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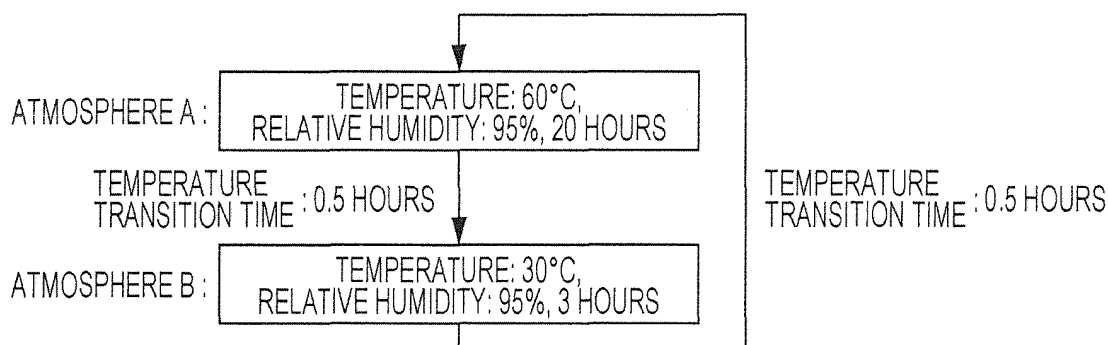
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(54) **CORROSION-RESISTANT STEEL FOR HOLD OF COAL CARRYING VESSEL OR COAL/ORE CARRYING VESSEL**

(57) The present invention provides a corrosion-resistant steel for a coal carrier or ore/coal carrier hold, wherein corrosion after peeling of a coating film can be inhibited under a cyclic wet and dry environment and a low pH environment. Specifically, the corrosion-resistant steel for a coal carrier or ore/coal carrier hold is characterized in that the chemical composition of the steel con-

tains C: 0.010 to 0.200 percent by mass, Si: 0.05 to 0.50 percent by mass, Mn: 0.10 to 2.0 percent by mass, P: 0.0250 percent by mass or less, S: 0.010 percent by mass or less, Al: 0.0050 to 0.10 percent by mass, Sb: 0.010 to 0.50 percent by mass, N: 0.0010 to 0.0080 percent by mass, and in addition, the remainder composed of Fe and incidental impurities.

FIG. 1



Description

[Technical Field]

5 **[0001]** The present invention relates to a steel with excellent corrosion resistance used for a coal carrier or ore/coal carrier hold (may be referred to as belly of a ship).

[Background Art]

10 **[0002]** At the beginning of the 1990s, successive maritime accidents of bulk carriers caused international problems. In particular, many accidents of coal carriers and ore/coal carriers were reported and most of causes thereof were damages in bellies of ships. In the bulk carrier, a cargo is loaded directly in a hold and, therefore, an influence of a corrosive cargo is exerted easily. It is believed to be a problem that the strength is reduced locally by corrosion in a belly of a ship (hereafter may be referred to as "hold"), in particular, pitting corrosion of a side shell in a hold of a coal carrier or ore/coal carrier. Instances in which this pitting corrosion proceeded significantly and instances in which the plate thickness of a side frame portion to ensure the strength of a carrier was reduced considerably have been reported. In order to prevent an accident, Non Patent Literature 1 stipulates that renewal of a hold side shell steel is required in the case of 70% or less of the as-built thickness and renewal of a hold side frame steel is required in the case of 75% or less of the as-built thickness (where a value larger than the as-built thickness - corrosion allowance - voluntary thickness addition is not required).

20 **[0003]** The side shell of a bulk carrier in which the above-described pitting corrosion occurs is a single-hull, and a cargo and the seawater is separated by only a plate of steel. Then, the temperature in the hold increases on the basis of self-heating inherent in the coal. Consequently, dew condensation water is generated easily on the hold side shell because of a temperature difference between the seawater and the inside of the hold. The inside of the hold is in a low pH environment in which sulfuric acid corrosion occurs easily because SO_4^{2-} in the coal is eluted into the above-described place where dew condensation water has been generated on the hold side shell and reacts with the dew condensation water to generate sulfuric acid. Therefore, two corrosion protection mechanisms are required, where "inhibition of hydrogen generation reaction" is performed against the low pH environment and "inhibition of SO_4^{2-} permeation in rust layers" is performed against SO_4^{2-} permeation to rust/steel interface, while SO_4^{2-} serves as a counter anion to dissolution of iron.

30 **[0004]** Modified epoxy resin coating having a coating thickness of about 150 to 200 μm is applied to the inside of the hold as the above-described corrosion control method in the hold. However, in many cases, the coatings are peeled because of mechanical damages by coals and iron ores and flaws abrasions due to heavy machinery in cargo carrying out, so that a sufficient effect of corrosion protection is not obtained.

35 **[0005]** Then, periodic repainting and partial touch-up methods have been employed as further corrosion control methods. However, such methods require very large costs. Therefore, reduction in the life cycle cost including the maintenance cost of ship remains an issue.

[0006] Meanwhile, as for corrosion-resistant steels for ships, steels developed for cargo oil tanks and ballast tanks have been known.

40 **[0007]** An upper deck of cargo oil tank side is exposed to an environment of corrosive gases, e.g., O_2 , CO_2 , and SO_2 contained in an inert gas blown into a tank for the purpose of explosion protection and H_2S and the like volatilized from crude oil. Although a bottom plate has a protective film (may be referred to as "oil coat") derived from crude oil, a place where the film has been peeled is exposed to an environment in which bowl-shaped local corrosion occurs. For example, Patent Literature 1 proposes a corrosion-resistant steel by utilizing corrosion protection mechanisms for "improvement in corrosion resistance on the basis of inhibition of pH reduction" and "improvement in local corrosion resistance on the basis of sulfide fine dispersion".

45 **[0008]** Also, when no cargo is loaded, the ballast tank is poured with the seawater to perform a function of allowing a ship to achieve stable navigation and, therefore, is placed in a very severe corrosive environment. The upper deck of ballast tank side is not immersed into the seawater, nor is in the state of being sprayed with the seawater. Consequently, cathodic protection does not function and, in addition, this area comes into a severe corrosive environment because the temperature of the steel increases by sunshine, and undergoes severe corrosion. Meanwhile, the side shell surface and the bottom of the ballast tank are portions immersed in the seawater completely and are in a corrosive environment, although a cathodic protection action functions.

50 **[0009]** However, in the navigation with cargo, the seawater is not poured into the ballast tank, and the cathodic protection does not function at all with respect to the whole ballast tank. Therefore, severe corrosion occurs because of a cyclic wet and dry environment and actions of residual adhesion salts. For example, Patent Literature 2 proposes that Cl^- permeation is inhibited by densification of rust and Patent Literature 3 proposes a corrosion-resistant steel by utilizing a corrosion protection mechanism in which Cl^- permeation is electrochemically inhibited by WO_4^{2-} .

[0010] As described above, in the coal carrier or ore/coal carrier, it is necessary that a hydrogen generation reaction be inhibited and SO_4^{2-} permeation to rust/steel interface be inhibited in the case of low pH environment in which concentration of sulfuric acid occurs because of the cyclic wet and dry environment. As described above, the corrosive environments and the corrosion protection mechanisms are different between the coal carrier or ore/coal carrier holds, ballast tanks, and the oil tanks and, therefore, the corrosion-resistant steels for the ballast tank or the oil tank cannot be diverted on an "as is" basis. Consequently, as for the steel for the coal carrier or ore/coal carrier hold, original material design and characteristic evaluation are required.

[0011] Also, Patent Literatures 1, 4, and 5 are mentioned as the related art referring to the coal carrier or ore/coal carrier hold use. As for the chemical compositions of corrosion-resistant steels for shipbuilding in the use environment of the coal carrier or ore/coal carrier hold, Patent Literature 1 discloses a steel containing Cu and Mg as indispensable chemical compositions, Patent Literature 4 discloses a steel containing Cu, Ni, and Sn as indispensable chemical compositions, and Patent Literature 5 discloses a steel containing Cu and Sn as indispensable chemical compositions for the purpose of further improving the cost.

[Citation List]

[Non Patent Literature]

[0012] [NPL 1] Nippon Kaiji Kyokai, COMMON STRUCTURAL RULES FOR BULK CARRIERS (RULES FOR THE SURVEY AND CONSTRUCTION OF STEEL SHIPS PART CSR-B), p. 384-394, (2006)

[Patent Literature]

[0013]

[PTL 1] Japanese Unexamined Patent Application Publication No. 2000-17381

[PTL 2] Japanese Unexamined Patent Application Publication No. 2008-144204

[PTL 3] Japanese Unexamined Patent Application Publication No. 2007-46148

[PTL 4] Japanese Unexamined Patent Application Publication No. 2007-262555

[PTL 5] Japanese Unexamined Patent Application Publication No. 2008-174768

[Summary of Invention]

[Technical Problem]

[0014] However, the subject of the steel shown in Patent Literature 1 is a steel excellent in the use environment common to ship shells, ballast tanks, cargo oil tanks, ore carrier cargo holds, and the like. Therefore, good results in the corrosion test of the cargo oil tank and the ballast tank are mentioned as the method for evaluating the corrosion resistance of the steel, although test results in consideration of the use environments of the coal carrier and ore/coal carrier holds are not shown.

[0015] Also, in Patent Literatures 4 and 5, the corrosion resistance under coating film is evaluated, where an environment of the coal carrier or ore/coal carrier hold is simulated. However, an evaluation test simulating the case where peeling occurs easily because of mechanical damages by coals and iron ores, which can be said to be unavoidable in the use environment of the hold, and an evaluation of maximum pitting corrosion depth serving as a renewal guideline of the steel plate are not performed.

[0016] As described above, consideration of corrosion environment specific to the coal carrier or ore/coal carrier hold and, in addition, an evaluation of corrosion of a steel in the state of having no coating film because of peeling of the coating film are important for the development of a steel with excellent corrosion resistance to be used for the coal carrier or ore/coal carrier hold. However, these viewpoints are not taken into consideration in the related art.

[0017] Accordingly, it is an object of the present invention to provide a corrosion-resistant steel for a coal carrier or ore/coal carrier hold, wherein corrosion after peeling of a coating film can be inhibited under a cyclic wet and dry environment and a low pH environment.

[Solution to Problem]

[0018] In general, a ship is built by welding steels, e.g., steel plates, steel sheets, shaped steels, and steel bars, and corrosion protection coating films are applied to the surfaces of the steels to be used. However, in the environment of the coal carrier or ore/coal carrier hold, the coating is in the circumstances of being peeled easily because of mechanical

damages by coals and ores, and the steel is exposed to a cyclic wet and dry environment and a low pH environment. Here, a steel capable of exerting the corrosion resistance even after peeling of a surface corrosion protection coating film of the steel has been developed.

[0019] In this regard, the present inventors developed a testing method simulating an environment in a coal carrier or ore/coal carrier hold, and studied influences of the individual alloy elements by using the resulting testing method. As a result, it was found that the corrosion resistance of the steel after peeling of a coating film of the coal carrier or ore/coal carrier hold was improved by adding Sb or further adding Cu and Ni and, thereby, the present invention has been completed. Meanwhile, the testing method simulating an environment in the coal carrier or ore/coal carrier hold will be described later in the example.

1. A corrosion-resistant steel for a coal carrier or ore/coal carrier hold, characterized in that the chemical composition of the steel contains C: 0.010 to 0.200 percent by mass, Si: 0.05 to 0.50 percent by mass, Mn: 0.10 to 2.0 percent by mass, P: 0.0250 percent by mass or less, S: 0.010 percent by mass or less, Al: 0.0050 to 0.10 percent by mass, Sb: 0.010 to 0.50 percent by mass, N: 0.0010 to 0.0080 percent by mass, and in addition, the remainder composed of Fe and incidental impurities.

2. The corrosion-resistant steel for a coal carrier or ore/coal carrier hold, according to the item 1, characterized by further containing at least one selected from Cu: 0.010 to 1.0 percent by mass and Ni: 0.010 to 1.0 percent by mass in addition to the above-described steel.

3. The corrosion-resistant steel for a coal carrier or ore/coal carrier hold, according to the item 1 or item 2, characterized in that in the above-described steel, Cr is 0.050 percent by mass or less.

4. The corrosion-resistant steel for a coal carrier or ore/coal carrier hold, according to any one of the items 1 to 3, characterized by further containing at least one selected from W: 0.005 to 0.5 percent by mass and Mo: 0.005 to 0.5 percent by mass in addition to the above-described steel.

5. The corrosion-resistant steel for a coal carrier or ore/coal carrier hold, according to any one of the items 1 to 4, characterized by containing at least one selected from Ti: 0.0010 to 0.030 percent by mass, Nb: 0.0010 to 0.030 percent by mass, Zr: 0.0010 to 0.030 percent by mass, and V: 0.0020 to 0.20 percent by mass in addition to the above-described steel.

6. The corrosion-resistant steel for a coal carrier or ore/coal carrier hold, according to any one of the items 1 to 5, characterized by further containing Ca: 0.0005 to 0.0040 percent by mass in addition to the above-described steel.

7. The corrosion-resistant steel for a coal carrier or ore/coal carrier hold, according to any one of the items 1 to 6, characterized by containing at least one selected from REM: 0.0001 to 0.0150 percent by mass and Y: 0.0001 to 0.10 percent by mass in addition to the above-described steel.

8. The corrosion-resistant steel for a coal carrier or ore/coal carrier hold, according to any one of the items 1 to 7, characterized by containing at least one selected from Se: 0.0005 to 0.50 percent by mass, Te: 0.0005 to 0.50 percent by mass, and Co: 0.010 to 0.50 percent by mass in addition to the above-described steel.

[Advantageous Effects of Invention]

[0020] According to the present invention, a corrosion-resistant steel for a coal carrier or ore/coal carrier hold can be obtained, wherein corrosion after peeling of a coating film can be inhibited under a cyclic wet and dry environment and a low pH environment in the coal carrier or ore/coal carrier hold.

[Brief Description of Drawings]

[0021]

[Fig. 1] Fig. 1 is a diagram showing an example of temperature-humidity cycle in a coal corrosion test.

[Fig. 2] Fig. 2 is a diagram to estimate a maximum thickness decrease of a coal carrier or ore/coal carrier hold steel 25 years later.

[Fig. 3] Fig. 3 is a diagram showing the results of S mapping after a coal corrosion test of an invention example and a comparative example on the basis of electron probe micro-analysis.

[Description of Embodiments]

[0022] The embodiments according to the present invention will be described below. To begin with, reasons for the limitation of the chemical composition of the steel to the above-described range in the present invention will be described.

C: 0.010 to 0.200 percent by mass

[0023] Carbon is an element effective in enhancing the strength of the steel. In the present invention, it is necessary that the content be 0.010 percent by mass or more to ensure the strength. On the other hand, if the content is more than 0.200 percent by mass, the weldability and the toughness of a heat-affected zone are degraded. Therefore, C is specified to be within the range of 0.010 to 0.200 percent by mass, and preferably within the range of 0.050 to 0.150 percent by mass.

Si: 0.05 to 0.50 percent by mass

[0024] Silicon is added as a deoxidizing agent and is an element to enhance the strength of the steel. In the present invention, the content is specified to be 0.05 percent by mass or more. However, if the content is more than 0.50 percent by mass, the toughness of the steel is degraded. Therefore, the upper limit of Si is specified to be 0.50 percent by mass. In addition, Si forms a corrosion protection film in an acidic environment to improve corrosion resistance. In order to obtain this effect, Si is preferably within the range of 0.20 to 0.40 percent by mass.

Mn: 0.10 to 2.0 percent by mass

[0025] Manganese is an element capable of enhancing the strength of the steel at a low cost and, furthermore, capable of preventing hot brittleness. Therefore, the content is specified to be 0.10 percent by mass or more. However, if the content is more than 2.0 percent by mass, the toughness and the weldability of the steel are degraded. Therefore, Mn is specified to be within the range of 2.0 percent by mass or less, and preferably within the range of 0.80 to 1.4 percent by mass from the viewpoint of ensuring of the strength and reduction of inclusions.

P: 0.0250 percent by mass or less

[0026] Phosphorus is a harmful element which degrades not only the base material toughness of the steel but also the weldability and the welded portion toughness and, therefore, is desirably minimized. In particular, if the P content is more than 0.0250 percent by mass, degradation in the base material toughness and the welded portion toughness become significant. Therefore, P is specified to be 0.0250 percent by mass or less, and preferably 0.0150 percent by mass or less.

S: 0.010 percent by mass or less

[0027] Sulfur forms MnS serving as a start point of local corrosion and degrades the local corrosion resistance. In addition, sulfur is a harmful element which degrades the toughness and the weldability of the steel and, therefore, is desirably minimized. In the present invention, S is limited to 0.010 percent by mass or less, preferably 0.007 percent by mass or less, and further preferably 0.005 percent by mass or less.

Al: 0.0050 to 0.10 percent by mass

[0028] Aluminum is added as a deoxidizing agent. For this purpose, it is necessary that the content be 0.0050 percent by mass or more. If the content is more than 0.10 percent by mass, when welding is performed, the toughness of a welded metal portion is degraded. Therefore, Al is limited to within the range of 0.0050 to 0.10 percent by mass, and preferably 0.010 to 0.050 percent by mass.

Sb: 0.010 to 0.50 percent by mass

[0029] When 0.010 percent by mass or more of Sb is contained as an alloy element in the steel, Sb is concentrated in the vicinity of the steel in a low pH environment. Antimony has a large hydrogen overvoltage, so that a hydrogen generation reaction is inhibited in a portion where Sb has been precipitated and the corrosion resistance is improved. Furthermore, Sb densifies corrosion products and inhibits diffusion of H_2O , O_2 , SO_4^{2-} , and Cl^- into the steel.

[0030] On the other hand, if more than 0.50 percent by mass of Sb is added, the toughness is degraded. Therefore, Sb is limited to within the range of 0.010 to 0.50 percent by mass, preferably within the range of 0.010 to 0.30 percent by mass, and further preferably within the range of 0.010 to 0.20 percent by mass.

N: 0.0010 to 0.0080 percent by mass

[0031] Nitrogen is an element to degrade the toughness and is desirably minimized. However, it is difficult to decrease

to less than 0.0010 percent by mass industrially. On the other hand, if the content is more than 0.0080 percent by mass, significant reduction in the toughness is caused. Therefore, in the present invention, N is limited to within the range of 0.0010 to 0.0080 percent by mass, and preferably 0.0010 to 0.0050 percent by mass.

[0032] Furthermore, the steel according to the present invention can contain at least one selected from Cu and Ni within the following range in addition to the above-described indispensable components.

Cu: 0.010 to 1.0 percent by mass

[0033] Copper densifies corrosion products and inhibits diffusion of H_2O , O_2 , SO_4^{2-} , and Cl^- into the steel. Consequently, the corrosion resistance of the steel is improved. This effect is exerted when the content is 0.010 percent by mass or more. However, as the amount of addition increases, the weldability and the toughness of the base material are degraded. Therefore, in the case where Cu is contained, Cu is preferably within the range of 0.010 to 1.0 percent by mass, further preferably within the range of 0.010 to 0.50 percent by mass, and still more preferably within the range of 0.010 to 0.35 percent by mass. Also, Cu forms Cu_2Sb , which is an intermetallic compound, under coexistence with Sb and, therefore, has an effect in improving the corrosion resistance.

Ni: 0.010 to 1.0 percent by mass

[0034] Nickel densifies corrosion products and inhibits diffusion of H_2O , O_2 , SO_4^{2-} , and Cl^- into the steel as with Cu. Consequently, the corrosion resistance of the steel is improved. This effect is exerted when the content is 0.010 percent by mass or more. However, if the content is more than 1.0 percent by mass, the effect is saturated and, in addition, the cost increases. Therefore, in the case where Ni is contained, Ni is preferably within the range of 0.010 to 1.0 percent by mass, and further preferably within the range of 0.010 to 0.50 percent by mass.

[0035] The steel according to the present invention can contain Cr within the following range in addition to the above-described components.

Cr: 0.050 percent by mass or less

[0036] Chromium is an element to cause hydrolysis in a low pH environment and, thereby, degrade the corrosion resistance. Therefore, Cr is not necessarily added. Chromium can be added to adjust the strength. However, in particular, if the content is more than 0.050 percent by mass, the corrosion resistance is degraded significantly. Therefore, in the case where Cr is contained, the content is preferably 0.050 percent by mass or less, and further preferably 0.030 percent by mass or less.

W: 0.005 to 0.5 percent by mass and Mo: 0.005 to 0.5 percent by mass

[0037] Tungsten and molybdenum form oxoacids when being eluted from the base material, the oxoacids electrically repel anions and prevent anions from entering up to the steel surface, so that the corrosion resistance is improved. Furthermore, Mo and W improve the corrosion resistance by forming sparingly soluble corrosive materials, e.g., $FeMoO_4$ and $FeWO_4$. In order to obtain these effects, the content of each of them is preferably 0.005 percent by mass or more. However, even when addition is more than 0.5 percent by mass, not only the effect is saturated but also the cost increases. Therefore, in the case where W and Mo are contained, the content is preferably 0.5 percent by mass or less, and further preferably 0.010 to 0.3 percent by mass.

[0038] The steel according to the present invention can further contain at least one selected from Ti, Nb, Zr, and V within the following range in addition to the above-described components for the purpose of enhancing the strength.

[0039] At least one selected from Ti: 0.0010 to 0.030 percent by mass, Nb: 0.0010 to 0.030 percent by mass, Zr: 0.0010 to 0.030 percent by mass, and V: 0.0020 to 0.20 percent by mass

[0040] Each of Ti, Nb, Zr, and V is an element to enhance the strength of the steel and can be selected and contained in accordance with the required strength. In order to obtain such an effect, the contents of Ti, Nb, and Zr are preferably 0.0010 percent by mass or more and the content of V is preferably 0.0020 percent by mass or more. However, if each of the content of Ti, Nb, and Zr is more than 0.030 percent by mass or the content of V is more than 0.20 percent by mass, the toughness is degraded. Therefore, in the case where Ti, Nb, Zr, and V are contained, the content of each of them is preferably within the above-described range, and Ti: 0.0050 to 0.020 percent by mass, Nb: 0.0050 to 0.020 percent by mass, Zr: 0.0050 to 0.020 percent by mass, and V: 0.0050 to 0.10 percent by mass are further preferable.

[0041] The steel according to the present invention can contain Ca within the following range in addition to the above-described components.

Ca: 0.0005 to 0.0040 percent by mass

[0042] Calcium is an element to control the forms of inclusions and enhance the ductility and the toughness of the steel. In order to exert such effects, the content is preferably at least 0.0005 percent by mass. However, if the content is too large, coarse inclusions are formed and the toughness of the base material is degraded. Therefore, in the case where Ca is contained, the upper limit is specified to be preferably 0.0040 percent by mass, and 0.0010 to 0.0030 percent by mass is further preferable.

[0043] The steel according to the present invention can further contain at least one selected from REM and Y within the following range in addition to the above-described components for the purpose of improving the toughness.

REM: 0.0001 to 0.0150 percent by mass and Y: 0.0001 to 0.10 percent by mass

[0044] Each of REM (rare earth metal) and Y is an element to enhance the toughness of a heat-affected zone and can be contained as necessary. This effect is obtained when the content of each of REM and Y is 0.0001 percent by mass or more. However, if the content of REM is more than 0.0150 percent by mass or the content of Y is more than 0.10 percent by mass, degradation in the toughness is caused. Therefore, in the case where REM and Y are contained, the content of each of them is preferably within the above-described range.

[0045] The steel according to the present invention can further contain at least one selected from Se, Te, and Co within the following range in addition to the above-described components for the purpose of enhancing the strength.

[0046] At least one of Se: 0.0005 to 0.50 percent by mass, Te: 0.0005 to 0.50 percent by mass, and Co: 0.010 to 0.50 percent by mass Selenium, tellurium, and cobalt are elements to enhance the strength of the steel and can be contained as necessary. In order to obtain this effect, the contents of Se and Te are preferably 0.0005 percent by mass or more and the content of Co is preferably 0.010 percent by mass or more. However, if each of the contents of Se, Te, and Co is more than 0.50 percent by mass, the toughness and the weldability are degraded. Therefore, in the case where Se, Te, and Co are contained, the contents are preferably specified to be within the above-described range.

[0047] Among the chemical components according to the present invention, the components other than those described above are Fe and incidental impurities. However, components other than those described above may be contained within the bounds of not impairing the effects of the present invention. For example, Mg: 0.0001 to 0.010 percent by mass can be contained for the purpose of improving the toughness.

[0048] On the other hand, as shown in the examples later, even when Sn is contained in stead of Sb, an effect of reducing the corrosion weight loss and the maximum pitting corrosion depth is not exerted. Furthermore, coexistence of Sn with Cu lowers the melting point of Cu and further reduces the solid solubility into iron, so that Cu is precipitated at grain boundaries on the steel surface and hot brittleness is caused. Consequently, Sn is not added, although the content of less than 0.005 percent by mass is permissible as an impurity because hot brittleness is not caused.

[0049] Next, a preferred method for manufacturing the corrosion-resistant steel according to the present invention will be described, although the present invention can be applied to manufacturing methods other than this.

[0050] A steel produced by continuous casting or the like is hot-rolled on an "as is" basis or while reheat is performed after cooling. The heat treatment condition to exhibit the corrosion resistance is not specifically limited, but it is preferable that an appropriate reduction ratio be ensured from the viewpoint of the mechanical property. If the finishing temperature of hot rolling is lower than 750°C, deformation resistance increases and a defective shape is caused. Therefore, the finishing temperature is specified to be preferably 750°C or higher.

[0051] For example, a steel having a tensile strength of 490 MPa-grade or more can be produced by specifying the finishing temperature to be 750°C or higher and, thereafter, controlling the cooling rate in such a way that cooling to 600°C or lower is performed at a cooling rate of 150°C/min or more.

[EXAMPLES]

[0052] A steel to contain components shown in Table 1 was smelted with a vacuum melting furnace or smelted with a converter and, thereafter, a slab was produced by continuous casting. Subsequently, the slab was put into a furnace and was heated to 1,200°C. A steel plate having a thickness of 25 mm was produced by hot rolling at a finishing temperature of 800°C.

[0053] The present inventors examined the mechanism of an occurrence of pitting corrosion which has a largest influence on breakage of ship among corrosion in a coal carrier or ore/coal carrier hold. The results were as described below. The side shell of a bulk carrier is a single-hull, and a cargo and the seawater is separated by only a plate of steel. Consequently, dew condensation water is generated on the hold side shell because of a temperature difference between the seawater and the inside of the hold, so that the surfaces of the steel and the coal are wetted and H₂SO₄-derived substances adsorbed to the coal surface are leached into a water film. Pitting corrosion proceeds under the coal forming a meniscus, and H⁺ is consumed in corrosion of the steel, so that the H⁺ concentration is reduced in the meniscus

portion. On the other hand, the coal surface is rich in H^+ , and a difference in the H^+ concentration occurs between the coal surface and the meniscus portion. It is considered that the difference in the chemical potential serves as a driving force and H^+ is fed from the coal surface to the meniscus portion. Then, in a drying step, unreacted H^+ adheres to the coal surface again and is used for a corrosion reaction in the next dew condensation step. This steps occur over a long-term cycle, corrosion is facilitated in the meniscus portion, and pitting corrosion proceeds. In order to perform laboratory simulation of pitting corrosion in a coal carrier or ore/coal carrier hold, the following condition was employed on the basis of the present mechanism.

(EXAMPLE 1)

[0054] Initially, in order to measure the maximum pitting corrosion depth by using the steel plate shown in Table 1, an example was obtained in the procedure described below (the present testing method is referred to as Corrosion test a). A test piece of $5\text{ mm}^t \times 50\text{ mm}^W \times 75\text{ mm}^L$ was taken from the steel plate containing components shown in Table 1. The surface of the test piece was subjected to shot blasting to remove scales and oil contents on the surface. The resulting surface was specified to be a test surface and the corrosion resistance of the steel after peeling of a coating film was evaluated. The back and the end surface were coated with silicon base adhesive tape, the test piece was fit into an acrylic cell, and 5 g of coal was laid thereon. A temperature-humidity cycle of Atmosphere A (temperature 60°C , humidity 95%, and 20 hours) $\leftrightarrow$ Atmosphere B (temperature 30°C , humidity 95%, and 3 hours) with transition time of 0.5 hours, as shown in Fig. 1, was applied for 28 days with a temperature and humidity chamber. Here, the symbol " $\leftrightarrow$ " is used in the sense of repetition (the same goes hereafter). In this regard, the coal employed was specified in such a way that when 5 g of coal was weighed and immersed in 100 ml of distilled water at ambient temperature for 2 hours and, thereafter, filtration was performed, the pH of a liquid leached from the coal and diluted to 200 ml became 3.0. The present example was allowed to simulate the temperature-humidity environment and the dew condensation situation having a large influence on corrosion in a coal carrier or ore/coal carrier hold by performing an examination under such conditions. After the test, rust of each test piece was peeled by using a rust peeling liquid, and the amount of weight decrease of the steel was measured and taken as the amount of corrosion. Also, the resulting maximum pitting corrosion depth was measured with a depth meter. The results thereof are shown in Table 2.

[0055] As is clear from Table 2, in all Test Nos. 1-a to 27-a (the numerical part of Test No. and Steel plate No. agreed with each other, the same goes hereafter) and Nos. 33-a to 40-a which were the invention examples, both the weight decrease and the maximum pitting corrosion depth were good as compared with those of comparative materials, the weight decrease was controlled to be 2.5 g or less, and the maximum pitting corrosion depth was controlled to be 0.30 mm or less. On the other hand, in Test Nos. 28-a and 29-a which were comparative materials, more than 0.050 percent by mass of Cr was contained and in Test Nos. 30-a and 32-a, Sb was not contained but Sn was contained, so that the weight decrease was 2.7 g or more and the maximum pitting corrosion depth was 0.35 mm or more in all cases. In this regard, in Test No. 31-a, Sb was not contained and, therefore, the weight decrease was 2.71 g and the maximum pitting corrosion depth was 0.34 mm, so that the corrosion resistance was inferior to the corrosion resistance of the invention examples in spite of the fact that the amount of elements other than Sb were within the scope of the present invention.

(EXAMPLE 2)

[0056] Next, an example to estimate a maximum thickness decrease 25 years later will be described. As with Example 1, a test piece of $5\text{ mm}^t \times 50\text{ mm}^W \times 75\text{ mm}^L$ was taken from the steel plate shown in Table 1. The surface of the test piece was subjected to shot blasting to remove scales and oil contents on the surface. The resulting surface was specified to be a test surface and the corrosion resistance of the steel after peeling of a coating film was evaluated. The back and the end surface were coated with silicon base adhesive tape, the test piece was fit into an acrylic cell, and 5 g of coal was laid thereon. A temperature-humidity cycle of Atmosphere A (temperature 60°C , humidity 95%, and 20 hours) $\leftrightarrow$ Atmosphere B (temperature 30°C , humidity 95%, and 3 hours) with transition time of 0.5 hours, as shown in Fig. 1, was applied for 28, 56, 84, 168, or 336 days with a temperature and humidity chamber (the present testing method is referred to as Corrosion test b).

[0057] In this regard, the coal employed was specified in such a way that when 5 g of coal was weighed and immersed in 100 ml of distilled water at ambient temperature for 2 hours and, thereafter, filtration was performed, the pH of a liquid leached from the coal and diluted to 200 ml became 3.0. The present example was allowed to simulate the temperature-humidity environment and the dew condensation situation having a large influence on corrosion in a coal carrier or ore/coal carrier hold by performing an examination under such conditions. After the test, rust of each test piece was peeled by using a rust peeling liquid, and the maximum pitting corrosion depth in each time period was measured. However, the value of maximum pitting corrosion depth increased as a subject area increased. Then, in order to predict the maximum pitting corrosion depth in each time period of an actual ship, the maximum pitting corrosion depth in an area equivalent to the actual ship hold area was calculated from the measurement value in the present test piece area

by using extreme value statistics. Here, the hold side frame portion, which is an application area of the present development steel, is corroded from both surfaces. Therefore, the maximum pitting corrosion depth in each time period was doubled, and the maximum thickness decrease 25 years later, which was a life time of ship, was estimated by extrapolation of those values. The results thereof are shown in Table 3. The criteria of the maximum thickness decrease 25 years later were specified to be 4.0 mm on the basis of the steel plate renewal guideline of RULES FOR THE SURVEY AND CONSTRUCTION OF STEEL SHIPS PART CSR-B (IACS common structure rule for bulk carrier) on the precondition that the plate thickness of the application area was 15 to 20 mm, the corrosion allowance was 3.5 to 4.0 mm, and the voluntary thickness addition was 0.5 mm.

[0058] In addition, S mapping of rust cross-sections of Invention example No. 37-b and Comparative example No. 44-b after the test for 84 days were performed on the basis of the electron probe micro-analysis. As for the electron probe micro-analysis, EPMA1600 produced by SHIMADZU CORPORATION was used, and a region of $100 \times 100 \mu\text{m}$ was measured at acceleration voltage: 20 kV, beam diameter: $1 \mu\text{m}$, and $0.4 \mu\text{m}$ pitch in the X and Y directions.

[0059] Fig. 2 shows a graph to estimate a maximum thickness decrease 25 years later. Here, the maximum thickness decrease refers to the thickness of steel plate in the portion which has been lost by local corrosion and at which the thickness decrease from the as-built thickness of a ship is maximum. Invention example No. 37-b and Comparative example No. 44-b are described. The maximum thickness decrease in each time period used for forming Fig. 2 was as described below in Invention example No. 37-b. 28 days: 0.85 mm, 56 days: 1.11 mm, 84 days: 1.28 mm, 168 days: 1.36 mm, and 336 days: 1.47 mm. In this regard, those in Comparative example No. 44-b were as described below. 28 days: 0.96 mm, 56 days: 1.39 mm, 84 days: 1.62 mm, 168 days: 1.91 mm, and 336 days: 2.11 mm. Meanwhile, in all of Test Nos. 1-b to 27-b and Test Nos. 33-b to 40-b of Invention examples shown in Table 3, estimated maximum thickness decreases 25 years later were less than or equal to 4.0 mm, which was the criteria. In this regard, No. 31-b, in which only addition of Sb was out of the present claim, did not satisfy the criteria. Therefore, it is clear that Sb has a large influence on corrosion protection in the present environment.

[0060] Also, Fig. 3 shows the results of S mapping of rust portion cross-sections after 84 days in Corrosion test b on the basis of the electron probe micro-analysis. In Comparative example No. 44-b, an interface layer rich in S is present between a rust layer and a steel, whereas in Invention example No. 37-b, an interface layer rich in S is hardly observed. Consequently, it is estimated that in Invention example, SO_4^{2-} permeation to rust/steel interface is inhibited by densification of rust due to Sb and electrical repulsion of SO_4^{2-} due to an oxoacid of W. Accordingly, it is clear that the present invention is a steel which forms a rust layer to inhibit SO_4^{2-} permeation in a coal carrier or ore/coal carrier hold environment.

[0061] As described above, the effects of the present invention were ascertained. In the present example, the method shown in Fig. 1 was employed as the testing method simulating the coal carrier or ore/coal carrier hold environment, and results very consistent with those in the case where evaluation was performed on the basis of placement in an actual coal carrier or ore/coal carrier hold were obtained. In this regard, the conditions of Atmospheres A and B, the transition times, the cycle, the method for adjusting the coal, and the conditions, e.g., the value of pH of the liquid leached from the coal, are not limited to the above-described examples and can be changed appropriately in accordance with the use environment of the steel in the hold.

[Industrial Applicability]

[0062] The steel according to the present invention can be used as a constituent member of a coal carrier or ore/coal carrier hold, where the coating film is peeled easily because of mechanical damages by coals and ores, and the steel is exposed to a cyclic wet and dry environment and a low pH environment.

[Table 1-1]

Table 1-1															(mass%)			
Steel plate No.	C	Si	Mn	P	S	Al	Sb	Cu	Ni	Cr	Sn	Mo	W	Remarks				
1	0.144	0.27	1.06	0.012	0.004	0.034	0.01	-	-	-	-	-	-	Invention example				
2	0.145	0.28	1.07	0.012	0.004	0.032	0.11	-	-	-	-	-	-	Invention example				
3	0.142	0.28	1.07	0.011	0.004	0.032	0.49	-	-	-	-	-	-	Invention example				
4	0.145	0.28	1.06	0.011	0.004	0.036	0.10	0.01	-	-	-	-	-	Invention example				
5	0.143	0.28	1.06	0.011	0.004	0.035	0.10	0.10	-	-	-	-	-	Invention example				
6	0.142	0.29	1.07	0.012	0.004	0.034	0.11	0.98	-	-	-	-	-	Invention example				
7	0.145	0.28	1.07	0.012	0.004	0.033	0.10	-	0.01	-	-	-	-	Invention example				
8	0.144	0.28	1.06	0.012	0.004	0.034	0.09	-	0.11	-	-	-	-	Invention example				
9	0.143	0.28	1.06	0.011	0.004	0.048	0.11	-	0.96	-	-	-	-	Invention example				
10	0.141	0.29	1.06	0.012	0.004	0.033	0.10	-	-	0.010	-	-	-	Invention example				
11	0.146	0.28	1.07	0.012	0.004	0.035	0.11	-	-	0.030	-	-	-	Invention example				
12	0.146	0.28	1.07	0.012	0.004	0.037	0.11	0.25	0.11	-	-	-	-	Invention example				
13	0.103	0.25	0.46	0.013	0.007	0.048	0.11	0.30	0.17	-	-	-	-	Invention example				
14	0.146	0.24	1.06	0.012	0.004	0.031	0.10	0.32	0.15	0.020	-	-	-	Invention example				
15	0.144	0.28	1.08	0.011	0.004	0.032	0.10	0.35	0.11	-	-	0.10	-	Invention example				
16	0.146	0.27	1.06	0.011	0.004	0.030	0.11	0.35	0.10	-	-	-	0.11	Invention example				
17	0.145	0.28	1.07	0.012	0.004	0.032	0.11	-	-	-	-	-	-	Invention example				
18	0.141	0.29	1.06	0.012	0.004	0.030	0.12	0.19	-	-	-	-	-	Invention example				
19	0.146	0.24	1.08	0.010	0.005	0.033	0.10	-	0.31	-	-	-	-	Invention example				
20	0.142	0.28	1.07	0.011	0.004	0.034	0.31	-	-	0.010	-	-	-	Invention example				
21	0.101	0.25	0.49	0.013	0.007	0.048	0.11	0.35	0.21	-	-	-	-	Invention example				
22	0.102	0.25	1.08	0.010	0.005	0.032	0.11	0.20	-	0.011	-	-	-	Invention example				

[Table 1-2]

Table 1-2														(mass%)	
Steel plate No.	Ti	Nb	Zr	V	Ca	REM	Y	Se	Te	Co	N	O	Remarks		
1	-	-	-	-	-	-	-	-	-	-	0.0029	0.0012	Invention example		
2	-	-	-	-	-	-	-	-	-	-	0.0027	0.0011	Invention example		
3	-	-	-	-	-	-	-	-	-	-	0.0029	0.0015	Invention example		
4	-	-	-	-	-	-	-	-	-	-	0.0026	0.0024	Invention example		
5	-	-	-	-	-	-	-	-	-	-	0.0026	0.0017	Invention example		
6	-	-	-	-	-	-	-	-	-	-	0.0029	0.0021	Invention example		
7	-	-	-	-	-	-	-	-	-	-	0.0020	0.0013	Invention example		
8	-	-	-	-	-	-	-	-	-	-	0.0022	0.0013	Invention example		
9	-	-	-	-	-	-	-	-	-	-	0.0038	0.0018	Invention example		
10	-	-	-	-	-	-	-	-	-	-	0.0020	0.0013	Invention example		
11	-	-	-	-	-	-	-	-	-	-	0.0026	0.0017	Invention example		
12	-	-	-	-	-	-	-	-	-	-	0.0023	0.0021	Invention example		
13	-	-	-	-	-	-	-	-	-	-	0.0038	0.0018	Invention example		
14	-	-	-	-	-	-	-	-	-	-	0.0021	0.0010	Invention example		
15	-	-	-	-	-	-	-	-	-	-	0.0028	0.0019	Invention example		
16	-	-	-	-	-	-	-	-	-	-	0.0025	0.0013	Invention example		
17	0.010	-	-	-	-	-	-	-	-	-	0.0027	0.0011	Invention example		
18	-	0.009	-	-	-	-	-	-	-	-	0.0021	0.0010	Invention example		
19	-	-	0.011	-	-	-	-	-	-	-	0.0020	0.0013	Invention example		
20	-	-	-	0.01	-	-	-	-	-	-	0.0022	0.0013	Invention example		
21	-	-	-	-	0.002	-	-	-	-	-	0.0038	0.0018	Invention example		
22	-	-	-	-	-	0.005	-	-	-	-	0.0027	0.0011	Invention example		

Table 1-3

Table 1-3															(mass%)			
Steel plate No.	C	Si	Mn	P	S	Al	Sb	Cu	Ni	Cr	Sn	Mo	W	Remarks				
23	0.030	0.50	1.01	0.011	0.005	0.033	0.32	-	0.19	0.031	-	-	-	Invention example				
24	0.144	0.24	1.03	0.012	0.004	0.034	0.10	0.21	0.10	-	-	-	-	Invention example				
25	0.031	0.48	0.94	0.008	0.007	0.037	0.11	0.10	0.05	-	-	-	-	Invention example				
26	0.030	0.50	0.93	0.008	0.006	0.039	0.30	0.11	-	0.010	-	-	-	Invention example				
27	0.146	0.24	1.06	0.012	0.004	0.045	0.10	0.20	0.10	0.010	-	-	-	Invention example				
28	0.031	0.45	0.93	0.008	0.006	0.038	0.09	0.01	0.01	0.220	-	-	-	Comparative example				
29	0.101	0.45	0.94	0.008	0.006	0.037	0.10	0.01	0.01	0.710	-	-	-	Comparative example				
30	0.139	0.28	1.05	0.012	0.004	0.032	-	-	0.01	-	0.35	-	-	Comparative example				
31	0.144	0.28	1.01	0.010	0.003	0.033	-	0.20	0.11	0.011	-	0.04	-	Comparative example				
32	0.159	0.28	1.12	0.018	0.002	0.027	-	0.21	0.01	0.020	0.10	-	-	Comparative example				
33	0.144	0.27	1.06	0.012	0.004	0.034	0.02	-	-	-	-	-	-	Invention example				
34	0.146	0.28	1.07	0.012	0.004	0.035	0.11	-	-	0.030	-	-	-	Invention example				
35	0.144	0.28	1.08	0.011	0.004	0.032	0.10	0.35	0.11	-	-	0.10	-	Invention example				
36	0.146	0.24	1.08	0.010	0.005	0.033	0.10	-	0.31	-	-	-	-	Invention example				
37	0.144	0.30	1.03	0.007	0.002	0.034	0.10	0.21	0.10	-	-	-	0.05	Invention example				
38	0.031	0.48	0.94	0.008	0.007	0.037	0.11	0.16	0.05	-	-	-	0.05	Invention example				
39	0.030	0.50	0.93	0.008	0.006	0.039	0.11	0.20	0.10	-	-	-	0.05	Invention example				
40	0.146	0.24	1.06	0.012	0.004	0.045	0.10	0.20	0.10	0.010	-	-	-	Invention example				
41	0.031	0.45	0.93	0.008	0.006	0.038	-	0.01	0.01	0.220	-	-	0.05	Comparative example				
42	0.101	0.45	0.94	0.008	0.006	0.037	-	0.01	0.01	0.710	-	-	0.10	Comparative example				
43	0.139	0.28	1.05	0.012	0.004	0.032	-	-	0.01	-	-	0.35	-	Comparative example				
44	0.159	0.28	1.12	0.018	0.002	0.027	-	0.02	0.01	0.020	0.10	-	-	Comparative example				

[0064]

[Table 1-4]

Table 1-4												(mass%)	
Steel plate No.	Ti	Nb	Zr	V	Ca	REM	Y	Se	Te	Co	N	O	remarks
23	0.011	-	-	-	-	-	0.006	-	-	-	0.0020	0.0013	Invention example
24	-	0.010	-	-	-	-	-	0.001	-	-	0.0022	0.0013	Invention example
25	-	-	-	-	0.002	-	-	-	0.0011	-	0.0023	0.0022	Invention example
26	-	-	0.012	-	-	-	0.005	-	-	0.014	0.0025	0.0013	Invention example
27	0.01	-	-	0.001	0.001	-	-	-	-	0.009	0.0028	0.0018	Invention example
28	-	-	-	-	-	-	-	-	-	-	0.0044	0.0018	Comparative example
29	-	-	-	-	-	-	-	-	-	-	0.0043	0.0014	Comparative example
30	-	-	-	-	-	-	-	-	-	-	0.0030	0.0016	Comparative example
31	0.011	0.013	-	-	0.002	-	-	-	-	0.008	0.0026	0.0018	Comparative example
32	0.015	0.010	-	-	-	-	-	-	-	-	0.0029	0.0013	Comparative example
33	-	-	-	-	-	-	-	-	-	-	0.0029	0.0012	Invention example
34	-	-	-	-	-	-	-	-	0.0011	-	0.0026	0.0017	Invention example
35	-	-	-	-	-	-	-	-	-	0.014	0.0028	0.0019	Invention example
36	-	-	0.011	-	-	-	-	0.001	-	-	0.0020	0.0013	Invention example
37	0.011	0.015	-	-	-	-	-	-	-	-	0.0022	0.0013	Invention example
38	0.011 i	0.015	-	-	0.002	-	-	-	0.0011	-	0.0023	0.0022	Invention example
39	0.011	-	-	-	-	-	0.005	-	-	-	0.0025	0.0013	Invention example
40	0.012	-	-	0.001	0.001	-	-	-	-	-	0.0028	0.0018	Invention example
41	-	-	-	-	-	-	-	-	-	-	0.0044	0.0018	Comparative example
42	-	-	-	-	-	-	-	-	-	-	0.0043	0.0014	Comparative example
43	-	-	-	-	-	-	-	-	-	-	0.0030	0.0016	Comparative example
44	0.015	0.010	-	-	-	-	-	-	-	-	0.0029	0.0013	Comparative example

[Table 2-1]

Table 2-1				
Test No.	Steel plate No.	Weight decrease (g)	Maximum pitting corrosion depth (mm)	Remarks
No.1 - a	1	2.49	0.28	Invention example
No.2 - a	2	2.37	0.27	Invention example
No.3 - a	3	2.19	0.24	Invention example
No.4 - a	4	2.23	0.24	Invention example
No.5 - a	5	2.05	0.23	Invention example
No.6 - a	6	1.92	0.23	Invention example
No.7 - a	7	2.31	0.25	Invention example
No.8 - a	8	2.11	0.23	Invention example
No.9 - a	9	2.02	0.23	Invention example
No.10 - a	10	2.38	0.26	Invention example
No.11 - a	11	2.43	0.28	Invention example
No.12 - a	12	2.02	0.26	Invention example
No.13 - a	13	1.94	0.22	Invention example
No.14 - a	14	1.96	0.24	Invention example
No.15 - a	15	1.99	0.23	Invention example
No.16 - a	16	1.95	0.22	Invention example
No.17 - a	17	2.35	0.25	Invention example
No.18 - a	18	2.24	0.23	Invention example
No.19 - a	19	2.18	0.23	Invention example
No.20 - a	20	2.17	0.24	Invention example
No.21 - a	21	1.97	0.23	Invention example
No.22 - a	22	2.25	0.24	Invention example
No.23 - a	23	2.28	0.26	Invention example
No.24 - a	24	1.99	0.24	Invention example
No.25 - a	25	2.02	0.24	Invention example
No.26 - a	26	1.91	0.22	Invention example
No.27 - a	27	1.98	0.23	Invention example
No.28 - a	28	3.28	0.38	Comparative example
No.29 - a	29	3.49	0.38	Comparative example
No.30 - a	30	3.11	0.45	Comparative example
No.31 - a	31	2.71	0.34	Comparative example
No.32 - a	32	2.74	0.35	Comparative example

[0065]

[Table 2-2]

Table 2-2				
Test No.	Steel plate No.	Weight decrease (g)	Maximum pitting corrosion depth (mm)	Remarks
No.33 - a	33	2.45	0.28	Invention example
No.34 - a	34	2.40	0.27	Invention example
No.35 - a	35	2.00	0.24	Invention example
No.36 - a	36	2.20	0.24	Invention example
No.37 - a	37	2.24	0.25	Invention example
No.38 - a	38	2.31	0.25	Invention example
No.39 - a	39	2.26	0.25	Invention example
No.40 - a	40	2.29	0.26	Invention example
No.41 - a	41	3.11	0.35	Comparative example
No.42 - a	42	3.30	0.36	Comparative example
No.43 - a	43	2.72	0.32	Comparative example
No.44 - a	44	2.99	0.40	Comparative example

[Table 3-1]

Table 3-1			
Test No.	Steel plate No.	Estimated value of maximum thickness decrease 25 years later (mm)	Remarks
No.1- b	1	3.96	Invention example
No.2- b	2	3.46	Invention example
No.3- b	3	3.09	Invention example
No.4- b	4	3.36	Invention example
No.5- b	5	3.23	Invention example
No.6- b	6	3.07	Invention example
No.7- b	7	3.42	Invention example
No.8- b	8	3.31	Invention example
No.9- b	9	3.19	Invention example
No.10- b	10	3.55	Invention example
No.11- b	11	3.71	Invention example
No.12- b	12	3.25	Invention example
No.13- b	13	3.19	Invention example
No.14- b	14	3.21	Invention example
No.15- b	15	3.14	Invention example
No.16- b	16	3.09	Invention example
No.17- b	17	3.50	Invention example
No.18- b	18	3.19	Invention example
No.19- b	19	3.27	Invention example
No.20- b	20	3.42	Invention example

(continued)

Table 3-1

Test No.	Steel plate No.	Estimated value of maximum thickness decrease 25 years later (mm)	Remarks
No.21- b	21	3.16	Invention example
No.22- b	22	3.39	Invention example
No.23- b	23	3.41	Invention example
No.24- b	24	3.30	Invention example
No.25- b	25	3.19	Invention example
No.26- b	26	3.13	Invention example
No.27- b	27	3.21	Invention example
No.28- b	28	6.01	Comparative example
No.29- b	29	7.90	Comparative example
No.30- b	30	6.66	Comparative example
No.31- b	31	4.69	Comparative example
No.32- b	32	5.93	Comparative example

[Table 3-2]

Table 3-2

Test No.	Steel plate No.	Estimated value of maximum thickness decrease 25 years later (mm)	Remarks
No.33- b	33	3.94	Invention example
No.34- b	34	3.69	Invention example
No.35- b	35	3.11	Invention example
No.36- b	36	3.24	Invention example
No.37- b	37	3.12	Invention example
No.38- b	38	3.19	Invention example
No.39- b	39	3.22	Invention example
No.40- b	40	3.26	Invention example
No.41- b	41	5.77	Comparative example
No.42- b	42	7.55	Comparative example
No.43- b	43	5.56	Comparative example
No.44- b	44	6.33	Comparative example

Claims

1. A corrosion-resistant steel for a coal carrier or ore/coal carrier hold, wherein the chemical composition of the steel contains C: 0.010 to 0.200 percent by mass, Si: 0.05 to 0.50 percent by mass, Mn: 0.10 to 2.0 percent by mass, P: 0.0250 percent by mass or less, S: 0.010 percent by mass or less, Al: 0.0050 to 0.10 percent by mass, Sb: 0.010 to 0.50 percent by mass, N: 0.0010 to 0.0080 percent by mass, and in addition, the remainder composed of Fe and incidental impurities.

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2. The corrosion-resistant steel for a coal carrier or ore/coal carrier hold, according to Claim 1, further comprising at least one selected from Cu: 0.010 to 1.0 percent by mass and Ni: 0.010 to 1.0 percent by mass in addition to the steel.
3. The corrosion-resistant steel for a coal carrier or ore/coal carrier hold, according to Claim 1 or Claim 2, wherein in the steel, Cr is 0.050 percent by mass or less.
4. The corrosion-resistant steel for a coal carrier or ore/coal carrier hold, according to any one of Claims 1 to 3, further comprising at least one selected from W: 0.005 to 0.5 percent by mass and Mo: 0.005 to 0.5 percent by mass in addition to the steel.
5. The corrosion-resistant steel for a coal carrier or ore/coal carrier hold, according to any one of Claims 1 to 4, comprising at least one selected from Ti: 0.0010 to 0.030 percent by mass, Nb: 0.0010 to 0.030 percent by mass, Zr: 0.0010 to 0.030 percent by mass, and V: 0.0020 to 0.20 percent by mass in addition to the steel.
6. The corrosion-resistant steel for a coal carrier or ore/coal carrier hold, according to any one of Claims 1 to 5, further comprising Ca: 0.0005 to 0.0040 percent by mass in addition to the steel.
7. The corrosion-resistant steel for a coal carrier or ore/coal carrier hold, according to any one of Claims 1 to 6, comprising at least one selected from REM: 0.0001 to 0.0150 percent by mass and Y: 0.0001 to 0.10 percent by mass in addition to the steel.
8. The corrosion-resistant steel for a coal carrier or ore/coal carrier hold, according to any one of Claims 1 to 7, comprising at least one selected from Se: 0.0005 to 0.50 percent by mass, Te: 0.0005 to 0.50 percent by mass, and Co: 0.010 to 0.50 percent by mass in addition to the steel.

FIG. 1

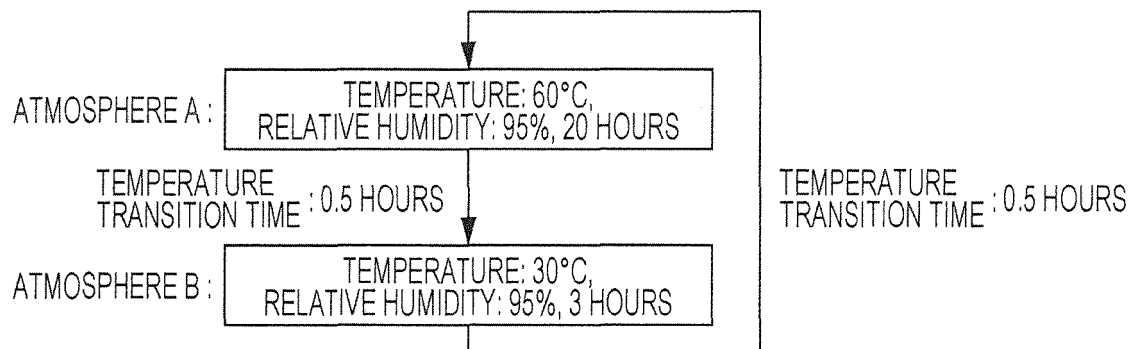


FIG. 2

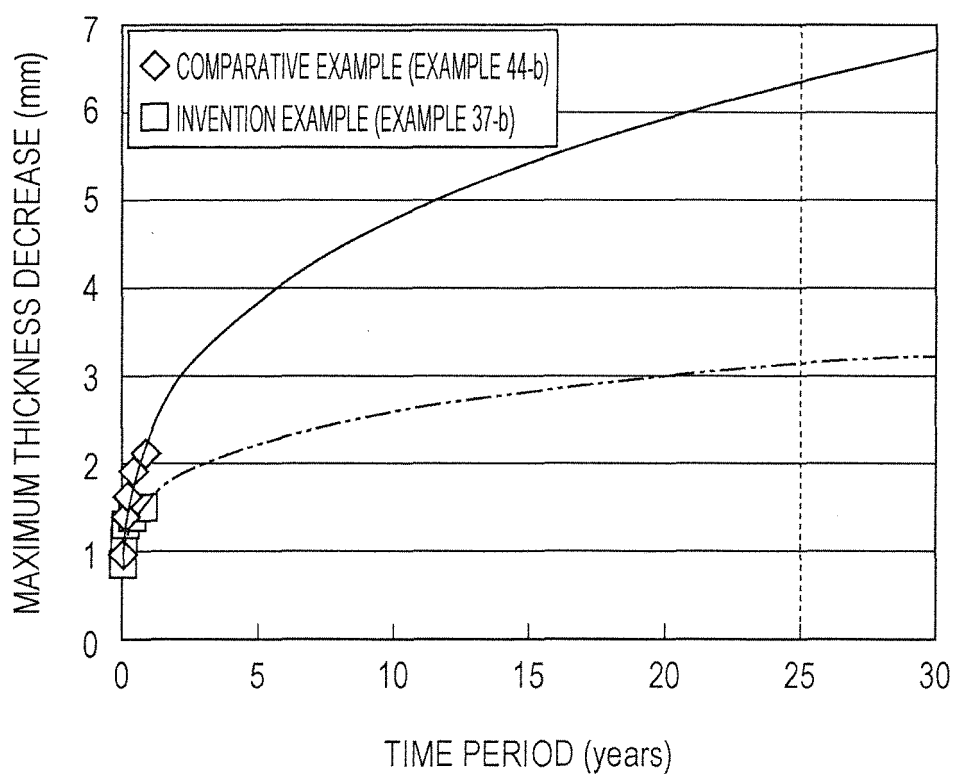
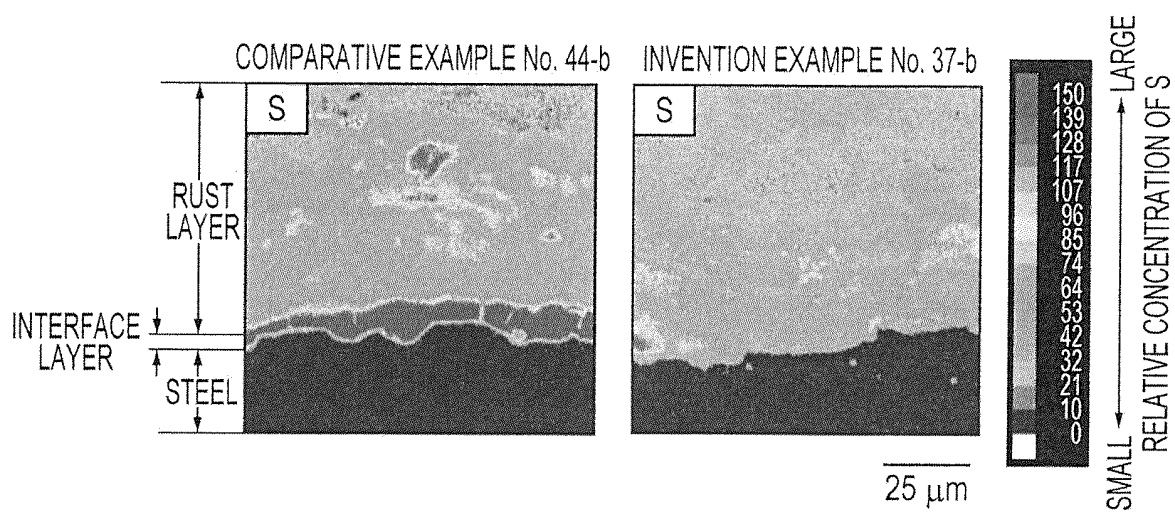


FIG. 3



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2012/061624

A. CLASSIFICATION OF SUBJECT MATTER

C22C38/00(2006.01)i, C22C38/60(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)

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	1996-2012
Kokai Jitsuyo Shinan Koho	1971-2012	Toroku Jitsuyo Shinan Koho	1994-2012

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.
Y A	Yuki KOBAYASHI et al., "Corrosion and Corrosion Fatigue of a Ship Structural Steel in Dilute Sulfuric Acids Substituted for a Corrosion Environment of a Coal Cargo Hold", Journal of the Society of Naval Architects of Japan, no. 185, 1999.06, pages 221 to 232	2-8 1
Y A	Akira USAMI et al., "New S-TEN1: an Innovative Acid Resistant Low Alloy Steel", Shinnittetsu Giho, no.380, 15 June 2004 (15.06.2004), pages 86 to 90	2, 3 1
Y A	D.P.Le et al., Effect of antimony on the corrosion behavior of low-alloy steel for flue gas desulfurization system, CORROSION SCIENCE, Vol.50 No.4, 2008.04, Page.1195-1204	2, 3 1

☒ 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

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"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
04 June, 2012 (04.06.12)Date of mailing of the international search report
12 June, 2012 (12.06.12)Name and mailing address of the ISA/
Japanese Patent Office

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INTERNATIONAL SEARCH REPORT

International application No.

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C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y A	JP 2007-262558 A (JFE Steel Corp.), 11 October 2007 (11.10.2007), claims 1, 3, 4; examples (Family: none)	4-7 1
Y A	JP 2003-213367 A (Nippon Steel Corp.), 30 July 2003 (30.07.2003), examples & US 2005/0013722 A1 & US 2007/0269335 A1 & EP 1460145 A1 & WO 2003/044236 A1 & CN 1589333 A	4-8 1
A	JP 2000-17382 A (Nippon Steel Corp.), 18 January 2000 (18.01.2000), examples (Family: none)	1-8

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REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

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- JP 2008144204 A [0013]
- JP 2007046148 A [0013]
- JP 2007262555 A [0013]
- JP 2008174768 A [0013]

Non-patent literature cited in the description

- **NIPPON KAIJI KYOKAI.** COMMON STRUCTURAL RULES FOR BULK CARRIERS (RULES FOR THE SURVEY AND CONSTRUCTION OF STEEL SHIPS PART CSR-B), 2006, 384-394 [0012]