



(12) **EUROPEAN PATENT APPLICATION**
published in accordance with Art. 153(4) EPC

(43) Date of publication:
31.01.2018 Bulletin 2018/05

(51) Int Cl.:
C22C 38/00 (2006.01) **C22C 38/58** (2006.01)
C22C 38/60 (2006.01) **C21D 9/46** (2006.01)

(21) Application number: **16768525.4**

(86) International application number:
PCT/JP2016/057967

(22) Date of filing: **14.03.2016**

(87) International publication number:
WO 2016/152622 (29.09.2016 Gazette 2016/39)

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
Designated Validation States:
MA MD

(30) Priority: **26.03.2015 JP 2015065028**

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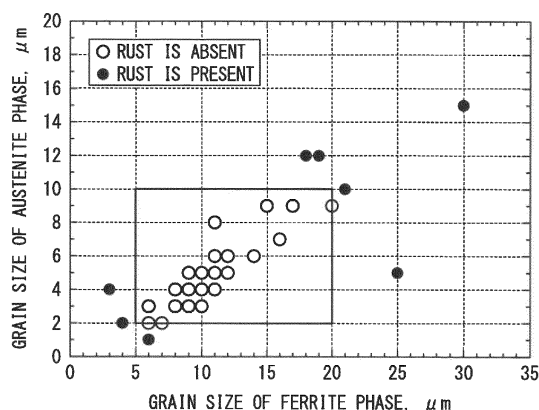
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(54) **FERRITE-AUSTENITE STAINLESS STEEL SHEET WITH EXCELLENT SHEARED END FACE CORROSION RESISTANCE**

(57) The present invention relates to a ferritic-austenitic stainless steel sheet that is used in an atmospheric environment without performing a corrosion resistance treatment, and provides a ferritic-austenitic stainless steel sheet in which the corrosion resistance of the sheared line is improved. The ferritic-austenitic stainless steel sheet of the present invention includes, in terms of % by mass: C: 0.03% or less; Si: 0.1% to 1.0%; Mn: 0.5% to 5.0%; P: 0.04% or less; Al: 0.015% to 0.10%; Cr: 19.0% to 24.0%; Ni: 0.60% to 2.30%; Cu: 0.5% to 1.5%; Co: 0.05% to 0.25%; V: 0.01% to 0.15%; Ca: 0.002% or less; N: 0.06% to 0.20%; and S: 0.0002% to 0.0040%, with the remainder being Fe and unavoidable impurities, wherein a value of Co + 0.25V is 0.10 or more and less than 0.25, a metallic structure consists of ferrite phases and austenite phases, an average crystal grain size of the ferrite phases is 5 to 20 μm , and an average crystal grain size of the austenite phases is 2 to 10 μm , and sulfides having major axes of 1 to 5 μm exist at an amount of 5 to 20 pieces per 5 mm^2 .

FIG. 1



Description

TECHNICAL FIELD

[0001] The present invention relates to a ferritic-austenitic (dual phase, duplex) stainless steel sheet with excellent sheared end face corrosion resistance (excellent corrosion resistance of a sheared end face (sheared line)). Particularly, the present invention relates to a ferritic-austenitic (ferrite-austenite) stainless steel sheet that is suitable for use in an atmospheric environment in a state just as a sheared state where the steel sheet is just as it is sheared and a sheared line is not subjected to a corrosion resistance treatment.

[0002] The present application claims priority on Japanese Patent Application No. 2015-065028 filed on March 26, 2015, the content of which is incorporated herein by reference.

BACKGROUND ART

[0003] Ferritic-austenitic (dual phase, duplex) stainless steel is used in a wide range of applications due to excellent strength and corrosion resistance. Examples of the applications include various uses such as a solar cell frame that is not necessary to be processed, and a support component for an outdoor pipeline that is difficult to be processed.

[0004] In the process of manufacturing the ferritic-austenitic stainless steel sheet, cutting-out, shaping, and punching of the steel sheet by shearing are frequently performed in many cases due to convenience of the shearing. In addition, typically, the ferritic-austenitic stainless steel sheet is used in a state just as a sheared state where the steel sheet is just as it is sheared and a sheared line is not subjected to a corrosion resistance treatment.

[0005] If a ferritic-austenitic stainless steel is used in a state where the ferritic-austenitic stainless steel is sheared and the end face is not subjected to a corrosion resistance treatment, corrosion of the end face (end face corrosion and end face rust) is severer than corrosion of a smooth surface. The end face corrosion becomes a cause of flowed rust and another iron originated rust, and as a result, the end face corrosion becomes a cause of deteriorating the corrosion resistance of the whole steel sheet. The problem related to the end face rust is not considered as an important matter in a ferritic-austenitic stainless steel because corrosion resistance is maintained to a certain degree due to passivation even in the end face of the ferritic-austenitic stainless steel that is unlike a plated steel sheet in which a base material is exposed.

[0006] However, usage environments of the ferritic-austenitic stainless steel are expanded as the market of the ferritic-austenitic stainless steel is expanded, and a difference in the corrosion resistance between the smooth surface and the end face becomes a problem. In the ferritic-austenitic stainless steel sheet, ferrite phases and austenite phases exist at room temperature, and the ferrite phases that exist in the sheared line become a cause of rust.

[0007] It is known that rust on the end face of ferritic stainless steel occurs due to micro-crevice corrosion due to unevenness. The crevice corrosion has been examined in the related art, and recently, Patent Document 1, Patent Document 2, and the like disclose ferritic stainless steel sheets with excellent crevice corrosion resistance.

[0008] These ferritic stainless steel sheets have an effect on local corrosion such as the crevice corrosion. However, it cannot be said that the effect is sufficient for reducing rusting (occurrence of rust) on the sheared line, and end face corrosion occurred in some cases.

[0009] In view of these circumstances, Patent Document 3 which focuses on burr morphologies on the end face discloses a ferritic stainless steel sheet with excellent corrosion resistance of a sheared line. In addition, Patent Document 4 discloses a processing method for obtaining a favorable shape of a sheared line.

[0010] As a method for improving the corrosion resistance of the end face of the ferritic stainless steel, various technologies have been examined and developed until now.

[0011] However, the ferritic-austenitic stainless steel has high-strength characteristics in comparison to the ferritic stainless steel. Therefore, properties of a sheared surface of the ferritic-austenitic stainless steel are greatly different from properties of a sheared surface of the ferritic stainless steel. In addition to a shape of the shear plane, a minute crevice shape is likely to be formed due to a difference in strength between the austenite phase and the ferrite phase, and this minute crevice shape has an effect on the corrosion resistance. Therefore, mere the methods of the related art disclosed in the above-described Patent Documents are not sufficient to improve the corrosion resistance of a sheared line of the ferritic-austenitic stainless steel, and a problem related to the occurrence of rust on the sheared line still remains.

PRIOR ART DOCUMENTS

Patent Documents

[0012]

Patent Document 1: Japanese Unexamined Patent Application, First Publication No. 2005-89828

Patent Document 2: Japanese Unexamined Patent Application, First Publication No. 2006-257544

Patent Document 3: Japanese Patent No. 5375069

Patent Document 4: Japanese Unexamined Patent Application, First Publication No. 2010-137344

DISCLOSURE OF THE INVENTION

Problems to be Solved by the Invention

[0013] The present invention has been made in consideration of the above-described problem, and an object thereof is to provide a ferritic-austenitic stainless steel sheet in which corrosion resistance of a sheared line is improved with respect to the ferritic-austenitic stainless steel sheet that is used in the atmospheric environment in a state of not being subjected to a corrosion resistance treatment.

Means for Solving the Problem

[0014] The present inventors have made various examinations to realize an improvement of the corrosion resistance of a sheared line of the ferritic-austenitic stainless steel sheet. Particularly, the present inventors have made a thorough observation with respect to a corrosion state of the sheared line. As a result, they found that the origin of corrosion exists on a fracture surface, and a reduction in the fracture surface and a reduction in surface roughness of the fracture surface lead to prevention of corrosion.

[0015] Here, the fracture surface is one of surface states called "undercut", "sheared surface (shear plane)", "fracture surface", and "burr" which are confirmed when observing a processed surface after shearing the steel sheet.

[0016] Accordingly, the present inventors have made a further examination on the improvement of the corrosion resistance. As a result, they obtained the following finding. That is, when controlling crystal grain sizes of ferrite phases and austenite phases in appropriate ranges and when generating sulfides to exist appropriately in a steel, it is effective for an improvement of the fracture surface. In addition, the present inventors also obtained the following finding. When minute amounts of Co and V are added as a component that improves the corrosion resistance, the corrosion resistance of the austenite phase and the ferrite phase is improved. As a result, the corrosion resistance of a shared portion is improved.

[0017] An aspect of the invention is made on the basis of the above-described findings, and the features thereof are as follows.

(1) According to the aspect of the invention, there is provided a ferritic-austenitic stainless steel sheet with excellent corrosion resistance of a sheared line. The ferritic-austenitic stainless steel sheet has a chemical composition containing, in terms of % by mass: C: 0.03% or less; Si: 0.1% to 1.0%; Mn: 0.5% to 5.0%; P: 0.04% or less; Al: 0.015% to 0.10%; Cr: 19.0% to 24.0%; Ni: 0.60% to 2.30%; Cu: 0.5% to 1.5%; Co: 0.05% to 0.25%; V: 0.01% to 0.15%; Ca: 0.002% or less; N: 0.06% to 0.20%; and S: 0.0002% to 0.0040%, with the remainder being Fe and unavoidable impurities. A value of $Co + 0.25V$ is 0.10 or more and less than 0.25, a metallic structure consists of ferrite phases and austenite phases, an average crystal grain size of the ferrite phases is in a range of 5 to 20 μm , an average crystal grain size of the austenite phases is in a range of 2 to 10 μm , and sulfides having major axes of 1 to 5 μm exist at an amount of 5 to 20 pieces per 5 mm^2 .

(2) The ferritic-austenitic stainless steel sheet with excellent corrosion resistance of a sheared line according to (1) may further contain one or more selected from the following groups.

[0018] First group: one or more selected from, in terms of % by mass, Nb: 0.005% to 0.2%, Ti: 0.005% to 0.2%, W: 0.005% to 0.2%, and Mo: 0.01% to 1.0%.

[0019] Second group: one or more selected from, in terms of % by mass, Sn: 0.005% to 0.2%, Sb: 0.005% to 0.2%, Ga: 0.001% to 0.05%, Zr: 0.005% to 0.5%, Ta: 0.005% to 0.1%, and B: 0.0002% to 0.0050%.

(3) In the ferritic-austenitic stainless steel sheet with excellent corrosion resistance of a sheared line according to (1) or (2), a value of $Co + 0.25V$ may be 0.12 or more and less than 0.25.

(4) In the ferritic-austenitic stainless steel sheet with excellent corrosion resistance of a sheared line according to any one of (1) to (3), the amount of each of one or more selected from Co, V, S, N, Cr, and Ni may satisfy the following range in terms of % by mass,

Co: 0.05% to 0.12%, V: 0.08% to 0.12%, S: 0.0003% to 0.0010%, N: 0.08% to 0.17%, Cr: 20.0% to 23.0%, and Ni: 1.0% to 1.5%.

(5) In the ferritic-austenitic stainless steel sheet with excellent corrosion resistance of a sheared line according to any one of (1) to (3), the amount of V may satisfy the following range in terms of % by mass,

V: 0.01% or more and less than 0.05%.

(6) In the ferritic-austenitic stainless steel sheet with excellent corrosion resistance of a sheared line according to (5), the amount of each of one or more selected from Co, S, N, Cr, and Ni may satisfy the following range in terms of % by mass,

Co: 0.05% to 0.12%, S: 0.0003% to 0.0010%, N: 0.08% to 0.17%, Cr: 20.0% to 23.0%, and Ni: 1.0% to 1.5%.

Effects of the Invention

[0020] According to the aspect of the invention, in a ferritic-austenitic stainless steel sheet that is used mainly in an atmospheric environment in a state in which a sheared line is not subjected to a corrosion resistance treatment, it is possible to realize an improvement of the corrosion resistance of the sheared line. Therefore, it is possible to improve the corrosion resistance of the entire ferritic-austenitic stainless steel sheet. As a result, it is possible to prevent loss of aesthetic exterior appearance, a decrease in lifespan, and the like due to corrosion of the steel sheet.

BRIEF DESCRIPTION OF THE DRAWINGS

[0021]

FIG. 1 is a graph showing a relationship between the average crystal grain size of ferrite phases and the average crystal grain size of austenite phases which have an effect on corrosion resistance after shearing.

FIG. 2 is a graph showing a relationship between the size and the number of sulfides which have an effect on the corrosion resistance after the shearing.

EMBODIMENTS FOR CARRYING OUT THE INVENTION

[0022] Hereinafter, an embodiment of a ferritic-austenitic stainless steel sheet (hereinafter, may also be referred to as "steel sheet" in brief) of the present invention will be explained.

[0023] First, the reason why a component composition of the steel sheet according to the present embodiment is limited will be explained. "%" in components of steel represents "% by mass" unless otherwise stated.

C: 0.03% or less

[0024] C is an element that is unavoidably mixed in steel. In the case where the amount of C is more than 0.03%, Cr_{23}C_6 precipitates in an austenite phase and a ferrite phase, and a crystal grain boundary is sensitized. Accordingly, the corrosion resistance deteriorates. As a result, the amount of C is preferably as small as possible, and can be permitted up to 0.03%. The lower limit of the amount of C is not particularly limited. From the viewpoints of productivity and cost, the amount of C is preferably 0.002% or more, and more preferably 0.008% or more. The upper limit of the amount of C is preferably 0.025% or less.

Si: 0.1% to 1.0%

[0025] Si is an element that is useful as a deoxidizing agent. However, in the case where the amount of Si (content rate) is less than 0.1%, a sufficient deoxidizing effect is not obtained, and a large amount of oxides are dispersed in steel. Accordingly, an amount of origins of fracture during press working increases. On the other hand, in the case where Si is added at an amount of more than 1.0%, a ferrite phase becomes hard, and workability deteriorates. Accordingly, the amount of Si is set to be in a range of 0.1 % to 1.0%. The amount of Si is preferably 0.3% or more, and is preferably set to be 0.7% or less so as to further prevent the deterioration of workability.

Mn: 0.5% to 5.0%

[0026] Mn has a deoxidizing effect. In addition, in the present embodiment, the inventors found that when controlling a dispersion state of MnS, there is an effect of preventing an increase in surface roughness at a fracture surface portion in a sheared line. Although not clear, this mechanism is assumed as follows.

[0027] Specifically, when MnS particles exist which are relatively fine to a certain extent that does not have an effect on the corrosion resistance, propagation of cracks on a fracture surface becomes easy; and as a result, a linear shape of fracture surface is likely to occur. However, in the steel sheet of the present embodiment in which the amount of S is small, the effect is not obtained in the case where the amount of Mn is less than 0.5%. On the other hand, in the case where the amount of Mn is more than 5.0%, a Mn oxide starts to be generated in a passivation film, and deterioration

of the corrosion resistance is caused on the contrary. Accordingly, the amount of Mn is limited to a range of 0.5% to 5.0%. The amount of Mn is preferably set to be 1.0% or more from the viewpoint of preventing a decrease in surface roughness. It is preferable that the amount of Mn is set to be 4.0% or less so as to further prevent the generation of Mn oxide in the passivation film.

P: 0.04% or less

[0028] P is an element that deteriorates the corrosion resistance. In addition, P segregates at a crystal grain boundary; and thereby, P deteriorates hot workability. Therefore, in the case where P is added in an excessive amount, it becomes difficult to manufacture the steel of the present embodiment. Accordingly, the amount of P is preferably as small as possible. However, the amount of P can be permitted to 0.04% or less. As a result, the amount of P is limited to 0.04% or less. The amount of P is preferably 0.03% or less.

Al: 0.015% to 0.10%

[0029] Al is an effective component for deoxidation, and it is necessary for Al to be contained at an amount of 0.015% or more. On the other hand, in the case where the amount of Al is more than 0.10%, a surface defect due to Al-based non-metallic inclusions increases and Al-based non-metallic inclusions become the origins of fracture. Accordingly, the amount of Al is set to be 0.015% to 0.10%. The amount of Al is preferably set to be 0.02% or more from the viewpoint of sufficiently obtaining the deoxidizing effect. It is preferable that the amount of Al is set to be 0.05% or less so as to further prevent the generation of the Al-based non-metallic inclusions.

Cr: 19.0% to 24.0%

[0030] Cr is an important element that determines the corrosion resistance of stainless steel. In the present embodiment, approximately 50% of the ferrite phases and approximately 50% of the austenite phases are mixed in a structure. In the case where the structure is separated into two phases, Cr is concentrated in the ferrite phase. On the other hand, in the austenite phase, the amount of Cr decreases, but N that is an austenite generating element is concentrated. 19.0% or more of Cr is contained so as to secure the corrosion resistance of the austenite phase. The amount of Cr is preferably 20.0% or more.

[0031] On the other hand, in the case where the amount of Cr is more than 24.0%, a σ -phase is likely to be generated in the ferrite phase, and the generation of the σ -phase leads to hardening of a steel and deterioration of the corrosion resistance. Accordingly, the amount of Cr is set to be 24.0% or less. The amount of Cr is preferably 23.0% or less.

Cu: 0.5% to 1.5%

[0032] Cu has an effect of forming a film on a surface of stainless steel after occurrence of corrosion, and reducing dissolution of a base material due to an anodic reaction. Accordingly, Cu is an element that is also useful for an improvement of rust resistance and an improvement of crevice corrosion resistance.

[0033] In the case where the amount of Cu is less than 0.5%, it is difficult to expect the above-described effects. On the other hand, in the case where the amount of Cu is more than 1.5%, embrittlement at a high temperature is promoted, and hot workability deteriorates. Accordingly, the amount of Cu is limited to a range of 0.5% to 1.5%. The amount of Cu is preferably set to be 0.7% or more from the viewpoint of improving the rust resistance and the crevice corrosion resistance. The amount of Cu is preferably set to be 1.2% or less so as to further prevent the deterioration of the hot workability.

Ni: 0.60% to 2.30%

[0034] Ni is an element that prevents an anodic reaction due to an acid, and is capable of maintaining passivation at a relatively low pH. That is, Ni is highly effective on the crevice corrosion resistance, and greatly prevent the progress of corrosion at an actively dissolved state. In the case where the amount of Ni is less than 0.60%, the effect of improving the crevice corrosion resistance is not obtained, and in addition, a ratio of the austenite phases decreases. Accordingly, workability greatly deteriorates. On the other hand, in the case where the amount of Ni is more than 2.30%, the ratio of the austenite phases increases, and the hot workability deteriorates. Accordingly, the amount of Ni is limited to a range of 0.60% to 2.30%. The lower limit of the amount of Ni is preferably 1.0% or more, and more preferably 1.5% or more. The upper limit of the amount of Ni is preferably 1.5% or less.

N: 0.06% to 0.20%

[0035] N is an important element that stabilizes the austenite phase, and improves the corrosion resistance. In the case where the amount of N is less than 0.06%, the ratio of the austenite phases is small. Accordingly, workability deteriorates, and the corrosion resistance of the austenite phase deteriorates. On the other hand, in the case where the amount of N is more than 0.20%, a large amount of the austenite phases are generated, and the hot workability greatly deteriorates. Accordingly, the amount of N is set to be 0.06% to 0.20%. The amount of N is preferably set to be 0.08% or more from the viewpoint of stabilization of the austenite phase. The amount of N is preferably set to be 0.17% or less so as to further prevent the deterioration of the hot workability.

Co: 0.05% to 0.25%

[0036] Co is an element that exhibits the same behavior as that of Ni, and stabilizes the austenite phase. Even in the case where a slight amount of Co is added together with Ni, the effect is exhibited. However, in the case where the amount of Co is less than 0.05%, the effect is not recognized. In addition, Co stabilizes precipitation of the austenite phases in a high temperature region. Accordingly, the concentrating of N in the austenite phase is promoted, and the amount of N in the ferrite phase is greatly decreased. Accordingly, Co operates to prevent the precipitation of Cr carbonitrides (particularly, Cr nitrides). The main cause of deterioration of the corrosion resistance in the steel sheet of the present embodiment is a decrease in a Cr concentration in the vicinity of the Cr carbonitrides in accordance with the precipitation of the Cr carbonitrides. Accordingly, particularly, Co operates to prevent the precipitation of the Cr carbonitrides; and thereby, Co prevents the deterioration of the corrosion resistance at a ferrite grain boundary or an interface between the ferrite phase and the austenite phase. On the other hand, an excessive amount of Co is added, a ratio of the austenite phases increases, and the hot workability deteriorates. In addition, since Co is a rare element and is expensive, the cost increases excessively when a large amount of Co is added. Accordingly, the upper limit of the amount of Co is set to be 0.25% or less. The amount of Co is preferably set to be 0.08% or more from the viewpoint of stabilizing the austenite phase. The upper limit of the amount of Co is preferably 0.20% or less and more preferably 0.12% or less so as to further prevent the deterioration of hot workability.

V: 0.01% to 0.15%

[0037] V is a strong carbonitride generating element. When V exists in the ferrite phase, carbonitrides are easily generated in a high temperature region. The main cause of deterioration of the corrosion resistance in the steel sheet of the present embodiment is a decrease in a Cr concentration in the vicinity of the Cr carbonitrides in accordance with the precipitation of the Cr carbonitrides. Accordingly, when V carbonitrides precipitate in a high temperature region, it is possible to prevent the precipitation of Cr carbonitrides in a low temperature region. This effect is recognized when 0.01% or more of V is added. Accordingly, the lower limit of the amount of V is set to be 0.01% or more. On the other hand, in the case where an excessive amount of V is added, hardening is caused. Accordingly, the upper limit of the amount of V is set to 0.15% or less. From the viewpoint of promoting the generation of V-based carbonitrides and preventing the precipitation of Cr carbonitrides, the amount of V is preferably set to be 0.05% or more, and more preferably 0.08% or more. The amount of V is preferably set to be 0.12% or less so as to further prevent the hardening. In the case where the above-described effect is exhibited by adding a small amount of V, the amount of V is preferably set to be less than 0.05%.

Ca: 0.002% or less

[0038] Ca is a component that is effective for deoxidation. In addition, Ca is an element that generates sulfides. Ca is an element that is effective to stabilize sulfides which contribute to satisfactory properties of a sheared fracture surface. In order to obtain these effects, the amount of Ca is preferably set to be 0.0003% or more. However, in the case where the amount of Ca is more than 0.002%, coarse CaS is generated, and the coarse CaS becomes the origin of rust. Accordingly, the amount of Ca is set to be 0.002% or less.

S: 0.0002% to 0.0040%

[0039] S is an important element in the present embodiment. S forms sulfides with Mn, Ca, and the like in stainless steel. In the related art, it was recognized that it was preferable to reduce the amount of S because these sulfides became the main cause of deteriorating the corrosion resistance. However, according to research made by the present inventors, even in a case of MnS or CaS which were recognized as unfavorable sulfides, it was found that when a grain size and a dispersion state of the sulfides are appropriately controlled, it is possible to stably maintain surface properties of a

sheared line in a good state, and the corrosion resistance does not deteriorate.

[0040] In order to set the amount of S to be less than 0.0002%, it is necessary to carefully select a raw material, and a load in desulfurization process increases. Accordingly, the lower limit of the amount of S is set to be 0.0002% or more. On the other hand, in the case where the amount of S is more than 0.0040%, coarsening of sulfides is confirmed, and the coarsened sulfides become a cause of rust. Accordingly, the amount of S is limited to a range of 0.0002% to 0.0040%. The lower limit of the amount of S is more preferably 0.0003% or more, and the upper limit of the amount of S is more preferably 0.0010% or less. Accordingly, a more preferable range of the amount of S is 0.0003% to 0.0010%.

Value of $\text{Co} + 0.25\text{V}$: 0.10 or more and less than 0.25

[0041] The main cause of deterioration of the corrosion resistance in the steel sheet of the present embodiment is a decrease in a Cr concentration in the vicinity of the Cr carbonitrides in accordance with the precipitation of the Cr carbonitrides. In the present embodiment, in order to prevent the generation of Cr carbonitrides, particularly, Cr nitrides, it is important to precipitate a sufficient amount of austenite phases until a temperature reaches the upper limit of a precipitation temperature of the Cr nitrides to reduce the amount of N in the ferrite phase. For this, it is effective to promote precipitation of the austenite phases by the addition of Co, and to fix N remained in the ferrite phase by V. In the case where a value of $\text{Co} + 0.25\text{V}$ is less than 0.10, there is no effect of reducing the amount of N in the ferrite phase. Accordingly, the Cr nitrides are generated in a ferrite/ferrite grain boundary (grain boundary between ferrites), and the corrosion resistance deteriorates. Accordingly, the lower limit of the value of $\text{Co} + 0.25\text{V}$ is set to be 0.10 or more. In the case where the value of $\text{Co} + 0.25\text{V}$ is set to be 0.12 or more, the generated amount of Cr definitely decreases. Accordingly, the lower limit of the value of $\text{Co} + 0.25\text{V}$ is preferably 0.12 or more. On the other hand, in the case where the value of $\text{Co} + 0.25\text{V}$ is too large, a ratio of the austenite phases excessively increases, and there is a concern that deterioration of hot workability may be caused. Accordingly, the upper limit of the value of $\text{Co} + 0.25\text{V}$ is set to be less than 0.25.

[0042] In the expression of $\text{Co} + 0.25\text{V}$, Co and V represent the amounts (% by mass) of Co and V, respectively.

[0043] Hereinbefore, description has been given of basic components of the steel sheet of the present embodiment. However, in the present embodiment, in addition to the components, the following elements may be appropriately contained so as to improve the corrosion resistance.

Nb: 0.005% to 0.2%

[0044] Nb is an element that fixes C and N, Nb prevents sensitization due to the Cr carbonitrides, and Nb improves the corrosion resistance. However, in the case where the amount of Nb is less than 0.005%, the effects are small. On the other hand, in the case where the amount of Nb is more than 0.2%, the ferrite phase becomes hard due to solid-solution hardening, and workability deteriorates. Accordingly, the amount of Nb is preferably set to be in a range of 0.005% to 0.2%.

Ti: 0.005% to 0.2%

[0045] Ti is an element that fixes C and N, Ti prevents sensitization due to the Cr carbonitrides, and Ti improves the corrosion resistance. However, in the case where the amount of Ti is less than 0.005%, the effects are small. On the other hand, in the case where the amount of Ti is more than 0.2%, hardening of the ferrite phase is caused, and toughness decreases. In addition, a decrease in surface roughness is caused due to Ti-based precipitates. Accordingly, the amount of Ti is preferably set to be in a range of 0.005% to 0.2%.

W: 0.005% to 0.2%

[0046] As is the case with Ti, W has an effect of fixing C and N, and W prevents sensitization due to the Cr carbonitrides. However, in the case where the amount of W is less than 0.005%, the effect is not recognized. On the other hand, in the case where the amount of W is more than 0.2%, hardening is caused, and workability deteriorates. Accordingly, the amount of W is preferably set to be in a range of 0.005% to 0.2%.

Mo: 0.01% to 1.0%

[0047] Mo is an element that improves the corrosion resistance. However, in the case where the amount of Mo is less than 0.01%, the effect is small. On the other hand, in the case where the amount of Mo is more than 1.0%, hardening is caused, and workability deteriorates. Accordingly, the amount of Mo is preferably set to be 0.01% to 1.0%.

[0048] In the present embodiment, the following elements may be further contained in an appropriately manner.

Sn, Sb: 0.005% to 0.2%

[0049] Sn and Sb are elements which improve the corrosion resistance, and are also solid-solution strengthening elements of the ferrite phase. Accordingly, the upper limit of the amount of each of Sn and Sb is set to be 0.2%. In the case where the amount of any one of Sn and Sb is 0.005% or more, an effect of improving the corrosion resistance is exhibited. Accordingly, the amount of each of Sn and Sb is set to be 0.005% to 0.2%. The lower limit of the amount of each of Sn and Sb is preferably 0.03% or more. The upper limit of the amount of each of Sn and Sb is preferably 0.1% or less.

Ga: 0.001% to 0.05%

[0050] Ga is an element that contributes to an improvement of the corrosion resistance. In the case where the amount of Ga is 0.001% or more, the effect is exhibited. In the case where the amount of Ga is more than 0.05%, the effect is saturated. Accordingly, Ga can be contained at an amount of 0.001% to 0.05%.

Zr: 0.005% to 0.5%

[0051] Zr is an element that contributes to an improvement of the corrosion resistance. In the case where the amount of Zr is 0.005% or more, the effect is exhibited. In the case where the amount of Zr is more than 0.5%, the effect is saturated. Accordingly, Zr can be contained at an amount of 0.005% to 0.5%.

Ta: 0.005% to 0.1%

[0052] Ta is an element that improves the corrosion resistance by modification of inclusions, and Ta may be contained as necessary. The effect is exhibited by 0.005% or more of Ta. Accordingly, the lower limit of the amount of Ta may be set to be 0.005% or more. However, in the case where the amount of Ta is more than 0.1%, deterioration of ductility at the room temperature or toughness is caused. Accordingly, the upper limit of the amount of Ta is preferably 0.1% or less, and more preferably 0.050% or less. In a case where the above-described effect is exhibited by a small amount of Ta, the amount of Ta is preferably set to be 0.020% or less.

B: 0.0002% to 0.0050%

[0053] B is an element that is useful to prevent secondary working embrittlement or deterioration of the hot workability, and B does not have an effect on the corrosion resistance. Accordingly, B can be contained on the condition that the lower limit of the amount of B is set to be 0.0002% or more. However, in the case where the amount of B is more than 0.0050%, the hot workability deteriorates on the contrary. Accordingly, the upper limit of the amount of B may be set to be 0.0050% or less. The upper limit of the amount of B is preferably 0.0020% or less.

[0054] In the steel sheet of the present embodiment, the remainder other than the above-described elements is Fe and unavoidable impurities. However, another element other than the above-described elements may be contained in a range not deteriorating the effect of the present embodiment.

[0055] Hereinbefore, description has been given of a component system. However, in the steel sheet of the present embodiment, it is not sufficient that only the component composition is set to be in the above-described range, and it is important to set the average crystal grain sizes of the ferrite phases and the austenite phases, and a precipitation state of MnS to the following ranges.

<Average Crystal Grain Size of Ferrite Phases: 5 to 20 μm >

<Average Crystal Grain Size of Austenite Phases: 2 to 10 μm >

[0056] The metallic structure (metallographic structure, microstructure) of the ferritic-austenitic stainless steel sheet consists of the ferrite phases and the austenite phases. The crystal grain size of each of the ferrite phase and the austenite phase has a great effect on mechanical properties and surface properties of the sheared line.

[0057] A recrystallization temperature of the ferrite phase is different from that of the austenite phase, and grain growth of the ferrite phase occurs in a recrystallization temperature region of the austenite phase. Accordingly, the average crystal grain size of the ferrite phases becomes more than the average crystal grain size of the austenite phases. However, when the difference in the grain size between the ferrite phase and the austenite phase increases, the difference in strength becomes large (increases). When the difference in strength is large, fracture occurs at an interface between the ferrite phase and the austenite phase during shearing, and the fracture becomes the origin of crevice corrosion.

[0058] Accordingly, an investigation has been made to a limit value of the average crystal grain size at which fracture does not occur during shearing. Results are shown in FIG. 1.

[0059] FIG. 1 is a graph showing a relationship between the average crystal grain size of the ferrite phases and the average crystal grain size of the austenite phases which have an effect on corrosion resistance after shearing. As is clear from FIG. 1, an appropriate combination exists in the average crystal grain sizes of the ferrite phases and the austenite phases. From the results in FIG. 1, the upper limit of the average crystal grain size of the ferrite phases is set to be 20 μm .

[0060] Here, in the case where the average crystal grain size of the ferrite phases is less than 5 μm , the strength is improved and burrs are less likely to be formed because recrystallization of the austenite phase is not completed. However, an area of a fracture surface greatly increases. Accordingly, the corrosion resistance deteriorates. Even in the case where an average crystal grain size of the austenite phases is less than 2 μm , the strength greatly increases, and the corrosion resistance deteriorates due to the same reason as described above.

[0061] On the other hand, in the case where the average crystal grain size of the austenite phases is more than 10 μm , burrs increase due to an softening effect, roughness of a fracture surface decreases, and micro-gaps are formed. In addition, coarse grains are generated at a part of the ferrite phase, and interface fracture is promoted. Accordingly, the corrosion resistance greatly deteriorates.

[0062] Accordingly, the average crystal grain size of the ferrite phases is set to be 5 to 20 μm , and the average crystal grain size of the austenite phases is set to be 2 to 10 μm .

<Sulfides: Particles (Sulfides) Having Major Axes of 1 to 5 μm Exist at Amount of 5 to 20 Pieces per 5 mm^2 >

[0063] Hereinafter, a description will be given of the reason why a precipitation state of sulfides in a steel sheet is limited to the above-described range.

[0064] According to the present inventors, it was confirmed that the origin of corrosion on an end face subjected to shearing is a boundary portion between the shear plane and a fracture surface, and the fracture surface. Since a gap is likely to be formed at the boundary portion between the shear plane and the fracture surface, deposition of a corrosion factor is likely to occur. A minute gap shape due to unevenness corresponded to a dimple fracture surface promotes lowering of pH and high salinity in an adhered solution (the gap shape lowers pH of the adhered solution and concentrates salt in the adhered solution). As a result, corrosion is likely to occur in an environment at the boundary portion between the shear plane and the fracture surface. Accordingly, it is considered that the boundary portion and the fracture surface become the origin of corrosion. Therefore, in the case where the formation of a gap at the boundary portion between the shear plane and the fracture surface is prevented, it is assumed that a sheared line is formed at which corrosion is less likely to occur. Herein, the sulfides represent CaS, MnS, CrS, TiCS, CuS, and the like.

[0065] In view of these circumstances, the present inventors have performed a corrosion resistance test by using test pieces obtained under various manufacturing conditions. The present inventors extracted several test pieces in which corrosion resistance was satisfactory, and several test pieces in which the corrosion resistance was poor for comparison, and they analyzed the microstructures of the test pieces. Results thereof are shown in FIG. 2. FIG. 2 is a graph showing a relationship between the size and the number of sulfides which have an effect on the corrosion resistance after shearing. Herein, the size of the sulfides in FIG. 2 represents the maximum value of the major axes of extended sulfides. The number of the sulfides in FIG. 2 represents the number (pieces per 5 mm^2) of sulfides having major axes of 1 to 5 μm . As shown in FIG. 2, it becomes clear that a precipitation condition of sulfides and properties of a sheared line have a correlation, and conditions at which corrosion is less likely to occur are present. That is, it becomes clear that it is important to allow sulfides having major axes of 1 to 5 μm to exist in steel at an amount of 5 to 20 pieces per 5 mm^2 . Herein, with regard to sulfides having major axes of less than 1 μm (in FIG. 2, the size (the maximum value of the major axes) of sulfides is less than 1 μm), an effect of preventing propagation of cracks, which occur during fracture, is small. On the other hand, with regard to sulfides having major axes of more than 5 μm (in FIG. 2, the size (the maximum value of the major axes) of sulfides is more than 5 μm), sulfides were chipped on a surface, and relatively large cracks are formed. Accordingly, the targeted major axis of the sulfide is set in a range of 1 to 5 μm . Therefore, in the present embodiment, sulfides having the major axes of 1 to 5 μm are set as a control target. Herein, the major axis of the sulfide as a control target represents the major axis of the individual sulfide.

[0066] In addition, in the present embodiment, it is preferable that the maximum value of the major axes of sulfides is 1 to 5 μm .

[0067] Next, the present inventors have made an investigation on the precipitation state of the sulfides, and the following situations were proved. In the case where the number of precipitates (sulfides) per unit area of 5 mm^2 is less than 5 pieces, it was proved that the effect of preventing propagation of cracks is small. In the case where the number of the precipitates (sulfides) per 5 mm^2 is more than 20 pieces, it was proved that many gaps are formed and corrosion resistance deteriorates. Accordingly, in the present embodiment, sulfides having major axes of 1 to 5 μm are generated to exist at an amount of 5 to 20 pieces per 5 mm^2 . Preferably, sulfides having major axes of 1 to 5 μm are generated to

exist at an amount of 6 pieces to 15 pieces per 5 mm².

[0068] Next, description will be given of a method of manufacturing the ferritic-austenitic stainless steel sheet of the present embodiment.

[0069] In the present embodiment, as described above, the average crystal grain sizes of the ferrite phases and the austenite phases, and the precipitation and dispersion state of the sulfides are important. Accordingly, it is important to carry out manufacturing of a steel sheet under the following conditions.

[0070] Rolling reductions in a hot-rolling process and a cold-rolling process are important so as to control the average crystal grain sizes of the ferrite phases and the austenite phases in the above-described ranges. In a rough rolling process of the hot-rolling, it is necessary to set a reduction in at least one pass to be 30% or more, and it is necessary to perform five passes or more of working (rolling) at a temperature of 1000°C or higher in the rough rolling process. In addition, it is necessary to set a rolling reduction of cold-rolling to be 75% or more, and it is necessary to set a sheet temperature at the cold-rolling to be 150°C or higher at the time of termination of a final pass.

[0071] A strain that is introduced during the cold-rolling becomes a generation nucleus of a recrystallized grain. In high-strength steel similar to the present embodiment, if work hardening proceeds, a great load is applied on the cold-rolling process. Therefore, the load is reduced by raising the sheet temperature during the cold-rolling. Thereby, not only the load in the cold-rolling process is reduced, but also the generation nuclei of recrystallized grains do not become excessive. Accordingly, it is also useful for controlling a crystal grain size. It is necessary to control the sheet temperature after the final pass to 150°C or higher so as to set the average crystal grain size of the ferrite phases to be 5 to 20 μm and to set the average crystal grain size of the austenite phases to be 2 to 10 μm, respectively. The sheet temperature after the final pass can be controlled by changing a rolling reduction per one pass and a rolling speed.

[0072] A processing temperature in each of hot-rolled sheet annealing (process of annealing a hot-rolled sheet) and cold-rolled sheet annealing (process of annealing a cold-rolled sheet) is important to control the size and the precipitation number of the sulfides in the above-described range. With regard to conditions of the processing temperature, it is preferable that a hot-rolled sheet annealing temperature is set to be 1000°C to 1100°C, and a cold-rolled sheet annealing temperature is set to be 950°C to 1050°C.

[0073] In addition, a method that is known in the related art is applicable to the other processes without particular limitation. In addition, representative manufacturing conditions are as follows.

[0074] First, the ferritic-austenitic stainless steel having the above-described component composition is heated to a temperature of 1150°C to 1250°C. Then, hot-rolling is performed under conditions where a finish temperature is set to be 950°C or higher to obtain a sheet thickness of 3.0 to 6 mm. At this time, a rolling reduction of at least one pass in the rough rolling process is set to be 30% or more. In the case where cooling is performed at a typical cooling rate after finish rolling, precipitation of the austenite phase is not sufficient. Therefore, a temperature of finish rolling is set to be 950°C or higher, and a hot-rolled sheet is coiled without performing cooling positively. Mild cooling is performed up to 500°C or lower, and then, the hot-rolled sheet is put into a water bath for rapid cooling.

[0075] A cooling rate after coiling is not particularly defined. However, a decrease in toughness due to so-called 475°C brittleness occurs at or in the vicinity of 475°C. Accordingly, the cooling rate in a temperature range of 425°C to 525°C is preferably 100°C/h or higher.

[0076] The a hot-rolled strip that is manufactured as described above is subjected to hot-rolled sheet annealing at a temperature of 1000°C to 1100°C, and then pickling is performed.

[0077] Next, when performing cold-rolling under conditions where a rolling reduction is set to be 75% or more, reverse rolling is continuously performed so that processing heat generated due to cold-rolling is not cooled down to room temperature, and the cold-rolling is performed so that a sheet temperature on a final pass output side becomes 160°C or higher. The obtained cold-rolled sheet is subjected to cold-rolled sheet annealing at a temperature of 950°C to 1050°C. Then, pickling is performed to obtain a cold-rolled product.

[0078] It is possible to obtain the ferritic-austenitic stainless steel of the present embodiment in accordance with the manufacturing method as described above; however, the present embodiment is not limited by the above-described processes and conditions.

[0079] A description will be given of a shearing method capable of reducing a fracture surface when shearing the ferritic-austenitic stainless steel sheet of the present embodiment. Furthermore, methods for reducing the fracture surface may be appropriately adjusted and set when shearing the steel sheet without particular limitation thereto. Hereinafter, description will be given of an example of a processing method capable of reducing the fracture surface.

[0080] The present inventors have performed a lot of experiments by variously changing shearing conditions so as to accomplish the above-described object; and as a result, it was proved that a control of a clearance is particularly effective to reduce a fracture surface ratio. Herein, the clearance represents a ratio of a gap x between a blade and a stage to the thickness d of the steel sheet.

[0081] The clearance in the shearing is affected by an area of a fracture surface in a sheared line, and the height of burrs. From a result of examination on various clearances, it was clear that with regard to the ferritic-austenitic stainless steel of the present embodiment, in the case where the clearance is set to be 5% to 20%, the area of the fracture surface

and the height of the burrs are reduced to be small values, and the corrosion resistance is improved. The clearance in the shearing is preferably set to be 10% to 15%.

EXAMPLES

[0082] Examples of the invention will be described below. However, a condition in the examples is only a conditional example employed to confirm reproducibility and an effect of the invention, and the invention is not limited to the condition that was used in the examples. The invention may employ various conditions as long as the object of the invention can be accomplished without departing from the features of the invention.

[0083] Furthermore, an underlined value in Tables represents a value out of a range of the present embodiment.

[0084] Ingots of ferritic-austenitic stainless steels making chemical compositions shown in Tables 1 and 2 were prepared. Then, each of the ingots was heated to a temperature of 1200°C, and hot-rolling was performed under conditions where a finish temperature was 980°C to obtain a hot-rolled sheet having a sheet thickness of 4 mm. A rolling reduction of at least one pass in a rough rolling process of the hot-rolling was set to be 30% or more. The hot-rolled sheet was coiled, and the hot-rolled sheet was mildly cooled down up to 500°C or lower and then was rapidly cooled down.

[0085] Next, the hot-rolled sheet was annealed at an annealing temperature described in Tables 3 and 5 (hot-rolled sheet annealing), and then pickling was performed. Then, cold-rolling was performed to obtain a cold-rolled sheet having a sheet thickness of 0.6 to 1.2 mm. In the cold-rolling, a rolling temperature of the 1st pass was set to be 60°C, and rolling was continuously performed so that a sheet temperature was not lowered. A cold-rolling reduction and a sheet temperature after a final pass (final pass temperature) were set to be values shown in Tables 3 and 5. The obtained cold-rolled sheet was subjected to annealing (cold-rolled sheet annealing), and a surface thereof was adjusted by finish pickling; and thereby, a test piece was obtained.

[0086] The sizes and the number of sulfides in the obtained test piece were measured by an optical microscope and a SEM-EDS method. The measurement method is as follows. At first, a surface of the test piece was polished with #600, and was mirror-polished. Then, a square of 5 mmx5 mm was marked on the surface of the test piece. Inclusions were observed in a marked area by using the optical microscope, and inclusions, which existed in the area and had sizes of approximately 1 μm or more, were marked. The approximate size of the inclusion was grasped through the above-described observation, and an inclusion to be measured was selected.

[0087] Then, only in the case where a total number of the inclusions was more than five pieces, the composition of the inclusion was measured at two sites per piece by using the SEM-EDS method. In the case where a composition including 50% or more of S was confirmed at even one site, the inclusion was determined to be a sulfide.

[0088] With regard to the inclusion which was determined to be a sulfide, the major axis of the inclusion was measured by the following method. Sulfides have relatively soft characteristics. Accordingly, a lot of sulfides exist in a state of being extended in a rolling direction. Accordingly, a length in the rolling direction was set as the major axis, and the length (maximum length) of the sulfide from a front end to a rear end was measured as the major axis. Furthermore, a measurement value of the major axis of the sulfide was calculated as an integer by rounding off the measurement value at the first decimal place (rounding off the measurement value to the nearest one). The maximum value among the obtained measurement values of the major axes is described in a column of "Major axis of sulfide" in Tables 4 and 6.

[0089] In addition, the number of sulfides, in which the measurement values of the major axes were 1 to 5 μm, (the number of sulfides having major axes of 1 to 5 μm) was measured, and the number of the sulfides per 5 mm² was calculated. The number (pieces per 5 mm²) of the sulfides having the major axes of 1 to 5 μm is described in "Number of sulfides" in Tables 4 and 6.

[0090] In addition, the ferrite phase and the austenite phase were separated from each other in accordance with a back-scattering electron beam diffraction (EBSD) method by using a field emission scanning electron microscope JSM-7000F manufactured by JEOL Ltd., and the crystal grain sizes of the ferrite phases and the austenite phases were measured. In the measurement, an acceleration voltage was set to 25 kV, the step size was set to be 0.5 μm, and a measurement position was set to the central portion of a sheet thickness on a cross-section in a rolling direction at the central position of the width of the test piece. In orientation analysis, a boundary of crystal grains, in which an orientation difference between adjacent crystal grains was 15° or more, was determined to be a crystal grain boundary, and the crystal grain sizes of the ferrite phases and the austenite phases were measured by using OIM software available from TSL Solutions. With regard to each of the ferrite phases and the austenite phases, the average value of the measured crystal grain sizes was calculated to obtain the average crystal grain size.

[0091] The average crystal grain size of the ferrite phases is described in a column of "Grain size of ferrite phase" in Tables 4 and 6. The average crystal grain size of the austenite phases is described in a column of "Grain size of austenite phase" in Tables 4 and 6.

[0092] Each of the test pieces of the ferritic-austenitic stainless steel sheets, which were obtained under the above-described manufacturing conditions, was cut-out in a size of 120 mmx75 mm, and a silicon tape was attached to a cut-out end face so as to eliminate an effect of cross-sections in all directions. The clearance (shear clearance) between a

male die and a female die of a punching tool was adjusted by using female dies of the punching tool which have various diameters. The central portion of a sample was subjected to circular shearing processing at various shear clearances. Herein, the shear clearance (%) was a value calculated by the following expression.

$$\{(\text{Difference between a diameter of a male die and a diameter of a female die of a}$$

$$\text{punching tool}) / \text{thickness of a test piece (steel sheet)} \} \times 100$$

[0093] After the cutting-out (shearing processing), degreasing with acetone was performed. The sample was disposed in a cycle corrosion tester at an inclination of 75° in such a manner that a surface from which burrs lead out was set to face an upward side. Then, a cycle corrosion test in accordance with JASO M 609-91 was performed for six cycles. After the test, in the case where corrosion did not occur on a sheared line, the sample was evaluated as "rust occurrence is absent", and in the case where corrosion occurred, the sample was evaluated as "rust occurrence is present".

[0094] The obtained results are shown in Tables 4 and 6.

[0095] From results of Test Nos. 1, 2, 4, 5, 8 to 11, 13, 14, 16, and 19 to 27, it could be seen that corrosion resistance of a sheared line was good in the case where the ranges of the present embodiment were satisfied.

[0096] From results of Test Nos. 3, 6, 7, 17, and 22, it could be seen that in the case where either one or both of the average crystal grain size of the ferrite phases and the average crystal grain size of the austenite phases were out of the ranges of the present embodiment, rust occurred on the sheared line. Particularly, in Test No. 22, the sheet temperature after the final pass in the cold-rolling was lower than 160°C. Thereby, a lot of strains were introduced due to cold-rolling, and the strains could be nuclei of recrystallization. As a result, fine crystal grains were formed, and the fine crystal grains became the cause of rust.

[0097] From results of Test Nos. 12, 15, 17, and 18, it could be seen that in the case where either one or both of the number and the major axis of the sulfides were out of the ranges of the present embodiment, rust occurred on the sheared line.

[0098] From results of Test Nos. 28 to 46, it could be seen that in the case where the chemical composition were out of the range of the present embodiment, rust occurred on the sheared line.

Table 1

Steel	Chemical composition (% by mass)																		Remark	
	C	Si	Mn	P	Al	Cr	Ni	N	Cu	Co	V	Ca	S	Nb	Ti	W	Mo	Others		Co + 0.25V
A	0.008	0.15	4.5	0.020	0.028	20.7	2.10	0.168	1.11	0.18	0.08	0.0010	0.0014	-	-	0.05	0.06	-	0.20	Present Examples
B	0.012	0.22	4.5	0.025	0.021	20.1	2.05	0.185	1.26	0.16	0.06	0.0018	0.0008	-	-	-	-	-	0.18	
C	0.007	0.80	4.1	0.020	0.051	21.0	1.98	0.188	0.98	0.11	0.05	0.0012	0.0009	-	0.180	0.01	-	-	0.12	
D	0.012	0.40	3.1	0.024	0.034	20.9	2.12	0.160	1.04	0.09	0.03	0.0016	0.0004	0.03	-	-	0.40	-	0.10	
E	0.013	0.14	2.8	0.015	0.037	23.1	2.30	0.110	0.84	0.11	0.06	0.0008	0.0005	-	-	-	-	-	0.13	
F	0.025	0.28	4.8	0.020	0.032	23.5	0.80	0.084	1.38	0.16	0.11	0.0005	0.0027	-	0.005	-	0.64	-	0.19	
G	0.008	0.51	0.8	0.020	0.035	20.8	1.20	0.177	1.37	0.12	0.06	0.0017	0.0017	-	-	-	-	-	0.14	
H	0.009	0.35	3.9	0.025	0.029	21.0	2.01	0.154	1.45	0.06	0.15	0.0013	0.0008	0.03	-	0.06	-	-	0.10	
I	0.008	0.60	4.2	0.020	0.055	20.8	2.08	0.188	1.32	0.18	0.06	0.0012	0.0005	-	-	0.08	-	-	0.20	
J	0.011	0.45	2.5	0.020	0.080	23.5	1.95	0.187	0.94	0.22	0.05	0.0011	0.0004	-	0.170	-	-	-	0.23	
K	0.015	0.45	3.2	0.023	0.035	21.3	2.10	0.184	1.01	0.11	0.07	0.0014	0.0003	-	-	-	0.57	-	0.13	
L	0.006	0.31	4.8	0.020	0.048	20.7	1.96	0.175	1.28	0.18	0.07	0.0004	0.0011	0.12	-	-	-	-	0.20	
M	0.003	0.12	4.8	0.025	0.024	21.8	2.11	0.162	1.36	0.11	0.03	0.0016	0.0025	-	-	-	0.03	-	0.12	
N	0.012	0.21	4.3	0.023	0.021	20.2	2.05	0.180	1.26	0.15	0.07	0.0016	0.0008	-	-	-	-	Sn: 0.05	0.17	
O	0.011	0.23	4.4	0.024	0.023	20.5	1.99	0.185	1.22	0.14	0.06	0.0018	0.0009	-	-	-	-	Sb: 0.06	0.16	
P	0.013	0.20	4.5	0.026	0.020	20.7	2.03	0.188	1.23	0.13	0.05	0.0019	0.0004	-	-	-	-	Ga: 0.005	0.14	
Q	0.009	0.19	4.2	0.020	0.022	20.3	2.10	0.180	1.29	0.16	0.08	0.0012	0.0007	-	-	-	-	Zr: 0.02	0.18	
R	0.012	0.21	4.5	0.022	0.024	21.0	2.22	0.186	1.19	0.11	0.07	0.0014	0.0009	-	-	-	-	B: 0.0015	0.13	

Table 2

Steel	Chemical composition (% by mass)																	Remark	
	C	Si	Mn	P	Al	Cr	Ni	N	Cu	Co	V	Ca	S	Nb	Ti	W	Mo		Others
AA	0.035	0.27	3.4	0.025	0.066	20.1	0.87	0.090	0.80	0.11	0.05	0.0008	0.0021	-	-	-	-	-	0.12
AB	0.008	0.08	3.8	0.025	0.035	19.7	0.91	0.065	0.74	0.12	0.03	0.0010	0.0027	-	-	-	-	-	0.13
AC	0.011	0.27	5.5	0.020	0.047	19.7	1.20	0.181	0.92	0.09	0.03	0.0007	0.0011	-	-	-	-	-	0.10
AD	0.021	0.35	4.1	0.045	0.051	22.4	2.14	0.167	0.98	0.08	0.08	0.0014	0.0017	-	-	-	-	-	0.10
AE	0.005	0.48	1.8	0.015	0.120	19.8	2.11	0.144	1.14	0.09	0.11	0.0012	0.0009	-	-	-	-	-	0.12
AF	0.017	0.55	4.2	0.025	0.087	18.5	2.18	0.183	1.25	0.16	0.13	0.0010	0.0017	-	-	-	-	-	0.19
AG	0.009	0.52	3.9	0.025	0.037	22.1	2.50	0.127	1.38	0.21	0.08	0.0012	0.0024	-	-	-	-	-	0.23
AH	0.018	0.48	3.8	0.023	0.042	20.8	2.20	0.211	1.09	0.23	0.05	0.0012	0.0023	-	-	-	-	-	0.24
AI	0.022	0.41	3.2	0.020	0.037	20.9	1.97	0.163	1.62	0.19	0.06	0.0014	0.0028	-	-	-	-	-	0.21
AJ	0.009	0.38	1.9	0.025	0.058	21.4	2.14	0.157	0.85	0.31	0.03	0.0009	0.0014	-	-	-	-	-	0.32
AK	0.008	0.77	2.4	0.023	0.069	22.0	0.84	0.182	0.81	0.18	0.26	0.0014	0.0008	-	-	-	-	-	0.25
AL	0.016	0.75	2.5	0.020	0.038	19.8	2.10	0.162	1.08	0.11	0.05	0.0025	0.0009	-	-	-	-	-	0.12
AM	0.001	0.64	2.7	0.003	0.049	20.4	2.24	0.182	1.07	0.08	0.04	0.0017	0.0048	-	-	-	-	-	0.09
AN	0.070	0.65	3.8	0.025	0.043	21.9	1.16	0.131	1.14	0.15	0.08	0.0011	0.0027	0.25	-	-	-	-	0.17
AO	0.024	0.38	3.7	0.031	0.058	22.8	1.57	0.124	1.25	0.18	0.11	0.0009	0.0006	-	0.310	-	-	-	0.21
AP	0.006	0.27	3.9	0.020	0.047	23.7	2.04	0.117	1.30	0.21	0.06	0.0011	0.0007	-	-	0.28	-	-	0.23
AQ	0.027	0.36	4.8	0.023	0.066	22.7	2.08	0.085	0.94	0.20	0.06	0.0014	0.0024	-	-	-	1.20	-	0.22
AR	0.006	0.27	3.9	0.020	0.047	23.7	2.04	0.117	1.30	0.02	0.06	0.0008	0.0018	-	-	-	-	-	0.04
AS	0.027	0.36	4.8	0.023	0.066	22.7	2.08	0.085	0.94	0.20	0.006	0.0009	0.0029	-	-	-	-	-	0.20

Comparative Examples

Table 3

Test No.	Steel	Hot-rolled sheet annealing temperature (°C)	Cold-rolling reduction (%)	Cold-rolled sheet thickness (mm)	Final pass temperature in cold-rolling (°C)	Cold-rolled sheet annealing temperature (°C)	Remark
1	A	1080	75	1.00	180	980	Present Example
2	B	1050	80	0.80	200	1000	Present Example
3		1100	85	0.60	250	<u>1100</u>	Comparative Example
4	C	1050	75	1.00	160	1020	Present Example
5	D	1080	80	0.80	200	1020	Present Example
6		<u>1120</u>	75	1.00	200	1020	Comparative Example
7		<u>1120</u>	<u>70</u>	1.20	195	1050	Comparative Example
8	E	1080	80	0.80	185	1020	Present Example
9	F	1020	85	0.60	200	1000	Present Example
10	G	1050	75	1.00	205	1050	Present Example
11		1050	75	1.00	200	1020	Present Example
12		1100	75	1.00	200	<u>1100</u>	Comparative Example
13	H	1080	80	0.80	190	1050	Present Example
14	I	1100	80	0.80	200	1020	Present Example
15		1050	85	0.60	205	<u>940</u>	Comparative Example
16	J	1100	75	1.00	200	1050	Present Example
17		<u>1120</u>	<u>70</u>	1.20	190	1050	Comparative Example
18		1080	<u>70</u>	1.20	180	1050	Comparative Example
19	K	1050	80	0.80	200	1020	Present Example
20	L	1050	75	1.00	180	1000	Present Example

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(continued)

Test No.	Steel	Hot-rolled sheet annealing temperature (°C)	Cold-rolling reduction (%)	Cold-rolled sheet thickness (mm)	Final pass temperature in cold-rolling (°C)	Cold-rolled sheet annealing temperature (°C)	Remark
21	M	1050	75	1.00	210	1050	Present Example
22		1050	75	1.00	<u>140</u>	1050	Comparative Example
23	N	1050	80	0.80	200	1000	Present Example
24	O	1050	75	1.00	180	1020	Present Example
25	P	1050	80	0.80	200	1050	Present Example
26	Q	1050	75	1.00	180	950	Present Example
27	R	1050	75	1.00	180	1000	Present Example

Table 4

Test No.	Steel	Grain size of ferrite phase (μm)	Grain size of austenite phase (μm)	Major axis of sulfides (μm)	Number of sulfides (pieces/5 mm ²)	Shear clearance (%)	Rust occurrence	Remark
1	A	7	2	1	12	10	Absent	Present Example
2	B	10	4	2	7	5	Absent	Present Example
3		<u>25</u>	5	2	6	12	Present	Comparative Example
4	C	9	3	2	6	15	Absent	Present Example
<u>5</u>	D	8	4	2	5	10	Absent	Present Example
<u>6</u>		18	<u>12</u>	2	6	10	Present	Comparative Example
7		<u>30</u>	<u>15</u>	3	6	10	Present	Comparative Example
8	E	10	4	1	10	15	Absent	Present Example
9	F	8	3	2	7	20	Absent	Present Example

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(continued)

5	Test No.	Steel	Grain size of ferrite phase (μm)	Grain size of austenite phase (μm)	Major axis of sulfides (μm)	Number of sulfides (pieces/5 mm ²)	Shear clearance (%)	Rust occurrence	Remark
10	<u>10</u>	G	14	6	3	10	8	Absent	Present Example
	<u>11</u>		11	5	3	11	10	Absent	Present Example
	12		16	7	<u>8</u>	10	10	Present	Comparative Example
15	13	H	9	5	2	7	15	Absent	Present Example
20	14	I	9	5	2	8	15	Absent	Present Example
	15		6	2	1	<u>3</u>	15	Present	Comparative Example
25	16	J	17	9	3	17	10	Absent	Present Example
	17		19	<u>12</u>	<u>6</u>	18	10	Present	Comparative Example
	18		15	9	<u>6</u>	<u>24</u>	10	Present	Comparative Example
30	19	K	11	6	2	5	10	Absent	Present Example
	20	L	9	4	2	9	20	Absent	Present Example
35	21	M	12	5	4	17	15	Absent	Present Example
	22		4	1	4	17	15	Present	Comparative Example
40	23	N	10	3	3	10	10	Absent	Present Example
	24	O	14	4	3	9	5	Absent	Present Example
45	25	P	18	8	1	12	10	Absent	Present Example
	26	Q	9	2	2	6	5	Absent	Present Example
50	27	R	15	6	2	10	10	Absent	Present Example

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Table 5

Test No.	Steel	Hot-rolled sheet annealing temperature (°C)	Cold-rolling reduction (%)	Cold-rolled sheet thickness (mm)	Final pass temperature incold-rolling (°C)	Cold-rolled sheet annealing temperature (°C)	Remark
28	AA	1050	75	1.00	180	1020	Comparative Example
29	AB	1050	75	1.00	180	1020	Comparative Example
30	AC	1050	75	1.00	200	1020	Comparative Example
31	AD	1050	75	1.00	185	1020	Comparative Example
32	AE	1050	75	1.00	180	1020	Comparative Example
33	AF	1050	75	1.00	205	1020	Comparative Example
34	AG	1050	75	1.00	185	1020	Comparative Example
35	AH	1050	75	1.00	180	1020	Comparative Example
36	AI	1050	75	1.00	200	1020	Comparative Example
37	AJ	1050	75	1.00	185	1020	Comparative Example
38	AK	1050	75	1.00	170	1020	Comparative Example
39	AL	1050	75	1.00	165	1020	Comparative Example
40	AM	1050	75	1.00	170	1020	Comparative Example
41	AN	1050	75	1.00	160	1020	Comparative Example
42	AO	1050	75	1.00	160	1020	Comparative Example
43	AP	1050	75	1.00	185	1020	Comparative Example
44	AQ	1050	75	1.00	205	1020	Comparative Example
45	AR	1050	75	1.00	175	1020	Comparative Example
46	AS	1050	75	1.00	180	1020	Comparative Example

Table 6

Test No.	Steel	Grain size of ferrite phase (μm)	Grain size of austenite phase (μm)	Major axis of sulfides (μm)	Number of sulfides (pieces/5 mm^2)	Shear clearance (%)	Rust occurrence	Remark
28	AA	6	2	6	12	10	Present	Comparative Example
29	AB	10	5	4	10	15	Present	Comparative Example
30	AC	11	4	2	7	15	Present	Comparative Example
31	AD	12	5	4	12	15	Present	Comparative Example
32	AE	11	4	3	10	15	Present	Comparative Example
33	AF	10	4	2	7	10	Present	Comparative Example
34	AG	9	4	4	<u>25</u>	10	Present	Comparative Example
35	AH	10	5	2	5	10	Present	Comparative Example
36	AI	12	6	2	5	15	Present	Comparative Example
37	AJ	12	5	4	9	10	Present	Comparative Example
38	AK	8	3	3	13	10	Present	Comparative Example
39	AL	7	2	2	6	15	Present	Comparative Example
40	AM	10	3	<u>10</u>	<u>34</u>	15	Present	Comparative Example
41	AN	4	2	4	6	15	Present	Comparative Example
42	AO	6	3	2	6	15	Present	Comparative Example
43	AP	10	4	6	18	10	Present	Comparative Example
44	AQ	16	8	4	14	15	Present	Comparative Example
45	AR	12	3	4	15	10	Present	Comparative Example
46	AS	11	5	4	12	15	Present	Comparative Example

Industrial Applicability

[0099] According to the ferritic-austenitic stainless steel sheet of the present embodiment, even when being used in the atmospheric environment in a state where a sheared line is not subjected to a corrosion resistance treatment, the

corrosion resistance of the sheared line is excellent. Accordingly, the ferritic-austenitic stainless steel sheet of the present embodiment can be appropriately used for various uses such as case bodies (chassis) of a power conditioner and a photovoltaic (PV) inverter, a duct hood, a frame of a solar cell, and a waste channel and a lid thereof.

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Claims

1. A ferritic-austenitic stainless steel sheet with excellent corrosion resistance of a sheared line, the ferritic-austenitic stainless steel sheet having a chemical composition comprising, in terms of % by mass:

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C: 0.03% or less;

Si: 0.1% to 1.0%;

Mn: 0.5% to 5.0%;

P: 0.04% or less;

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Al: 0.015% to 0.10%;

Cr: 19.0% to 24.0%;

Ni: 0.60% to 2.30%;

Cu: 0.5% to 1.5%;

Co: 0.05% to 0.25%;

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V: 0.01% to 0.15%;

Ca: 0.002% or less;

N: 0.06% to 0.20%; and

S: 0.0002% to 0.0040%,

with the remainder being Fe and unavoidable impurities,

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wherein a value of $Co + 0.25V$ is 0.10 or more and less than 0.25,

a metallic structure consists of ferrite phases and austenite phases,

an average crystal grain size of the ferrite phases is in a range of 5 to 20 μm , and an average crystal grain size

of the austenite phases is in a range of 2 to 10 μm , and

sulfides having major axes of 1 to 5 μm exist at an amount of 5 to 20 pieces per 5 mm^2 .

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2. The ferritic-austenitic stainless steel sheet with excellent corrosion resistance of a sheared line according to claim 1, the ferritic-austenitic stainless steel sheet further comprising:

one or more selected from the following groups,

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first group: one or more selected from, in terms of % by mass,

Nb: 0.005% to 0.2%,

Ti: 0.005% to 0.2%,

W: 0.005% to 0.2%, and

Mo: 0.01% to 1.0%,

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second group: one or more selected from, in terms of % by mass,

Sn: 0.005% to 0.2%,

Sb: 0.005% to 0.2%,

Ga: 0.001% to 0.05%,

Zr: 0.005% to 0.5%,

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Ta: 0.005% to 0.1%, and

B: 0.0002% to 0.0050%.

3. The ferritic-austenitic stainless steel sheet with excellent corrosion resistance of a sheared line according to claim 1 or 2,

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wherein a value of $Co + 0.25V$ is 0.12 or more and less than 0.25.

4. The ferritic-austenitic stainless steel sheet with excellent corrosion resistance of a sheared line according to any one of claims 1 to 3,

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wherein the amount of each of one or more selected from Co, V, S, N, Cr, and Ni satisfies the following range in terms of % by mass,

Co: 0.05% to 0.12%,

V: 0.08% to 0.12%,

S: 0.0003% to 0.0010%,
N: 0.08% to 0.17%,
Cr: 20.0% to 23.0%, and
Ni: 1.0% to 1.5%.

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5. The ferritic-austenitic stainless steel sheet with excellent corrosion resistance of a sheared line according to any one of claims 1 to 3,

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wherein the amount of V satisfies the following range in terms of % by mass,
V: 0.01% or more and less than 0.05%.

6. The ferritic-austenitic stainless steel sheet with excellent corrosion resistance of a sheared line according to according to claim 5,

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wherein the amount of each of one or more selected from Co, S, N, Cr, and Ni satisfies the following range in terms of % by mass,

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Co: 0.05% to 0.12%,
S: 0.0003% to 0.0010%,
N: 0.08% to 0.17%,
Cr: 20.0% to 23.0%, and
Ni: 1.0% to 1.5%.

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FIG. 1

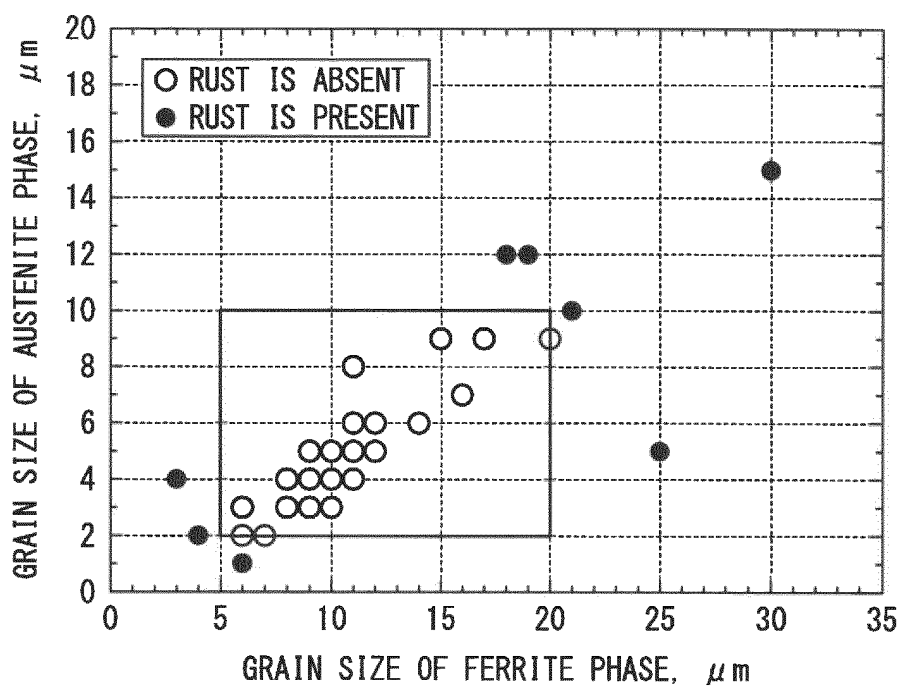
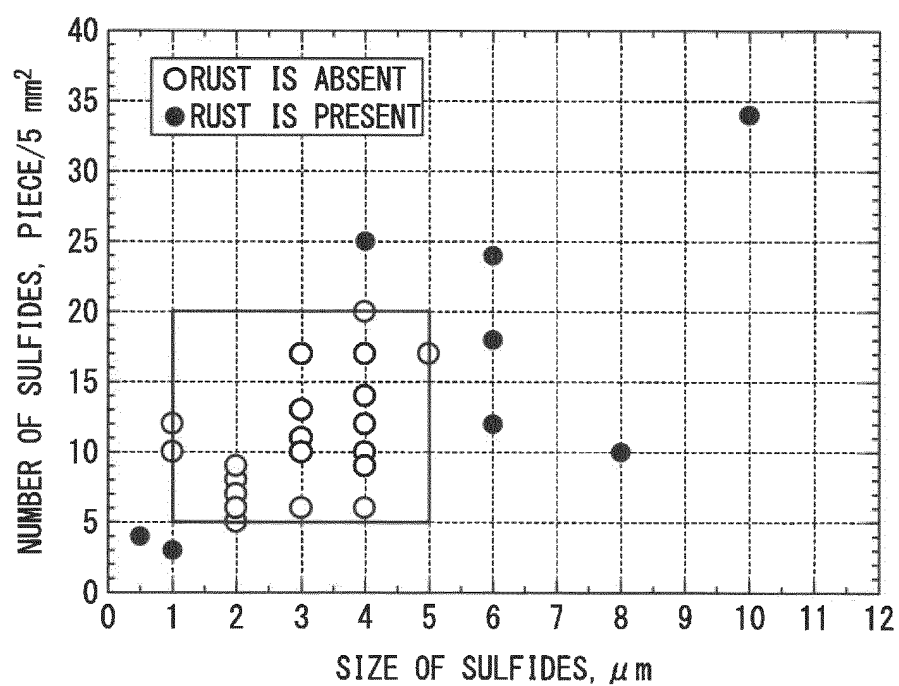


FIG. 2



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2016/057967

A. CLASSIFICATION OF SUBJECT MATTER

C22C38/00(2006.01)i, C22C38/58(2006.01)i, C22C38/60(2006.01)i, C21D9/46(2006.01)n

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)

C22C38/00-38/60

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

Jitsuyo Shinan Koho 1922-1996 Jitsuyo Shinan Toroku Koho 1996-2016
Kokai Jitsuyo Shinan Koho 1971-2016 Toroku Jitsuyo Shinan Koho 1994-2016

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2011-168838 A (Nippon Steel & Sumikin Stainless Steel Corp.), 01 September 2011 (01.09.2011), & WO 2011/102499 A1 & CN 102770572 A & KR 10-2012-0112794 A	1-6
A	JP 5375069 B2 (JFE Steel Corp.), 25 December 2013 (25.12.2013), (Family: none)	1-6

☐ Further documents are listed in the continuation of Box C.

☐ See patent family annex.

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Date of the actual completion of the international search
18 May 2016 (18.05.16)

Date of mailing of the international search report
31 May 2016 (31.05.16)

Name and mailing address of the ISA/
Japan Patent Office
3-4-3, Kasumigaseki, Chiyoda-ku,
Tokyo 100-8915, Japan

Authorized officer

Telephone No.

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