformity in which a stress is concentrated in a weak part of a steel material. As strength of a steel material increases, such embrittlement and plastic non-uniformity tend to increase, and thus elongation of steel materials having a high strength as in the present disclosure likely deteriorates. In consideration thereof, an upper limit of the value of Expression (4) may be set to 17.

[0050] Since Cr-Mn steels, in which the Ni content is reduced compared to commercially available 300 series austenitic stainless steels, have inferior hot workability, an actual yield may decrease due to occurrence of edge cracks during a hot processing and correcting costs may increase or there may be a need to invest additional equipment to reduce edge cracks. According to the present disclosure, excellent hot workability may be obtained by satisfying the above-described composition of alloying elements and appropriately designing the composition of alloying elements using Expressions (1) to (4) without adding a separate process and equipment. According to an embodiment of the present disclosure, the slab having the above-described composition of alloying elements may have a reduction of area of 50% or more at a high temperature of 800°C or higher.

[0051] In the low-cost austenitic stainless steel having high strength and high formability according to an embodiment of the present disclosure, a yield strength of a cold-rolled, annealed steel sheet may be 400 MPa. In addition, in the low-cost austenitic stainless steel having high strength and high formability, an elongation of the cold-rolled, annealed steel sheet may be 55% or more. In this regard, the "cold-rolled, annealed steel sheet" refers to a steel material prepared by treating a slab by hot rolling, annealing, cold rolling, and annealing.

[0052] In the low-cost austenitic stainless steel having high strength and high formability according to an embodiment of the present disclosure, a yield strength of a skin pass-rolled steel sheet may be 800 MPa or more. In addition, according to an embodiment, particularly, a yield strength may be 800 MPa or more and an elongation may be 25% or more. In this regard, the "skin pass-rolled steel sheet" refers to a steel material prepared by skin pass rolling the above-described cold-rolled, annealed steel sheet.

[0053] Hereinafter, a method for manufacturing the low-cost austenitic stainless steel having high strength and high formability according to the present disclosure will be described.

[0054] The method for manufacturing the low-cost austenitic stainless steel having high strength and high formability according to an embodiment of the present disclosure includes: preparing a slab including, in percent by weight (wt%), greater than 0% and at most 0.08% of C, 0.2 to 0.25% of N, 0.8 to 1.5% of Si, 8.0 to 9.5% of Mn, 15.0 to 16.5% of Cr, greater than 0% and at most 1.0% of Ni, 0.8 to 1.8% of Cu, and the remainder of Fe and other unavoidable impurities and satisfying Expressions (1) to (4); hot rolling the slab to prepare a hot-rolled steel sheet and hot annealing the hot-rolled steel sheet to prepare a hot-rolled, annealed steel sheet; cold rolling the hot-rolled, annealed steel sheet to prepare a cold-rolled steel sheet and cold annealing the cold-rolled steel sheet at a temperature of 1050°C or higher to prepare a cold-rolled, annealed steel sheet, and skin pass rolling the cold-rolled, annealed steel sheet to prepare a skin pass-rolled steel sheet.

[0055] Reasons for numerical limitations on the contents of the alloying elements and Expressions (1) to (4) are as described above. Hereinafter, each of the manufacturing steps will be described in detail.

[0056] The slab having the above-described composition of alloying elements may be hot-rolled at a temperature of 1000 to 1300°C to prepare a hot-rolled steel sheet, and then annealed at a temperature of 1000 to 1100°C to prepare a hot-rolled, annealed steel sheet. In this regard, annealing heat treatment may be performed for 10 seconds to 10 minutes.

[0057] Subsequently, the hot-rolled, annealed steel sheet is cold-rolled to prepare a cold-rolled steel sheet and then annealed to prepare a cold-rolled, annealed steel sheet. Conventionally, as a method for improving a yield strength of an austenitic stainless steel, low-temperature annealing heat treatment was performed at a low temperature of 1000°C or below after cold rolling as described above. The low-temperature annealing heat treatment is a method for increasing strength using energy accumulated in the steel material during cold rolling without completing recrystallization. However, in such an austenitic stainless steel that has undergone low-temperature annealing heat treatment, under pickling may occur during a subsequent picking process or aesthetic appearance may not be obtained as well as the possibility of non-uniform quality.

[0058] According to an embodiment of the present disclosure, the hot-rolled, annealed steel sheet is cold-rolled to prepare a cold-rolled steel sheet, and then annealed at a temperature of 1050°C or higher to prepare a cold-rolled, annealed steel sheet. In this case, the annealing heat treatment may be performed for 10 seconds to 10 minutes.

[0059] According to the present disclosure, excellent elongation may be obtained because low-temperature annealing is not performed after cold rolling, and an appropriate level of yield strength may be obtained by designing the composition of alloying elements.

[0060] The cold-rolled, annealed steel sheet according to the present disclosure may have a yield strength of 400 MPa or more.

[0061] The cold-rolled, annealed steel sheet according to the present disclosure may have an elongation of 55% or more.

[0062] By designing the composition of alloying elements as described above, a cold-rolled, annealed steel sheet may have an appropriate yield strength without performing low-temperature annealing treatment via a process which does not cause loads on production.

[0063] In addition, according to the present disclosure, high yield strength may be obtained via adjustment of the composition of alloying elements and subsequent skin pass rolling without performing low-temperature annealing treatment after cold rolling. According to an embodiment of the present disclosure, the yield strength of the skin pass-rolled steel sheet may be 800 MPa or more. The skin pass rolling may be performed at a reduction ratio 20% or more according to the present disclosure.

[0064] Skin pass rolling may increase strength by using a high work hardening phenomenon while the austenite phase is transformed into strain-induced martensite during cold deformation or using dislocation pile-up of a steel material. However, elongation of the steel material may rapidly deteriorate by skin pass rolling.

[0065] According to the present disclosure, a rapid decrease in elongation of a steel material, which is caused by skin pass rolling, may be prevented by appropriately controlling phase transformation and dislocation behavior by designing the composition of alloying elements as described above. As a result, a low-cost austenitic stainless steel having high strength and high formability, in which a skin pass-rolled steel sheet has a yield strength of 800 MPa or more and an elongation of 25% or more, may be provided according to an embodiment of the present disclosure.

[0066] Hereinafter, the present disclosure will be described in more detail through examples. However, it is necessary to note that the following examples are only intended to illustrate the present disclosure in more detail and are not intended to limit the scope of the present disclosure. This is because the scope of the present disclosure is determined by matters described in the claims and able to be reasonably inferred therefrom.

{Examples}

[0067] Slabs having compositions of allying elements shown in Table 1 below were prepared by ingot melting, heated at 1250°C for 2 hours, and hot-rolled to prepare hot-rolled steel sheets. Then, the hot-rolled steel sheets were subjected to annealing heat treatment at 1100°C for 90 seconds to prepare hot-rolled, annealed steel sheets. Subsequently, the steel materials were cold-rolled at a reduction ratio of 70% to prepare cold-rolled steel sheets and subjected to annealing heat treatment at 1100°C for 10 seconds to prepare cold-rolled, annealed steel sheets.

[0068] Compositions of alloying elements of each of inventive examples and comparative examples and values obtained by substituting the contents of the alloying elements into Expressions (1) and (4) are shown in Table 1 below.

$$\text{Ni}+0.47\text{Mn}+15\text{N} \geq 7.5 \tag{1}$$

$$23(\text{C}+\text{N})+1.3\text{Si}+0.24(\text{Cr}+\text{Ni}+\text{Cu})+0.1\text{Mn} \geq 12 \tag{2}$$

$$551-462(\text{C}+\text{N})-9.2\text{Si}-8.1\text{Mn}-13.7\text{Cr}-29(\text{Ni}+\text{Cu}) \leq 70 \tag{3}$$

$$11 \leq 1+45\text{C}-5\text{Si}+0.09\text{Mn}+2.2\text{Ni}-0.28\text{Cr}-0.67\text{Cu}+88.6\text{N} \leq 17 \tag{4}$$

Table 1

	Elements (wt%)							Expressi on (1)	Expressi on (2)	Expressi on (3)	Expressi on (4)
	C	Si	Mn	Ni	Cr	Cu	N				
Comparative Example 1	0.06	0.4	1.1	8.1	18.2	0.1	0.04	9.22	9.27	5.07	18.00
Comparative Example 2	0.05	2.0	9.5	0.1	16.0	2.0	0.13	6.52	12.03	92.39	0.02
Comparative Example 3	0.08	1.0	7.0	0.5	15.0	1.0	0.16	6.19	11.48	125.22	10.64
Comparative Example 4	0.08	0.5	6.0	0.5	15.0	1.0	0.16	5.72	10.73	137.92	13.05
Comparative Example 5	0.06	1.0	7.0	0.2	15.0	2.0	0.17	6.04	11.42	109.54	9.29
Comparative Example 6	0.06	2.0	8.0	0.2	15.0	2.0	0.19	6.81	13.28	83.00	6.15
Comparative Example 7	0.06	1.0	8.0	0.2	15.0	1.5	0.20	6.96	12.09	102.08	12.38
Comparative Example 8	0.06	1.2	8.1	0.6	15.6	2.1	0.21	7.56	12.97	57.59	12.58
Comparative Example 9	0.06	1.7	8.9	0.2	16.0	2.0	0.21	7.53	13.68	55.53	9.23
Comparative Example 10	0.06	2.2	8.2	0.7	15.3	2.2	0.19	7.40	13.80	55.13	6.05
Comparative Example 11	0.30	1.0	6.0	0.2	16.0	0.0	0.18	5.72	16.83	46.44	21.95
Comparative Example 12	0.20	1.0	7.0	0.2	16.0	0.0	0.18	6.19	14.63	84.54	17.54
Inventive Example 1	0.08	1.0	8.9	1.0	16.0	1.0	0.20	8.18	12.95	63.15	15.17
Inventive Example 2	0.06	1.0	8.6	0.8	15.7	1.7	0.21	7.99	12.74	59.81	14.31
Inventive Example 3	0.06	1.0	9.0	1.0	15.8	1.3	0.23	8.68	13.21	51.76	16.79
Inventive Example 4	0.07	1.05	8.7	0.9	15.6	1.3	0.21	8.14	12.95	63.99	15.03

[0069] Yield strength, tensile strength, and elongation of the each of the cold-rolled, annealed steel sheets of the inventive examples and comparative examples were measured. Also, yield strength, tensile strength, and elongation of skin pass-rolled steel sheets respectively prepared by skin pass rolling the cold-rolled, annealed steel sheets according to the inventive examples and comparative examples by 20% were measured.

[0070] The measurement of the yield strength, tensile strength, and elongation was carried out according to the ASTM standards, and the measured yield strength (YS, MPa), tensile strength (TS, MPa) and elongation (EL, %) are shown in Table 2 below. Also, occurrence of cracks in annealed materials was measured after a 180° adhesion bending test and results are shown in Table 2 below.

Table 2

	Cold-rolled steel sheet			Skin pass-rolled steel sheet			Cracks by bending test (○/×)
	YS (MPa)	TS (MPa)	EL (%)	YS (MPa)	TS (MPa)	EL (%)	
Comparative Example 1	300.0	697.0	52.2	624.4	876.3	32.1	×
Comparative Example 2	501.6	862.1	55	940.8	1205.3	20.2	○
Comparative Example 3	379.7	1133.7	38.1	850.4	1517.5	14.9	○
Comparative Example 4	311.4	1324.0	28.1	893.7	1652.2	11.9	○
Comparative Example 5	362.9	958.3	39.8	920.3	1430.5	20.3	○
Comparative Example 6	435.9	1050.8	58.7	918.1	1397.8	26.1	○
Comparative Example 7	461.9	1028.2	50.3	953	1413.9	22.8	○
Comparative Example 8	427.7	878.8	59.7	802.8	1210.7	26.7	×
Comparative Example 9	457.6	888	58.7	848	1220.2	27.7	×
Comparative Example 10	462.6	930.6	57.3	933.6	1332.6	23.7	○
Comparative Example 11	508.7	948.2	32.2	881.1	1416.8	15.9	○
Comparative Example 12	464.3	914.4	25.8	840.5	1313.5	12.3	○
Inventive Example 1	435.2	938.1	57.6	801.7	1288	25.5	×
Inventive Example 2	432.5	878.7	59.5	841.8	1233.6	25.5	×
Inventive Example 3	453.1	876.6	60.1	894.6	1261	25.3	×
Inventive Example 4	442.7	860.5	60.4	851.8	1233.1	26.3	×

[0071] Referring to Table 2, in the case of Inventive Examples 1 to 4 satisfying the composition of alloying elements suggested by the present disclosure and satisfying Expressions (1) to (4), it was confirmed that the cold-rolled, annealed steel sheets had yield strengths of 400 MPa or more and elongations of 55% or more. In addition, referring to Table 2, the skin pass-rolled steel sheets of Inventive Examples 1 to 4 had yield strengths of 800 MPa or more and sufficient elongations of 25% or more even after skin pass rolling. In addition, it was confirmed that the steel materials according to Inventive Examples 1 to 4 had price competitiveness due to relatively low Ni contents of 1.0 wt% or less.

[0072] Referring to Tables 1 and 2, the steel materials according to comparative examples will be evaluated.

[0073] The steel material according to Comparative Example 1, as a commercially available standard austenitic stainless steel, had a low yield strength because the steel material did not satisfy the composition of alloying elements of the present disclosure and Expressions (2), (3), and (4). Also, the commercial austenitic stainless steel of Comparative Example 1 had inferior price competitiveness due to the high Ni content of 8.1 wt% which is far higher than that of the Ni content according to the present disclosure.

[0074] Because Comparative Example 2 does not satisfy Expression (1), a considerable amount of initial delta ferrite remains in the steel material after cold rolling and annealing. Cracks easily occur at an interface between delta ferrite phase and austenite phase during a forming process such as bending a steel material due to a phase difference, and thus a low value of Expression (1) involves cracks when bent. As a result, although Comparative Example 2 exhibited a high yield strength due to the high Si content and a high elongation, cracks occurred by the bending test due to the remaining delta ferrite indicating inferior formability including bending characteristics.

[0075] All of the steel materials according to Comparative Examples 3 to 5 are steel types not satisfying Expressions (1) to (4). Because Expression (1) was not satisfied, considerable amounts of initial delta ferrite remained in the steel materials after cold rolling and annealing, and thus formability including bending characteristics was inferior. In addition, because Expression (2) was not satisfied, low yield strengths were obtained. In addition, because the value of Expression (3) exceeds 100, plastic non-uniformity easily occurs due to phase transformation into strain-induced martensite. In addition, due to the too low value of Expression (4), serious dislocation pile-up occurred by planar slip. As a result, elongation deteriorated. Particularly, elongations of Comparative Examples 3 to 5, which deteriorate because Expressions (3) and (4) were not satisfied, further deteriorated after skin pass rolling, so that physical properties of the steel materials were not suitable as skin pass-rolled steel sheets.

[0076] In Comparative Example 6, inferior formability including bending characteristics was obtained because Expression (1) was not satisfied and thus a considerable amount of initial delta ferrite remained in the steel material after cold rolling and annealing. In addition, although the steel material of Comparative Example 6 had the high yield strength due to the high Si content and Expression (2), the elongation was not sufficient due to effects of Expressions (3) and (4).

[0077] The steel material of Comparative Example 7 had inferior formability including bending characteristics because Expression (1) was not satisfied and thus a considerable amount of initial delta ferrite remained in the steel material after cold rolling and annealing. Also, plastic non-uniformity easily occurs during deformation due to phase transformation into strain-induced martensite because the value of Expression (3) was over 100, which did not satisfy Expression (3). Therefore, the cold-rolled, annealed steel sheet and the skin pass-rolled steel sheet had inferior elongation.

[0078] The steel material of Comparative Example 8 satisfied the contents of the alloying elements except for Cu and satisfied Expressions (1) to (4). Thus, the cold-rolled, annealed steel sheet had excellent yield strength and elongation. However, Comparative Example 8 had inferior hot workability due to an excessive Cu content. Evaluation thereof will be described below in more detail with reference to Table 3.

[0079] The steel materials according to Comparative Examples 9 and 10 had inferior hot workability due to excessive amounts of Si and Cu. Evaluation thereof will be described below in more detail with reference to Table 3.

[0080] The steel materials according to Comparative Examples 11 and 12 had inferior formability including bending characteristics due to a considerable amount of initial delta ferrite remaining in the steel material after cold rolling and annealing because Expression (1) was not satisfied. Also, plastic non-uniformity, in which stress is concentrated on weak parts of the steel materials, increased due to frequent cross slip in Comparative Examples 11 and 12 because the values of Expression (4) were too high. As a result, the cold-rolled, annealed steel sheet and the skin pass-rolled steel sheet had inferior elongation. Although effects of the stress concentrated by cross slip on elongation are negligible in commercial steel materials, elongation significantly deteriorate in high-strength steel materials having too high values of Expression (2) as in Comparative Examples 11 and 12.

[0081] The austenitic stainless steel according to the present disclosure has excellent price competitiveness due to high productivity and high actual yield due to excellent hot workability. For comparative evaluation of hot workability, reduction of area was measured in slabs of several comparative examples with high elongation and the inventive examples at different temperatures. Measurement of the reduction of area was performed according to the ASTM standards by a high-temperature tensile test, and results are shown in Table 3.

Table 3

	Reduction of area at different temperatures (%)				
	800°C	900°C	1000°C	1100°C	1200°C
Comparative Example 1	81.4	78.7	76.3	84.7	96.3

(continued)

	Reduction of area at different temperatures (%)				
	800°C	900°C	1000°C	1100°C	1200°C
Comparative Example 2	40.3	43.6	53.4	66.6	88.2
Comparative Example 6	42.5	50.5	69.5	88.1	95.2
Comparative Example 7	52.8	57.2	69.3	82.4	95.2
Comparative Example 8	43.2	48.7	64.7	85.3	93.4
Comparative Example 9	41.2	48.5	55.2	68.2	91.0
Comparative Example 10	40.9	45.6	55.4	66.6	90.2
Inventive Example 1	53.3	64	75.1	88.7	96.6
Inventive Example 2	50.1	54.7	71.1	87.1	97.0
Inventive Example 3	60.0	56.9	66.2	84.5	95.8
Inventive Example 4	55.8	52.8	58.2	85.2	96.9

[0082] Referring to Table 3, it was confirmed that reductions of area of 50% or more were obtained at a high temperature of 800°C or higher in the case of Inventive Examples 1 to 4 satisfying the composition of alloying elements suggested by the present disclosure and satisfying Expressions (1) to (4).

[0083] As a commercial standard austenitic stainless steel, the steel material according to Comparative Example 1 had excellent hot workability due to low amounts of Cu and N added to reduce the amounts of Si and Ni, which are required to increase strength. However, a large amount of Ni, which is an expensive element, is contained in the commercial 300 series austenitic stainless steels, the 300 series austenitic stainless steels have considerably low price competitiveness. In addition, as evaluated in Table 2, the steel material had inferior yield strength because the composition of alloying elements and Expressions (2), (3), and (4) were not satisfied.

[0084] In Comparative Examples 2, 6, 9, and 10, excessive amounts of Si were added to improve yield strength of the cold-rolled, annealed steel sheets and excessive amounts of Cu replacing Ni were added for price competitiveness. The steel materials according to Comparative Examples 2, 6, 9, and 10 had low hot workability due to excessive amounts of Si and Cu.

[0085] Because Si and Cu, which deteriorate hot workability, were added within the ranges suggested in the present disclosure, the steel material according to Comparative Example 7 had excellent hot workability. However, as evaluated in Table 2, the steel material had inferior formability because Expression (1) was not satisfied and had inferior elongation of the cold-rolled, annealed steel sheet and the skin pass-rolled steel sheet because Expression (3) was not satisfied.

[0086] The Cu content of Comparative Example 8 exceeded the range suggested by the present disclosure. Excessive Cu was segregated on edges or surface of slabs causing liquid metal embrittlement, thereby deteriorating hot workability of Comparative Example 8. In Comparative Example 8, due to inferior hot workability, actual yield may decrease due to edge cracks occurring after hot rolling, correcting costs therefor may increase, or investment for additional equipment to reduce edge cracks may be required.

[0087] While the present disclosure has been particularly described with reference to exemplary embodiments, it should be understood by those of skilled in the art that various changes in form and details may be made without departing from the spirit and scope of the present disclosure.

[Industrial Applicability]

[0088] According to the present disclosure, a low-cost austenitic stainless steel having high strength and high formability applicable throughout various industrial fields may be provided.

Claims

1. A low-cost austenitic stainless steel having high strength and high formability comprising, in percent by weight (wt%), greater than 0% and at most 0.08% of C, 0.2 to 0.25% of N, 0.8 to 1.5% of Si, 8.0 to 9.5% of Mn, 15.0 to 16.5% of Cr, greater than 0% and at most 1.0% of Ni, 0.8 to 1.8% of Cu, and the remainder of Fe and other unavoidable

impurities and
satisfying Expressions (1) to (4) below:

(1) $Ni+0.47Mn+15N \geq 7.5$

(2) $23(C+N)+1.3Si+0.24(Cr+Ni+Cu)+0.1Mn \geq 12$

(3) $551-462(C+N)-9.2Si-8.1Mn-13.7Cr-29(Ni+Cu) \leq 70$

(4) $11 \leq 1+45C-5Si+0.09Mn+2.2Ni-0.28Cr-0.67Cu+88.6N \leq 17$

(wherein C, N, Si, Mn, Cr, Ni, and Cu represent contents (wt%) of the elements, respectively).

2. The low-cost austenitic stainless steel according to claim 1, wherein a yield strength of a cold-rolled, annealed steel sheet is 400 MPa or more.

3. The low-cost austenitic stainless steel according to claim 1, wherein an elongation of a cold-rolled, annealed steel sheet is 55% or more.

4. The low-cost austenitic stainless steel according to claim 1, wherein a yield strength of a skin pass-rolled steel sheet is 800 MPa or more.

5. The low-cost austenitic stainless steel according to claim 4, wherein an elongation of the skin pass-rolled steel sheet is 25% or more.

6. A method for manufacturing a low-cost austenitic stainless steel having high strength and high formability, the method comprising:

preparing a slab including, in percent by weight (wt%), greater than 0% and at most 0.08% of C, 0.2 to 0.25% of N, 0.8 to 1.5% of Si, 8.0 to 9.5% of Mn, 15.0 to 16.5% of Cr, greater than 0% and at most 1.0% of Ni, 0.8 to 1.8% of Cu, and the remainder of Fe and other unavoidable impurities and satisfying Expressions (1) to (4) below;
hot rolling the slab to prepare a hot-rolled steel sheet and hot annealing the hot-rolled steel sheet to prepare a hot-rolled, annealed steel sheet;
cold rolling the hot-rolled, annealed steel sheet to prepare a cold-rolled steel sheet and cold annealing the cold-rolled steel sheet at a temperature of 1050°C or higher to prepare a cold-rolled, annealed steel sheet; and
skin pass rolling the cold-rolled, annealed steel sheet to prepare a skin pass-rolled steel sheet:

(1) $Ni+0.47Mn+15N \geq 7.5$

(2) $23(C+N)+1.3Si+0.24(Cr+Ni+Cu)+0.1Mn \geq 12$

(3) $551-462(C+N)-9.2Si-8.1Mn-13.7Cr-29(Ni+Cu) \leq 70$

(4) $11 \leq 1+45C-5Si+0.09Mn+2.2Ni-0.28Cr-0.67Cu+88.6N \leq 17$

(wherein C, N, Si, Mn, Cr, Ni, and Cu represent contents (wt%) of the elements, respectively).

7. The method according to claim 6, wherein the skin pass rolling is performed at a reduction ratio of 20% or more.

8. The method according to claim 6, wherein the slab has a reduction of area of 50% or more at a high temperature of 800°C or higher.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/KR2021/001345

A. CLASSIFICATION OF SUBJECT MATTER

C22C 38/58(2006.01)i; **C22C 38/42**(2006.01)i; **C22C 38/00**(2006.01)i; **C21D 8/02**(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

C22C 38/58(2006.01); C21D 8/02(2006.01); C22C 38/00(2006.01); C22C 38/04(2006.01); C22C 38/18(2006.01); C22C 38/38(2006.01); C22C 38/40(2006.01); C22C 38/60(2006.01)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Korean utility models and applications for utility models: IPC as above
Japanese utility models and applications for utility models: IPC as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

eKOMPASS (KIPO internal) & keywords: 스테인리스강(stainless steel), 오스테나이트(austenite), 조질압연(skin pass), 고강도(high strength), 고성형(high formability), 항복강도(yield strength), 연신율(elongation)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	KR 10-2008-0106200 A (NIPPON STEEL & SUMIKIN STAINLESS STEEL CORPORATION) 04 December 2008 (2008-12-04) See paragraphs [0046]-[0047], [0049] and [0052] and claim 1.	1-8
A	JP 2015-206118 A (OUTOKUMPU OY) 19 November 2015 (2015-11-19) See paragraphs [0012]-[0027] and claims 1-7.	1-8
A	KR 10-2006-0075725 A (POSCO) 04 July 2006 (2006-07-04) See claims 1-4 and table 2.	1-8
A	KR 10-1952818 B1 (POSCO) 28 February 2019 (2019-02-28) See claims 1-5 and 7-10.	1-8
A	KR 10-0641577 B1 (POSCO) 31 October 2006 (2006-10-31) See claim 1.	1-8

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

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
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"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
26 July 2021	**27 July 2021**

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/KR2021/001345

Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
KR 10-2008-0106200 A	04 December 2008	CN 101410543 A	15 April 2009
		CN 101410543 B	06 April 2011
		EP 2060646 A1	20 May 2009
		EP 2060646 B1	17 June 2015
		JP 2008-163358 A	17 July 2008
		JP 5165236 B2	21 March 2013
		US 2010-0233015 A1	16 September 2010
		WO 2008-078457 A1	03 July 2008
JP 2015-206118 A	19 November 2015	AU 2011-249711 A1	10 January 2013
		AU 2011-249711 B2	12 May 2016
		BR 112012028294 A2	01 November 2016
		CA 2797328 A1	10 November 2011
		CN 102985579 A	20 March 2013
		CN 102985579 B	06 May 2015
		EA 024633 B1	31 October 2016
		EA 201290986 A1	30 May 2013
		EP 2566994 A1	13 March 2013
		FI 125442 B	15 October 2015
		FI 20100196 A0	06 May 2010
		JP 2013-527320 A	27 June 2013
		JP 6148174 B2	14 June 2017
		JP 6236030 B2	22 November 2017
		KR 10-1473072 B1	15 December 2014
		KR 10-2013-0004513 A	10 January 2013
		MX 2012012874 A	29 November 2012
		MX 339084 B	10 May 2016
		MY 162515 A	15 June 2017
		TW 201204842 A	01 February 2012
		TW I510648 B	01 December 2015
		US 2013-0039802 A1	14 February 2013
		US 9039961 B2	26 May 2015
		WO 2011-138503 A1	10 November 2011
KR 10-2006-0075725 A	04 July 2006	None	
KR 10-1952818 B1	28 February 2019	CN 111133122 A	08 May 2020
		EP 3674435 A1	01 July 2020
		WO 2019-059660 A1	28 March 2019
KR 10-0641577 B1	31 October 2006	KR 10-2006-0110103 A	24 October 2006

Form PCT/ISA/210 (patent family annex) (July 2019)